Arsenic in drinking water in Bangladesh: causes and measures

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Arsenic in groundwater

Arsenic in groundwater is a global problem. However, in some particularly affected countries such as India (West Bengal), Bangladesh, Pakistan and Vietnam, the groundwater is used directly as drinking water. Regular ingestions of even very small amounts of arsenic has multiple negative health effects and it increases the cancer risk significantly, which is why the World Health Organization (WHO) recommends a maximum threshold of 10 µg/l for drinking water. In Bangladesh, around 40 million people are affected by high-arsenic drinking water, about 25% of the mostly very poor population. The problem has been known for almost 30 years, but mitigation measures are progressing very slowly or are lacking in rural areas.

Fig. 6: Map of the three research areas in Bangladesh

The arsenic contamination is widely distributed within Bangladesh, although some regions are severely affected. These areas are not necessarily related to sedimentary arsenic concentrations, which are commonly low. Different natural and anthropogenic factors are considered as causes for arsenic mobilization.

Geomorphology and hydraulic situation

According to the current state of knowledge, natural processes are the main cause of the high arsenic levels. They often occur together with fluviatile inundation and young deltaic sedimentation respectively (Chakraborty et al. 2015). Additionally, the geomorphology is a relevant factor where groundwater levels reach the influence of anthropogenic land use, especially during rainy season. In these areas, the groundwater is extremely vulnerable towards insufficiently filtered recharge from the surface. Consequently, the areas with a high groundwater table seem to be mostly affected by the arsenic problem (Fig. 2, right side). Therefore, either the infiltration of surface water is a trigger for arsenic release (Sahu et al. 2015, Kulkarni et al. 2018) or the fluctuating release of arsenic from the confining top layer covering Bangladesh almost entirely (Polizzotto et al. 2005, 2006, Aziz et al. 2008, Biswas et al. 2014). A special hydraulic situation is given by the very low gradient of groundwater table together with mainly fine-grained sediments, leading to slow groundwater flow velocities. This means, that the vertical fluctuations of the groundwater table are higher than the horizontal annual flow distance, leading to increased recharge and an oscillating movement of groundwater (Mukherjee et al. 2007, Dhar et al. 2008). This can possibly lead to an enrichment of infiltrated substances (e.g. organic carbon) and thus the enhancement of geochemical processes.

Geochemical processes

Two main processes are regularly regarded as the main cause of arsenic mobilization from sediment into groundwater. First, phosphate is considered to behave geochemically very similar to arsenic in building up surface complexes on iron (hydr-)oxides and calcite (Smedley et al. 2002, Sø et al. 2008, Anawar et al. 2011). High phosphate concentrations, as found frequently in Bangladesh, might lead to the exchange of arsenic by phosphate from mineral surfaces and consequently arsenic enrichment in the groundwater (Maier et al. 2017, 2019).

The second release mechanism is based on geochemical dissolution. Biochemical degradation of organic carbon is combined with the depletion of oxygen and nitrate in the groundwater. Becoming successively more anoxic, manganese and iron are

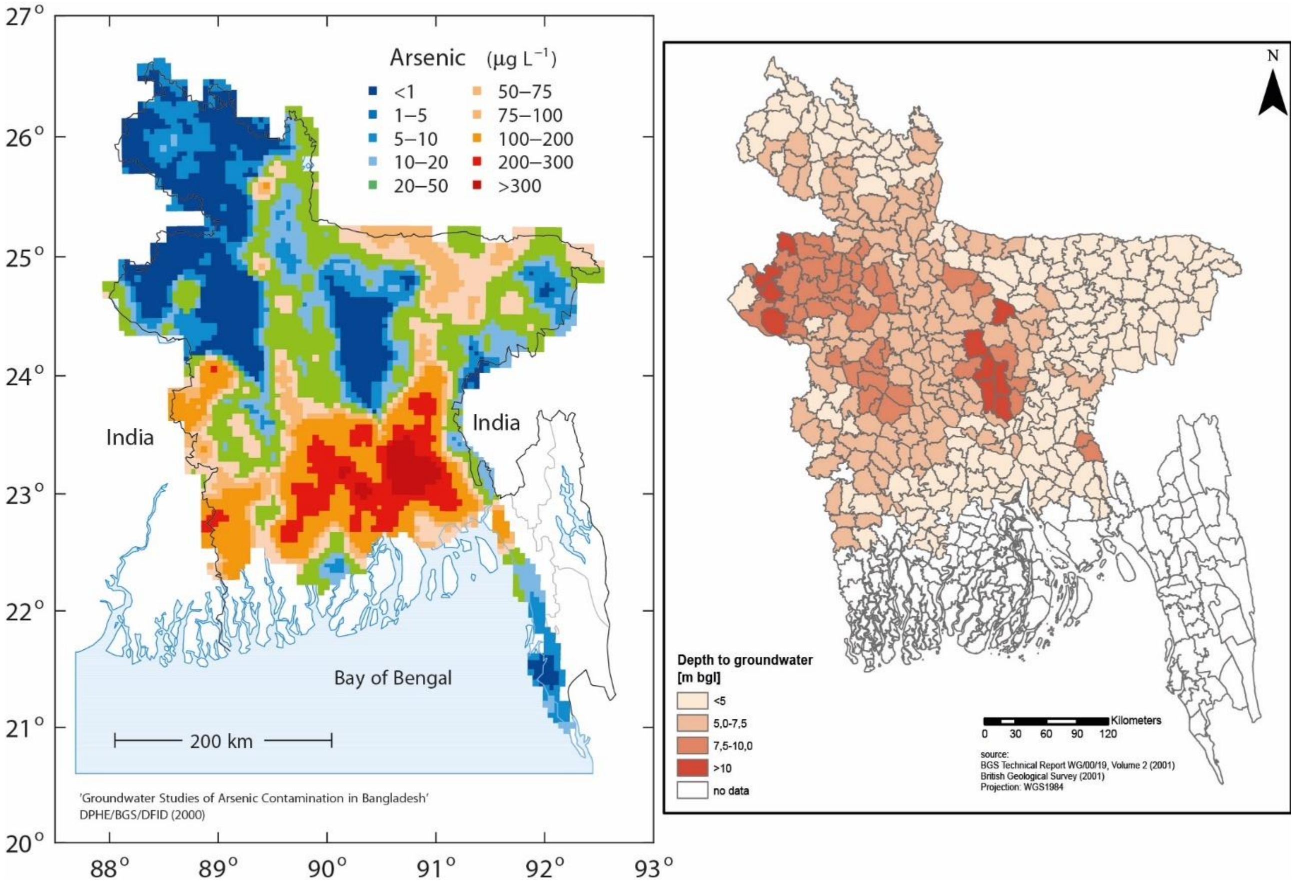

*Fig. 7:Arsenic groundwater contamination in relation to groundwater level (*BGS *et al.* 2001*).*

chemically reduced. Under iron reducing conditions, sedimentary adsorbed arsenic is getting released. Within these processes the adsorbed Arsenate As(V) is chemically reduced to Arsenite As(III) that is considered not to form stable complexes with the sediment. For driving the microbial processes, and thus the dissolution of iron minerals, the decomposition of organic carbon, i.e. peat plays a central role (McArthur et al. 2001, Ravenscroft et al. 2001).

Both substances, organic carbon and phosphate, are frequently investigated for their role in arsenic release (Anawar et al. 2013, Mailloux et al. 2013, Lawson et al. 2016, Aziz et al. 2017, Neidhardt et al. 2018), but the processes are very complex and might vary in space and time.

Anthropogenic factors

Besides the natural factors involved with arsenic release processes, there are more recent theories of negative anthropogenic influences (Neumann et al. 2010, McArthur et al. 2012, Whaley-Martin et al. 2017). This is supported by the observation that at least in some areas of Bangladesh the high arsenic groundwater contamination is in accordance with densely populated areas. The increased cultivation of wet rice instead of dry rice, combined with increasing seepage of phosphate fertilizer and young bioavailable organic carbon into the groundwater, are supposed to contribute to the arsenic problem. Another probably significant role plays domestic wastewater from latrines or household ponds. Distributed directly into groundwater by open-pit latrines, septic tank infiltration or indirectly by wastewater receiving surface waters, wastewater might at least worsen the problem. Negative influences of sewage by tracing E. coli frequently indicates a human impact on groundwater quality (van Geen et al. 2011).

Own research

The aim of our own investigations at three locations in Bangladesh from 2014 to 2020 was to consider the interactions between sediment and groundwater in a temporal and spatial context. In addition to the investigation of geogenic processes, possible anthropogenic influences via domestic wastewater (latrines) were also taken into account, since this organic- and phosphate rich sewage usually seeps into the underground and thus the groundwater without any treatment. This wastewater could explain the high levels of phosphate, ammonium and partially of chloride, which all correlate with the arsenic levels according to our studies. Similar observations are also described by other studies and considered as primarily geogenic (Anawar *et al.* 2004). Furthermore, we found in the northeast of Bangladesh (Sylhet) and the southeast (Chandpur) that arsenic is related with dissolved organic carbon (DOC) and methane.

In the course of further work, we plan to examine the complex processes in the subsoil through vertical groundwater sampling over one year to understand the seasonally varying impact of different factors (geogenic, anthropogenic) on groundwater quality. In the past two years, around 1,500 wells were sampled and the corresponding households interviewed about their sanitary infrastructure (wells, drinking water use and latrines) through a cooperation project between the Institute for Geosciences and the Heidelberg Institute for Global Health, financed by the Heidelberg Center for the Environment (HCE).

As a result, we found that less than 10% of the families used a water filter to remove the iron, which is perceived as a bad taste. Examination of these simple filters showed that they are not suitable for the removal of arsenic. No arsenic filters are currently available on the markets in the examined areas, which is why another project in cooperation with the Karlsruhe Institute of Technology (KIT) is developing and testing inexpensive filters with innovative filter media. In addition to the simple maintenance of these filters, the sustainability aspect is focus of these investigations, since disposal of the used filter media is no option in Bangladesh due to the lack of the necessary infrastructure.

In cooperation with the German non-governmental organization AGAPE e.V. we set up arsenic filters at household scale and investigate the social acceptance of the volunteer participants of the study. The filters are constructed with rechargeable cartridges and are regularly controlled and sampled by the NGO. A preliminary study already shows that the acceptance is very good and the filters fit within quality and socioeconomic perception of their users.

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