Groundwater Quality: eSwatini

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 eSwatini (renamed from Swaziland in April 2018) is a small landlocked country of some 17,400 square kilometres, located in Southern Africa between South Africa and Mozambique. Population is estimated at 1.4 million people (2013), 80% of whom live in rural areas. Swaziland is divided into four districts: Hhohho, Lubombo, Manzini and Shiselweni (Figure 1).

Terrain is principally mountainous, but can be divided into four physiographic areas: rugged mountains of the 'Highveld' occupy the west (highest point Emlembe, 1,862 m), rolling grassy hills form a central plateau, the 'Middleveld', and the east comprises lower-lying ground of the 'Lowveld' with elevation typically 100–500 m, but with the lowest point on the Great Usutu (Lusutfu) River (21 m) (Figure 1). The N-S aligned Lubombo Plateau borders Mozambique in the east. The west-facing Lubombo Escarpment rises to 777 m with a gentle east-facing dip slope.

Climate varies from tropical to temperate. Rainfall is strongly influenced by topography and average annual figures vary from 1800 mm in the Highveld to 600 m in the Lowveld. The rainy season typically occurs during September to March. Average annual temperatures lie in the range 15–23°C (Highveld and Lowveld respectively).

The main rivers are the Mlumati, Komati, Mbuluzi, Great Usutu (Lusutfu) and Ngwavuma, which flow eastwards from the Highveld towards Mozambique. Most streams in the Highveld are perennial but Lowveld stream flows are more variable. Many in this zone dry up completely in the dry season.

Subsistence agriculture occupies around 70% of the

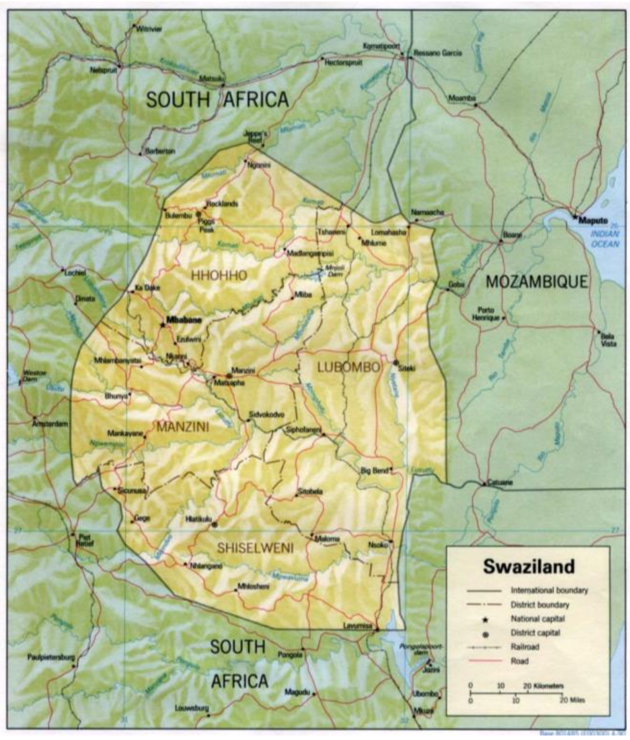

Figure 1. Relief map of the Kingdom of eSwatini (courtesy University of Texas Libraries, The University of Texas at Austin).

population, although only 10% of land coverage is arable. Most farming activity is concentrated in the Middleveld. Principal subsistence crops are maize, sorghum and vegetables and principal exports sugar cane, cotton, corn, tobacco, rice, citrus fruits and pineapples. Cattle, goats and sheep are principal animal products. The Kingdom relies heavily on South Africa for its imports (90%) and exports (60%) and currency is pegged to the South African rand. Although sugar is the main export, wood pulp was also an important revenue earner until the demise of the industry in 2010. Current mining activity (around 2% GDP) concerns coal and quarry stone.

Principal environmental issues include soil erosion and degradation, over-grazing, diminishing biodiversity, drought and resulting water shortages.

Geology

The geology of the country is divided into two distinct stratigraphic provinces. The western two-thirds of the country consist of Precambrian (Archaean; 3500–2000 million years old) crystalline igneous and metamorphic rocks. The mountains of the Highveld consist of gneiss, granite and greenstone formations, with more minor quartzite, phyllite and schist of the Mozaan Group metasediments. The Archaean rocks are intruded by the Usushwana gabbro/pyroxenite complex, a prominent rugged outcrop some 15 km south-west of Mbabane. Granite and gneiss also occupy the rolling hills of the Middleveld, covering 26% of the land area. The Lowveld (37% of the land area) is composed of Permo-Triassic and younger Karoo (300 million years onwards) sedimentary rocks. Sediments are dominated by deltaic sandstone and mudstone and aeolian sandstone, with coal horizons. The basal part comprises glacial clays (tillites). Coals and carbonaceous shales are a feature of the Ecca Series which overlie the tillites within the Karoo sequence. Karoo volcanic rocks (200 million years old), consisting of basalt, rhyolite and dacite, form the higher terrain of the Lubombo Plateau (8% of the land area). Recent alluvial (river-borne) and colluvial (slope-eroded) deposits occupy some of the lower river valleys and slopes. Alluvium is of limited lateral extent and has a maximum thickness of 30 m (Robins, 1978). Superficial deposits are in places cemented to calcrete and ferricrete (Watson et al., 1984).

All rocks represented have been heavily affected by folding and faulting. Two major N-S orientated shear zones occupy the Middleveld and affect principally granite and gneiss formations.

The basement rocks are deeply weathered in some places, especially granitic areas of the Highveld (Piteau Associates, 1992).

Natural resources include asbestos, coal, tin (cassiterite), clay, talc, iron ore and minor gold and diamond deposits. Copper, nickel and tin are also found in some basement areas (NIRAS PINSISI, 2006). Coal deposits are recorded at Mhlume, Sulutane (Area I), Mpaka (Area II), Mabhekaphansi (Area III), Lubhuku and Maloma. Gold has been mined in Malolotja and around Pigg's Peak in Hhohho District, although reserves were small. Iron ore was also mined at Ngwenya mountain massif on the north-western border until 1980.

Groundwater Availability

The geological formations mainly consist of poorly-permeable rock types including crystalline basement rocks and indurated Karoo sandstones or mudstones. Hence availability of groundwater is strongly dependent on development of secondary permeability along faults, joints and dyke margins or via heavily weathered bedrock overburden. Groundwater availability in alluvial deposits is limited by their restricted extent. Groundwater flow is expected to be dominantly along shallow flow lines and numerous springs and seepages are recorded. Springs are most prevalent in the Highveld and some of these have been developed for water supply. Groundwater boreholes average around 40 m depth in the basement rocks and about 60 m deep in the Karoo strata (Robins, 1978; Piteau Associates, 1992).

A hydrogeological survey carried out in the 1980s involved geological and geophysical surveying of potential borehole sites, drilling of 395 new boreholes with associated pump tests and chemical testing and establishment of a database (Piteau Associates, 1992). Borehole yields in granite and gneiss averaged around 1.2–1.6 L/s, <1 L/s in massive basalt and rhyolite. The study considered the most productive groundwater formations to be the greenstone belt, Mozaan Group quartzite, weathered basalt and fault zones. In these, borehole yields were found to average slightly over 2 L/s. Except for the Lubumbo basalts, the productive zones are mostly located in the Highveld. The report noted the existence of 1400 boreholes at that time with overall yields averaging 1.4 L/s (Piteau Associates, 1992).

Groundwater Quality

Overview

Groundwater chemical compositions vary from Ca-(Mg)-HCO_3 to Na-HCO_3 in the recharge areas of the Highveld basement to Na-Cl types in the discharge areas of the Lowveld. Groundwater salinity varies accordingly and while groundwaters in the basement areas (Highveld and Middleveld) are mainly fresh, higher salinity is noted in groundwaters further east and many of these are unsuitable for potable use. Some groundwater in the upland basement areas appears to be mildly acidic (Robins, 1978).

Fluoride is a particular problem, occurring above recommended limits (WHO guideline value 1.5 mg/L) in some groundwaters from the granitic basement and from the Lowveld sedimentary aquifers.

Thermal springs (water temperature 36–52°C) have been recorded in areas of granitic and metamorphic basement in the Highveld and Middleveld (Robins, 1978; Robins and Bath, 1979). Most occur around Ezulwini, Mkoba, Madubula and Siphofaneni (Piteau Associates, 1992). Many are associated with faults, although flow lines appear to be largely shallow. The springs are typically alkaline, Na-HCO_3 waters (pH 9) although some are more saline and of Na-Cl type. Dissolved sulphide appears to be detectable in some (Robins, 1978).

Nitrogen species

Spatial distributions of nitrate in the groundwater appear to be extremely variable. Pollution from urban, domestic (pit latrines) and agricultural contaminants are likely sources. Fadiran et al. (2005) reported concentrations of nitrate in the range 0.05–28.4 mg/L as NO_3-N in 88 groundwater samples from dug wells, boreholes and springs taken across the country; 10% of sample concentrations were above the WHO guideline value for nitrate in drinking water. The greatest proportion of exceedances occurred in dug wells, followed by boreholes; none of the sampled springs had concentrations in excess of the guideline value.

Some of the highest nitrate concentrations appear to occur in groundwaters from the Karoo sedimentary strata and among the lowest in the basement rocks of the Highveld. Concentrations up to 38 mg/L (as NO_3-N) and averaging 3.8 mg/L were found in the groundwaters of the Lowveld (Piteau Associates, 1992). Concentrations are likely to vary according to groundwater flow regime and local land use. Shallow groundwaters in dug wells appear to be particularly vulnerable, probably as these are open to contamination from surface contaminants and may be commonly sited close to dwellings and latrines.

Fadiran et al. (2005) also measured concentrations of nitrite in the groundwater samples from their study. Concentrations were in the range 0.3–297 μg/L; none exceeded the WHO guideline value for nitrite. No data for ammonia could be found for the groundwaters.

Salinity

Salinity variation depends on rock type and topography. In the crystalline basement, where recharge rates are high and flow paths shallow and short-term, concentrations of total dissolved solids are predominantly <800 mg/L. Those in the Karoo sedimentary rocks of the Lowveld are more variable, with many over 1500 mg/L (Robins, 1978; Piteau Associates, 1992). The higher values reflect geological differences, longer residence times and evapotranspiration. Patterns of electrical conductivity (EC) vary similarly from 120–1600 μS/cm in the granitic and metamorphic rocks, 120–3000 μS/cm in the volcanic rocks (highest values in the Lowveld) and 180–4000 μS/cm in the Karoo sedimentary aquifers (Piteau Associates, 1992). Piteau et al. (1992) produced a national map of EC values which demonstrated the regionally high values of groundwater from the Lowveld Karoo aquifers, particularly within the shales, coals and carbonaceous sediments of the Ecca Series. The majority of analyses from the Karoo had values >800 μS/cm. Groundwater in the Lubombo Mountains is also said to be relatively saline (Robins, 1978) though the Piteau et al. (1992) EC map shows values typically <800 μS/cm in the eastern Lubombo uplands.

Salinity of the geothermal springs appears to be mostly low, probably reflecting dominantly shallow flow lines and short residence times.

Fluoride

Concentrations of F in groundwater above 3 mg/L (up to 18 mg/L), have been reported in some areas. Piteau Associates (1992) presented a national map of fluoride in groundwater, which showed the distribution of high concentrations to be patchy. Relatively high values were found in association with granite, gneiss, mylonite (along fault zones), Lubombo Rhyolite and Karoo sediments, although in each of these cases, averages were reported around 1 mg/L (Piteau Associates, 1992). Fluoride appears to be a particular problem in groundwaters of the Ecca Series (Karoo), where concentrations up to 40 mg/L have been found (Kieser et al., 1951; reported in Robins, 1978). Association of increased fluoride concentrations with calcium-poor rocks (granite, rhyolite) and/or calcium-poor groundwaters appears likely. Concentrations up to 31 mg/L have also been recorded in the hot springs. Most analysed samples appear to have concentrations <0.5 mg/L, however. In the Lowveld sedimentary aquifers, increased fluoride concentrations show some associations with high salinity.

Iron and manganese

Concentrations of iron and manganese are expected to be mostly low, except where groundwater is acidic in parts of the granitic basement; and in areas of the Karoo sequence especially where coal and carbonaceous horizons are present. Here, aquifer conditions may be locally reducing and facilitate mobilisation of these trace elements from metal-oxide minerals. Neither element is now considered by WHO (2011) to be of health consequence at the concentrations typically found in drinking water, although their presence may prove unacceptable to consumers.

Arsenic

The concentrations of arsenic in groundwaters are not currently known as data appear to be limited. Concentrations in areas of granite and gneiss of the Highveld are likely to be low on the assumption that groundwaters are mostly shallow, oxic, pH-neutral to acidic and of low salinity. Higher concentrations may be found in alkaline waters (Na-HCO_3-dominated) and particularly in Karoo aquifers bearing carbonaceous deposits (notably the Ecca Series). Locally high concentrations may be found in areas associated with gold (Hhohho District), and alkaline geothermal springs together with groundwaters impacted by them could have high concentrations. Testing for arsenic in the groundwaters, particularly in the areas associated with gold mineralisation, coal and those impacted by hot springs is recommended.

Iodine

No data are known to be available for iodine in groundwater. Concentrations would be expected to be low (a few μg/L) in groundwaters from the basement rocks of the Highveld and Middleveld, both because of the expected iodine-poor status of these rocks, and low iodine concentrations in continental rainfall. Concentrations may be higher in the sedimentary aquifers of the Lowveld however, especially the carbonaceous formations, in line with increased salinity there. Iodine deficiency has been reported in populations in the Highveld of Swaziland, though those in the Lowveld appear to be less at risk (Kieser et al., 1951; Lwenje et al., 1999). This would appear consistent with the above assumptions.

Other trace elements

Concentrations of dissolved phosphate were found to be in the range 0.10–0.49 mg/L (as P) in groundwater (15 sites) from Manzini and Lubombo regions by Fadiran et al. (2008). These values are not of concern from a drinking-water perspective although the upper end of the range is relatively high. Many were from rural sites so natural dissolution reactions, especially from granites, is considered likely. There may be associations between high concentrations of dissolved phosphorus and fluoride in some of the granitic aquifers and derivation from similar mineral sources (phosphates and silicates) is possible.

No other information is currently available on trace elements in the groundwaters. Trace metals may be above background concentrations locally in groundwaters close to occurrences of gold mineralisation (e.g. copper, nickel, zinc, chromium). Concentrations of various trace metals may also be relatively high in the Karoo aquifers with carbonaceous deposits. Uranium may be present in groundwater from the granitic basement in the Highveld and Middleveld, though significant occurrences of concentrations above the WHO guideline value of 30 μg/L are unlikely.

Data sources

NIRAS PINSISI, 2006. Swaziland Country Environment Profile. Report to The Commission of the European Communities.

Fadiran, A.O., Dlamini, S.C. and Mavuso, A. 2008. A comparative study of the phosphate levels in some surface and ground water bodies of Swaziland. *Bulletin of the Chemical Society of Ethiopia*, 22, 197-206.

Fadiran, A.O., Mdlulie, W.F. and Simelane, B.K. 2005. Analysis of nitrates and nitrites in subsoil and ground water samples in Swaziland. *Bulletin of the Chemical Society of Ethiopia*, 19, 45-54.

Kieser, J.A., Odendaal, W.A., Snyman, H., Naude, C.P. and Steyn, D.G. 1951. Report on an investigation into the incidence of endemic goitre in Swaziland. University of Pretoria, Dept Pharmacology, Unpublished Report.

Lwenje, S.M. Okonkwo, J.O., Mtetwa, V.S.B., Gamedze, A.G., Mavundla, J.A. and Sihlongonyane, M.M. 1999. Determination of urinary iodine in school children of the Hhohho region in Swaziland. *International Journal of Environmental Health Research*, 9, 207-211.

Piteau Associates, 1992. Groundwater Resources of Swaziland. Piteau Associates, Vancouver, Canada.

Robins, N.S. 1978. Hydrogeology and groundwater development in Swaziland. Report WD/OS/78/36.

Robins, N.S. and Bath, A.B., 1979. Assessment of the thermal springs of Swaziland. Unpublished

Report No. WD/OS/79/16, Swaziland Department of Geological Survey and Mines.

Watson, A., Price Williams, D. and Goudie, A.S. 1984. The palaeoenvironmental interpretation of colluvial sediments and palaeosols of the late Pleistocene hypothermal in Southern Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 45, 225-249.

WHO (2011). Guidelines for Drinking-Water Quality, Fourth edition. World Health Organization, Geneva.