

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

Nepal is a landlocked country in southern Asia, between China and India, with a total land area of 140,800 square kilometres. Topographic variations are extreme and the terrain has a general southward slope. The topography ranges from rugged high Himalaya in the north, to the central hill region, to the lower-lying Siwalik Range (south-central) and down to the 'terai' or flat river plain in the south. Elevations range from greater than 8000 m (Mount Everest range) on the north border with China (Tibet; Figure 1) to 70 m (Kanchan Kalan, terai region) in the south. Nepal has eight of the ten highest mountains in the world.

The large topographic variations give rise to a variable climate, ranging from cool summers with severe winters in the north to subtropical summers and mild winters in the south. Average annual rainfall in the capital city, Kathmandu, is about 1300 mm (Jacobson, 1996), most falling during the summer monsoon (June to September). Monsoon rains can give rise to severe flooding, especially in the terai plains.

Agriculture is an important part of the Nepalese economy, with over 80% of the population being employed in the agricultural sector and 34% of the land given over to arable or permanent pasture. Around 42% of the land area is forested, although deforestation is widespread and resultant soil erosion has become a major environmental issue.



Figure 1. Location map of Nepal (after University of Texas at Austin map library).

Nepal has suffered from rapid population growth and increasing urbanisation, particularly in the Kathmandu Valley (Khadka, 1993). Industrial activity, much of it concentrated in the Kathmandu Valley, involves mainly processing of agricultural produce including jute, tobacco, sugar cane, rice, corn and wheat and production of textiles and carpets (CIA, 2000).

## Geology

Geology controls the topographic variations in Nepal. High mountains of the Himalaya and central hill regions are dominated by ancient crystalline rocks. These have variable compositions, including metamorphic rocks, granites and old indurated sediments and have been strongly contorted and faulted as a result of the uplift of the Himalayan mountains.

Young sediments (of Mesozoic to Quaternary age) are largely restricted to the southern, lower-lying parts of Nepal and to isolated intermontane basins in the hill regions (e.g. Kathmandu Valley, Mugu Karnali Valley). Sediments of Tertiary age (mixed sandstone and shale) outcrop the length of southern Nepal in the Siwalik Range. To the south of these deposits, unconsolidated recent alluvial sediments form the low-lying terai plain along the Indian border (Figure 1). The Kathmandu Valley is a down-faulted intermontane basin infilled with young sediments (of Pliocene-Quaternary age) up to 500 m thick (Khadka, 1993; Jacobson, 1996). The Mugu Karnali Valley is also infilled with recent alluvial deposits.

Mineral veins are present in some areas of the crystalline rocks. Veins of sulphide ores (including pyrite, chalcopyrite, arsenopyrite, galena) occur in several areas, including Wapsa, Siddhi Khani, the Markhu-Kulekhani-Arkhaule area, Baais Khani (Baglung), Nangre-Bhorle area, Gyazi Sikpasor and Jantar Khani. Pyrite (iron sulphide) has also been recorded in black shale deposits in the Andhi Mohan Ghat area, Gandaki Anchal (Khan and Tater, 1969).

## Groundwater Availability

High rainfall totals generally give rise to abundant water supplies, at least seasonally, and surface water and groundwater are both important sources for domestic, industrial and agricultural use. Groundwater is abundant in the aquifers of the terai and the Kathmandu Valley. About 50% of the water used in the city of Kathmandu is derived from groundwater. Groundwater availability is more limited in the populated hill regions because of the lower permeability of the indurated and crystalline rock types. Despite abundant rainfall, agricultural development is restricted by the limited development of irrigation.

In the Kathmandu Valley (area around 500 square kilometres), groundwater is abstracted from two main aquifers within the thick alluvial sediment sequence. A shallow unconfined aquifer occurs at around 0–10 m depth and a deep confined aquifer occurs at around 310–370 m (Khadka, 1993). Exploitation of these aquifers, especially the shallow aquifer, has increased rapidly in recent years as a result of the increasing urbanisation of the region. In 1993, groundwater was abstracted from the aquifers of the Kathmandu Valley via 22 government production wells and 334 private wells (of which, 188 were shallow and 146 were deep). Recent abstraction of groundwater from the deep aquifer has led to a decrease in the groundwater level by around 15–20 m since the mid 1980s (Khadka, 1993).

Below the alluvial sediments in the Kathmandu Valley, karstic limestone aquifers also exist. A small number of natural springs issue from these and are used for water supply in the southern part of the valley. The limestone aquifer has not been developed and has received little hydrogeological investigation.

Shallow and deep aquifers are also present in the young alluvial sediments throughout most of the terai region (e.g. Jacobson, 1996). The shallow aquifer appears to be unconfined and well-developed in most areas, although it is thin or absent in Kapilvastu and Nawalparasi (Upadhyay, 1993). The deep aquifer of the terai (depth unknown) is reported to be artesian (i.e. free-flowing; Basnyat, 2001).

## Groundwater Quality

### *Overview*

There is an overall lack of water-quality data for Nepal and hence assessment of the main quality problems is difficult. Many of the documented problems are related to pollution of both surface

waters and shallow groundwaters from domestic, agricultural and industrial wastes. Much of the Nepalese population uses surface water for potable supply which is most vulnerable to pollution. Hence only 34% of the population are thought to have access to safe drinking water (NepalNet, 2001).

Shallow groundwaters are also at risk from contamination: pathogenic bacteria, pesticides, nitrate and industrial effluents (urban and peri-urban areas) are likely to be the greatest problems encountered. Shallow groundwaters in the Kathmandu Valley in particular are reported to have been contaminated with industrial and domestic pollutants in recent years (Jacobson, 1996). The nature of the industrial effluents present is not known in detail, but the greatest sources are likely to be from the textiles and carpet-manufacturing industries. These may introduce effluents with high salinity and containing organic chemicals and some trace metals (from dyes and finishing treatments).

The chemistry of shallow groundwaters in the terai region depends to a large extent on the lithology of the sediments: the shallow aquifers are vulnerable to pollution if surface sediments are sandy and permeable, but less so if a protective layer of low permeability (clay or silt) is present. This also has an impact on the amount of oxygen present in the shallow aquifers, which in turn will affect the water chemistry. As the shallow aquifer is reported to be largely unconfined, the vulnerability to surface pollution may be relatively high, at least in some areas. However, in some parts of the shallow aquifer of the terai, anaerobic conditions are observed as some shallow groundwater has high concentrations of arsenic iron. Arsenic in the terai groundwaters is a newly emerging problem and although no arsenic-related health effects have been recognised in the region, sufficient concern has been raised among the government and NGOs to launch an arsenic and health testing programme.

Deep groundwaters present in the Kathmandu Valley and the terai are also largely anaerobic and hence vulnerable to increased concentrations of iron, manganese, ammonium and possibly arsenic. However, to date, no high-arsenic deep groundwaters have been documented in these areas.

Springs from the karstic limestone aquifers at depth in the Kathmandu Valley are reported to be of calcium-bicarbonate type with good chemical quality, although the amount of data is limited.

### *Nitrate, nitrite and ammonium*

In the shallow groundwaters, concentrations of nitrate and other pollutants from domestic and agricultural sources may be high and nitrate

concentrations could fail WHO guidelines frequently. Groundwater in many of the urban areas, especially Kathmandu, has been contaminated by seepage from septic tanks and soakaways. Ammonium concentrations may also be high in these affected areas from domestic pollution and the use of ammonium-based fertilisers.

In the deep aquifers of the Kathmandu Valley, high observed concentrations of ammonium (<3–35 mg/l as N, mostly <4 mg/l) are of natural rather than pollutant origin. The deep aquifers are protected from surface pollutants by the thick overlying layers of poorly permeable sediment (e.g. clay and silt). The high ammonium concentrations are indicative of anaerobic aquifer conditions in the aquifer and are associated with high iron, manganese and occasionally methane. Under the anaerobic conditions, concentrations of nitrate and nitrite are low (<1 mg/l as NO<sub>3</sub> and <0.01 mg/l as NO<sub>2</sub> respectively; Khadka, 1993).

High ammonium concentrations and low nitrate and nitrite concentrations are also likely to be found in the deep anaerobic aquifers of the terai. However, no data are available to indicate the concentration ranges.

The WHO guideline for ammonium is set on aesthetic grounds (taste and smell) rather than on health grounds and so the presence of ammonium in drinking water is not believed to be detrimental to health.

### ***Iron and manganese***

Few data exist for these elements in Nepalese groundwaters. Concentrations of iron and manganese are likely to be mostly low in the shallow groundwaters where the aquifers are aerated. However, they are higher in the deep anaerobic aquifers of the terai region and Kathmandu Valley. Iron concentrations in the range <0.5–9 mg/l and manganese in the range <0.1–0.7 mg/l have been found in groundwaters from the deep aquifers of the Kathmandu Valley (Khadka, 1993). The higher concentrations of these elements render the groundwaters unusable without prior treatment.

Presence of iron and manganese in the shallow groundwaters of the terai will depend on the degree of aeration of these aquifers. If aerobic, concentrations are expected to be low.

### ***Arsenic***

Of the aquifers present in Nepal, those potentially at greatest risk from contamination with arsenic are the recent sediments of the terai region. A number of surveys of groundwater quality have revealed the

presence of arsenic in some samples at concentrations above desirable limits. The Department of Water Supply and Sewerage (DWSS) found 1% of water sources analysed had arsenic concentrations of greater than 50 µg/l (the Indian and Bangladesh standard for arsenic in drinking water; Table 1). Highest concentrations were found in groundwater from the active floodplain of the River Koshi. The Nepal Red Cross Society (NRCS), from testing in 17 of the 20 terai districts, found some 3% of groundwater sources sampled had concentrations above 50 µg/l, the highest observed concentration being 205 µg/l and the worst affected districts being Nawalparasi (Western Region), Rautahat and Bara (Central Region) and Bardia (Midwestern Region). NRCS (2001) has listed these districts, together with Parsa, Rupandehi, Kapilbastu and Banke as priority areas for testing, water-supply mitigation and health screening. Finnida found 12% and Tandukar found 9% of samples analysed in their respective investigations had concentrations exceeding 50 µg/l (Table 1). Whilst these exceedance percentages are generally small, they are nonetheless cause for concern and further action. The highest arsenic concentrations observed by Tandukar (2001) were around 120 µg/l, most of the high-arsenic samples being from the River Bagmati area. The high concentrations appear to occur in anaerobic groundwaters and are often associated with high dissolved iron concentrations (Tandukar, 2001).

From the available data, it appears that the arsenic contamination occurs in the shallow aquifers of the terai (tubewells completed at <50 m depth). Deeper tubewells appear to have lower arsenic concentrations (<10 µg/l), although it is stressed that the volume of available data for the deeper aquifer is so far very limited.

Although more localised, occurrences of arsenic, along with other potentially toxic trace elements, may also occur where mineralised veins (containing sulphide minerals) occur in the crystalline basement rocks and minor occurrences of black shale (see

**Table 1. Distribution of arsenic concentrations in analysed groundwater samples from Nepal (from summary by Tandukar, 2001).**

Agency	<10 µg/l (%)	10–50 µg/l (%)	>50 µg/l (%)	Total samples
DWSS	244 (91)	22 (8)	2 (1)	268
NRCS	2206 (79)	507 (18)	77 (3)	2790
Finnida	55 (71)	14 (18)	9 (12)	78
Tandukar	54 (61)	27 (30)	8 (9)	89

Percentage values are percent exceeding 50 µg/l.

above). If contamination of water with arsenic has occurred in these areas, the contamination is likely to be localised rather than of regional extent.

### **Fluoride**

No data are available for fluoride in Nepalese groundwater. However, given the climatic conditions (high rainfall), the presence of fluoride at high concentrations is unlikely. Concentrations are likely to be much below 1 mg/L, i.e. less than the WHO guideline value for fluoride in drinking water, in both the hill regions and the terai.

### **Iodine**

Given the climate and geography of Nepal, iodine concentrations are potentially low in the groundwaters (although no substantiating data are available). The populations may therefore be vulnerable to dietary iodine deficiency from water and local food produce. However, a recent nationwide survey of 15,000 Nepalese people concluded that iodine-deficiency disorders have been practically eliminated in Nepal as a result of the widespread distribution and use of iodised salt (The Times of India, 2001). Iodine is therefore no longer thought to be a problem.

### **Other trace elements**

No other data are available for trace elements. Shallow groundwaters, especially in industrial areas, are potentially vulnerable to contamination from a range of trace metals, depending on the nature of the local industry. The greatest industrial impact on groundwater quality in Nepal is likely to be from the carpet and textiles industries. Trace-metal pollutants from these may include chromium, copper and zinc in particular, as well as a range of organic pollutants. Increased loadings of organic chemicals in leached effluent may also enhance the mobilisation of a number of other trace elements (e.g. iron, manganese, arsenic) by depleting the oxygen concentrations locally in the aquifers.

Areas of the crystalline basement with sulphide mineral veins may also be prone to localised contamination of groundwaters with trace metals (e.g. zinc, copper, cobalt, lead, cadmium).

Although speculative, it is possible that groundwaters from the terai and the Kathmandu Valley contain uranium at concentrations greater than the WHO guideline value for drinking water of

2 µg/l. No data are available for Nepal but high uranium concentrations have been found in groundwaters under similar geological and hydrogeological conditions in Bangladesh (BGS and DPHE, 2001).

### **Data sources**

- Basnyat, K. 2001. Sustainable manageable models essential. The Rising Nepal (Daily), Kathmandu, January 12, 2001.
- BGS and DPHE, 2001. *Arsenic Contamination of Groundwaters in Bangladesh*. Eds: Kinniburgh, D.G. and Smedley, P.L. BGS Technical Report, WC/00/19.
- CIA, 2000. The World Factbook – Nepal. <http://www.cia.gov/cia/publications/factbook/geo/n/p.html>.
- Jacobson, G. 1996. Urban groundwater database. AGSO Report, Australia, <http://www.clw.csiro.au/UGD/DB/Kathmandu/Kathmandu.html>.
- Khadka, M.S. 1993. The groundwater quality situation in alluvial aquifers of the Kathmandu Valley, Nepal. *AGSO Journal of Australian Geology & Geophysics*, **14**, 207-211.
- Khan, R.H. and Tater, J.M. 1969. An outline on the geology and mineral resources of Nepal. Ministry of Industry and Commerce, Nepal Geological Survey, Kathmandu.
- NepalNet, 2001. Contamination of drinking water in Nepal. <http://www.panasia.org.sg/nepalnet/water/watercon.html>.
- NRCS, 2001. Drinking water quality improvement program, September 2000–Mid January 2001. Report of the Nepal Red Cross Society, Kathmandu, Nepal.
- Tandukar, E.N. (2001). Scenario of arsenic contamination in groundwater in Nepal. Report posted at <http://groups.yahoo.com/group/arsenic-source/files>.
- The Times of India (Online), 22 January 2001.
- Upadhyay, S.K. 1993. Use of groundwater resources to alleviate poverty in Nepal: policy issues. *In: Groundwater Irrigation and the Rural Poor: Options for Development in the Gangetic Basin*. Eds: Kahnert, F. and Levine, G. World Bank, Washington DC, USA.

British Geological Survey  
© NERC 2001

2001