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# Surface Water Quality Assessment in the Southeastern Part of the Noun Catchment Area in Cameroon (Central Africa)

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## Abstract

This study aims to assess water quality and its suitability in terms of consumption and irrigation in the Noun Catchment Area (NCA) in the Western Highlands of Cameroon. To achieve this objective, 19 water samples were collected along the NCA. The measurement of physicochemical parameters, such as pH, electrical conductivity, alkalinity, salinity, suspended solids, along with eleven major elements ($Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $NH_4^+$, $Cl^-$, $NO_3^-$, $HCO_3^-$, $SO_4^{2-}$, $PO_4^{3-}$, and $F^-$) was also analyzed using conventional hydrochemical methods, Multivariate Statistical Analysis, and a geostatistical approach for spatialization of WQI, $HCO_3^-$, EC, Salinity, $PO_4^-$. The water quality index (WQI) illustrates three types of water: water of excellent quality, poor water quality, and water unsuitable for drinking purposes. Most of the samples from the NCA fall within the permissible limit of WHO (6.50 - 8.50) and ANOR (6.5 - 9) except for 3 samples from Koup in Baigom, Bameka, and Noun in Dioma, which are slightly above the standard limit for safe drinking water. The spatial distribution of WQI, $HCO_3^-$, EC, Salinity, and $PO_4^{2+}$ was performed. The northern and central parts of the study area exhibit high EC values. Fresh water availability was indicated by higher EC values in the north and central part of the study area and lower values in the south and their surroundings. Salt is present everywhere in that zone since the conductivity of water depends on the amount of salt in the area. The $PO_4^-$ is present in the northern part of the study area, whereas the $HCO_3^-$ is mainly found in the center of the study area. The southwestern and a small portion of the southeast section of the research area are heavily polluted by anthropogenic waste. The spatial distribution map of WQI shows the highest concentration in the central part of the study area. This suggests that the water in this part needs to be seriously treated before any use in conformity with the standards prescribed by the WHO and ANOR.

## Keywords

Water Quality, Drinking Purpose, WQI, Spatial Distribution, Noun Catchment Area (NCA)

## 1. Introduction

In Cameroon, surface resources (rivers, streams, lakes, swamps) play a crucial role in the country's economy as they are used for drinking, domestic purposes, industry, hydroelectricity, mining activities, fishing, tourism, leisure, and agricultural practices (Rakotondrabe et al., 2017; Owoyemi et al., 2019; Poetra et al., 2020; Mfonka et al., 2021). Cameroon has one of the largest reservoirs of groundwater and surface water in Africa. It has 103 urban drinking water stations and more than 3,000 rural stations and water points (MUA, 2023). Nevertheless, in rural and semi-urban areas, only 43.5% of the population has access to groundwater for drinking purposes, while the remainder have only surface water for their supply. Thus, in the southern part of Cameroon, especially in the West and Northwest regions made up of basement formations, water supply is mostly provided by means of surface water because groundwater availability is limited for the local communities. Moreover, this surface water is vulnerable to diverse sources of pollution through anthropogenic activities, with agriculture at the top of the list. Cameroon is heavily dependent on the agricultural sector. Agriculture is one of the key sectors of the economy, ensuring self-sufficiency in food and foreign currency. It contributes 17.38% to the annual GDP growth rate and accounts for around 23% of the country's total exports. Agriculture is the leading employer, accounting for 62% of the working population (MINADER 2020). In addition, agriculture is the primary activity practiced in the West and Northwest regions. Indeed, the West and Northwest regions in general, and the Noun Catchment Area (NCA) in particular, is one of the largest, if not the largest, agricultural areas in the country due to its natural fertility composed of volcanic soils (Mouncherou et al., 2018). Because of its high agricultural productivity, the NCA supplies most of Cameroon's major cities (Bafoussam, Yaoundé, Douala, Kyé-Ossi, etc.) and even some countries in the CEMAC zone (Chad, Gabon, Equatorial Guinea, Congo, etc.); hence the appellation "granary of Cameroon and the Central African subregion" (Kpoumié et al., 2020). Despite this great agricultural potential, waterborne or water-related diseases such as cholera, diarrhea, typhoid fever, hepatitis

A, bilharzia, poliomyelitis, etc., regularly occur in the area.

In western Cameroon in general, and in the NCA especially, a number of scientific studies have been carried out, focusing on other aspects of geology, in particular petrography, petrology, geochemistry, and volcanology (Moundi et al., 2007; Ziem à Bidias et al., 2018). In addition, other work carried out in the field of water (Mouncherou et al., 2018; Kpoumié et al., 2020; Mfonka et al., 2021) has focused on hydrogeology, hydrology, and the study of water quality in relation to lithology in the NCA and their surroundings. Not all these studies have taken into account the assessment of surface water quality and its suitability in terms of consumption and irrigation. Thus, the main objective of this work is to evaluate the status of surface water quality for drinking and agricultural purposes, and to determine the spatial distributions of surface water parameters. The result will provide valuable information on surface water quality and relevant health risks for decision-makers to properly tackle issues in such headwater basins of the Noun catchment with a large population and urgent water issues.

## 2. Materials and Methods

### 2.1. Location of the Study Area

The Noun catchment area (NCA) is located at latitudes 4˚80'N to 6˚60'N and longitudes 10˚10'E to 11˚05'E (Figure 1).

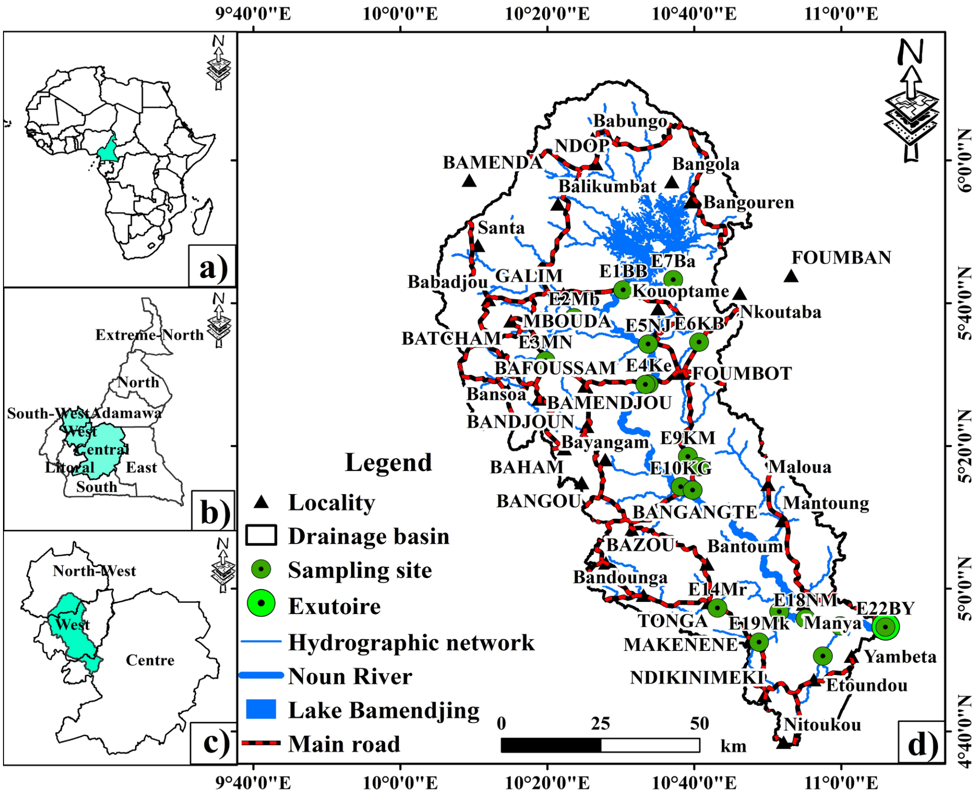

Figure 1. Location, hydrological, and sampling map of the study area. (a) Cameroon in Africa; (b) NCA in Cameroon; (c) NCA location; (d) hydrological and sampling map of NCA.

It drains three regions of Cameroon and ten departments. The watershed covers several major agricultural zones in Cameroon, including Santa, Batcham, Galim, Bamougoum-Baleng, Foumbot, and Bamendjing.

### 2.2. Climate, Hydrography, and Slope

Due to its geographical location, the NCA is subjected to two principal climatic zones: the tropical mountain climate in the west and the equatorial transition climate at its outlet at Bayomen (Central Cameroon). Generally, it is a wet tropical climate, with a 3-month dry season and a 9-month rainy season. According to the work of Kpoumié (2015), this zone is covered by isohyets of 1800 and 1900 mm. It stretches from Dschang to Foumban, and from Bamenda to Nkambé, and covers the mountains of the western regions. It is characterised by much lower temperatures than the rest of Cameroon (average monthly temperatures range from 23.79˚C to 20.89˚C, and the average inter-annual temperature is 21.3˚C) and by an oceanic influence, which results in high rainfall. From a hydrological point of view, the Noun catchment area rises from Mount Oku in the northwest and drains the Ndop plain in the North West region, ending up in a marshy basin. Its main tributaries are: Mifi-Nord, Mifi-Sud, Nkoup, Ngam, and Nde before its confluence with the Mbam. Through the Bamenjing reservoir, the Noun regulates the Sanaga with a reserve of nearly 1.85 billion cubic meters ($m^3$) (Kpoumié et al., 2020).

### 2.3. Geology

The geology of the NCA is diverse and composed of different lithological types, bearing witness to numerous geodynamic activities (tectonics, faults, etc.), and above all, its position along the Cameroon line. The latter is a tectonic and pluto-volcanic megastructure stretching between the Lake Chad basin and the Gulf of Guinea over a distance of around 900 km (Moundi et al., 2007; Ziem à Bidias et al., 2017, 2018; Tchakounté et al., 2017). In the northern part, metamorphic rocks such as trachytes, rhyolite, and granite are predominant. In the southern part of the basin, magmatic rocks such as micaceous quartzites and embrechite gneisses, and anatexites in the south-eastern part of the basin include volcanic rocks, mainly aphyric basalts, anatexites, and aphyric basalts. Several types of soil develop on these different geological formations, specifically ferralitic soils resulting from the alteration of eruptive basaltic and volcanic rocks; red ferralitic soils formed from an accumulation of laterite on metamorphic rocks; hydromorphic soils, formed in areas subject to permanent or frequent water saturation; and alluvial soils, originating from sediments transported by rivers.

### 2.4. Description of the Sampling and Analytical Procedure

To achieve this study, the sampling was made in January 2025 because this month represents the transition period between the rainy and dry seasons. Then, nineteen samples of surface water were taken using the conventional surface water sampling technique described by several authors (Rodier et al., 2009; Ndam

Ngoupayou et al., 2016; Rakotondrabe et al., 2018; Khosravi et al., 2018; Mfonka et al., 2021). This method involves manual sampling using a bucket fitted with a rope at a depth of 1 meter in the center of the river, preferably where the current speed is high enough to allow good homogenization of solid particles and dissolved matter. The samples were taken in 1.5-litre plastic bottles that had been cleaned and rinsed with distilled water and then three times with the water to be sampled. The bottles were filled to the brim, sealed to prevent gas exchange, labelled and stored in a cooler at around 4˚C. These were sent to the Laboratoire d'Analyses Géochimiques des Eaux (LAGE/IRGM) at Nkolbisson in Yaoundé, Cameroon. These samples were followed by in-situ measurements of physical parameters such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS) and salinity using an ORTON multi-parameter calibrated with appropriate solutions. Turbidity was also measured in situ using a turbidimeter that had also been calibrated with 00 and 100 NTU solutions. For the laboratory analyses, the raw water samples were first separated into two phases: a particulate phase for estimating suspended solids (SS) and a dissolved phase (filtrate), using the frontal filtration method with an electric vacuum pump and 0.45 µm millipore cellulose filters (NALGENE filter) of 0.45 µm. The samples were oven-dried at 105˚C for three hours and weighed. The filtrate obtained for each sample was used to determine alkalinity, major cations and anions ($Ca^{2+}$, $Mg^{2}$, $Na^{+}$, $K^{+}$, $NH_4^+$, $Cl^-$, $NO_3^-$ $PO_4^{2+}$ $SO_4^{2-}$ $F^-$ $HCO_3^-$). For this research, pearson's correlation matrix was used to determine the relationship between parameters and several indices. Furthermore, the correlation matrix is a popular method for determining how parameter pairs influence water quality (Rakotondrabe et al., 2018; Yenugu et al., 2020).

### 2.5. Data Treatment

The results obtained from the laboratory in this study were processed using the standard method of hydrochemistry for Statistical Analysis, and the calculation of the Water Quality Index (WQI). In addition, the geostatistical approach for spatialization of WQI, CE, Salinity, $HCO_3^-$, and $PO_4^{2-}$ was also achieved (Rakotondrabe et al., 2018; Yenugu et al., 2020; Saha et al., 2023; Newaz et al., 2024; Tiabou et al., 2024; Onana et al., 2025).

#### 2.5.1. Statistical Analysis

Statistical analysis consisted to determine a descriptive parameters as minimum, maximum and mean among chemical values of different samples, for assessing water chemical quality with respect to drinking water standards (WHO, 2022 and ANOR). This calculation was followed by determination of Pearson correlation coefficient, using Statistica 7.0 software to establish relationships among many variables and their hydrochemical roles (Kumar et al., 2009; Njueya Kopa et al., 2021). This aims to analyze the degree of dependence between variables in the form of a matrix (Belkhiri and Mouni 2012). The correlation coefficient may have a value from (−1) to (+1). (+1) means a perfect positive relationship exists between the variables, while (−1) indicates a perfect inverse relationship (Mudgal et al., 2009; Kazi et al., 2009), and a zero value (0) indicates the absence of a relationship between variables (Houria et al., 2020; Mudgal et al., 2009; Zhao et al., 2011). Pearson correlation values of $r > 0.7$ are generally considered highly correlated, while r values ranging from 0.5 to 0.7 are moderately correlated. The dependence of the variables on each other is represented by the Pearson correlation matrix.

### 2.5.2. Water Quality Index (WQI) Calculation

The Water Quality Index (WQI) is a quantification that defines the main reasons for inconsistencies in water quality (Singha & Pasupuleti, 2020; Krupavathi et al., 2022; Ravi-Kumar et al., 2024). It was calculated on eleven (11) water quality parameters (pH, EC, $Mg^{2+}$, $Ca^{2+}$, $Na^{+}$, $NH_4^{+}$, $K^{+}$, $Cl^{-}$, $HCO_3^{-}$ −, $SO_4^{2-}$, $F^{-}$) to ascertain the suitability of surface water in the study area for drinking purposes (Rakotondrabe et al., 2017; Tiabou et al., 2024; Onana et al., 2025). The WQI is calculated as follows (**Table 1**; Equation (1)): each chemical parameter was assigned different weights (wi) on a scale of 1 (least effect on water quality) to 5 (highest effect on water quality). This is based on their perceived effects on primary health and according to their relative importance in drinking water quality (Rakotondrabe et al., 2017; Tiabou et al., 2024; Onana et al., 2025). The highest weight of 5 was assigned to parameters that have critical health effects and whose presence above the critical concentration limits could limit the usability of the resource for domestic and drinking purposes ( $NO_3^{-}$ ); the minimum weight of 1 was assigned to $K^{+}$ because of its insignificant role in water quality assessment. Other parameters such as pH, EC, TDS, salinity, $HCO_3^{-}$, $Cl^{-}$, $SO_4^{2-}$, $F^{-}$, $Ca^{2+}$, $Mg^{2+}$, were assigned weights between 2 and 4 based on their relative significance in water quality evaluation (Rakotondrabe et al., 2017). For this study, the weighted arithmetic WQI was calculated as follows (Horton 1965; Ouarekh et al., 2021):

$$\text{WQI} = \sum SIi = \sum\left(Wi \times qi\right) = \sum\left[\left(\frac{wi}{\sum wi}\right) \times \left(\frac{Ci}{Si} \times 100\right)\right] \tag{1}$$

where:

- *Si is the WHO standard for drinking water of parameter (i).*
- *wi is the relative weight (Wi); the values of each parameter are given in* **Table 1**.
- *qi represents the quality rating scale,*
- *Ci is the observed value of each chemical parameter in mg/L.*
- *and Ci is the concentration of parameter (i).*

The computed WQI values of data from **Table 2** are classified into five categories as follow:

- $WQI \leq 25\%$, Excellent water;
- $25 < WQI < 50\%$, Good Water;
- $50 < WQI < 75\%$, Poor water;
- $75 < WQI < 100\%$, Extremely poor Water;
- $100 \leq WQI$, Unsuitable for drinking purposes.

Table 1. Weight and relative weight of each parameter used for the WQI calculation.

| Parameters | Units | WHO (2017) | Weights (Wi) | Relative Weights |
|---|---|---|---|---|
| **$HCO_3^-$** | mg/L | 300 | 1 | 0.027027027 |
| **Cl-** | mg/L | 250 | 3 | 0.081081081 |
| **$SO_4^{2-}$** | mg/L | 200 | 4 | 0.108108108 |
| **$NO_3^-$** | mg/L | 50 | 5 | 0.135135135 |
| **F-** | mg/L | 1.5 | 5 | 0.135135135 |
| **$NH_4^+$** | mg/L | 0.2 | 3 | 0.081081081 |
| **$Na^+$** | mg/L | 20 | 4 | 0.108108108 |
| **$K^+$** | mg/L | 12 | 2 | 0.054054054 |
| **$Ca^{2+}$** | mg/L | 75 | 2 | 0.054054054 |
| **$Mg^{2+}$** | mg/L | 30 | 2 | 0.054054054 |
| **CE** | µs_cm | 1500 | 3 | 0.081081081 |
| **Ph** | - | 6.5 - 8.5 | 3 | 0.081081081 |
| | | Σ | 37 | 1 |

## 3. Results and Discussions

### 3.1. Physico-Chemical Characteristics of Surface Water in the Study Area

A statistical summary of physicochemical parameters has been done. Thus, the pH of overall samples varied from 7.32 to 8.85 with a mean of 8.18. Most of the samples from the NCA fall within the permissible limits of WHO (2022) (6.50 - 8.50) and ANOR (6.5 - 9), except for 3 samples from Koup in Baigom, Bameka, and Noun in Dioma, which are slightly above the standard limit. This shows that most of the sampled water was basic, reflecting the highly intensive agricultural activity zones dominated by the use of chemical fertilizers. The pH values observed in NCA are generally higher than those observed in other forest areas of southern Cameroon (Ribinu et al., 2023; Tiabou et al., 2024). This factor generally influences the activity of enzymes, the solubilization and uptake of specific ions, and the distribution of biodiversity in aquatic environments (Dirisu et al., 2019). The values of pH of the water samples analyzed in this research fell within the suggested range (WHO, 2017, 2022). Electrical conductivity (EC) is a material's capacity to conduct an electric current; a high EC value suggests that salts have accumulated in surface water (Tiabou et al., 2024). The range of electrical conductivity (EC) measured in the NCA samples was between 35.50 and 258 µs/cm (**Table 2**), with a mean of 61.69 µs/cm. All the water samples of the study area show low to medium mineralization (up to the permissible limit prescribed by WHO (2022). This type of water is very weakly to weakly mineralized (Mfonka et al., 2018, 2021), like most of the water in the woody savannah and forested parts of western and southern Cameroon respectively, which flows on a plutono-metamorphic basement, contrary to water in the sedimentary milieu which is very mineralized (Rakotondrabe et al., 2018; Mfonka et al., 2021). The quality of irrigation and drinking water is determined by the total dissolved solids (TDS) level. It is also crucial for maintaining a balanced cell density in aquatic life (Tiabou et al., 2024; Onana et al., 2025). The range of total dissolved solids in the study area varies between 25 mg/l and 182 mg/l, with an average of 63.35 mg/l (**Table 2**). The WHO does not set health guidelines for TDS, but a TDS concentration above 1000 mg/l may affect the acceptability of water for drinking purposes. These values indicate that the water in the study area is classified as fresh (TDS < 1000 mg/L) according to Onana et al. (2025). According to Tiabou et al. (2024), temperature is a critical factor governing species' distribution, growth, survival, and reproduction within an ecosystem. The typical ambient temperature of the Noun river is reflected in the temperature values of water samples, which vary from 17˚C (E7Ba) to 24˚C (E19Mk), with an arithmetic mean of 20.91 ˚C (**Table 2**).

**Table 2.** Statistical values of physicochemical parameters of samples in the study area.

| | T˚C | Ph | CE | TDS | Sal | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | $NH_4^+$ | $Cl^-$ | $NO_3^-$ | $PO_4^{2-}$ | $SO_4^{2-}$ | $F^-$ | $HCO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min (n = 19) | 17 | 7.32 | 35.5 | 25 | 19.7 | 7.54 | 5.36 | 1.1 | 0.1 | 0.01 | 0.12 | 0.01 | 0.05 | 0.12 | 0 | 2.013 |
| Max (n = 19) | 24 | 8.85 | 258 | 182 | 102 | 13.67 | 9.83 | 5.1 | 4.8 | 5.12 | 1.32 | 0.95 | 1.42 | 0.85 | 0.19 | 199.84 |
| Means (n = 19) | 20.91 | 8.18 | 88.88 | 63.35 | 39.16 | 10.06 | 7.66 | 2.6 | 2 | 0.55 | 0.37 | 0.14 | 0.46 | 0.48 | 0.04 | 44.4 |
| WHO limits | 0 - 30 | 6.5 - 8.5 | 1000 | 20 - 40 | NM | 75 | 30 | 20 | 12 | 0.2 | 250 | 50 | 3000 | 500 | 1.5 | 300 |

NM = not mentioned.

The major cations evaluated are sodium, calcium, potassium, magnesium, and ammonium, whereas anions are bicarbonate, chloride, nitrate, sulphate, and fluoride. The order of abundance of cations in the water samples of the study area is as follows: $Ca^{2+} > Mg^{2+} > NH_4^+ > Na^+ > K^+$, and anions were in the decreasing order of $HCO_3^- > PO_4^{2+} > Cl^- > NO_3^- > SO_4^{2-} > F^-$. $Ca^{2+}$ in the samples ranges from 7.54 to 13.67 mg·L$^{-1}$ with mean values of 10.06 mg·L$^{-1}$. $Mg^{2+}$ in samples ranges from 5.36 to 9.83 with an arithmetic value of 7.66 mg·L$^{-1}$. $NH_4^+$ in samples varies from 0.01 to 5.12 mg·L$^{-1}$ with mean values of 0.55 mg·L$^{-1}$. $Na^+$ in samples varies from 1.10 to 5.10 mg·L$^{-1}$, with mean values of 2.60 mg·L$^{-1}$. Sodium in the study can be attributed to silicate weathering, mineral dissolution, and anthropogenic (Ribinu et al., 2023). All samples are noted below the permissible limit of WHO (2022) and ANOR. The release of $Ca^{2+}$ and $Mg^{2+}$ into the water is made through the ion exchange process during water–rock interaction and mineral dissolution. The $K^+$ concentrations in the samples vary from 0.10 to 4.80 mg·L$^{-1}$ with mean values of 2.00 mg·L$^{-1}$. The main cause of $K^+$ in the water is K-minerals such as micas and orthoclase or from anthropogenic sources of potassium, such as potash fertilizers due to the agricultural practices in the study area. In addition, the $HCO_3^-$ is the most abundant anion in the study area. It ranges from 2.01 to 199.84 mg·L$^{-1}$ and the mean value is 44.40 mg·L$^{-1}$. The abundance of $HCO_3^-$ is an indication of the mineral dissolution process (Ribinu et al., 2023). The $PO_4^{2+}$ in water samples varies from 0.05 to 1.42 mg·L$^{-1}$, with the arithmetic mean of 0.46 mg·L$^{-1}$. The $Cl^-$ ranges from 0.12 to 1.32 mg·L$^{-1}$ with an average of 0.37 mg·L$^{-1}$. $NO_3^-$ concentration varies from 0.01 to 0.95 mg·L$^{-1}$ with an average of 0.14 mg·L$^{-1}$. The highest nitrate value during this study is recorded from E15NT in Tonga, another agricultural zone where agricultural practices used intensive fertilizers. Thus, this can be attributed to the higher values of nitrate in the water. The same result was obtained by Khan et al. (2020) in the east coast of Tamil Nadu and Puducherry in India, and also by Ribinu et al. (2023) in Thoothapuzha River Basin, Kerala, South India. The $SO_4^{2-}$ concentration in the samples varies from 0.12 to 0.85 mg·L$^{-1}$ with mean values of 0.48 mg·L$^{-1}$. The watery old soil consisting of sedimentary materials in this part of the study area can be the main source of all these elements.

## 3.2. The Correlation Matrix for Various Pollution Indices

Relationships between the major hydrochemical variables were assessed by the Pearson correlation coefficient, which is either positive or negative (**Table 3**). Then, the values presented three categories of relationships:

**Table 3.** Correlation matrix of physico-chemical parameters in the water of the study area.

| | T°C | Ph | CE | MES | TDS | Sal | Ca | Mg | Na | K | $HCO_3^-$ | F | Cl | $SO_4$ | $PO_4$ | $NO_3$ | $NH_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T°C** | 1 | | | | | | | | | | | | | | | | |
| **pH** | −0.30 | 1 | | | | | | | | | | | | | | | |
| **CE** | −0.11 | −0.08 | 1.00 | | | | | | | | | | | | | | |
| **MES** | −0.40 | 0.22 | −0.17 | 1.00 | | | | | | | | | | | | | |
| **TDS** | −0.12 | −0.08 | **1.00** | −0.14 | 1.00 | | | | | | | | | | | | |
| **Sal** | −0.08 | −0.04 | **0.99** | −0.17 | **0.99** | 1.00 | | | | | | | | | | | |
| **Ca** | −0.30 | 0.29 | 0.26 | 0.14 | 0.27 | 0.28 | 1.00 | | | | | | | | | | |
| **Mg** | **−0.62** | 0.25 | 0.40 | −0.02 | 0.41 | 0.37 | 0.35 | 1.00 | | | | | | | | | |
| **Na** | **0.62** | −0.13 | −0.21 | −0.31 | −0.22 | −0.20 | −0.30 | −0.43 | 1.00 | | | | | | | | |
| **K** | −0.19 | 0.22 | 0.45 | −0.17 | 0.45 | 0.46 | 0.25 | 0.42 | −0.24 | 1.00 | | | | | | | |
| **$HCO_3^-$** | 0.08 | −0.12 | **0.94** | −0.16 | **0.94** | **0.94** | 0.31 | 0.22 | −0.11 | 0.32 | 1.00 | | | | | | |
| **F** | −0.48 | 0.16 | −0.24 | 0.21 | −0.23 | −0.28 | 0.11 | 0.28 | −0.21 | 0.08 | −0.27 | 1.00 | | | | | |
| **Cl** | 0.03 | 0.20 | 0.06 | −0.06 | 0.07 | 0.06 | 0.44 | 0.40 | 0.14 | 0.13 | 0.08 | 0.06 | 1.00 | | | | |
| **$SO_4$** | −0.17 | 0.38 | 0.30 | 0.17 | 0.30 | 0.27 | 0.14 | 0.26 | 0.15 | 0.18 | 0.23 | 0.02 | −0.03 | 1.00 | | | |
| **$PO_4$** | −0.31 | 0.33 | −0.24 | −0.05 | −0.23 | −0.25 | 0.40 | 0.39 | −0.08 | 0.26 | −0.30 | 0.31 | **0.63** | −0.05 | 1.00 | | |
| **$NO_3$** | 0.22 | 0.23 | −0.20 | −0.12 | −0.20 | −0.16 | 0.00 | −0.26 | −0.02 | −0.09 | −0.11 | −0.20 | 0.06 | −0.42 | 0.00 | 1.00 | |
| **$NH_4$** | 0.22 | −0.03 | 0.47 | −0.27 | 0.47 | **0.50** | 0.13 | 0.16 | 0.08 | 0.05 | **0.63** | 0.11 | 0.18 | −0.05 | −0.18 | −0.03 | 1.00 |

Variables with correlation values greater than 0.90 indicate a high correlation. Therefore, we have a high and strong positive correlation of TDS with CE, Salinity, $HCO_3^-$, between CE with Salinity, $HCO_3^-$, and between $HCO_3^-$ and Salinity. Variables with correlation values ranging between 0.50 and 0.70 indicate a moderate correlation. According to **Table 3**, we have a moderate positive relationship between $NH_4^+$ with $HCO_3^-$ and Salinity, and between $PO_4^-$ and Salinity. Variables with correlation values less than 0.50 indicate a weak correlation, such as $K^+$ with other variables like Salinity, TDS, CE, and $Mg^+$. These correlation values among variables (**Table 3**) mean that paired variables have a strong to moderate influence on water mineralization (Njueya Kopa et al., 2021). Moreover, these correlations show that the order of contribution in water mineralization by ions is as follows: $HCO_3^-$, $Ca^{2+}$, $SO_4^{2-}$, $Cl^-$. The strong to moderate positive relationship between major ions implies that these ions were derived from the same source, which is the leaching of some materials in this area. In addition, the strong correlation between salinity and the electrical conductivity implies the presence of salt in the study area.

### 3.3. Water Quality Index (WQI)

The water quality indices vary between 4.065 and 215.9, with an average of 28.31. Three categories types of water are recorded for the 19 samples: water of excellent quality, water of poor quality, and water unsuitable for drinking purposes (Onana et al., 2025). According to the water quality index classification, 10.53% of this water falls into Class V: unsuitable for drinking purposes (Ravi-Kumar et al., 2024), and is represented by the water from the E9KM and E10KG samples, which are drained by one of the most important agricultural basins of the study area. In contrast, 84.21% of the waters are of excellent quality, consisting of the E1BB, E2Mb, E3MN, E4Ke, E5NJ, E6KB, E7Ba, E8PN, E11Ma, E12NZ, E14Mr, E15NT, E18NM, E19Mk, E21ND, and E22BY samples. Moreover, 5.26% have poor water quality (E20NM) (**Table 4**).

**Table 4.** WQI values location for all the sampling sites.

| **Sample** | **E1BB** | **E2Mb** | **E3MN** | **E4Ke** | **E5NJ** | **E6KB** | **E7Ba** |
|---|---|---|---|---|---|---|---|
| **WQI** | 4.065 | 4.239 | 6.349 | 9.367 | 7.757 | 11.304 | 19.450 |
| **Sample** | **E8PN** | **E9KM** | **E10KG** | **E11Ma** | **E12NZ** | **E14Mr** | **E15NT** |
| **WQI** | 7.23881 | 215.856 | 145.296 | 14.5746 | 7.53992 | 5.92014 | 6.677 |
| **Sample** | **E18NM** | **E19Mk** | **E20NM** | **E21ND** | **E22BY** | | |
| **WQI** | 7.72142 | 6.33696 | 40.1576 | 8.13529 | 9.83793 | | |

The unsuitable and poor water quality represented 15.79% of the entire water in the research zone. These waters are subject to mineralogical and metallic pollution from human activities, probably agriculture, which is the main activity in that area. Therefore, they can be useful for household chores such as washing, bathing, washing dishes, and laundry. For consumption, this water requires prior treatment to comply with the standards prescribed by the WHO (WHO, 2017, 2022) and ANOR (Onana et al., 2025). The spatial distribution map of WQI shows the highest concentration in the central part of the study area (**Figure 2**).

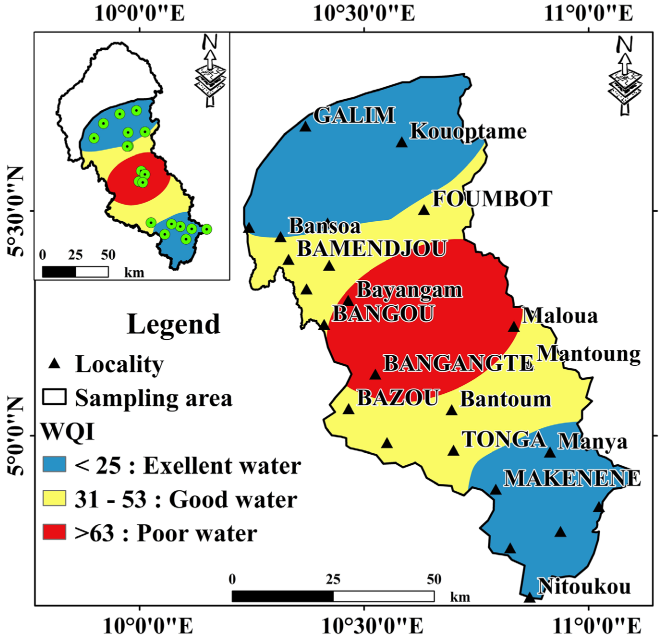

**Figure 2.** Spatial distribution of WQI values in the study area.

This suggests that the water in this part needs to be seriously treated before any use in conformity with the standards prescribed by the WHO and ANOR.

### 3.4. Spatial Distribution and Identification Source of $HCO_3^-$, EC, Salinity, $PO_4^-$ in the Study Area

The spatial distribution of $HCO_3^-$, EC, Salinity, and $PO_4^-$ in water is displayed in **Figure 3**. In these figures, yellow and red colors denote higher concentrations, and blue denotes lower concentrations. Since EC is a material's capacity to conduct an electric current, a high EC value suggests that salts have accumulated in surface water. The EC values for this investigation vary from 35.5 µS/cm to 258 µS/cm (**Table 2**). The northern and central parts of the study area exhibit high EC values, whereas the southern part does not. In contrast, the lowest values are dispersed unevenly throughout the region, according to the spatial distribution map (**Figure 3**).

Fresh water availability was indicated by higher EC values in the north and central part of the study area and lower values in the south and their surroundings (**Figure 3**). As shown by the map, salt is present everywhere in that zone since the conductivity of water depends on the amount of salt in the area. The $PO_4^-$ is present in the northern part of the study area, whereas the $HCO_3^-$ is mainly found in the center of the study area.

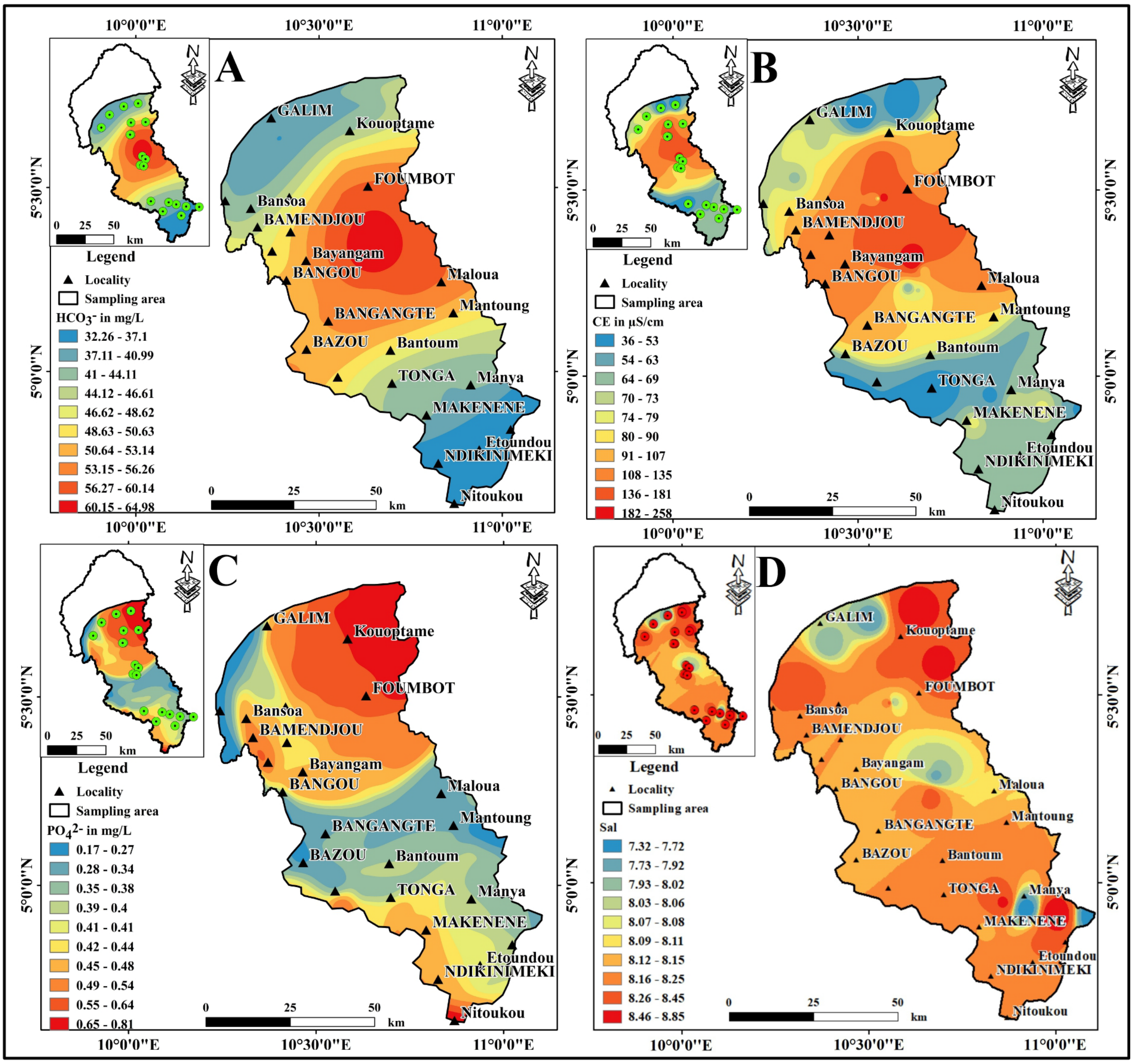

**Figure 3.** Spatial distribution of $HCO_3^-$ (A), EC (B), $PO_4^-$ (C), and Salinity (D) in the study area.

## 4. Conclusion

The NCA watershed is located, from a hydrogeological point of view, on the Cameroon Volcanic Line. The famous and long chain of volcanoes extends from the Atlantic Ocean into Cameroon. The main objective of this research was to assess water quality and its suitability in terms of consumption and irrigation in the Noun Catchment Area (NCA) in the Western Highlands of Cameroon. Therefore, eleven (11) water quality parameters (pH, EC, $Mg^{2+}$, $Ca^{2+}$, $Na^+$, $NH_4^+$, $K^+$, $Cl^-$, $HCO_3^-$, $SO_4^{2-}$, $F^-$) were evaluated in order to ascertain the suitability of surface water in the study area for drinking purposes because surface water is the main source of water supply in the area. The order of abundance of cations in the water samples of the study area is as follows: $Ca^{2+} > Mg^{2+} > NH_4^+ > Na^+ > K^+$, and anions were in the decreasing order of $HCO_3^- > PO_4^{2+} > Cl^- > NO_3^- > SO_4^{2-} > F^-$. In this study, there is a high and strong positive correlation of TDS with CE, Salinity, $HCO_3^-$, between CE with Salinity, $HCO_3^-$, and between $HCO_3^-$ and Salinity. Also, there is a moderate positive relationship between $NH_4^+$ with $HCO_3^-$ and Salinity, $PO_4^-$ and Salinity. The variables with correlation values less than 0.50 indicate a weak correlation, like $K^+$ with other variables like Salinity, TDS, CE, and $Mg^+$. The strong to moderate positive relationship between major ions implies that these ions were derived from the same source, which is the leaching of some materials in this area. In addition, the strong correlation between Salinity and Electrical Conductivity implies the presence of salt in the study area. Beyond analyzing the spatial distribution of WQI, $HCO_3^-$, EC, Salinity, and $PO_4^{2+}$ was performed in order to examine their influence in the study area. The northern and central parts of the study area exhibit high EC values, whereas the southern does not. In contrast, the lowest values are dispersed unevenly throughout the region, according to the spatial distribution map. Fresh water availability was indicated by higher EC values in the north and central part of the study area and lower values in the south and their surroundings. As shown by the map, salt is present everywhere in that zone since the conductivity of water depends on the amount of salt in the area. The $PO_4^-$ is present in the northern part of the study area, whereas the $HCO_3^-$ is mainly found in the center of the study area. The southwestern and a small portion of the southeast section of the research area are heavily polluted by anthropogenic waste. As a result, adequate remedial procedures or treatments are required to avoid water vulnerability. The spatial distribution map of WQI shows the highest concentration in the central part of the study area.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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