Arsenic in Drinking Water – Vietnam, New Focus of Attention

In some countries, arsenic is the most important chemical pollutant in groundwater and drinking water. The Bengal Delta region is particularly affected as 35 million people have been drinking arsenic-rich water for the past 20–30 years, of which one million are currently suffering from chronic arsenic poisoning. In the Red River Delta around the Vietnamese capital of Hanoi, EAWAG researchers have recently identified another highly arsenic contaminated groundwater area. In some locations, the contamination in Vietnam exceeds the standard value of 10 µg arsenic per liter recommended by the World Health Organization (WHO) 300 times. Measures to mitigate the arsenic problem include not only the development of low-cost arsenic detection and easy to use arsenic removal methods, but also dissemination of information to professionals and consulting services to public authorities.

Recently, news about arsenic contaminated drinking water has hit the headlines. Chronic levels of 50 µg arsenic per liter can already cause health problems after 10–15 years of exposure. The development of the disease is strongly dependent on the exposure time and the resulting arsenic accumulation in the body. The first symptoms of the disease are characterized by a noticeable skin pigmentation which can lead to skin cancer (Fig. 1 on page 13). The subsequent health problems are affections of the cardiovascular and nervous system. After 15–30 years of exposure, victims often develop lung, kidney or bladder cancer.

The European Union allows a maximum arsenic concentration of 10 µg/l, and the World Health Organization (WHO) recommends the same value as a guideline. However, in many developing countries, but also in Switzerland and in the USA, the drinking water limit for arsenic has been established at 50 µg/l. Efforts are currently being undertaken in the USA to lower the allowable concentration value to 5–10 µg/l in the near future.

Arsenic – A Global Problem

Regions with arsenic-rich drinking water can be found around the globe: Taiwan, Chile, Argentina, Mexico, Ghana, Hungary, Mongolia, India, and Bangladesh are among the most notorious regions [1]. However, larger regions in the USA are also affected. Vulnerable areas in Nepal, Pakistan, Thailand, Laos, Cambodia, and Sumatra have barely or not been examined so far.

To combat serious infectious diseases in Bangladesh, UNICEF promoted the use of abundantly available and germfree groundwater at the end of the 1970s. In rural households, the groundwater is pumped by small handpumps (see photograph, this page) and consumed as drinking water without further treatment. Since then, this measure has contributed to a significant decrease in infectious diseases and infant mortality. However, the potential high arsenic content in the water was unknown at that time. Only when cases of chronic arsenic poisoning had increasingly been diagnosed by 1989, could the reason be attributed to the arsenic contaminated groundwater, where it was found that the local geological and hydrogeological conditions have lead to a reductive dissolution of arsenic-containing sediments.

In Bangladesh, over one million people currently suffer from chronic arsenic poisoning. This tendency is on the increase. The first systematically conducted study on the water quality in Bangladesh revealed that 25% of the population drink water whose arsenic concentration exceeds 50 µg/l [2]. A report published in the WHO bulletin in 2000 stated

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Arsenic-rich groundwater in Bangladesh and Vietnam drawn by simple handpumps poses a major health risk. Picture of a groundwater handpump in the backyard of a private household located in a rural area of Vietnam.

that “the contamination of groundwater by arsenic in Bangladesh is the largest poisoning of a population in history, with millions of people exposed”.

Natural Occurrence of Arsenic in River Sediments

Arsenic predominantly pollutes the groundwater and drinking water through natural processes (see also article of H.-R. Pfeifer and J. Zobrist, p. 15). Weathering of arsenic containing minerals dissolves the arsenic contained in the rock stratum. The dissolved arsenic is, in turn, highly adsorbed to iron (hydr)oxide containing particles that are transported by rivers and deposited mainly in sediments of river deltas. Under oxygen-rich conditions in the groundwater arsenic remains fixed in the sediments. However, if the sediments come into contact with oxygen-poor groundwater, the arsenic-rich iron (hydr)oxide particles are dissolved by microbial activity and the arsenic is redissolved [3]. This process, which also occurs in the Bengal Delta formed by the Ganges and Brahmaputra rivers, is the cause for the arsenic contamination in Bangladesh and West Bengal (Indian federal state) [4], both located in this delta.

Latest Focus of Attention: The Red River Delta in Vietnam

Since the Red River Delta in the north of Vietnam exhibits similar geological and hydrogeological properties as the Bengal Delta, the EAWAG assumed there would also be higher arsenic contamination of the groundwater in this region. Therefore, groundwater samples from Hanoi were analyzed by EAWAG for the first time in 1998 in the frame of a long-term research collaboration between EAWAG and the Vietnamese National University, which is financed by the Swiss Agency for Development and Cooperation (SDC). The presence of critical arsenic concentrations in these samples incited EAWAG to conduct several systematic measuring campaigns from April 1999 through July 2000. The analyzed groundwater originated from:

- 68 groundwater handpumps (tubewells) from randomly selected private households in the rural districts A–D around Hanoi,
- raw and treated drinking water from the eight largest drinking water supplies of the city of Hanoi.

Figure 2 illustrates the results of the measuring campaign of September 1999 in the rural districts A–D. The results from the investigated family-based tubewells reveal that 50 % of the samples exceed the Vietnamese guideline value of 50 µg arsenic per liter with an average concentration of all the samples amounting to 159 µg/l. Peak values of 3000 µg arsenic per liter were measured in district D, south of Hanoi. Figure 3 shows as cumulative frequency the results of three measuring campaigns in districts A–D. The situation in district D is particularly alarming: with an average value of 432 µg/l, 90 % of the analyzed samples revealed concentrations of 51–3000 µg/l.

Moreover, the groundwater treated for drinking water purposes in the city of Hanoi contains arsenic concentrations of up to 430 µg/l. Although treatment partly eliminates some of the arsenic, concentrations of roughly 90 µg/l arsenic remained in the treated drinking water of four water sup-

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Fig. 1: Skin cancer is one of the symptoms caused by chronic arsenic poisoning.

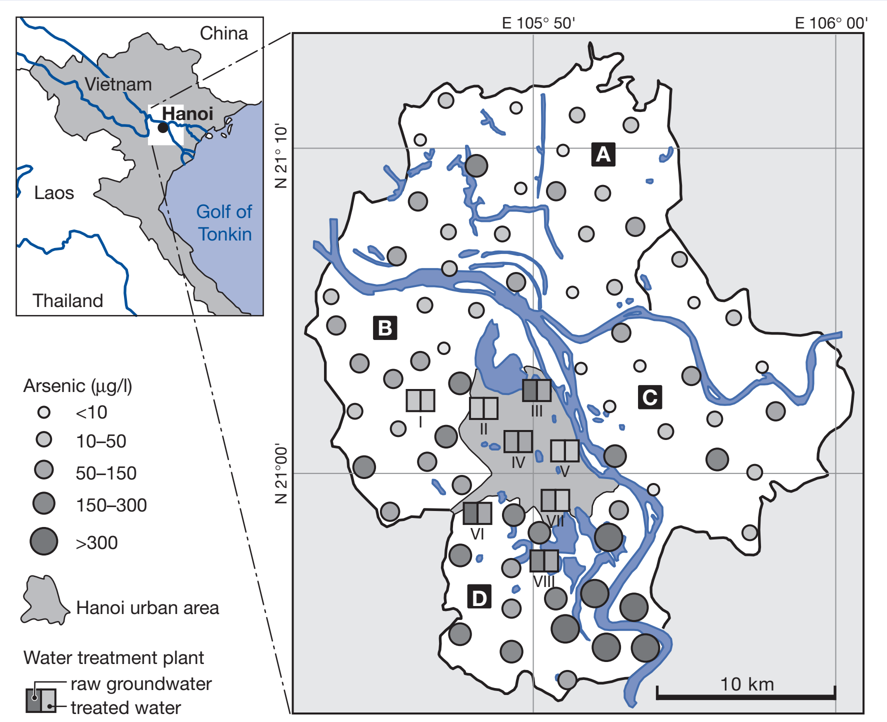

Fig. 2: Arsenic concentrations in groundwater samples from Hanoi and surroundings. 68 samples of randomly selected households were analyzed in the rural districts A–D. In Hanoi city, raw groundwater and treated drinking water samples from the eight largest drinking water supplies were analyzed. Measuring campaign: September 1999.

plies, and thereby, clearly exceed the drinking water limit (Fig. 4).
The results of the present survey [5–7] confirm our assumption that the 11 million inhabitants of the 11,000 km^2 delta of the Red River are exposed to a risk of chronic arsenic poisoning, yet no disease symptoms have been diagnosed so far. This could possibly be attributed to the fact that in Vietnam, arsenic contaminated groundwater has only been used as drinking water for the past 7–8 years. Experience shows that it can take up to 10 years before the first symptoms of arsenic poisoning become apparent. Compared to Bangladesh, one might further speculate that the general nutrition of the Vietnamese population is much better and could have a retarding influence on the outbreak of the disease. Nevertheless, the expected number of cases of the disease occurring in the near future should not be underestimated.

Mitigation Measures

The results obtained clearly reveal that mitigation measures to solve the arsenic problem have to be applied at several levels, as millions of households draw their drinking water from private groundwater wells, but also municipal water supplies are confronted with the same difficulty. Efficient and low-cost arsenic detection and removal methods as well as implementation of a focused information policy are therefore required. With a view to attaining these objectives, EAWAG is participating in an overall project "Sustainable Water Management in Arsenic Contaminated Asian Regions" jointly financed by the Alliance for Global Sustainability.

For a number of years already, several international research teams have been trying to develop inexpensive and simple techniques for arsenic removal from drinking water. EAWAG has developed a low-cost removal technique based on arsenic oxidation and subsequent precipitation using sunlight. This method could be used in households without requiring significant effort (SORAS) [1, 8].
The currently available arsenic measuring methods represent an additional problem. In Bangladesh for example, three million tubewells have to be analyzed due to significant local variations in arsenic concentrations, an undertaking which well exceeds the sample throughput capacity of high-tech laboratory instruments for arsenic analysis. In practice, field test kits for arsenic detection using a wet chemical method have not proved satisfactory so far. EAWAG is, therefore, working on the development of a simple and inexpensive biosensor for quantitative arsenic determination [9].

In addition, both the population and public authorities of the most affected regions must be fully informed about the arsenic problem. EAWAG is actively involved in Vietnam, where it provides scientific and technical consulting services to government authorities and fosters the exchange of ideas and experience with specialists of other research and development organizations.

Additional information on EAWAG's activities in arsenic related research is available at www.eawag.ch/arsenic.

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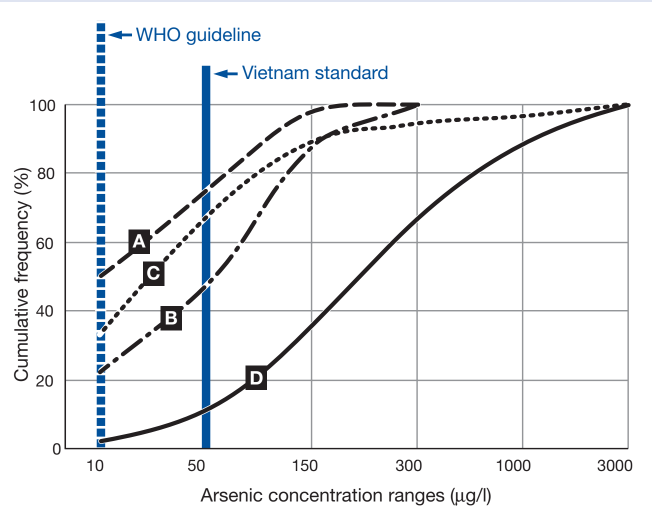

Fig. 3: Cumulative frequencies of the measured arsenic contents in 196 groundwater samples pumped through family-based tubewells in the rural districts A–D around Hanoi. Measuring campaigns: September and December 1999 as well as May 2000.

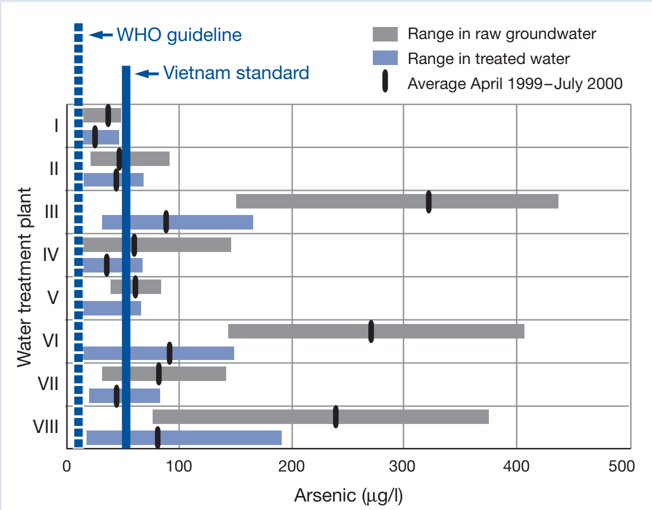

Fig. 4: Arsenic concentrations in raw groundwater and treated drinking water from the eight drinking water supplies of Hanoi. Concentration ranges and average values from 7 measuring campaigns (from April 1999 through July 2000, 7x16 samples).