

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

Mozambique lies in south-eastern Africa between South Africa and Tanzania, with the Mozambique Channel forming its eastern border (Figure 1). Lake Nyasa forms part of the north-western border with Malawi and Tanzania. The country has an area of 801,600 square kilometres and some 2500 kilometres of coastline.

Terrain consists mainly of coastal lowlands around 200–500 m above sea level, but with upland central areas and high mountains in the west and upland plateau in the north-west. Altitude varies from 2436 m at Monte Binga on the western border with

Zimbabwe (west of Beira), down to sea level. The coastal area is marshy. Most of the population is concentrated in the coastal lowlands, including the capital city of Maputo in the extreme south-east (Figure 1).

The climate is tropical to sub-tropical. Average annual precipitation is around 970 mm but varies from 330 mm per year in Pafuri in the south-west to in excess of 2600 mm per year in Gurue in the northern mountains (FAO, 1995). There is a distinct rainy season between October and April. Average annual temperatures are over 20°C in the coastal lowlands. The region is prone to droughts



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

and southern and central areas also to flooding.

Rivers flow mostly south-eastwards across the country and include from north to south the Ruvuma, Louria, Zambezi, Save and Limpopo. The main river, the Zambezi, is the fourth largest in Africa. A large man-made lake, Lake Cabora Bassa, has been created on the river in the west (Figure 1). This houses a major hydroelectric plant. Discharge entering the Cabora Bassa from the Zambezi is estimated to be around 77.5 km<sup>3</sup> per year. At its mouth, the Zambezi forms a broad, marshy delta. Annual discharge of river water to the Mozambique Channel is estimated at some 106 km<sup>3</sup> and accounts for around 85% of the total national river volume discharged (UN, 1989).

Land use is mainly rural, with pastureland dominating (around 56% of the land area). Arable cropping amounts to only around 4% of the land area, much of this in the fertile Zambezi valley of north-central Mozambique. More than 80% of the labour force is employed in the agricultural sector and the main crops produced include cotton, cashew nuts, sugar cane, tea and cassava. Irrigation is mainly along the Zambezi River basin and water is taken almost exclusively from surface sources (mainly rivers).

Principal industries include food and drinks production, chemicals (soap, paints, fertiliser), petroleum products and textiles. Recent industrial investments also include metal production (aluminium and steel) and natural gas. The main ports and harbours are in Beira, Nacala, Maputo, Inhambane, Pemba and Quelimane.

## Geology

The geology of Mozambique comprises mainly ancient crystalline rocks in the north and young, Tertiary and Quaternary sediments and volcanic rocks in the south. The southern limit of the East African Rift Valley extends down through neighbouring Malawi.

Crystalline Precambrian basement covers almost the whole area north of the Zambezi River, over approximately 500,000 km<sup>2</sup> (NU, 1971). The basement consists mainly of gneiss, schist, quartzite and limestone. Intrusions of Precambrian granite also occur, mainly in Tete Province and western Zambezia. Younger dykes of mafic composition cross-cut the crystalline rocks, particularly around the town of Tete and along the western Zimbabwean border (Dias and Wilson, 2000). Parts of the crystalline basement contain mineral veins and associated alluvial gold deposits have been found in the valleys of the Cocone, Metuisse and Namirroe Rivers (Dias and Wilson, 2000). The

basement is covered by a surface weathered ('overburden') layer of variable thickness.

Sediments and volcanic rocks of Karroo age (180–300 million years) crop out in a narrow band along the western border. Karroo formations consist largely of conglomerate, sandstone, schist and coal seams with some basalt (NU, 1971; UN, 1989).

Jurassic sediments (135–180 million years) include sandstones, conglomerates and limestones. These are minor but are found in Lupata, Nampula and Cabo Delgado Provinces.

Cretaceous sediments (65–135 million years) form the westerly limits of the lowland areas. These sediments consist of sandstones, some being calcareous, as well as clays and carbonates with occasional conglomerate which crop out to the south-east of the town of Tete, along the south-western border and in a narrow elongate strip along the north-east coast of Mozambique.

Tertiary sediments (2–65 million years) mainly consist of marine carbonates and sandstones and are found in the coastal region of Cabo Delgado and in large parts of southern Mozambique (NU, 1971; UN, 1989).

Quaternary sediments consist mainly of unconsolidated sand, clay and limestones as coastal dunes, river alluvium and lacustrine deposits.

## Groundwater Availability

Cenozoic sediments form by far the most productive aquifers in Mozambique. In the south, these form an extensive unconfined aquifer which is well replenished as a result of high rainfall and is easily exploited. Miocene carbonates also form good aquifers where they are karstic. These cover around 25,000 km<sup>2</sup> south of the Save River. The water table in this aquifer occurs at around 50 m depth (UN, 1989). Quaternary alluvium has in places been exploited for urban supplies in the coastal areas.

Much lower yields are found in the crystalline basement rocks, volcanic formations and indurated sediments, except where weathered overlying layers are well-developed. Groundwater yields in the crystalline basement rarely exceed 2 litres per second and groundwater storage is restricted to fractures. Boreholes in northern Mozambique are often deep as a result of poor groundwater yields. A number of boreholes in Cretaceous and Cenozoic formations in Cabo Delgado Province exceed 100 m depth as a result of poor yields (UN, 1989).

## Groundwater Quality

### *Overview*

Little information is available on the quality of groundwater in the aquifers of Mozambique. That available, suggests that the groundwaters are for the most part fresh, although significant salinity problems are experienced in some parts of the Tertiary aquifers in the south as a result of seawater intrusion. In addition, potential for pollution exists in the vicinity of industrial and urban developments (including that from sewage effluent and from centres of petroleum and chemicals manufacture and ports) as well as from agricultural activity. Pollution incidence is likely to be greatest in the coastal lowlands.

### *Salinity*

Limited reporting of groundwater quality suggests that most aquifer formations contain relatively fresh groundwater with low concentrations of total dissolved solids (TDS), being typically less than 1000 mg/l. Concentrations increase substantially in groundwater from aquifers in the southern lowlands where saline intrusion has occurred. Some wells south of the Save River have been found to have TDS contents of 4000–10,000 mg/l and in the Dindiza, Chigubo and Alto Changane areas, TDS concentrations up to 45,000 mg/l have been recorded (UN, 1989). Groundwater from the lower part of the Pungue River basin (around Beira) is also reported to have elevated salinity (UN, 1989).

### *Nitrogen species*

Although no data could be found to ascertain the concentrations of nitrate in the Mozambican groundwaters, it is likely that concentrations are elevated in groundwater from some wells in the urban and agricultural areas. Groundwaters from fractured crystalline rocks and from the unconfined Cenozoic aquifer of southern Mozambique are likely to be aerobic such that any nitrate derived from pollution sources can be maintained in solution in the groundwaters rather than being removed by chemical and microbiological processes. Concentrations of NO<sub>3</sub>-N may be expected to exceed the WHO guideline value for drinking water of 11.3 mg/l in some groundwater supplies. The concentrations of nitrite and ammonium are unknown.

### *Fluoride*

The geology of Mozambique is such that minerals and rocks containing high fluoride concentrations are likely to exist in the northern upland areas.

These include the granitic outcrops in particular. The southern limit of the East African Rift Valley also extends along the border area with Malawi. Since this is a well-known high-fluoride province, there is clearly potential in northern Mozambique for groundwaters to contain high fluoride concentrations, in excess of the WHO guideline value for drinking water of 1.5 mg F/l. However, high rainfall and hence high infiltration rates in northern Mozambique are likely to reduce the risk of high fluoride concentrations significantly. Despite this, the fact that high concentrations have been found in groundwater from neighbouring Malawi suggests that groundwater testing for fluoride would be advisable, particularly in northern Mozambique. Groundwater from sedimentary aquifers in lowland southern Mozambique is considered less likely to contain high concentrations.

### *Iron and manganese*

No reports of groundwater water quality are known to have identified high concentrations of iron and manganese as a problem in Mozambique. High concentrations of these elements are only expected in anaerobic or in strongly acidic groundwaters, neither of which have been reported in the country. Some areas of young (Quaternary) alluvium and coastal marshes may contain anaerobic groundwaters, but these are of limited lateral extent and the degree to which they are exploited is not known. Salinity is likely to be a prime factor limiting potability in groundwaters from the coastal lowlands.

### *Arsenic*

Of the aquifers in Mozambique, those most vulnerable to contamination by arsenic are likely to be areas of mineralisation associated with gold, including alluvial gold deposits. Areas of young alluvium, particularly along the river valleys, the Zambezi delta and the coastal marshes may also be at increased risk. As noted above, the extent of exploitation of groundwater in these areas is uncertain.

### *Iodine*

No iodine data could be found for the groundwaters. Given the maritime location, abnormally low (and potentially detrimental) concentrations are not expected. Highest concentrations (several tens of µg/l or higher) are expected to be present in the saline groundwaters of the south.

### ***Other trace elements***

Assessment of groundwater quality with respect to other trace elements is highly speculative because of the paucity of available data. Groundwater from areas of mineralisation (particularly sulphide mineralisation, including gold deposits) may have increased concentrations of a number of trace elements including zinc, copper, lead and cadmium as well as arsenic, although the scale of any problems in terms of concentrations and areal extent is uncertain. As noted above, of the rock types present in Mozambique, the crystalline basement is most likely to contain areas of mineralisation. No studies are known to have been carried out on the trace-metal concentrations of water from Mozambique, although a number of studies have been carried out in mining areas from neighbouring countries. Grobler et al. (1994) investigated the concentrations of cadmium, mercury, lead and arsenic and a number of other metals in surface waters and soils from the Olifants River catchment of South Africa. This forms a tributary of the Limpopo River. The study revealed that the concentrations of a number of trace elements were elevated in some samples, although the extent of contamination was minor, with most samples having trace-metal compositions close to natural background levels. Jonnalagadda and Nenzou (1996) studied the area around the abandoned Champion mine of eastern Zimbabwe, close to the Mozambican border. These authors found slightly increased concentrations of elements such as copper, nickel, manganese, arsenic and lead in river waters from the area. In each of these areas, the mining-related contamination of river waters appears to be a local phenomenon, the extent of contamination most likely being restricted due to the strong retention (adsorption) of trace metals by sediments and soils. Groundwaters are also likely to be less vulnerable to contamination from mining effluents and seepages than surface waters.

Nonetheless, trace elements such as copper, zinc, lead, cadmium and arsenic are worthy of investigation in groundwater supplies which are close to (within a few kilometres of) areas of mineralisation and mining activity.

Other areas of potentially increased trace-element concentrations are groundwaters from the urban centres of the coastal zone of Mozambique, resulting from point sources of pollution.

### **Data sources**

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