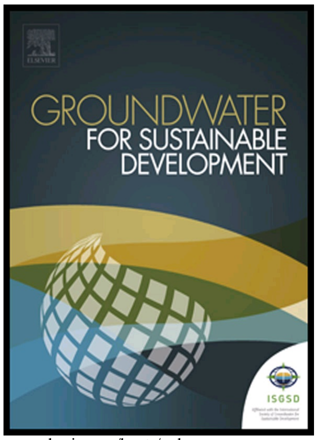

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Assessing groundwater recharge in crystalline and karstic aquifers of the Upper Crocodile River Basin, Johannesburg, South Africa

Khahliso Leketa[1*], Tamiru Abiye[1], Silindile Zondi[1], Michael Butler[2]

[1] School of Geosciences, University of the Witwatersrand, Private Bag X3, P.O Box Wits 2050, Johannesburg, South Africa *Corresponding author, kleketa@gmail.com

[2] iThemba Labs, Gauteng, Private Bag 11, Wits, 2050, South Africa.

Abstract:

Groundwater recharge and flow conditions were assessed in the Upper Crocodile River Basin, Johannesburg South Africa. This study revealed high elevation recharge from rainfall that is depleted in stable isotopes of water molecule ($\delta^{18}O$ and δ^2H) occurring prior to extreme evaporation. The effective recharge occurs from rainfall of varying moisture source and humidity conditions. The $\delta^{13}C$ (‰) value in groundwater indicates both open and closed system carbon evolution. Open system was observed in shale, andesite and granitic gneiss aquifers indicating that soil CO_2 is a dominant source of carbon in bicarbonate. Enriched $\delta^{13}C$ observed in Malmani dolomite aquifers deduced the presence of carbonate dissolution, which indicates a closed system carbon evolution. Mixing of water from open and closed systems, or evolution from closed to open system is also observed in groundwater samples that had intermediate $\delta^{13}C$ (‰) values, particularly groundwater samples that are positioned at the periphery of the Basement Complex granitic gneiss near the Malmani dolomite aquifers. The integrated mean annual recharge estimates obtained from BFS for the UCRB is 6.7% while the distributed point recharge estimates in the Malmani dolomite obtained from application of WTF on 43 individual boreholes ranged between 2.5% and 39% with an average of 15% as a percentage of MAP. A comparison between estimated recharge and groundwater abstractions conducted for each sub-catchment revealed that there is an excess of groundwater recharge over groundwater use in most sub-catchments. The CMB point recharge estimates obtained from the Albert Fam spring and the Malmani dolomite springs are 2.5% and 27.8% of MAP, respectively. The low CMB recharge estimates in the shale and quartzite has been attributed to possible anthropogenic chloride sources such as leakage of chlorinated potable water in the pipelines of the city of Johannesburg, which elevate chloride concentrations in groundwater.

Key words: Groundwater recharge; Stable isotopes of ^{18}O, ^2H and ^{13}C; Open carbon evolution; Closed carbon evolution; Johannesburg.

1. Introduction

In a region dominated by the semi-arid/arid climate, groundwater is usually the driving force behind economic development and the main source of water supply as the local surface water bodies are usually ephemeral (Scanlon et al., 2006; Manghi et al., 2009; Healy, 2010; Rivard et al., 2014; Abiye, 2016). The progressively changing climate setting, characterised by low rainfall and high temperatures leads to reduced terrestrial moisture (Engelbrecht et al., 2015; ASSAf, 2017). This condition has invoked more groundwater dependence in South Africa, which already has 60-90% groundwater dependence (Braune and Xu, 2008).

The city of Johannesburg, which is the economic hub of South Africa, is supported by inter-basin surface water supply due to its water scarce nature (Department of Water Affairs and Forestry, 2008). However, groundwater also plays a role in the socioeconomic development of the Johannesburg area, which is characterised as a semiarid climate (Abiye *et al.*, 2018). The highly intensive farming, industrial and rural domestic activities in the area tend to rely more on groundwater abstractions from aquifers made of weathered and fractured crystalline rocks (basement granites and meta-sedimentary