IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402, p- ISSN: 2319-2399.Volume 20, Issue 2 Ser. 1 (February 2026), PP 27-32
www.iosrjournals.org

Arsenic In Groundwater And Associated Human Health Risk In Murshidabad: A Deterministic Dose-Response Assessment

Kismode Doha, Syed Naushad Ahmad
Department Of Geography, Faculty Of Science, Aligarh Muslim University, Aligarh, India -202002

Abstract:
Groundwater is the primary source of drinking water in many parts of eastern India, yet arsenic contamination poses a serious threat to human health. This study evaluates non-carcinogenic and carcinogenic health risks associated with arsenic-contaminated groundwater in Murshidabad district using a deterministic dose–response approach. Well-specific arsenic concentration data were used to estimate average daily dose (ADD) under two exposure scenarios: drinking only and combined drinking and cooking. Risk characterization was performed using the Hazard Quotient (HQ) for non-carcinogenic effects and lifetime Cancer Risk (CR) for carcinogenic effects following USEPA guidelines. The results indicate widespread exceedance of safe limits across the district. The mean HQ was 12.73 for drinking-only exposure and increased to 24.61 under combined exposure, substantially exceeding the acceptable threshold of unity. The estimated lifetime cancer risk for combined exposure reached approximately 55.73 cases per 10,000 inhabitants, far above regulatory limits. Spatial variation was observed across blocks, with Jalangi, Raninagar-II, and Domkal exhibiting particularly high exposure levels. Comparative analysis suggests that risk levels in Murshidabad are higher than many reported global cases. The findings highlight the severity of arsenic contamination in the region and emphasize the need for targeted mitigation strategies, regular monitoring, and improved access to safe drinking water to reduce long-term health risks.

Keywords: *Arsenic contamination; Health risk; Hazard quotient; Carcinogenic risk; Dose-response assessment.*

Date of Submission: 09-02-2026 Date of Acceptance: 19-02-2026

I. Introduction:

Water is fundamental for human survival and socio-economic development. Among available freshwater resources, groundwater constitutes one of the most reliable sources for drinking water worldwide. Nearly 2.5 billion people depend on groundwater for domestic use (Li et al., 2021), and approximately 22% of the Earth's freshwater reserves occur in groundwater form (Sarath Prasanth et al., 2012). Despite its significance, over-extraction and contamination have placed severe pressure on groundwater resources across many regions (Takem et al., 2010). Sustainable management of freshwater is therefore critical, particularly in densely populated areas where groundwater remains the primary source of drinking water (Asadi et al., 2019). South Asia represents one of the most groundwater-dependent regions of the world. Although the region contains major river systems such as the Indus, Ganges, and Brahmaputra, safe and accessible groundwater remains a concern due to widespread geogenic contamination (Nickson et al., 2000; Chakraborti et al., 2003). India is currently the largest user of groundwater globally (Baboo et al., 2022), and a substantial portion of the population relies on untreated aquifers for drinking purposes. Rapid population growth, agricultural intensification, and land-use transformation have increased pressure on aquifer systems, while both natural and anthropogenic sources contribute to groundwater degradation (Thambidurai et al., 2013). Contaminated groundwater not only reduces potable water availability but also creates long-term health and socio-economic challenges (Li et al., 2021; Doha & Ahmad, 2025; Doha et al., 2025).

Among various contaminants, arsenic (As) poses one of the most serious threats to groundwater quality in South Asia. The region is home to millions of people exposed to arsenic concentrations exceeding permissible limits, with India and Pakistan together accounting for approximately 125 million people at risk (Kumar et al., 2020). Arsenic contamination is frequently reported in the alluvial plains of the Ganga River Basin, where geochemical processes release arsenic from sediments into groundwater (Chakraborti et al., 2003). In India, several states along the Ganga basin have reported arsenic concentrations beyond safe limits, particularly in eastern regions (Kumar et al., 2020). The primary pathway of arsenic exposure is through the ingestion of contaminated groundwater and food products cultivated using arsenic-rich water (Thakur et al., 2013). Prolonged exposure is associated with skin lesions, keratosis, melanosis, cardiovascular disorders, endocrine dysfunction, reproductive anomalies, and various cancers (Doha et al., 2025). Even low-level exposure can induce genotoxic effects, including DNA damage and chromosomal abnormalities (Jha et al., 2019). Because arsenic is persistent and capable of bioaccumulation, chronic exposure remains a serious public health issue (He & Li, 2020).

In recent years, research emphasis has shifted from merely identifying contamination hotspots to quantifying associated human health risks (Tokatli et al., 2021). Risk assessment frameworks such as Hazard Quotient (HQ), Hazard Index (HI), and Cancer Risk (CR) have been widely applied to evaluate potential health impacts of heavy metals in drinking water (Tokatli et al., 2021; Jafarzadeh et al., 2022). These approaches are based on exposure assessment and dose-response relationships following the guidelines of the United States Environmental Protection Agency (USEPA) (Tokatli et al., 2021; Jafarzadeh et al., 2022). Such methods enable translation of measured contaminant concentrations into quantitative estimates of non-carcinogenic and carcinogenic risks. Within this broader context, Murshidabad district of West Bengal represents one of the severely arsenic-affected regions of the lower Ganga basin. A large proportion of the rural population depends on tube wells for drinking and cooking water, making groundwater the principal exposure pathway. Although arsenic contamination in this district has been widely acknowledged, systematic block-wise evaluation of dose-response health risk using extensive monitoring data remains limited. Therefore, the present study applies a deterministic well-specific dose-response framework to assess non-carcinogenic and carcinogenic health risks associated with arsenic-contaminated groundwater in Murshidabad. By integrating large-scale monitoring data with household-level intake information, the study aims to provide a comprehensive spatial understanding of exposure and its relationship with observed disease prevalence.

II. Methodology:

Study Design and Data Sources

The study adopts an integrated approach combining primary field investigation and secondary monitoring records to assess arsenic exposure and associated health risk in Murshidabad district. Secondary data on groundwater arsenic concentration were obtained from the Public Health Engineering Department (PHED), Murshidabad. The dataset comprised 9,053 tube-well samples distributed across all 26 administrative blocks of the district. These well-specific measurements served as the principal basis for exposure estimation and spatial risk assessment. Primary data were collected through structured house-to-house surveys conducted across all blocks to capture demographic information, water consumption behaviour, and arsenicosis status. The survey ensured complete geographic representation of the district and provided block-level intake data required for dose estimation. In total, 780 households were surveyed, covering 3,531 individuals. Among them, 370 individuals were identified as suffering from arsenicosis.

Sampling Design:

Murshidabad district consists of 26 blocks, and the study design ensured representation from each administrative unit. Approximately 30 households were surveyed per block, resulting in balanced spatial coverage. A mixed sampling approach was applied to maintain both field feasibility and statistical reliability.

Initially, purposive sampling was employed to ensure inclusion of arsenicosis-affected households within each block. The target was to include at least 5–8 affected households per block; however, in blocks with lower arsenic concentrations, this threshold could not always be achieved due to limited symptomatic cases. To minimize selection bias and improve representativeness, the remaining households were selected using systematic random sampling. This combined strategy enabled inclusion of both affected and non-affected households while preserving comparability across blocks.

Exposure Assessment and Risk Estimation

Groundwater arsenic concentration derived from PHED monitoring records was used directly for exposure calculation. Rather than averaging concentrations, well-specific values were retained to preserve spatial variability in contamination. Daily water intake information obtained from the household survey was aggregated at the block level to derive mean consumption values separately for drinking and cooking purposes. These intake rates were used to represent typical exposure conditions within each block. In the absence of individual body weight data, a standard adult body weight of 70 kg was adopted following USEPA recommendations. Exposure frequency was assumed to be 365 days per year, reflecting continuous reliance on groundwater for domestic use. Exposure duration was considered 30 years to represent long-term residential exposure. Averaging time differed by risk type: for non-carcinogenic assessment it was calculated as exposure duration multiplied by 365 days, while for carcinogenic assessment a lifetime averaging time of 25,550 days (70 years) was applied. Toxicological reference values were selected according to USEPA guidelines. The reference dose (RfD) for inorganic arsenic was taken as 0.0003 mg kg^{-1} day^{-1} for non-carcinogenic evaluation, and the cancer slope factor (CSF) was assumed to be 1.5 (mg kg^{-1} $day^{-1})^{-1}$ for lifetime carcinogenic risk estimation. Using these parameters, the average daily dose (ADD) was calculated for both drinking-only and combined drinking and cooking exposure scenarios.

The hazard quotient (HQ) was derived as the ratio of exposure dose to reference dose, while lifetime cancer risk (CR) was estimated by multiplying exposure dose with the cancer slope factor. Risk indices were computed individually for each well and subsequently aggregated at the block level to examine spatial variation.

Table 1: Input Parameters of the Health Risk Model.

Parameter	Symbol	Unit	Value/Source
Arsenic concentration	AC	$\mu g\ L^{-1}$	Measured well data
Drinking water intake	IR_D	$L\ day^{-1}$	Household Survey Block mean
Cooking water intake	IR_C	$L\ day^{-1}$	Household Survey Block mean
Body weight	BW	kg	70
Reference dose	RfD	$mg\ kg^{-1}\ day^{-1}$	0.0003
Cancer slope factor	CSF	$(mg\ kg^{-1}\ day^{-1})^{-1}$	1.5

Methods:

Unit conversion

Since laboratory measurements were reported in micrograms per litre, concentrations were converted into milligrams per litre:

AC_(mg/L) = C_(µg/L) / 1000

Average Daily Dose (ADD)

Exposure through ingestion was quantified using the Average Daily Dose (ADD), representing the mass of arsenic consumed per unit body weight per day.

Drinking only

$$ADD_{total} = \frac{AC \times IR_d \times EF \times ED}{BW \times AT}$$

Drinking and cooking combined

$$ADD_{total} = \frac{AC \times (IR_d + IR_c) \times EF \times ED}{BW \times AT}$$

For non-carcinogenic assessment:

$$AT = ED \times 365$$

For carcinogenic assessment:

$$AT = 25,550\ days$$

ADD is expressed in $mg\ kg^{-1}\ day^{-1}$.

Non-carcinogenic risk (Hazard Quotient)

Potential non-cancer effects were evaluated using the Hazard Quotient (HQ), defined as the ratio of exposure dose to the reference dose:

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

Thus,

HQ_drink = ADD_drink / RfD

HQ_total = ADD_total / RfD

Carcinogenic risk (Cancer Risk)

The lifetime cancer risk was estimated by multiplying the exposure dose by the cancer slope factor:

$$CR = \frac{ADD}{CSF}$$

Accordingly,

CR_drink = ADD_drink × CSF

CR_total = ADD_total × CSF

Well-specific computation

All calculations were performed individually for each tube well using its measured arsenic concentration. This well-specific deterministic procedure maintains observed variability in groundwater quality and provides a realistic representation of exposure at the local scale. Block-level risk characteristics were subsequently derived from these well-wise estimates for comparative analysis across the district.

Table 2: Arsenic Contamination Human Health Risk Interpretation (US EPA, 1999)

Non-carcinogenic Risk			Lifetime Carcinogenic Risk		
Hazard Quotient (HQ)	**Risk Level**	**Interpretation**	**Carcinogenic Risk**	**Cases per 10,000 Inhabitants**	**Risk Level**
< 0.1	Negligible	No observable health concern	**< 1×10⁻⁶**	< 0.01	Very low
≥ 0.1 – < 1	Low	Minor exposure, unlikely adverse effects	**1×10⁻⁶ – < 1×10⁻⁵**	0.01 – 0.1	Low
≥ 1 – < 4	Medium	Potential for adverse health effects	**1×10⁻⁵ – < 1×10⁻⁴**	0.1 – 1	Medium
≥ 4	High	Significant non-carcinogenic risk	**1×10⁻⁴ – < 1×10⁻³**	1 – 10	High
			≥ 1×10⁻³	≥ 10	Very high

III. Result And Discussion:

Table 3: Estimated Non-carcinogenic and Carcinogenic Risk across the blocks in Murshidabad

Blocks	Average Non-carcinogenic Risk		Carcinogenic Risk (per 1000 population)	
	Drinking only	**Combined**	**Drinking only**	**Combined**
Berhampore	10.97	22.10	4.94	9.95
Beldanga-I	12.14	25.47	5.46	11.46
Beldanga-II	14.36	25.91	6.46	11.66
Bhagowangola-I	16.12	30.29	7.26	13.63
Bhagowangola-II	18.60	35.08	8.37	15.79
Bharatpur-I	4.41	8.66	1.98	3.90
Bharatpur-II	3.34	5.91	1.50	2.66
Burwan	5.47	10.50	2.46	4.72
Domkal	17.06	37.50	7.68	16.88
Farakka	13.24	26.84	5.96	12.08
Hariharpara	16.63	31.52	7.48	14.19
Jalangi	22.08	46.02	9.94	20.71
Kandi	5.95	11.53	2.68	5.19
Khargram	5.32	9.46	2.39	4.26
Lalgola	14.80	28.82	6.66	12.97
Msd-Jiaganj	11.79	23.67	5.30	10.65
Nabagram	3.83	7.47	1.72	3.36
Nawda	16.82	29.33	7.57	13.20
Raghunathganj-I	13.93	24.49	6.27	11.02
Raghunathganj-II	15.57	28.91	7.01	13.01
Raninagar-I	16.39	31.66	7.37	14.25
Raninagar-II	20.84	40.17	9.38	18.08
Sagardighi	7.34	15.66	3.30	7.05
Samserganj	10.26	19.78	4.62	8.90
Suti-I	14.98	28.95	6.74	13.03
Suti-II	18.65	34.22	8.39	15.40
Mean	**12.73**	**24.61**	**5.73**	**11.08**

Source: Calculated by the Researcher based on PHED data (2022-23) and Field Survey (2023)

The analysis results (Table 3) show that across the district, the mean non-carcinogenic risk was estimated at 12.73 for drinking-only exposure and 24.61 for combined drinking and cooking exposure. Both values are substantially greater than the safe limit of unity, indicating that average exposure levels are 12-25 times higher than the acceptable reference dose. According to the USEPA risk classification, these values fall within the high-risk category. At the block level, combined exposure produced consistently higher HQ values compared with drinking alone, demonstrating the additional contribution of cooking water to daily arsenic intake. The highest HQ_total values were observed in Jalangi (46.02), Raninagar-II (40.17), Domkal (37.50), Bhagowangola-II (35.08), and Suti-II (34.22), indicating severe exposure conditions. In contrast, comparatively lower but still unsafe HQ_total values were recorded in Bharatpur-II (5.91), Nabagram (7.47), and Bharatpur-I (8.66). Even these lower-risk blocks exceed the threshold of 1, suggesting that complete safety is rarely achieved within the district.

Lifetime cancer risk estimates further highlight the seriousness of exposure. The district mean CR was 5.73 cases per 1000 population for drinking-only exposure and 11.08 cases per 1000 population for combined exposure. When expressed per 10,000 inhabitants, these values correspond to approximately 57 and 111 potential cancer cases, respectively, which are far above the acceptable regulatory limit of 1 case per 10,000. These estimates fall within the very high-risk category (Table 2). Block-wise analysis shows that Jalangi exhibited the highest cancer risk (20.71 per 1000), followed by Raninagar-II (18.08), Domkal (16.88), Bhagowangola-II

(15.79), and Suti-II (15.40). Conversely, relatively lower risks were found in Bharatpur-II (2.66), Nabagram (3.36), and Bharatpur-I (3.90). Nevertheless, even these minimum values exceed acceptable limits by several-fold, indicating a persistent carcinogenic risk across the region.

The estimated health risks in Murshidabad are higher than those reported in many arsenic-affected regions worldwide. The district mean hazard quotient of 12.73 and cancer risk of 55.73 cases per 10,000 inhabitants exceed values observed in several South Asian locations, including the Patna district of Bihar, with values around 8 (Singh), while the Vaishali district reported values near 2.68 (Kumar et al., 2025). Similarly, lower exposure levels were recorded in Pakistan (Khalid et al., 2024) and Sylhet, Bangladesh (Chowdhury et al., 2024). In contrast, severely contaminated areas of the Ganga–Brahmaputra floodplains exhibited elevated risks where HQ reached 18, comparable to the present study (Patel et al., 2021). Comparison with global studies further emphasises the severity of exposure. The Yanchi Region of northwestern China reported a much lower hazard quotient of 0.93 and cancer risk of 4.29 cases per 10,000 inhabitants (Wu et al., 2019). Overall, the mean HQ and CR values in the present study are slightly higher than those in most South Asian regions but far greater than those in many other global studies. This difference may be attributed to elevated groundwater arsenic concentrations combined with higher daily water consumption. Due to the hot and humid climate and livelihoods that involve considerable manual labour, residents tend to consume larger quantities of water, thereby increasing ingestion exposure and cumulative health risk (Bhowmick et al., 2018).

IV. Conclusion

The study demonstrates that arsenic-contaminated groundwater poses significant non-carcinogenic and carcinogenic health risks in Murshidabad district. The mean hazard quotient was 12.73 for drinking-only exposure and increased to 24.61 when cooking water was included, indicating that combined exposure substantially elevates daily arsenic intake. Both values far exceed the acceptable safety limit. Similarly, the estimated lifetime cancer risk for combined exposure reached approximately 55.73 cases per 10,000 inhabitants, which is considerably higher than regulatory thresholds. Spatial variation across blocks reveals those certain areas, including Jalangi, Raninagar-II, and Domkal, experience particularly severe exposure conditions. The observed consistency between calculated risk indices and reported health conditions supports the validity of the dose–response framework. Overall, the findings confirm that chronic ingestion of arsenic-contaminated groundwater remains a serious public health concern in Murshidabad and highlights the urgent need for safe water interventions and sustained monitoring efforts.

Reference:

[1]. Aryan, Y., Pon, T., Panneerselvam, B., & Dikshit, A. K. (2024). A Comprehensive Review Of Human Health Risks Of Arsenic And Fluoride Contamination Of Groundwater In The South Asia Region. Journal Of Water And Health, 22(2), 235-267.

[2]. Asadi, E., Isazadeh, M., Samadianfard, S., Ramli, M. F., Mosavi, A., Nabipour, N., ... & Chau, K. W. (2019). Groundwater Quality Assessment For Sustainable Drinking And Irrigation. Sustainability, 12(1), 177.

[3]. Bhowmick, S., Pramanik, S., Singh, P., Mondal, P., Chatterjee, D., & Nriagu, J. (2018). Arsenic In Groundwater Of West Bengal, India: A Review Of Human Health Risks And Assessment Of Possible Intervention Options. Science Of The Total Environment, 612, 148-169.

[4]. Chakraborti, D., Sengupta, M. K., Rahman, M. M., Chowdhury, U. K., Lodh, D., Ahamed, S., ... & Saha, K. C. (2003). Groundwater Arsenic Exposure In India. In Arsenic Exposure And Health Effects V (Pp. 3-24). Elsevier Science BV.

[5]. Chowdhury, T. N., Hasan, M. M., Munna, G. M., Alam, M. J. B., Nury, A. H., Islam, S., & Naher, T. (2024). Hazard-Mapping And Health Risk Analysis Of Iron And Arsenic Contamination In The Groundwater Of Sylhet District. Journal Of Water And Health, 22(4), 757-772.

[6]. Doha, K., & Ahmad, S. N. (2025). Living With Arsenicosis In Rural India: Unveiling The Hidden Struggles And Societal Attitudes Towards Victims. Geojournal, 90(4), 210.

[7]. Doha, K., Ahmad, S. N., Ali, S. A., Samim, M., & Parvin, F. (2025). Elixir Of Adversity: Unearthing The Alchemical Link Between Groundwater Arsenic Contamination And Socio-Economic Metamorphosis Through A Systematic Review. Pollution, 11(4), 1174-1198.

[8]. Habib, M. A., Reza, A. S., Hasan, M. I., Ahsan, M. A., Moniruzzaman, M., Hasan, A. B., ... & Hridoy, K. M. (2024). Evaluating Arsenic Contamination In Northwestern Bangladesh: A GIS-Based Assessment Of Groundwater Vulnerability And Human Health Impacts. Heliyon, 10(6).

[9]. He, X., & Li, P. (2020). Surface Water Pollution In The Middle Chinese Loess Plateau With Special Focus On Hexavalent Chromium (Cr6+): Occurrence, Sources And Health Risks. Exposure And Health, 12(3), 385-401.

[10]. Jafarzadeh, N., Heidari, K., Meshkinian, A., Kamani, H., Mohammadi, A. A., & Conti, G. O. (2022). Non-Carcinogenic Risk Assessment Of Exposure To Heavy Metals In Underground Water Resources In Saraven, Iran: Spatial Distribution, Monte-Carlo Simulation, Sensitive Analysis. Environmental Research, 204, 112002.

[11]. Jha, D. K., Sayrav, K., Mishra, G. P., Mishra, B. B., Kumari, A., Kumar, A., & Khan, P. K. (2019). Risk Assessment Of Low Arsenic Exposure Using Biomarkers Of Oxidative And Genotoxic Stress In A Piscine Model. Ecotoxicology, 28(6), 669-679.

[12]. Khalid, S., Shahid, M., Bibi, I., Nadeem, H. M., Younis, M., Natasha, N., ... & Niazi, N. K. (2024). Assessing The Arsenic Contents And Associated Risks In Groundwater Of Vehari And Lodhran Districts, Pakistan. Water, 16(21), 3055.

[13]. Kumar, A., & Singh, C. K. (2020). Arsenic Enrichment In Groundwater And Associated Health Risk In Bari Doab Region Of Indus Basin, Punjab, India. Environmental Pollution, 256, 113324.

[14]. Kumar, P., Khan, P. K., & Kumar, A. (2025). Health Risk Assessment Upon Exposure To Groundwater Arsenic Among Individuals Of Different Sex And Age Groups Of Vaishali District, Bihar (India). Toxicology Reports, 14, 102024.

[15]. Li, P., Karunanidhi, D., Subramani, T., & Srinivasamoorthy, K. (2021). Sources And Consequences Of Groundwater Contamination. Archives Of Environmental Contamination And Toxicology, 80(1), 1-10.
[16]. Nickson, R. T., Mcarthur, J. M., Ravenscroft, P., Burgess, W. G., & Ahmed, K. M. (2000). Mechanism Of Arsenic Release To Groundwater, Bangladesh And West Bengal. Applied Geochemistry, 15(4), 403-413.
[17]. Patel, A. K., Singh, A., Das, N., & Kumar, M. (2021). Health Risk Associated With Consumption Of Arsenic Contaminated Groundwater In The Ganga And The Brahmaputra Floodplain Of India. Case Studies In Chemical And Environmental Engineering, 3, 100103.
[18]. Sarath Prasanth, S. V., Magesh, N. S., Jitheshlal, K. V., Chandrasekar, N., & Gangadhar, K. J. A. W. S. (2012). Evaluation Of Groundwater Quality And Its Suitability For Drinking And Agricultural Use In The Coastal Stretch Of Alappuzha District, Kerala, India. Applied Water Science, 2(3), 165-175.
[19]. Takem, G. E., Chandrasekharam, D., Ayonghe, S. N., & Thambidurai, P. (2010). Pollution Characteristics Of Alluvial Groundwater From Springs And Bore Wells In Semi-Urban Informal Settlements Of Douala, Cameroon, Western Africa. Environmental Earth Sciences, 61(2), 287-298.
[20]. Thakur, B. K., Gupta, V., & Chattopadhyay, U. (2013). Arsenic Groundwater Contamination Related Socio-Economic Problems In India: Issues And Challenges. Knowledge Systems Of Societies For Adaptation And Mitigation Of Impacts Of Climate Change, 163-182.
[21]. Thambidurai, P., Chandrashekhar, A. K., & Chandrasekharam, D. (2013). Geochemical Signature Of Arsenic-Contaminated Groundwater In Barak Valley (Assam) And Surrounding Areas, Northeastern India. Procedia Earth And Planetary Science, 7, 834-837.
[22]. Tokatli, C. (2021). Health Risk Assessment Of Toxic Metals In Surface And Groundwater Resources Of A Significant Agriculture And Industry Zone In Turkey. Environmental Earth Sciences, 80(4), 156.
[23]. Wu, C., Fang, C., Wu, X., & Zhu, G. (2020). Health-Risk Assessment Of Arsenic And Groundwater Quality Classification Using Random Forest In The Yanchi Region Of Northwest China. Exposure And Health, 12(4), 761-774.