HYDROGEOCHEMICAL CHARACTERISATION AND EVALUATION OF GROUNDWATER RESOURCES AND REVIEW OF GROUNDWATER MANAGEMENT SCHEMES IN KAMIESBERG, NORTHERN CAPE

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ABSTRACT

Kamiesberg, located in the semi-arid regions of South Africa, depends primarily on subsurface water resources for domestic, agricultural and industrial use. In order to assess geochemical evolution of groundwater and to identify salinization, a constant threat, regular monitoring is required. Here we evaluate decadal hydrogeochemical data collected by water management schemes applied in Kamiesberg to improve our understanding of the success of groundwater supply and management schemes in sustainable use of groundwater resources. IC and ICP-MS results proved a distinct Na-Cl character of the groundwater as well as elevated salinity of 100-350 mS/m towards the interior, along the Kamiesberg Mountains, and 730-1165 mS/m towards the west coast. Several towns are subjected to microbial contamination as well as fluoride concentrations above the allowable drinking water limit. Municipal water chlorination may be a contributing factor to increased chloride levels (>400mg/L). Potable water quality at towns served with treated (desalinated) water complies with the national drinking water standard for major element composition, emphasising necessity for wider distribution of desalinated and disinfected potable water. Soils analysed for U mainly indicated concentrations higher than the world mean value of 0.7-9mg/L, however, no correlation between U levels in groundwater and host rock was established.

INTRODUCTION

Kamiesberg, located in the semi-arid to arid western interior and coast of South Africa, depends primarily on subsurface water resources for domestic, agricultural and industrial use. Water supply developments have faced variable challenges associated with the heterogeneous yield, poor groundwater quality and scarcely populated land with an approximate population size of 12 117 (1) that prevail across Kamiesberg. Several studies have developed and piloted technologies for treatment and storage of water in Kamiesberg, conversely due to insufficient management of operations, including inconsistent monitoring and data collection, water yield and quality has deteriorated over the years of utilisation. By means of a hydrogeochemical transdisciplinary evaluation of the water resources and socio-economic dynamics of Kamiesberg an improved understanding of water supply and management schemes was obtained for the sustainable use of groundwater resources.

METHODOLOGY

The Kamiesberg study area was selected based on environmental factors including geological formations, hydrology (aquifer types, recharge), salinity, rainfall, land cover,

land use and population density. The National Groundwater Database was used to review historical groundwater chemistry data (2) whereas the South African Water Quality Guidelines were used as specification of the quality of water required for different domestic uses (3). Evaluation of the Kamiesberg socio-ecological system involved consecutive community workshops, household questionnaires, direct observation, water and rock sampling. Physico-chemical analyses included measurements of pH, reduction-oxidation potential (Eh), electrical conductivity (EC), temperature and GPS coordinates at each sampling point. Ion chromatography and ICP-MS were used for groundwater and drinking (tap) water quality assessment as well as whole rock analysis. On site microbiological quality was determined using the hydrogen sulphide strip test followed by laboratorial total coliform count. By means of geochemical, spatial and statistical modelling spatial trends and areas of potential concern were estimated and identified.

RESULTS AND DISCUSSION

The sosio-ecological evaluation identified aspects and/ or issues involving water quality, quantity (supply and demand), services and management which formed the basis for establishment and improvement of the water supply scheme. As formulated by the Kamiesberg community, the primary vision for Kamiesberg water resources and the communities that it serve was to improve the quality of life of its people through the sustainable, cost effective and integrated planning, management, development and protection of 1) water sources, 2) water usage and 3) water supply and distribution.

In order to support and develop the vision stipulated by the Kamiesberg community data obtained from various consulting firms and municipalities involving physical and chemical properties of the groundwater resources were investigated. It was found that few boreholes possessed data of regular or similar time intervals, making comparison of the overall geochemistry of groundwater in Kamiesberg complex.

As depicted on a hydrogeological map of the Springbok area (4) boreholes located in topographic higher areas near the Kamiesberg Mountains showed seasonally varied chemical data due to slightly higher rainfall and varied quantities of summer rainfall (between 100 and 520 mm year) compared to topographic low and flat areas with low cyclonic winter rainfall (20-290mm/year). The groundwater has a distinct Na-Cl character, mainly due to the geochemical composition of the crystalline rocks and alluvium from the Namaqua Metamorphic Complex (5, 6, and 7) which primarily hosts groundwater in the study area. The Na-Cl dominant rainfall chemistry, dissolution and leaching of evaporites further augments the salinity.

Chemical data plotted using ArcMAP and Microsoft Excel visually and graphically indicated distribution of the various geochemical parameters. The salinity measurements for boreholes along the mountain range varied between 100-150 mS/m and 250-350 mS/m during the wet and dry seasons respectively. Boreholes towards the west of the mountain range on low lying flat areas indicated relatively constant salinity values between 730-1165 mS/m over the monitored 8 year period. All borehole salinity measurements exceeded the national and international guideline for drinking water quality, which is <150 mS/m. Towns with potable water supplied from the local municipal desalination plants did however comply with the standard drinking water quality. A high chloride content (>400 mg/l) might be derived from the chlorination process applied as disinfect for drinking and domestic purposes.

Six of the fifteen towns in Kamiesberg were at risk of microbial contamination of drinking water, five of which form part of eleven towns with drinking water fluoride concentrations above the 1.5 mg/l maximum allowable limit (8). The high natural fluoride concentrations measured in fractured rock aquifers, with no significant change over a time period of 10 years, may be due to long residence times in deeper situated bedrock. This is an

indication that the drinking water quality in some of the towns are below the chemical and microbiological standard for drinking water.
Radiometric data indicated intrusions of highly radioactive granites near Garies (9). The core of the Namaqua belt consist of high-T granulite-facies gneisses and charnokites with 46 ppm U; 90 ppm Th and 52 ppm U; 400 ppm Th respectively, which exceed the upper continental crust average U (2.5 ppm) and Th (10.3 ppm). During weathering the mobility of U and Th depends on the host minerals and are likely to precipitate as hydrolysates or absorbed by organic matter and accumulated by microorganisms. It also forms stable oxides, carbonates, phosphates, vanates and arsenates. Soils analysed for U mainly indicated concentrations higher than the world mean value of 0.7-9mg/L, however, no correlation between U levels in groundwater and host rock was established.

CONCLUSION

Hydrogeochemical characteristics, as obtained from this investigation, suggest poor groundwater quality. Several towns in the study area have been supplied with municipal treated (desalinated and chlorinated) water that did not comply with the national standard for drinking water quality. These factors in conjunction with limited water supply in the area make a case for active measures required to improve and manage Kamiesberg water supply schemes.
Further, the towns in the eastern Kamiesberg can benefit from desalinisation, a practice currently only followed in western Kamiesberg. Previously discontinued artificial recharge, which demonstrated lower salinity and improved water quality in the area, should be re-established alongside an effective maintenance plan and training programmes to assure optimal and sustainable water resource usage.

REFERENCES

1. Statistics South Africa, 2009, “Community Survey 2007: Basic Results - Northern Cape”, Pretoria, Report No. 03-01-29.
2. Department of Water Affairs. National Groundwater Archive.
3. Department of Water Affairs and Forestry, 1996, “South African Water Quality Guidelines”, 2nd ed, Volume 1: Domestic Use. Holmes, S. (Ed).
4. Department of Water Affairs and Forestry, 2001. Springbok. Hydrogeological map series of the Republic of South Africa, 2916, 1:500000, South Africa: Department of Water Affairs and Forestry.
5. Titus, R.; Pietersen, K.; Williams, M.; Adams, S., Xu, Y., Saayman, I. & Colvin, C. 2002, “Groundwater assessment and strategies for sustainable resource supply in arid zones – The Namaqualand case study”, WRC Report No. 721/1/02
6. Xu, Y. & Braune, E. 2010, “Groundwater resources in Africa”,*In*: Xu, Y. & Braune, E. (Eds.). 2010, “Sustainable groundwater resources in Africa: Water supply and sanitationenvironment.”, pp. 19, 22-23.
7. Xu, Y., Kanyerere, T.,Braun, E., Nel, J., Hobbs, P., Bradbury, K. & Robins, N. 2010, “Best practice for groundwater quality protection”, University of Western Cape, Council for Scientific and Industrial research, Wisconsin Geological and Natural History Survey, British Geological Survey, *In*: Xu, Y. & Braune, E. (Eds.). 2010, “Sustainable groundwater resources in Africa: Water supply and sanitationenvironment.”, pp. 64-65.
8. Department of Water Affairs, 2011, “Blue Drop Report 2011: Northern Cape Province”.
9. Andreoli, M. A., Hart, R.J., Ashwal, L.D. & Coetzee, H 2006,. “Correlations between U, Th Content and Metamorphic Grade in the Western Namaqualand Belt, South Africa, with Implications for Radioactive Heating of the Crust”. Journal of Petrology Vol 47, Number 6, pp. 1095–1118.