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Hydrogeochemical characteristics of shallow groundwater in volcanic rock aquifer systems in the western and northern flanks of Mount Meru, Tanzania

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Introduction

- In the Arusha volcanic region in northern Tanzania (Fig. 1), water shortage is common and much of the surface water carries unacceptable levels of dissolved fluoride.
- Groundwater is the main source of drinking water.
- Unfortunately the quality of groundwater in this region also is very poor due to high fluoride content as a result of natural contamination from surrounding geological environment, leading to dental and skeletal fluorosis among the local population (Ghiglieri et al., 2012; Mckenzie et al., 2010).
- The lithology in this region is dominated by volcanic rocks from Mount Meru (Fig. 2), the eastern flank of Mount Meru is dominated by debris avalanche deposits while the western flank is dominated by pyroclastic deposits (Fig. 3).
- In this study, groundwater samples from springs, stream point and hand dug wells in the western and northern flanks of Mount Meru, Tanzania (Fig. 3) were collected and analysed to determine their chemical characteristics.

Figure 1. Location of Mount Meru in Arusha region, Tanzania.
(Source: modified after Wikimedia; commons.wikimedia.org)

Figure 2. Western flank of Mount Meru, Tanzania.

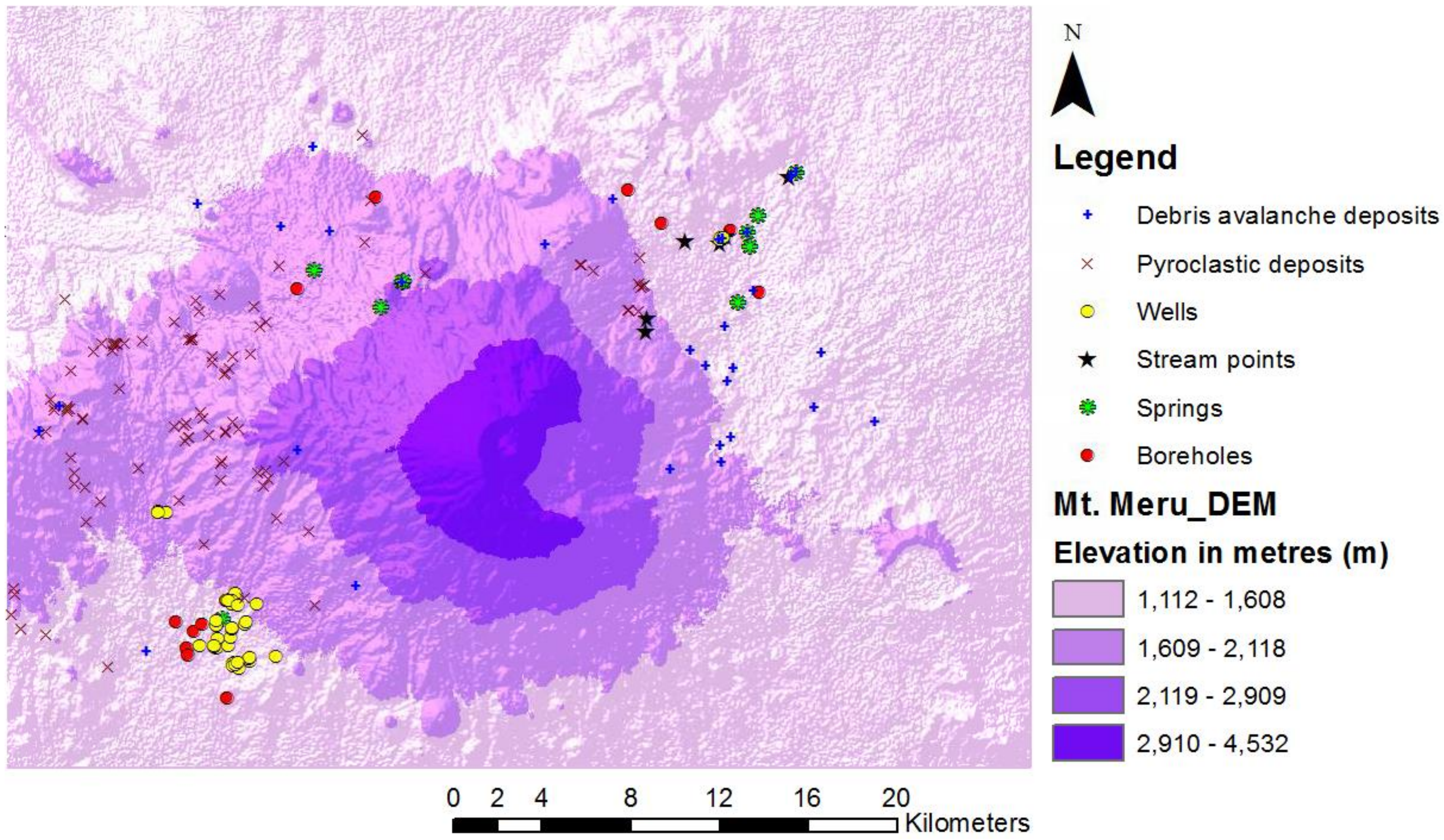

Figure 3. Spatial distribution of wells, springs, stream points, boreholes, debris avalanche deposits and pyroclastic deposits in the Eastern, Western and Northern flanks of the Mount Meru. (Note: Stream points are considered as seasonal springs).

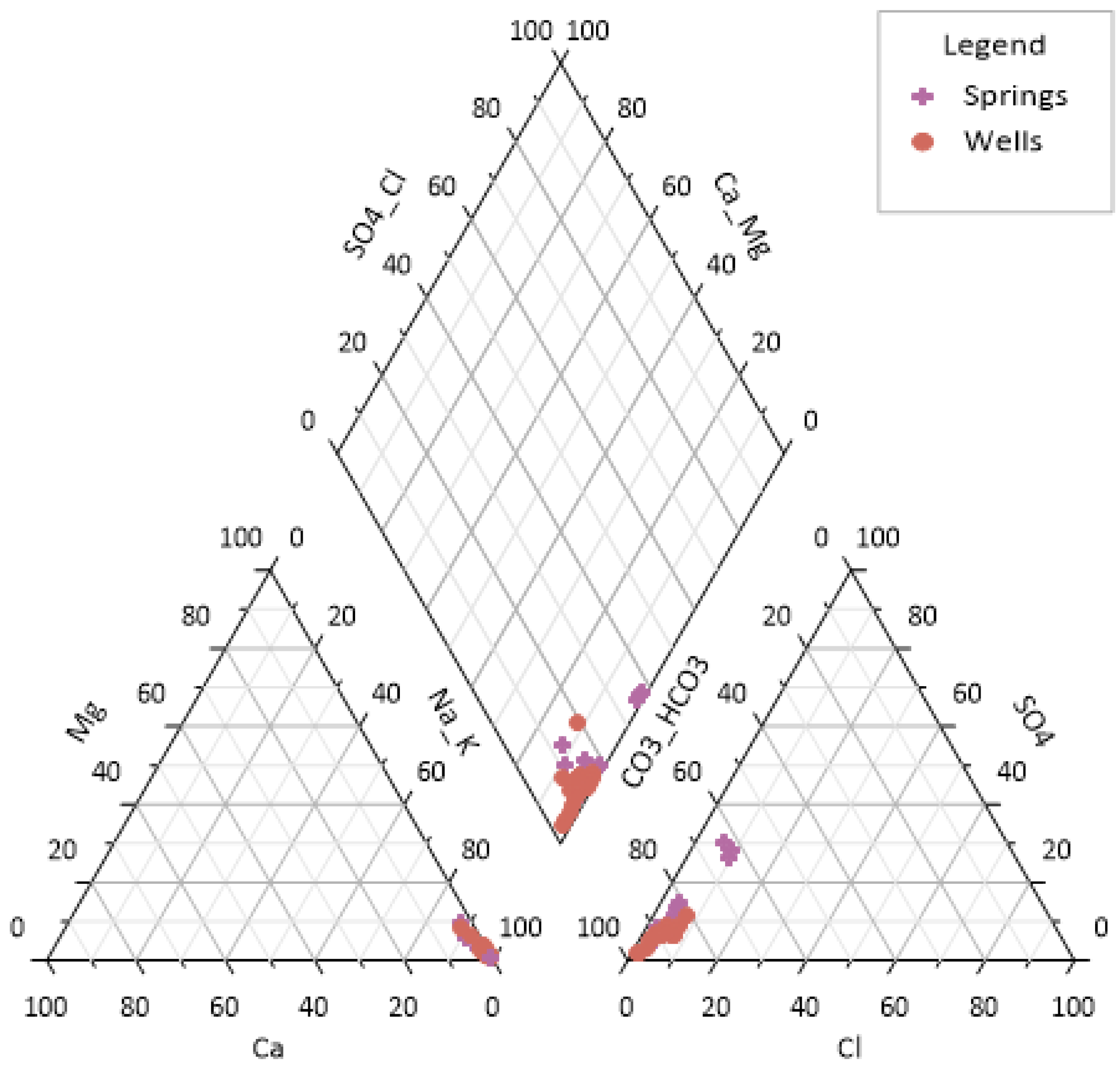

Figure 4. Piper diagram with classification of major ions from groundwater samples taken from springs and hand dug wells in the western and northern flanks of Mount Meru, Tanzania.

Methods

- A field campaign was conducted from 9th July – 26th September 2017.
- A portable device Aquaread AP-700 was employed in the field to record temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), and total dissolved solids (TDS) in the groundwater (from15 springs and 41 wells).
- 35 groundwater samples (from 15 springs and 20 wells) were collected for 4 days from 23rd – 26th September 2017.
- Groundwater samples were transported to Belgium and analysed for chemical properties at the Laboratory for Applied Geology and Hydrogeology, Ghent University.

Results

- Preliminary results obtained from analyses show contrast in pH, electrical conductivity (EC), total dissolved solids (TDS) and F^- concentration across the study area, with some significant spatial patterns for water samples from springs where pH, EC, TDS and F^- concentration increase with decrease in elevation.
- Sodium (Na^+) and bicarbonate (HCO_3^-) are the dominant ions hence the main water type in this area is $NaHCO_3$ type water as represented in Fig. 4 (Piper, 1944).
- Table 1 shows the range and average values for pH, EC, TDS, Na^+ and HCO_3^- in the groundwater.
- High values of F^- (up to 41.2 mg/l) were recorded. The concentration of fluoride in the groundwater varies from 3.87 to 41.2 mg/l with an average value of 15.7 mg/l.
- In all 35 groundwater samples, F^- exceeds the WHO limit (1.5 mg/l), whereas the 97% (34 samples) are above the Tanzanian limit (4 mg/l). The only sample with lower F^- value (3.87 mg/l) than the Tanzanian limit is from a hand dug well in the western flank of Mount Meru.

Table 1. Range of values for pH, EC, TDS, Na^+ and HCO_3^- in the groundwater

Parameter	PH	EC (µS/cm)	TDS (mg/l)	Na^+ (mg/l)	HCO_3^- (mg/l)	F^- (mg/l)
Minimum value	6.97	439	336	75.7	188.49	3.87
Maximum value	8.11	3500	2781	711.5	1342	41.2
Average value	7.51	1302	1073	265.9	627	15.7

Conclusions

- Results indicate that most water samples are not suitable for human consumption under both WHO and Tanzanian standards due to high fluoride content. This represents a challenge as most people do not have any alternative for drinking water.
- The only sample with lower F^- value than the Tanzanian limit gives hope for the presence of low fluoride groundwater hence the search for safe (low fluoride) groundwater in this region is of great significance.
- The different geological formations (pyroclastic vs debris avalanche deposits) have a first-order control on the spatial distribution of fluoride contamination.
- High fluoride concentrations are linked to high sodium contents and pH, and low Ca^{2+} concentrations. The weathering of Na-rich volcanic rocks increases pH which in turn triggers the dissolution of CO_2. The dissolution of CO_2 increases HCO_3^-, which at high pH is producing CO_3^{2-}, causing oversaturation in the groundwater compared to calcite, and leading to the precipitation of this mineral. This precipitation lowers the Ca^{2+} concentration in solution and leads to a sub-saturation with respect to fluorite in the system. As a result, fluorite will dissolve and an increase in F^- concentration is observed (Coetsiers et al., 2008).

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