Failure of rural schemes in South Africa to provide potable water

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Abstract The impact of water-borne disease in South Africa is significant. An estimated 43,000 deaths per annum, including 20% of deaths in the 1–5 years age group, are directly attributable to diarrhoeal diseases. Drinking water quality provision in many rural areas is substandard. This paper describes the results of sampling drinking water supplies in rural communities in the Western and Eastern Cape, South Africa. The majority of samples collected failed microbial drinking water quality standards. Overall, schemes dependent on groundwater provided a worse quality water at point of use than surface-water-dependant schemes. This is thought to be the result of pump breakdown, deterioration of the storage and reticulation system, and insufficient monitoring and management of the schemes. Importantly, it is shown that the implementation of well-considered, community accepted drinking-water quality management procedures can effectively change an unacceptable water quality to one that satisfies drinking-water specifications.

Keywords Failure of rural schemes · Potable water · South Africa

Introduction

In almost all South African metropolitan areas, the consumer is provided with high-quality drinking water. However, in many rural communities, the situation is very different. In 1996, an estimated 12 million South Africans were without access to an adequate water supply (DWAF 1996) and, even where a water supply exists, quality is often poor (Mackintosh and Linde 1997) and the impact of water-borne disease is significant. In South Africa, diarrhoea is responsible for about 20% of all deaths in the 1–5 years age group (Bourne and Coetzee 1996) and an annual estimated 43,000 deaths and 3 million incidences of illness, with an associated treatment cost of some R3.4 billion (approximately US$ 523 million, April 2000; Pegrum and others 1998).

Groundwater plays an important role in meeting basic human needs for drinking water. Well-managed groundwater supply schemes reliably provide water of high microbiological and physico-chemical quality. Typically, groundwater is advantageous for rural water supply in that it is protected from surface contamination and abstraction can be maintained during (short-term) periods of drought. However, where poorly designed groundwater schemes are installed, users are often supplied with water of very poor quality. The challenge exists for hydrogeologists and water utilisation engineers to ensure sustainable high-quality drinking-water provision.

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The purpose of this paper

This paper has three main objectives:

- To document typical drinking-water microbial quality in existing rural water supply schemes in the Eastern and Western Cape, South Africa;
- To draw attention to the very poor drinking-water quality that results from a high proportion of the groundwater supply schemes assessed.
- To introduce the concept of 'drinking-water quality management' procedures for implementation in rural communities and show that their introduction can change an unacceptable drinking-water quality to one that satisfies drinking-water specifications.

Rural drinking-water quality investigation

Selection of rural supply schemes

Rural communities of the Eastern and Western Cape of South Africa were studied. The rural communities of these

two provinces differ considerably. The population of the Eastern Cape is largely non-urban, poor, and with an inadequate water-supply infrastructure. Rural communities of the Eastern Cape comprise both scattered villages and subsistence farmers, and formalised towns serving subsistence farmers. The poverty rate in 1998 was 71%, and only 25% of the households had a tap inside the dwelling (CSS 1998; Mey 1998). The Western Cape is largely urban, relatively wealthy, and with a relatively well-developed water-supply infrastructure. Rural communities of the Western Cape typically are formalised towns connected to commercial agriculture and enterprise.
Rural communities typical of each region were identified. Communities selected included both smaller communities of about 1,000 to 4,000 inhabitants, and larger communities of about 40,000 inhabitants. Three larger communities and 16 smaller communities were studied in the Eastern Cape. Two larger communities and 18 small communities were studied in the Western Cape.

Sampling

Once-off sampling was carried out in the selected communities. Sampling was focused on points of use (e.g. tap stands, homes, schools, municipal offices and hospitals). Storage reservoirs and the distribution system were also sampled, but no well-head samples were obtained. The number of samples varied with the size of community.

Selection of water-quality variables

Microbiological testing was limited to SABS 241-1984 guideline indicator organisms; namely heterotrophic plate count, total coliform and faecal coliform counts (SABS 1984, 1990). In addition, chemical and physical determinants that are linked to the survival of microorganisms (such as pH, temperature and turbidity), and those that provide an indication as to the condition of the distribution network (calcium, total alkalinity, iron and electrical conductivity) were measured according to standard techniques (APHA, AWWA and WPCF 1995; Table 1).

Further observations

Assessment included consideration of the type of raw water source, water-supply management, disinfection practices, other water-treatment practices and water-quality monitoring practices.

Results

A total of 39 communities were assessed: 19 were in the Eastern Cape. In each province, groundwater was the sole water source for seven communities.
In the Eastern Cape, five of the seven groundwater supply schemes were non-functional (71%) and users were forced to procure alternative untreated water supplies, whereas in the Western Cape all groundwater schemes visited were functional.
In both regions, a high number of schemes have no disinfection capability. In the Eastern Cape, all the surface water schemes visited practised forms of flocculation and settling as a result of the high turbidity of surface waters in the region. In the Western Cape, where the mountain catchment's streams generally have low turbidity, a large number of the communities practice no additional water treatment other than disinfection (65%).

Limitations of the data

In addition to the microbiological results presented in this paper, physico-chemical results were obtained. However, it is the aim of this paper to indicate broadly the drinking-water quality of rural schemes and, in this regard, the microbiological indicators were the critical parameters. Figures 1 and 2 present the results in a qualitative manner with respect to compliance or non-compliance with microbial guidelines. The results are not correlated with aquifer types, abstraction methods, land-use, point of use, etc. Time series monitoring would also be required to give a further indication of the mechanisms of scheme failure. In both provinces fewer samples from groundwater schemes were obtained. It is recommended that a further phase of study pursue these issues. Nevertheless, despite these quantitative limitations to the data, the results indicate the existing state of the schemes visited, their vulnerability to contamination and the general state of drinking-water quality management.

Overall drinking-water quality

The overall efficiency of drinking-water provision in the Eastern Cape regarding microbiological water quality is very poor with about 50% of samples failing the maximum allowable limit (MAL; Fig. 1). Figure 1 testifies that of the worst cases of drinking-water quality exist in failed groundwater supply schemes where consumers were forced to make do with very poor alternatives (e.g. ponds). The overall efficiency of drinking-water provision in the Western Cape regarding microbiological water quality is very poor with about 62% of samples failing MALs (Fig. 2). Surprisingly, the percentage failure of MALs was higher in the Western Cape, despite a higher standard of living and level of supply infrastructure.

Groundwater quality

The microbiological quality of samples from groundwater schemes was worse than surface water samples. All

Table 1
South African Bureau of Standards microbial drinking-water quality limits (1984)

Determinants	Recommended limit	Maximum allowable limit
Heterotrophic plant count (per 1 ml)	100	None
Total coliforms (per 100 ml)	0	5
Faecal coliforms (per 100 ml)	0	0

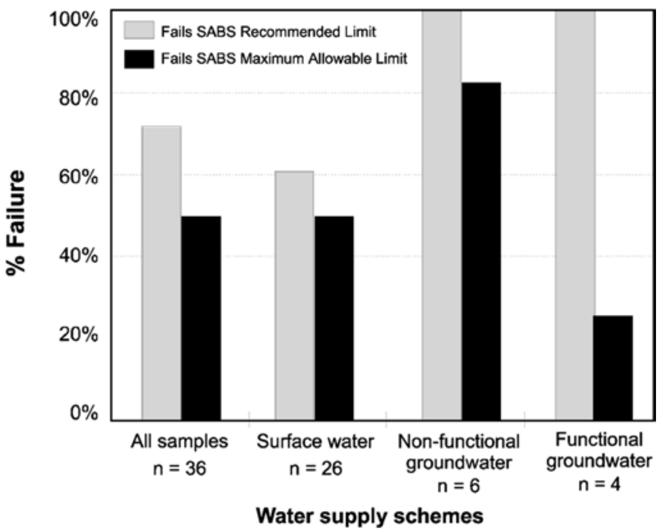

Fig. 1
Per cent failure regarding microbiological indicator organisms of drinking-water quality as tested at rural water-supply schemes in the Eastern Cape, South Africa

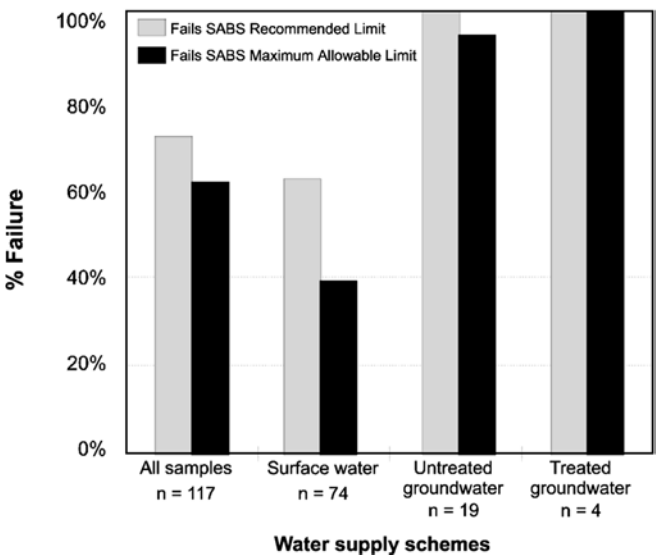

Fig. 2
Per cent failure regarding microbiological indicator organisms of drinking-water quality as tested at rural water-supply schemes in the Western Cape, South Africa

groundwater samples failed the recommended limits. In the Western Cape, almost all groundwater samples failed the MALs. In the Eastern Cape, the majority of non-functional schemes failed MALs. Three of the four samples from the two functional schemes passed the MALs.

Monitoring

Only 26% of communities visited in the Eastern Cape monitor drinking-water quality; in nearly all cases this was limited to ad hoc microbiological sampling. In the Western Cape, some 80% of communities monitor drinking-water quality. Again, in most instances, this is ad hoc and ineffective, as evidenced by the generally very poor microbiological quality of the drinking water.

Summary of results

In brief, the investigation has shown that drinking-water quality is very poor in rural communities in both the Eastern and Western Cape, with a high incidence of failure regarding MALs for microbiological indicator organisms. Additional points of interest are:

- In the more developed Western Cape, almost all groundwater samples failed the MALs.
- Non-functional groundwater schemes in the Eastern Cape resulted in substandard supplies being used.
- The equally poor overall microbiological drinking-water quality in both regions despite the Western Cape being more affluent and having better services.
- In both regions, drinking-water quality management is inadequate.

Discussion

The failure of rural groundwater schemes to deliver acceptable quality drinking water to consumers has been previously shown in several areas of Southern Africa.
For example, in 1991, a survey of almost all the Transkei government water-supply schemes revealed only 10% to be delivering on acceptable quality and quantity of water (Ravenscroft and Cain 1997). Observations concluded that almost all boreholes with wind pumps were not functional; functional schemes relied on hand pumps and springs. In many of the former ‘homeland’ areas there is a legacy of inappropriate delivery systems.
Observed reasons for the failure of rural groundwater schemes to deliver adequate quality drinking water are:

- Failure of the pump (particularly wind pumps) forcing people to use water from contaminated sources.
- Contamination via the reticulation system, particularly where corrosive waters are abstracted (such as in the Western Cape).
- Contamination via the storage reservoir (many are open and others have broken roofs with nesting birds, etc).
- Failure to chlorinate.
- In particular, inadequate or non-existent water-supply management practices fail to prevent or remedy microbial pollution.
- Where water-quality monitoring was carried out it was typically ad hoc, and the results had little or no impact on supply management practices.

Microbiological sampling and analyses pose particular problems for remote rural areas. Current practices are very costly and there is a high risk that quality assurance procedures are not adhered to. The current international drive towards developing rapid field detection methods for microbial quality indication would benefit rural water-supply management tremendously.

Development of rural drinking-water quality management procedures

A common denominator to the poor water quality results observed above is the lack of regular assessment/management of water quality, including source protection, optimisation of water treatment, ensuring reliability of supply, and the maintenance of drinking-water quality within the distribution network. An appropriate procedure was developed to address these problems as outlined below.

Stage one: initial familiarisation with the water supply scheme

Basic information relating to the water scheme is collected: water sources, vulnerability of sources, water treatment requirements and existing treatment procedures, the drinking-water distribution network, drinking-water quality records and existing drinking-water quality management procedures and local capacity.

Stage two: preliminary water-quality investigation

Potentially problematic issues and areas where historical data are insufficient are targeted. Special consideration is given to sampling raw water sources, post-water treatment works, network dead-ends, high occupancy buildings, hospitals and schools, areas perceived to be problematic and any regions using untreated water.

Stage three: define operations, local management team and responsibilities

A series of meetings are held with local operators responsible for drinking-water supply. The operations and management structure, and associated responsibilities, are clearly defined. Focus is given to skills training, capacity building, technical support, planning and facilitation of project implementation. Consensus on community responsibilities is negotiated with the objective of maximising community involvement and responsibility for operation of the water supply scheme.

Stage four: implementation of monitoring process

A monthly sampling programme is designed such that water quality is monitored from the raw water source, through treatment and distribution, to the end user and in such a manner that problematic issues relating to the treatment and supply of drinking-water can be identified. The collection, handling, transport and storage of samples are carried out by trained members of the local community and in accordance with standard techniques (SABS 1990; APHA, AWWA and WPCF 1995). The collected data and relevant observations are reviewed in terms of criteria agreed upon during the design of the sampling program. Depending on results from the review of information, actions are carried out. Where no failures occur, information is used to optimise treatment procedures. Where failures occur, a process of investigation and troubleshooting takes place. Where necessary, consumers are notified of relevant details, and measures to implement temporary and medium-term solutions are initiated. A monthly summary report displaying the location of sampling points, the month's data, discussion and recommended actions is produced.

Implementation of drinking-water quality management procedures: case studies

The drinking-water quality management procedure outlined above was introduced by the CSIR at one of the larger communities and at six of the smaller communities in the Western Cape. Considerable improvement of drinking-water quality was seen.

Six smaller communities

In the six smaller communities, a 100% failure regarding MALs for microbiological indicator organisms was improved to total compliance in a period of 3 months in five of the six communities. These improvements have been maintained. In the sixth community there were water quality improvements during the period that CSIR were able to assist with monitoring, evaluation and mentoring. Unfortunately, despite community support and enthusiasm, these improvements lapsed as a result of the lack of necessary resources to upgrade water-treatment facilities.

One larger community/town

The original failure of 24% for MALs was improved to total compliance in a period of 3 months.

Conclusions and recommendations

In conclusion, this paper clearly demonstrates that:

- Substandard quality drinking water is supplied to the majority of rural communities sampled in the Eastern and Western Cape, South Africa.
- Although groundwater resources have advantages over surface water sources for rural water supply, rural groundwater supply schemes fail more frequently.
- The most important reasons for the incidence of failure of groundwater to supply quality drinking water are thought to be pump breakdown, deterioration of the storage and reticulation system and, most importantly, insufficient monitoring and management.
- The implementation of well-considered, community-accepted drinking-water quality management procedures can effectively change an unacceptable water quality to one that satisfies drinking-water specifications.
- Skills training, capacity building, technical support and mentoring are vital to ensure the successful implementation of drinking-water quality management procedures in rural communities.

Recognising the considerable impact of poor drinking-water quality, it is recommended that the Departments of Local Government, Health, and Water Affairs and Forestry assist in achieving a broader implementation of drinking-water quality management procedures in rural communities. These procedures should form a blueprint for monitoring requirements of water service providers under the new Water Services Act. Further study and research are required to refine implementation of drinking-water quality management procedures in rural communities and identify supporting technologies, for example, easy tools and methodologies for field assessment of microbiological water quality. Source-directed and resource-directed measures under the National Water Act, should give due consideration to wellhead protection and the prevention of on-site sanitation pollution.

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