American Journal of Climate Change, 2024, 13, 599-610
https://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

Present Arsenic Status in Drinking Water and Its Impacts on Human Health: A Socio-Environmental Study on Villagers Living in Most Arsenic Prone Area in Bangladesh

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How to cite this paper: Uddin, Md. J., Paul, A., Ullah, Md. A., Akter, B., Hasan, Md. M., Sardar, Md. M., Hasan, Md. A., Golder, H., & Akter, I. (2024). Present Arsenic Status in Drinking Water and Its Impacts on Human Health: A Socio-Environmental Study on Villagers Living in Most Arsenic Prone Area in Bangladesh. *American Journal of Climate Change, 13,* 599-610.
https://doi.org/10.4236/ajcc.2024.134027

Received: November 1, 2024
Accepted: November 12, 2024
Published: November 15, 2024

Abstract

Bangladesh is an agricultural country facing severe natural hazards in recent times. This results in agricultural damage, ecological damage, economic damage and human health damage. Keshabpur upazilla, Jashore district is considered one of the most arsenic prone areas in Bangladesh. However, there was no research data found regarding presence of arsenic in ground water and its transfer to crops and impacts on human health. A questionnaire-based research was conducted to evaluate the present scenario of this area. However, two representative water samples were collected and analyzed. The data showed that 24% people didn't know about As, 27% people didn't know about arsenic effects on human health, 61% people depends on neighbor's deep tubewell (600 - 750 feet depth) for drinking water, 40% people depend on government-provided deep tubewell for irrigation water, 19% peoples are suffering water scarcity in dry season because groundwater level decreased at that time and people mostly suffered with fever. The other diseases were headache, diarrhea, vomiting, stomach ache, allergy, water pox and asthma. Doctors are providing general treatments but never try to find out the reasons based on As. Therefore, it is still unknown to them about which diseases are caused by As. Water analysis data showed that free CO_2, EC, BOD, NH_4^+, NO_3^-, Ca^{2+}, Mg^{2+}, As and Fe for drinking water and NH_4^+, NO_3^-, As and Fe for irrigation water were found to be higher than the DoE permitted safe water standards. The soil data collected from SRDI also supported the present research data. Continuous

irrigation with water builds higher concentration of Ca, Mg, Cu, Fe and Mn in the soil. Unfortunately, no data on As was found from SRDI. This research might work as a baseline research for policy makers and researchers to apply proper management plan in this area.

Keywords

Arsenic, Drinking Water, Toxicity, Health Hazards, Socio-environmental Impacts

1. Introduction

Arsenic is one of the most hazardous pollutants in Bangladesh (Islam et al., 2023b). The major source of arsenic is considered as natural but anthropogenic activity also increased arsenic concentrations in drinking water in recent times (Frisbie et al., 2024). To provide food for a huge population, farmers are using as much of their lands as possible for crop production. As a result huge amount of ground water is extracting every year. Besides, the extracted water does not fill through groundwater recharge. As a result, the groundwater table decreases every year, which changes the chemistry of the groundwater. Alternate wetting and drying release a huge concentration of arsenic into water. This water is used as drinking and irrigation purpose. Therefore, peoples are suffering with arsenic related health problems (Habib et al., 2024).

Arsenic is a metalloid and ubiquitous element considered as most toxic heavy metals in nature. The oxidation numbers of arsenic in environment are +5, +3, 0 and −3. However, the most available oxidation states in ground water are +3 and +5. Arsenic (III) is more toxic then arsenic (v). The most common diseases caused by arsenic are keratosis, melanosis, skin damage, skin cancer, nausea, vomiting, lung diseases, brain damage etc. (Uddin & Jeong, 2020). According to World Health Organization (WHO), arsenic is a carcinogenic element presents mostly in ground water. They provided the maximum permissible arsenic concentration is 0.01 mg/L. However, the Department of Environment (DoE) in Bangladesh set the maximum concentration limit is 0.05 mg/L. Because Bangladesh water contains more arsenic and if it will set to 0.01 mg/L then most of the water from shallow and deep tubewell will become unsafe for drinking purpose (Yunus et al., 2016). Most arsenic presents as arsenic pyrite (FeAsS) mineral form in the environment. These minerals are decomposed and release arsenic into the environment. The anthropogenic sources are, coal fly ash, electronic industries, ceramic and manufacturing industries, petroleum refining, sewage sludge, mining waste, ship breaking, textile industry, agricultural chemicals etc. (Hossain et al., 2023). Arsenic-rich parent materials formed soils with higher concentrations of arsenic. In addition, continuous application of arsenic-contaminated water increases the concentration of arsenic in soil. Phosphate (PO_4^{3-}) and arsenate (AsO_4^{3-}) are similar in chemical nature. Phosphorous is an essential element whereas arsenic is a

toxic element. AsO_4^{3-} compete with PO_4^{3-} and taken up by plants. Also, arsenic compete with silicon (a beneficial element) and taken up through silicon absorption tract into plant. Different morphological and physiological impact of arsenic is caused in plant and ultimately comes to human health. Every year millions of people suffering with arsenic related health problems owing to the consumption of arsenic contaminated food. Peoples drinking arsenic contaminated water are severely affected by it (Islam M.S. et al., 2023a; Rahman et al., 2023; Uddin & Jeong, 2020).

Jashore district is severely affected by higher concentrations of arsenic presents in ground water (Alam et al., 2003; Habib et al., 2024; Khan et al., 2016; Kumar Chakraborty, 2016; Shaibur et al., 2019; Sultana et al., 2013; Tani et al., 2012). A project report showed that more than 50% tubewell water was found contaminated with higher concentrations of arsenic (Bangladesh Archives, 2003). Considering that, government has established 1013 tubewells in Jashore and out of which only 125 tubewells were established in Keshobpur upazilla of Jashore district which is the target area of this research. Geographical location of Keshobpur upazilla is 22˚48' to 22˚58' N and 89.22˚E. The total area is 258.53 km^2, and about 253291 people live there. Total 62309 families are living in Keshobpur upazilla which divided with 144 villages and 11 unions. Five major rivers named Kopotakkho, Horihor, Burivodra, Srinodi and Vodra has crossed the area. Total land area is 25903 ha and total agricultural land is 21123 ha. Total number of tubewell is 420 which are for 62309 families. Keshobpur upazilla have an upazilla health complex where 17 doctors provide medical support. Beside this, about 17 village doctors are providing medical support from long time. Keshobpur has 21 bills which are considered nutrient rich area for crop production (Soil Resource Development Institute (SRDI), 2018). Therefore, Keshobpur is very much important agriculturally, socioeconomically and environmentally. However, very much limited data was found regarding arsenic pollution and its impact on human health in that area. In 2009, Begum was showed higher concentrations of arsenic in soil and irrigation water which is higher than maximum permissible limit in Bangladesh. Beside this, there was no data found for Keshobpur area (Begum, 2009). Therefore, the main objective of this research is to find out the present scenario regarding arsenic contamination and its health complications in Keshobpur upazilla through personal interview, group discussion and data collection from SRDI (Soil Research and Development Institute), DoE and Upazilla health complex. Finally, this research will draw a conclusion on overall situation and provide structured recommendation for emergency policy development.

2. Methods and Materials

The research was implemented to assess the present arsenic problem in the Keshobpur, Jashore (**Figure 1**). The geographic location is 22˚48' to 22˚58' N and 89.22˚E and total families living about 62309. About 400 families were covered under present research randomly. The research was conducted in January 2024.

This research was designed in three parts: (a) a field survey including data collection from different sources such as Soil Resource Development Institute (SRDI), Department of Public Health Engineering (DPHE) and other published literature was done to observe the previous information about the studied area, (b) based on the information, a questionnaire formed to collect present condition of arsenic problem, (c) one drinking water sample (Location: 22˚54'45"N and 89˚19'10"E) and one irrigation water sample (Location: 22˚90'55"N and 89˚32'91"E) was collected and determined the physicochemical parameters following standard methods (Huq & Alam, 2005; Jackson, 1958) and (d) finally a recommendation was made for researcher and policy makers to ensure smart environment of the studied area. The questionnaire study was done through personal interviews following a multiple methodological participatory rural appraisal (PRA) tools like single interview, focal group discussion and cross check interviews (CCI) with key informants (Uddin & Rajonee, 2016). Present arsenic status was evaluated from the recent report collected from upazilla health office and DoE. The environmental condition and soil information were collected from SRDI. Representative drinking and irrigation water samples were collected, determined, and compared with SRDI and DPHE data to determine the present arsenic status of that area. All analyses were done using standard methods (Huq & Alam, 2005; Jackson, 1958).

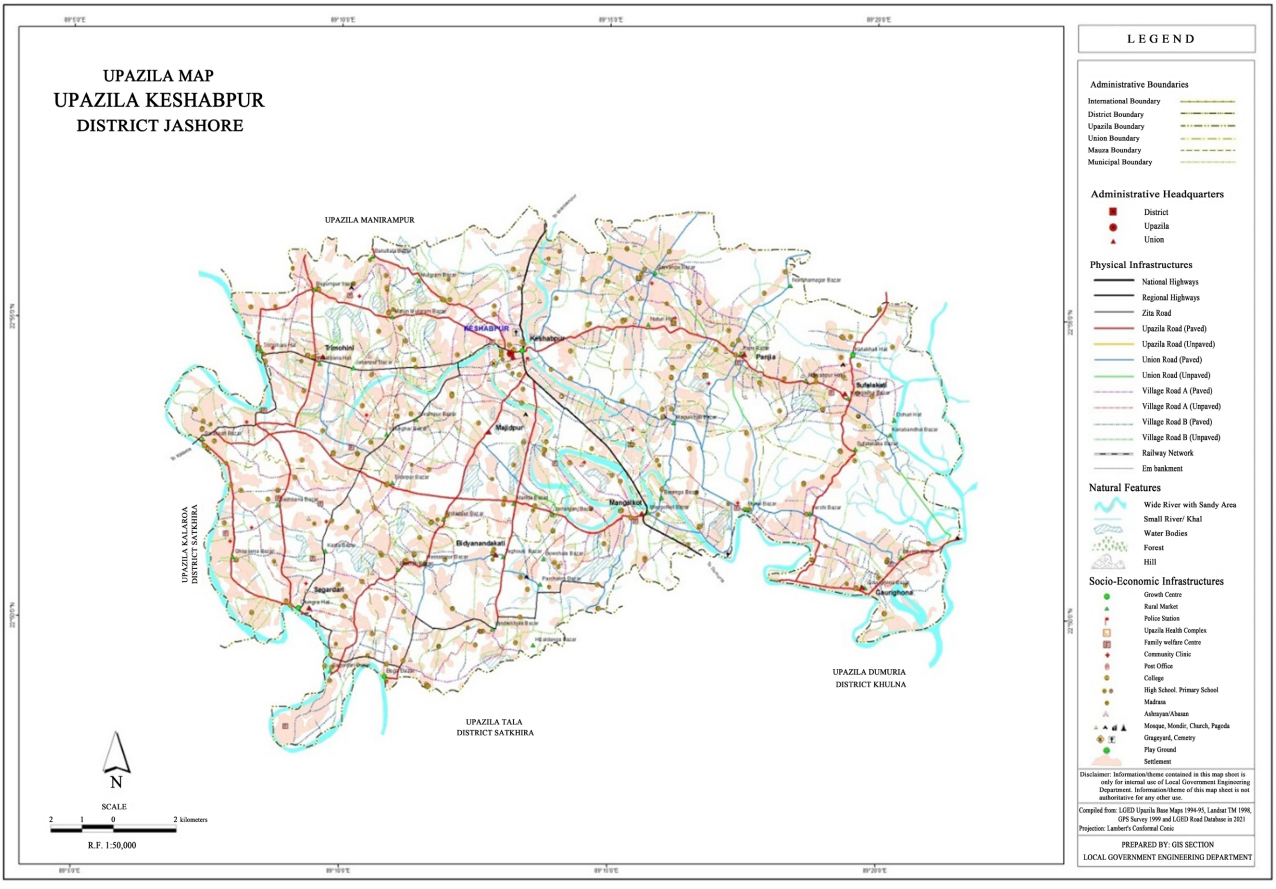

Figure 1. Keshabpur upazilla map.

3. Results and Discussions

The research area Keshabpur is surrounded by five major rivers. Also, there are 25 beels, 21 khals and 1 baor name "Morsina" in Keshabpur upazilla respectively (Bangladesh National Portal, 2024). Based on that, the area is ecologically and environmentally important for Bangladesh. A well-reputed daily newspaper named Prothom alo was published an article in 2021 based on the devastating situation of arsenic in Keshabpur upazilla. In this modern era, when Bangladesh has vision to become a smart country by 2041, peoples are living such miserable life in Keshabpur upazilla owing to arsenic in ground water (Prothom Alo, 2021).

3.1. Initial Condition of the Research Area

The questionnaire survey was covered about 400 families randomly in Keshabpur upazilla. Among the respondents there were 60% male and 40% were female (**Figure 2**). The respondents were classified in 4 groups based on age and higher (38%) respondents were from 25 - 50 years, respectively. Approximately 36% of respondents belongs to 50 - 75 years. Therefore, the research obtained experienced answers from these middle age and aged groups to compare present data with past condition in that area. Based on the data, 76% of respondents knew about arsenic in drinking water through television, newspaper, government's authority and different non-government organizations. However, approximately 24% respondents didn't know about arsenic and arsenic related health problems. Although, the portion is only 24% but it is also a major issue for future policy generation and management steps. The data showed that 73% respondents were known about arsenic related health issues. They were directly affected, and their neighbors were affected by continuous drinking of arsenic-contaminated water. Some were heard that peoples from other village were affected by arsenic. However, at present 27% respondent didn't know about effect of arsenic on human health.

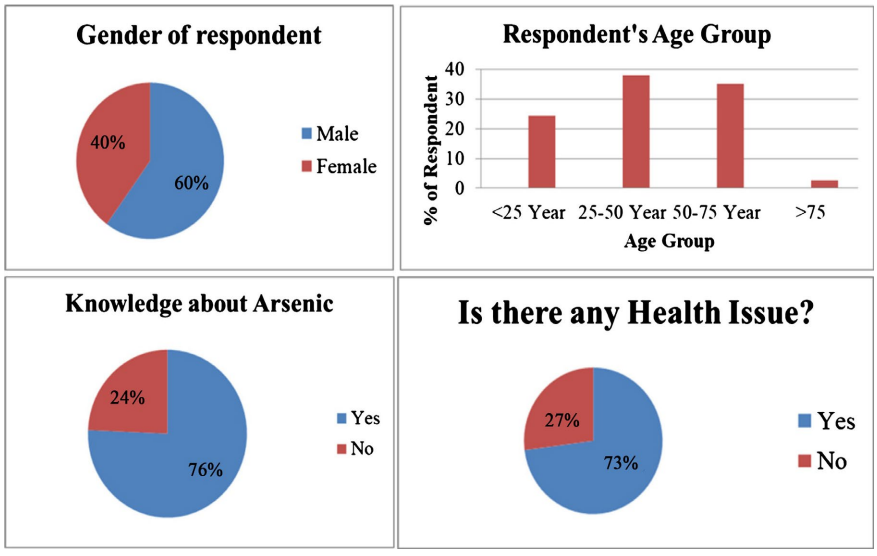

Figure 2. General information of the inhabitants participated in the survey.

3.2. Sources of Water and Its Effects

For drinking water, approximately 61% respondent depends on neighbor's tubewell, 28% using their own tubewell and 11% collecting water from government provided tubewell water. From the data, 65% respondents using deep tubewell water (depth: 600 - 750 feet) for drinking purpose and 35% respondents using shallow tubewell (depth: 100 - 270 feet) water for drinking purpose (Figure 3). Most of the people in this area live in families below the middle class or are almost poor. They cannot afford to install a deep tubewell for their consumptive use. An installation expanse of approximately 50000 BDT for a deep tubewell is very difficult for them to manage. As a result, they depend on neighbors who have deep tubewells. Most of the time in a day they were lined up to collect water for drinking use which takes so much time. Besides, to avoid such difficulties everyday, some peoples using arsenic-contaminated water for consumptive use which injurious for health. For washing, 86% respondents were using tubewell water and 14% respondents using pond water. The respondents were suffering different water-borne diseases from using pond water. The result showed that 40% of respondent were depends on government-provided deep tubewell water, 30% were use neighbors deep tubewell, 22% used surface water and 8% respondent were depends on personally installed deep tubewell water for irrigation purpose.

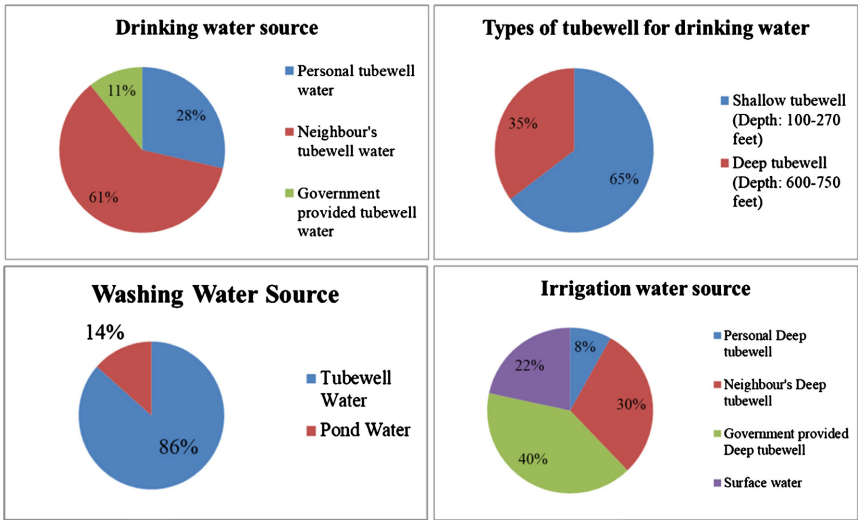

Figure 3. Sources of water.

3.3. Tubewell Water Status

Research data revealed that approximately 56% tubewell was established before 2010, 30% was established in 2010-2020 and 15% was established in after 2020 respectively (Figure 4). Deep tubewells were established mostly after 2020 based on the concern on arsenic toxicity. Almost 81% of respondents said that there was no water scarcity during the year. However, approximately 19% of respondents said that there is a water scarcity in last few years and the scarcity is mostly in dry season. This means that in dry season, some parts of Keshabpur upazilla already facing

water crisis which might be increase in future. Approximately 49% people think that the main reason of ground water scarcity is over extraction of ground water and less recharge of it. Other possible reasons are the filling up of ponds and khals, desertification, urbanization, sedimentation in rivers, and excess heat in recent years. About 76% respondents were believed that presence of arsenic in ground water is increased in recent times which might be increased higher in near future. However, there was no monitoring system in that area. The respondents said that in 2021, an arsenic test experiments was done by using arsenic testing kit and marked the tubewell which has higher arsenic concentration compared to DoE permissible limit. But there was no expert engagement in those tests. Only some students were involved in that test who has no knowledge on arsenic experiments and they just involved because of some money earning. Health office said that recently they will implement a project again to determine arsenic correctly. The question is "Are they able to determine ground water arsenic correctly?"

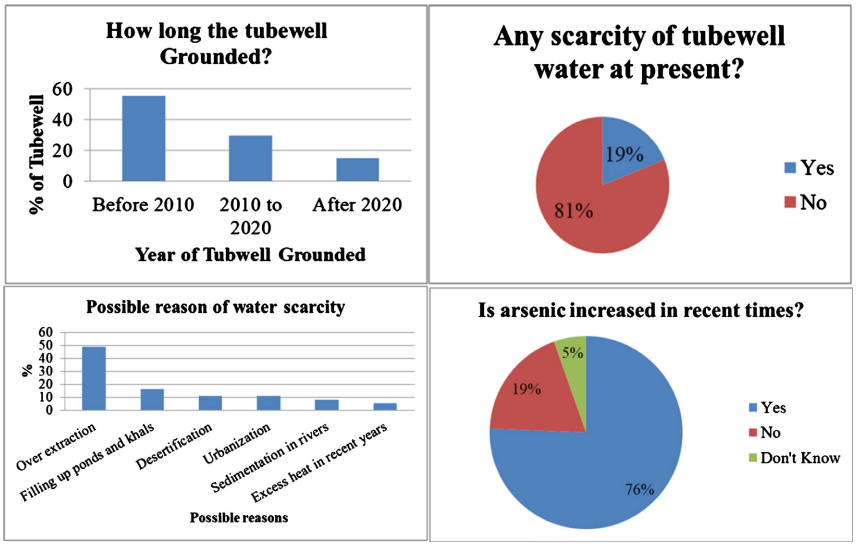

Figure 4. Present status and possible reasons of arsenic.

3.4. Physicochemical Properties of Ground Water Collected from the Studied Area

To evaluate the present status of drinking and irrigation water, two representative samples were collected. The drinking water sample was collected from a shallow tubewell and irrigation water sample was collected from a deep tubewell. The detailed physicochemical analysis of water samples were represented in Table 1.

Table 1. Physicochemical status of collected water samples from the studied area.

Water quality parameters	Drinking water	Irrigation Water	DoE standards	
			Drinking	Irrigation
pH	8.19	7.91	6.5 - 8.5	6.0 - 8.5
Free CO_2 (mg/l)	6.97	5.61	5.3	-

Continued

EC (μS/cm)	1005.00	920.00	600.0 - 1000.0	1200.0
TDS (mg/l)	500.00	460.00	1000.0	2100.0
DO (mg/l)	9.66	9.66	6.0	4.5 - 8.0
BOD (mg/l)	3.52	1.09	0.2	<10.0
Cl^- (mg/l)	143.0	136.0	150 - 600	600
NH_4^+ (mg/l)	63.0	30.24	0.5	3.0
NO_3^- (mg/l)	110.88	20.16	10.0	10 (mg/l) as N_2
PO_4^{3-} (mg/l)	5.0611	6.1601	6.0	10.0
SO_4^{2-} (mg/l)	11.51	3.93	400.0	1000.0
K^+ (mg/l)	5.67	6.29	12.0	-
Na^+ (mg/l)	29.24	36.35	200	-
Ca^{2+} (mg/l)	480.0	700.0	75.0	-
Mg^{2+} (mg/l)	68.14	66.47	30 - 50	-
As (mg/l)	0.13	0.06	0.05	1.0
Fe (mg/l)	9.11	8.66	0.3 - 1.0	1.0 - 2.0

Based on the research data, all the studied parameters except free CO_2, EC, BOD, NH_4^+, NO_3^-, Ca^{2+}, Mg^{2+}, As and Fe in drinking water were found lower than the DoE recommended drinking water quality standards. However, free CO_2, EC, BOD, NH_4^+, NO_3^-, Ca^{2+}, Mg^{2+}, As and Fe were found higher than the standards which means that the water is toxic for human health of that area. Continuous drinking of this toxic water may cause severe health injuries of the inhabitants living in this area. Besides, in case of irrigation water, NH_4^+, NO_3^-, As and Fe were found higher than the irrigation water standards (Begum, 2009). So, extensive research on water quality evaluation of this area is urgently needed to save the people from severe health injuries.

3.5. Effect of Arsenic on Human Health

Based on questionnaire data, the local inhabitants of Keshabpur upazilla are suffering headache, vomiting, allergy, fever, stomach ache, asthma, diarrhea and water pox in a year. Most of the people (36%) responded that they are suffering with fever (**Figure 5**). For treatment, the local inhabitants mostly go to the local doctors and sometimes go to the Upazilla health complex.

Under present research, local doctors and upazilla health complex doctors interview also taken. The local doctors giving treatment for a long time in that area and they said that there was no patient came with arsenic health injuries. They also said that common health problems are like fever, diarrhea, allergy, asthma, stomach ache etc. of treated patient. Some of them were cured and some of them were referred to upazilla health complex for better treatment. The doctors from upazilla health complex also said that they were never found any arsenic-affected people. Patients came to hospital mostly with diseases like fever, diarrhea, allergy, asthma, stomach ache, vomiting, food poisoning etc. However, they never suggested the patient for arsenic test in their body which might be causing their health

injuries. Therefore, it is still unknown about which diseases are causing in that area because of high concentration arsenic in drinking water.

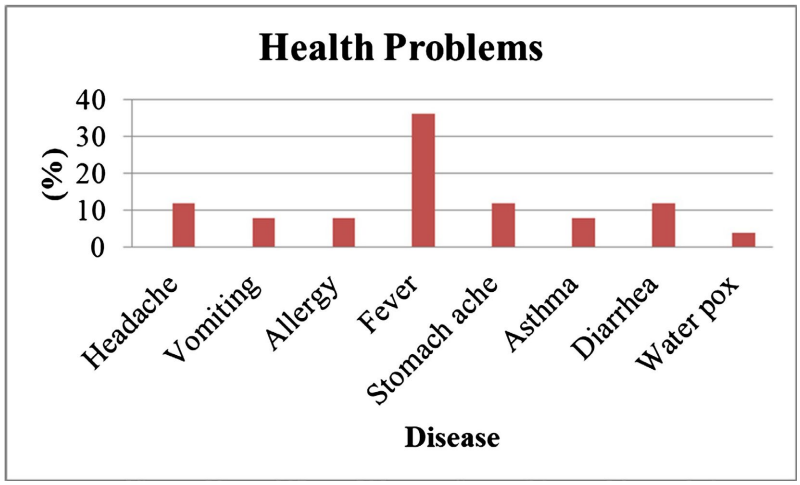

Figure 5. Diseases suffered by the inhabitants in a year of the studied area.

4. Collected Information's from Different Organization

According to Soil Resource Development Institute (SRDI), Jashore, the soils of Keshabpur upazilla is divided into 8 different soil families named Sara, Gopalpur, Ishwardi, Ghior, Ramdia, Narail, Harta and Satla. Physicochemical composition of these soils are like pH is 4.35 - 8.33, organic matter is 2.00% - 32.49%, EC is 0.84 - 15.10 dS/m, total N is 0.10% - 1.624%, P is 10.26 - 25.12 µg/g, K is 0.13 - 0.58 meq/100 g, S is 13.88 - 58.15 µg/g, Zn is 0.49 - 4.93 µg/g, B is 0.21 - 0.71 µg/g, Ca is 96.44 - 270.08 meq/100 g, Mg is 12.75 - 26.27 meq/100 g, Cu is 0.11 - 5.36 µg/g, Fe is 18.12 - 416.73 µg/g and Mn is 5.12 - 25.14 µg/g respectively (Soil Resource Development Institute (SRDI), 2018). They also analyzed the irrigation water and found that the water from Kopotakkho, Candra, and trimohini showed higher EC (2.9 dS/m; class: toxic), water from Beel, katakhali and Sufolakathi has EC 26.4 dS/m which is very much toxic, water from Kopotakkho river and Sagordari also showed higher EC (17.00 dS/m; class: very toxic) and water from Shallow tubewell, rejakathi and hasanpur showed EC 1.2 dS/m (class: toxic and other samples showed safe limit of EC respectively. Based on the data, it is confirmed that most of the area has higher concentration of Ca, Mg, Cu, Fe and Mn. In addition, the soils from Satla series are under low land area showed exceptionally higher organic matter content. The water sample analysis data under present research also found higher concentrations of Ca, Mg, Fe, As, NO_3^- and NH_4^+ respectively. The irrigation of this water continuously enhanced the respective elements concentrations in soil. The EC of drinking water under present found 1.005 dS/m which is toxic and EC of irrigation water is 0.920 dS/m which is also toxic. Therefore, data obtained under present research is well supported by SRDI soil data. Department of Public Health Engineering (DPHE) was provided the information that they did a survey on presence of As in tubewell water and measured

the water for As with a portable Kit. However, they said that they are not satisfied on the results because the survey was done by inexperienced personnel and simple kit which has low accuracy. So, they didn't want to provide the data. Therefore, it is a great concern now to apply relevant research project to extensive evaluation of As problem in Keshabpur upazilla.

5. Recommendation

Present research is a preliminary investigation of Keshabpur upazilla for As problem in this area. Based on the data, environmental hazards increased in recent times. The most alarming issue is the unavailability of ground water in dry-summer season. Most of the people are collecting drinking water from their neighbor's tubewell. Therefore, they are expending almost 3 - 4 hours for water collection. Peoples are suffering different health injuries but they don't know the actual reason of the injury. Viewing the data from present research, it is highly recommended that extensive evaluation of As in ground water, surface water, Fish, soil and plant is required in emergency basis. Additionally, installation of more deep tubewell is required so that peoples can collect water easily. Finally, inhabitants and doctors needed proper training and knowledge so that they can ensure safety for themselves. Most of the area was found to be saline, which is harmful to crop production. So, management of saline soil is required to ensure food security in this area. Beel soils are highly productive for rice cultivation. To ensure sustainability and smart agriculture, a salinity and arsenic management program is highly recommended for this area.

6. Conclusion

Keshabpur upazilla is agriculturally, ecologically and socioeconomically important area in Bangladesh. It composed of several beels, khals and one baors which are natural reservoir of water, fish and many ecological components. As the water transported huge sediment in this area, the soil from this area is highly productive with minimum agricultural cost. According to DPHE, most of the shallow tubewell water contains higher amount of arsenic. The local inhabitants also said that they use shallow tubewell water only for washing and cooking but for drinking they mostly depend on neighbor's deep tubewell. Installation of deep tubewell is highly expensive. So, most of the inhabitants cannot afford to install it. In this digital era, almost 24% of inhabitants didn't know about As which is a serious concern. Approximately 40% of inhabitants use government-provided deep tubewell water, and 30% use neighbor's deep tubewell water for irrigation. Approximately 19% inhabitants said that there is serious water scarcity which is 2 - 3 months long in dry season of this area. This means that desertification has begun and it might be increased in near future if a proper management plan is not applied. About 76% inhabitants said that the presence of arsenic in water has increased at present time which might increase to higher concentration in near future. The physicochemical analysis data showed that free CO_2, EC, BOD, NH_4^+,

NO_3^-, Ca^{2+}, Mg^{2+}, As and Fe for drinking water were found higher than the DoE permitted safe limit. Additionally, NH_4^+, NO_3^-, As and Fe were found higher than the irrigation water standards. The soil data from SRDI also supported the data found in present research. Therefore, considering present research data, a well-designed research program needed to apply in this area on emergency basis to find out the main reasons and present status so that proper management plan will be applied.

Acknowledgements

This research work is the part of BU-Project/2022-2023 funded by University of Barishal under the name Dr. Md. Jamal Uddin. We also want to acknowledge the Department of Soil and Environmental Sciences, University of Barishal for providing all kinds of logistical support during the research work.

Declaration

The authors confirmed that there was no known financial competing interest or personal relationship that could have appeared to influence the work reported in this manuscript.

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