

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

Tanzania, located in east Africa, is bordered by Kenya, Uganda, Mozambique and the Indian Ocean with a total land area of 945,000 sq. km (including Mafia, Pemba and Zanzibar). The terrain consists of lowland plains along the coast, a central plateau (1000-1500 m) and highlands over 2000 m in the north and south. Kilimanjaro, the highest mountain in Africa, lies in north-eastern Tanzania with an altitude of 5895 m. Lakes Tanganyika and Victoria lie partially within Tanzania, along the western and northern borders respectively.

Climate varies from tropical in coastal areas to temperate in the highlands and semi-arid in the central plateau. Annual rainfall ranges from 2500-3000 mm on the flanks of Mount Meru in the north, to 1000 mm at the coast, down to 550 mm in the central plateau (Dodoma). Highest points in northern Tanzania are snow-covered. Mean annual temperature in the Mount Meru area (north) is 19°C (range 12-28°C), but increases to 26°C at the coast.

Tanzania's economy is heavily dependent on agriculture (57% of GDP), although topography and climatic conditions limit the area of cultivated land to just 4% of the total. Irrigated land area amounts to just 1500 sq. km (1993 estimate).

## Geology

The topographic variations in Tanzania are strongly controlled by geology. The central plateau is composed of ancient crystalline basement rocks. These are predominantly faulted and fractured metamorphic rocks with some granites.

The northern and southern highland regions are parts of the major East African Rift system which extends northwards through Kenya and Ethiopia, and which has developed over the last 30 million years through extreme crustal tension, rift faulting and volcanic activity. The Gregory Rift (Figure 1) extends with a north-north-west trend through northern Tanzania and the Western Rift extends north-west to south-east along the south-western margin of Tanzania. The geology of the Rift zones

comprises volcanic and intrusive rocks, largely of basaltic composition, but with some rare sodic alkaline rocks and igneous carbonates (e.g. Oldoinyo Lengai volcano). Some of the volcanic centres are active (producing new lava and ash formations periodically) and associated with hot springs.

Some of the large lakes of Tanzania are 'soda lakes', which are highly alkaline (pH>8), sodium-rich lakes associated with the volcanic activity.

Much of the south-eastern part of the country is composed of sedimentary rocks of various ages (Palaeozoic to Recent), including the Karroo Sandstone which extends from the coast at the Kenyan border south-westwards to Lake Nyasa. The sediments are mixed formations, including sandstones, mudstones and limestones. The Karroo Sandstone includes some coal seams.

The coastal plain consists of largely unconsolidated sediments (beach sands, dunes and salt marsh) together with some limestone deposits (Nkotagu, 1989).

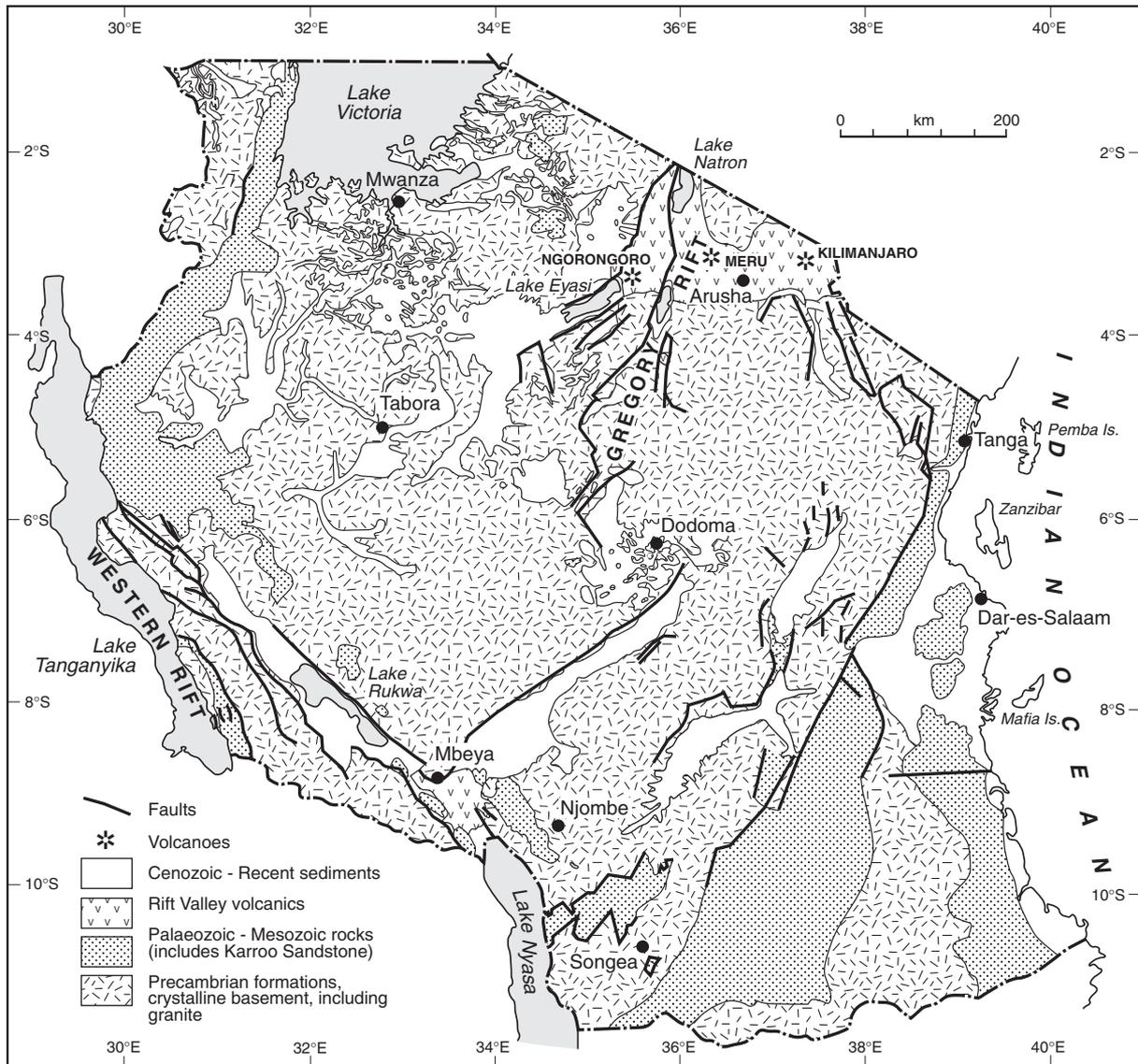
Unconsolidated recent sediments also infill depressions in parts of the eroded crystalline basement in central Tanzania.

## Groundwater Availability

In the crystalline basement of the central plateau, groundwater flow is restricted to joints and fractures and is therefore limited. Groundwater is potentially more abundant in the topmost part of the basement which has been highly weathered in places and is hence friable and more permeable. The thickness of the weathered layer ('regolith') is variable but in the Dodoma area averages around 50 m (Nkotagu, 1996).

The water table in the region is typically shallow and drinking water is abstracted from both hand-dug wells (<10 m) and deeper hand-pump tubewells.

Groundwater resources are available in the Rift areas, and are used for potable supply. Hot springs



**Figure 1. Simplified geological map of Tanzania**

also occur, and can affect groundwater chemistry considerably.

Groundwater in the coastal sedimentary aquifer typically lies at shallow depth (<10 m) and groundwater abstraction is apparently largely from shallow hand-dug wells (Nkotagu, 1989).

## Groundwater Quality

### Overview

Groundwater quality is controlled largely by geology. Groundwaters in the Rift zone of the north are typically alkaline and soft (low calcium and magnesium concentrations) with high pH values and relatively high sodium concentrations. Some are saline, although groundwaters around the extinct volcano, Mount Meru, are reported to be generally fresh (total-dissolved solids usually less than 1000 mg/l; Issar, 1978).

Groundwaters from the ancient crystalline basement of central Tanzania also typically have high alkalinity and relatively high sodium concentrations and with slightly acidic to highly alkaline pH values (6.1 to 9.1; Nkotagu, 1996). Salinities vary but can be high with total-dissolved solids between 1000 and 3000 mg/l.

Groundwaters from the recent sediments in the coastal plain are vulnerable to marine intrusion, particularly where groundwater-pumping rates are high. Evidence of marine intrusion has been found in the coastal aquifer of the Kigamboni Peninsula (Dar Es Salaam) with elevated chloride, sulphate and sodium concentrations and with total-dissolved solids up to 1700 mg/l (Nkotagu, 1989).

Little information is available for groundwater quality in the sedimentary aquifers from the south-eastern part of Tanzania.

In groundwaters from both the volcanic terrains and crystalline basement rocks in the central plateau, fluoride concentrations are known to be high and consequently far more information is available for fluoride than for other trace elements of health significance.

### **Fluoride**

Of the reported groundwater-quality problems in Tanzania, fluoride is by far the most severe and widespread. It represents a major problem for water supply nationally. The problem occurs in both the Rift zones in northern and south-western Tanzania, associated with volcanic activity, and in the crystalline basement complex of the central plateau.

Concentrations as high as several tens to hundreds of milligrams per litre have been reported for some groundwaters and high concentrations have also been found in some rivers, soda lakes and hot springs in the Rift zones. Nanyaro et al. (1984) reported concentrations of various water sources in northern Tanzania:

rivers:	12-26 mg/l;
springs:	15-63 mg/l;
alkaline lakes:	60-690 mg/l.

Bugaisa (1971) identified particular fluoride problems in groundwaters from:

- i) Shinyanga/Tabora region:
  - Isanga Basin;
  - Seke (21-250 mg/l);
  - Wembere Depression (7-40 mg/l);
- ii) Dodoma/Singida region:
  - Bahi depression (up to 180 mg/l);
  - Kongwa (up to 90 mg/l);
  - Kondoa (4-7 mg/l, up to 80 mg/l);
- iii) Arusha/Kilimanjaro region:
  - Sanya Corridor (up to 170 mg/l; 4-8 mg/l further north);
  - Ngorogoro Crater and Lemagrut volcanic cone;
  - Serengeti (up to 150 mg/l);
  - Ol Balbal Depression (over 86 mg/l);
  - Mbulu District (up to 99 mg/l);
  - Lake Natron Basin (up to 330 mg/l);
- iv) Musoma region;
- v) Mbeya region:
  - Rukwa Depression (up to 75 mg/l).

Such concentrations are extremely high, even when compared to other high-fluoride groundwater provinces elsewhere in the world.

Incidence of dental fluorosis is very high in these affected areas, and skeletal fluorosis is also serious

in parts. Severe cases have been reported in Kitefu village, east of Arusha (Nanyaro et al., 1984).

Fluorine-rich minerals are abundant in the lavas, intrusions and ashes of the Rift zone, and concentrations are much higher than in similar rock types elsewhere in the world (Kilham and Hecky, 1973). In addition, fine-grained ash deposits present in the Rift are readily leachable. Hot springs are also important sources and account for some of the most extreme concentrations observed in the groundwaters of the northern Rift zone. Some concentration of fluoride in groundwaters from the major depressions also appears to have occurred through extreme evaporation of lake water and subsequent infiltration to the shallow aquifers.

Fluoride build-up in groundwaters from the crystalline basement of the central plateau derives by dissolution of fluorine minerals (e.g. fluorite, apatite) and is facilitated by relatively low dissolved calcium concentrations.

Concentrations in groundwaters from the coastal plain appear to be low. Nkotagu (1989) quoted values in the range 0.002 to 0.38 mg/l.

### **Iron and manganese**

Iron and manganese data are not reported in many published water-quality investigations. Their distribution is therefore not well known. Nkotagu (1989) reported iron values up to 1 mg/l in groundwaters from the coastal aquifer of the Kigamboni Peninsula, although it is not clear whether these were dissolved (filtered) concentrations or whether they included particulate matter (unfiltered samples). It is therefore uncertain whether they are representative of true groundwater compositions.

Since few data have been reported for iron and manganese and since they are readily detectable by taste and appearance if present in significant amounts, they are assumed not to represent a serious regional water-quality problem.

### **Nitrate**

The distribution of nitrate in groundwaters nationally is not known. However, some high concentrations (0.002 mg/l to 102 mg/l as N, mean value 34 mg/l) have been reported in both shallow and deep groundwaters in the Dodoma area of central Tanzania (Nkotagu, 1996 a, b). High values were linked to pollution from sewage effluents, with penetration of the pollution to deep levels in the crystalline aquifer via fractures.

### **Arsenic**

No data are known to exist for arsenic in Tanzanian groundwaters. Concentrations in most areas are likely to be low. However, in the Rift zones where groundwater pH values, alkalinities and fluoride concentrations are high, and especially where groundwaters interact with hot springs, elevated concentrations may occur and would merit investigation.

### **Iodine**

No data are known to exist for iodine concentrations in Tanzanian groundwaters. However, goitre has been reported in the Engari Nanyuki area, east of Mount Meru (Nanyaro et al., 1984) and suggests that drinking water, soils and crops are deficient in iodine in the affected area. Low iodine concentrations in groundwater are most likely to occur in the interior of the country, away from influences of maritime (iodine-enriched) rainfall.

### **Other trace elements**

No other trace-element data are readily available for Tanzanian groundwaters. The alkaline condition of some of the groundwaters and lakes of northern Tanzania suggests that high concentrations of elements such as boron, vanadium, may accompany high fluoride concentrations, although this would need testing for verification.

### **Data sources**

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