Geogenic groundwater pollution in volcanic rock aquifer systems on the eastern, western and northern flanks of Mount Meru, Tanzania – special reference to fluoride

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Abstract

In the Arusha volcanic region in northern Tanzania, within the eastern branch of the East African Rift, water shortage is common and much of the surface water carries unacceptable levels of dissolved fluoride; hence groundwater is the main source of drinking water. Unfortunately, the quality of groundwater in this region is also very poor due to a high fluoride (F^-) content because of natural contamination from the surrounding geological environment. Consumption of this water leads to dental and skeletal fluorosis among the local population. The lithology in this region is dominated by volcanic rocks from Mount Meru. The surface sediments on the eastern flank of Mount Meru are dominated by debris avalanche deposits, while the western flank is dominated by pyroclastic deposits. Existing borehole completion reports and field stratigraphic description of sub-surface sediments during the digging of new hand dug wells were used to characterise the geology of aquifers. On the western flank, the main aquifer is a fractured and weathered basalt while on the south-western and north-eastern flanks the aquifers are composed of volcanic deposits (ash, tuffs, pumice, lapilli) and fractured and weathered basalt.

Two field campaigns were conducted between July – September 2017 and March – September 2018 where a total of 182 water points (96 wells, 51 springs, 17 boreholes, 11 stream points, 4 tap water points (for remote springs), and 3 lakes) were mapped and inventoried with the aim of quantifying and characterising the water resources on the flanks of Mount Meru. A portable device Aquaread AP-700 was employed in the field to record temperature, oxidation-reduction potential (ORP), pH, electrical conductivity (EC) and dissolved oxygen (DO) in the groundwater.

A total of 159 groundwater samples from 114 water points (61 hand-dug wells and 53 springs) were collected for chemical analysis from the two field campaigns conducted. Sodium (Na^+) and bicarbonate (HCO_3^-) are the dominant ions hence the main water type in this area is Sodium bicarbonate ($NaHCO_3$). Preliminary results show strong contrasts in pH, EC, TDS and F- concentration across the study area, with some spatial patterns for water samples from springs (on the north-eastern flank) where pH, EC, TDS and F- concentration increase with a decrease in elevation.

In all 159 groundwater samples, 91% (144 samples) have F^- concentration higher than the WHO limit (1.5 mg/l) recommended for drinking water. The 9% (15 samples) with F^- concentration lower than the WHO limit are water from the springs found in the recharge area at higher elevation on the eastern flanks of Mount Meru inside the Arusha National Park. Based on the Tanzanian limit (4 mg/l), 80% (127 samples) are above the limit, while the 20% (32 samples) which are below or within the limit.

The chemistry of the groundwater shows that weathering and dissolution of silicate minerals (especially chemical weathering of Na-K-rich volcanic rocks), dissolution of fluoride-rich minerals and calcite precipitation play great roles on the chemical evolution of groundwater in the study area while long residence time and nature of the geological formations (including degree of weathering) play great roles in the groundwater fluoride contamination in the area.