Groundwater Quality: Lesotho

This is one of a series of information sheets prepared for each country in which WaterAid works. The sheets aim to identify inorganic constituents of significant risk to health that may occur in groundwater in the country in question. The purpose of the sheets is to provide guidance to WaterAid Country Office staff on targeting efforts on water-quality testing and to encourage further thinking in the organisation on water-quality issues.

Background

The Kingdom of Lesotho, formerly Basutoland until independence in 1966, occupies an enclave within South Africa. Total area is 30,355 square kilometres (Figure 1).

The terrain is mountainous. Some 80% of the land area lies more than 1800 m above sea level and elevation varies from a maximum at Thabana Ntlenyana (3,482 m) in the north-east to a minimum at the confluence of the Senqu and Makhaleng rivers (1,400 m). Lowlands form a 20–50 kilometre wide strip aligned north-east to south-west along the north-westerly fringe of the country. Elevation rises through foothills to mountains in the central and north-eastern part of the country (Figure 1). Most of the population inhabits the lower-lying western and north-western fringes. Population is sparse in the mountainous central and north-eastern parts.

Climate is temperate to semi-arid with cool, dry winters and warm, wet summers. Average annual precipitation is around 800 mm, varying from 1150 mm in the north-east highlands to 450 mm in the south and west. The wettest months are October–April (summer). Temperatures vary from minima below 0°C to maxima around 35°C.

The main drainage basins are the Senqu, Mohokare/Clarens and Makhaleng river systems (Figure 1). The Mohokare River forms the north-western border with South Africa. The Senqu River forms a deeply incised valley in the south-east. Flows are dependent on rainfall and smaller rivers are ephemeral.

Subsistence agriculture, mainly livestock, is the principal livelihood. Although only 11% of the land, mainly in the lowlands, is given over to arable agriculture, this occupies around 86% of the labour

Figure 1. Relief map of Lesotho (courtesy University of Texas Libraries, The University of Texas at Austin).

force. Mountains are used for summer grazing.

Principal industries are milling, canning, leather and jute. Mining and quarrying activities are mainly for diamonds, dolerite, sandstone and river sand. Lesotho generates revenue from export of water to South Africa from dams created as part of the Lesotho Highlands Water Project. The country is also 90% self-sufficient in electricity thanks to the development of hydropower from the major dams installed at Katse, 'Muela and Mohale.

Environmental issues include population pressure, drought, extreme soil erosion due to mountainous terrain, desertification and over-grazing.

Geology

The geology of Lesotho is composed almost entirely of igneous and sedimentary rocks of the Karoo Supergroup (Triassic to upper Jurassic age). Karoo sedimentary rocks compose (in age order) the Burgersdorp, Molteno, Elliot and Clarens formations. These crop out, in turn, from the west to east of the country. Karoo sediments (Molteno, Elliot and Clarens formations) also occupy the deeply incised Senqu valley. The fluvio-deltaic Karoo sediments comprise dominantly fine-grained sandstone, siltstone and mudstone with less common coarse sand and gravel and thin coal seams (Davies, 2003a, b). Coal occurs dominantly in the Burgersdorp Formation. Coarser-grained sandstones and some gravels occur in the Molteno Formation. Elliot Formation sediments are mainly red clays and mudstones.

The eastern two-thirds of the country are occupied by Karoo volcanic rocks of the Lesotho Formation. These are younger than and overlie the Karoo sedimentary rocks. The Lesotho Formation consists of lava flows and ashes almost entirely of basaltic composition.

Intrusive rocks of late Cretaceous to early Palaeogene age include prominent dykes, ring dykes and sills of dolerite and basalt which intrude both the Karoo volcanic and sedimentary sequences. These are dominantly orientated NW–SE or NNE–SSW and commonly form ridges or trenches. Less common pipes and dykes of diamondiferous kimberlite (Cretaceous) also occur. Medium-scale diamond mining is located in north-central Lesotho, at the Kao, Kolo and Liqhobong operations (UNDP, 1984; Motsamai et al., 2003). Numerous small-scale operations also exist elsewhere. There are no recorded occurrences of sulphide ore mineralisation.

Recent alluvial deposits and some Quaternary terrace gravels occupy the river valleys (Davies, 2003a).

Groundwater Availability

Despite limited aquifer potential, Karoo sedimentary rocks, volcanics and younger alluvial deposits have been developed widely for water supply and irrigation in the western lowland area (TAMS, 1996; Davies, 2003a). The overwhelming majority of boreholes are located in this zone. Davies (2003b) mapped the locations of boreholes and aquifer formations in the lowlands. From the Karoo sedimentary rocks, Davies (2003b) estimated that some 3200 boreholes have been developed in the Burgersdorp Formation (>450 being dry) between Maseru and Mafeteng, more than 2800 boreholes in the Molteno Formation east of Maseru and the Mafeteng–Mohale's Hoek area, more than 1600 boreholes in the Elliot Formation north-east of Maseru, and more than 800 boreholes in the Clarens Formation north-east of Maseru. In these areas, groundwater abstraction has focussed on high-permeability zones, particularly in sediment/dyke contact zones. Borehole yields in these formations are typically <1.5 L/s and transmissivity values of the order of 20 m^2/day, but yields can reach up to 8 L/s close to dyke boundaries (Davies, 2003a). The Molteno Formation is the most productive of the Karoo aquifers, especially where intruded by dykes. Yields are low in the mudstone-dominated Burgersdorp Formation and very low in the Clarens Formation (Clarens Formation yields <1 L/s, transmissivity 5 m^2/day). Water levels in the Karoo sedimentary rocks of the western lowland area are usually in the range 20–30 m below ground level.

Within the volcanic Lesotho Formation, more than 300 boreholes east of Morja and Roma have been catalogued, mainly along the Clarens/Lesotho formation contact. Highest groundwater yields (>10 L/s) occur in the weathered mantle of basalts, along dykes and within fractures (Davies, 2003b).

Borehole yields are higher in the recent alluvial deposits (typically 3 L/s; 40 L/s in Maputsoe wellfield), although their extent, thickness and therefore aquifer potential is limited. In these, water levels are typically 15 m below ground level (Davies, 2003b).

Springs occur in all Karoo formations, mainly following weathered horizons, fractures and dykes. Springs, together with shallow hand-pump boreholes, supply water in many rural areas. Urban areas are served from boreholes with high-capacity pumps, or smaller supplies from boreholes and wells in alluvium, or from surface supplies (Bee Pee and SRK, 2002). The indurated aquifers are generally unsuitable for dug wells.

Groundwater Quality

Overview

A limited amount of data for groundwater quality exists in accessible form (UN, 1989; TAMS, 1996; Davies, 2003a). Groundwater-chemistry data likely exist from the era of an Italian-funded exploration and development programme which started in 1982 but this is difficult to access. Monitoring of groundwater quality in boreholes and springs has since been carried out by the Department of Water Affairs (DWA) and the Water and Sewerage Authority (WASA) (Bee Pee and SRK, 2002) but access to this is also difficult.

Available data from the 1990s indicate that Ca-Mg-HCO_3 groundwater compositions dominate in unconfined shallow groundwaters from the Karoo sedimentary and volcanic rocks and alluvial aquifers, but that deeper groundwaters from confined Karoo sedimentary aquifers (presumably having had longer residence times) have Na-HCO_3 compositions (Arduino et al., 1994; Bee Pee and SRK, 2002). Mg-HCO_3 and Na-Mg-HCO_3 types have also been described from the Karoo basaltic aquifers of neighbouring South Africa (Leyland and Witthüser, 2008).

The major-ion compositions indicated and the rock types present suggest that groundwater is likely to be largely pH-neutral or alkaline. Groundwater from test boreholes in a rural area close to Maseru, abstracting from Clarens Group clay-rich sediments, indicated a mildly alkaline composition (pH 8.1; Tollow and Lekonyana, 2008).

Shallow groundwaters in the fractured and weathered aquifers are vulnerable to pollution due to increasing numbers of pit latrines and waste dumps (Davies, 2003a). Urban landfill also represents a risk. This conclusion is supported by results from a study of bacterial quality of drinking water from various groundwater sources in Manonyane community, Maseru District (Gwimbi, 2011). Of 35 sources investigated (34 from springs, boreholes or wells; 1 from surface water), 97% contained coliforms and 71% contained *E coli*. Wellhead protection proved a significant determinant of degree of contamination from animal wastes, laundry waste and pit latrines. Unprotected springs and wells contained groundwater with larger bacterial populations than groundwater from protected springs and boreholes.

Mining represents an additional risk factor for groundwater quality, although the extent of mining is limited and the exploitable minerals less environmentally detrimental (diamonds within kimberlite) than the sulphide mineralisation that is widespread elsewhere in southern Africa.

Nitrogen species

The vulnerability of shallow groundwater to surface contamination means that concentrations of nitrogen (especially nitrate, but also nitrite and ammonium) could be high, and increasing as pit latrines increase in number. Such contamination is likely to be localised and highly dependent on land use. A map of nitrate concentrations in groundwater from the Gariep Basin including Lesotho, compiled as part of the Southern African Millennium Ecosystem Assessment (Bohensky, 2004), suggested that <10% of groundwater sources in Lesotho have concentrations above 10 mg/L NO_3. Such values were shown to be comparatively low on a regional scale.

Salinity

Available data suggest that total dissolved solids (TDS) concentrations in the Lesotho groundwaters are typically low. Average values for borehole and spring waters (Karoo and alluvial aquifers) have been reported as 260 mg/L and 112 mg/L respectively (Arduino et al., 1994), although the numbers of analyses included in this evaluation are uncertain. The Southern African Millennium Ecosystem Assessment (Bohensky, 2004) highlighted the overall low salinity of groundwater in Lesotho. A regional map of TDS indicated that groundwater from the whole country had <500 mg/L TDS, although again, the number of analyses contributing to the assessment is unknown. Low salinity values are consistent with the mountainous terrain, impact of recharge, shallow fracture flow and overall low groundwater residence times, although variable TDS values might be expected in the Karoo sedimentary rocks, with potentially higher values in association with argillaceous deposits and coal-rich seams.

Shallow groundwater impacted by evaporation (including by irrigation) could have TDS concentrations above these values (Christelis et al., 2007). Higher concentrations, if present, would be more likely to impact the north-western lowlands where water levels are shallower and irrigation returns more significant. These are also areas more likely to be impacted by urban, industrial or domestic contamination. Mohobane (2008) reported electrical conductance values (analogous to TDS) around 1600 μS/cm in groundwater proximal to the Maseru landfill, compared to values closer to 250 μS/cm under natural conditions nearby. Such urban contamination is likely to be localised.

Fluoride

The Southern African Millennium Ecosystem Assessment of the Gariep Basin (Bohensky, 2004) also presented a map of distributions of fluoride in Lesotho groundwater. This suggested that <10% of groundwater sources nationally have fluoride concentrations above the WHO guideline value for drinking water of 1.5 mg/L. Usually low concentrations are consistent with Ca-Mg-HCO_3 groundwater compositions. Increased fluoride concentrations are possible however, in alkaline Na-HCO_3 waters which have been noted in deeper confined aquifers (Arduino et al., 1994).

High fluoride concentrations (up to 15 mg/L) have been identified in a small number of groundwater sources (TAMS, 1996). Three villages in Berea, Mafeteng and Maseru Districts have groundwater sources with concentrations reported at up to 15 mg/L (Davies, 2003a). Some groundwater from Karoo lavas in neighbouring South Africa has also been observed to contain groundwater with fluoride concentrations above 1.5 mg/L (Leyland and Witthüser, 2008).

Concentrations of fluoride in groundwater close to the Maseru landfill site were low (<0.1 mg/L; Mohobane, 2008) and likely to reflect the natural concentrations in the local groundwater from shallow Karoo sedimentary rocks.

The combined evidence suggests that fluoride is unlikely to be a widespread problem in Lesotho groundwater but given the high degree of uncertainty in regional distributions and even major-ion chemistry, testing for fluoride in water-supply programmes is strongly recommended.

Iron and manganese

Availability of data for iron and manganese is limited. The major-ion chemistry, patterns of shallow flow via fractures and weathered mantle, lack of sulphide mineralised areas and the likelihood of short groundwater residence times overall, all suggest that most groundwater should have low concentrations of these trace elements. Nonetheless, several groundwater sources in western Lesotho are said to have high concentrations of dissolved iron (TAMS, 1996). Where deeper confined aquifers exist (Davies, 2003a), groundwater could contain unacceptably high concentrations of these elements if anaerobic, but knowledge on their distribution, chemistry and regional significance is limited. Concentrations could also be relatively high in groundwaters associated with the coal-rich horizons of the Karoo sedimentary pile. Boreholes in these might in any case be low-yielding and of limited use for water supply.

Concentrations of iron can also increase due to the presence of reducing leachate in close proximity to urban landfill sites. Mohobane (2008) found iron in groundwater at concentrations up to 1 mg/L in boreholes close to Maseru landfill. Again, this is likely a local phenomenon.

Arsenic

No data are available for arsenic in the groundwaters at the time of writing. Given the shallow nature of flows in the indurated sandstone and igneous aquifers, the limited extent of alluvial aquifers, and the absence of evidence for sulphide mineralisation, the risk of arsenic concentrations significantly above drinking-water limits on a regional scale is thought to be low. Potential exceptions include the areas of the Karoo sedimentary formations where coal horizons are present (these might be associated with sulphide minerals which are known to be enriched in arsenic). Increased risk is also associated with deeper flows in confined aquifers, especially if they are reducing. The arsenic status of groundwaters in the Karoo basalt aquifer is difficult to predict. The large uncertainty means that testing for arsenic in Karoo groundwaters is warranted, at least on a reconnaissance scale.

Sites of urban and industrial contamination (e.g. landfills) also represent localised areas potentially at risk.

Iodine

No data could be found on iodine concentrations in Lesotho groundwater. Concentrations are expected to be low overall (order of a few µg/L), in line with topography and rainfall patterns, low salinity of groundwater and dominance of indurated sedimentary or volcanic rock aquifers which can largely be considered iodine-poor. Iodine-deficiency disorders have been recorded as a long-term problem in Lesotho as a result of low exposure to iodine in food and drinking water. However, in recent years these have been well-controlled by dietary iodine supplementation (iodised salt) (Sebotsa et al., 2003; 2005).

Other trace elements

Little information is available for the occurrence of other trace elements in Lesotho groundwater. No special risk factors are identified for specific trace elements, although in general local contamination from urban, industrial and domestic sources may lead to increases above background concentrations. Landfill leachates represent potential sources of trace-element contamination of groundwater, depending on the nature of the waste. Chemical analysis of leachate from the large landfill at Maseru indicated relatively high concentrations of lead (Mohobane, 2008). Concentrations reached up to 60 µg/L in the small number of groundwater samples investigated, although the accuracy of the results is uncertain.

The leather industry in Maseru uses chromium compounds in the tanning process and so chromium contamination of shallow groundwater in proximity to tanneries is possible. Chromium concentrations may also be relatively high in alkaline groundwater from the Karoo basaltic aquifers, although concentrations are thought unlikely to approach the WHO guideline value for chromium in drinking water (50 µg/L).

Commercial mines (e.g. Kao, Kola mines) are potential sources of other contaminants including trace metals into the groundwater, though the degree of contamination is likely to be less severe in comparison to that observed in metal- (sulphide-) mining areas.

Data sources

Arduino, G., Bono, P. and Del Sette, P. 1994. Hydrogeological Map of Lesotho. Scale 1:300,000. Lesotho Government, Ministry of Natural Resources, Department of Water Affairs, Groundwater Division.

Bee Pee and SRK, 2002. Situation Analysis Report Annex D – Lesotho. Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, SADC Water Sector Coordinating Unit.

Bohensky, E. (ed.) 2004. Ecosystem services in the Gariep Basin. Sun Press, Stellenbosch University, South Africa.

Christelis, G, Heyns, P., Kirchner, J., Makarigakis, A. and Margane, A. 2007. Transboundary groundwater management in the river basin organisations of SADC with special reference to the Namibian case. World Water Week 2007, Stockholm, Sweden.

Davies, J. 2003a. Hydrogeology of Lesotho. http://www.bgs.ac.uk/sadcreports/lesotho2003daviescr03176.pdf.

Davies, J. 2003b. Hydrogeological atlas of lowland Lesotho. British Geological Survey Report: http://www.bgs.ac.uk/sadc/fulldetails.cfm?id=LS4009.

Gwimbi, P. 2011. The microbial quality of drinking water in Manonyane community: Maseru District (Lesotho). African Health Science, 11, 474-480.

Leyland, R.C. and Witthüser, K.T. 2008. Regional description of the groundwater chemistry of the Kruger National Park. WRC Report No KV 211/08. Water Research Commission, South Africa.

Mohobane, T. 2008. The characteristics and impacts of landfill leachate from Horotiu, New Zealand and Maseru, Lesotho: a comparative study. Unpublished MSc thesis, University of Waikato, New Zealand.

Motsamai, B., Keatiliwe, K. and Pomela, M. 2003. Lesotho. http://www.saiea.com/SAIEA-Book/Lesotho1.pdf.

Sebotsa, M.L., Dannhauser, A., Jooste, P.L., Joubert, G. 2003. Prevalence of goitre and urinary iodine status of primary school children in Lesotho. *Bulletin of the World Health Organization*, 81, 28-34.

Sebotsa, M.L., Dannhauser, A., Jooste, P.L., Joubert, G. 2005. Iodine status as determined by urinary iodine excretion in Lesotho two years after introducing legislation on universal salt iodization. *Nutrition*, 21, 20-24.

TAMS, 1996. Water Resources Management: Policy and Strategies, Final Report. TAMS Consultants, New York; Sechaba Consultants, Maseru; Beepee Groundwater Consultants, Maseru, Groundwater Resources, pp 19-35.

Tollow, A. J. and Lekonyana, R. 2008. A possible water resource for Likotsi, Lesotho. British Hydrological Society 10th National Hydrology Symposium, Exeter, 2008.

UN, 1989. Lesotho. In: Groundwater in Eastern, Central and Southern Africa. Natural Resources/Water Series No. 19. United Nations, pp 126-131.

UNDP, 1984. Geology and Mineral Resources of Lesotho. Exploration for Diamonds (phase 1) and Exploration for Minerals (Phase 2). Technical report DP/UN/LES-71-503/8 and DP/UN/LES-73-021/9, 252 pp.