

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 Republic of Ghana, bordered by the Gulf of Guinea, Togo and the Cote d'Ivoire in West Africa, has a total land area of 238,540 sq km. Terrain comprises mostly low-lying plains, divisible into six physiographic regions:

- i) the low-lying coastal plain (up to 132 m);
- ii) the Voltaian Basin (100-200 m), 103,600 sq km in area and surrounded by highlands with outward-facing escarpments. The Basin incorporates Lake Volta, occupying around 8,500 sq km;
- iii) the Voltaian Highlands rising to around 800 m, on the western border of the Voltaian Basin (Koforidua-Mpreaso-Mampong);
- iv) The Akwapim-Togo Hill Range, up to 885 m, extends east of Accra, via Ho along the border with Togo;
- v) the north and north-west plateau, 150-300 m altitude, existing north of the Black Volta through Bole, Wa, Bolgatanga and Gambaga;
- vi) the south-west plateau, also 150-300 m in altitude with occasional hills up to 800 m, occurs south of the Black Volta and west of the Voltaian Highlands and includes Kumasi and Sunyani.

Climate is tropical and varies from warm and relatively dry in the south-east coastal region, hot and humid in the south and south-west and hot and arid (Sahelian) in the north. Average annual rainfall varies between 1600 mm in the south to 1000 mm in the north.

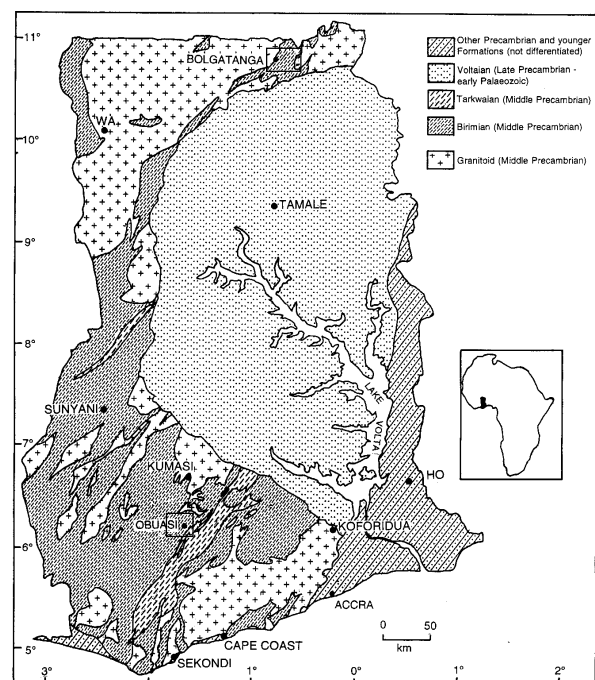
## Geology

Geology is dominated by ancient crystalline rocks, incorporating mainly metamorphosed sediments and granite. Minor occurrences of more recent unconsolidated sands, clays and gravels are restricted to small areas along the coast.

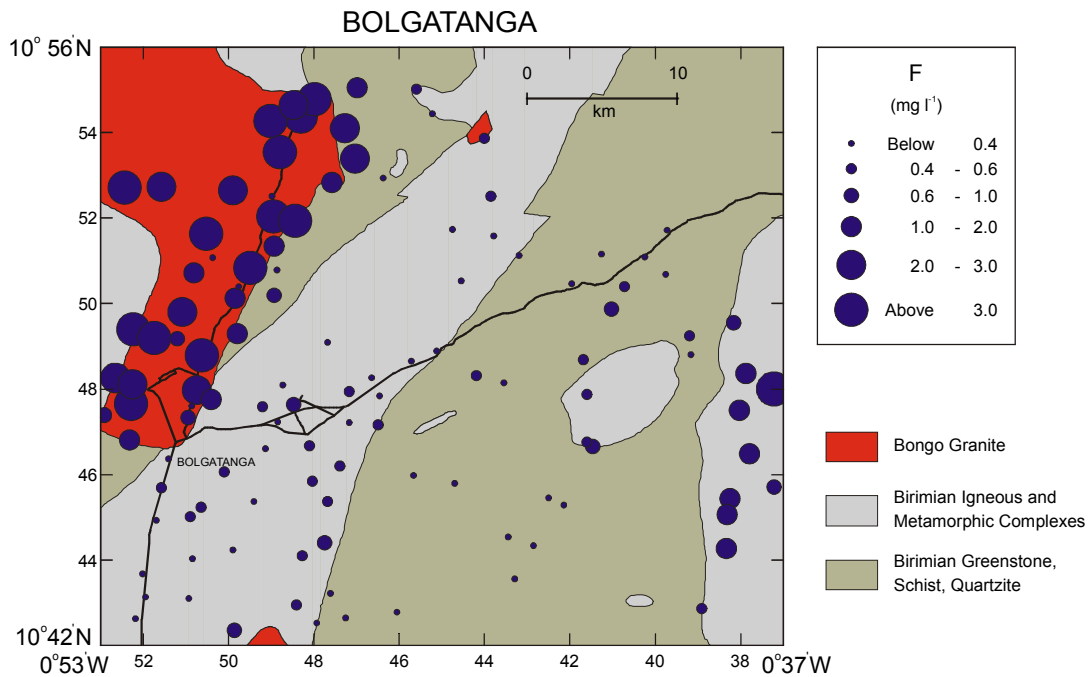
A simplified geological map of the country is shown in Figure 1. The north-west and south-west plateaux are composed of the oldest crystalline rocks of the

'Birimian' and 'Tarkwaian' Formations, with common major intrusions of granite ('granitoids'). South-eastern Ghana, incorporating the Akwapim-Togo Hill Range, is also composed of a mixed sequence of ancient metamorphosed sedimentary and igneous rocks. The Voltaian Basin, covering a large part of central and eastern Ghana, and the Voltaian Highlands along its western margin are composed of consolidated sandstones, mudstones and limestones of the 'Voltaian' Formation. The younger sediments of the coastal basins are composed of river-borne, wind-blown, beach or marine deposits of sand, clay and gravel, largely unconsolidated and of mixed age.

The oldest rocks in the country have been variably metamorphosed, contorted and intruded by granitic rocks since their formation. Major episodes of mineralisation have also produced major mineral veins, many of which are gold-bearing and of significant economic value. The most important



**Figure 1. Simplified geological map of Ghana showing locations of BGS study areas**



**Figure 2. Geological map of the Bolgatanga area, Upper East Region (northern Ghana), showing distribution of fluoride in groundwater**

gold-bearing areas occur within the non-granitoid Birimian rocks (Figure 1; Kesse, 1985).

### Groundwater Availability

Groundwater flow is mostly restricted to joints and fractures within the crystalline rock formations. Borehole yields are therefore often limited. In some areas, a thick layer of weathered friable material ('regolith') overlies the crystalline basement and provides potential for increased groundwater storage. This weathered layer can be in excess of 100 m thick in places, though is more typically in the range 1-70 m thick (e.g. Asomaning, 1992). Groundwater supplies may be higher in the minor sedimentary deposits of the coastal basins.

In the tropical southern part of the country, hand-pump tubewells and dug wells are in common usage, though surface water is still used in parts where tubewells are absent or not working. In the arid north where surface water is more scarce, water supply is dominantly from tubewells and dug wells.

### Groundwater Quality

#### Overview

Geology plays an important role in the determination of groundwater quality and potential water-quality problems. As the country is dominated by crystalline silicate rocks and weathered derivatives (regolith), groundwater is mainly of low salinity and commonly acidic in composition ( $\text{pH} < 6.5$ ), with low values of total hardness. Exceptions occur in areas of limestone (parts of the south-east) and along the coastal

margins where hardness and pH values are higher and where seawater intrusion of the coastal aquifers may increase groundwater salinity. Minor occurrences of saline groundwater have also been noted in isolated boreholes in rocks of the Voltaian Basin. Here the salinity is typically related to high sulphate concentrations (Pelig-Ba, 1999). The principal groundwater-quality problem observed in Ghana is high iron concentrations, seen in many groundwater supplies. The most serious direct health problems related to drinking water are considered to be from fluoride excess and iodine deficiency which have been noted in parts of the Upper Regions of northern Ghana. Arsenic has also been detected in a few groundwater supplies, though not usually at concentrations significantly above guideline values. Arsenic problems are unlikely to be of large lateral extent.

#### Iron and manganese

High concentrations of iron in groundwater occur in many places throughout Ghana. They are generally associated with acidic groundwater or anaerobic (oxygen-free) groundwater. Concentrations as high as 57 mg/l have been found in some sources (Pelig-Ba, 1989). It is important to note that these are likely to be total concentrations (including particulate material), rather than dissolved concentrations measured after filtering of the water samples. Particulate iron may be derived from steel pumps and casings as well as occurring naturally in the groundwater, hence high total iron concentrations can be found in groundwater from any of the aquifers without predictable patterns.

**Table 1. Summary of potential groundwater-quality problems in Ghana**

Determinand	Potential Problem	Geology	Location
Iron (Fe)	Excess, often significant	All aquifers	Many locations
Manganese (Mn)	Excess	All aquifers	Several locations
Fluoride (F)	Excess (up to 4 mg/l)	Granites and some Birimian rocks	Upper Regions
Iodine (I)	Deficiency (less than 0.005 mg/l)	Birimian rocks, granites, ?Voltaian	Northern Ghana (especially Upper Regions)
Arsenic (As)	Excess (>0.01 mg/l)	Birimian	Especially south-west Ghana (gold belt)

High concentrations of iron are not directly problematic for human health but may cause indirect problems because of abandonment of affected water sources due to unpleasant odour and taste, in favour of surface waters which may be contaminated by harmful bacteria.

Manganese typically occurs in association with iron, though concentrations are much lower in Ghanaian groundwaters. Few observed results exceed the WHO recommended guideline (0.5 mg/l, health-based limit). Results from two comprehensive BGS surveys of groundwater (Obuasi, Ashanti Region and Bolgatanga, Upper East Region) indicate that respectively 3% and 0% of potable groundwater sources exceeded the WHO guideline for manganese (Smedley et al., 1995).

#### **Fluoride**

The dominant controls on fluoride occurrence in groundwater are climate and geology. The regions of Ghana most vulnerable to high fluoride concentrations (and associated dental fluorosis) are the arid zones of the north and areas where bedrock geology is dominated by granite. The Upper Regions of Ghana are therefore considered to be the most likely areas to experience potential problems. Concentrations of fluoride in excess of 1.5 mg/l (up to 3.8 mg/l) have been observed in Bolgatanga and Sekoti (Upper East Region, Figure 2) in close association with granitic rock types (Smedley et al., 1995). Occurrence of dental fluorosis is common in these areas. Groundwaters in granitic rocks of the south-west plateau are considered to be less at risk because of higher rainfall and its diluting effect on groundwater compositions.

Marked variations in fluoride concentration with depth were observed in groundwaters from the problem areas of Bolgatanga (e.g. the Bongo Granite, Figure 2). Shallow groundwaters from dug

wells had significantly lower concentrations than tubewell waters as a result of dilution by recent recharge.

#### **Arsenic**

Arsenic poses a potential problem locally in Ghanaian groundwater because of the abundance of arsenic-bearing minerals, particularly arsenopyrite, which occurs in close association with gold in sulphide-mineralised veins. Surface waters close to gold mines have been found to contain relatively high concentrations (>0.01 mg/l, the WHO recommended guideline) of arsenic in localised areas. However, analysed groundwaters have not revealed major arsenic problems. Of 78 potable groundwater samples analysed by BGS in the Obuasi gold-mining area, only 14 (18%) exceeded the WHO guideline (maximum concentration, 0.064 mg/l). In the Bolgatanga area, where sulphide mineralisation is present but less prevalent, only 2 samples out of 118 analysed (<2%) exceeded the guideline value, although one of these was as high as 0.14 mg/l. The results suggest that groundwater arsenic concentrations are not likely to be problematic in general, and any problems related to mining activity are likely to be localised. However, screening of representative groundwaters would be advisable, particularly in the Birimian Formations of the south-west province close to where mining activity is most prevalent to give more information about arsenic distributions.

#### **Iodine**

Deficiency in iodine has been observed in populations of northern Ghana, particularly the Upper East Region. Smedley et al. (1995) found concentrations of iodine in groundwater from the Bolgatanga area to vary mostly between <0.001 mg/l and 0.011 mg/l, with a mean value of 0.005 mg/l. This is in marked contrast to concentrations found in groundwaters from the

Obuasi area which ranged between 0.001 mg/l and 0.15 mg/l (mean 0.015 mg/l). Populations drinking water with concentrations of 0.005 mg/l or less are considered potentially vulnerable to iodine-deficiency disorders (although dietary intakes are also an important consideration). The Upper Regions (with Birimian rocks) are likely to be most at risk from iodine-deficiency problems. Southern Ghana is less likely to be vulnerable.

### **Nitrate**

Concentrations of nitrate (as N) in most groundwater analyses reported from Ghana are below the WHO guideline value of 10 mg/l. Almost all groundwater samples from the BGS surveys of Obuasi and Bolgatanga had NO<sub>3</sub>-N concentrations less than 10 mg/l. Only a few shallow hand-dug wells from the Obuasi area had values in excess of this (observed range <0.2 mg/l to 22 mg/l). The nitrate in these wells is derived from surface pollution. Nitrate appears not to be a serious water-quality problem in areas studied but more study is needed to characterise nitrate concentrations in other parts of the country.

### **Other trace elements**

Few data exist for other trace elements in Ghanaian groundwaters, although those available suggest that few are present in concentrations of concern to public health. Concentrations of analysed Cd, Cu, Hg, Co and Zn vary but are mostly below WHO guideline values.

**Aluminium:** data are lacking for most areas. However, Pelig-Ba (1998) found some relatively high concentrations in groundwaters from the Upper Regions (mean value 4.5 mg/l, n=60). Results from the two BGS field study areas (Obuasi, Bolgatanga) indicate few cases where concentrations exceed the WHO guideline value of 0.2 mg/l. Areas most likely to have elevated concentrations are those where the groundwaters are most acidic, particularly from the Birimian province (Figure 1). Although occasional exceedances are to be expected, aluminium is not likely to be a major regional groundwater-quality problem.

**Lead:** Pelig-Ba et al. (1991) and Pelig-Ba (1999) reported concentrations of lead for selected samples from the Upper Regions, Accra Plains and Voltaian Basin) that were occasionally in excess of the WHO guideline limit for drinking water (0.01 mg/l), although data quality is uncertain. The values observed are in marked contrast to BGS surveys of the Obuasi and Bolgatanga areas which showed no

high lead concentrations. Samples had mostly less than 0.003 mg/l and none exceeded the WHO guideline. Pelig-Ba (1998) also found mainly low concentrations (mean value 0.0018 mg/l) in groundwaters from the Upper Regions of Ghana. It is doubtful whether lead represents a significant water-quality problem in Ghana, but some limited groundwater screening would help to clarify the concentration ranges.

**Chromium:** similarly, Pelig-Ba et al. (1991) found high chromium concentrations in some groundwaters from the Upper Regions and Accra Plains, although BGS surveys found no significant concentrations of chromium in groundwaters from Obuasi or Bolgatanga (Smedley et al., 1995). Concentrations in these study areas were all significantly below the WHO guideline value. Chromium concentrations are probably not of major regional concern.

### **Data sources**

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