Groundwater Quality: Madagascar

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

Madagascar is a large island, some 1600 km in length (north to south) and 587,000 square kilometres in area. The island lies around 300 km off Mozambique (south-east Africa) in the Indian Ocean. Topography consists of a central mountainous region with an average altitude of 2000 m, which covers around two thirds of the island. The highest point is Maromokotro (2876 m). The uplands are surrounded by a number of narrow coastal plains.

Madagascar has a variable climate, ranging from tropical along the coast, to temperate in the inland plateau areas, to arid in the south. Average annual rainfall is 1700 mm, but with large regional variations from 3000 mm in the east to less than 400 mm in the extreme south (Sourdat, 1977; UN, 1989). The rainy season, influenced by the north-west monsoon, occurs during November to April, and the dry season, influenced by the south-east trade winds, occurs from May to October. The average annual temperature is 17.8ºC, but is hottest in the western coastal area. The high plateau areas have a tropical mountain climate with average temperatures in the range 16–20ºC (UN, 1989).

Land use is dominated by pasture and woodland (each covering around 40% of the land area). The dominant arable crops are coffee, vanilla, sugarcane, cocoa, rice and cassava.

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

Geology

The geology of Madagascar is composed substantially of ancient (Precambrian) crystalline basement rocks ('socle'), largely of granite, gneiss and schist, which form the high plateau regions. Younger rocks are present in sedimentary basins which form the coastal lowlands and young alluvium occurs in intermontaine valleys in the plateaux. These often have intercalations of volcanic rocks, largely of basaltic composition.

There are four main coastal sedimentary basins in Madagascar, each with mixed sequences of sands and clays and with abundant carbonate material (marls, limestones) as well as volcanic formations. Quaternary sediments in these areas are dominantly beach sands and dunes with alluvium and some coastal mangrove swamps.

The western basin consists of an elongate tract of mainly Karroo (Upper Carboniferous to Jurassic age) continental sediments with overlying younger deposits. The Karroo sediments are mainly sandstones, clays, some conglomerates and metamorphosed sediments. In the extreme north of Madagascar, the Diégo-Suarez Basin consists of mixed sediments of Permian to Quaternary age, with an additional outcrop of basaltic volcanic rocks (Massif d'Ambre). The eastern coastal strip of the island comprises a sedimentary basin of Cretaceous to Quaternary age, with abundant sandstone and some volcanic deposits. In the flat-lying area of the far south, sediments consist of Tertiary clays and sandstones, with a number of young (Quaternary) dune formations.

Mineral deposits in the crystalline basement rocks include graphite, coal and some uranium deposits. Copper deposits are also present in some basement areas, notably the south-western part of Madagascar (Besairie, 1952). Exploration for gold is also ongoing in some areas of basement.

The crystalline basement rocks are generally covered by a layer of weathered material ('overburden'), typically 10–40 m thick (Grillot, 1992). Overlying soils in these areas are often hard and lateritic. Peat is also developed in some upland areas over the weathered basement (Grillot and Dussarrat, 1992).

Groundwater Availability

Groundwater is a major source of public supply for Madagascar, and in some drier areas (e.g. the south) it is the only source of available water. Surface water is used as a complementary supply in some areas, notably the towns of Fianarantsoa and Antsirabe in central Madagascar (Figure 1). Groundwater abstraction is from a large number of different formations, but usually the sedimentary aquifers. Of the sediments present, the limestone strata form the best aquifers. The largest towns supplied with groundwater are Majunga and Toliary, which each use groundwater from an Eocene (Tertiary) limestone aquifer (UN, 1989).

Groundwater availability in the basement areas is generally more sparse, except where fractures are developed in the crystalline bedrock, principally at shallow levels, and where the weathered overburden is best-developed. In the southern part of the basement complex, UNICEF has installed 150 tubewells with handpumps in an area north and west of Antanimora (east of Ampanihy, Figure 1). The World Bank is also financing the construction of an additional 500 tubewells in this area.

Groundwater Quality

Overview

Little information is so far available on the quality of groundwater in Madagascar's aquifers and almost no chemical analyses were available for interpretation at the time of writing. Various descriptions suggest that salinity is a problem in some of the coastal aquifers, especially in southern Madagascar. Deeper groundwater from the basement complex is also affected by high salinity in some areas.

Little is known of the pollution status of Madagascar's groundwaters, but surface water is noted to be polluted in places with raw sewage and other organic wastes (CIA, 2000). Hence, shallow groundwaters have the potential to be likewise influenced.

Many of the groundwaters have high alkalinity values. High-iron groundwaters are also present in some areas, especially in Cretaceous and young alluvial aquifers (UN, 1989).

Nitrogen species

Shallow groundwater samples from many parts of Madagascar are expected to show evidence of pollution from domestic and agricultural sources. Although no data are currently available, it is likely that nitrogen species, particularly nitrate, are present in some groundwaters at above-background concentrations. Nitrate concentrations are likely to be low in the high-iron groundwater from the coastal alluvial aquifers, though concentrations of ammonium in these may be increased.

Salinity

In the high plateau areas, shallow groundwater from crystalline basement rocks and their weathered overburden commonly has a low degree of mineralisation (low concentrations of dissolved solids) where rainfall is high and water infiltration to the aquifers rapid. Grillot (1989) gave conductivity values of less than 35 μS/cm (i.e. very low) for springs from shallow weathered rocks in the high plateau of north-central Madagascar. Deeper fluids in parts of the crystalline basement appear to be saline (sodium-chloride-rich) brines. Upwelling of these to shallower levels may increase the salinity of shallow water in some areas. Around 30% of the UNICEF boreholes completed in the basement rocks of Antanimora area had prohibitively high salinity for potable purposes and a number were abandoned after completion. Salinity appears to increase with depth but in the Antanimora area has been found to vary significantly over small distances (UNICEF/World Bank, 2001). The distribution of saline groundwaters in the region suggests that a preferable borehole site selection would be at shallowest depths and close to alluvial channels where groundwater recharge is greatest.

Groundwater in the sedimentary basins is generally fresh, but becomes more saline in young (Tertiary and Quaternary) sand aquifers in the far-south of the island with some evidence of saline intrusion problems, especially in the deeper parts of the coastal aquifers (UN, 1989).

Fluoride

Fluoride concentrations in the Malagasy groundwaters are unknown. Concentrations are likely to be very low in groundwaters from the humid plateau areas of large parts of Madagascar, especially the spring waters of low salinity. Circumstantial evidence from dental practitioners suggests that concentrations are generally likely to be low as Madagascar has a relatively high rate of dental caries despite having a relatively low sugar intake (The Sugar Bureau, 1999).

Fluoride concentrations may be higher in the more saline deeper basement groundwaters, although these are unlikely to be used significantly for water supply. Increased concentrations may be expected in the groundwater from aquifers in the more arid south-west of Madagascar. Whether these exceed the WHO guideline for fluoride in drinking water (1.5 mg/l) is uncertain and could only be determined by water testing. Exceedances are possible in some sources. However, there are no known records of dental fluorosis in the country.

Iron and manganese

As noted above, iron concentrations are high in some groundwater sources from the Cretaceous and young alluvial aquifers. Concentration ranges are not known. If present in sufficiently high quantity (greater than around 1 mg/l), they may be considered unfit for use by the local communities given availability of alternative low-iron sources nearby. While high iron concentrations may promote acceptability problems, they are not known to pose a health problem. Where iron problems occur in these aquifers, it is likely that manganese concentrations are also generally high. In some sources, they may exceed the WHO health-based guideline value for manganese in drinking water of 0.5 mg/l.

Arsenic

No data are so far available for arsenic in the groundwater. Most are expected to have low concentrations, below drinking-water standards. However, the recognised occurrence of high-iron groundwaters in some Cretaceous and recent alluvial sediments means that arsenic concentrations may potentially be elevated in some of these abstraction sources. Testing for arsenic should be a priority in wells from these high-iron areas to assess the degree of risk posed.

Iodine

Given the maritime location of Madagascar, it is likely that iodine concentrations of the groundwaters will be sufficiently high to prevent the significant development of water-related iodine-deficiency disorders (IDDs; see Iodine Fact Sheet). Relatively high concentrations of iodine (tens to hundreds of μg/l) may be expected in some of the more saline waters found at depth in the basement rocks and in coastal areas affected by saline intrusion. Nonetheless, such concentrations are not considered to pose a health risk. WHO has no health-based guideline value for iodine in drinking water.

Other trace elements

There is little other information on inorganic groundwater quality. Occurrence of uranium mineral deposits in some areas of the crystalline basement (mobilised at depth by hypersaline brines) leads to the prospect that uranium concentrations may be high in some groundwaters from the basement areas (e.g. Tsarasaotra area, north central Madagascar; Besairie, 1952). Since the WHO guideline value for uranium in drinking water is low (2 μg/l), it is possible that a number of sources will

have concentrations close to or in excess of this value. Reconnaissance analysis of uranium in a selection of Malagasy groundwaters is recommended.

Data sources

Besairie, H. 1952. Madagascar carte géologique, échelle au 1: 1,000,000. Service Géographique de Madagascar.

Grillot, J.C. 1989. Analyse de l'estimation des débits souterrains en domaine altéritique (Hauts plateaux de Madagascar). *Journal of African Earth Sciences*, **8**, 51-55.

Grillot, J.C. 1992. Régime des eaux souterraines en milieu cristallin altéré: un exemple en zone intertropicale humide d'altitude (Madagascar). *Hydrological Sciences Journal*, **37**, 105-117.

Grillot, J.C. and Dussarrat, B. 1992. Hydraulique des unites d'interfluves et de bas-fond tourbeux: un exemple en zone de socle altéré (Madagascar. *Journal of Hydrology*, **135**, 321-340.

Sourdat, M. 1977. Travaux et Documents de L'ORSTROM No. 70. Le sud-ouest de Madagascar: morphogenèse et pédogenèse. Office de la Recherche Scientifique et Technique Outre-Mer (ORSTROM), Paris.

The Sugar Bureau, 1999. A quantitative dietary guideline (dietary reference value) for sugar?. Report for UK Department of Health, 11 pp. Website: http://www.doh.gov.uk/coma/sugar/sugar1.pdf.

UN, 1989. Madagascar. In: *Groundwater in Eastern, Central and Southern Africa*, Natural Resources/Water Series No. 19, United Nations, New York, pp 133-149.

UNICEF/World Bank 2001. Madagascar. Developing water supplies from fractured-rock aquifers. Website: http://www-tc.iaea.org/tcweb/sf_raf8029/countrysummaries/madagascar_summary_update01.pdf.