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Prevalence and Multisystemic Health Manifestations of Arsenicosis in Krishnanagar Union, Brahmanbaria District, Bangladesh

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Abstract

Arsenic contamination in drinking water is a major environmental and public health concern in Bangladesh and is responsible for chronic multisystemic illness known as arsenicosis. This study was conducted in Krishnanagar union of Nabinagar Upazila, Brahmanbaria District- one of the most arsenic-prone areas- to assess the extent of arsenic exposure and its associated health complications. Data were collected under the UNICEF Bangladesh–funded arsenic mitigation project Lot 2, implemented by Village Education Resource Center (VERC), through community-based participatory rural appraisal (PRA) techniques and door-to-door household visits. Among 6,864 families surveyed, 1,953 were consuming arsenic-contaminated water, 3,217 relied on untested tube wells, and only 1,694 used wells within acceptable limits. Of the tested wells, 47% contained arsenic above 50 ppb (unsafe), 32% were within the WHO guideline (≤10 ppb) as safe and 21% were within the national permissible limit (≤50 ppb), while 46% remained untested. Clinical observation identified 129 individuals with dermatological and systemic manifestations, of whom 56 were clinically confirmed as arsenicosis cases. Among the confirmed cases, the predominant manifestations included melanosis and leukomelanosis (62.5%), palmoplantar keratosis (76.8%), ulcerated keratosis (64.3%), conjunctivitis (42.9%), gangrene (12.9%), mees' lines (3.6%), peripheral neuropathy (83.9%), fatigue (89.3%), odynophagia (26.8%), chronic cough and dyspnea (32.1%), dental caries (39.3%), chronic abdominal pain (8.9%), anorexia and nausea (23.2%), altered bowel habits (5.4%), and alopecia (32.1%). Spearman's correlation showed no significant link between exposure duration and symptom severity ($\rho=0.038$, $p=0.779$), suggesting that biological susceptibility or arsenic concentration may be more decisive than exposure length alone. These results highlight a significant multisystemic health burden within the study area, necessitating urgent safe water access, increased awareness, and targeted health interventions.

***Keywords*:** Arsenicosis, Arsenic toxicity, Chronic exposure, Multisystem health effects.

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Introduction

Chronic arsenic contamination of groundwater constitutes a major public health emergency in Bangladesh, as the World Health Organization recognizes as one of the largest mass poisonings in human history. Globally, an estimated 140 million people in at least 70 countries drink water containing arsenic levels that exceed safe guidelines (WHO 2022). Earlier investigations indicate that approximately 45 million people in Bangladesh were exposed to groundwater arsenic concentrations exceeding the WHO guideline of 10 μg/L and about 20 million exceeding the national standard of 50 μg/L, causing dermatological, neurological, and various malignancies (Flanagan et al. 2012). Recent studies demonstrate that arsenic contamination remains a persistent challenge in Bangladesh and South Asia. Contemporary risk assessments show millions still rely on shallow wells, resulting in ongoing exposure (Rahaman et al. 2021, Islam et al. 2023). Beyond characteristic dermatological lesions- like melanosis and keratosis- prolonged ingestion causes peripheral neuropathy, respiratory issues, and cardiovascular disorders. Furthermore, chronic exposure significantly elevates malignancy risks, particularly of the skin, lung, and urinary bladder.

Hydrogeochemical analyses have shown that the Bengal deltaic aquifer system possesses unique geological and hydrochemical characteristics that strongly control arsenic mobilization, highlighting the importance of region-specific exposure assessment (Hoque et al. 2017). These processes, including reductive dissolution of iron oxyhydroxides and sediment-specific mineral composition, result in marked spatial variability of arsenic concentrations, even within relatively small geographic areas, emphasizing the need for localized epidemiological investigations.

In the rural context of Krishnanagar Union (under Nabinagar Upazila, Brahmanbaria District), an arsenic mitigation project implemented by the Village Education Resource Center (VERC) with support from UNICEF Bangladesh was underway during the study period, with a scheduled conclusion on 31 December 2025. The population of this union largely depends on shallow tube wells as the primary source of drinking water, making the community particularly vulnerable to groundwater-based arsenic exposure. However, there is still a critical gap in localized documentation regarding the interplay between local drinking-water arsenic levels, household water-use practices, and the clinical profile of affected individuals. Moreover, routine surveillance data often underestimate the burden of arsenicosis, as early clinical manifestations may remain unrecognized in rural healthcare settings.

Although numerous epidemiological studies have documented the adverse health effects of chronic arsenic exposure, the pattern and severity of clinical manifestations may vary across affected populations depending on local exposure conditions and population characteristics (Rahaman et al. 2021, Wu et al. 2025). In many rural areas of Bangladesh, including Krishnanagar, detailed community-level evidence linking household arsenic exposure with the spectrum of multisystem clinical manifestations remains limited, particularly at the union level where groundwater contamination patterns can vary considerably.

Based on these considerations, it was hypothesized that prolonged consumption of arsenic-contaminated drinking water may be associated with a higher occurrence of arsenicosis-related clinical manifestations in affected communities. This study therefore aimed to (i) quantify the magnitude of arsenic exposure via tube-wells among 6,864 families in Krishnanagar Union, (ii) characterize the prevalence and clinical pattern of arsenic-related health outcomes, and (iii) assess the relationship between exposure duration and multisystemic symptoms of arsenicosis, thereby addressing an important knowledge gap regarding arsenic exposure and health outcomes in Krishnanagar Union. By generating union-level evidence, the study seeks to support ongoing mitigation efforts and inform Upazila-level public health planning for arsenic risk reduction.

Materials and Methods

Study area

This study was conducted in Krishnanagar Union, situated within Nabinagar Upazila of Brahmanbaria District, Bangladesh. This region has been identified as highly vulnerable to arsenic contamination in groundwater based on arsenic concentration data sourced from the Arsenic Risk Reduction Project (Hoque et al. 2025). The area comprises 6,864 households, a significant number of which rely on shallow tube wells for their primary drinking water. The local population is predominantly engaged in agriculture and small-scale trade, with the region being geographically characterized by its proximity to numerous rivers and canals

Study design

A community-based cross-sectional study was carried out under the Arsenic Mitigation Project Lot 2, implemented by the Village Education Resource Center (VERC) with financial support from UNICEF Bangladesh. The primary objective was to assess the prevalence of arsenic exposure and related health outcomes among the rural population.

Data Collection and Participant Selection

Data were collected through a systematic approach combining Participatory Rural Appraisal (PRA) techniques and comprehensive door-to-door household surveys. Trained field investigators visited every village cluster (para) to identify potential participants. The inclusion criteria for the initial screening required individuals to exhibit any dermatological or systemic symptoms potentially linked to arsenic exposure, which led to the identification of 129 symptomatic individuals. To ensure data integrity, the exclusion criteria removed those whose symptoms were clinically unrelated to arsenicosis or who lacked a documented history of consuming water from contaminated sources (>50 ppb). Consequently, 56 individuals were purposively selected as they met the clinical diagnostic criteria for arsenicosis. These confirmed cases were then interviewed using a structured questionnaire to capture detailed socio-demographic profiles, water consumption patterns, and specific health manifestations of chronic toxicity.

Arsenic concentration data

Tube-well arsenic concentration data were generate using Arsenic Safety in Bangladesh (v 0.3) web application, managed by the Department of Public Health Engineering (DPHE). The classification of water safety levels followed both Bangladesh national standards and World Health Organization (WHO) guidelines:

- Safe: ≤10 μg/L (WHO guideline)
- Acceptable: ≤50 μg/L (Bangladesh standard)
- Unsafe: >50 μg/L

Clinical observation

Physically examined individuals were screened for major clinical signs of arsenicosis, including melanosis, leukomelanosis, palmoplantar keratosis, ulcerated keratosis, conjunctivitis, dental caries, alopecia, Mees' lines, and peripheral neuropathy. Information on digestive and neurological symptoms was also recorded through patient interviews.

Ethical considerations

Formal ethical approval from an institutional review board was not required for this observational study. Permission was obtained from the administrative and health authorities of Nabinagar Upazila (Upazila Health Complex and Upazila Administration) before data collection. The study adhered to the ethical principles of the Declaration of Helsinki (World Medical Association 2013). Informed verbal consent was obtained from all participants, and sensitive information was kept confidential and used solely for research purposes.

Data analysis

The collected data were cleaned, coded, and analyzed using IBM SPSS Statistics version 22.0 and Microsoft Excel 2019. Data regarding the participants' socio-demographic profiles were processed through SPSS, employing descriptive statistical frequencies to summarize the information. The overall analysis was structured as follows:

For the arsenic exposure assessment, the distribution of households was determined by compiling data in Microsoft Excel 2019, derived from Participatory Rural Appraisal (PRA) conducted across all village clusters (paras). This enabled the quantification of total households and their categorization into families consuming water from unsafe (above 50 ppb), acceptable (≤ 50 ppb), and untested tube-wells. Additionally, the percentage distribution of arsenic concentrations in tube-wells (unsafe, safe, and within national permissible limits) was generated using the Arsenic Safety in Bangladesh (v 0.3) web application to ensure alignment with national and WHO guidelines.

Regarding the clinical pattern characterization, data obtained from structured interviews of 56 confirmed arsenicosis cases (screened from 129 symptomatic individuals) were processed in SPSS. Frequency distributions were calculated to characterize specific multisystemic physical manifestations and health complications associated with chronic exposure.

To determine the statistical association between the duration of arsenic exposure and the severity of clinical manifestations, Spearman's rank correlation (ρ)—a non-parametric bivariate method—was employed. This test was specifically selected because the symptom count data followed a discrete distribution and did not meet the assumptions of normality. Scatter plots with regression slopes were further utilized to visualize the dispersion of data points and confirm the direction of the relationship. For all inferential analyses, a p-value of <0.05 was considered the threshold for statistical significance.

Results

The present investigation in Krishnanagar Union of Nabinagar Upazila, Brahmanbaria District, revealed an alarming scenario of arsenic contamination and its adverse health consequences. Among the tested tube-wells, 47% contained arsenic concentrations exceeding the national permissible limit (>50 ppb), categorizing them as highly unsafe for consumption. In contrast, the remaining 53% fell within the permissible range, comprising 32% that were safe according to the WHO guideline value (≤10 ppb) and 21% that remained within the national standard (11–50 ppb). This geospatial and statistical distribution (Fig. 1) was generated using the Arsenic Safety in Bangladesh (v 0.3) web application. Furthermore, field-level observations from the Participatory Rural Appraisal (PRA) revealed that 46% of the tube-wells in the union remain untested, indicating a substantial potential risk of undetected arsenic exposure among the residents.

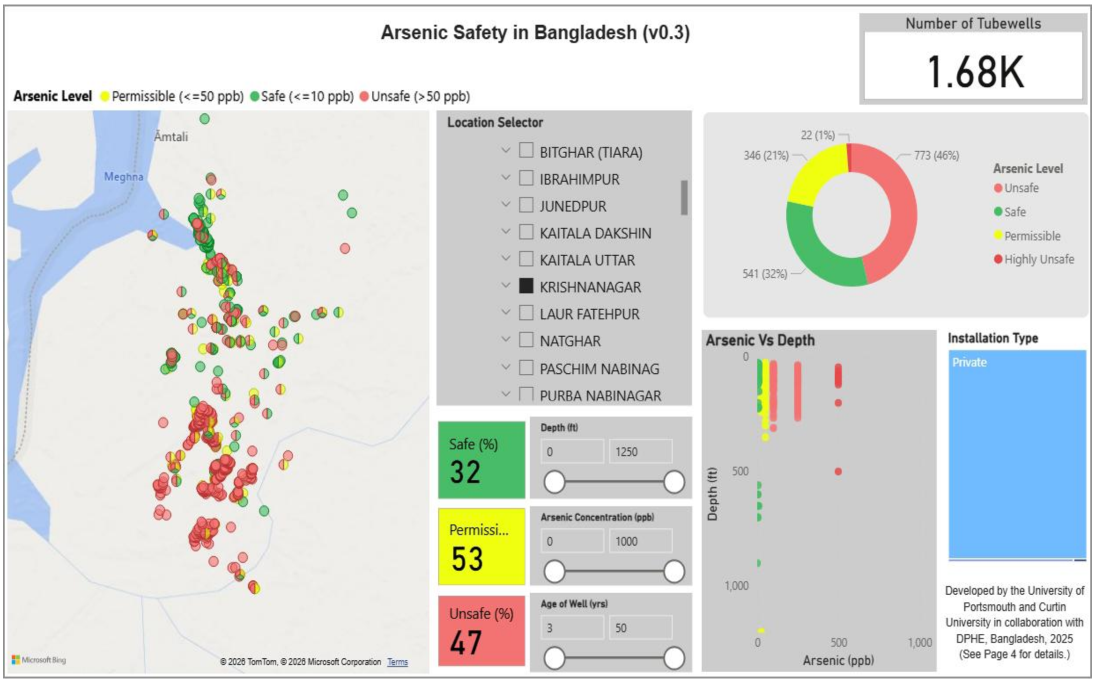

Fig. 1: Distribution of arsenic concentrations in tested tube-wells of Krishnanagar, generated via the Arsenic Safety in Bangladesh (v 0.3) web application, categorized by Safe, Permissible, and Unsafe levels. Source: https://iarsenic.com/landing – manu – arrp data.

Out of 6,864 households, 1,953 families were found to be consuming arsenic-contaminated water, while 3,217 families were drinking untested water, representing a severe exposure risk. Only 1,694 families were consuming water within the tolerable range. This indicates that more than three-quarters of the population is at significant risk of chronic arsenic exposure. These household-level data were derived from Participatory Rural Appraisal (PRA) activities conducted under the Arsenic Mitigation Lot 2 project. The socio-demographic characteristics of the respondents, including gender, age, education, and current water sources, are summarized in Table 1.

Table 1: Socio-demographic characteristics of the respondents (n = 56).

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	28	50.00
	Female	28	50.00
Age (years)	≤20	4	7.14
	21–30	5	8.93
	31–40	12	21.43
	41–50	10	17.86
	>50	25	44.64
Education level	No formal education	17	30.36
	Primary	26	46.43
	SSC	12	21.43
	HSC	0	0.00
	Degree_or_above	1	1.79
Occupation	Farmer	17	30.36
	Laborer	1	1.79
	Business	5	8.93
	Service holder	2	3.57
	Housewife	26	46.43
	Other	5	8.93
Present source of drinking water	Contaminated tube well	22	39.29
	Not contaminated tube well	5	8.93
	Untested tube well	29	51.79

Among the 56 clinically confirmed arsenicosis cases, clinical observations revealed that 62.5% of patients exhibited melanosis and leukomelanosis, the hallmark cutaneous indicators of chronic arsenic toxicity. Palmoplantar keratosis (PPK) was observed in 76.8%, while ulcerated keratosis affected 64.3% of patients. Alopecia was noted in 32.1%, and Mees' lines appeared in 3.6% of cases. Ocular involvement, such as conjunctivitis, was observed in 42.9%, and gangrene affected 12.5%.

Neuromuscular involvement was prominent, peripheral neuropathy was seen in 83.9%, and fatigue affected 89.3% of patients. Odynophagia was reported in 26.8%, while chronic cough and dyspnea were noted in 32.1%. Gastrointestinal manifestations included chronic abdominal pain in 8.9%, anorexia and nausea in 23.2%, and altered bowel habits in 5.4%. Dental caries were reported in 39.3% of patients. Fig. 2 depicts representative clinical features of arsenicosis observed in the study population.

a b c d e

Fig. 2: Representative clinical features of arsenicosis patients observed in the study area: (a) palmoplantar keratosis, (b) ulcerated keratosis, (c) keratotic nodules on the feet, (d) melanosis on the chest, and (e) gangrenous lesions on the toes.

Spearman's rank correlation analysis revealed a negligible positive relationship between the duration of arsenic exposure and the overall severity of clinical manifestations (Table 2). This association is further illustrated by the scatter plot (Fig. 3), where the regression line remains nearly flat ($R^2 = 4.975 \times 10^{-5}$), confirming that the correlation was statistically non-significant. These findings indicate that exposure duration alone may not be a reliable predictor of symptom severity in this study population. Potentially, other confounding factors—such as age, nutritional status, individual metabolic variations, and specific arsenic concentrations—exert a greater collective impact on clinical outcomes alongside the duration of exposure.

Table 2: Spearman's rank correlation between total years of arsenic exposure and clinical manifestations count (n = 56).

Correlation type	Row variable	Spearman's ρ	p-value
Spearman's Rho	Total years of arsenic exposure vs. Total count of clinical manifestations	0.038	0.779

Spearman's rank correlation (ρ)—a non-parametric bivariate method was used due to the non-normal distribution of variables. A p-value <0.05 was considered statistically significant.

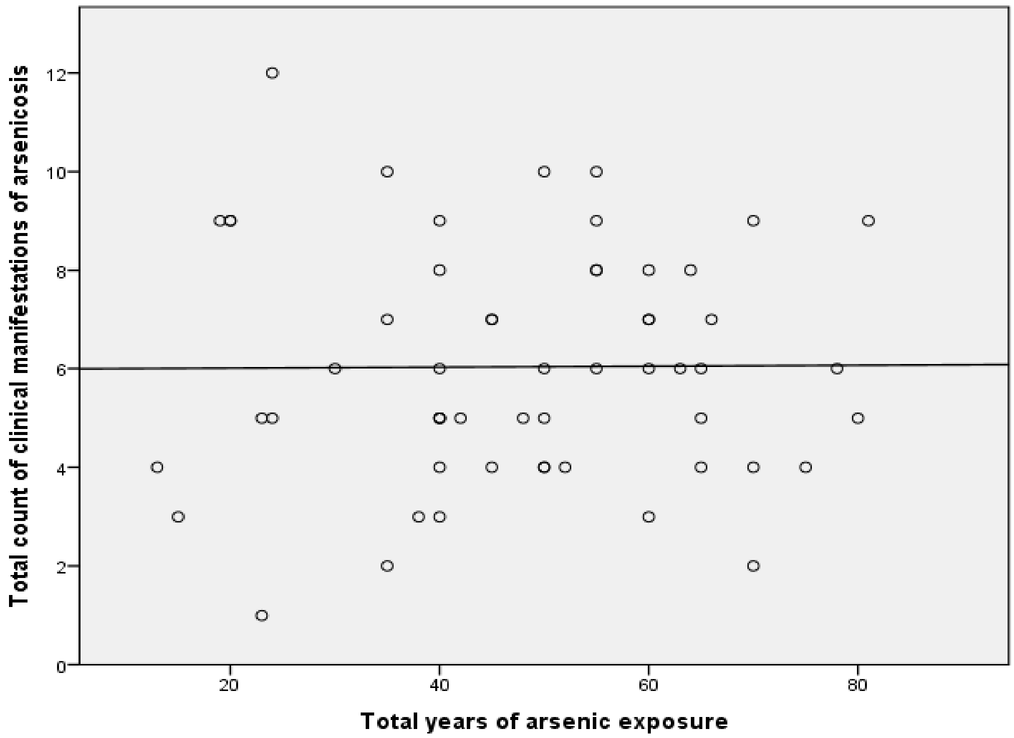

Fig. 3: Scatter plot illustrating the relationship between the total years of arsenic exposure and the total count of clinical manifestations among the study participants. The near-zero R2 value indicates a non-significant correlation (Computed primary study data using IBM SPSS Statistics v.22.0).

Discussion

These findings are consistent with prior epidemiological and risk-assessment studies in Bangladesh, which report multi-systemic health impacts, including skin lesions, neuropathy, and non-carcinogenic health risks associated with arsenic exposure (Ahmad et al. 2020, Islam et al. 2023). The high proportion of untested wells highlights persistent gaps in safe-water monitoring and equitable access to arsenic-free water sources.

The absence of a significant exposure–severity relationship may be explained by variations in arsenic concentrations across wells, along with unmeasured confounders such as nutritional deficiencies and genetic susceptibility factors previously documented to modify arsenic toxicity (Shen et al. 2016, Ahsan et al. 2006).

Evidence from earlier studies indicates that cumulative dose (concentration × duration) is a stronger determinant of arsenic-related health outcomes than duration alone (McDonald et al. 2007, Chen et al. 2009, Boffetta et al. 2020, Xu et al. 2020, Rahaman et al. 2021). Several investigations have shown that the severity of clinical manifestations depends on both the length of exposure and the concentration of arsenic in drinking water, with higher concentrations consistently associated with progressively advanced features, ranging from early skin changes to severe multisystem arsenicosis. The absence of a statistically significant relationship between exposure duration and symptom severity in this study points toward this multifaceted nature of arsenic toxicity. To contextualize these findings, Table 3 provides a critical synthesis of existing evidence, demonstrating how the interplay between arsenic concentration and duration typically dictates clinical progression. By referencing this synthesized data, it becomes evident that the high prevalence of advanced symptoms like ulcerated keratosis (64.3%) and peripheral neuropathy (83.9%) observed in our study population is consistent with the prolonged exposure to high arsenic concentrations reported in broader literature. This reference is essential as it serves as a benchmark to validate that the clinical manifestations in Krishnanagar align with established toxicological dose-response patterns.

Table 3: Arsenic concentration and exposure duration associated with clinical manifestations.

Arsenic concentration (μg/L)	Exposure duration (Years)	Clinical manifestations
<10 μg/L (WHO guideline)	Any / long-term	Considered low risk for classic arsenicosis; some studies note no clear increases in skin lesions at <10 μg/L, though susceptible subgroups may show subtle effects (Chen et al. 2009).
>10–50	5–10	Mild skin hyperpigmentation, early neuropathy, GI irritation (Ahsan et al. 2006)
>50 (Bangladesh threshold)	10+	Melanosis, leukomelanosis, and early keratosis (McDonald et al. 2007).
50–150	10–20	Palmoplantar keratosis, neuropathy, fatigue, and conjunctivitis (Ahsan et al. 2006).
>100	15+	Ulcerated keratosis, neuropathy, liver enzyme changes (Rahaman et al. 2021).
150–300	10–20	CVD risk, hypertension, and atherosclerosis (Xu et al. 2020).
>300	10–25	Severe multisystemic arsenicosis: gangrene, cancers, severe neuropathy (Boffetta et al. 2020).
High urinary MMA%	Long-term	Higher toxicity; increased risk of skin lesions and CVD (Boffetta et al. 2020).

While this investigation primarily focused on the common clinical manifestations of consuming arsenic-contaminated water, the potential for more debilitating long-term outcomes cannot be ignored. Previous studies have shown that chronic arsenic exposure is associated with several severe health outcomes—including various malignancies, Type 2 diabetes mellitus, cardiovascular diseases, neurological impairment, and chronic liver and kidney disorders (Navas-Acien et al. 2006, Moon et al. 2012, Tyler and Allan 2014, Zheng et al. 2014, Palma-Lara et al. 2020). Table 4 provides a comprehensive overview of these severe systemic diseases that are statistically associated with chronic arsenic ingestion but were not directly assessed in this study. In the context of Krishnanagar, where 47% of tested wells exceed safe limits and 46% remain untested, the aforementioned table highlights the gravity of the impending public health crisis if mitigation is not expedited.

Evidence from multiple epidemiological and toxicological studies further demonstrates that long-term ingestion substantially increases the risk of developing these life-threatening conditions. Therefore, this illustrative reference is indispensable for underscoring the necessity of multisectoral health surveillance and emphasizing that the current findings are likely only the 'tip of the iceberg' regarding the total disease burden in this region.

Table 4: Severe health outcomes associated with chronic arsenic exposure.

Disease name	Health outcomes associated with chronic arsenic exposure
Cancers	Arsenic significantly increases the risk of malignant tumors, particularly in the skin, lungs, and bladder. It is a confirmed human carcinogen (Palma-Lara et al. 2020).
Type 2 diabetes mellitus	Chronic arsenic exposure promotes insulin resistance and damages pancreatic beta-cells, impairing glucose metabolism and elevating blood sugar levels (Navas-Acien et al. 2006).
Cardiovascular diseases	Increased risk of hypertension (high blood pressure), atherosclerosis (artery hardening), and peripheral vascular disease (PVD) leading to stroke and myocardial infarction (Moon et al. 2012).
Neurological disorders	Causes peripheral neuropathy (numbness, tingling, weakness in extremities) and cognitive impairment in children (Tyler and Allan 2014).
Liver and kidney diseases	Associated with increased risk of chronic kidney disease, portal fibrosis, and non-cirrhotic portal hypertension (Zheng et al. 2014).

Field interviews further revealed a lack of institutional support, as neither local authorities nor elected representatives regularly monitor affected families. Moreover, technical documentation from the DPHE indicates that arsenic contamination data are not adequately considered in site selection for safe water technologies, leading to inequitable access to safe drinking water.

Arsenic-contaminated wells generally do not become arsenic-free over time, because the contamination is derived from geogenic sources within the aquifer sediments (Smedley and Kinniburgh 2002). Sustainable mitigation, therefore, requires identification of arsenic-safe aquifers, routine arsenic tests at least the previously green-marked tube wells every six months. Preventing people in affected areas from drinking arsenic-contaminated water, community awareness campaigns in collaboration with local health workers, LGIs, and NGOs are essential.

Under the UNICEF-funded Arsenic Mitigation Project, implementation began simultaneously in four unions Krishnanagar, Paschim-Nabinagar, Bitghar and Shibpur. Although the investigation focused on only Krishnanagar but based on field experience and observations, it can be assumed that similar exposure patterns and health risks may exist in other unions of the Upazila.

Conclusion

This study demonstrates a substantial burden of arsenic contamination in drinking water in Krishnanagar Union, where nearly half (47%) of tested tube-wells exceeded the national safety limit, and 46% remained untested, indicating widespread chronic exposure. Clinically, 56 individuals were confirmed as arsenicosis cases with prominent multisystem manifestations. The findings of this study underscore the urgent need for comprehensive, Upazila-wide arsenic mitigation strategies, including systematic testing of all tube wells, expansion of safe water alternatives, and strengthened public health surveillance to reduce the long-term adverse health effects of arsenic poisoning.

Recommendations

There is no specific curative treatment for chronic arsenicosis. Recent evidence indicates that reduction of arsenic exposure through use of arsenic-safe drinking water is associated with improved health outcomes and remains the most effective intervention. To ensure access to arsenic-free safe water, the DPHE should integrate and consider arsenic contamination data in their documentation process for appropriate site selection of safe water technology, prioritize the most affected communities, and allocate resources based on contamination severity rather than uniform distribution across all unions.

Future efforts should focus on developing improved arsenic detection and mitigation technologies and conducting similar studies to investigate the intensity of arsenic exposure in the unions surrounding the study area. Enhanced inter-sectoral collaboration among DPHE, Health Complex, Union parishad and local NGOs will be essential to ensure sustainable arsenic mitigation and resilience in vulnerable rural affected communities.

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Conflict of interest: The authors declare no conflict of interest regarding the publication of this article.

Author's contribution: SR and MSI designed the experiment, supervised the study, and performed the final correction of the manuscript. SR was responsible for data collection, comprehensive analysis, and drafting the initial manuscript. MSI provided clinical oversight for the identification and confirmation of arsenicosis cases, supervised the medical aspects of data collection, and contributed to the final correction and refinement of the manuscript.

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Data availability: The data supporting the findings of this study are reported within the manuscript. Original unprocessed data, including Participatory Rural Appraisal (PRA) records and interview questionnaires, are maintained by the corresponding author and are available upon reasonable request.

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