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A study of trace element contamination using multivariate statistical techniques and health risk assessment in groundwater of Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India

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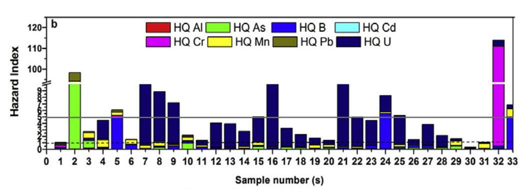
HIGHLIGHTS

- Spatio-chemical of trace and toxic elements in the groundwater of an industrial area.
- Comparative analysis of concentration with WHO and BIS standards for elements.
- Survey study on background radiation in the study area.
- Estimation of total daily intake and body burden from ingestion of trace elements.
- Health risk assessment for trace and toxic elements.

GRAPHICAL ABSTRACT



Hazard Index for Al, As, B, Cd, Cr, Mn, Pb and U reported in Chhaprola Industrial Area, India

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ABSTRACT

This study is an investigation on spatio-chemical, contamination sources (using multivariate statistics), and health risk assessment arising from the consumption of groundwater contaminated with trace and toxic elements in the Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India. In this study 33 tubewell water samples were analyzed for 28 elements using ICP-OES. Concentration of some trace and toxic elements such as Al, As, B, Cd, Cr, Mn, Pb and U exceeded their corresponding WHO (2011) guidelines and BIS (2012) standards while the other analyzed elements remain below than those values. Background γ and β radiation levels were observed and found to be within their acceptable limits. Multivariate statistics PCA (explains 82.07 cumulative percent for total 6 of factors) and CA indicated (mixed origin) that natural and anthropogenic activities like industrial effluent and agricultural runoff are responsible for the degrading of groundwater quality in the research area. In this study area, an adult consumes 3.0 L (median value) of water therefore consuming 39, 1.94, 1461, 0.14, 11.1, 292.6, 13.6, 23.5 μg of Al, As, B, Cd, Cr, Mn, Pb and U from drinking water per day respectively. The hazard quotient (HQ) value exceeded the safe limit of 1 which for As, B, Al, Cr, Mn, Cd, Pb and U at few locations while hazard index (HI) > 5 was observed in about 30% of the samples which indicated potential health risk from these tubewells for the local population if the groundwater is consumed.

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1. Introduction

Groundwater comprises only 0.61% of the entire world's water resources, (including oceans and permanent ice caps), however, it makes up 20% of the world's fresh water supply (Khanam and Singh, 2014). It plays an important role in our life as it is used in various sectors such as agriculture, domestic, industries, etc. It is also an important source of drinking water throughout the world. In developing countries, like India, it plays an important role in strengthening the economic growth of the country (Ravikumar et al., 2011). Due to insufficient accessibility and contamination of surface water, groundwater is a suitable alternative (Tyagi et al., 2009). The active fresh groundwater resources of India have been estimated as 432 km^3/year, in which 396 km^3 is expected to be exploitable as reported by Central Groundwater Board (Planning Commission, 2011). Rapid population growth, coupled with anthropogenic activities such as unplanned increase of industrialization, urbanization and haphazard disposal of domestic, industrial, agricultural and mining wastes have led to serious environmental concerns on the deterioration of groundwater (Singh et al., 2011). Due to the chemical and biochemical interactions between water and the geological materials, groundwater consists of different inorganic chemical components in various concentrations. Many studies have been conducted on groundwater quality assessment and risk caused by trace and toxic elements such as Mn, Ba, B, Se, As, Ni, Cd, Fe, Cr, V, Co, Cu, Zn, Mo, Sn, Sb, Pb, and U present in groundwater from different countries in South-east Asia like India, China, Cambodia, Pakistan, Vietnam and Bangladesh and others parts of Northern Greece (Kumar et al., 2015, 2016; Rahman et al., 2015; Jain et al., 2010; Jan et al., 2010; Krishna et al., 2009; Zhou et al., 2008; Buschmann et al., 2007, 2008; Agusa et al., 2006; Katsoyiannis and Katsoyiannis, 2006; Frisbie et al., 2009).

Increasing groundwater contamination caused by anthropogenic activities needs more investigation to combat the issue and to fulfill the current and future potable water demand. Insufficiency of potable water in the Indian metropolitan cities including National Capital Region (NCR) is a major environmental concern and requires scientific attention to combat the problem. In a study conducted in Ghaziabad, India (near to current study area), groundwater samples were analyzed for Cr, Cd, Cu, Ni, Pb, and Zn. The concentrations of six metals were found to be within the WHO (2011) guidelines and BIS (2012) standards except for Fe (range 106.5–7623 μg/L) (Singh et al., 2012). In an another study groundwater contamination with Fe (range 329–944), Mn (range 10–1342), Pb (range 39–531) and Ni (range 0.3–85.7) μg/L respectively were reported in part of NOIDA Metropolitan City, Uttar Pradesh indicating human perturbations towards groundwater quality (Singh et al., 2011). These studies are mainly focused on water quality assessment, and no attempt was made to identify the source of contamination and health risk assessment associated with the metals. Various national dailies have reported that due to the improper disposal of industrial waste effluents, there is an increase in ground water pollution which in turn has led to increased incidence of cancer (Zee News, 2015; TOI, 2014). Therefore, it's imperative to conduct a study in this area because of the occurrence of many anthropogenic activities as mentioned above. The present study area covered a few villages of Bisrakh block of Greater Noida West, Gautam Buddha Nagar also known as “Chhaprola Industrial Area”. The objective of this study was to analyse 28 trace and toxic elements (As, B, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Mo, Cd, Sb, Ba, Pb, U, Al, Cs, Ga, Ge, Li, Pb, Rb, Sr, Th, Ti, Y) present in groundwater, tracing the source of these contaminants to study area, and assessing the potential risk to the residing population as a result of the consumption of the contaminated water. Background radiation levels were also measured to determine the radiation toxicity.

2. Material and methods

2.1. Study area description

The present study site is a part of the Chhaprola Industrial Area located in the district of Gautam Buddha Nagar, India. The Gautam Buddha Nagar district comes under Yamuna sub-basin and is a part of Ganges-Yamuna Doab (Joshi, 2009). Fig. 1 shows the map of the study area in Uttar Pradesh, India with the corresponding sampling locations. The villages (Khera Dharampura, Bishnuli, Dujana, Achchheja, Sadullapur, Sadopur and Jon Samana) flanking the heavy industrial setup in Chhaprola Industrial area of Bishrakh block of Greater Noida West, Gautam Buddha Nagar was selected as the field of study and site for collecting the samples. The majority of the tubewells sampled (n = 33) by us in January 2014–15 are logged in shallow aquifers (15–60 m, below ground level) and are commonly consumed by residents of this area.

2.2. Sample collection, preservation and transportation

The total area of Bisrakh block is 129.54 km^2 with a population of 184,521 (Census, 2011). Representative groundwater was sampled following simple randomization method from selected tubewells of different depths available in Chhaprola Industrial area. The standing water was pumped out for 5 min before taking any reading or sample. Water samples were collected using a method as described in (Kumar et al., 2016). Pre-cleaned (washed with concentrated nitric acid followed by 2–3 Milli-Q water wash) polypropylene bottles were used to collect samples of water which were stored at 4 °C until analysis. The groundwater samples (250 ml) were passed through 0.45-Millipore membrane filter paper with the help of hand operated vacuum-pump with the specification of 15 cc/stroke pumping rate and 7 psi positive pressure (Code: 402,002) followed by acidification.

2.3. Daily consumption of drinking water

A survey was conducted during field sampling regarding the daily intake quantity of drinking water. The daily consumption rate for adult males and females were based on 32 families (32 females and 32 males; age range 12–70 years). To know the correct volume of daily water consumption, two calibrated glasses of volume 250 and 500 mL respectively were used. The amount and frequency of the intake of drinking water from their vessel were confirmed with our calibrated glasses.

2.4. Instrumentation used

Polimaster survey meter PM1405 was used to measure the background γ and β radiation levels present in the study area. An inductively coupled plasma optical emission spectrometer (ICP-OES, Varian Vista-PRO) was used to determine the concentration of elements in groundwater. The instrumental detection limits (DLs) of ICP-OES for Al, As, Be, Cd, Co, Cr, Cs, Cu, Fe, Ga, Ge, Li, Mn, Mo, Ni, Pb, Rb,Sb, Se,Sr, Th, Ti, U, V, W, Y, Zn were 2.0, 0.03, 0.10, 0.01, 0.005, 0.50, 0.001, 0.20, 10.0, 0.01, 0.01, 1.0, 0.10, 0.10, 0.30,0.01, 0.005, 0.01, 0.20, 0.04, 0.001, 0.10, 0.001, 0.10, 0.02, 0.003, 0.50 in solution matrix respectively.

2.5. Data compilation and statistical methods used

Arc Map 10.2 was used to prepare a map of the study area. Spatial distribution was done with the help of Surfer 8.0. The Pearson correlation coefficient was used to determine the strength of relationships among reported trace and toxic elements in this

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