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Trace Elements Occurrence in Drinking Water Sources of Industrial area of Manpur block of Gaya district of Bihar

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Abstract: *Groundwater samples were collected from fourteen principal aquifers across the Manpur block in Gaya district to investigate the occurrence and spatial distribution of antimony (Sb). Significant amounts of antimony are also known to be present in textile industries wastewater which can cause serious environmental harm, if not properly treated. This study analyzes the concentrations of Sb in groundwater to evaluate the environmental impacts and potential sources of contamination in the concerned region. The presence of strontium (Sr), Molybdenum (Mo) and selenium (Se) are also analyzed as trace elements.*
Keyword: *Trace metals, Metal pollution index (MPI), Heavy metal risk indexing (HPI), Elemental analysis, Textile industry.*

INTRODUCTION:

Anthropogenic metal pollution's impact on water quality is a serious environmental issue due to inadequate industrial waste management systems especially in developing countries. Surface and groundwater contamination is largely caused by industrial activity, which poses major threats to human health and ecological balance. The origin of metal pollution in the aquatic system nearby Manpur block -India is assessed in this study using statistical and chemical techniques. In order to evaluate ecological risks and develop efficient environmental management plans, it is crucial to comprehend the spatial distribution and concentration of metals in these water bodies. Toxic metal contamination of surface and ground water has grown to be a major worldwide environmental concern in recent decades [1]. Hazardous metals like cobalt (Co), copper (Cu), chromium (Cr), lead (Pb), cadmium (Cd), and nickel (Ni) are commonly found in industrial effluents, which are frequently released into natural water bodies without treatment. These metals seriously harm aquatic ecosystems and drastically reduce water quality [2]. Rapid industrialization since the beginning of the Industrial Revolution impacts the ecological health of soil, sediments, and water resources, leading to various detrimental effects like reduced biodiversity, impaired ecosystems, and human health risks [3]. These effects have been exacerbated by unplanned urban development and uncontrolled industrial growth, which have weakened ecosystems and threatened biodiversity [4].Water pollution in Manpur block India is largely caused by the textile and apparel industries' explosive growth, many of which are situated along Falgu river banks [5]. Organic and Inorganic pollutants produced by industries are discharged into the eco system as hazardous solid, liquid and gaseous waste [6]. These contaminants build up in nearby communities, agricultural areas, and water bodies, causing long-term ecosystem imbalance and detrimental health effects [7]. In surrounding areas of Manpur, the major source of toxic metals is waste water effluents coming from cotton and textile industries. Significant threats to both potable water supplies and agricultural productivity are observed when the heavy metals from perpetual discharge of wastewater without treatment intrude into groundwater which results in heavily impediment of aquatic ecosystems. Additionally, the bioaccumulation of these metals within the food chain gives rise to significant health hazards. Protracted exposure to toxic metals is kindred with a range of adverse health effects, including neurotoxicity, organ damage, and an increased risk of carcinogenic outcomes [8].

MATERIALS AND METHODS

2.1 Sampling

Research scholars collected fourteen samples from the drinking water sources of Manpur block area between February and March 2024. Groundwater samples were collected in one-liter polypropylene (PP) bottles and preserved by acidification to a pH below 2.0 using high-purity nitric acid suitable for trace element analysis, in compliance with ISO 5667-11:2009. The water samples were kept at room temperature until they were analyzed, which happened within 30 days [9] Fig.1

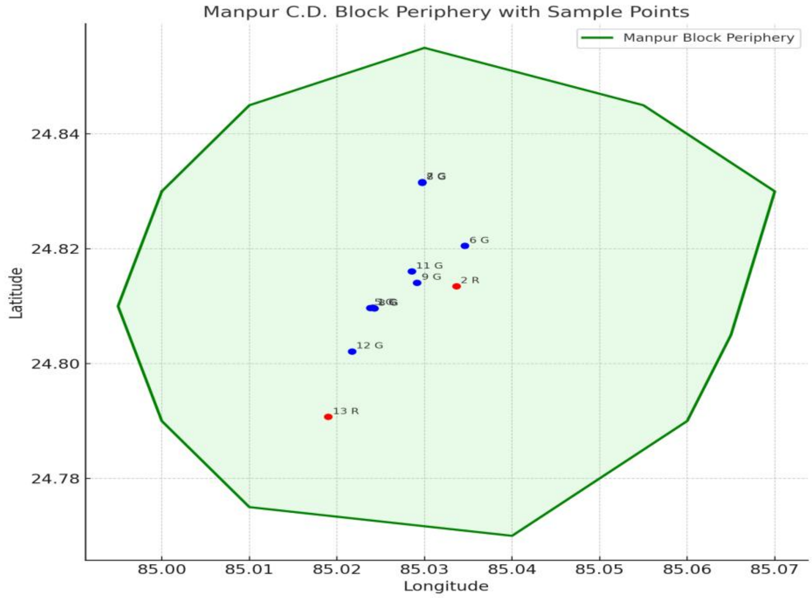

Fig.1 Sample Point with Longitude and Altitude

2.2 Chemical analysis

We used inductively coupled plasma mass spectrometry (ICP-MS) with an iCAP RQ instrument (Inductively Coupled Plasma – Radial Quadrupole) to analyze the elements, as required by ISO 17294-2:2016 [10]. We made standard solutions from certified reference standards that were 1000 mg/L. These standards were used to calibrate the instrument, and every tenth sample was checked with a multi-element certified reference material to make sure the calibration was correct. During the analysis, a helium collision gas was used to reduce spectral interferences by breaking up polyatomic species and lowering background noise. This improved the accuracy of the analysis. Table 1 shows the ICP-MS method's detection limits, quantification limits, and other important operational parameters. The reagents and standards used were all of analytical grade for trace elements. The amounts of the following trace elements were measured: strontium, antimony (Sb), and others.

Table 1.

Trace Element	Min. (μg/L)	Max. (μg/L)	Average value (μg/L)
Se	0	0.887	0.14022
Sr	134.599	391.415	0.151905
Mo	0	4.623	0.161647
Sb	1.071	10.775	0.139618

2.3 Heavy Pollution Index

The Heavy Metal Pollution Index (HPI) is a good way to figure out how much heavy metal is in groundwater [11]. Using an arithmetic weighted average, the HPI values of the water samples were computed, as illustrated in Equation (1) [12]. As shown in Equation (2), the weight given to each heavy metal (Wi) is the opposite of its standard permissible value (Si). Equation (3) shows how to find the quality rating or sub-index (Qi) for each metal. It uses the monitored value of the metal (Mi) and the standard value (Si).

$$MPI = \frac{\sum_{i=1}^{N} \quad (Q_i \times W_i)}{N} \quad (1)$$

where, Qi = the sub index of the ith parameter, Wi = the unit weightage of the ith parameter, and N = the number of parameters considered. The weighted arithmetic index method is employed for MPI calculation.

The unit weight (Wi) is determined by:

$$W_i = K \times \frac{1}{S_i} \quad (2)$$

where, K = the proportionality constant, and Si = the standard permissible value of the ith parameter.

The sub index (Qi) of the parameter is calculated as:

$$Q_i = \left|\frac{M_i - I_i}{S_i}\right| \quad (3)$$

where, Mi = the monitored value of the metal of the ith parameter, Ii = the ideal value of the ith parameter, and Si = the standard value of the ith parameter. The sign (-) indicates the numerical difference between the two values, disregarding the algebraic sign.

Groundwater samples with HPI values over 100 were deemed polluted for drinking water purposes [13].

2.4 Pearson correlation coefficients

As emphasized by [14], knowing how heavy metals interact with each other is critical for pinpointing their possible origins and patterns of dispersion. Lack of strong relationships between some metals indicates that these metals might come from many different sources and be influenced by a variety of ecological or human-made factors. Table 2 provides the Pearson correlation coefficients for the assessed trace metals.

Table 2
Pearson correlation coefficients recorded in Manpur area

Variables	Se	Sr	Mo	Sb
Se	1			
Sr	0.2638	1		
Mo	0.3501	0.1046	1	
Sb	-0.242	-0.8064	-0.3	1

3. RESULT AND DISCUSSION:

3.1 Physicochemical and chemical properties

Table 1 lists the concentrations and physicochemical characteristics of trace elements, as well as descriptive statistics and comparisons with other water quality standards. Assessing the groundwater's suitability for various uses, especially drinking and farming, require comparing the measured water quality parameters with established reference standards.

3.2 Metal pollution index calculation (MPI)

A popular technique for evaluating water quality with an emphasis on metal contamination is the Metal Pollution Index (MPI). It gives a general indication of the level of toxic metals in the water. Based on their applicability and possible environmental impact, four important metal parameters were chosen for MPI computation in this study. A thorough assessment of the cumulative metal pollution in the groundwater samples was made possible by the use of a standardized methodology to calculate the MPI for each metal. This index provides a thorough evaluation of the metal contamination levels in water. According to [15, 16, 17], the MPI calculation entails comparing the measured concentrations to the corresponding standard values (Si) and allocating a weight (Wi) to each metal parameter, imparting its relative significance. Because the chosen parameters directly relate to water quality and its suitability for a variety of applications, they are essential for assessing metal pollution. The MPI is a useful instrument for

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estimating the total effect of metal contamination on water quality, as [15] has confirmed. There are several man-made and natural sources of trace metal contamination in soil, surface water, and groundwater. One helpful tool for estimating the level of metal pollution in water is the Metal Pollution Index (MPI). Higher MPI values are linked to greater health risks; 100 is usually considered the critical threshold. The groundwater samples in this study had a computed MPI of 50.47, which indicates acceptable contamination levels and satisfactory water quality. The conclusion that the water is generally safe with regard to metal contamination is supported by the fourteen samples that all had MPI values below the critical threshold of 100. This suggests that the water quality is generally good in terms of metal contamination. It is crucial to recognize that ongoing wastewater discharge into the Falgu River may eventually change these circumstances and have a detrimental impact on groundwater quality.
In the nature, antimony can be readily absorbed by plant roots, leading to irreversible damage and posing a significant threat to ecosystems [18]. Moreover, previous studies have shown that antimony is toxic and potentially carcinogenic to humans. It plays as a solid irritant to the eyes and skin, and prolonged exposure may cause serious damage to the heart and liver [19]. Due to the toxicity of antimony, strict discharge standards have been implemented worldwide. The maximum Sb concentration in drinking water is 5 μg/L permitted by the European Union (EU) and India while 10 μg/L is limited in both the United States (US) and Environmental Protection Agency (USEPA) [20]. In India, the Sb discharges from the textile printing and dyeing industry are not set for direct or indirect into water bodies [21]. Antimony concentration in collected water sample was found from 1.071 to10.775 μg/L Fig.1

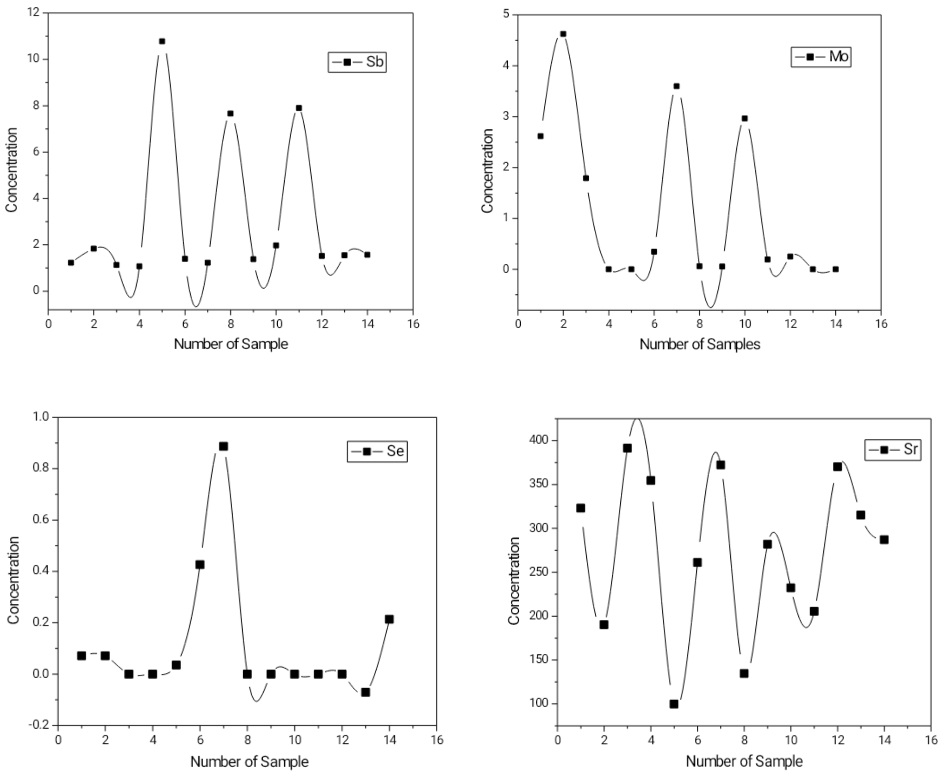

Fig.2 Variation of concentration (μg/L)

Strontium, a common trace element found in soils, rocks, and water, is nearly ubiquitous in groundwater. The accumulation of strontium in underground drinking water is a critical concern, as strontium is a bio-active element. It is particularly hazardous when the groundwater consumption with a calcium-to-strontium (Ca/Sr) ratio of less than 100, which serves as a hydro geochemical indicator for Urovendemic, also known as Kashin-Beck disease. Sr concentration in collected water sample from Manpur block area min. and max was 99.879 - 391.415 μg/L. Fig.1

Molybdenum (Mo) and selenium (Se) are considered as essential trace elements, though their optimal intake ranges—particularly for selenium—are relatively narrow. Cardiomyopathy and joint disorders are

caused due to selenium deficiency, whereas excessive intake, or selenosis, can result in symptoms such as brittle hair, hair loss, nail malformations, and diarrhea [22]. Based on updated scientific findings, the parametric value for selenium in drinking water was increased from 10 to 20 µg/L in regulatory revisions [23, 24], while the World Health Organization (WHO) currently sets the guideline value at 40 µg/L. The concentrations of Se in environment are normally below 10 µg/L, with dietary intake being the primary source—except in certain seleniferous regions [25, 26].
Molybdenum concentrations in drinkable water are usually low (<10 µg/L); however, they can exceed 200 µg/L in mining operations premises. The WHO's health-related guideline value for Mo in drinking water is 70 µg/L. Concentration of Mo, and Se were 0 - 4.623 µg/L and 0 – 0.887 µg/L respectively. Fig.1
Manpur block hosts numerous textile and cotton industries, many of which are located along the Falgu River for water intake and effluent discharge. In some cases, Sb levels in drinking water near these enterprises are found to be close to or even exceeding the regulatory limits. The trace elements Sr, Mo and Se are also present in the same ground water.

4.CONCLUSION

The experiment's findings indicate that the groundwater sampled from the Manpur industrial area had a generally low and acceptable level of trace element contamination. However, the release of untreated wastewater from textile industries may be the cause of the groundwater's unappealing appearance. Within certain bounds, certain chemical elements found in water can be advantageous for aquaculture and agriculture; however, their presence above accepted limits may present health and environmental hazards.

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