Groundwater Quality: Rwanda

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-central Africa, Rwanda is a small country, 26,000 square kilometres in area, bordered by Uganda in the north, Republic of Congo in the west, Burundi in the south and Tanzania in the east. Lac Kivu forms a large part of the western border (Figure 1). Rwanda's terrain is hilly with high mountains in the west and north-west and rolling hills with savannah grassland further east (Figure 2). Altitude varies between 1000 m and 4500 m above sea level. The highest point, 4519 m is Volcan Karisimbi in the Virunga Mountains volcanic chain, along the northern border with Congo and Uganda.

The watershed between the Congo and Nile drainage systems runs north–south across western Rwanda (Figure 2). To the west of the watershed, the terrain slopes steeply to the shores of Lac Kivu and the Rusizi River. Together with the Virunga Mountains these form part of the East African Rift Valley. To the east of the watershed, numerous swamps and lakes occupy land at lower elevation.

Rwanda lies just south (2°) of the equator but the

Figure 1. Administrative map of Rwanda (source: Nations Online Project, www.vidiani.com, Creative Commons Attribution).

high altitude makes the climate temperate. Average daytime temperatures at 1500 m (Lac Kivu) are 23°C. Frost and snow are possible in the mountains. Average annual rainfall is 1200 mm and rainfall tends to be highest (2000 mm) in the western and north-western uplands and lower (700 mm) in the eastern savannah. Rwanda has two rainy seasons (February–April, November–January) during which heavy rainfall occurs.

Wracked by years of ethnic tensions culminating in civil war and genocide, Rwanda emerged from the conflict in 1994. Most populations exiled during the tensions have since returned although several thousands remain in neighbouring Congo. Today, the country has relative political stability with some progress in economic development, although rates of poverty exacerbated by the tensions remain high.

With a population estimated at some 10 million people, Rwanda is the most densely populated country in Africa. Despite this, the population is dominantly (83%) rural. Rainforest covers 23% of Rwanda's land area. Around 40% of the land is given over to arable crops and agriculture accounts for a third of the country's GDP, although subsistence farming occupies around 90% of the population. Main domestic crops are plantain, sweet potato, cassava, potato, beans and maize. Principal export crops are coffee and tea, though a growing export market in pyrethrum exists. Industrial development is minimal, though a minerals industry (tin, tantalum, tungsten, gold) provides about 15% of Rwanda's export revenue. Mining is small-scale and largely artisanal. Other manufacturing is dominantly in the agricultural sector. Exploration for geothermal energy has been underway at Volcan Karisimbi for a number of years. Deforestation, along with associated soil erosion, constitute major environmental concerns although reforestation efforts have been instigated in some areas.

Geology

The geology of Rwanda is dominated by Proterozoic (≥1000 million years) crystalline basement rocks akin to those of neighbouring Burundi and southern Uganda. The basement comprises older Palaeoproterozoic (Rusizian) migmatites, schists and gneisses and younger overlying Mesoproterozoic (Kibara) meta-sedimentary schists, quartzites and metapelites, together with several generations of granite. Kibaran rocks dominate; Rusizian formations occur mainly in the south-west, and east of Lac Kivu.

The western border region of Rwanda is a distinctive province which forms part of the East African Rift Valley. Associated features are the Quaternary to Recent volcanoes and volcanic rocks of the Virunga range (north-west), Cenozoic volcanics of the Bukuvu area (south-west) and the rift lake Kivu. The volcanoes are not active though recent eruptions have affected neighbouring Congo;

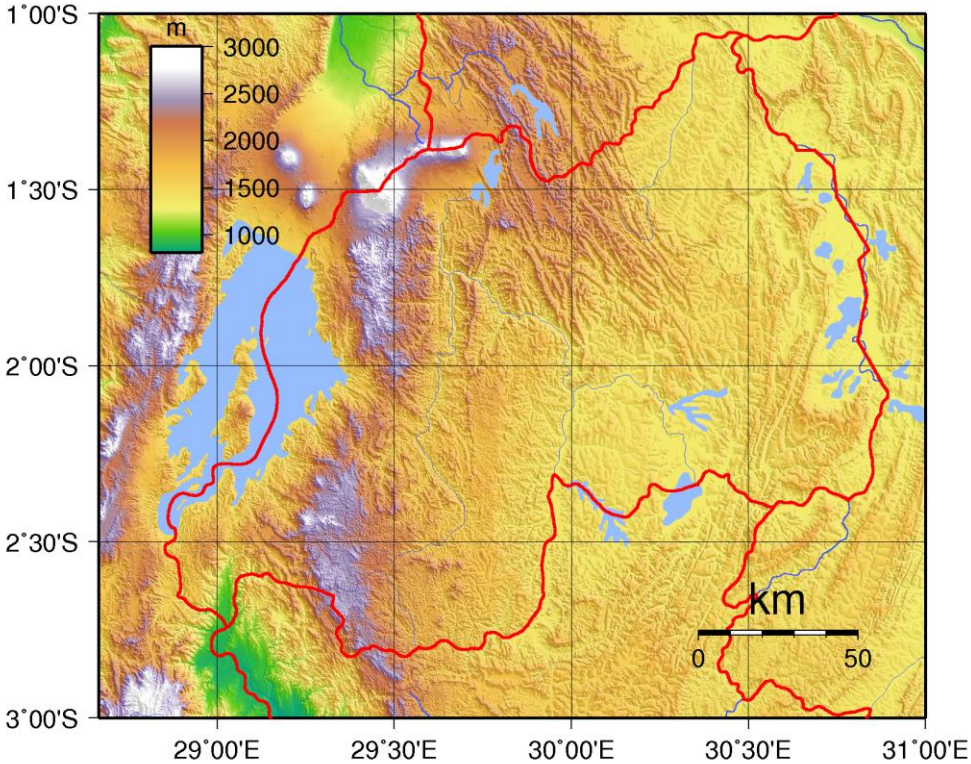

Figure 2. Topographic map of Rwanda highlighting the watershed of western Rwanda, location of the Rift Valley to the west and rolling hills of the east (source: Sadalmelik, Wikimedia Commons).

seismic activity continues. The volcanic rocks are dominantly alkali basalt and associated tuff (ash). Cenozoic and younger sediments infill parts of the Rift (Schlüter, 2008).

Mineral resources include gold, cassiterite (tin ore), coltan (niobium-tantalum ore) and wolframite (tungsten ore). Cassiterite is the dominant ore. Much of the tin mineralisation is associated with later granitic intrusions (dated at 986 million years; the so-called "tin granites"; Dewaele et al., 2010), within the Mesoproterozoic formations. These rocks form a major mineralised belt stretching from Katanga in Congo to southern Uganda. Tin deposits are particularly developed in a north-south tract from Nyabarongo–Gatumba in western Rwanda and in the Rutongo area of central Rwanda. The cassiterite mineralisation is hosted by pegmatites and quartz veins and found as secondary mineralisation in alluvial deposits (Dewaele et al., 2010). Cassiterite is also accompanied by other sulphides (arsenopyrite, pyrite, chalcopyrite and galena). Mining of the ore deposits began during the 1930s, mainly from the alluvial deposits, but developed later in areas of primary mineral veining. Rutongo area was mined until the mid 1980s (Dewaele et al., 2010). Gold mineralisation is most prevalent in Nyungwe area of western Rwanda.

A weathered overburden layer of variable thickness occurs in most areas of basement. Soils are generally permeable and dominantly composed of highly altered schists, quartzites and granites in line with the dominant geology. Soils are lateritic in places and peats occur in low-lying marshland areas. Fertile volcanic soils are developed in the north-west and south-west (Zoghbi, 2007).

Groundwater Availability

Seasonal heavy rainfall ensures rich water resources, including numerous rivers, lakes, marshlands and groundwater. Despite this, access to safe managed water supplies is low, in large part set back by destruction of the water supply infrastructure during the civil war (Zoghbi, 2007). Groundwater accounts for some 86% of drinking-water supply in rural areas. There are an estimated 22,000 groundwater points across the country (Nile Basin Initiative, 2005), apparently mainly springs. In Eastern and large parts of Southern province, most supplies are from boreholes which have been drilled during and since the 1990s. As of 2009, there were reported to be around 400 boreholes and wells for water supply in Rwanda (Ministry of Natural Resources, 2011). Nonetheless, information on groundwater use and availability is not readily accessible. Water demand is highest in the capital Kigali and water shortages are reported there.

Aquifer permeability is largely limited but relatively high in the quartzites (UN, 1989). Alluvial deposits are also relatively permeable and frequently used for water supply (NU, 1971). In most areas of basement, springs are generally low-yielding and some dry out in the dry season.

Groundwater Quality

Overview

The limitations of wastewater management and treatment in both urban and rural settings constitute a pollution risk to shallow groundwater. Pollution from pit latrines is of particular concern (Ministry of Natural Resources, 2011). Impacts from municipal and domestic waste including sewage include risk from pathogenic organisms, increased salinity and concentrations of nutrients (e.g. nitrogen compounds). Use of agricultural fertilisers is limited (Twagiramungu, 2006). Industrial emissions to surface water and groundwater courses, mainly from agricultural processing, breweries, textiles, tanneries, and paint, also potentially impact water quality in urban areas. Mining potentially affects water quality in mineralised areas. In addition, natural water-rock interactions within basement rocks and volcanic terrains also have potential to increase the concentrations of natural contaminants. Despite these risks, few data are available to assess the groundwater quality.

Rift-associated hot springs occur in the Virunga mountains area, and around Gisenyi and Bugarama (Figure 1). These are dominantly of sodium-bicarbonate type (UN, 1989), have relatively high temperatures (30–70°C) and high salinity (electrical conductivity up to 4000 μS/cm; Ngaruye and Jolie, 2008), and therefore have potential to contaminate local groundwater sources with dissolved salts and a number of trace elements, including fluoride, lithium and boron.

Nitrogen species

Shallow groundwater in both urban and rural areas is at high risk from contamination by nitrogen compounds because of the lack of control on release of domestic and municipal wastes. In aerated waters, nitrate poses a significant risk, although ammonium and nitrite could also be present in some sources. High concentrations of nitrate and ammonium have been reported in north-eastern Rwanda (Nile Basin Initiative, 2005), although the precise locations affected are unclear. No other data are available at the time of writing.

Salinity

Salinity variations are likely to be most affected by urban, industrial and domestic contamination of shallow aquifers. If deep boreholes exist in some areas, salinity could be high as a result of long groundwater residence time. Further impacts are likely in groundwaters with geothermal inputs. At greatest risk are the volcanic terrains of Virunga, Bukuvu and the areas marginal to Lac Kivu.

Fluoride

The East African Rift is well-known to have regionally high concentrations of fluoride, especially in water from hot springs, rift valley lakes and some deep groundwaters. The groundwaters of western Rwanda are therefore at increased risk of containing fluoride at concentrations above the WHO guideline value (1.5 mg/L).

Other areas of Rwanda are also at increased risk, especially groundwater from boreholes in crystalline basement and areas of granitic rocks. Broadly, concentrations are likely to increase with increased borehole depth in response to increased residence time and degree of water-rock reaction. High concentrations of fluoride have been mentioned, albeit without further detail, in basement rocks of north-eastern Rwanda (Nile Basin Initiative, 2005). Testing for fluoride in groundwater is recommended in all areas of investigation.

Iron and manganese

The redox conditions in the Rwandan aquifers are unknown but assumed to be largely oxic in shallow basement, volcanic and minor alluvial aquifers. In such conditions, concentrations of iron and manganese are expected to be mostly low. Concentrations could increase locally if reducing conditions occur, or if groundwaters from deep aquifers are abstracted. Concentrations could also be high in areas of metalliferous mineralisation, in association with oxidation of the iron-bearing ore minerals. Urban areas affected by industrial contamination could also see locally high concentrations.

Arsenic

To the best of our knowledge, no data on arsenic in groundwater are currently available. Areas considered to be at greatest potential risk of arsenic contamination are those affected by metalliferous mineralisation (cassiterite, gold, coltan and wolframite) as these are areas with accumulated sulphide mineral deposits and their reaction products, many of which are likely to be enriched in arsenic. The mineralised (Kibara) belt of Rwanda covers a large part of central, eastern and north-western Rwanda, and gold mineralisation is concentrated in Nyungwe area of western Rwanda. Testing for arsenic is strongly recommended especially in these areas. Arsenic contamination as a result of industrial contamination is also possible.

Iodine

No data on iodine in groundwater are known to be available. High rainfall, likely high recharge, dominance of crystalline basement rocks, and remoteness from the coast, mean that high concentrations of iodine in most groundwater sources are unlikely. More likely are regionally low concentrations (of the order of 5 μg/L or less). The prevalence of iodine-deficiency disorders, which is generally low, may be skewed by the importation and use of iodised salt. Some higher concentrations of iodine may be present in groundwaters impacted by inputs of geothermal water (Twagiramungu, 2006).

Other trace elements

The Ministry of Natural Resources (2011) report noted exceedances of some trace metals above WHO guideline values for drinking water in some analysed water samples. Concentrations of barium up to 8.5 mg/L, lead up to 155 μg/L and cadmium up to 155 μg/L were reported, though information on the quality of the data, numbers of samples analysed and locations and sources (surface water/groundwater) were not specified. Baligira (2007) also noted high concentrations of some metals in tributaries of the Nyabarongo River around Kigali as a result of industrial discharges, though details were similarly unclear.

Trace metals such as copper, zinc, cadmium, lead, nickel, antimony and chromium may be present locally in and around the larger urban centres as a result of uncontrolled urban and industrial waste emissions. These trace metals could also be present in groundwater in mineralised (and mining) areas. Mercury has also been highlighted as a potential concern in such areas (Twagiramungu, 2006).

Concentrations of uranium in excess of the WHO guideline value for drinking water could occur in some groundwaters from the basement rocks, particularly granites, and a reconnaissance survey of groundwaters for uranium is recommended.

Data sources

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