28th WEDC Conference Kolkata (Calcutta), India, 2002

SUSTAINABLE ENVIRONMENTAL SANITATION AND WATER SERVICES

Groundwater arsenic in central Thailand

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ARSENIC IS A naturally occurring dissolved element in ground and surface waters throughout the world. Long-term exposure to trace levels of arsenic causes chronic skin and cardiovascular disease. It is also a suspected carcinogen and mutagen. Skin lesions, cancers, and cardiovascular diseases are traceable to arsenic poisoning (Jones 2000). The Ganges delta in Bangladesh and West Bengal are now well known to have very high levels of arsenic. Many other regions are also becoming aware of the presence of this element at levels damaging to health.

The first case of arsenicosis in Thailand was reported in 1987 in Ron Pibul District of Nakorn Si Thammarat Province, in the southern peninsula (Williams et al 1996). Arsenic there may be from both point sources (leachate from ore dressing plant wastes) and diffuse sources (underground placer deposits) (Fordyce et al 1995). Although arsenicosis has not been reported from Central Thailand, this area is suspected of having a groundwater arsenic problem (Ravenscroft et al., 2001)

This hypothesis is based on geological features that the Chao Phraya river basin shares with other areas in South and Southeast Asia where high levels of ground water arsenic contamination have been found. According to Sinsakul (1997):

The [Chao Phraya basin] can be roughly divided into two parts. The Lower Central Plain, which extends north as far as the province of Ang Thong (ca. 15° N), represents an area of Quaternary deposits of silt, of 15-30 m depth, overtopping the soft marine clays laid down when the area was once a huge bay of the South China Sea, about 6,000 to 8,000 years b.p., when sea levels were approximately 4 m higher than at present. The area is flat and low lying. The Lower Central Plain has an average elevation of about 2 m above mean sea level. Above this, the Upper Central Plain extends north up the Chao Phraya River and lower parts of the valleys of the Ping and Nan rivers and lies at >20 m above sea level. This plain was never subject to significant tidal flooding (Sinsakul 1997, reported in Round et al 2001).

The upper reaches of the watershed lie at approximately 19° N, in the provinces of Mae Hong Son, Chiang Rai, and Chiang Mai.

Many areas with arsenic problems are similar: deltaic, alluvial plains of watersheds whose origins lie in the Himalayan massif of south-central Asia. The arsenic contamination in Bangladesh and West Bengal, India is in the Ganges delta. Other documented sites include: the Red River basin near Hanoi, Vietnam (Berg, et. al, 2001), the Mekong delta in both Vietnam (Truy't and Long 1999, Olsson and Palmgren 2001) and Kandal Province of Cambodia (CSI 2002) and the flood plains of the Koshi and Bagmati Rivers in Nepal (Tandukar, 2001).

It is believed that Pleistocene periods of riverine flooding, during glacial maxima, and marine inundation during interglacials formed the alternating strata of alluvial sands and gravels and marine clays and silts which are seen today. Arsenic bearing material from the upper watersheds thus was buried within the coarsely grained aquifers themselves (BGS 2000).

To examine the hypothesis, first advanced by Ravenscroft et al (2001), that conditions in the Chao Phraya basin should support high levels of dissolved arsenic, a survey of ground and surface water sources was carried out. If high arsenic levels were found to occur, the degree of potential public health threat could be estimated.

It should be emphasized however that high levels of dissolved groundwater arsenic have not been reported here. The two major sources of drinking water in Central Thailand are commercially purified, bottled water, and the centralized municipal water system for the Bangkok metropolis. (Raw water for the municipal system is delivered from surface reservoirs through a canal system.) Although ground water was used in large quantities up to the mid 90's, the availability of quality water at the tap and the market means that most ground water today is used primarily for washing, cooking and industrial purposes, not direct consumption.

Materials and methods

Figure 1 indicates the survey area in the Buddhamonthon Sub-District of Nakorn Chaisi District, Nakhon Pathom Province. The area is typical of the lower Chao Phraya basin. The surface is flat, low-lying, and marshy. Eight aquifers, ranging from 50 m to 550 m in depth exist in the survey area. The study wells tapped the relatively shallow Bangkok and Phrapadaeng aquifers, at 80 to 200 m depth.

All wells were equipped with electrical pumps that normally delivered the water to above ground storage tanks on towers (Figs. 2a, 2b). Samples were gathered from locations as close to the underground source as was feasible to avoid aeration and contamination. Relief valves on the pumps, or outflow pipes into the storage tanks were typical sources of samples. Pumps were left to flow until the temperature of the outflow exceeded approximately 35° C., well above the ambient surface temperature. Samples were collected in acid-washed PVC bottles and testing was performed immediately after collection.

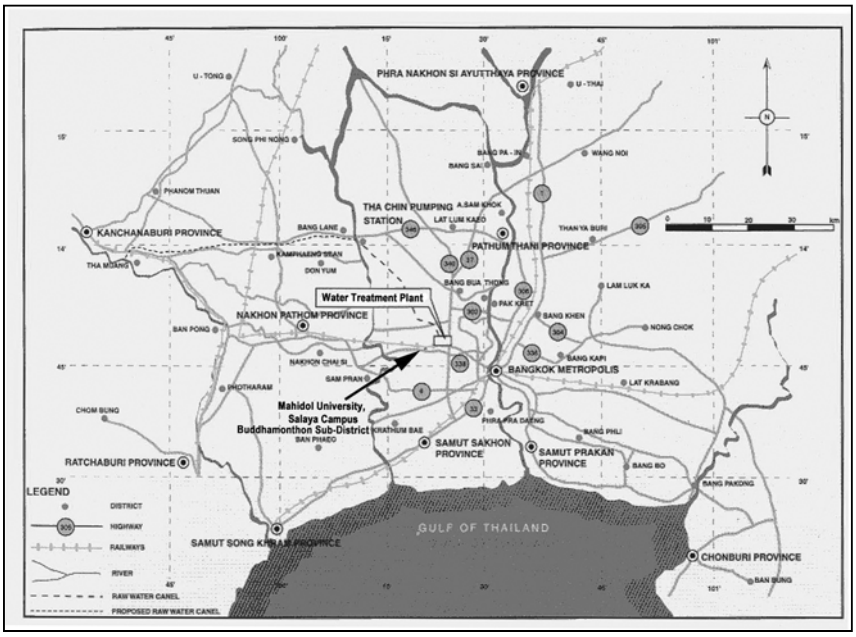

Figure 1. Location of Buddhamonton Subdistrict, where the survey was conducted

Figures 2a and b. Rajasuda College water tower and pump house with aerating system. Buddhamonton, Nakorn Pratom, Thailand.

Arsenic concentrations were determined using an arsenic test kit developed at Mahidol University in Thailand by the Department of Chemistry, Faculty of Science. This kit is based on the Gutzeit method where dissolved arsenic is converted to arsine gas, which produces a yellow to brown color on mercury (II) bromide impregnated test paper; the color change is proportional to the arsenic concentration.

Extensive laboratory tests using standard arsenic solutions indicate that this kit yields results comparable to those of commercial arsenic test kits, such as the Merck and Hach kits. These comparisons were confirmed using graphite furnace atomic absorption spectroscopy as a standard method (unpublished data).

Dissolved iron was determined using Merckoquant Iron Test Strips (3 to 500 mg/L, Merck), pH was determined using Whatman Full Range pH Indicator papers, and salinity and water temperature was determined using a Ysi Model 30 Handheld Conductivity System.

Samples were collected between June and October, 2001, from the early rainy season to the early dry season.

Results

Table 1 summarizes the results. In all, 37 different wells were tested, some repeatedly. Including surface water tests, over 60 tests were run in all. For the great majority of wells, 5 µg/L of arsenic or less was detected. This was true in both the rainy and dry seasons, though positive correlations with rainfall have been noted previously (Kohnhorst and Paul 2000, Berg et al 2001). The mean of all tests was just 11 µg/L. Well depth (as reported by the owners) did not show any relationship to arsenic concentration, and other factors (iron, pH, and conductivity) showed little variation between locations.

Only one well, Rajamangala 1, showed high arsenic levels after repeated tests:

100 µg/L on 1 August 2001 and 30 µg/L on 31 August 2001. Both dissolved iron (17.5 mg/L), and conductivity

Table 1. Results summary

Mean As (µg As/L)[1]	11	Range (µg As/L)[2]	0 to 100
Wells tested	37	Median (µg As/L)	2
Tests conducted	51	Standard deviation	24

[1]Calculated with ‘trace’ results = 2 ug/L.
[2]Two out of 37 wells tested at 100 ug/L. These may tap the shallow, Bangkok Aquifer, which is too saline for use.

were high (9.6 milliSiemens; approximately 1 % dissolved solids). This well had been used by a vocational-technical college until the water became saline, apparently after the casing cracked. Although this particular well was reportedly driven into the deeper, low-salinity Phrapadaeng aquifer, water from the shallow, saline Bangkok Aquifer may have been leaking into it.

Surface water from canals and ponds also showed low arsenic levels, from 0 to 5 μg/L.

Discussion

The WHO suggested standard of 10 μg/L was rarely exceeded, nor did many samples exceed the Thai standard of 50 μg/L. Thus, it appears that arsenic in groundwater is not of public health significance in the Central Thai Region. As noted previously, most end users have easy access to high quality treated water. For the western Bangkok suburbs where this survey took place, the completion of the Mahasawat Water Treatment Plant in 1996 has made the possibility of arsenicosis even less likely.

The few wells that remain in use exceed 100 m in depth. The depth requires the use of powerful electric pumps to raise the water into water towers, with much concurrent turbulence. The water is therefore well-oxygenated; in the tanks, any solids usually settle before the water reaches end users. Thailand may therefore provide a model for other developing countries facing possible arsenic problems in groundwater.

The negative results reported here should not be regarded as definitive. The geological history of the Chao Phraya Basin supports the hypothesis that arsenic bearing alluvial sediments accumulated in this region. However, future studies should consider two aspects that differentiate the Chao Phraya. Its northernmost extent is far south and east of the central Himalaya where the Mekong, Red and Ganges river systems arise, and the sediments in the Chao Phraya basin are much thinner, 2,000 to 3,000 m (Yamamoto 1984) versus 15,000 m in the Ganges basin (BGS 2000).

Well depth is another issue that deserves further study. Arsenic contaminated wells in both Bangladesh and in the Red River delta of Vietnam are mostly shallow (respectively, less than 50 m (BGS 2000), and 12 to 45 meters (Berg et al 2001)). The shallowest well in the present study was reported as 80 m. No study has systematically tested for arsenic in the shallowest depths of the Bangkok Aquifer since high salinity precludes its exploitation. Nevertheless, data on this aquifer may help to clarify current questions concerning the origin and distribution of diffuse arsenic pollution in Asia.

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