

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

Situated in east Africa, Uganda has a total area of around 236,000 square kilometres. The terrain consists mainly of plateau with a rim of high mountains. Altitudes range from the lowest point at Lake Albert (621 m) to the highest point on Mount Stanley (5110 m) on the western border with Congo.

The climate is tropical, becoming semi-arid in the north-east. Annual rainfall varies from over 2000 mm over Lake Victoria and Mt. Elgon, to less than 700 mm in the north-eastern parts of the country (Figure 1). In the south and areas around Lake Victoria, there are two distinct rainy seasons (December–February and June–August), while in the northern parts, the rainy seasons are less well-defined (WRAP, 1999). Average daily temperatures vary from 28°C in January to 25°C in July (in Kampala). Despite the equatorial position, the temperatures are depressed as a result of the high altitudes.

A large part of the area of Uganda (36,000 square kilometres) is occupied by lakes, including the largest, Lake Victoria, which forms part of the south-east border. Most are freshwater lakes with good chemical quality (although with often high bacterial counts). The exceptions are the crater lakes of the Rift Valley (Lakes Albert, George and Edward; Figure 1) which are alkaline and have higher salinity (Mungoma, 1990).

Much of the land area of Uganda is rural, with 43% of the land use being arable, pasture and permanent crops and 28% being forested. Agriculture is the most important sector of the national economy. Agriculture is aided by the often fertile soils and regular rainfall over most of the country. Despite the importance of agriculture nationally, the use of fertiliser and agricultural pesticides is apparently limited (DWD, 1994).

## Geology

The geology of Uganda is dominated by ancient (Precambrian) crystalline rocks (including granites),

which constitute around 90% of the land area. The remaining rock types are dominantly younger volcanic and sedimentary rocks. The volcanic rocks are either associated with the major East African Rift Valley which extends along the western border and incorporates the crater lakes; or in the east, along the border with Kenya. In this area, volcanic rocks outcrop around the town of Mbale (Figure 1) and form the highlands of Mounts Elgon and Moroto.

Mineral veins occur in parts of the basement and mining for copper and cobalt are important industries in Uganda. Kilembe, some 60 km south-west of Fort Portal, is one of the main copper mining centres. Mineral deposits of apatite (a calcium phosphate mineral) also occur at Tororo (Sukulu Hills) on the south-east border.

The crystalline rocks of Uganda are generally covered by 'regolith', a layer of weathered material which varies from rock fragments near the interface with the bedrock, to well-weathered soil and hardened laterite at the ground surface. The regolith layer varies in thickness but is typically of the order of 30 m (Taylor and Howard, 1994).

## Groundwater Availability

Groundwater is the most important source of potable water in Uganda, especially in the rural areas, and provides 80% or more of the water supply. Water is abstracted from both the fractured bedrocks and from the overlying weathered regolith. The regolith aquifer is seen increasingly as a usable resource which aid agencies are seeking to develop on grounds of favourable yields and lower cost than the deeper groundwaters from the basement (Taylor and Howard, 2000). Tubewells are the most common means of groundwater abstraction, although the use of protected dug wells has been a recent NGO-led development. There are also an estimated 200,000 protected and unprotected springs in Uganda which form an important resource, especially in the south-east and the mountainous areas (DWD, 1994).



Figure 1. Location map of Uganda (courtesy of CIA World Factbook).

The regolith layer typically has an upper horizon of clayey sediment which is effective at filtering out some surface-derived pollutants (e.g. bacteria) and in restricting entry of air to the underlying aquifers. This has some implications for the degree of aeration of the aquifers and of the resulting groundwater chemistry.

The basement aquifer has poor permeability but is variably fractured (typically in the topmost 30 m; Taylor and Howard, 1994). The development of fractures is crucial for the availability and yield of groundwater; hence the productivity of the aquifer is highest at the shallowest levels.

## Groundwater Quality

### Overview

Data for groundwater quality in Uganda are usually restricted to major constituents and no time-series data are known to exist. From available data, groundwater chemistry is shown to be highly variable and variations are seen between different types of water source (springs, tubewells) and between different rock types (regolith or crystalline bedrock). Nonetheless, the groundwaters mostly have calcium and bicarbonate as the major dissolved constituents, with sodium and chloride becoming more important in the more saline waters. Spring waters are often the least mineralised with compositions often approaching those of surface waters (WRAP, 1999) and reflecting the lack of reaction with aquifer minerals.

Groundwaters have very variable hardness values. Many with low hardness are described as aggressive

and are acidic ( $\text{pH} < 7$ ). These have the capability to corrode ferrous casings and pumps in tubewells and can lead to impaired water quality (especially iron) and maintenance problems. Some groundwaters are also hard (with high concentrations of calcium and magnesium) and have near-neutral to alkaline pH values.

The dominant groundwater-quality problems in Uganda are likely to be related to poor sanitation. Faecal coliforms have been found in some groundwaters and high nitrate concentrations also occur in some. The main inorganic groundwater-quality problems are fluoride, iron and manganese. Groundwaters with higher salinity (chloride concentrations of several thousand mg/l) have also been reported in some eastern parts of the country (DWD, 1994), perhaps related to the occurrence of volcanic rocks. In addition, the concentrations of a number of other trace elements in the groundwaters have been reported above desirable limits, but the scale of the exceedances is often small. Compared to fluoride, these are likely to be significantly less important.

Despite these water-quality problems, groundwater remains the most important source of safe drinking water in rural Uganda.

### Fluoride

Fluoride is likely to be one of the most serious of the inorganic contaminants as it has well-recognised health effects. High fluoride concentrations (greater than the WHO guideline value of 1.5 mg/l) are found in the Rift Valley of western Uganda and in the volcanic areas of the east (Mbale, Elgon, Moroto areas). The incidence of fluorosis is known to be high as a result. The crater lakes of western Uganda often have high concentrations (e.g. 4.5 mg/l F in Lake Kikorongo; Mungoma, 1990) and concentrations in groundwaters having interaction with these lake waters are likewise expected to be high (and the waters correspondingly saline). High fluoride concentrations are particularly noted in groundwaters from the Rwenzori Mountains on the western border and the Sukulu Hills in eastern Uganda (WRAP, 1999). In the Sukulu Hills, fluoride may also be associated with occurrences of phosphate minerals which are currently being investigated for mining development.

While increased concentrations of fluoride are noted in the rift and other volcanic areas, the concentrations in other parts of the country with ancient basement aquifers and regolith derived from them are not certain. Reports suggest that these aquifers do not have a problem, although the

amount of data is unclear. Problems are not likely in basement areas with high rainfall but concentrations may be higher in groundwaters from granites and in aquifers from the semi-arid north-east. Groundwaters with high alkalinity values are likely to be more at risk. As fluoride is a recognised problem in parts of Uganda, groundwater-quality testing should include fluoride as a routine measurement.

### **Iron and manganese**

High concentrations of iron and manganese are a common problem in Ugandan groundwaters. Iron concentrations frequently exceed the WHO guideline value of 0.3 mg/l, although this is a recommendation made on aesthetic rather than health grounds. Concentrations of manganese also occasionally exceed the WHO health-based guideline of 0.5 mg/l. Some of the high iron concentrations may be related to breakdown of the ferrous parts in the tubewells in acidic conditions, but much of the iron and manganese is likely to be naturally occurring in the groundwaters themselves. Occurrence of shallow clayey regolith horizons are likely to restrict the degree of aeration of the underlying aquifers and some of the high iron and manganese occurrences may be related to the generation of anaerobic conditions in the groundwaters.

Dissolved iron data for groundwaters from the Hoima area (east of Lake Albert) have been recorded in the range 0.3–4.9 mg/l (GIBB, 1998). Concentrations of iron up to 45 mg/l have been found in groundwaters from basement rocks in the Nyabisheki area and up to 3.6 mg/l in the Aroca Basin (Taylor and Howard, 1994; Table 1). These authors also found maximum concentrations of manganese up to 2 mg/l and 0.36 mg/l in these two

**Table 1. Concentration ranges of iron and manganese in groundwaters from study areas in the Aroca and Nyabisheki Basins of Uganda (averages in parentheses; data from Taylor and Howard, 1994).**

	No.	Fe (mg/l)	Mn (mg/l)
Basement rocks, Aroca Basin	15	0.22–3.58 (1.10)	0.007–0.29 (0.089)
Regolith, Aroca Basin	10	0.04–3.41 (0.75)	0.016–0.36 (0.13)
Basement rocks, Nyabisheki Basin	87	0.02–44.7 (4.00)	0.004–2.0 (0.39)
Springs, Nyabisheki Basin	7	0.008–0.22 (0.060)	0.005–1.1 (0.20)

study areas respectively. The regional distribution of high iron and manganese concentrations in groundwaters across Uganda is not certain.

### **Nitrate**

Reported nitrate concentrations in groundwaters are highly variable and problematic in some areas (e.g. the Aroca Basin). Values up to 26 mg/l (as N), more than twice the WHO guideline value, have been reported (Taylor and Howard, 1994). As fertiliser is not used extensively in Uganda, the main sources of nitrate are taken to be of domestic and urban origin. One study showed that highest nitrate concentrations were centred in urban areas and resulted mainly from local inputs from latrines and markets (Taylor and Howard, 1994). Coliform counts are also higher in groundwaters affected by such localised pollution (DWD, 1994). Groundwaters from the shallowest wells and with high water tables are expected to be most at risk from pollutant inputs. In this respect, groundwater from dug wells and springs has been found to be of poorer quality than that abstracted from tubewells (DWD, 1994). Although the use of agricultural chemicals, including nitrogen compounds, has so far been limited in Uganda, their use is increasing and future concentrations of nitrate and related pollutants in the groundwaters may rise.

### **Arsenic**

Few analyses are available for arsenic in Ugandan groundwaters. Taylor and Howard (1994) reported only two arsenic measurements: one for a groundwater from the regolith aquifer and one from the fractured basement aquifer, both in Aroca region (north central Uganda). The values obtained were 9 µg/l and 5 µg/l respectively, both below the WHO guideline value for arsenic in drinking water of 10 µg/l. The nature of the rock types in most of Uganda (old metamorphic rocks, most without recorded incidence of metalliferous mineral veins) suggests that arsenic is not likely to be a significant problem in the groundwaters. There is no known precedent for arsenic problems in groundwaters from old basement rocks such as those of Uganda. Possible exceptions are the groundwaters close to areas of metal mining (e.g. Kilembe area) and those in the Rift Valley where influenced by geothermal activity. No data are known to exist for arsenic in groundwaters from the East African Rift and testing needs to be carried out in these areas in order to establish if an arsenic problem exists.

## **Iodine**

The only data found for iodine in Ugandan groundwaters is also from the data set of Taylor and Howard (1994). These authors reported concentrations for groundwaters from fractured bedrock in the Aroca area in the range 0.3–68 µg/l (average 5 µg/l, 52 samples). This is a large range and while those at the upper end are high values, the lowest concentrations may be insufficient for dietary requirements without other sources of dietary iodine. Endemic goitre and other iodine-deficiency disorders may be a problem for communities in areas with low-iodine water supplies. The extent of low-iodine groundwaters in Uganda is not known. However, iodine-deficiency disorders have been recognised in neighbouring Ethiopia and signal a potential problem in the region as a whole.

## **Other trace elements**

Few data are available for other trace elements in the groundwaters. As a result of mining activity for copper and cobalt, there is a possibility that concentrations of these and other trace metals may be increased above background values in the vicinity of the mines (e.g. around the western town of Kilembe). Bugenyi (1982) found slightly higher concentrations of copper, iron and cadmium for example in lake waters from Lake George, compared to other lakes in western Uganda and related these to inputs from mine wastes. Only cadmium was found in concentrations in excess of WHO guidelines (concentrations found up to 9 µg/l; Bugenyi, 1982). No data are available for groundwaters in the mining areas.

Of the other trace elements considered by Taylor and Howard (1994) for groundwaters in Uganda, barium, nickel, lead, uranium and cadmium showed minor exceedances above WHO health-based guideline values in some groundwater samples from regolith in Aroca region and some exceedances in nickel, barium and chromium in groundwaters from the basement aquifer (Aroca and Nyabisheki regions). Maximum observed values for these were: barium: 1000 µg/l, nickel: 120 µg/l, lead: 11 µg/l, uranium: 4.3 µg/l, chromium: 200 µg/l and cadmium: 13 µg/l. The highest exceedances of these are for nickel and chromium. It is possible that some of this is derived by corrosion of the pumps and ferrous casings in the sampled tubewells, although care was taken to filter out particulate materials and to minimise such sampling artefacts. It is therefore likely that these contaminants are aquifer-derived and representative of the natural water quality. Aluminium was also high in several

analysed samples (up to 8 mg/l). Values were especially high in the groundwaters from the regolith. Such values are considerably higher than the WHO recommended upper limit of 200 µg l<sup>-1</sup>, although this is an aesthetic guideline and there is little convincing evidence that aluminium constitutes a health problem. It may however, lead to an acceptability problem.

Data from other sources suggest that groundwater quality is not seriously impaired with respect to trace metals. Data for 24 metals analysed besides iron and manganese in groundwaters from Mbarara (south-west) and Apac (north-central) districts indicated that none was present in concentrations greater than the corresponding WHO guideline values (EASD, 2000).

## **Data sources**

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