Groundwater Quality: East Timor

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 recent history of East Timor (Timor-Leste) has been overshadowed by the violence and destruction that followed the Independence referendum in 1999. The unrest left large parts of the Timorese infrastructure damaged or destroyed and efforts post-1999 have been focussed on rebuilding. East Timor was first recognised as an Independent State in 2002.

East Timor forms part of the island of Timor in south-east Asia. It is the easternmost island of the Lesser Sunda Islands and forms the eastern end of the Indonesian Archipelago. Timor is the largest island of the Outer Banda Arc. East Timor also includes the Oecussi (Ambeno) enclave in north-western Timor and the islands of Pulau Atauro and Pulau Jaco (Figure 1). The country has a total area of 15,007 square kilometres.

The terrain of much of East Timor is mountainous. The central Ramelau mountain range extends with an east-west axis across the country. The highest point is at Foho Tatamailau (2963 m). The northern side of the range extends almost to the coast. By contrast, a coastal plain some 20–30 km wide extends across the breadth of the country to the south of the Ramelau range. The highest elevation in the Oecssi Ambeno enclave is Nipan Peak (1561 m).

Figure 1. Relief map of East Timor (courtesy of the General Libraries, University of Texas at Austin).

East Timor has a tropical climate with distinct rainy and dry seasons. Monsoon rains fall during December to April although the dry season varies in length in different parts of the country. Average annual rainfall is around 1300 mm. In the north, the average temperature is around 24ºC and annual rainfall around 500–1000 mm with a dry season lasting for around five months. In the south, rainfall is around 1500–2000 mm per year and the dry season lasts for around three months. In the mountainous central belt, annual rainfall exceeds 2500 mm and the dry season extends over about four months (Pederson and Arneberg, 2000).

The high mountains are dissected by numerous streams which are prone to flash flooding at times of heavy rainfall. Several streams cross-cut the mountains, but many of these are seasonal. Some perennial streams flow southwards across the coastal plain. Lake Ira Lalaro (area around 100 square kilometres) to the east of Los Palos, is the largest lake in East Timor. Mangroves occupy many of the coastal mud flats.

The majority of East Timor's population (close to 1 million people) lives in small rural communities and around 75% of the workforce is employed in subsistence agriculture (Pederson and Arneberg, 2000). Most arable production is concentrated in the southern coastal plain and the Maliana Plateau which occupies the western border with West Timor. In the mountainous areas, soils developed on the steep slopes are often thin and of poor quality and are largely unsuitable for agriculture. Only around 8% of the land area is used for arable crops, with only around 1000 square kilometres being irrigated. Poor agricultural production results from poor irrigation infrastructure and erratic rainfall.

Deforestation and soil erosion are recognised problems in some areas, arising from poor agricultural management including the adoption of 'slash and burn' agriculture, uncontrolled grazing, seasonal bush burning and firewood collection (UNDP, 2005). Natural forest now occupies only a small area of East Timor, being replaced by scrub, savannah and grassland. These together occupy around 75% of the land area (Pederson and Arneberg, 2000).

East Timor is one of the poorest nations in Asia. As a result of the 1999 unrest, industry, transport and water and sanitation infrastructure were largely destroyed. Today, industrial development is small-scale, the most important industries being printing, soap manufacture, textiles and handicrafts. Agriculture forms around 9% of GDP. Principal crops include coffee, rice, corn, cassava, sweet potatoes, soya beans and vanilla. The main exports are coffee and livestock. East Timor also had a significant sandalwood industry during the times of Portuguese and Indonesian rule, though historical over-harvesting means that today the resource is greatly depleted. The petroleum industry has significant additional revenue potential although no processing plants exist in-country. East Timor and Australia have a joint agreement on the revenues from oil and gas developments in the Timor Sea which should pave the way for future economic development in East Timor.

Geology

Timor is part of the non-volcanic Outer Banda Arc. The island is located in a major fold and thrust belt which evolved by the collision of the Eurasian and Indo-Australian Plates in Neogene times (Charlton, 2000; 2002). As a result of major tectonic movements, the island is structurally complex and tectonic relationships between strata have long been debated (Audley-Charles, 1968; Hamilton, 1979; Charlton, 2000; 2002). The geology of East Timor comprises emplaced metamorphic basement rocks and both syn- and post-orogenic sediments (Charlton, 2002). Many of the sedimentary rocks in the sequence are limestones.

Metamorphic rocks of the Lolotoi Formation occur in western and central parts of East Timor. These are presumed to be of pre-Permian age (Charlton, 2002) though are thought to have been emplaced in their present position in the Lower Eocene (UNESCAP, 2003a). Outcrops include the Laclubar massif, to the east of the Laclo River (Figure 1) and the south-west around Lolotoi. The formation is dominated by metavolcanic rocks and phyllites (metamorphosed fine-grained sediments) (Charlton, 2002) and is believed to comprise Australian continental basement entrained by thrust faulting into an arc-continent collision complex (Grady and Berry, 1977; Charlton, 2002).

The metamorphic Aileu Formation occupies the north-western corner of East Timor, mainly to the west of the Laclo River. The formation includes metamorphosed shale, sandstone and limestone, with some amphibolite (Berry and Grady, 1981). Deposits of the Aileu Formation were possibly originally of Palaeozoic origin but with evidence of several phases of deformation, the latest dating back to the late Miocene. This date of the deformation places a link with the collision of the Indo-Australian plate and the Inner Banda Arc (Berry and Grady, 1981).

The Permian Maubisse Formation, a marine limestone, crops out in west-central part of the country, along the Ramelau Range and around Legumau in the east. This is interpreted as an allochthonous unit, emplaced from elsewhere by faulting (Audley-Charles, 1968).

These oldest formations of East Timor are overlain by strongly deformed though autochthonous (formed in-situ) sedimentary rocks of Permian to Jurassic age, likely to be of Australian continental margin origin (Charlton, 2002). The junction between the Lolotoi Formation and these sedimentary rocks is unconformable (Charlton, 2002). Autochthonous Permian deposits include the basinal clastic sediments of the Atahoc and Cribas formations. The Atahoc Formation is dominated by black pyritic marine shale and has limited extent. The Cribas Formation is a marine silty shale with calcareous nodules and varies from black pyritic shale at the base, through red and green shale in the middle, to limestone in the upper part of the sequence (UNESCAP, 2003a). This has limited outcrops including around Cribas and exposures in eastern and southern coastal areas.

The Triassic Aitutu Formation is a deep marine deposit consisting mainly of calcilutite (lime mud) with subordinate shale and calcareous sandstone (Audley-Charles, 1968). This also has a minor outcrop in the eastern part of the island (Junta de Investigações do Ultramar, 1968).

The Aitutu Formation is overlain conformably by the Jurassic Wai Luli Formation. This is dominantly a marine shale, with clay, marl and limestone horizons. The deposit is around 600–1000 m thick (UNESCAP, 2003a).

Cretaceous strata overlie unconformably the Jurassic strata (Audley-Charles, 1968) and include marls and shales of the Wai Bua Formation, the Borolalo Limestone and the marls and shales of the

Seical Formation. These occur in a limited near-coastal area to the east of the River Sue.

More recent deposits of Cenozoic to Recent age occur dominantly along the southern coastal plain and the northern and eastern coastal areas. These deposits are dominated by limestone. The Eocene Dartollu Limestone and the Oligocene Barique Formation have limited extent. Miocene deposits include the Aliambata Limestone and the Cablac Limestone. This latter deposit forms the caps of many of the mountains along the central E-W-trending 'backbone' of East Timor, including Taroman (1750 m), Cablac (2346 m), Mundo Perdido (1769 m) and the Santa de Mata Bia range (2373 m). The formation is a hard massive limestone, around 400–600 m thick.

Orogenic movements in the Neogene resulted in the placement of large thrust sheets of the Permian rocks, along with the deposition in the Middle Miocene of the Bobonaro Scaly Clay, interpreted as an allochthonous gravity-slide deposit (Audley-Charles, 1968). This was deposited over a large part of East Timor (UNESCAP, 2003a) and today represents one of the most extensive strata.

The Upper Miocene to Pliocene saw deposition of the marine Viqueque Formation. This is a post-orogenic interbedded massive white marl, clay and limestone with rare volcanic tuff (UNESCAP, 2003a). The Viqueque Formation was folded in the Late Pliocene.

The Pleistocene Baucau and Poros Limestones overlie older strata unconformably (Junta de Investigações do Ultramar, 1968; White et al., 2006). The Baucau Formation is a marine coral limestone and outcrops on the Baucau and Lautern plateaux and the north coast. The Poros Formation is a lacustrine deposit. Both have been uplifted to form raised plateaux and in response to the recent and probably ongoing tectonic activity on the island. Both the Baucau and Poros formations are karstic. Lake Ira Lalaro (Figure 1) occupies a 'polje' (large, flat, enclosed depression in karstic terrain) around 100 km^2 in areal extent, developed on recent alluvial deposits overlying the Poros Limestone.

Recent deposits include the coastal Suai Formation and the Ainaro Gravels, the latter being an alluvial terrace gravel found on several of the river courses (UNESCAP, 2003a). Alluvial deposits are also developed on the southern coastal plains and lacustrine deposits occur in the Maliana Plateau in the west (Pederson and Arneberg, 2000).

The geology of the enclave of Oecussi within West Timor is dominated by Bobonaro Clay with minor occurrences of Viqueque sediments and some volcanic rocks. Atauro is a volcanic island dominated by Pliocene volcanic rocks with some Pleistocene coastal coral reef deposits.

East Timor's natural resources include gold, petroleum, natural gas, copper, manganese and marble. Most of the gold and base-metal mineralisation occurs in northern East Timor, in correspondence with the location of the arc collision zone. Gold deposits are epithermal in origin and are best-developed in Viqueque and Bacau districts. Native copper has also been found at Virac (UNESCAP, 2003b). Base-metal mineralisation is most prevalent in ultrabasic metamorphic rocks, which represent fragments of obducted Miocene oceanic crust. Copper deposits occur in Oecussi district. A prominent copper-mining industry existed in East Timor in pre-historic times and exploration for copper was again initiated in Oecussi district in the 1980s (UNESCAP, 2003b). The gold and base-metal deposits are associated with sulphide mineralisation, especially pyrite and chalcopyrite, often in veins with quartz (UNESCAP, 2003b).

Minor deposits of chromite and manganese occur in Manatuto, Baucau and Lautern districts and on Atauro Island (UNESCAP, 2003b). As noted above, reserves of oil and natural gas occur in the Timor Sea between East Timor and Australia. Several onshore oil and gas seeps are also known, especially in south-western East Timor and south of Viqueque. Some onshore exploration has been carried out by various companies over the last few decades (UNESCAP, 2003b).

Soils are thin on steep mountainous slopes and topsoils are frequently eroded by flash flooding. Soils are also thin and alkaline on limestone bedrock. However, they can be more fertile where developed on the alluvial and lacustrine sediments.

Groundwater Availability

Documentation on groundwater availability in East Timor is limited. Indurated rocks of the metamorphic complexes and deformed Permian–Jurassic strata are likely to constitute much less productive aquifers than recent alluvial deposits and Cenozoic and Quaternary limestones, although faulting may have a large impact on groundwater flow even in the poorly-permeable rocks. Groundwater is especially important in the karst areas (White et al., 2006).

Groundwater availability for potable supply is also dependent on water infrastructure. Pre-Independence, it was estimated that just under half the population of East Timor had access to safe drinking water (ADB, 2001). The destruction of the water and sanitation infrastructure and capability during the 1999 conflict has required a major nationwide reconstruction and rehabilitation programme. This was started in the early 2000s with funding provided by ADB and numerous other agencies (ADB, 2001). These programmes have led to significant infrastructural improvements although still a significant part of the population does not have access to safe drinking water.

Water supply is provided by piped supplies in some urban areas, although because around 70% of the population lives in rural areas, these are few compared to numerous small-scale rural sources. Springs are the dominant sources of water supply in rural areas, where they serve around 60% of the population (ADB, 2001). These, together with streams, are particularly important water sources in the mountainous areas.

Numerous shallow wells also exist across the country, both in urban and rural areas. Many of these were also damaged or contaminated during the conflict. A small number of boreholes also exist, especially in the southern alluvial plain.

Groundwater Quality

Overview

Little information is currently available on the quality of groundwater in East Timor. The concentrations of inorganic constituents in the groundwaters will be dependent on the pH and redox (oxidising/reducing) conditions in the aquifers. These are largely unknown and assessments of likely groundwater quality can therefore only be made on the basis of basic geological information. The interpretations are necessarily tenuous and would require groundwater surveys to support the assessments made.

Reports of inadequate sanitation and waste-management systems (Pederson and Arneberg, 2000) imply that shallow groundwater is potentially under considerable threat from pollution, especially in urban and peri-urban areas. In rural areas, pollution from agricultural sources is also a potential problem. Fertilisers and some pesticides are used in East Timor, particularly for wet rice production. Principal among the fertilisers are urea and phosphorus compounds. Fertiliser and pesticide usage varies widely across the country (Pederson and Arneberg, 2000). The limited industrial development of East Timor means that industrial pollution is a comparatively minor threat to water quality.

Nitrogen species

The distribution of N species in groundwater is unknown but the vulnerability of shallow groundwater to contamination from latrines and waste dumps means that concentrations of nitrate (and perhaps also nitrite and ammonium) could be significant, especially in urban and peri-urban areas.

Salinity

No information is available on the salinity of groundwater in the aquifers. Coastal areas, especially some of the alluvial deposits in the southern plain and limestones in eastern East Timor are potentially vulnerable to saline intrusion, depending on the amount of groundwater pumping undertaken in these areas.

Fluoride

High fluoride concentrations tend to be a feature of high-pH (Na-HCO_3-dominated) groundwaters in sedimentary basins or in fluorine-rich granitic rock types. The overall water chemistry of Timorese groundwaters has not been established but under the tropical climatic conditions, the occurrence of high-pH (>8) groundwaters is considered unlikely, at least at shallow levels from where most of the groundwater is likely to be abstracted. The island also lacks granitic rocks. At the present state of knowledge, high-fluoride groundwaters are not expected on a regional scale.

Iron and manganese

The occurrence of iron and manganese in groundwaters is critically dependent on the pH and redox conditions in the aquifers. Concentrations can increase in either acidic or anoxic conditions in response to the increased solubility of iron and manganese oxides under these conditions. Limestone aquifers, especially karstic areas, are likely to have mainly oxic groundwaters with neutral to alkaline pH. They are therefore considered unlikely to have high concentrations of iron or manganese. Metamorphic basement and other indurated sedimentary rocks may have more variable pH and redox conditions. Concentrations of iron and manganese could therefore be higher than desirable for potable supplies in some areas, though the distribution of high concentrations may be patchy. Alluvial aquifers may support locally anoxic conditions and high iron and manganese concentrations could occur in some.

Arsenic

There are currently no available data for arsenic in the Timorese groundwaters. In other parts of the world, concentrations of arsenic are generally low under oxic, neutral-pH conditions. They are also typically low in groundwater from carbonate aquifers. Concentrations in drinking water may potentially be above acceptable limits in anoxic groundwaters. These could occur locally in the metamorphic terrains of northern East Timor, especially in areas with sulphide mineralisation. Testing of the groundwaters would be needed to assess whether arsenic constitutes any potential problems for Timorese water supply.

Iodine

Local maritime rainfall is likely to have an important influence on groundwater chemical composition. Water recharging the aquifers is expected to have a relatively high iodine concentration, derived from marine aerosols. It is concluded that iodine deficiency is not likely to be a problem to the groundwater-dependent Timorese people, although no data were available at the time of writing to confirm this.

Other trace elements

Data for other trace elements in the groundwaters are also lacking. Trace-metal cations (e.g. lead, nickel, copper, zinc) are unlikely to be present at unacceptably high concentrations in groundwaters from the carbonate aquifers because of expected neutral to alkaline pH conditions. Concentrations of trace metals in the metamorphic and siliciclastic sedimentary rocks are more uncertain because of the lack of information on the local pH and redox conditions in these rock types. Areas with gold and base-metal mineralisation are potentially vulnerable to elevated concentrations of these trace metals.

Data sources

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