Arsenic groundwater contamination in parts of middle Ganga plain, Bihar

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Arsenic contamination of groundwater in low-lying Bhagarathi–Ganga deltaic plain is known for more than two decades. The problem was recognized in 1984 (ref. 1) in West Bengal, when 16 patients from a village of 24 Parganas district reported arsenicosis. Subsequent investigations revealed extensive arsenic contamination in groundwater in the Bengal Basin affecting the eastern part of West Bengal and a major part of Bangladesh[2,3]. About 40 million inhabitants of this densely populated part of the world are residing in the risk-zone having groundwater arsenic level >0.5 mg/l (ref. 4). If the guideline value of 0.01 mg/l of World Health Organisation[5] is to be considered, the affected population would be much more. In the Asian countries, contamination has been recorded from Hanoi city and the upper end of the Red River delta[6]. In addition, the reported high load from flood and delta plains of the Mekong valley in Cambodia and Vietnam, Irrawaddi delta in Mynamar[4] and in the Indus basin[7], indicated that the lower flood plains and delta regions of south-eastern Asia are prone to arsenic groundwater contamination.

The middle Ganga plain covering about 89% geographical area of Bihar (~94,000 km^2) holds potential alluvial aquifers. The tract is known for surplus food production and intensive groundwater extraction for drinking, irrigation, and industrial uses. The middle and upper Ganga plains covering the upstream part from Rajmahal Hills, were earlier considered to be free from arsenic groundwater contamination. Initially, the contamination (>0.05 mg/l) was reported in 2002 from two villages, Bariswan and Simaria Ojhapatti of Bhojpur district of Bihar[8]. The area is located in the middle Ganga plain, amid the flood-prone belt of Sone-Ganga interfluve region. Studies by the Central Ground Water Board and the Public Health Engineering Department, Government of Bihar have indicated the contamination as high as 0.178 mg/l in the surrounding villages, affecting the hand pumps which are generally of 20–40 m depth[9]. The dug wells (depth 8–12 m) have been marked with low arsenic (max 0.008 mg/l). Arsenic in groundwater exhibited a wide spatial variation, even more than 90 times within a distance of 150 m. The area is underlain by a multi-layer sequence of sand (aquifer) alternating with aquitards like sandy-clay and clay, down to depth of 300 m. In an affected village Bariswan, an aquifer-specific groundwater analysis revealed a rapid decline in arsenic load with depth, from 0.095 mg/l at 19 m to 0.006 mg/l at 194 m below ground[9]. Hydrostratigraphic analysis based on drill cutting samples at four locations (Shahpur, Paharpur, Karnamipurpur and Bharauli) in arsenic affected areas in Son–Ganga interfluve, reveals that the Quaternary deposits within 300 m below ground can be divided into two-tier aquifer system. The shallow aquifer system is confined within 120–130 m depth, followed by a laterally continuous 20–30 m thick clay/sandy-clay zone forming the aquitard. The deeper aquifer system exists below this aquitard, which continues down to 240–260 m below ground. The upper part of the shallow aquifer (within ~50 m below ground) is affected by groundwater arsenic contamination.

The lowland Terai belt in Nepal, where groundwater is an important source for agriculture and drinking, recorded high load of arsenic (0.02–2.6 mg/l) in shallow tube wells, where cases of arsenicosis have also been reported[10]. Arsenic-contaminated areas are reported from the areas close to the debouching zones of Himalayan rivers, like Jamuna River flood plain, in northern parts of Bangladesh[11]. In nine districts of north Bihar bordering Nepal, an extensive arsenic testing (total sample analysed ≈3100) by UNICEF has revealed arsenic contamination below 0.05 mg/l (ref. 9). In district-wise sum-up, the highest number of samples exceeding 0.01 mg/l were in east Champaran district (8.3% of total samples).

Initial detection of high arsenic in Bhojpur district has entailed apprehension that a major part of the Ganga Alluvial Plain in Bihar may be polluted by arsenic[8], whereas Acharya[12] had pointed out that the contamination may not be widespread. Detailed hydrogeochemical study in Bhojpur district reveals that in the southern part of the Ganga River, arsenic contamination is confined in the post-Holocene deposits in the oscillation zone of the river Ganga and in the older flood plain of the newer alluvium[13]. The older alluvium (Upper Holocene to Lower Pleistocene) aquifers recorded concentration in the range of 0.001–

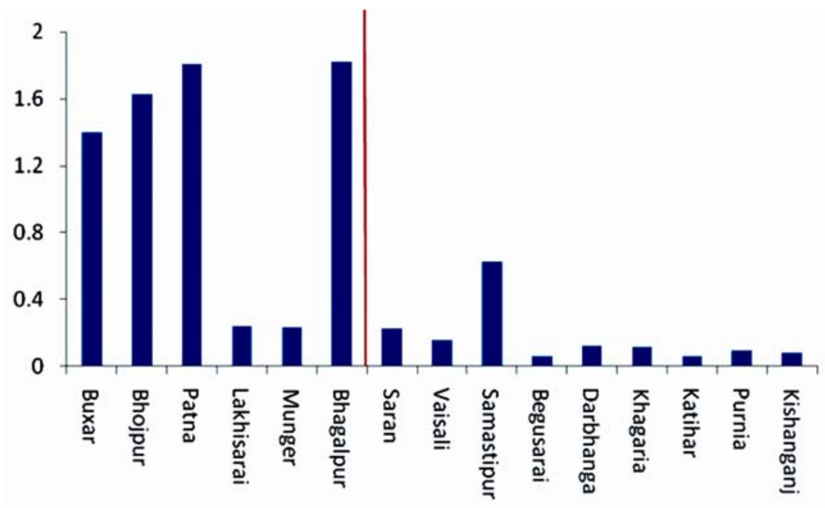

Figure 1. Maximum arsenic concentration in groundwater in affected districts of Bihar state. Arsenic concentration is expressed in mg/l. The districts on the left side of the red line are on the southern bank of River Ganga and remaining districts are from the northern plain.

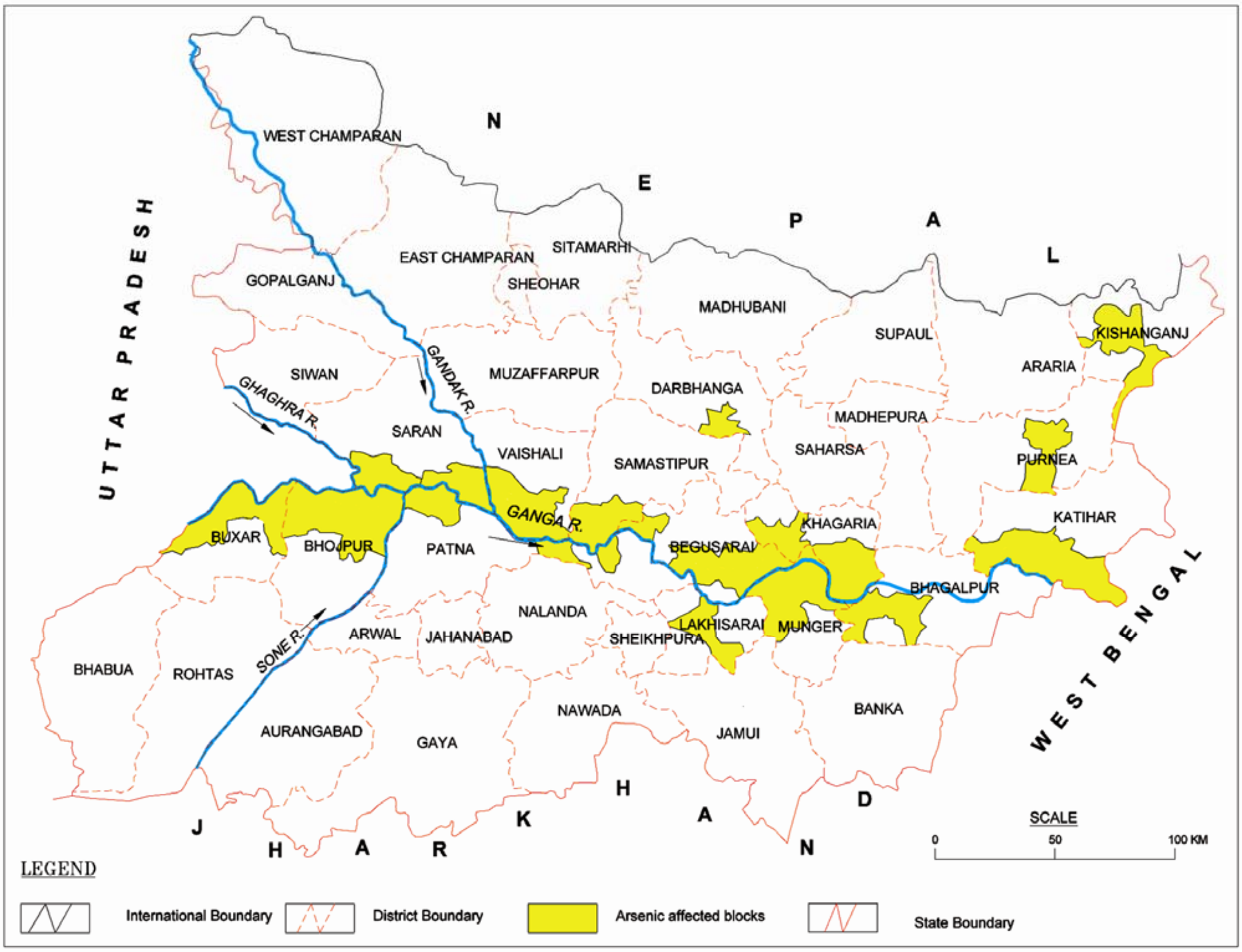

Figure 2. Community development blocks in Bihar state affected with groundwater arsenic contamination (>0.05 mg/l).

0.009 mg/l. In the middle Ganga Plain, sedimentation in the newer alluvium was influenced by sea level fluctuation during the Holocene, causing increased aggregation and forming fluvial swamps[14].

A campaign for arsenic testing from spot groundwater sources for drinking use (hand pumps and dug wells) has indicated that the contamination is spread in the districts all along the river Ganga, both in northern and southern banks[15]. The testing was confined to a 20 km wide corridor along the Ganga course, in which the active flood plain of the river is mostly confined. The samples were first tested with the field test kit, and if the concentration was found >0.04 mg/l, were re-sampled and tested by UV-Spectrophotometer. Besides, samples were collected from the hotspots by Central Ground Water Board and analysed by atomic absorption spectrophotometer (detection limit 0.003 mg/l). Out of ~82,000 samples, about 11% have been found with arsenic load >0.05 mg/l from about 950 habitations. The hotspots are distributed in 57 community development blocks spread in 15 districts (Figure 1). Contamination is more frequently detected in Bhojpur, Buxar and Patna districts. Maximum concentration is detected as 1.82 mg/l, both in Patna and Bhagalpur districts. In Bhojpur and Buxar districts, the number of samples has exceeded 1.2 mg/l. All four districts are located on the southern bank of the Ganga River. The samples from the northern districts have shown less arsenic load (Figure 2), the highest being detected at Samastipur district (0.63 mg/l).

The Quaternary deposits laid down by the Ganga River system are more than 300 m thick, except for the marginal alluvial areas adjoining the Precambrian Highlands in south[16] bordering Jharkhand state. Recent estimation by Central Ground Water Board and Ground Water Directorate, Government of Bihar[17], has pegged the replenishable groundwater resource of the middle Ganga plain at 26.4 bcm with stage of development as 36%.

Abundance of Quaternary aquifers, conducive hydrogeological conditions, absence of any geogenic or anthropogenic contamination and available resources have encouraged groundwater-based drinking water supply system both in household and community scale. In rural and semi-urban areas, with persuasion in the past two decades, the age-old mindset of using open dug well has been shifted to hand pump. The shift was encouraged primarily because of less bacteriological contamination in hand pumps. With the detection of high arsenic load in hand pumps (depth ~20–50 m) the focus is whether the deep aquifers can be used for safe community based water supply.

Local-scale and basin-scale hydrostratigraphic analyses and aquifer hydraulic characters determined from long-duration pumping tests conducted by the Central Ground Water Board have indicated long-term sustainability of the deeper aquifer system. The storage coefficient values determined by long-duration pumping tests (4.0×10^{-5} to 7.5×10^{-3}), conducted on bore wells in the affected Bhojpur district revealed that the groundwater in deep aquifer remains under confined to semi-confined condition. The deep aquifer can be developed for safe community based drinking water supply. The aquifer geometry, hydraulic characters of aquifers and aquitards need to be studied from the entire affected belts.

The origin of arsenic is geogenic. Groundwater sample analyses from the affected areas of Sone–Ganga Interfluve[18] show strong positive correlation (r^2 = 0.674) between arsenic and iron. Better correlation is observed in samples with higher arsenic load. pH is mildly acidic to near neutral. Arsenic-dominated samples are frequently distributed in HCO_3-dominated groundwater facies. The area represents a flood-prone tract characterized by fluvial swamps. The water level remained shallow (less than 6 m bgl during pre-monsoon period) with pre- and post-monsoon water level fluctuation mostly within 2–3 m. No long-term decline of water level is observed in the area. Biomass accumulated in the seasonal water bodies is the source of organic carbon in groundwater which appears to trigger reductive dissolution of iron oxy-hydroxides present in the deposits, releasing arsenic and iron in groundwater.

The distribution of hotspots indicated that the contaminated areas may not be confined in the narrow entrenched flood plain of the Ganga only. Detection of high arsenic groundwater from Biraul block in Darbhanga district (Figure 1) located about ~80 km north of the Ganga, indicates that contamination may be spread even to areas far-off from the river course within the newer alluvial deposits. A detailed analysis of water and sediments are needed to understand the arsenic distribution in different morpho-statigraphic units and to have a comprehensive understanding of distribution and its mobilization processes in the middle Ganga plain.

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