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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Groundwater

Sampling and monitoring radioactive elements in groundwater

A WRC-funded project sought to develop a sampling and monitoring protocol for radioactive elements in fractured rock environments.

Background

The issue of radioactive pollution of groundwater in South Africa was first raised in 1967. In uranium mining areas, where uranium is liberated from the lithosphere at faster accelerated rates than that in nature, the high aquatic mobility of uranium frequently results in large-scale pollution of groundwater and surface water.

In the light of possible demand for uranium mining in South Africa, sampling and monitoring of the uranium element in borehole water needs to be assessed for the purpose of water security.

Beaufort West

During this WRC-funded project a number of field investigations were conducted in order to understand and verify hydrogeological settings. Beaufort West is a drought-prone area with a mean annual precipitation of about 225 mm. As a result of ongoing exploratory drilling and monitoring commissioned by the Department of Water Affairs and Beaufort West Municipality starting in the 1970s, geohydrological related data was readily available for this area.

The occurrence of radioactive elements in the Karoo Supergroup was first detected in the Karoo in 1964 during kimberlite exploration. Early in 1970, an America exploration company embarked on systematic search of uranium in the Karoo, which resulted in the discovery of uraniferous sandstone on a farm 20 km west of Beaufort West.

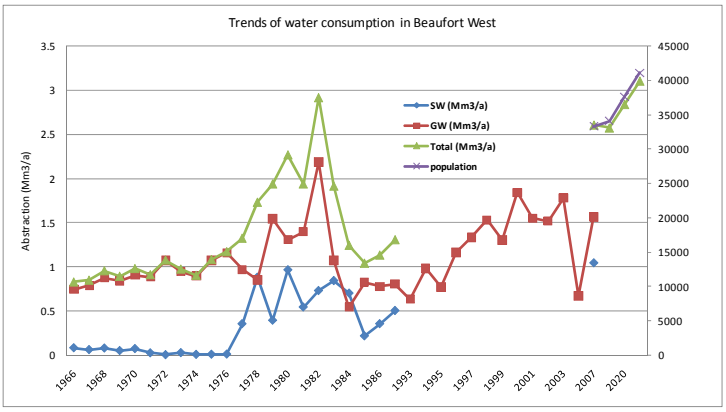
Subsequently, uranium mineralisation was discovered 40 km south of Beaufort West in 1973. The Geological Survey of South Africa undertook a detailed aeral-radiomatric survey, which started in 1976, to delineate major uranium occurrences in the Main Karoo Basin.

Despite a potential health hazard imposed by uranium waste to groundwater, which provides more than 50% of the total water supply of Beaufort West, no protection measures were ever initiated.

WRC project phases

This WRC project contained the following phased activities:

- *Phase 1* focused on a literature review of radioactivity in groundwater and compiling a database on the physic-chemical characteristics of radioactive elements.
- In *Phase 2* a hydrocensus of the study area was undertaken to assess the water resources utilisation of Beaufort West and its surroundings. This aimed to characterise the aquifer system and delineate the groundwater flow regimes of the aquifers in the area. The hydrocensus showed that in terms of groundwater radioactivity, the presence of uranium mines presented a major potential impact. A follow-up hydrocensus was conducted, especially to the south of the town in the vicinity of the mines in order to establish baseline pre-mining conditions. Based on data and information



Trends of surface and groundwater resources in Beaufort West.

available, no evidence of uranium contamination was established in any of the boreholes sampled during this project.
- In ***Phase 3*** the data and information of the first two phases were used to set up a practical sampling and monitoring protocol for radioactive elements for use in southern African fractured aquifers.
- A need was identified for a proactive approach to protect Beaufort West's groundwater resources from potential contamination that would, to a large degree, avoid the costly and technologically difficult exercise of groundwater remediation. Thus, as part of ***Phase 4*** of the project, aquifer protection zoning was recommended for implementation.

The final report of the project, which is now available, summarises all the activities leading from a survey of the hydrology of the Beaufort West area to the radioactive protocols needed for proper evaluation of the threats posed to the water resources of the town by uranium mines in the south of the well fields and paving the way forward.

Key issues

During the project, the available existing data were collated into a database in the form of spreadsheets. The information was derived from a variety of sources.

The sampling and monitoring for radioactive elements in fractured rock aquifers in South Africa should consist of pre-sampling procedure such as borehole selection, borehole purging, appropriate devices and reporting. Sampling hole location, for instance, must be able to reflect intended uraniferous formations.

As illustrated in the Beaufort West case study, background radioactivity was generally acceptable except for a few samples, which were anomalously high. Taking cognisance of the methods used, as well as those previously applied in the area and abroad, the sampling protocol for radioactive elements in fractured rock aquifers was conceptualised and developed for local adoption and further improvement in due course, if necessary.

The adapted protocol applied in the case of Beaufort West is documented in the report. A functional chart of the protocol is also provided to guide the user through the proposed protocol.

As a recommendation it was suggested that multiple methods be tested in the boreholes or wells of interest in order to check whether similar results would occur. This would thus determine the best applicable methods. It could also be clearly seen, by comparing historical data and the current data, that the methods used for sampling heavy metal can be applied to radioactivity.

In order to delineate wellhead protection zones, the specific land and geographic area should be included in the protection zoning programme. As fractured rocks usually offer less opportunity for natural attenuation or degradation of contaminants than do porous rocks and uranium-like all heavy metals not being particularly biodegradable, many fractured aquifers can transport the contaminants rapidly for long distances with little attenuation of the contaminants. This was manifested in a tracer test carried out in the project.

Important factors that need to be considered for protection zoning in fractured rock environments are, firstly, a clear understanding of the purpose and scale of the desired protection and, secondly, a clear and accurate conceptual model of the local groundwater system. This can be used as a basis for further in-depth numerical modelling to identify the importance of different types of dykes and faults.

As compartments are isolated from each other, the protection of water-yielding compartments becomes a top priority. Instead of focus on detail simulation for delineation of capture zones within a compartment, emphasis is placed on how to conceptualise a protection zone in fractured rock aquifers in general, and particularly in Beaufort West.

Guiding criteria for numerical zone simulation have been established. Two sets of criteria, e.g. volume and penetration factors, are proposed for determination. These criteria involve parameters such as recharge, abstraction, and borehole penetration of the aquifer, among others. The proposed criteria were tested and verified through actual simulations.

In addition to protection against conventional contaminants, such as pathogenic bacteria and nitrate, a thought was given to the possibility of contamination from uranium waste sites. As uranium mining occurs mainly to the southwest, south and southeast of Beaufort West, a worst-case scenario was discussed.

Judging from historical point of view, water demand in Beaufort West has been expanding. In addition to the four municipal wellfields, more wellfields were being developed to augment the current groundwater supply. A groundwater protection strategy must be incorporated in any water-supply strategy and a holistic water safety plan should be developed.

Finally, it is recommended that the monitoring procedure presented in the final report be fully implemented and incorporated into a water conservation and water demand management strategy for the municipality of Beaufort West.

Further reading:
To order the report, ***Towards a sampling and monitoring protocol of radioactive elements in fractured rock aquifers for groundwater resource security in Beaufort West*** (**Report No. 1694/1/12**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za, or Visit: www.wrc.org.za to download a free copy.