Groundwater resources for domestic and irrigation purposes in Melong (Littoral Region, Cameroon): Hydrogeochemical constraints

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Groundwater is a valuable natural resource whose quality is threatened by natural and man-made pollutants. This study aims to perform a hydrochemical characterization of groundwater resources used for domestic and irrigational activities in Melong (Littoral Cameroon). Thus, 26 subsurface water samples were collected in the dry season (six sampling points) and rainy season (seven sampling points) of the years 2019 and 2020. Physical water quality parameters were measured on the field while ionic constituents and bacteriological parameters were determined in the laboratory. The main findings revealed that the pH of the water samples was slightly acidic to neutral, fluctuating from 5.3 to 7.1; electrical conductivity ranged from 0.03 to 0.33 µS/cm and turbidity varied from 0.5 to 33.7 NTU revealing that the water is weakly mineralized. The ionic constituents were such that Ca²⁺ > K⁺ > Mg²⁺ > Na⁺ for cationic constituents while anions appeared as HCO₃⁻ > NO₃⁻ > Cl⁻ > PO₄³⁻. The major ions fell within the acceptable limits of World Health Organisation (WHO) drinking water standards. Bacteria indicators of faecal pollution were identified in all the water samples, including Enterobacteria, Escherichia coli, Streptococcus, Salmonella, Shigella, Staphylococcus and Vibrio. This indicates an exposure of water sources to unhygienic conditions that may place consumers at risk of water-borne diseases, hence necessitating basic treatment of the water before consumption.

Key words: Hydrochemistry, Melong, groundwater quality, bacteriological analysis, Littoral Cameroon.

INTRODUCTION

Water, an essential constituent of life, is vulnerable to tremendous stress as a result of rapid urbanization, agricultural innovations and industrialization (Sudha, 2007; Yildiz, 2017; Olalekan et al., 2018; Raimi et al., 2019). Groundwater alone provides a substantial amount of about 97% out of all potentially available fresh water
resources for human use (Annapoorna and Janardhana, 2015; Olalekan et al., 2020). It is one of the most prominent and reliable sources of fresh water all over the world, owing to its high quality and potential availability (Kemper, 2004; Nickson et al., 2005; Sujay and Paresh, 2015; Raimi and Sabinus, 2017; Morufu and Clinton, 2017). Access to safe drinking water is a fundamental right of all human beings (Gift et al., 2020; Gift and Olalekan, 2020). Therefore, sustainable management as well as development of underground water is primordial to ascertain the provision of adequate water supply (Macdonald et al., 2012; Olalekan et al., 2019). The issue of sustainability and maintenance of drinking water sources is a major challenge to developing countries, including Cameroon where groundwater is currently the main reserve for domestic water supply and irrigation, amongst other uses. Despite the country’s richness in water resources (Katte et al., 2003; Molua and Lambi, 2006), most communities cannot boast of adequate supply of potable water for various activities as a greater proportion of the rural population, especially in rural settings, use precarious water sources for drinking (Kuitcha et al., 2010; Raimi et al., 2017; Olalekan et al., 2018; Raimi et al., 2019). Groundwater is increasingly being exploited for domestic use in many urban and peri-urban communities which necessitates a thorough hydrogeochemochemical investigation. Also, most surface water reservoirs are progressively deteriorating as a result of inadequate waste management facilities and uncontrolled usage of agrochemicals in agricultural fields (Isah et al., 2020a, b; Morufu, 2021; Hussain et al., 2021a, b). Related studies have been carried out in several other areas of Cameroon in the past years including, among others, the works of Katte et al. (2003) reporting the quality of water for domestic activity in Dschang, Ako et al. (2011) documenting nitrate contamination in the Banana Plain, Tita et al. (2013) highlighting microbial pollution in the Mezam River basin, Akochere and Ngwesse (2017) unfolding the occurrence of water borne diseases in Kumba while Alakeh et al. (2017) carried out spring water assessment in Awing village.

The population of Melong (Littoral Region of Cameroon), made up mostly of low income peasant farmers, relies entirely on subsurface water for their daily provision and there is currently no water quality monitoring mechanism to assess the potability of the water sources. This therefore necessitates monitoring the quality of the various groundwater sources in this Municipality. Thus, this research was conceived to evaluate the suitability of various water sources for drinking and irrigation, as well as to identify the hydrogeochemochemical processes influencing water quality in this locality. The data obtained will provide groundwater quality information in the area thus contributing to the sustainable management of groundwater resources.

MATERIALS AND METHODS

Study area description

The town of Melong in the Mounngo Division of the Littoral Region (Cameroon) is found between latitudes 5°30’ and 5°9’ N and longitudes 9°54’ and10°3’ E (Figure 1). This town covers a total surface of about 590 km² and is elevated at 790 m above sea level. The climate is the Guinean equatorial type, composed of two seasons (Molua and Lambi, 2006); a longer rainy season of seven months (from April to October) and a shorter dry season of about five months (from November to March). Temperatures vary between 21 and 23.8°C and the average annual precipitation is about 2484 mm. The relief of the area has an influence on the drainage pattern with rivers such as Ngoedi and Marrigo draining the area. The major channels are characterized by rapids, representing exposed lava flow fronts and flanks. The major soils in Melong area the red ferrallitic soils formed mainly on volcanic material while the lowlands are occupied by hydromorphic soils.

Geologically, the study area lies on the flanks of Mount Manengouba (2411 m above sea level), which consists of a mountainous chain of two stratovolcanoes affected by double subsidence that resulted in the formation of two calderas: the Eboga and the Elengoum (Itiga et al., 2004). Studies by Sato et al. (1990) have shown that Mount Manengouba is a polygenic volcano characteristic of Ocean Island Basalts (OIB). Detailed geochemical studies of basaltic lavas from Mount Manengouba are reported by Kagou et al. (2001) (Figure 1).

Data collection

Twenty six water samples were collected from seven sampling points in the wet period and six sampling points in the dry period in 0.5 L polyethylene containers; July for the wet season and February for the dry period. Six water samples were rather collected during the dry period because sampling point MS7 was an intermittent spring and had dried up. Two water samples were collected from each sampling point in view of physicochemical and bacteriological analyses. The sampling containers were initially cleansed using distilled water and finally with the water from the respective sampling points. Each sampling point was then georeferenced using a Garmin 78 Global Position System. Samples from shallow wells were obtained with the use of a bucket to which a rope was fastened while water samples from the spring and tap were collected directly into the sampling containers. After collection, the sampling bottles were immediately capped, labeled and placed in an ice-cooled flask to maintain the temperature at 4°C (APHA, 1995) and were conveyed to the laboratory for analyses within 24 h. The various water sources, sample codes and coordinates are compiled in Table 1.

Physical properties

Some physical properties of water, such as, pH, electrical conductivity and turbidity were measured in situ with the aid of a
Table 1. Sampling points and their coordinates.

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Neighbourhood</th>
<th>Coordinates</th>
<th>Elevation (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW11</td>
<td>Quartier Pond</td>
<td>N05° 06’ 55.1” E009°5705.2”</td>
<td>835</td>
<td>11 m deep, dug in basaltic rocks</td>
</tr>
<tr>
<td>MW30</td>
<td>Quartier Bonanjo</td>
<td>N05°06’ 48.0” E009°5635.5”</td>
<td>847</td>
<td>1.5 m deep, poorly constructed besides a polluted stream and is susceptible to floods in the wet period</td>
</tr>
<tr>
<td>MW45</td>
<td>Quartier Functionaries</td>
<td>N05°07’ 23.9” E009°56350.9”</td>
<td>882</td>
<td>32 m deep, found at an uphill direction to habitation and its water appeared clear.</td>
</tr>
<tr>
<td>MS7</td>
<td>Quartier pond</td>
<td>N05°06’ 54.4” E009°5659.1”</td>
<td>830</td>
<td>Intermittent spring with much waste littered in its surroundings.</td>
</tr>
<tr>
<td>MS46</td>
<td>Quartier Hausa</td>
<td>N05°07’ 00.0” E009°5650.4”</td>
<td>842</td>
<td>Poorly constructed well with no protection. Pit latrines at less than 10 m away as well as dump sites. Used widely by the population for domestic chores including drinking.</td>
</tr>
<tr>
<td>MS50</td>
<td>Quartier Nancy</td>
<td>N05°07’ 15.7” E009°5721.4”</td>
<td>796</td>
<td>Situated in a thickly populated area, with farmland around. Used widely by the population for domestic chores.</td>
</tr>
<tr>
<td>MT64</td>
<td>Quartier Bonanjo</td>
<td>N05°06’ 52.0” E009°5642.1”</td>
<td>835</td>
<td>Reference sampling point. Used widely by the population for domestic chores including drinking.</td>
</tr>
</tbody>
</table>

multi-parameter probe (PC Stestre 35).

Chemical properties

Ionic constituents (cations and anions) of the water samples were dosed in the Research Unit of Soil analysis and Environmental Chemistry (URASCE) of University of Dschang, Cameroon. Sodium (Na⁺) and Potassium (K⁺) ions were determined by flame photometry method. Calcium (Ca²⁺) and Magnesium (Mg²⁺) were analysed by titration as described by Hounslow (1995). Chloride ion (Cl⁻) and bicarbonate ion (HCO₃⁻) were dosed by titration according
These results corroborate with those of Alakeh et al. (2017) on spring water in Awing (Bamenda Highlands, North West Cameroon). On the other hand, turbidity values fluctuated from 33.7 NTU at MW30 in the dry season to 0.5 NTU at MS46 in the rainy season (Figure 2c). 15.38% of the analysed water samples recorded turbidity values above the recommended value (5 NTU) of WHO (2017). Turbidity can seriously impede the efficiency of disinfection by providing protection for organisms.

Ammonium ion, carbonate and sulphate ions were absent in the analysed water samples throughout the campaign period (Table 2). The insignificant values of EC are generally recorded in the dry period (Table 2). The very high EC values of 7.44 µS/cm were recorded in the wet season at MW11 (Figure 2a). The pH values were below neutrality and ranged from 5.3 to 7.1 (Table 2). The highest pH value (7.1) was observed in the dry season at MW30 and the lowest (5.3) was noted in the rainy season at MW11 (Figure 2a). The pH values revealed that only 16.67% of the studied groundwater samples fell in permissible limits of 6.5 to 8.0 for domestic use as prescribed by WHO (2017) while 83.33% fell outside the limits. The slightly acidic nature of the groundwater might stem from precipitation and dissolution of minerals, as well as the degradation of organic matter by microorganisms in the aquifer system (Winter et al., 1998). Similar results have been documented by Alakeh et al. (2017) in the Njombe-Penja area, Sabrina et al. (2013) in the Logone Valley (North-Cameroon), Magha et al. (2015) and Akoanung et al. (2019) in Bamenda (North West Cameroon). The pH of water can disrupt many biogeochemical processes and absorption of some ions like ammonium ion as well as limit biodiversity allotment in water bodies (Dirosu et al., 2019). The values of electrical conductivity fluctuated between 0.03 and 0.33 µS/cm. Higher values were generally recorded in the dry period while lower values prevailed in the wet period (Figure 2b). The values of EC were much lower when compared with the recommended levels of WHO (2017). The insignificant values of EC are an indication of minimal dissolved components in the aquifer system. These results corroborate with those of Alakeh et al. (2017) on spring water in Awing (Bamenda Highlands, North West Cameroon). On the other hand, turbidity values fluctuated from 33.7 NTU at MW30 in the dry season to 0.5 NTU at MS46 in the rainy season (Figure 2c). 15.38% of the analysed water samples recorded turbidity values above the recommended value (5 NTU) of WHO (2017). Turbidity can seriously impede the efficiency of disinfection by providing protection for organisms.

### Chemical characteristics

Ammonium ion, carbonate and sulphate ions were absent in the analysed water samples throughout the campaign period (Table 2).

### Table 2. Summary statistics of physicochemical parameters of the sampled groundwater.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Wet season</th>
<th>Dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>6.6</td>
<td>5.5</td>
</tr>
<tr>
<td>EC</td>
<td>µS/cm</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>6.6</td>
<td>0.5</td>
</tr>
<tr>
<td>K⁺</td>
<td>mg/L</td>
<td>5.78</td>
<td>0</td>
</tr>
<tr>
<td>Na⁺</td>
<td>mg/L</td>
<td>2.45</td>
<td>0.63</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>mg/L</td>
<td>6.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>mg/L</td>
<td>2.19</td>
<td>0.97</td>
</tr>
<tr>
<td>Fe²⁺</td>
<td>mg/L</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>mg/L</td>
<td>152.5</td>
<td>12.2</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>mg/L</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>mg/L</td>
<td>17.37</td>
<td>0</td>
</tr>
<tr>
<td>CO₃²⁻</td>
<td>mg/L</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>mg/L</td>
<td>42.6</td>
<td>17.75</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>mg/L</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>mg/L</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Analysis of data

Data were analysed using Microsoft Excel and Aquachem Scientific software version 1.5.

### RESULTS AND DISCUSSION

#### Physical parameters

Statistical data of the physicochemical characteristics of the water waters are compiled in Table 2. Mean values of pH were below neutrality and ranged from 5.3 to 7.1 (Table 2). The highest pH value (7.1) was observed in the dry season at MW30 and the lowest (5.3) was noted in the rainy season at MW11 (Figure 2a). The pH values revealed that only 16.67% of the studied groundwater samples fell in permissible limits of 6.5 to 8.0 for domestic use as prescribed by WHO (2017) while 83.33% fell outside the limits. The slightly acidic nature of the water waters are compiled in Table 2. Mean values of pH were below neutrality and ranged from 5.3 to 7.1 (Table 2). The highest pH value (7.1) was observed in the dry season at MW30 and the lowest (5.3) was noted in the rainy season at MW11 (Figure 2a). The pH values revealed that only 16.67% of the studied groundwater samples fell in permissible limits of 6.5 to 8.0 for domestic use as prescribed by WHO (2017) while 83.33% fell outside the limits. The slightly acidic nature of the
Cations

Major cations were ranked thus: Ca$^{2+}$>K$^+$>Mg$^{2+}$>Na$^+$. The highest concentration (5.78 mg/L) of potassium ion (K$^+$) during the rainy period was recorded at MW30 and MS46 while the highest level (4.04 mg/L) in the dry period was noted at MW30. The highest average value of 4.91 mg/L was observed at MW30 and the lowest (0.33 mg/L) was observed at MW45 and MS50 (Figure 2d). The K$^+$ could probably come from the hydrolysis of K-feldspar (albite) or K-fertilizer from nearby farmlands (Appelo and Postma, 2005). The higher (2.45 mg/L) concentrations of sodium ion (Na$^+$) were noted in the wet period whereas the lowest value of 0.07 mg/L was reported in the dry period (Figure 2e). The highest average value of 1.45 mg/L was observed at MS7 while the lowest one (0.35 mg/L) was noted at MW11, MW45 and MT64. A higher (7.04 mg/L) concentration of Ca$^{2+}$ was measured during the dry period while the lowest value (6.4 mg/L) was obtained in the wet period (Figure 2f). The highest average value (4.62 mg/L) was noted at MW11 and the lowest (2.06 mg/L) at MS50. The highest value was noted for Mg$^{2+}$ in the wet period (2.43 mg/L) whereas the lowest value of 0.97 mg/L was observed in the dry period (Figure 2g). The highest average Mg$^{2+}$ concentration (1.7 mg/L) was observed at MT64 meanwhile, lowest one (0.59 mg/L) was noted at MW11. The Ca$^{2+}$ may stem from the dissociation of gypsum in the aquifer system (Gountié et al., 2017). In both seasons the levels of Ca$^{2+}$, Mg$^{2+}$, Na$^+$ and K$^+$ were by far lower than the permissible limits of WHO (2017) for drinking water and therefore would not pose any threat on the health of the consumers.

Anions

The HCO$_3^-$ was detected in the water samples in both seasons with the highest value of 219.6 mg/L noted during the dry period while the lowest value of 12.2 mg/L was observed during the wet period. The highest average value (186.05 mg/L) was observed in MW30 whereas the lowest value of 18.30 mg/L was recorded at MS7 (Table 2). Just 15.38% of the analysed samples recorded HCO$_3^-$ in the permissible limit of 152 to 350 mg/L as stipulated by WHO (2017) for drinking water. HCO$_3^-$ could stem from input from the atmosphere as well as the biodegradation of organic compounds like petroleum and hydrocarbons (Winter et al., 1998). This may be a reflection of the extent to which hydrogeochemical processes take place in aquifers (Zheng et al., 2004). The NO$_3^-$ concentration, on the other hand, was higher in the dry season (19.85 g/L) compared to the rainy season (6.20 mg/L). The highest average value (18.61 mg/L) was observed at MS46 while the lowest (6.20 mg/L) was obtained at MS7. The NO$_3^-$ was noted in almost all the sampled water throughout the research period, except for MW45 and MS50. Nitrates could result from the breakdown of organic and inorganic constituents in the aquatic system, oxidation of nitrogen compounds, animal feed lots and from domestic waste water. Human activities can increase nitrate concentration up to about 1 to 5 mg/l in water sources (Eneke et al., 2011). The NO$_3^-$ level was below the permissible level of WHO (2017) of 50 mg/L. The highest value of the chloride ion of 42.6 mg/L was noted in the wet period meanwhile the lowest value of 3.55 mg/L was gotten during the dry period. The highest average value (17.75 mg/L) was recorded at MT64 and the lowest (8.87 mg/L) at MW11. The average values of Cl$^-$ in the water samples were above WHO (2017) permissible level of 5 mg/L. The Cl$^-$ ions might stem either from the disintegration of Cl$^-$ minerals that are in contact with the water in the aquifer or from human-induced activities through disinfection of wells as owners often pour chlorine in wells to treat the water after a certain time interval. The analysed water was devoid of phosphate ion during the wet period meanwhile during the dry period, it was recorded from all sampling points except for MS46 and MT64. Agriculture is practiced extensively in the area, in addition to septic tanks, pit latrines and domestic effluent and may contribute to the input of HCO$_3^-$, Cl$^-$, Na$^+$, K$,^+$, NH$_4^+$, NO$_3^-$ to the groundwater.

Hydrogeochemical facies

In order to better appreciate the chemical facies of the water samples, the Piper diagram (Piper, 1944) (Figure 3a and b) and Durov’s plot (Durov, 1948) (Figure 4a and b) were plotted. From the Piper trilinear diagrams, it was observed that 85.7% of the analysed water plotted in the Ca-Mg-Cl-SO$_4^-$ domain in the rainy period, while 14.3% fell in the Ca-Mg-HCO$_3^-$ domain; this is indicative of the abundance of alkaline earth metals. In the dry period, on the other hand, all water samples fell inside the Ca Mg-HCO$_3^-$ field (Figure 3b). Durov’s diagrams (Figure 4a and b) enabled the confirmation of the existence of mixed water type as most of the samples plotted along the dissolution or mixing and ion exchange fields. On the basis of a classification by Artimes et al. (2011), the pattern could be assigned to freshly recharged water displaying simple mixing without any dominant ionic constituent.

Mechanism controlling water chemistry

The dissolved load of ionic constituents in aquifer systems is a function of geochemical processes operating in the aquifer. Plots of Na$^+$/ (Na$^+$+K$^+$+Ca$^{2+}$) and Cl$^-$/ (Cl$^-$/ (Cl$^-$/HCO$_3^-$) in relation to TDS are used to elucidate the possible origin of dissolved components in aquifers.
The chemistry of subsurface water is a reflection of the geology of the surroundings, the residence time of the water, deposition from the atmosphere as well as diffuse pollutants from point and non-point sources (Lloyd and Heathcost, 1985). Studies carried out by Gibbs (1990) revealed an intrinsic link between water chemistry and hydrochemical processes in the aquifer. From Figure 5, it is evident that the principal control of subsurface water chemistry in Melong is rock-weathering as supported by all the cations and anions plotting in that field for both seasons.

**Bacteriological characteristics**

The bacteriological properties of the analysed water are presented in Table 3. Species indicative of faecal pollution were detected from most of the sampled water with elevated counts recorded
during the wet period and lower counts during the dry period. The highest count of *Enterobacteria* (700 CFU/100 ml) was obtained during the wet period in sample MS7 and the lowest value (50 CFU/100 ml) was obtained from sample MW11 in the dry period. *E. coli* counts were higher during the wet period in sample MS7 and the lowest value (50 CFU/100 ml) was obtained from sample MW11 in the dry period.
(500 CFU/100 ml) and the lowest value (10 CFU/100 ml) was noted in sample MW11 in the dry period. *Streptococcus* count was also higher during the wet period in sample MS7 (150 CFU/100 ml) and lowest in sample MS46 (5 CFU/100 ml) in the dry period. *Salmonella* spp. was highest during the wet period in sample MT64 (300 CFU/100 ml) and lowest (15 CFU/100 ml) during the dry period in sample MW11. The highest load of *Shigella* during the wet period was noted in sample MS7 (50 CFU/100 ml) and the lowest in sample MW30 (10 CFU/100 ml) during the dry period. The highest value of *Staphylococcus* (300 CFU/100 ml) during the wet period was gotten from sample MS7 and the lowest from sample MS46 (5 CFU/100 ml) in the dry period.

Figure 4. Durov plot of Melong water samples for the rainy season (a) and dry season (b).
The highest value of Vibrio was noted in the wet period from sample MS7 (150 CFU/100 ml) and the lowest (10 CFU/100 ml) from samples MW30 and MW45 was obtained during the dry period. There was no spectacular variation in indicator bacteria amongst the sampling points. High counts prevailed during the wet period whereas lower counts were noted during the dry period, with Enterobacteria portraying the highest counts of 700 CFU/100 ml in MS7 during the wet period. This same sampling point presented high counts of Vibrio (150 CFU/100 ml). On the other hand, Streptococcus was not detected in water samples from MS46 during the wet period but was recorded during the dry period. All species were absent in MT64 in the dry season.

Fitness of the studied water sources for domestic uses

The results obtained were assessed to appraise the potability of the analysed water for domestic use with reference to WHO (2017) guidelines. pH values of the
subsurface water was slightly acidic to neutral and water samples from MW11, MW45, MS46 and MS50 had values out of the permissible limits of WHO in the rainy season. Turbidity values higher than 5 NTU were obtained from MS7, MW30 and MT64. This is an indication of exposure of the water sources to physical contaminants as a result of lack of protective measures. The values of Cl− exceeded the recommended levels in the wet period in all the water samples whereas all the other parameters were within acceptable limits for drinking water. With respect to water hardness, the analysed samples had values fluctuating from 9.22 to 24.98 mg/L during the wet season and 6.01 to 24.96 mg/L during the dry period. Water hardness is of prime importance in appreciating water quality for domestic use and is ascribed to the occurrence of alkaline earth metals (Ca2+ and Mg2+). Hard water may pose no impact on health but rather an aesthetic issue due to disagreeable taste. With reference to Pandian and Sanka (2007) hardness classification, all groundwater samples in Melong can be classed as soft in both seasons, thus would have no potential health risk on the users. From a bacteriological perspective, the sampling points were grossly polluted with the exception of MW11 and MT64 in the dry season in which the level of indicator bacteria could be acceptable with respect to Cheesbrough (1991) classification. All the other sampling points require basic treatment before the water can be used for domestic purposes.

Suitability of the studied groundwater for agriculture

Characterizing water for agriculture is primordial because low quality water may adversely affect the output of some plant species (Mohammad et al., 2018). Watering of crops during the dry period is a common practice in Melong. This therefore necessitates investigating the category of water employed because contaminated water would have negative consequences on the crops that are watered. Irrigation water that contains high concentration of sodium salts would cause the salts to pile up in the root zones of crops thereby impeding the flow of water in the soil by physically damaging the soil structure. The classification of the water sources based on SAR values revealed that all samples from the water sources were below permissible levels according to Mohammad et al. (2018) and thus fit for agriculture.

Vulnerability of groundwater sources to pollution in Melong

Groundwater is easily accessed in Melong through hand-dug shallow wells which are in most cases not protected from pollution from diverse sources. The area is susceptible to floods during the wet season as the flood water overflows into the wells, thereby, raising the level of contaminants of the water. The indiscriminate use of fertilizers by farmers to increase crop yield, as well as cattle rearing upland by the Bororo grazers, where cow dung is often carried by overland flow to lower altitude where the poorly constructed wells are found poses a great threat to the quality of groundwater resources. In most cases, poorly constructed latrines are not far from the hand-dug shallow wells and faecal waste could easily infiltrate and flow with groundwater to contaminate the water.

Conclusion

This current research was designed to investigate groundwater characteristics used in Melong (Littoral Cameroon) for domestic and irrigation activities. Subsurface water in Melong is acidic to neutral in nature, soft and lightly mineralized. Major water type is CaHCO3 whereas the main hydrogeochemical facies present were Ca-Mg-Cl-SO4 and Ca-Mg-HCO3. Water chemistry is predominantly controlled by weathering of the host rock through mineral dissolution and ion exchange processes as well as anthropogenic sources. Analytical results of the water samples revealed that tap water which served as the reference sampling point was of reasonable good quality thus, healthier than the well and spring water. Chemically, groundwater sources in Melong are fit for home use as well as for agricultural activities. As concerns bacteriological quality, all analysed samples presented indicators of pollution except for the tap water sample in the dry season. The subsurface water sources may threaten human health if the water is consumed without pre-treatment. A heavy metal investigation is therefore recommended for the groundwater sources so as to establish their suitability for various activities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES


