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Evaluation of Arsenic Exposure in the Drinking Water Across Different Districts of Eastern Uttar Pradesh

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Abstract: Arsenic contamination in groundwater is harmful to environmen and public health due to its carcinogenic and toxic properties, particularly in the Gangetic Belt of India, including eastern Uttar Pradesh. The present study examines the amounts of arsenic in drinking water in 15 districts of eastern Uttar Pradesh, India, an area known for its agricultural activity. Using an Arsenic Field Test Kit, 236 water samples were taken from India Marka II hand pumps. Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS) has been used to validate the results. The study utilized SPSS for statistical analysis, utilizing one-way ANOVA and Dunnett's test to identify statistically significant variations in arsenic levels. The results showed that there were varying amounts of arsenic pollution; districts like Bahraich and Faizabad remained arsenic-free, while districts like Gorakhpur and Basti had significant levels (up to 95.03 ppb and 61.8 ppb, respectively). The study highlights the geographical connection between the amount of arsenic present and the closeness to rivers, pointing out that the Aami River has greater levels of arsenic and the districts near the Ganga River have a lower concentration of arsenic. To reduce exposure to arsenic and the health hazards that come with it, our findings highlight the necessity of deeper hand pumps, routine monitoring, and community education.

Keywords: Arsenic, Eastern Uttar Pradesh, Aami, Graphite Furnace Atomic Absorption Spectroscopy

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Introduction

A high rise of diseases like cancer, lung diseases as well as skin disorders was observed around the Gangetic belt. To reach the core of reason, a study was conducted to find the reason for the increased

disease (mainly cancer) rate. Heavy metals were found to be a contributing factor in it. Heavy metals play a crucial role in our environment, but their abundance has raised scientific concerns. They pose a significant threat, necessitating the use of efficient methods to achieve a desirable concentration.

With this concern of spread of diseases, different regions have been tested to determine the heavy metal concentrations. Drinking water is the primary source of heavy metals reaching humans, so waters from various areas were collected and tested for heavy metals. Some heavy metals, including arsenic, mercury, cadmium, and lead, are carcinogenic and toxic to humans. These can be found in our environment due to both natural and human activities. Arsenic is a defined group-1 carcinogen, discovered to be the main cause of cancer because of its concentration in the groundwater. The Gangetic belt, which includes Uttarakhand, Uttar Pradesh, Bihar, and West Bengal states, is India's most popular region. This belt's fertile land makes agriculture the primary source of income for the local population. Arsenic-related health problems were first observed in West Bengal, India, in the 1980s, and were linked to groundwater poisoning (UNICEF 1998**;** Acharyya *et al*.**,** 1999**;** Haque *et al*.**,** 2003). Currently, over 50 lakh people in the state consume arsenic-contaminated water with concentrations exceeding 10 µg/l (i.e., the standard permis**s**ible limit). Recently, similar issues have emerged in districts of Bihar and Uttar Pradesh. Currently, 16 districts in Bihar have reported arsenic poisoning in their groundwater (Ghosh *et al*.**,** 2007**,** 2009; Saha**,** 2009; Singh *et al*.**,** 2014). The first arsenic-affected area in the state of Bihar was Semria Ojha Patti village in Bhojpur district. High concentrations of arsenic in groundwater led to serious health issues among the population (Chakraborti *et al*.**,** 2001). Groundwater in the Ballia, Varanasi, and Ghazipur districts of Uttar Pradesh contains high levels of arsenic (Ahamed *et al*., 2006). High arsenic levels in groundwater have led to health issues for village residents, including hyperkeratosis, keratosis, melanosis, loss of appetite, anaemia, gangrene, skin lesions, peripheral neuropathy, cardiovascular disease, myocardial infarction, stroke, chronic obstructive pulmonary disease (COPD), gout, lung cancer, diabetes, and skin cancer **(**Bagla and Kaiser**,** 1996**;** Karim**,** 2000**;** ATSDR**,** 2005**,** 2006).

In India, drinking water and groundwater are the primary sources of heavy metal toxicity in humans. As in agricultural practices, chemical pesticides and herbicides containing heavy metals, particularly arsenic, are used, which seep into groundwater and cause contamination. People are unaware of their effects, so using them in everyday practices increases toxicity. As a result, a study of 15 districts in **e**astern Uttar Pradesh was conducted to determine the presence of arsenic in the water bodies of Ayodhya, Azamgarh, Bahraich, Ballia, Basti, Deoria, Ghazipur, Gonda, Gorakhpur, Jaunpur, Mirzapur, Pratapgarh, Prayagraj, Sultanpur, and Varanasi. In this study, the drinking water samples collected from India Marka II handpumps of each block of **e**astern Uttar Pradesh were selected as the arsenic-contaminated source, and their physicochemical characteristics were analyzed by using an Arsenic field kit followed by Arsenator, UV-Visible Spectrophotometer and Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS).

Materials and Methods

Study area

The research was carried out in India in different districts of eastern Uttar Pradesh. The population of Eastern Uttar Pradesh is approximately 92208723 in 2024. This zone is divided into 15 districts namely Azamgarh, Bahraich, Ballia, Basti, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Jaunpur, Mirzapur, Pratapgarh, Prayagraj (formerly Allahabad), Sultanpur and Varanasi. This zone is situated at the confluence of the Ganga and Aami Rivers.

Arsenic analysis and survey

For water sample collection, 500 ml polypro-pylene bottles were used, which were cleaned

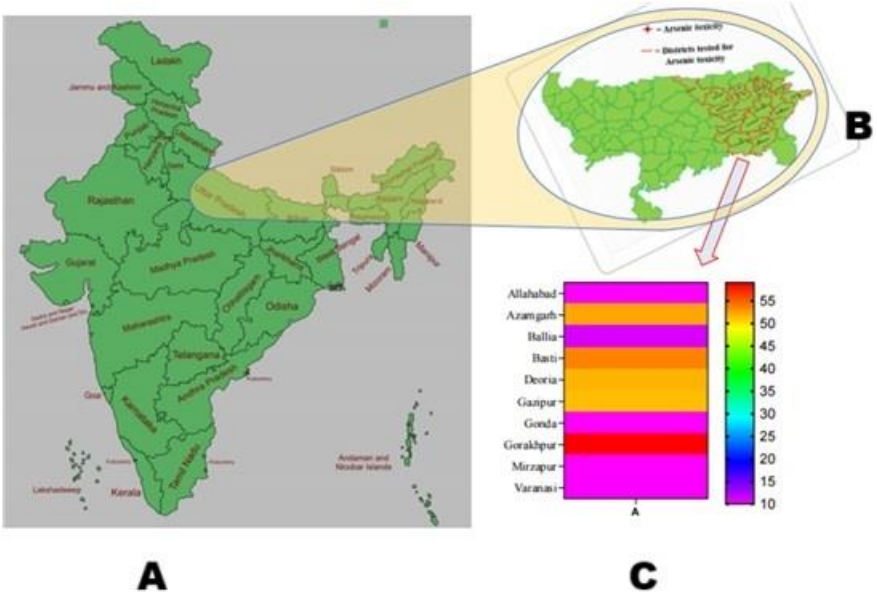

Fig. 1: (A) Political Map of India, (B) Map of Uttar Pradesh with highlighted parts of eastern Uttar Pradesh region showing arsenic contamination in different districts, and (C) Heat Map of Arsenic contamination in ppb (µg/l) in eastern Uttar Pradesh.

and pre-treated with hydrochloric acid. A total of 236 water samples in triplicates were collected from India Marka II handpumps of each block of eastern Uttar Pradesh. After the collection, water samples were tested on the spot utilizing an Arsenic Field test kit (Technosurge, India) utilizing arsenic reagent A, B and C comprising of zinc dust, tartaric acid, ferrous and nickel salt followed by mercuric bromide on the filter paper test strip. This test was followed by Arsenator which employed Gutzeit method. Final confirmation was done using Ultraviolet-Visible Spectrophotometer (Thermo Fisher) through the silver diethyldithio-carbamate method against a blank at 535 nm followed by Graphite furnace atomic absorption spectrophotometer (GF-AAS) (Pinnacle 900 T, Perkin Elmer, Singapore) in which samples were digested in 3:1 nitric acid and hydrochloric acid, respectively followed by arsenic estimation in ppb (µg/l).

Statistical analysis

Statistical analysis was performed by using statistical software (SPSS), and the result is reported as mean ± standard deviation. The differences between the groups were assessed by using one-way Analysis of Variance (ANOVA) using Dunnett's test. p-value 0.05 was considered as statically significant.

Results

Drinking water arsenic contamination in eastern Uttar Pradesh

Eastern Uttar Pradesh is situated near the vicinage of the river Ganga (Fig. 1). The study also highlights that arsenic concentration in groundwater from hand pumps increases with greater distance from the river. Analysis of 236 water samples revealed a high prevalence of arsenic contamination in drinking water (Table 1). Different districts exhibited different patterns of contamination. Notably five districts- Bahraich, Faizabad, Jaunpur, Pratapgarh, and Sultanpur had arsenic-free drinking water, while Gorakhpur and Basti experienced severe contamination in hand pumps. Among the most severely affected districts are Gorakhpur and Basti where the arsenic contamination was much higher in most of the

Table 1: Analysis of arsenic concentration in drinking water in positive samples of different districts of eastern Uttar Pradesh

S. No.	Locations	Arsenic (in ppb)
1	Prayagraj	10.03 ± 0.05
2	Azamgarh	52.65 ± 0.05
3	Ballia	11.43 ± 0.05
4	Basti	54.61 ± 1.03
5	Deoria	52.1 ± 0.00
6	Ghazipur	51.76 ± 0.00
7	Gonda	10 ± 0.00
8	Gorakhpur	58.8 ±0.69
9	Mirzapur	10 ± 0.00
10	Varanasi	10.13 ± 0.05

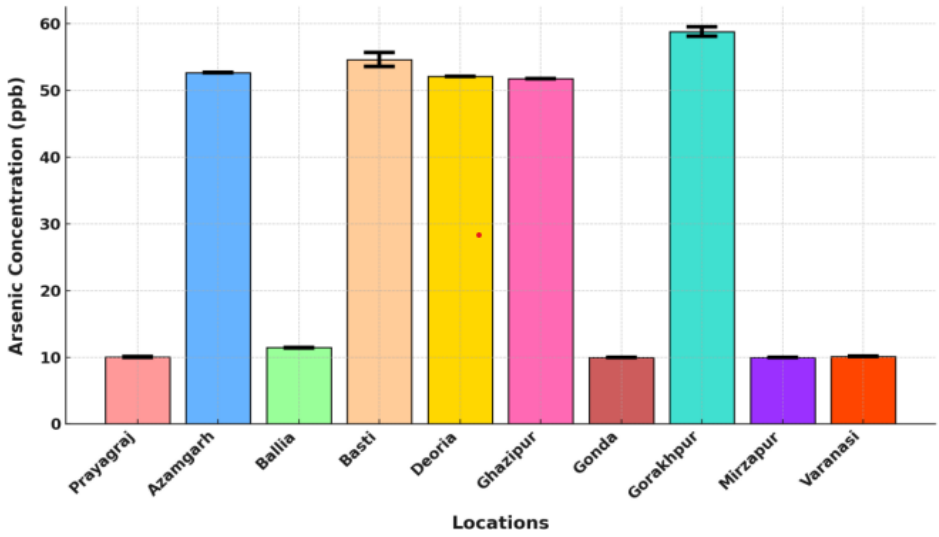

Fig. 2: Different districts show different patterns of arsenic (ppb) contamination in drinking water in eastern Uttar Pradesh.

analyzed water samples (Table 1; Fig. 2). The Gorakhpur showed hand pumps with arsenic contamination between 10 ppb and 95.03 ppb while Basti districts showed hand pumps with arsenic contamination between 10 ppb and 61.8 ppb. The average depth of the hand pumps in all the blocks was 80-90 feet (24.38 m - 27.43 m).

Discussion

Over time, arsenic poisoning has increasingly emerged as a significant global cause of pollution. But both natural and artificial sources can lead to arsenic contamination. The range of bacteria present in soil and water is significantly impacted by arsenic, a heavy metal. Groundwater in Bangladesh and West Bengal regions, particularly in Bihar, has been linked to cases of arsenic toxicity. Sixteen districts have been affected by the trend since it began in the district of Bhojpur in 2002 (Chakraborty *et al*., 2003; Nickson *et al*., 2007). Most affected districts are in the Gangetic Plain (Kumar *et al*., 2016). Due to the widespread usage of hand pumps in houses, the Gangetic plains suffered geological degradation in the late 1980s. Due to the oxidation of iron sulfide, which has a high concentration of arsenic, oxygen was able to infiltrate aquifers and contaminate the whole aquifer after water recharge. The Buxar

district in Bihar is also well-researched. This research, which examines the arsenic pollution of the groundwater and drinking water in eastern Uttar Pradesh, an area that is split into 15 districts, is the first of its type in this subject. Due to its geographical location near the meeting point of the Ganga and Aami rivers, the region is highly contaminated by arsenic.

The present study indicates a noteworthy geographical pattern in which the arsenic concentration is negatively correlated with the vicinity of the Ganga River. This suggests that the distance from the river affects the levels of pollution. The study found that there was a significant amount of variation in the levels of arsenic pollution in the various districts. It was discovered that five districts-- Bahraich, Ayodhya, Jaunpur, Pratapgarh, and Sultanpur are arsenic free. This finding may have been caused by the geology or by successful mitigating efforts in these regions. However, areas like Gorakhpur and Basti showed signs of significant pollution; in Gorakhpur, arsenic levels ranged from 10 ppb to 95.03 ppb, while in Basti, they were between 10 ppb and 61.8 ppb. These hand pumps were often located 80–90 feet (24.38 m–27.43 m) below the surface. The necessity for focused action in high-risk regions is highlighted by this gap.

The other most important finding also unravels that the strips closer to the Ganga River, especially Prayagraj and Varanasi have low concentrations of arsenic in the groundwater but the strips near Aami River such as Basti (Sant Kabir Nagar, Siddharth Nagar), and Gorakhpur are having higher arsenic concentrations in the groundwater. After these results, we tested the water from the Aami River and we found the highest concentration of Arsenic in it. There are two possible explanations for the origin of arsenic in these areas: natural and human activities. Groundwater is naturally contaminated by arsenic that seeps from the Aami plain's alluvial deposits. The overuse of fertilizers and pesticides, as well as inappropriate waste management and disposal, are likely human actions that make this problem worse.

Significant health hazards, such as skin lesions, cancer, cardiovascular illnesses, and developmental impacts, are associated with arsenic poisoning in drinking water. Public health actions are necessary due to the high frequency of contamination in several regions of eastern Uttar Pradesh. People who depend on hand pumps for their daily water requirements are the most affected, hence it is crucial to do thorough testing and offer substitute safe water sources. The research utilized a strong approach that involved first field testing with an Arsenic Field Test Kit followed by Arsenator and then sophisticated spectrophotometric methods for confirmation.

Geographical variables have a substantial influence on contamination levels. Several suggestions for addressing the arsenic pollution in Eastern Uttar Pradesh might be made in light of the findings. First and foremost, to locate and reduce the causes of pollution, groundwater must be regularly monitored. Second, since the quantity of arsenic often drops with depth, putting hand pumps farther down might potentially limit exposure. Thirdly, community awareness initiatives are essential for informing the public about the dangers of arsenic and the necessity of switching to treated or other water sources.

Conclusion

To our knowledge, this is the first study to investigate the sublethal and environmental concentrations of triclosan-induced gonadal toxicity mediated through oxidative stress, which could also impart genetic damages in erythrocytes of the fish, *Anabas testudineus*. Taken together, the evaluation of oxidative stress and cytogenetic damages provides a diagnostic and predictive tool for the environmental quality assessment.

Ethical Statement

No animal or microbes have been used or sacrificed for this study, hence Ethical Approval not required.

Author Contributions

Priyanka: initial draft preparation, data curation, writing and reviewing original draft; *Rupali*, *Praveen*, *Unnati* and *Taslima*: reviewing original draft and writing; Ojha and Mishra: final reviewing and extensive editing.

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Conflict of Interest

The authors declare no conflicts of interest.

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