Groundwater Quality: Zambia

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

Zambia is a landlocked country in southern Africa, lying to the south of Congo and north of Zimbabwe, with a total land area of around 752,600 square kilometres (Figure 1). Terrain consists mainly of high plateau with some mountains and hills. Elevation varies from greater than 2300 m in the Mafinga Hills on the north-east national border, to 329 m in the valley of the Zambezi River (Figure 1). The western part of the country consists mainly of plateau, typically at 1000–1300 m above sea level. The terrain is more variable in the east. The Muchinga Mountains form a north-east to south-west ridge (up to 1788 m) in the Central and Northern Provinces. Deep valleys occur along the Luangwa and Zambezi Rivers in south-eastern Zambia . Topographic depressions also occur in parts of Northern and Luapala Provinces, where many of the low-lying areas are occupied by swamps, of which the largest is the Bangweulu swamp (Figure 1).

Zambia's climate is tropical, although climatic variations relate to altitude. Annual rainfall averages 1010 mm (range 750–1400 mm) and increases progressively from south to north. A distinct rainy season occurs during October–April. Average daily temperatures are around 18–20ºC during the cool dry season (May–August) and 35ºC during the hot dry season (September–November), with an average of 30ºC during the rainy season (UN, 1989).

Zambia has five major river systems: the upper Zambezi in the west, the Kafue and Luangwa Rivers, a small drainage area of the Tanganyika in the north and the Luapula River which drains northwards into Congo. Water courses are prone to running dry seasonally. Zambia also has three large lakes. Lake Bangweulu lies in the north-east, Lake Mweru lies on the border with Congo and Lake Tanganyika lies on the northern border with Tanzania (Figure 1).

Much of Zambia's economy is based on mining and mineral processing, although this has declined markedly over the last few decades following reductions in world copper prices. Manufacturing has become progressively more important (contributing to around 43% of GDP in 1990; Aquastat, 1995) and agriculture has also increased in recent years. Today, around 40% of the land is used as permanent pasture and 7% as arable. Principal crops include corn, sorghum, rice, peanuts and tobacco. Around 58% of the Zambian population lives in rural areas.

Geology

The geology of Zambia is dominated by crystalline rocks, although a number of sedimentary sequences also occur. The rock types present have been divided into four main units (UN, 1989):

i) Ancient (Precambrian) crystalline basement rocks comprising gneisses and granitic rocks with some metasediments – mainly eastern and southern parts of the country;

ii) the Katanga System (Upper Precambrian to Lower Cambrian) comprising metamorphosed sediments including shales, dolomites and quartzites. The lower part of the sequence has abundant copper deposits, extending from the extreme north-west, through the Copper Belt to Southern Province. The sequence is also enriched in other metals such as cobalt, zinc and lead and has been extensively mined in some areas, especially the Copper Belt. Shales of the Katanga System occur extensively in the Bangweulu area and the west of the Copper Belt;

iii) the Karoo System (Upper Carboniferous–Jurassic) comprising sandstone, shale, limestone and conglomerate with some coal seams – mainly in Southern Province and along the Luangwa valley. In addition, Karoo volcanic rocks (basalts) underlie the Kalahari sediments in Western Province;

iv) the Kalahari Formation (Cenozoic) comprising loose sands, gravels, clays and marls up to 150 m thick – in the west and south-west (mainly Western Province).

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

In addition, extensive alluvium (up to 50 m thick) has been deposited in the Banweulu depression and along the floors of the Kafue and Luangwe valleys (MacDonald and Partners, 1990). The deep valleys of the Zambezi and Luangwa Rivers along the south-eastern border compose part of the major East African Rift system.

Groundwater Availability

There has been growing demand on the available water resources in Zambia and groundwater use is increasing steadily. Today, some 9% of water usage is from groundwater and groundwater provides 28% of domestic water supply. The best aquifers in Zambia occur within the limestone and dolomite horizons of the Katanga system. Yields in these are highest in the top 30 m or so of the sediment strata where fissures are best developed. These aquifers provide a significant proportion of the water supply for the municipalities of Lusaka, Kabwe and Ndole in particular, where boreholes yield up to 35–50 l/s in karstic sections of the aquifers (UN, 1989). The Kundelungu Limestone (part of the Katanga system, central Zambia) yields up to 40 l/s (MacDonald and Partners, 1990). Typical borehole depths are around 50–70 m below ground level.

The second best aquifer is found in the coarser sediments of the Kalahari system where groundwater yields are around 10–20 l/s. Large parts of the Kalahari system are poorly productive however due to abundance of fine-grained material. Within the Karoo system, coarse sediments (sandstones, conglomerates) form the best available aquifers.

Groundwater is of much more restricted occurrence in the crystalline basement rocks which are the dominate rock types. Consequently, water availability is a more significant problem in these areas. Nonetheless, groundwater is present within fractures and joints in the basement rocks and within the weathered overburden, which is typically of the order of 10–15 m thick, but up to 30 m in places.

Sporadic thermal or saline springs occur in parts of Southern, Central and Eastern Provinces (MacDonald and Partners, 1990).

Groundwater Quality

Overview

Very few chemical data are available for groundwater in Zambia on which to base an

assessment of the quality of available resources and reconnaissance testing programmes are urgently needed to establish the drinking-water quality.

Most investigations of water quality in Zambia appear to have been concentrated in the Kafue River basin (Norrgren et al., 2000; Pettersson et al., 2000) perhaps because some 50% of the population lives in the catchment and because mining, industrial and agricultural development has been particularly important in the region. Investigations have however, focussed on the river water quality with little or no investigation of groundwater (Norrgren et al., 2000).

Limited data suggest that Zambian groundwater has generally very low concentrations of dissolved constituents (total dissolved solids concentrations typically less than 200 mg/l; MacDonald and Partners, 1990). Given the geology of the region, the principal groundwater-quality problems are likely to be pollution problems associated with metal mining. Trace metals such as copper and zinc in particular, but also chromium, nickel, cadmium and arsenic may be present in increased concentrations in groundwaters and surface waters affected by inputs from mine adits, slimes dams and tailings piles. Parts of the Copper Belt are potentially most vulnerable.

Nitrate

Concentrations of nitrate as well as other anthropogenic inputs to groundwater are largely unknown but likely to be greatest in the urban and agricultural areas. Transport of these pollutants in the aquifers is potentially greatest via fractures in the crystalline bedrocks and karstic limestone formations. Although no measurements for nitrate were reported, Norrgren et al. (2000) found evidence for the presence of the pesticides DDT and metabolites, as well as PCB and dieldrin in Kafue River water in the Copper Belt. This provides evidence of pollutant inputs to river waters from agricultural sources and suggests that nitrate inputs may also be high. Groundwater is also potentially vulnerable to pollution in these areas, particularly where water tables are shallow.

Iron and manganese

Concentrations of iron and manganese are expected to be low (below recommended limits for potable water) in most shallow groundwaters, except potentially those where groundwater is acidic. Such conditions are most likely in groundwaters from the crystalline basement rocks. Increased iron and manganese concentrations are also likely in areas affected by mine drainage, notably in the Copper Belt. Iron and manganese have been recorded in groundwater from some boreholes at concentrations above 1 mg/l and 0.5 mg/l respectively (MacDonald and Partners, 1990). Much of the dissolved load of these elements is likely to be aquifer-derived, although additional iron may be derived from downhole steel pumps and pipework.

Arsenic

The dominance of crystalline basement rocks and the likely prevalence of slightly acidic groundwaters in these aquifers mean that concentrations of dissolved arsenic in the groundwater are likely to be low. Current understanding of the mobilisation processes of arsenic in aquifers also suggests that other sedimentary formations in Zambia are likely to yield groundwaters with low dissolved arsenic concentrations, especially carbonate rock types (limestone, dolomite of the Katanga system) and sand and gravel deposits (Kalahari system). In the Kalahari sediments, problems with arsenic mobilisation may occur in the finer-grained parts of the aquifer (e.g. clays) if the groundwater conditions become anaerobic, as would be suggested by the presence of significant concentrations of dissolved iron and manganese for example. However, the 'redox' (aerobic/anaerobic) characteristics of the Kalahari sediments are not known.

Problems from arsenic in groundwater may also occur in areas with prominent sulphide mineralisation and particularly where mining activity is important. Elevated concentrations of arsenic may be found in groundwaters from mineralised areas (e.g. the Copper Belt), although as noted above, high concentrations are expected to be a relatively local phenomenon (of the order of a few kilometres around the mineralised zone).

Fluoride

As with other elements, few data could be found for fluoride in Zambian groundwater. Concentrations are generally expected to be low but may be increased in some groundwaters from the areas of the East African Rift (Zambezi and Luangwa Valleys in the south-east). High fluoride concentrations have been found in groundwaters from the Rift areas of neighbouring Tanzania and Malawi. Areas of granite (e.g. within the Bangweulu depression, Northern Province and parts of Southern Province) are also potentially vulnerable to increased groundwater fluoride concentrations. Fluoride values above 1.5 mg/l (the WHO guideline value) have also been found in groundwater from parts of Lusaka and in springs at Chinyunn, Kassipe and Lubungu (MacDonald and Partners, 1990).

Iodine

No iodine data are available for Zambian groundwater. Iodine-deficiency disorders (IDDs), especially goitre, are known to exist in Zambia, the worst affected Provinces being Northwestern, Western, Central, and Southern Provinces. Each of these has some areas with goitre rates above 50% of the population and visible goitre rates above 10% (Bailey, 1991). The concentrations of iodine in the groundwater are not known but goitre prevalence suggests that concentrations are likely to be low in the most-affected provinces. Recent moves to import salt which has been iodised have attempted to address the IDD problem and are potentially the most effective means of mitigation.

Other trace elements

Investigations of water quality in the upper reaches of the Kafue River in the Copper Belt have found increased concentrations of some toxic metals including copper, cobalt, nickel, chromium and cadmium as a result of mining-related and other industrial pollution (Norrgren et al., 2000). Concentrations of these elements in the groundwater as well as further downstream in the river are likely to be mitigated to some extent by immobilisation of these trace metals through adsorption onto soils and sediments. However, concentrations in groundwater locally around the sites of mining and industrial activity are likely to be above background values and may be of some concern for potable water supplies.

Data sources

Aquastat, 1995. Website: http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/zambia.htm.

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