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The occurrence of high fluoride and arsenic in groundwater

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The Central Main Ethiopian Rift basin is a continental rift system characterized by volcano-tectonic depression endowed with huge geothermal resource and associated natural geochemical changes on groundwater quality that causes adverse health effect on the people in the area. Chemical composition of groundwater in the study area showed a well defined trend along flow from the highland and escarpment to the rift floor aquifer. The low TDS (< 500mg/l) Ca-Mg-HCO_3 dominated water at recharge area in the highlands and escarpments evolve progressively into Ca-Na-HCO_3 and Na-Ca-HCO_3 type waters along the rift ward groundwater flow paths. These waters finally appear as moderate TDS (mean 960mg/l) Na-HCO_3 type and as high TDS (> 1000 mg/l) Na-HCO_3-Cl type in volcano-lacustrine aquifers of the rift floor. The content of δ2H and δ18O in groundwater, surface water and rain water showed that the main recharge water for the geothermal system in the area originates largely from the highlands and escarpments areas.

High concentrations of fluoride (up to 97.2 mg/l) and arsenic (up to 98µg/l) are recognized feature of groundwaters which occur mostly in the vicinity of the geothermal fields and the rift lakes in the basin. Fluoride and arsenic content of dry volcaniclastic sediments close to these areas are in the range 666-2586mg/kg and 10-13mg/kg respectively.

The relationship between fluoride and calcium concentrations in groundwaters showed negative correlation. Near-equilibrium state attained between the mineral fluorite (CaF2) and the majority of fluoride-rich (>30mg/l) thermal groundwater and shallow cold groundwater. This indicated that the equilibrium condition control the high concentration of fluoride in the groundwaters. Whereas undersaturation state of fluorite in some relatively low-fluoride (<30mg/l) thermal waters indicated a dilution by cold waters.

Laboratory batch leaching experiments showed that fast dissolution of fluoride from the sediment samples suddenly leached into the interacting water at the first one hour and then remain stable throughout the experiment. The concentrations of leached fluoride from the hot spring deposits, the lacustrine sediments, and the pyroclastic rock are usually low (1% of the total or less than the content in the sediment or rock) but strongly correlated with the concentrations in groundwaters in the local vicinity. The readily leachable hot spring deposits and local lacustrine sediments, which were leached easily as high as three fold of other sediments leachability, are considered as the reservoir for the potential fluoride contamination of the rift groundwater.

Leaching of fluoride in the sub-surface system is simulated with sediment-packed column leached by flowing water and applying temporary interruption of flow during the experiment. The result indicated that a sharp increase of fluoride concentration (up to 58mg/kg) observed in leachates before one pore-volume of water eluted from the column. The concentration of leached fluoride consequently declined with the increased flowing pore-volume of water and finally the lowest concentrations of leached fluoride occurred in the end of the experiment. Flow interruption during column leaching experiment causes a noticeable fluoride concentration perturbation due to the heterogeneity of the sediment.

In this study chemical composition of thermal waters are used to estimate the geothermal reservoir temperature, salinity, and mixing relationship between cold and thermal waters. The estimated reservoir temperature ranges 208 oC - 373 oC. Chloride-enthalpy mixing model of the geothermal systems shows that ascending thermal water highly interacts with the surrounding cold groundwater and cause modification on groundwater quality (high fluoride and arsenic concentration).

The study of leaching characteristics of sediments from the geothermal fields and near the rift lakes in the area was very significant in understanding the source and mechanism of groundwater contamination. This leads to indicate tools in understanding the level of fluoride contamination, restoring of groundwater quality, and hence overcoming the existing adverse health effects from water quality problems. Characterizing the hydrothermal system also assists for the exploration and development of the geothermal resource in the basin.

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