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Groundwater Arsenic Contamination in Nadia: A Cross-Sectional Study from Laboratory to Community

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ABSTRACT

Groundwater arsenic contamination has been an important health and environmental concern over the past few decades. Arsenic compounds, when mixed with water, do not leave any trace and can only be detected through laboratory testing. The need for effective technology to remove arsenic from water as well as the lack of efficient treatment of arsenic-borne diseases make the situation more vulnerable. The impact of arsenic is particularly severe among lower socio-economic groups, who have limited access to modern technology and education. However, the problem of arsenic contamination has been exacerbated by decreasing water levels and consequently increasing arsenic concentration.

The concentration of arsenic in the groundwater of 17 blocks in Nadia district was determined using the Atomic Absorption Spectroscopy technique. Following this, a cross-sectional survey was carried out among 437 people spread over different blocks of Nadia district. Two questionnaires, one consisting of knowledge and attitude items and the other consisting of beliefs and practice items, have been used to gather information on the knowledge, attitude, beliefs, and practices of people in Nadia.

The study highlights significant differences in knowledge and attitude towards arsenic with respect to locality, gender, age, education, occupation, and economic status. A moderate and positive correlation between knowledge and attitude towards arsenic has been ascertained. Misconceptions, myths, and unscientific practices have been observed among the people of Nadia. Immediate awareness-raising activities should be performed for mitigation.

INTRODUCTION

Over the past few decades, groundwater arsenic pollution has become a serious health hazard. A hazard that cannot be detected by the senses directly affects about 200 million individuals in 70 different nations. The arsenic compounds, when dissolved in water, do not alter its taste or smell. This water, if used for drinking or irrigation purposes, causes fatal toxicity (Y. Chen *et al.*, 2009; Kanel *et al.*, 2023; Kumar, 2021; Moulick *et al.*, 2021; Pál *et al.*, 2022; Shaji *et al.*, 2021; S. K. Singh, 2017; Singha & Sikdar, 2021). Arsenic is a metalloid having properties both of metals and non-metals. Having four oxidation states (0, -3, +3 and +5) arsenic exists in various allotropic forms such as elemental, sulfides or carbonates. The compounds formed by arsenic are highly toxic and poisonous in nature. So it is known to humans as the "King of Poison" from very old time (Abdul *et al.*, 2015; Huq *et al.*, 2020; Shaji *et al.*, 2021; S. K. Singh, 2017; Swain *et al.*, 2021).

The sources of arsenic are categorized into two types. These are geogenic and anthropogenic sources. Geogenic sources, also called natural sources, are sedimentary deposits, volcanic activities, and geothermal activities. Anthropogenic sources, also called man-made sources, are mining and smelting, coal and petroleum extractions, and their combustion and production industries like paper, cement, chemicals, etc. (Adeloju *et al.*, 2021; Akter & Ali, 2011; Q. Y. Chen & Costa, 2021; Huq *et al.*, 2020; Kaur *et al.*, 2024; Patel *et al.*, 2023; Sen *et al.*, 2021; Shaji *et al.*, 2021; Swain *et al.*, 2021; Yadav *et al.*, 2021; Zuzolo *et al.*, 2020).

WHO sets the permissible arsenic limit in water at 10 µg/L, but studies indicate that adverse health effects can occur at levels below this limit (Bhattacharya *et al.*, 2015; Huq *et al.*, 2020; Pinchoff *et al.*,2022).

The long-term exposure to arsenic damages the major organs drastically. It includes failure of heart, kidney, bladder, liver, and brain functions. Various types of cancer, neurological disorders, Alzheimer's disease, Black-foot disease, and disorders in the skin and blood vessels have also been reported. Along with these disorders and effects, reproductive disorders, intellect, and motor dysfunction among children have also been observed (Engel & Lamm, 2008; Pinchoff *et al.*, 2022; Sanyal *et al.*, 2020; Shaji *et al.*, 2021; Sinha & Prasad, 2020; Yadav *et al.*, 2021).

Despite its fatal toxicity, there is no effective treatment for arsenic-borne diseases, and no cost-effective removal of arsenic from groundwater exists (Altowayti *et al.*, 2022; Chakraborti *et al.*, 2018; Khan *et al.*, 2015; Srivastava, 2020).

Although groundwater arsenic contamination has been detected all over the globe, the countries that belong to South Asia, Southeast Asia, and South America are suffering the most. Among them, Bangladesh and India are in the most dangerous situations (Adeloju *et al.*, 2021; Asadullah & Chaudhury, 2011; Hettick *et al.*, 2015; Jha *et al.*, 2017; Marghade *et al.*, 2023; Pinchoff *et al.*, 2022; Podgorski & Berg, 2020; Shaji *et al.*, 2021; Shankar *et al.*,

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2014; R. Singh *et al.*, 2015; S. K. Singh, 2017; Yadav *et al.*, 2021).

The first groundwater arsenic in India was noticed in Punjab, Haryana, and Himachal Pradesh. The states that belong to the basins of Ganga and Brahmaputra contain groundwater concentrations of arsenic many times more than the WHO permissible limit. Also, this riverside population density is considered to be the densest in the world. In India, twenty states and four union territories are affected by groundwater arsenic contamination (Bhattacharya *et al.*, 2015; Chakraborti *et al.*, 2003; Sen *et al.*, 2021; Shaji *et al.*, 2021; Swain *et al.*, 2021).

The districts of Howrah, Hooghly, and Bardhman on the western bank of the Bhagirathi River and Malda, Murshidabad, Nadia, the North 24 Parganas, the South 24 Parganas, and Kolkata on the eastern side are the most affected (Chakraborti *et al.*, 2003, 2018; Koley, 2023; D. Mazumder *et al.*, 2020; S. Rahaman *et al.*, 2013; Sen *et al.*, 2021; Shaji *et al.*, 2021; Swain *et al.*, 2021).

Figure 1: Map showing the location of Nadia

The Nadia District in West Bengal (Figure 1) is situated on the eastern side of the Bhagirathi River. The population density is high in this district. The economy of this district depends on agriculture, which cultivates all types of crops. The district has 17 blocks and each of them is contaminated with high level of arsenic (Das *et al.*, 2020; D. N. Mazumder *et al.*, 2010).

The impact of arsenic contamination is note-worthy. It has profound effects on human health, agriculture, society, and the economy of the country. The adverse health effects of arsenic come out after five to ten years of regular exposure, depending on the concentration of arsenic in groundwater and food intake by the people. Unfortunately, people from lower socioeconomic groups suffer the most due to a lack of arsenic-free water and nutrition (Abdul *et al.*, 2015; Adeloju *et al.*, 2021; Bhatia *et al.*, 2014; S. Flanagan *et al.*, 2012; Pinchoff *et al.*, 2022; Polya *et al.*, 2019; Safiuddin, 2011; Sarkar *et al.*, 2022; Shaji *et al.*, 2021; Shankar *et al.*, 2014; S. K. Singh, 2017; Swain *et al.*, 2021; Thakur & Gupta, 2015; Yadav *et al.*, 2021).

Although there are various studies related to arsenic-caused health issues, arsenic removal technologies, determination of arsenic concentration in water, social ostracism, economic and social effects, a grass-roots-level study that describes the victims' cognitive and affective area towards arsenic contamination is rare (Alka *et al.*, 2021; Bali & Sidhu, 2021; Baloch *et al.*, 2020; Bhat *et al.*, 2023; Dilpazeer *et al.*, 2023; Kanel *et al.*, 2023; Moreira *et al.*, 2021; Muzaffar *et al.*, 2023; Palma-Lara *et al.*, 2020; Md. S. Rahaman *et al.*, 2021; Rathi & Kumar, 2021; Sadee *et al.*, 2023; Sanyal *et al.*, 2020; Sodhi *et al.*, 2019; Wang *et al.*, 2021; Weerasundara *et al.*, 2021). Investigating what individuals know about arsenic, how they emotionally engage with it, and the beliefs and practices they uphold in affected areas takes on great significance. This study has been conducted with the aim of evaluating the knowledge, attitudes, beliefs, and practices of the local populace in relation to groundwater arsenic contamination.

MATERIALS AND METHODS

Study Participants and Procedure

This study is based on a cross-sectional survey carried out from October 2022 to April 2023. A random sampling method was performed among the people of Nadia district, spread over 17 blocks. Two questionnaires, one for assessment of knowledge and attitude and the other for collection of information regarding arsenic contamination have been used in this study. Both the questionnaires consist of items in Bengali language, which is the local language of Nadia. The knowledge and attitude questionnaire comprises the items in five point scale having options strongly agree, agree, neutral, disagree and strongly disagree. The beliefs and practices items in a separate questionnaire have only yes and no options. There are both negative and positive items in both questionnaires.

The knowledge and attitude questionnaire which has been used as an instrument is previously standardized (Singha *et al.*, 2022). The sample size has been calculated following the standard procedure. Considering the population size of Nadia (5167600) (Nadia District Population Religion - West Bengal, Nadia Literacy, Sex Ratio - Census India, n.d.), 95% confidence level, 5% marginal error, and 50% population proportion, the value of the sample size is 385. Here, we have taken 437 samples, which is more than the calculated sample size.

The researcher introduced himself to the respondents, offering a concise overview of their study's objectives and emphasizing its relevance to the participants' lives. A comprehensive explanation of the questionnaire completion process was then provided, with respondents instructed to select the most appropriate responses based on their own judgments. Notably, the questionnaire containing knowledge and attitude items spanned four pages, and respondents typically dedicated approximately one hour to completing it.

A questionnaire consisting of 10 items probing beliefs, 10 items evaluating practices, and demographic inquiries was utilized within the same 17 blocks of Nadia District, West Bengal. This questionnaire was administered to 223 respondents from diverse areas within the Nadia, including villages and towns. The researcher followed the same protocol as in the previous study, personally engaging with the respondents, presenting an overview of their research, and highlighting its significance in the lives of the respondents. The respondents required approximately 20 minutes to complete the answers.

Collection and Analysis of Water Samples

The tubewell water samples were collected from all 17 blocks of Nadia district. A total of 51 samples (3 samples from each block) were collected in such a manner that the distribution of samples followed a uniform pattern, covering all the area. The water samples were collected in 200 mL vinyl bottles. Then 0.5 mL of 50% HCl solution was added to it and shaken properly. The bottles were then sealed with Teflon tape and preserved for the determination of concentration of arsenic using the Atomic Absorption Spectroscopy (AAS) technique.

Collection of Data and Statistical Analysis

The knowledge and attitude scores are calculated taking the strongly agree as score 5 and strongly disagree as 1. The negative statements are scored reversely. The statistical analyses used in this study are independent sample t tests, 1-way ANOVA, and post hoc tests. The analysis was performed using IBM SPSS Statistics software version 26.0. In hypothesis testing, if the p value is greater than or equal to 0.05, then the null hypothesis was accepted, indicating no difference between groups. If the p value is less than 0.05, the null hypothesis was not accepted; rather, the alternative hypothesis was accepted, indicating a significant difference between groups (Banerjee *et al.*, 2009; Cronk, 2017; Davis & Mukamal, 2006; Emmert-Streib & Dehmer, 2019; Expósito-Ruiz *et al.*, 2010; Field, 2019; Pereira & Leslie, 2009).

If there is one metric dependent variable and one non-metric independent variable with two groups, an independent sample t test is the best choice to compare the means. If an independent variable has more than two categories, a 1-way ANOVA (analysis of variance) test is to be performed. The rule is that the data should be normal in both the cases. In this case, the samples do not follow a normal distribution, but the variance under each category was found to be equal. Also, the sample size was greater than 30. Therefore, normality is not a major issue here. So an independent sample t test may be used to compare the means of two categories, and a 1-way ANOVA may be used to compare the means of more than two categories of independent variables. In the latter case, the Tukey method was applied as a post hoc test to find out the differences between more than two categories. For the unequal variance, the Welch test followed by the Games-Howell post hoc method has been applied (Field, 2019; Ghasemi & Zahediasl, 2012; Kothari & Garg, 2019; Mishra *et al.*, 2019; Nargundkar, 2019; Panneerselvam, 2013).

RESULTS AND DISCUSSIONS

Analysis of Water samples

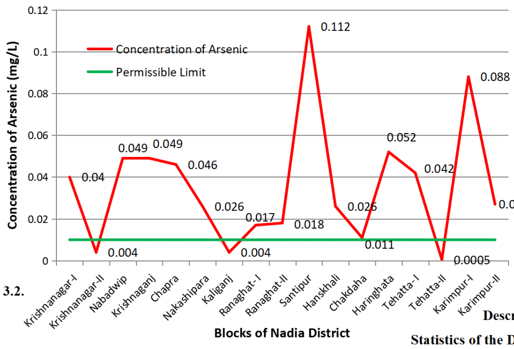
The drinking water sources of the respondents are given in Table 1. It can be seen that 80% of the people use tubewell water as their drinking water source. About 15.6% of the people collect their drinking water from other sources. This other source is bottled water, which they buy from the market.

Table 1: Source of drinking water

Water source	Frequency (n=437)	Percentage (%)
River	16	3.7
Pond	1	0.2
Tubewell	350	80.1
Well	2	0.5
Others	68	15.6

The source of drinking water is mainly tubewell. Other sources assigned here is predominantly bottled water which people bought from market.

The line graph showing the present groundwater arsenic concentration in different blocks of Nadia district is presented in Figure 2. The green line indicates the accepted concentration of arsenic, whereas the red line indicates the present arsenic concentration. It is seen that the groundwater concentration of arsenic is many times higher than the safe limit



3.2. Descriptive Statistics of the Data

Figure 2: Line graph showing groundwater arsenic concentrations in different blocks of Nadia. The green line indicates the safe limit assigned by WHO, whereas the red line depicts the recent arsenic concentration.

The total number of sample is 437. The demographic variables are locality (urban and rural), gender (male and female), age (18–35 years and more than 35 years), caste (general, OBC, SC, and ST), academic qualification (illiterate, primary, secondary, higher secondary, graduate, and postgraduate), occupation (unemployed, farmer, business, service, and others), and economic status (BPL, APL). Due to ethical consideration and fulfillment of the need of this study the age group under 18 is excluded from the study. The demographic variables with their frequency are presented in Table 2.

Table 2: Socio-demographic details of the respondents

Variables	**Frequency (n=437)**	**Percentage (%)**
Locality		
Urban	99	22.7
Rural	338	77.3
Gender		
Male	219	50.1
Female	218	49.9
Age		
18-35 years	168	38.4
>35 years	269	61.6
Caste		
General	252	57.7
OBC	75	17.2
SC	88	20.1
ST	22	5.0
Academic Qualification		
Illiterate	67	15.3
Primary	105	24.0
Secondary	83	19.0
Higher Secondary	58	13.3
Graduate & Post Graduate	124	28.4
Occupation		
Unemployed	97	22.2
Farmer	33	7.6
Business	79	18.1
Service	72	16.5
Others	156	35.7
Economic status		
BPL	225	51.5
APL	212	48.5

OBC=Other Backward Classes, SC=Schedule Caste, ST=Schedule Tribe, BPL=Below Poverty Line, APL=Above Poverty Line; the Others category under Occupation is predominantly housewives.

Comparison of Knowledge

The comparison of independent variables having two categories was conducted through an independent sample t test. The results are summarized in Table 4. The independent sample t test between urban and rural categories shows p =.129, t = 1.520, and df = 435. It indicates that there is no significant difference in knowledge between urban and rural populations regarding arsenic contamination.

The result of the independent sample t test between male and female categories was p =.001, t = 3.463, and df = 435. It indicates that there is a significant difference in knowledge between males and females concerning arsenic contamination.

Further, an independent sample t test comparing different age groups revealed p =.013, t =-2.503, and df = 435. So there is a significant difference in knowledge between the 18–35 and more than 35 age groups concerning arsenic contamination.

Finally, the independent sample t test comparing BPL and APL groups shows p <.001, t = -6.662, and df = 435, which indicates a significant difference in knowledge between the below poverty line (BPL) and above poverty line (APL) categories regarding arsenic contamination.

Table 3: Comparison of Knowledge through independent sample t test

Variables	**Mean (SD)**	**p**	**t**	**df**	**95% CI**	
					Lower	**Upper**
Locality						
Urban	92.46 (12.55)	0.129	1.520	435	-0.656	5.130
Rural	90.23 (12.98)					
Gender						
Male	92.84 (12.99)	0.001***	3.463	435	1.825	6.617
Female	88.62 (12.48)					
Age						
18-35 years	88.79 (12.24)	0.013*	-2.503	435	-5.635	-0.678
>35 years	91.95 (13.17)					
Economic status						
BPL	86.93 (11.89)	0.001***	-6.662	435	-10.159	-5.530
APL	94.77 (12.72)					

** p0.05, ** p0.05,*** p0.05.*

The comparison of independent variables with more than two categories was conducted through 1-way ANOVA, and the results are summarized in Table 4. The result of the 1-way ANOVA analysis for the comparison of knowledge among different caste, F (3,433)=1.875, p =.133, indicates that there is no significant difference in knowledge score between the different castes towards arsenic contamination.

In another analysis, the result of the 1-way ANOVA analysis F (4,432) = 16.139, p <.001, indicates that at least one category of academic qualification differs significantly from the rest in their mean scores. Subsequent paired comparisons by post hoc analysis using the Tukey method showed that the mean knowledge score of Graduates and Post-graduates (97.45) > Primary (88.67) = Secondary (90.05) = Higher Secondary (89.07) > Illiterate (83.84)

Furthermore, the result of the 1-way ANOVA analysis, F (4,432) = 22.529, p <.001, indicates that at least one category of occupation differs significantly from the rest in their mean scores. Post hoc analysis using the Tukey method showed that the mean knowledge score of serviceman (101.88) > businessman (92.57) = unemployed (88.23), others (87.33)> farmer (85.52). Here, the other option is predominantly housewives.

Table 4: Comparison of Knowledge through 1-way ANOVA

Variables	**Mean (SD)**	**df bg**	**df wg**	**F**	**p**	**Posthoc**
Caste						
General	91.91 (12.78)	3	433	1.875	0.133	
OBC	88.80 (11.59)					
SC	89.83 (14.15)					
ST	87.50 (12.51)					
Academic Qualification						
Illiterate	83.84 (12.53)	4	432	16.139	0.001***	Graduate & Post Graduate> Higher Secondary=Secondary= Primary>Illiterate
Primary	88.67 (11.51)					
Secondary	90.05 (11.11)					
HS	89.07 (12.87)					
Graduate & PG	97.45 (12.57)					
Occupation						
Unemployed	88.23 (11.17)	4	432	22.529	0.001***	Service> Business= Unemployed=Others> Farmer
Farmer	85.52 (12.09)					
Business	92.57 (11.98)					
Service	101.88 (11.59)					
Others	87.33 (12.09)					

*bg=between groups, wg=within groups, PG=Post Graduate, the Others category under Occupation is predominantly housewives.; * p0.05, ** p0.05,*** p0.05.*

Comparison of Attitude

The comparison of independent variables having two categories with respect to attitude was conducted through an independent sample t test, and the results are summarized in Table 5. The independent sample t test between urban and rural categories shows that p =.001, t = 3.292, and df = 435, which indicates a significant difference in attitude between urban and rural populations regarding arsenic contamination.

Similarly, the independent sample t test between male and female categories resulted in p=.067, t=1.833, and df=435, indicating no significant difference in attitude between males and females concerning arsenic contamination.

Further, an independent sample t test comparing different age groups revealed p=.020, t=-2.336, and df=435. So there is a significant difference in attitude between the 18-35 and more than 35-year age groups concerning arsenic contamination.

Finally, the independent sample t test comparing BPL and APL groups shows p<.001, t=-6.661, and df=435, indicating a significant difference in attitude between the below poverty line (BPL) and above poverty line (APL) categories regarding arsenic contamination.

Table 5: Comparison of Attitude through independent sample t-test

Variables	Mean (SD)	p	t	df	95% CI	
					Lower	Upper
Locality						
Urban	108.37 (13.25)	0.001***	3.292	435	2.062	8.171
Rural	103.26 (13.70)					
Gender						
Male	105.62 (14.40)	0.067	1.833	435	-0.173	4.984
Female	103.21 (12.97)					
Age						
18-35 years	102.48 (14.34)	0.020*	-2.336	435	-5.787	-0.498
>35 years	105.62 (13.25)					
Economic status						
BPL	100.36 (13.24)	0.001***	-6.661	435	-10.829	-5.895
APL	108.72 (12.97)					

** p0.05, ** p0.05,*** p0.05*

The comparison of independent variables with more than two categories was performed using 1-way ANOVA, and the results are summarized in Table 6. The result of 1-way ANOVA analysis, F (3,433) = 1.850, p =.137, indicates that there is no significant difference in attitude scores between the different castes towards arsenic contamination.

In another analysis, the result of the 1-way ANOVA analysis F (4,432) = 21.976, p <.001, indicates that at least one category of academic qualification differs significantly from the rest in their mean scores. Subsequent paired comparisons by post hoc analysis using the Tukey method showed that the mean attitude score of Graduates and Post-Graduate (112.57) > Primary (100.65) = Secondary (103.75) = Higher Secondary (103.84) > Illiterate (96.55). The attitude scores with respect to occupation differ from normality and variance. So in this case, the Welch test has been performed. The result of the Welch test F (4,146.934) = 31.468, p<.001, indicates that at least one category of occupation differs significantly from the rest in their mean scores. Post hoc analysis using the Games-Howell method showed that the mean attitude score of Service (116.46) > Business (106.77) = Unemployed (101.53) = Others (101.38)> Farmer (95.33). Here, the other option is predominantly housewives.

Table 6: Comparison of Attitude through 1-way ANOVA

Variables	Mean (SD)	df bg	df wg	F	p	Posthoc
Caste						
General	105.32 (13.29)	3	433	1.850	0.137	-
OBC	101.88 (14.58)					
SC	104.97 (14.68)					
ST	100.55 (11.08)					
Academic Qualification						
Illiterate						
Primary	96.55 (10.32)	4	432	21.976	0.001***	Graduate & Post Graduate> Higher Secondary=Secondary= Primary>Illiterate
Secondary	100.65 (13.78)					
HS	103.75 (13.13)					
Graduate & PG	103.84(13.36)					
	112.57 (11.90)					
Occupation						
Unemployed	101.53 (14.32)	4 (df1)	146.934 (df2)	31.468 (Asymptotically Distributed)	0.001***	Service> Business= Unemployed=Others> Farmer

Farmer	95.33 (15.04)					
Business	106.77 (10.51)					
Service	116.46 (9.94)					
Others	101.38 (12.46)					

*bg=between groups, wg=within groups, PG=Post Graduate, the Others category under Occupation is predominantly housewives.; * p0.05, ** p0.05,*** p0.05.*

Correlation of Knowledge and Attitude towards Arsenic

The Pearson product moment correlation (r) between knowledge and attitude has been found to be moderately positive and statistically significant (r =.639, p<.01). The result of the correlation analysis is presented in Table 7.

Table 7: Correlation between Knowledge and Attitude towards Arsenic Contamination

Correlation			
		Knowledge	**Attitude**
Knowledge	Pearson Correlation	1	.639**
	Sig. (two tailed)		.000
	N	437	437
Attitude	Pearson Correlation	.639**	1
	Sig. (two tailed)	.000	
	N	437	437

***. Correlation is significant at the 0.01 level (2-tailed).*

A scattered plot showing the relationship between knowledge and attitude towards arsenic contamination is depicted in Figure 3. Here, one can observe that an increase in knowledge leads to an increase in positive attitudes towards arsenic contamination.

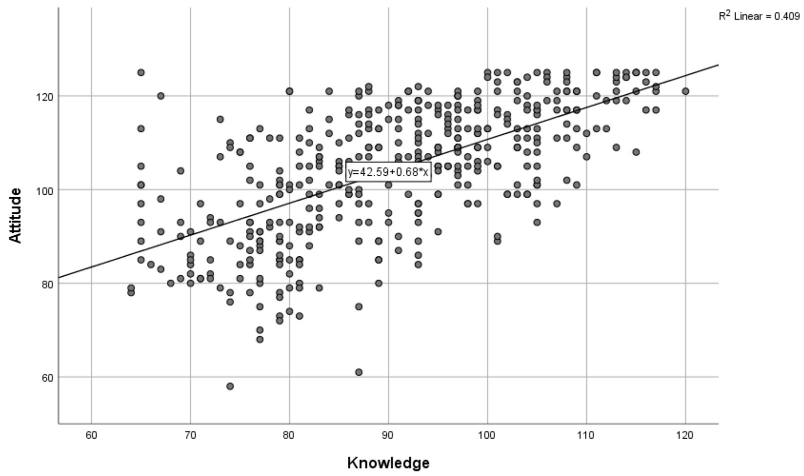


Figure 3: Scatter Plot Showing the Correlation between Knowledge and Attitude Scores

Beliefs and Practices

After analyzing the knowledge and attitude questionnaire, we were interested to know the beliefs and practices of the people of Nadia District towards arsenic. We prepared another questionnaire to study the beliefs and practices. This binary questionnaire consists of 10 belief items and 10 practice items. The result obtained is summarized in the Table 8.

Discussions

Impact of demographic variables on Knowledge

Though the average knowledge score of the urban individuals (92) is slightly greater than that of the rural individuals (90), the statistical analysis indicates no significant difference in knowledge scores between the urban and rural populations. The cause of the equality may be due to improved information source accessibility in rural areas, active participation by the government and NGOs, community engagement in education programs addressing arsenic contamination, and a robust social network. This outcome aligns with the similar research findings (Howat *et al.*, 2006; Steyn *et al.*, 2000).

However, there was a significant difference in the knowledge scores between males (93) and females (89),

Table 8: Percentage of yes and no responses against belief and practice items

Belief Statements (N=223)	**Yes (%)**	**No**(%)
The common water filters do not remove arsenic.	61	39
Arsenic cannot be removed by boiling.	55	45
Animals do not affected by arsenic.	40	60
Arsenic affected people are burden for their family and society.	38	62
Arsenicosis is not a genetic disease.	60	40
It is better to keep distance from arsenic affected people and his/her family.	50	50
Juice of guava leaves can detect arsenic in water.	33	67
Arsenic borne diseases can occur through food intake.	62	38
There is no problem to conceive child for arsenic victims.	46	54
People are affected by arsenic due to rage of God.	22	78
Practice Statements (N=223)	Yes (%)	No (%)
Are you using arsenic contaminated water unintentionally?	42	58
Are you using arsenic contaminated water for cooking?	47	53
Are you using arsenic contaminated water for irrigation?	65	35
Are you using arsenic contaminated water for bathing and drinking of animal?	65	35
Do you participate in arsenic related discussions?	29	71
Do you test your drinking water regularly?	22	78
Are you conscious about the quality of drinking water of child and aged persons in your family?	92	08
Is there any treatment facility of arsenic affected people in your place?	40	60
Do you collect water from the tubewell labeled as safe by the government?	50	50
Do you test your drinking water by paying the cost?	20	80

potentially attributed to a lower literacy rate among females. Social responsibility and occupational exposure are likely to play the pivotal roles. Existing studies support this observation (Paul, 2004; Yang *et al.*, 2020).

There is a significant difference in knowledge scores between the 18–35 age group (89) and those above 35 years old (92) concerning arsenic contamination. This discrepancy is possibly due to the greater experience of older individuals. Professional experience and social networks are potential factors contributing to this difference. This is also consistent with other research findings (George *et al.*, 2013; González-Herrera *et al.*, 2022; Paul, 2004; Sixpence *et al.*, 2020).

A noteworthy distinction in knowledge scores is evident between the Below Poverty Line (BPL) and Above Poverty Line (APL) categories regarding arsenic contamination. The APL community, with better educational access, shows higher receptiveness to modern health education and information. This aligns with the supporting studies (Bandyopadhyay *et al.*, 2017; Biswas *et al.*, 2022; S. K. Singh *et al.*, 2018).

There was no significant difference in knowledge scores among individuals of different castes regarding arsenic contamination. Equal information access facilities, modernization, government policies, community initiatives, and increased social awareness may be the reasons behind it.

The 1-way ANOVA reveals significant differences in knowledge scores based on academic qualifications. The post hoc test indicates a hierarchy: graduate and postgraduate > primary = secondary = higher secondary > illiterate. This aligns with expectations, as higher education correlates with increased curriculum coverage, better information retrieval skills, critical thinking ability, and professional exposure (Anthonj *et al.*, 2022; George *et al.*, 2013; Hines *et al.*, 1987; Hungerford & Volk, 1990; Kassahun & Mekonen, 2017; Newhouse, 1990; Paul, 2004).

Similarly, the 1-way ANOVA identifies significant differences in knowledge scores based on occupation. The posthoc test indicates the following hierarchy: Serviceman > Businessman = Unemployed = Others > Farmer. This outcome aligns with expectations, as individuals in service and business often possess higher education levels, providing greater access to information and awareness of environmental issues like arsenic contamination. This result is consistent with existing studies (Abbasi *et al.*, 2016; Kassahun & Mekonen, 2017; Paul, 2004; S. K. Singh *et al.*, 2018).

Impact of demographic variables on Attitude

There is a significant difference in attitude scores between urban and rural populations regarding arsenic contamination. This discrepancy may be explained by the fact that urban people have enhanced access to information and higher literacy rates compared to rural people. This finding is in close agreement with other studies (Ahadi *et al.*, 2014; Kassahun & Mekonen, 2017; Ripon *et al.*, 2021).

A significant variance in attitude scores is observed between males and females concerning arsenic contamination. Access to information and social networks may be contributing factors to this outcome.

There is a significant difference in attitude scores between the 18–35-year-old and more than 35-year-old age groups towards arsenic contamination. This may be due to the experience of older people compared to younger people. Older people are more motivated to learn to reduce arsenic consequences as they have seen long-term calamities caused by arsenic. Professional experience and social networks can also be the important reasons behind this difference. The result is consistent with the other studies (Domagała-Zyśk, 2021; Kassahun & Mekonen, 2017; Staddon, 2020; Sudarmadi *et al.*, 2001; Tek *et al.*, 2023).

There is a significant difference in attitude scores between the BPL and APL categories towards arsenic contamination. This outcome is also expected, as the APL community is more receptive to modern health education and related access to information since they have better educational access than BPL, who are more concerned with their basic needs for survival. This result is in close agreement with the other studies (Bandyopadhyay *et al.*, 2017; Behera *et al.*, 2022; S. V. Flanagan *et al.*, 2016; Guha *et al.*, 2020).

There is no significant difference in attitude score between the different castes towards arsenic; this can be explained on the basis of equal access to information. The digital era and modernization have shortened the gap between the accesses to information between different caste groups. Government policies, community-based initiatives, and social awareness also played an important role in this outcome. Since there is no difference in knowledge score between different castes, we may expect that there should not be any difference in attitude score either.

The 1-way ANOVA suggests that at least one category of academic qualification differs significantly from the rest in their mean scores. After applying the post hoc test, we can say that the attitude scores show a significant difference between graduates and postgraduates: primary, secondary, higher secondary, and illiterate. The result is expected as more educated people have more curriculum coverage, information retrieval skills, critical thinking ability, and professional exposure. The result is also consistent with other studies (S. V. Flanagan *et al.*, 2016; Hines *et al.*, 1987; Hungerford & Volk, 1990; Kassahun & Mekonen, 2017; Newhouse, 1990).

The 1-way ANOVA suggests that at least one category of occupation differs significantly from the rest in their mean scores. After applying the post hoc test, we can say that the attitude scores show a significant difference iniceman>Businessman=Unemployed=Others>Farmer. This outcome is expected, as servicemen and businessmen often have higher levels of education compared to unemployed individuals or farmers. Higher education provides access to more information and awareness about environmental issues. The result is also consistent with other studies (Behera *et al.*, 2022; Kassahun & Mekonen, 2017; S. K. Singh *et al.*, 2018).

Correlation of Knowledge and Attitude towards Arsenic Contamination

The Pearson product moment correlation (r) of knowledge and attitude was found to be moderately positive and statistically significant ($r = .639$, $p < .01$). Hence, the null hypothesis is not accepted, and there is a significant relationship between knowledge and attitude towards arsenic contamination. An increase in knowledge leads to an increase in positive attitudes towards arsenic contamination. People with more knowledge about arsenic contamination are likely to have a positive attitude toward it. Knowledgeable people are more aware about the health risks associated with arsenic exposure. A deeper understanding of the consequences of arsenic contamination may bring a positive attitude to them.

Community Beliefs and Practices towards Arsenic Contamination

The beliefs portion of the survey consists of ten yes-or-no questions. The outcomes were assessed in percentages which reveal intriguing insights. A substantial 39% of respondents believe that a standard filter can effectively separate arsenic from water. A significant 45% hold the opinion that boiling water can remove arsenic. A notable majority, accounting for 60%, believes that arsenic poses no threat to animals. Unfortunately, 38% of those surveyed still believe that individuals with arsenic-related issues are burdens on both their families and society. A significant 62% majority believes that arsenicosis is a genetic disease. Additionally, 49% express a sense of safety by maintaining a distance from individuals suffering from arsenic-related conditions. Unfortunately, 33% of respondents still believe that guava leaves can purify water contaminated with arsenic. A substantial 38% of participants do not believe that arsenic can enter the human body through food. A considerable 46% of those surveyed express opposition to conceiving a child if one of the parents is an arsenic victim. Strikingly, 22% of respondents still think that people are affected by arsenic due to the wrath of God. These findings not only illuminate the diverse range of beliefs related to arsenic but also underscore the need for education and awareness on this issue.

The practices part of the survey also comprises ten binary items, requiring respondents to answer either "yes" or "no." These were analyzed similarly in terms of percentages, revealing significant insights into the issue. It was observed that 42% of the surveyed population unknowingly uses water contaminated with arsenic. This revelation underscores the need for urgent attention and intervention. A substantial 47% of respondents admitted that they are using arsenic-contaminated water for cooking, posing a direct health risk to those consuming such food. A staggering 65% of individuals use arsenic-contaminated water for irrigation, raising agricultural concerns and potential crop contamination. Approximately 65% of the population relies on arsenic-contaminated water for bathing and providing drinking water for animals, placing animal health in danger. A substantial 71% of the population indicated a lack of participation in discussions related to arsenic issues, potentially hindering progress on this concern. A significant 78% of respondents do not regularly test their drinking water for arsenic contamination, posing a grave concern for public health. Conversely, 92% of surveyed individuals express awareness and concern about the quality of drinking water for children and the elderly within their families. A substantial 60% of respondents reported the absence of any treatment facility for diseases caused by arsenic exposure, highlighting a critical gap in health care infrastructure. Half of the respondents (50%) rely on water from government-directed safe tubewells, suggesting a degree of trust in public infrastructure. Unfortunately, a significant 80% of surveyed individuals do not take the initiative to test their water quality by bearing the associated costs. These findings underscore the urgent need for education, infrastructure development, and community engagement to address this critical issue.

Organization of Awareness Programme

In addition to these efforts, three consecutive awareness campaigns were conducted at three B.Ed. colleges located in Nadia. The primary objective of these campaigns was to inform B.Ed. students about the ill-effects of arsenic contamination, as they are the future teachers. Fostering their awareness has the potential to make the entire community aware.

Strength & Limitations of the Study

The KAP study related to arsenic contamination is rare, so it is an important study. However, like other studies, it is also not free from its limitations. Firstly, self-administered questionnaires have been used in this study, which may cause social desirability bias. Secondly, the data collection was performed soon after the Corona pandemic, and so we suspect that this may reflect in the data. Finally, we had to finish the work within a limited time period due to economic constraints.

CONCLUSION

This research presented a comprehensive analysis of the knowledge, attitudes, beliefs, and practices of the local population in Nadia District, West Bengal, regarding groundwater arsenic contamination. It was found that while there was a reasonable level of knowledge about arsenic contamination among the population, significant differences in knowledge based on factors such as gender, age, education, occupation, and economic status were observed. Urban residents, males, older individuals, educated people, servicemen, and those with higher economic status generally have better knowledge about arsenic contamination. This highlights the importance of targeted educational campaigns and interventions to reach vulnerable groups. Attitudes towards arsenic contamination also varied among different demographic groups. Urban residents and those with higher education exhibited more positive attitudes. A positive attitude is associated with higher knowledge levels, which emphasizes the importance of education in shaping public perception and concern about the arsenic issue. This study revealed a range of beliefs related to arsenic contamination, some of which are unscientific and illogical. For example, a significant portion of the population believes that common filters can remove arsenic from water or that arsenic can be removed by boiling. Addressing these misconceptions through education and awareness campaigns is essential. Alarmingly, a substantial portion of the population continued to use arsenic-contaminated water for various purposes, including cooking and irrigation. This poses a direct health risk to the community. Additionally, the lack of regular water quality testing and limited access to treatment facilities for arsenic-related diseases underscore the urgent need for infrastructure development and public health interventions. This study found a positive correlation between knowledge and attitude, indicating that increasing knowledge levels can lead to more positive attitudes towards arsenic contamination. This highlights the potential impact of education and awareness programs on changing public perception and behavior.

Suggestion

In light of the findings of this study and previous researches on arsenic contamination, this section presents some recommendations aimed at mitigating arsenic contamination and its associated health risks. Immediate medical assistance and the distribution of arsenic-free drinking water are immediate requirements in the affected area. Organization of awareness campaigns and regular monitoring and testing of water are the other essential requirements. Implementation of low-cost arsenic removal plants is highly recommended. In this case, support from the community, government, and NGO initiatives is mandatory. Research on the arsenic issue must be encouraged.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Abbreviations

AAS Atomic Absorption Spectrometry
ANOVA Analysis of Variance
APL Above Poverty line
B.Ed. Bachelor of Education
BPL Below Poverty Line
IBM International Business Machines
KAP Knowledge, Attitude and Practice
MS Microsoft

NGO Non-Governmental Organization
OBC Other Backward Class
PHEDPublic Health and Engineering Department
SC Scheduled Castes
SES Socioeconomic Status
SPSS Statistical Package for Social Sciences
ST Scheduled Tribes
WHO World Health Organization

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