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Arsenic in groundwater of the Kolkata Municipal Corporation (KMC), India: Critical review and modes of mitigation

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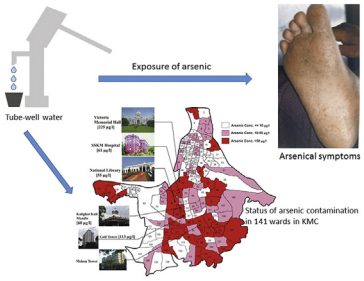
HIGHLIGHTS

- Arsenic concentrations in groundwater of mega city of Kolkata, India.
- 14.2% and 5.2% samples had arsenic >10 μg/l and >50 μg/l, respectively.
- Arsenic >10 μg/l and >50 μg/l was found in 77 and 37 wards, respectively.
- Enhanced lifetime cancer risk for the population in southern KMC.
- Issues involved in the water supply of Kolkata and mitigation strategies.

GRAPHICAL ABSTRACT



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ABSTRACT

This study represents the first comprehensive report of groundwater arsenic contamination status in the Kolkata Municipal Corporation (KMC). During the past 23 years, 4210 groundwater samples were analysed from all 141 wards in the KMC: 14.2% and 5.2% samples had arsenic >10 μg/l and >50 μg/l, respectively, representing 77 and 37 wards. The study shows that the number of arsenic contaminated samples (and wards) in the southern part of the KMC exceeds that of other parts of the city. The daily intake of arsenic from drinking water was estimated as 0.95 μg per kg bw and the cancer risk was estimated as $1425/10^6$. Analyses of biological samples (hair, nail and urine) showed elevated concentrations of arsenic indicating the presence of subclinical arsenic poisoning, predicting an enhanced lifetime cancer risk for the population in southern part of the KMC. In the KMC, groundwater is not a sustainable source of freshwater due to arsenic, high iron, hardness and total dissolved solids. Its continued use is impelled by the lack of an adequate infrastructure to treat and supply surface water and in some wards the unaccounted for water (UFW) is even >45% incurred during distribution. The rare imposition of a water tax makes the water supply systems unsustainable and fosters indifference to water conservation. To mitigate the arsenic problem, continuous groundwater monitoring for pollutants,

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a treated surface water supply with strict policy implications, rainwater harvesting in the urban areas and introduction of water taxes seem to be long-term visible solutions.

1. Introduction

Catastrophic arsenic contamination of groundwater has been a major public concern in different parts of the world for the last few decades. Arsenic contamination has been identified in 105 countries with an estimated exposed population of >200 million worldwide (Murcott, 2012; Naujokas et al., 2013). Asian countries, especially the Ganga–Meghna–Brahmaputra (GMB) Plain of India and Bangladesh are the worst affected. In GMB-Plain alone at present more than 100 million people are potentially at risk from groundwater arsenic contamination (Chakraborti et al., 2013).

The first arsenic contamination of groundwater in India and its health effects were reported from Chandigarh in North India and its surrounding villages in 1976 (Datta, 1976). The next incident of arsenic health effects in India was reported from the lower Ganges plain of West Bengal in 1984 (Garai et al., 1984). The School of Environmental Studies (SOES) began working on the groundwater arsenic contamination problem in West Bengal in 1988. In 1995, SOES arranged an international arsenic conference in Kolkata for 5 days including visits to arsenic affected villages (International Conference on Arsenic in Groundwater, 1995). During and after the conference, national and international news agencies covered the arsenic groundwater problem and its health effects in West Bengal. In 2002, SOES reported the groundwater arsenic contamination situation in West Bengal and critically discussed the attitude of various organizations including government of West Bengal toward this serious problem (Chakraborti et al., 2002). The complete situation of arsenic groundwater contamination from 1988 to 2009 in West Bengal was reported including a small report on Kolkata city itself in 2009 (Chakraborti et al., 2009). During that period, SOES analysed 140,150 hand tube-wells from all 19 districts of West Bengal. In 13 districts, groundwater arsenic exceeded the World Health Organization (WHO) guideline value (10 μg/l) in drinking water and in 9 districts arsenic was above 300 μg/l, the concentrations causing arsenical skin symptoms (Chakraborti et al., 2004). Only in six districts arsenic concentration in groundwater samples were less than 10 μg/l, but those districts are fluoride affected (Chakraborti et al., 2010a). Overall, 48.1% (n = 140,150) of hand tube-wells had arsenic concentrations above the WHO guideline value and 23.8% (n = 140,150) were above 50 μg/l (the standard for arsenic in many developing countries and (BIS, 2012) value if alternative water is not available). We further classified all districts in West Bengal based on the severity of arsenic contamination (Chakraborti et al., 2009). Nine districts (Malda, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas, Bardhaman, Howrah, Hoogly and Kolkata), mainly on the eastern side of Bhagirathi River are highly affected with arsenic in many hand tube-wells exceeding 300 μg/l. Thousands of patients were suffering from arsenic toxicity. We have already reported detailed findings of arsenic contamination and health effects from three of these highly arsenic affected districts, Murshidabad (Mukherjee et al., 2005; Rahman et al., 2005a, 2005b, 2005c, 2005d), North 24 Parganas (Rahman et al., 2003) and Nadia (Rahman et al., 2014).

The Kolkata Municipal Corporation (KMC), has a population of 4,496,694 and an area of 185 km^2 is the major Municipal Corporation in West Bengal, India. Arsenic in the groundwater of Kolkata city of India was detected in 1993 (Anandabazar-Patrika, 8th March, 1993). Few articles report the contamination of arsenic in the drinking water of major cities around the world. Peters et al. (1999) reported the presence of arsenic in the range of <0.0003–180 μg/l from 992 drinking water samples from randomly selected households of New Hampshire-USA. The domestic drilled bedrock wells contained significantly more arsenic than water from municipal sources (Peters et al., 1999). Berg et al. (2001) reported arsenic groundwater contamination from the city of Hanoi and the surrounding rural districts of the Red River alluvial tract. The average concentration was found to be 159 μg/l was with a range of 1–3050 μg/l in rural groundwater samples from private small-scale hand tube-wells (Berg et al., 2001). In a very recent study (Middleton et al., 2016), it was reported that private water supplies (PWS) in Cornwall, South West England exceeded the current WHO guidance value and UK prescribed concentration value for arsenic of 10 μg/l in 5% of properties surveyed out of 497. None of these was major municipalities, defining an urgent need to examine the contamination by arsenic in a major city (Kolkata) of India for the human exposure from both the municipal water supplies the KMC and private wells in the KMC. A recent study analysed 262 water samples from all 144 wards in the KMC and reported that 100 wards out of 144 are having alarming level of arsenic contamination in groundwater (Malakar et al., 2016). It was also found that 51 wards (35.4%) have been found to have arsenic level above the Indian standard of 50 μg/l, 49 wards have arsenic level between 11 and 50 μg/l; only 44 wards (30%) have been found to have arsenic below 10 μg/l in the groundwater (Malakar et al., 2016). As the number of samples were very limited (even <2 samples per ward) in their study, so preparation of comprehensive municipal ward-wise map of groundwater arsenic content in the KMC is questionable.

In this article for the first time, we report the consolidated findings of 23 years surveillance of the groundwater (in use for drinking and cooking) arsenic contamination and its health related effects in the KMC, the jurisdiction area of Kolkata city. This further highlights the critical issues of the existing water supply scenario and the need for arsenic safe water in the KMC.

2. Materials and methods

2.1. Description of the study area

The Kolkata Metropolitan Area (KMA) comprises three municipal corporations (KMC, Howrah and Chandhannagore), is the oldest and third largest urban agglomerate (UA) in India [after Greater Mumbai UA and National Capital Territory (NCT) of Delhi] extends over 1851 km^2 with a population of 14,112,536 (Census, 2011). The KMC, the economic and financial focal point of eastern India is the major Municipal Corporation in KMA (Supplementary Material Fig. S1). As per 2011 census report, the KMC is the 5th densest city in India (24,252 person per km^2). For administrative purpose, the city is divided into 141 wards (currently the administrative division of KMC is 144 wards since 2013. But the area of the newly subdivided wards has not been included in official KMC map. Hence, we have considered all 141 wards which consist the official map of KMC). Ward in an administrative division of a city or borough that typically elects and is represented by a counsellor.