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EVALUATION OF HEAVY METAL POLLUTION IN DRINKING WATER: A STUDY IN WEST BENGAL, INDIA

Environmental Science

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ABSTRACT

This study in North 24 Pargana, West Bengal, India, assessed heavy metals Arsenic (As), Iron (Fe), Cadmium (Cd), Lead (Pb) and Fluoride (F) in drinking water (ground and supply). Results revealed that all samples met recommended standards for As, Cd and Pb. However, 22% of groundwater and 40% of supply water samples exceeded recommended Fe levels. Fluoride was within limits for all samples. Heavy Metal Pollution Index (HPI) assessment showed that 22% groundwater and 33% supply water samples had high HPI. Non-carcinogenic and carcinogenic risks fell within safe limits by the US EPA (10-4-10-6). Supply water exhibited more contamination compared to groundwater. Our study evident HPI is a imperative tool in water quality analysis.

KEYWORDS

Heavy Metals, Pollution Index, Drinking Water, Hazard Quotient, Health Risk

INTRODUCTION

Over a billion people lack access to clean drinking water worldwide. Groundwater serves as a crucial source for residential, commercial, agricultural, and industrial use globally (1). Over-exploitation and contamination of aquifers, depleting groundwater quantity and quality, aggravated by population density(2). Heavy metal contamination, arising from natural and anthropogenic activities like urbanization and industrialization is a growing concern. In Kolkata, groundwater levels have dropped by 7-11mm in last 45years, leading to As contamination (3). Quality indices, such as HPI is important tools for assessing heavy metal contamination(4). Studies on groundwater found HPI was above the critical HPI value (i.e.100), indicating severe contamination(5,6).

In present study, domestic water needs were met by blending groundwater with surface water in study area. Each family received an average of 170L/day from Bidhannagar Municipality. Studies have focused on heavy metal in ground, particularly As contamination in West Bengal, there is a notable gap in the literature regarding HPI assessment in supply and groundwater; and health risk assessment in North 24 Pargana district, WB. Our study aimed to address this gap.

MATERIALAND METHODS

We collected 24 water samples (9 groundwater and 15 supply water) from randomly chosen locations in study area. Samples were collected in polyethylene bottles after thorough rinsing with source water. We determined fluoride using visual KIT Method. Heavy metals (Pb, Cd, As) were quantified via Graphite Furnace Atomic Absorption Spectroscopy (Perkin Elmer-AAS,AAnalyst-800,USA), Fe was assessed using spectrophotometer**(7)**.

Pollution index

HPI was used to determine quality and suitability of drinking water and calculated as below**(8)**.

$$HPI=\sum_{i=0}^{n}(Q_i*W_i)/\sum_{i=0}^{n}W_i$$

Where Q_i is sub-index of i^{th} parameter. W_i is unit weightage of i^{th} parameter, and n is number of parameters considered. Unit weightage (w_i) is taken as values inversely proportional to the recommended value (S_i) of the corresponding parameter. Sub index (Q_i) of parameter was calculated by

$$Qi=\sum\{(M_i-I_i)/(S_i-I_i)\}*100$$

where M_i is monitored value of heavy metal of i^{th} parameter, I_i is ideal value (maximum desirable value for drinking water) of i^{th} parameter, S_i is standard value (highest permissive value for drinking water) of i^{th} parameter. Sign(–) indicates numerical difference of two values, ignoring algebraic sign**(9)**.

Health Risk Assessment

The health risks associated with As in drinking water of study area was assessed by USEPA(2007) methodology and assumptions**(10)**. India lacks limits for carcinogenic and non-carcinogenic risk levels. We calculated chronic daily intake (CDI) to quantify exposure to As over a person's lifetime. Below equation used to calculate non-carcinogenic risk**(11)**.

$$CDI_{ingested}=\frac{Cw*DI*ABS*EF*ED}{BW*AT}$$

Where, $CDI_{ingested}$ is mean daily dose from ingestion of contaminants in drinking water (mg/kg/day).C_w is concentration of particular heavy metal measured in water (mg/L). ABS is dermal absorption factor(0.001). DI is daily average intake of water (2.2L/day). EF is annual exposure frequency (365days/year). ED is exposure duration (70year). BW is body weight (70Kg/person). AT is average time of the life expectancy (25550days).

To assess non-carcinogenic effects of metals on human health, Hazard Quotient (HQ) was calculated, which is the ratio of CDI to a specific heavy metal's reference dose (RfD).

$$HQ=\frac{CDI}{RfD}$$

When HQ<1, it suggests that RfD exceeds the average daily dose, posing no significant health risk. However, HQ>1, RfD falls below the average daily dose, indicating a higher likelihood of adverse health effects**(12)**. Carcinogenic risk quantifies the probability of an individual developing cancer over 70year lifetime and was calculated as follows.

CR=CDI*CSF

Where CDI is chronic daily intake. CSF is Cancer slope factor (Kg day/mg). RfD and CSF values for As is 0.0003 and 1.5kg day/mg respectively. As per USEPA accepted range of the lifetime risk for carcinogenic element ranges 10^{-6}-10^{-4}.

RESULTS

All ground water samples had F (mean 0.51ppm, range 0.4-0.7ppm) within Indian drinking water standards permissible limit (1ppm). As ranged 0.12-3.53ppb (mean 1.72ppb). Fe mean was 0.77ppm (ranged 0.12-1.36ppm). Cd ranged 0.01-0.09ppb(mean 0.05ppb). Pb was detected only in single sample 0.37ppb. All supply water samples met the permissible Fluoride limit. As was within the desirable range (0.06-14.88ppb, mean 3.60ppb), except for one sample (14.88ppb) exceeding BIS limit(10ppb). Fe ranged 0.12-1.12ppm(mean 0.53ppm). Cd(0.07ppb) was present in two samples below BIS limits. Pb was not detected in any supply water samples.HPI was calculated for As and Fe in drinking water using mean concentration. The calculation details for drinking water samples are presented in Tables1 and 2. We found mean HPI for ground and supply water was 54.62 and 41.32 respectively.

Table1: Ground water HPI calculation

Mean HPI	Mi	Si(ppb)	Ii(ppb)	Wi	Mi-Ii	Si-Ii	Qi	Wi*Qi
As	1.72	50.00	10.00	0.02	-8.28	40.00	-20.70	0.41
Fe	774.47	300.00	0.00	0.00	774.47	300.00	258.16	0.86
			Σwi	0.02				
			Σwi *Qi	1.27				
			HPI=	54.62				

Table2: Supply water HPI calculation

Mean HPI	Mi	Si(ppb)	Ii(ppb)	Wi	Mi-Ii	Si-Ii	Qi	Wi*Qi
As	3.57	50.00	10.00	0.02	-6.43	40.00	-16.08	0.32
Fe	578.27	300.00	0.00	0.00	578.27	300.00	192.76	0.64
			Σwi	0.02				
			Σwi *Qi	0.96				
			HPI=	41.32				

Comparison of mean HPI with individual sample HPI is presented in Figures1and 2. About 22% groundwater and 33% supply water samples exceeded mean HPI value. In groundwater 33%, 54% and 22% samples fell into low, medium and high HPI categories respectively. In supply water samples 33% samples were in each HPI category.

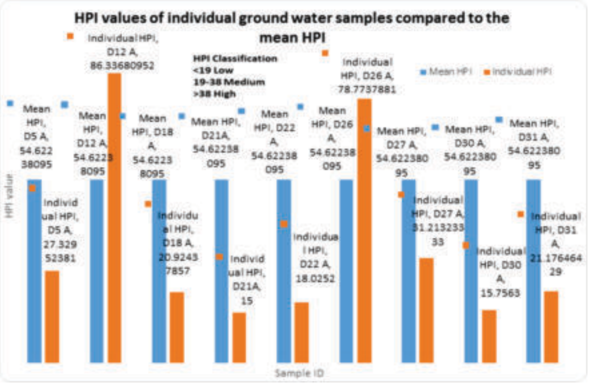

Fig.1 Mean HPI Vs individual HPI ground water

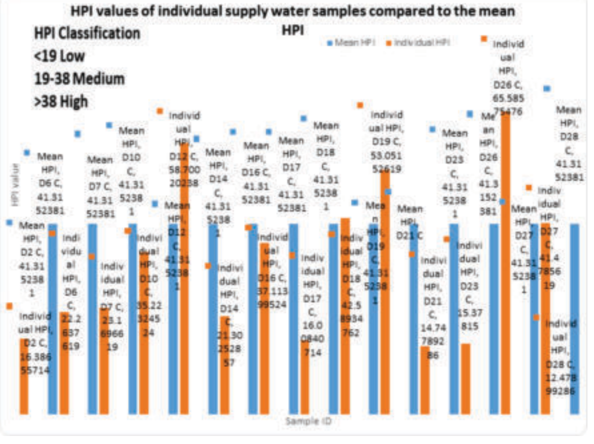

Fig.2 Mean HPI Vs individual HPI supply water

Health Risk

Assessing health risks associated with consumption of metal contaminated water is crucial. This study focused on toxic metals with low RfD. We estimated non-carcinogenic and carcinogenic health risks due to consumption of As, Fe and F in drinking water. To measure these risks, we calculated mean, minimum and maximum CDI values for these contaminants. Mean CDI values were 9.36976E^{-05}, 0.016369 and 0.018174 mg/kg/day for As, F and Fe respectively. These CDI values ranked Fe>F>As.

Non-Carcinogenic Risk

To evaluate non-carcinogenic risk from chronic exposure to As, F and Fe in drinking water, we calculated HQ. Drinking water samples mean HQ values obtained were 0.31, 0.41 and 0.06 for As, F, Fe respectively, remained within USEPA recommendation (i.e.1). Individual HQ values for As and F were notably high in few samples. This indicates that residents in areas with HQ near 1 face non-carcinogenic health risks due to elevated As and Fe in drinking water. Conversely, areas with HQ<1 indicate no significant non-carcinogenic risk from As and F.

Carcinogenic Risk

Prolonged consumption of heavy metals contaminated water could cause carcinogenic, mutagenic and teratogenic health effects**(13)**. In this study, calculated carcinogenic risk for As among residents ranged 2.77294E^{-06} to 0.000701599(mean 0.000140546). This estimated cancer risk falls within the US EPA recommendation (10^{-6}-10^{-4}) signifying that carcinogenic risk from ingestion of As contaminated water in study area was negligible.

DISCUSSION

All drinking water samples met permissible F limits. Groundwater samples complied with permissible As limits by BIS (50µg/l) and WHO (10µg/l)**(14,15)**. Results showed 22% groundwater and 40% supply water samples exceeded Fe limits (i.e. 0.3mg/L). Iron water pollution often stems from rock weathering, industrial effluents and urban landfill leaching**(3)**. Consuming Fe contaminated water could cause serious health issues like liver cancer, diabetes, liver cirrhosis, heart diseases, infertility and haemochromatosis. Cadmium was below BIS, 2012 permissible limits(3µg/l)**(14)**. No Pb contamination was found in drinking water samples. HPI was calculated for As and Fe, categorized as low (<19), medium (19-33) and high (>33)**(16)**. Individual HPI values of 22% groundwater and 33% supply water samples exceeded high HPI value, suggesting water contamination. It could be from industrial effluents, landfill leaching, rock weathering and urban waste**(17)**. HPI>100 (critical pollution index) considered unacceptable for drinking water, our obtained mean HPI for drinking water samples was <100**(18)**. Our findings revealed medium to high pollution for As and Fe, demands further water purification for safe drinking and cooking purposes. CDI mean values followed order Fe>F>As. Mostly HQ values of water samples complied with USEPA recommendation (i.e.1), few sites showed deviations. No carcinogenic risk was identified from Arsenic exposure. However low level chronic exposure to Fe, F and As could lead to non-carcinogenic health issues in future.

CONCLUSIONS

Although our sample size was limited, however our results evident utility of HPI in assessing composite heavy metal pollution in water. This tool is imperative for comparative water quality analysis.

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