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Studies on Toxic Level of Some Trace Elements in the Groundwater of Bhagalpur District

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ABSTRACT

Bhagalpur is in eastern Bihar state of Indian subcontinent is mostly famous for silk products. After silk production, rice, maize, and banana are mostly produced end-products from this city. Bhagalpur stands on the banks of Ganga basin, where the location lies at 25°15'N latitude and 87°0'E longitude. This city is situated at the height of 141 feet above the measurement of sea level. Groundwater from well, hand pumps, submersible is main drinking water in this area. The quality of groundwater varies area to area and season to season which is a natural phenomena. Some of the toxic trace elements are also observed during sampling. Groundwater samples were collected from the different locations of Bhagalpur district, to assess the presence of toxic trace elements viz. arsenic (As), boron (B), barium (Ba), chromium (Cr), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), and uranium (U) by using water quality index (WQI). Based on global positioning system (GPS) 100 groundwater samples were collected from the different sources at different depths. A single mathematical approach was identified using several parameters integrated to represent a single value for evaluating groundwater quality called as WQI. Chronic exposure to groundwater containing elevated concentrations of geogenic contaminants such as arsenic (As) and uranium (U) can lead to detrimental health impacts. In this study, we have undertaken a groundwater survey of representative sites across Bhagalpur districts of the State of Bihar, in the Middle Gangetic Plain of north-eastern India. The aim is to characterize the inorganic major and trace element aqueous geochemistry in groundwater sources widely used for drinking in Bihar, with a particular focus on the spatial distribution and associated geochemical controls on groundwater As and U. Concentrations of As and U are highly heterogeneous across Bihar, exceeding (provisional) guideline values in ~16% and 7% of samples (n = 273), respectively. The strongly inverse correlation between As and U is consistent with the contrasting redox controls on As and U mobility. High As is associated with Fe, Mn, lower Eh and is depth-dependent; in contrast, high U is associated with HCO3, NO3, and higher Eh. The improved understanding of the distribution and geochemical controls on trace elements in groundwater in Bhagalpur has important implications on remediation priorities and selection, and may contribute to informing further monitoring and/or representative characterization in Bihar and elsewhere in India.

1. Introduction

Bhagalpur is a city of historical importance on the southern banks of the river Ganges in the Indian state of Bihar. It is the 3rd largest city of Bihar and also the headquarters of Bhagalpur division. Silk City is a major educational, commercial, and political center, and listed for development under the Smart City program, a joint venture between Government and industry. The Gangetic plains surrounding the city are very fertile and the main crops include rice, wheat, maize, barley, and oilseeds. The river is home to the Gangetic dolphin (the National Aquatic Animal of India) and the Vikramshila Gangetic Dolphin Sanctuary is established near the town.

Groundwater quality is influenced by both the natural and anthropogenic activities. Groundwater has been the bastion for congregation of the domestic need of [80 % of rural and 50 % of urban inhabitants, executing the irrigation requirements of approximately 50 %] irrigated farming. It has been found that 70–80 % of agricultural production of India derives from groundwater irrigation. Observing of ground water quality is an attempt to attain information on chemical properties throughout representative sampling in various hydro-geological units. In recent times, intensive agricultural activities and pollution of surface due to population growth have tremendously affected groundwater quality (Adhikary & Biswas, 2011). In Bihar, drinking water quality primarily depends upon the ground water (Babiker et.al, 2007). The recent reports from Bihar government stated that the drinking water sources in rural areas are not safe in most of the area and the health of the rural population is at risk. Out of the 38 districts, 13 districts located along the river Ganges are partially affected by arsenic contamination (As [50 ppb) whereas the drinking water sources of 6373 habitations of 22 districts are affected with excess Fluoride (1.5 ppm)] and presence of excess iron in groundwater is in majority of the districts arsenic contamination is a major problem in and around the river Ganges in Bihar. Bhagalpur is directly affected by arsenic contamination in ground water (Ghosh, et al, 2009). The report of Central Ground Water Board (CGWB, 2015) in Bhagalpur area irrigated by varying sources comprise only 35.01 % of the total cropped area, out of which only 9.48 % is dish up by surface water and the remaining 25.53 % is provided by ground water (Kouras et.al, 2007, Magesh et.al, 2012). Assessment of groundwater quality for drinking and irrigation is important for present and future water management. Consequently, the characterizations of irrigation water quality play an imperative role in improving its management strategies for profitable farming. The improper management of water systems may cause serious problems in availability and quality of water in near future. Therefore, it is essential to study the quality of groundwater of Bhagalpur district.

Measuring the chemical composition of groundwater determines its suitability for the source of water for human and animal consumption, irrigation, and for industrial and other purposes. Hence, scrutinizing the quality of water is significant as clean water is obligatory for human well-being and the veracity of aquatic ecosystems. GIS based mapping of groundwater quality is a significant component of a groundwater planning strategy, provides potential contaminated zone and indicates suitability of water for drinking, irrigation.

2. Materials and Methods:

Bhagalpur is a large city in the state of Bihar, India. Its population is about 4,42,000 people. It is a key trade and commerce center of the state famous with its cotton and silk industry. The Bhagalpur district falls under the influence of three principal rivers – the Kosi River and the Ghagra River and its tributaries. The climate is subtropical with an average annual rainfall and evaporation value of about 1300 and 2100 mm, respectively (average of 30 years). Southwest monsoon (July–September) contributes 80 % of total rainfall. Generally the eastern and northeastern parts of the district receive higher amount of rainfall. The monthly mean temperature ranges from 20 to 45^{0}C, while the annual mean temperature is 31^{0}C. The study area consists mainly of alluvial soil formation. Soils are coarse loamy, mixed, hyperthermic, and Typic Haplustepts. The surface soils comprise mostly of ferruginous lime quartzite, granites, and schistose rock minerals (Verma et al. 2015).

Water sampling (n=273) was conducted predominately in early and mid-2015 in the pre-monsoon season in Bhagalpur, with the inclusion of a few additional samples collected in November 2015 (n = 3) and December 2015 (n = 4). Groundwater (from a depth range of approximately 5 to 180 m) was collected from existing private and government wells, either connected to a manual hand pump or on occasion an electrical submersible pump depending on the site (Mehrjardi et.al, 2008). All sampled wells were in regular use and were pumped for at least ~1–2 minutes prior to collecting samples. The subset of four samples from December 2015 were non-random samples collected Subsamples of groundwater for cation, anion and dissolved organic carbon (DOC) analyses were immediately filtered upon collection, using similar methods as previously described (Saha, 2009). Due to transport restrictions regarding nitric acid, subsamples for cation and trace metal (loid) analysis were acidified upon arrival at laboratories using 2% trace analysis-grade nitric acid distilled in-house. All samples were stored in bottles which had been prepared in advance by acid wash (10% nitric acid wash) followed by thorough rinsing with deionized water and furnacing at 40^0 C to remove trace contamination.

3. Results and Discussion:

The physicochemical characteristics of the groundwater were determined and represented in detail by (Verma et al. 2015). Using the relevant parameters mentioned above in materials and method, a single mathematical value was calculated called as WQI. The generated score for different locations with latitude and longitude of Bhagalpur district along with water quality status. Total of 100 ground water samples were collected from the dug wells (open well), hand pumps, submersible pump and deep tube well in the region during the post monsoon period between January 2015 to December 2015. The spatial locations of surveyed points were recorded through Global Positioning System. The groundwater samples were collected in 1 L narrow mouth pre-washed polyethylene bottles. Electrical conductivity (EC) and pH values were measured in the field using a portable conductivity and pH meter. In the laboratory, the water samples were filtered through 0.45 lm Millipore membrane filters to separate suspended particles. Concentrations of major anions (F-) were determined by UV spectrophotometer. Concentration of major cations (Ca2, Mg2, Na, and K) were determined by flame Photometry and flame atomic absorption spectrophotometer (AAS).

4. Aqueous Analytical Measurements:

Measurements on aqueous samples were conducted in both field and laboratory settings. Field measurements included pH, oxidation–reduction potential (Eh), temperature and electrical conductivity, collected in-situ using Hanna handheld meters. Cations were analysed using inductively coupled plasma atomic emission spectrometer (ICP-AES, Perkin-Elmer Optima 5300 dual view; for analysis of Ca, Mg, Na, K, Si, Fe, Mn and P) and/or inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7500cx; for analysis of toxic trace elements viz. arsenic (As), boron (B), barium (Ba), chromium (Cr), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), and uranium (U) (Singh et.al, 2014b). Anions were analysed using ion chromatography. The method detection limit was 0.01 mg.L/1 for ICP-AES (corresponding to 0.0002 mM for Ca, Fe and Mn; 0.0003 mM for K and P; and 0.0004 mM for Mg, Na and Si) and 1µg.L/1 for ICP-MS (corresponding to 0.01µM for As; 0.02µM for Cu and Zn; 0.004µM for U; and 0.005µM for Pb). For IC, the method detection limit was 0.1 mg.L/1 for Br- and NO2 (0.001 and 0.002 mM, respectively), 0.05 mg.L/1 for F (0.003 mM) and 0.2 mg.L/1 for Cl-, SO4 2 and NO3 (0.006, 0.002 and 0.003 mM, respectively). Alkalinity was estimated by charge balance.

5. Data Quality:

The mean calculated for ICP-MS analytic across analytical runs reported here (March 2015, April 2015, July 2015 and December 2015), based on CRM SPS-SW1, is as follows: –1% for Cu, 3% for Zn, 0% for As and 4% for Pb. For U, bias is –5% at 25.4µg.L/1 (CRM 1640a, only available for the March 2015 and December 2015 analytical runs) and 37% at 0.5µg.L/1 (CRM SPS-SW1, noting the certified value is below the lowest calibration standard used of 1µg.L/1). The July 2015 ICP-MS analytical run tended towards slightly higher analytical bias than the other analytical dates (Tiwari & Singh, 2014). For ICP-AES analytical runs in March, April and July 2015, the mean calculated bias on the basis of CRM SPS-SW1 is 0% for Fe, –3% for Mn, –7% for P, –11% for Ca, –12% for Mg, –20% for Na and –30% for K (Tyagi et.al, 2009). For IC analytical runs in March and August 2015, mean calculated bias on the basis of CRM LGC6020 is –6% for Cl, –8% for F, –1% for NO3 and –3% for SO4 (Vasanthavigar et. al, 2010).

No corrections were made on the basis of analytical bias, particularly due to the reasonable agreement observed for the parameters of primary interest. Methodological comparisons of filtration only in the field versus acidification (for a minimum of 48 h) followed by filtration in the laboratory showed reasonable agreement (Verma et.al, 2015). Duplicate analyses were typically within ~10%. While we have undertaken representative sampling across Bhagalpur district and to report any possible sampling bias with transparency, it is important to note that overall sampling density in this study remained relatively low (WHO, 2011). Thus, these results can not necessarily be considered comprehensive and in particular may not capture localized influences in particular locations which were not sampled.

6. Conclusion:

Available groundwater studies particularly for Bhagalpur district remain relatively limited as compared with the neighbouring districts in the Gangetic Basin of India. The lack of availability of systematic and representative (non-summarized) data in the public domain remains a major limitation to enable understanding of geochemical controls, prediction of future changes or developing effective monitoring and/or mitigation schemes. In this study, drinking water samples from the different areas of Bhagalpur districts were analyzed for multiple metal contamination in order to evaluate groundwater quality on the neighbourhood scale. Each sample was analyzed for arsenic (As), boron (B), barium (Ba), chromium (Cr), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), and uranium (U). Arsenic was found above the WHO health-based drinking water guideline in 50% of these tube wells. Mn and B were found at significant concentrations in 19% and 6% of these tube wells, respectively. The maps of As, Mn, and B concentrations suggest that approximately 75% of this area has no safe tube wells. The concentrations of As, Mn, B, and many other toxic elements are independent of each other. The concentrations of Pb and U were not found above WHO health-based drinking water guidelines but they were statistically related to each other (p-value= 0.001). An analysis of selected isotopes in the Uranium, Actinium, and Thorium Radioactive Decay Series revealed the presence of thorium (Th) in 31% of these tube wells. This discovery of Th, which does not have a WHO health-based drinking water guideline, is a potential public health challenge. In sum, the widespread presence and independent distribution of other metals besides As must be taken into consideration for drinking water remediation strategies involving well switching or home-scale water treatment. As such, the aim of this study is to systematically obtain, evaluate and interpret representative primary groundwater chemical quality data for Bhagalpur district to understand the distribution of toxic trace elements of groundwater contaminants and to characterise the dominant geochemical conditions and processes likely to peoples who are at risk from toxic trace elements contaminated groundwater in Bhagalpur. Multiple metal analysis in Bhagalpur has found other toxic elements above the World Health Organization (WHO) health-based drinking water guidelines which significantly increases the number of people at risk due to drinking groundwater.

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