March 2008

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

National water resources monitoring programmes are required by the National Water Act. It is essential that a National Microbial Monitoring Programme (NMMP) for groundwater be included among such programmes to reflect the risk to human health resulting from faecal pollution of South Africa's extensively-used groundwater resources.

National Microbial Monitoring Programme for Groundwater

Introduction

The NMMP aims to measure, assess and report on the status and trends of the microbial water quality of South African groundwater resources on a regular basis, and in a manner that is cost-effective, scientifically sound and able to support strategic management decisions in the context of sustainable fitness for use of such resources.

The development of the NMMP has taken place in two phases: a design phase and a testing and refinement phase. The design phase was mainly a desktop study that produced a general framework for the design of the monitoring programme. Before formal adoption of the NMMP by the Department of Water Affairs & Forestry (DWAF), the core design and a number of specific issues within the design framework needed to be field-tested and refined.

Design philosophy

The NMMP design philosophy is based on the fact that **faecal contamination of groundwater is very likely to be highly localised.** This is mainly because:

- Groundwater generally moves relatively slowly;
- The movement of microorganisms is restricted by the physical filtering of the medium through which they move; and
- Most microorganisms have limited survival times below the ground surface.

Therefore, the design provides for identifying significant faecal pollution sources (e.g. large sewage works or dense settlements with inadequate sanitation near vulnerable aquifers and monitoring the effectiveness of natural containment of the faecal pollution in the vicinity of these sources. If shown to be contained, general (albeit cautious) statements can then be made about the likely faecal quality of the groundwater down-gradient of the source, i.e. along the groundwater flow path.

However, given the degree of uncertainty, monitoring to back up such statements would also be recommended at strategic down-gradient points of groundwater abstraction and use. It is believed that this approach would allow the maximum amount of information to be obtained about the microbial quality of an aquifer as a whole from the minimum number of monitoring boreholes, thus optimising the cost-effectiveness of the programme.

Testing and refinement

The field testing of the core design, which used *E. coli* as the main monitoring variable, involved the choice of three pilot sites, the location and drilling of monitoring boreholes, data collection and data assessment. Pilot sites included both fractured hard-rock and coastal unconsolidated-sand aquifers.

Refinement of the NMMP was sought in the following areas:

- **Improvement of guidelines for defining a faecal-pollution attenuation zone in groundwater** (the three-dimensional zone down-gradient of a faecal pollution source, beyond which little or not faecal contamination is expected). Key questions to be answered in this regard concerns the suitability of potassium as an indicator or flow path and the appropriate distance from pollution source to the containment borehole.
- **Development of detailed virus monitoring protocols.** Inclusion of viruses (initially omitted) in the NMMP was considered essential if the stated objectives of the programme were to be achieved.
- **Final updating and refinement of the implementation manual for the NMMP to incorporate the latest insights gained from field tests.**

During the course of testing, the suitability of *E. coli* itself as an indicator microorganism was also investigated by comparing the occurrence of *E. coli* with that of enterococci, which live longer in the environment. This approach,

however, is complicated by the fact that not only the contaminated groundwater, but also the environment itself, could be a source of enterococci.

An extended range of monitoring values was consequently included in the field tests of the NMMP. The bacteria ***E. coli*** and enterococci as well as two groups of viruses (adenoviruses and enteroviruses) were monitored. A number of chemical variables were also monitored to investigate which would be the most useful in confirming that boreholes are indeed sited in the flow path of the contaminated groundwater. Potassium, at least, would be expected to serve this purposes, because of higher potassium levels downgradient of faecal pollution sources.

Outcomes of testing and refinement

- Considerably **improved guidelines for defining the attenuation zone** and, particularly, for the **locating of the contaminant borehole** were developed. The monitoring of potassium, in the source and containment boreholes, in particular, has been shown to be helpful in confirming that these boreholes lie in the path of groundwater flow from the pollution source.
- **The core design of the programme was shown to be workable**, despite the need to refine the interpretation of data from containment boreholes that could, for practical reasons, not be located in ideal positions.
- **A refined implementation manual** containing considerably more procedural detail than previously, and aimed at full-scale implementation of the NMMP, has been produced.
- **The implications of the inclusion of viruses in the programme have been clarified**. Issues relating to sample volume, the period between sampling and arrival at the laboratory, the choice of representative virus, recovery and analytical methods, and financial requirements have been considered in detail. Refined procedures suitable for sampling and analysis of viruses, as well as for bacteria, have been included in the implementation manual.

Recommendations

Particular recommendations pertaining to procedural detail in the NMMP are to be found in the implementation manual. General recommendations for facilitating the initial implementation and further refinement of the NMMP are:

- To improve cost-effectiveness, implementation of the NMMP should focus first on **high priority areas** with potentially significant faecal pollution sources and vulnerable aquifers;
- Regarding analytical capacity for the measurement of *E. coli* and potassium, local, preferably **accredited, laboratories** that are in the vicinity of the sites being monitored can be used.
- Regarding analytical capacity for measurement of viruses, it is recommended that at least during the initialisation phase it would be most cost-effective to use **existing centralised laboratory facilities** rather than attempt to create decentralised facilities around the country.
- Given the short duration of the testing phase and the consequent limited amount of available data, it is recommended that the **highest possible monitoring frequency** allowed by available human and financial resources be maintained for at least two more years.
- The irregularity in the behaviour of bacteria and particularly viruses in groundwater means that studies to better understand their dynamics should be conducted **over many years** in order to obtain sufficient data for detailed statistical analysis.
- Sampling of all NMMP boreholes should be **more frequent** than typical of unimpacted sites because effectiveness of containment of faecal pollution is the primary focus of the monitoring programme's philosophy.
- Considerable care must be taken in **estimating groundwater flow direction** and **locating monitoring boreholes** when the topographic gradient is small. In fact, the drilling of additional boreholes to establish the flow direction would be advantageous. Thereafter, however, monitoring need not take place at such boreholes, but only at those needed to provide sufficient information on the containment of faecal pollution.

Further reading:

Pilot Study to Refine the Design of the National Microbial Monitoring Programme for Groundwater, (**Report No: 1494/1/07**).
To order this report, contact Publications at
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