Spatial and temporal variations of stable isotopes in precipitation across Cameroon: The first Cameroon Meteoric Water Line

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Stable hydrogen and oxygen isotopes in precipitation are valuable tools in groundwater recharge studies and the study of atmospheric moisture sources/circulation. Despite their significance, the isotopic data on rainfall is limited in most regions of Cameroon. Accordingly, the stable isotopes in over 290 monthly rain samples from 2012 to 2015 in 15 locations/stations across Cameroon are being investigated. The rain sampling stations have been grouped into four regions as a function of distance from the Atlantic Ocean and elevation. These are the coastal (<100 km from the sea), inland (>100 km from the sea), highland (>244 km from the sea and >1000 m asl) and further inland (>600 km from the sea) regions. The primary objective is to produce local/regional meteoric water lines (L/RMWLs) over Cameroon and subsequently the Cameroon Meteoric Water Line (CMWL). Other goals are to describe the temporal and spatial variations in stable isotopes of the rainfall and their relationship to annual precipitation cycle and determine the main controls on isotopic variations. Present results reveal a very wide range in $\delta^{18}O$ and δD from -9.43‰ and -65.61‰ at high elevations in Kumbo (1715 m) to 3.86‰ and 38.61‰ in the Ndop plain, respectively. The significant variation suggests various controls on the isotopic composition of the rain. Rain stations (Mutengene, Douala, Lobe, Mundemba and Kumba) in the coastal region gives $\delta D = 7.87\delta^{18}O + 13.20$ ($R^2 = 0.96$, n = 90) as the RMWL. The relationship: $\delta D = 8.21\delta^{18}O + 14.40$ ($R^2 = 0.95$, n = 51) defines the RMWL for the inland stations (Mamfe, Yaounde and Bertoua). At the Bamenda Highland stations (Bamenda, the Ndop plain, Ndawara Tea Estate, Wum, Kumbo and Nkambe), the RMWL is defined by $\delta D = 8.07\delta^{18}O + 14.50$ ($R^2 = 0.98$, n = 139). Two stations (Ngaoundere and Garoua) further inland in northern Cameroon give a RMWL: $\delta D = 6.72\delta^{18}O + 5.21$ ($R^2 = 0.99$, n = 10) with a relatively lower slope and d-intercept. The low slope and d-intercept reflect partial evaporation of the falling rain drops under semi-arid conditions in northern Cameroon. Overall, the first CMWL is $\delta D = 8.08\delta^{18}O + 14.19$ ($R^2 = 0.97$, n = 290). The similarity of the slope to the Global Meteoric Water Line indicates equilibrium conditions during rain formation with a minor effect of evaporation during the fall of raindrops to the ground on a national scale. Additional inland sources of moisture other than the Atlantic Ocean explain the high d-intercept in rainfall across the country. High d-excess values (>>10‰) in coastal precipitation within the rainforest region of Cameroon reflect recycled moisture from the rainforest. Meanwhile, the high d-excess values in the high altitude rains in the Bamenda highlands suggest the interplay of altitude effect and inland recycled moisture from inland water bodies. Across the country, the stable isotopes show an inverse relationship between elevation and rainfall depths suggesting altitude and amount effects, respectively. However, there is no discernible decrease in the isotope values from the coastal to inland stations as would be expected; hence, a lack of continental effect. Enriched isotopic signatures clearly mark low convective activities at each site during the pre- and post-monsoon rains. Intense convection during the monsoon peak coincides with the most depleted isotope values in the precipitation. Thus, the generated rainfall isotopic data is useful as a marker of annual changes in rainfall patterns. Given the dependence of most Cameroonians on rainfed agriculture, such information from the isotopes offers an important monitoring tool for changes in rainfall patterns for subsequent remediation measures. The data is not only useful for groundwater recharge studies in Cameroon but

also for climatological research at a regional level (Central Africa).

Keywords: Stable isotope variations, Precipitation, Cameroon Meteoric Water Line, Deuterium excess, Moisture recycling, Amount effect

