Geophysical Research Abstracts
Vol. 21, EGU2019-12365, 2019
EGU General Assembly 2019

Controls on recharge and water quality trends in response to floods in semi-arid Southern Africa

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In many arid and semi-arid regions, it is known that high rainfall and associated floods provide an important, if not the only, opportunity for groundwater recharge. However, such events can also facilitate contaminant infiltration and transport in the sub-surface, especially in (peri-)urban and agricultural areas. In these generally water stressed environments, including Southern Africa, appropriate management of water resources both during floods and for droughts therefore relies on a good understanding of the controls and mechanisms that are associated with surface and groundwater recharge, point-source pollution and transport.

Here we explored spatial and temporal patterns in surface water and groundwater quality in the upper Limpopo, Botswana, to better understand controls and mechanisms of recharge and water quality. This involved the peri-urban Gaborone catchment area ($\sim$250 km^2) which is characterised by a warm semi-arid climate, contrasted geology (a fractured metamorphic basement and karstified dolomite), and intensely managed water resources via surface water reservoirs and groundwater abstraction.

We evaluated the impact of two consecutive flood events (in 2017 and 2018) on the surface water and groundwater hydrochemistry, and explored the relative roles of physiographical, climatological and anthropogenic factors. The 2017 flood event involved extreme rainfall, which was preceded by a four-year period of severe drought, while the 2018 flood event was caused by relatively less rainfall but with wet antecedent conditions. Data collection involved monthly sampling for stable water isotopes, major ions and trace metals to elucidate water source mixing, lithological controls and contaminations, respectively. We evaluated temporal patterns across 16 surface water sites and 11 boreholes, with their locations reflecting a good spatial coverage across the river network, and also including different lithology, soils and land use.

The combination of stable water isotope and other hydrochemical tracer analyses revealed a scale dependence in hydrological system response, surface water - groundwater connections, and controls on water quality trends. Large scale spatial patterns in recharge and water quality generally reflected lithology. However, patterns in the magnitude of response were distinctly different in response to the 2017 and 2018 events. Nevertheless, locally, there was a significant imprint of land use, e.g. dumpsites and agricultural activity, on the major ion and trace metal concentrations and trends. Our results suggest that implications for management are spatially variable, and effectiveness of implemented management measures could be temporally variable. They also showed that to fully understand the impact of, and support effective adaptation to, hydroclimatic extremes, multi-scale, temporal and integrated surface-groundwater investigation and modelling approaches are essential.