

SILDA GROUP

**DETERMINATION OF SPRING WATER FLOW – MINING CONCESSION 4762C,
NAMUNO DISTRICT – CABO DELGADO**

Preliminary Report

(Version I)

Pemba, May 2017

SILDA GROUP

**DETERMINATION OF SPRING WATER FLOW – MINING CONCESSION 47620,
NAMUNO DISTRICT – CABO DELGADO**

**Preliminary activity report to
be presented to the National
Directorate of Mines.**

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Pemba, May 2017

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1. Introduction

The present study refers to a strip of land with an approximately quadrangular shape, covering about 89.03 hectares, corresponding to a mining concession for the exploitation of mineral water.

The study carried out in this phase aimed to determine the water flow of the spring, interpret the physical, physicochemical, and chemical parameters of the water analyzed by the Provincial Water Laboratory of Cabo Delgado – Pemba, and present proposals for activities to be carried out in order to estimate the average annual flow as well as the evolution of the water quality control parameters.

In this report, the work carried out is described, the climatic, geological, hydrological, and topographical characterization of the study area is made, and the hydrochemical characterization of the groundwater is provided.

Regarding the methodological aspects, the study was conducted based on desk work (literature review) and fieldwork.

The desk study consisted of gathering relevant information for the characterization of the study area. In this phase, the following materials were used: geological map of the Namuno district, river shapefiles, among others.

The fieldwork was carried out in three phases. In the first phase, water samples were collected for laboratory analysis. These samples were analyzed at the Provincial Water Laboratory of Cabo Delgado on the day of collection, 05/05/2017.

In the second phase of the fieldwork, carried out on 05/13/2017, the spring flow rate was estimated using the direct method. This method consisted of placing a container of known volume in the spring's water channel, then recording the variation in time. The average flow rate equivalent to 1.5L/s results from the ratio between the volume and the variation in time.

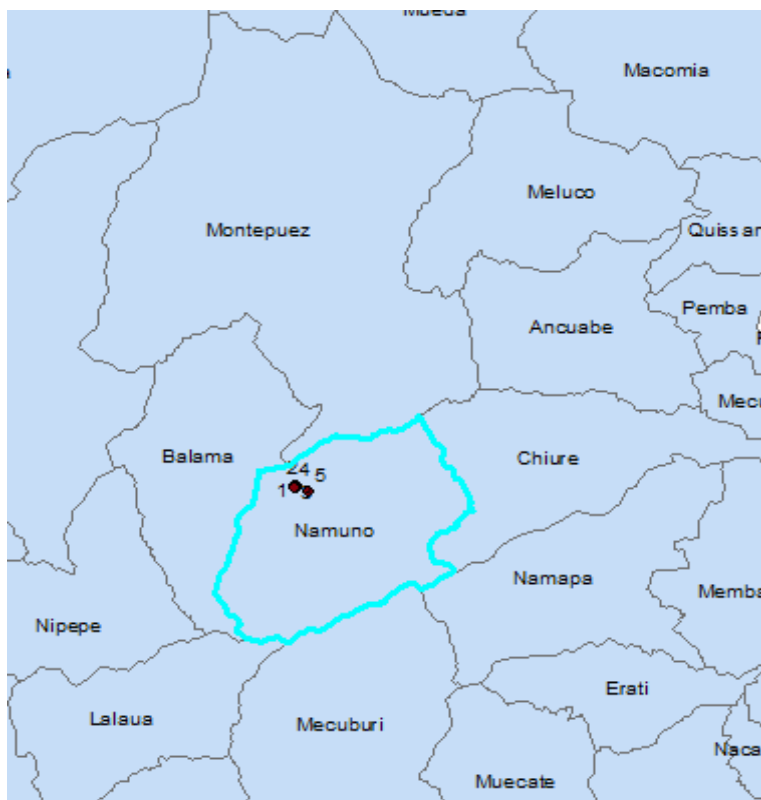
Finally, the third phase of the work was carried out on 05/29/2017 with the aim of recognizing the concessioned area together with the commission of potential investors in the project. After the recognition visit, a debate was held on 05/30/2017 with a view to operationalizing the spring water exploration project, which is expected to start in the very near future.

2. Characterization of the Namuno District

2.1. Location

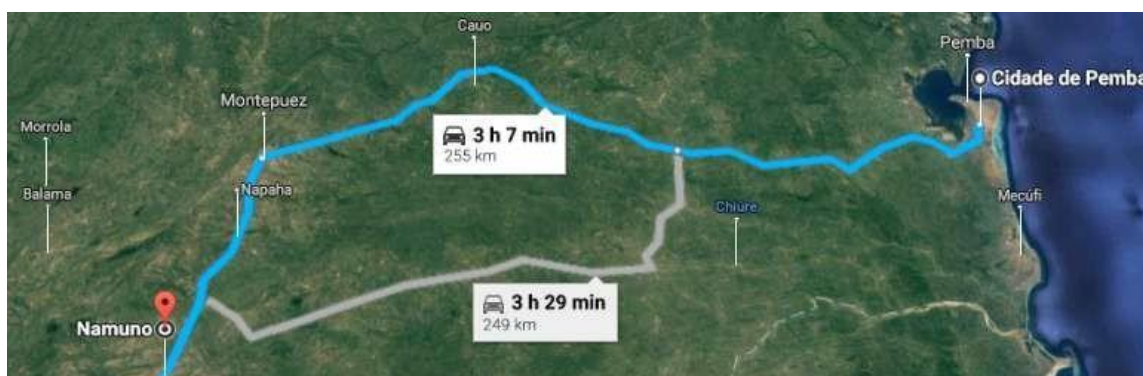
The district of Namuno is bordered to the north by the district of Montepuez, to the south by the province of Nampula (Lalaua, Mecuburi, and Erati), to the east by the district of Chiure, and to the west by the district of Balama (INE, 2013). This district is located approximately 255 km from the provincial capital – the city of Pemba (figure 2).

Figure 1: Geographical location of the Namuno district



Source of the author, 2017 (Adapted)

Figure 2: distance traveled between the city of Pemba and the village of Mamuno



Source: Google Earth (accessed on 05/30/2017)

2.2. General characteristics of the climate

According to INE, 2013, the average annual temperature in the period from 2008 to 2012 was 24.5°C and the average monthly precipitation was 122.9mm (table 1).

Table 1: Average annual temperature (2008 to 2012)

	2008	2009	2010	2011	2012
Temperatura Média °C	24.5	24.5	24.5	24.5	24.5
Temperatura Máxima Absoluta °C	36.5	36.5	36.5	36.5	36.5
Temperatura Mínima Absoluta °C	13.4	13.4	13.4	13.4	13.4
Humidade Relativa (%)	86.5	86.5	86.5	86.5	86.5
Precipitação Média Mensal mm	122.9	122.9	122.9	122.9	122.9

INE, 2013 according to INM

2.3. Topography of the study area

In the figures below, we present the topographic profile of each coordinate, with the first coordinate situated at 478m elevation, the second at 456m, the third at 464m, the fourth at 475m, and the fifth at 477m, respectively. All points are located on the inclined planes of the topographic profiles. Regarding the water outcrop source, it can be said that its topographic position makes it less vulnerable to contamination, since the flow of water resulting from atmospheric precipitation, which acts as a vehicle for transporting impurities deposited on the surface, tends to concentrate in the lower regions of the respective area.

Figure 3: Topographic profile of coordinate C1



Source: Google Earth (accessed on 05/30/2017)

Figure 4: Topographic profile of coordinate C2



Source: Google Earth (accessed on 05/30/2017)

Figure 5: Topographic profile of coordinate C3



Source: Google Earth (accessed on 05/30/2017)

Figure 6: Topographic profile of coordinate C4



Source: Google Earth (accessed on 05/30/2017)

Figure 7: Topographic profile of coordinate C5



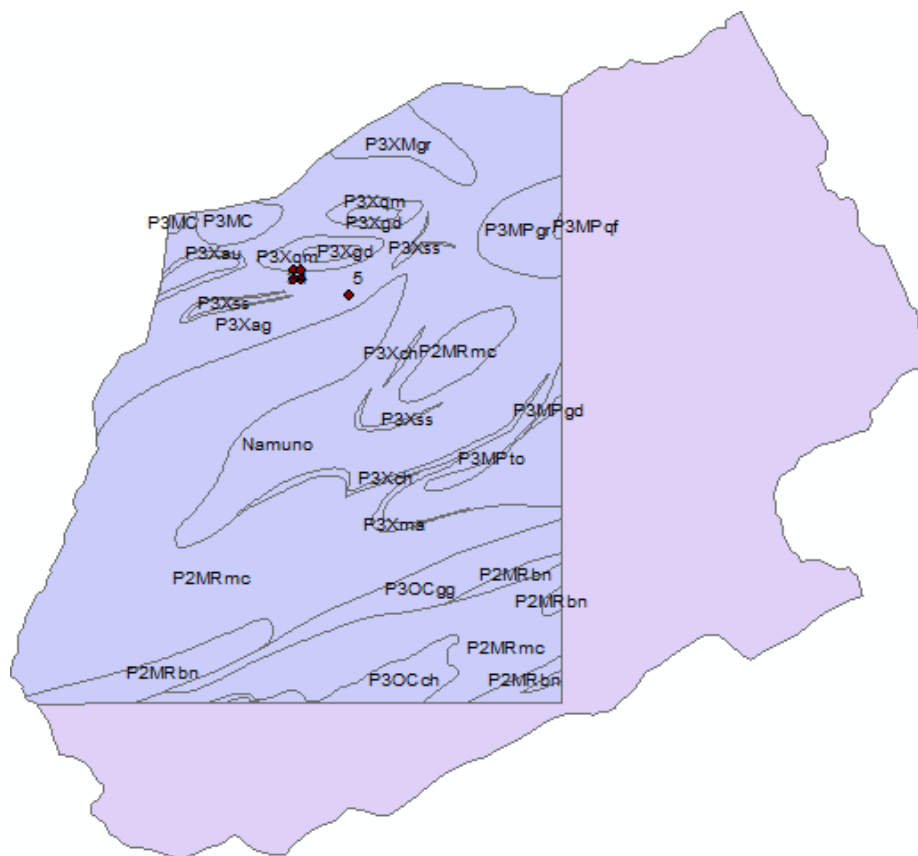
Source: Google Earth (accessed on 05/30/2017)

2.4. Geology, Hydrology, and Site Faults

Locally, the study area comprises rocks of Neoproterozoic age, which are part of the Xixano Complex, generally amphibolitic gneiss, charnockitic rocks, mica with quartz, and locally with graphite (figure 9).

The study area is located between the Namiculo and Mecuburi rivers. Both flow into the Muataze river, which is a tributary of the Lúrio river (figure 10). In addition to these rivers, the area is crossed by three faults located to the north (N), southeast (SE), and southwest (SW) of the study area (figure 10). Based on this observation, it can be said that there is a considerable number of recharge sources that can supply the aquifer.

Figure 9: Site geology



Source of the author, 2017 (Adapted)

According to the granulometric characteristics of the material that makes up the rings, it is hypothesized that the spring water is passing through a probable fault at the contact surface between two rings as a consequence of a slightly to moderately pronounced slip of one of them, associated with a probable settlement of the earthy strata underlying the well or a probable fracture in the well wall associated with the disintegration of the coarse particles (gravel) that make up the rings.

The average discharge rate (average flow) was determined by the direct method. This method consisted of placing a container of known volume (capacity of 5 liters) on a slope located along the channel and 29.75 meters from the water outcrop point. Then, the variation in the time taken to fill the container was recorded.

Three tests were carried out, which resulted in the calculation of the average flow rate equivalent to 1.5 L/s (table 2). This result allowed the spring to be classified as 5th magnitude, since the average discharge rate for this magnitude ranges from 1 to 10 L/s (table 3).

Table 3: Classification of sources based on the average discharge rate (Meinzer 1923 apud Davis and DeWiest 1966)

MAGNITUDE	DOWNLOAD	MAGNITUDE	DOWNLOAD
First	$\geq 10\text{m}^3/\text{s}$	Fifth	1 at 10L/s
Second	1 at 10m ³ /s	Friday	0.1 to 1 L/s
Third	0.1 to 1 m ³ /s	Seventh	10 to 100 cm ³ /s
Wednesday	10 to 100L/s	Eighth	$\leq 100\text{cm}^3/\text{s}$

From the unstructured interview that the team had with some farmers (practitioners of family farming), they gave their testimony that water continuously surfaces in all seasons of the year. In order to estimate a safe discharge rate that can contribute to the technical-economic feasibility study of the project, seven flow tests will be carried out during the dry season of the current year. These will be accompanied by the respective laboratory tests for water quality analysis for human consumption.

Regarding the vulnerability of aquifer contamination in relation to anthropogenic activities, it was found to be negligible, since there are no potentially polluting activities. The fact that the spring is located on an inclined topographic plane (figure 11) also makes it less vulnerable to contamination compared to cases where the spring is at the lower base of the elevation, since, during the rainy season, the water flow carries impurities deposited on the earth's surface to areas of lower elevation. These, in turn, infiltrate into the aquifers, contaminating them.

Figure 11: Source Position



4. Hydrochemistry of spring waters

The hydrochemical characterization of spring waters was based on the interpretation of the physicochemical, chemical, and microbiological parameters of the water sample analyzed by the Provincial Water Laboratory of Cabo Delgado.

The physical and physico-chemical parameters (pH, electrical conductivity, turbidity, deposits, total dissolved solids, taste, and alkalinity) are within the legally permissible limits except for the color, which appears slightly milky. It is assumed that this coloration is associated with the transport of clay material to which the water is subjected along its path. This is evidenced by the fact that the well is saturated with an earthy layer, which may be clay-sandy or sandy-clay. (Annex I)

Overall, these are waters with low mineral content since the recorded pH, equivalent to 6.9, is between 5.4 and 7.8. This pH value justifies the fact that the spring is not located in areas of mining activity or in areas of former mining operations. These findings, which reflect evidence of negligible anthropogenic actions, also justify the fact that the electrical conductivity is close to the minimum limit allowed by law.

The predominant anion is chloride Cl^- , with about 55.4%, followed by the hydrogen carbonate ion HCO_3^- , with about 44.6% (table 4). The percentage level

the chloride ion causes the waters to have an easy chlorinated hydrochemistry (figure 12). The presence of the hydrogen carbonate ion is controlled by the dissolution of minerals in the water, such as Calcium (Ca) and Magnesium (Mg).

The cationic group is dominated by calcium with 68.3%, followed by magnesium with about 31.7% (table 4). Thus, the waters have an easy calcareous hydrochemistry.

The spring shows low values of sulfate (SO_4^{2-}), nitrite (NO_2^-), and nitrate.

(NO_3^-). These values demonstrate the absence of mining contamination and anthropogenic activities (such as agriculture) that could be considered potential sources of contamination.

Ca^{2+} and Mg^{2+} are strongly correlated with the HCO_3^- ion, which may indicate the percolation of water through rocks and its successive enrichment in Ca^{2+} , Mg^{2+} , and HCO_3^- (LNEG, 2014 apud Appelo and Postma, 1996).

Iron appears in the chemical analysis of water at concentrations below the legislative limit. The mobility of iron depends on its valence state and the redox potential of the environment, which means that its variability in groundwater is sometimes very high.

According to the hydrochemical facies, the spring waters are classified as calcium chloride waters.

The hydrochemical facies were determined using Excel software. In order to ensure greater accuracy of the results, the facies were determined using the Hatachem software, which made it possible to sketch the Piper, Stiff, and Schoeller diagrams for the classification of the waters (figures 13, 14, and 15).

Table 4: Determination of the hydrochemical facies of the water

Ion	Atomic weight	z	football club
Ca^{2+}	40,08	2	0,0499
Mg^{2+}	24,312	2	0,082264
Na^+	22,9898	1	0,043498
K^+	39,098	1	0,025577
HCO_3^-	61,01732	1	0,016389
CO_3^{2-}	60,00935	2	0,033328
Cl^-	35,453	1	0,028206
SO_4^{2-}	96,0616	2	0,02082

Cation	Conc. (mg/l)	Conc. (meq/l)	%meq/l	Anion	Conc. (mg/l)	Conc. (meq/l)	%meq/l
Ca^{2+}	3,2	0,159680639	68,3	HCO_3^-	12,2	0,199943229	
Mg^{2+}	0,9	0,074037512	31,7	CO_3^{2-}	0	0	
Na^+	0	0		$\text{HCO}_3^- + \text{CO}_3^{2-}$		0,199943229	44,61433
K^+	0	0		Cl^-	8,8	0,248215948	55,38567
$\text{Na}^+ + \text{K}^+$		0	0	SO_4^{2-}	0	0	0
mEq/L		0,233718151	100	mEq/L		0,448159177	100
Equivalence (%)		100		Equivalence (%)		100	

HYDROGEOCHEMICAL FACIES	CLASSIFICATION OF MINERAL WATER	SOURCE COORDINATES
6(B) – Calcic Waters	1 – Calcium Chloride Waters	S13o35'20.8"
11 (G) – Chlorinated Waters		E38o46'55.2"

Figure 12: Piper diagram – Determined in Excel

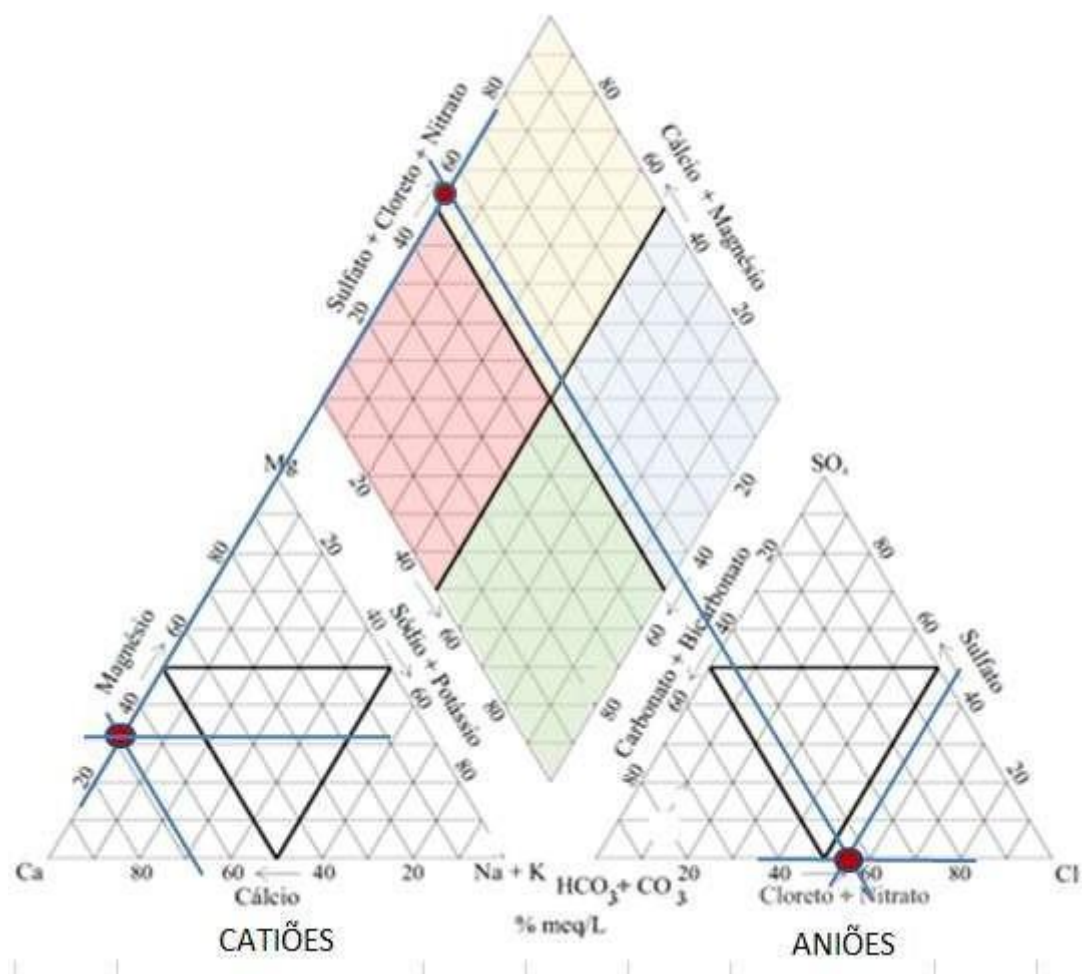


Figure 13: Piper Diagram – Using the Hatarichem software

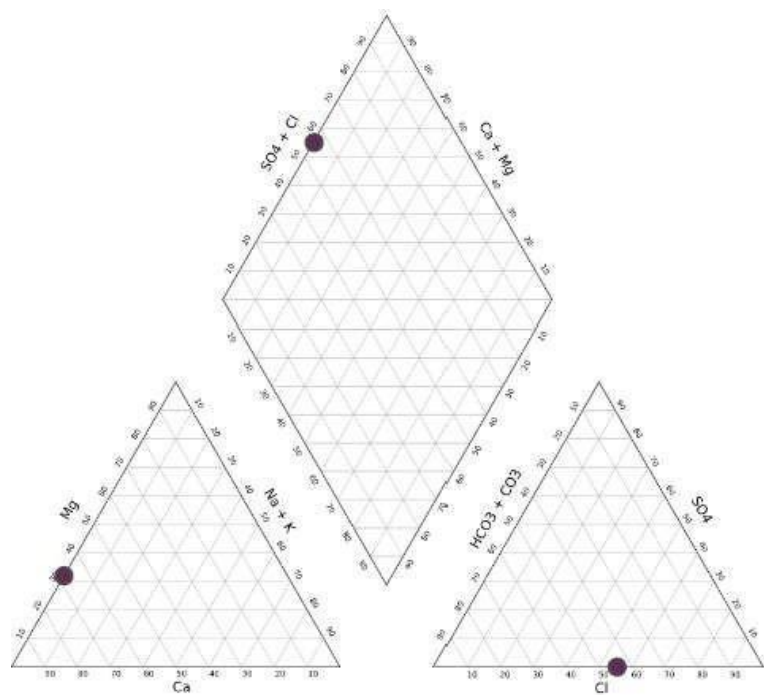


Figure 14: Stiff Diagram

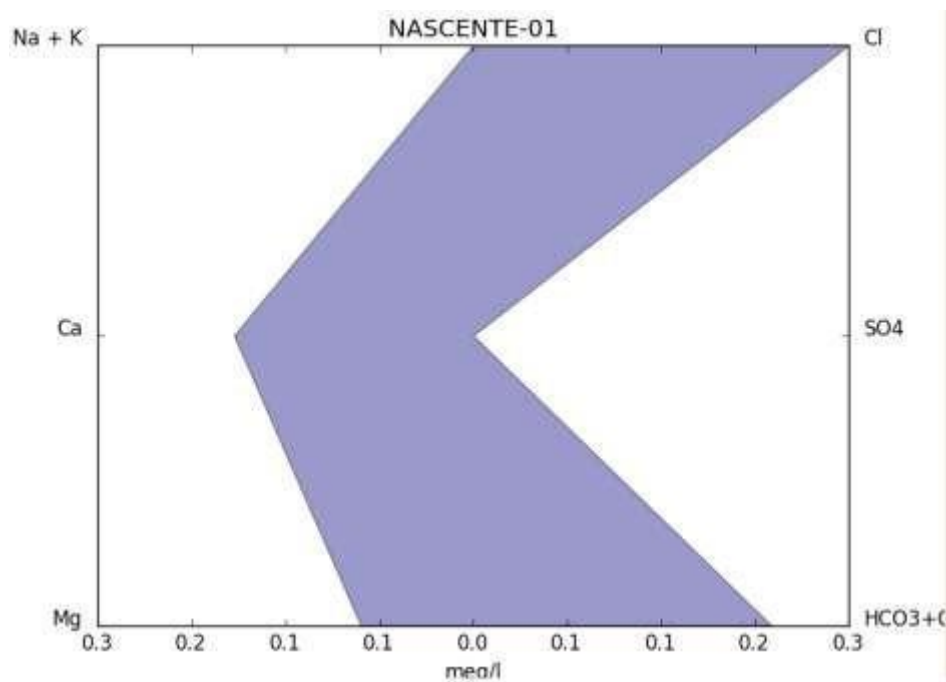
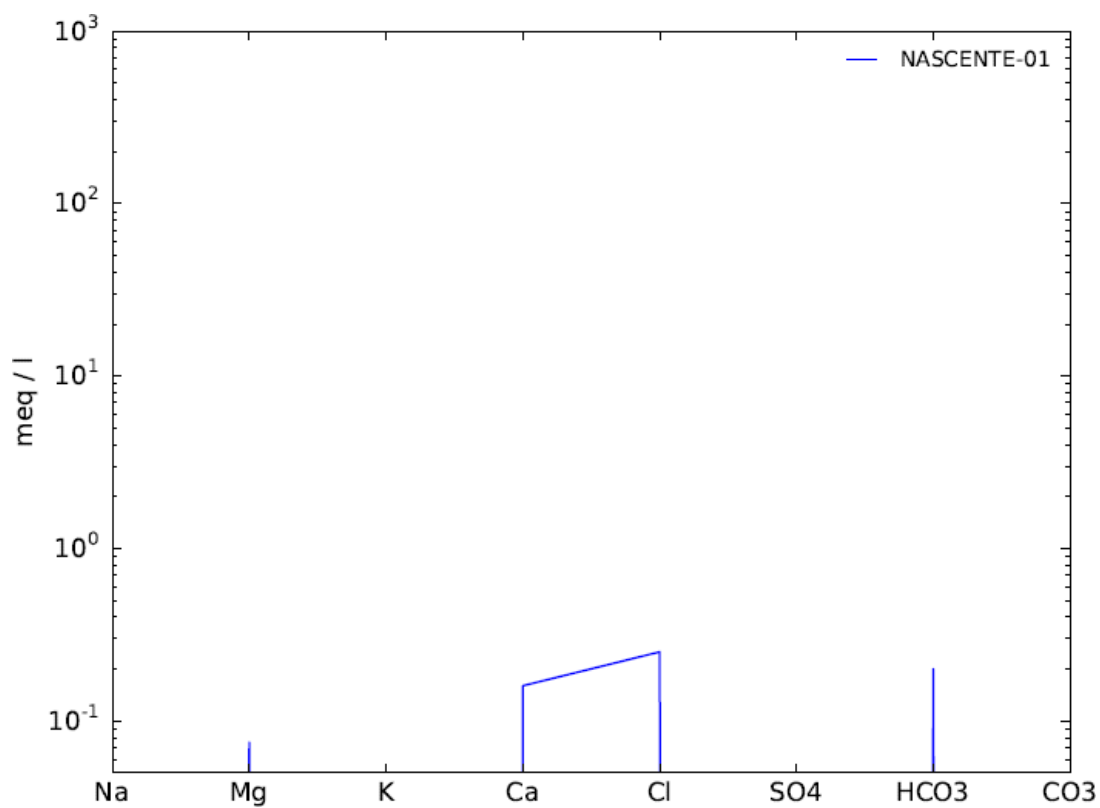


Figure 15: Schoeller Diagram



Conclusions and Recommendations

According to the source classification scale based on the discharge rate, it was concluded that the estimated water flow, equivalent to 1.5 L/s, is of the 5th magnitude. Therefore, this source proves to be very promising with regard to the possible capture and exploitation of mineral water.

Although the physical, physicochemical, and chemical parameters are within the admissible limits established by law (Ministerial Decree No. 180/2004 of September 15), it is recommended to repeat a minimum of seven tests in order to assess the evolution of the respective parameters in accordance with the geological characteristics of the study site. It is also recommended to carry out an equal number of flow tests to determine the average flow during the dry season and the annual average flow.

The spring waters are considered to be chlorinated calcareous. This conclusion was based on the determination of the hydrochemical facies of the groundwater, with calcium having the highest percentage among the cations, 68.3% followed by magnesium with 31.7%, and among the anions, chloride has the highest percentage, 55.4% followed by bicarbonate with 44.5%.