Hydrochemical and isotopic composition of groundwater in Douala, Cameroon: Effect of recharge and waste water on water contamination

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High water demand for domestic use in the Douala urban city with over 3 million inhabitants is met mainly by shallow groundwater through shallow wells, boreholes and springs in Pleistocene alluvium and Pliocene sand deposits. Chemical controls and recharge process of the groundwater have not been thoroughly investigated. Accordingly, this study examines the main controls on groundwater composition and spatial view of its contamination, timing of recharge and link between the recharge process and quality of the water. Conventional field measurements in January 2015 were followed by analysis of major ions and stable hydrogen and oxygen isotopes in 52 water samples. A significant range of EC values from 15 to 6890 µS/cm in both surface water and the groundwater suggests various controls on the chemical composition of the water. Low pH values in the groundwater from 3.61 to 6.92 with an average value of 5.04 indicate an acidic aquifer. The water types were Na-Cl, Ca-Mg-SO_4-Cl, Ca-Mg-HCO_3 and Na-HCO_3 with the Na-Cl water type being the most dominant in shallow open wells, boreholes and springs. Despite the nearness to the sea, only the River Wouri and few groundwater samples were strongly affected by salinization. Nitrate, which exceeded the WHO guide value of 50 mg/l in 22 % of the groundwater, poses a health problem, particularly infant methaemoglobinaemia. Mass ratios of Cl/Br in the groundwater ranged from 54 up to 3249 (with an average value of 652). The ratios scattered mostly along the mixing lines between dilute waters, septic-tank effluent and domestic sewage. The majority of samples especially the high NO_3^- shallow open wells clustered around the septic-tank effluent end member. This cluster indicates that shallow groundwater in the urban city of Douala is highly contaminated by seepage from the numerous and widely distributed pit latrines. The stable isotopes in the groundwater indicated its meteoric origin and rapid infiltration after rainfall. Most groundwater samples plotted between precipitation in the months of April and August along the Douala meteoric line showing no isotopic signatures of the most depleted and heaviest September to October monsoon rains. The narrow plot suggests a timing of the main recharge between the April and August rains and no considerable variation in recharge conditions during the hydrological year. The $\delta^{18}O$ values showed narrow ranges and overlaps in rivers (-3.10 to -2.13 ‰), springs (-3.09 to -2.90 ‰), shallow wells (-3.79 to -2.47 ‰), and boreholes (-3.53 to -2.88 ‰) with an even spatial distribution. These observations depict hydraulic connectivity, good water mixing and a homogeneous aquifer system mainly receiving local diffuse/direct uniform areal recharge from rainfall. The rapid and diffuse recharge through the permeable alluviums and sands favour the leaching of effluent from the pit latrines into the aquifer system; hence, the high NO_3^- and Cl^- in shallow wells. Based on ionic relations, the groundwater chemistry is mainly controlled by silicate weathering, ion exchange and leaching of waste from pit toilets. Drilling of deep boreholes is highly recommended.

Keywords: groundwater chemistry, Cl/Br ratio, waste water contamination, environmental isotopes, diffuse groundwater recharge, Douala-Cameroon

