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(RESEARCH ARTICLE)

Assessment of the tube-well water quality: A micro-level case study from Lower Gangetic Plain (LGP) in North 24 Parganas district, West Bengal, India

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Abstract

The purpose of this study is to investigate the quality of tubewell water (TW) in Barasat-I (Community Development Block) under North 24 Parganas District of Lower Gangetic Plain (LGP), West Bengal, India with respect to suitability for drinking purpose. This is the first micro-level ground water related study in this region. In total twenty (20) groundwater (GW) samples from tube-wells at different locations of nine (09) Gram Panchayats (GP) were collected and analyzed. The results have been compared with the Indian standard (IS) for drinking water based on eight parameters, such as pH, total dissolved solids (TDS), total suspended solid (TSS), conductivity, total alkalinity (TA), total hardness (TH), chloride (Cl), and arsenic (As). Moreover, TDS (50%) and Total Hardness (TH) (90%) were found to be above the desirable limit. However, pH, Chloride, has been found to be within the permissible limit. This micro-level study revealed that high contamination with arsenic of GW has been identified on the middle to eastern side of Barasat-I. As is found to be above acceptable limit at 70% sampling points. Therefore, rural people of the eastern side of the Barasat-I are prone to a higher risk of black-foot disease due to higher level of As. Overall, the groundwater in this block is not suitable and fit for direct drinking. It needs treatment to minimize pollution or contamination, where regular monitoring and analysis is recommended to determine the extent of contamination in the other parts of LGP. The findings of this study will be beneficial to manage and control ground water vulnerability in micro-level for water scientists, policy makers, and researchers as well in sustainable way and must be achieved by 2030.

Keywords: Ground Water; Lower Gangetic Plain; Arsenic; SDG-6; Drinking Water Quality; West Bengal

1. Introduction

Water below the land surface, both forms, unsaturated and saturated zones, is referred to as ground water. Groundwater is a very critical natural resource and plays a significant role in the economic progress, human's well-being and ecosystems because of its many inbuilt merits like good natural quality, consistent temperature, availability, less drought dependability and limited vulnerability [1,2]. Therefore, the practice of ground water use has increased significantly day by day [3]. Food production and water consumption are directly related to each other. Bouarfa and Kuper (2012) [4] explored that groundwater is deeply exploited to support the global food production. Worldwide, in total 111 million ha of land is irrigated using ground water resource out of 300 million ha land [5]. Moreover, ground water is difficult to observe and track directly, so that monitoring and mapping are crucial to its shared and sustainable uses.

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Several researchers have worked on ground water quality valuation and related health problems using different methods in diverse parts of the world. Yin et al., (2020) [6] and Teixeira et al (2020) [7] has examined the ground water contamination status of north China and Brazil, respectively. Bodrud-Doza et al. (2019) [8] worked on ground water contamination in terms of trace metals in central west part of Bangladesh. Sunkari et al. (2022) [9] and Dehghani et al (2019) [10] reported the fluoride contamination and human health risk in Ghana and southern Iran, respectively. South-east asian countries suffered immensely by arsenic contamination due to high population density and exposure of arsenic in ground water aquifers [11]. The concentration of heavy metals such as fluoride and arsenic are too high in the southern GBM region of India and Bangladesh in comparison to the other coastal areas of the world [11]. Such increasing contamination in ground water also shortened the stock of fresh drinking water in the aquifer day by day in the GBM region.

Moreover, in India, 92% groundwater extracted is used in the agricultural sector, whereas the consumption in industrial and domestic sectors are 5% and 3%, respectively [12]. Although, surface water is easily available, ground water is preferable because of the following reasons. First of all, ground water is tended to be less polluted and secondly, there are more availability of ground water than surface water during the drought period of any area [13]. But with the period of time, human population increased rapidly and impact on the ground water quality i.e. increased the ground water pollution [14, 15]. Ahamed (2013) [15] reported that 85% of rural drinking water supply depends on ground water in India. But in the present days, different reports have identified distinct major sources of ground water pollution, such as unscientific land filling, accidental spills, agricultural waste etc. [16]. So that, it is essential to analyze the ground water quality in the village or block level for the safety of human health and to achieve the SDG-6 (Clean water and sanitation) by 2030.

The preliminary survey revealed that most of the people in Barasat-I CD block (present study area) of north 24 pargana district are not using the tube-well water as drinking water purpose although there is a sufficient quantity of tube-wells are there. In this context, it was important to examine the tube-well water quality for drinking purpose. 20 tube-wells have been chosen from the nine-gram panchayat of Barasat-I block for this study. In this background the following micro-level study was conducted at Barasat-I CD block (as a pilot study) to determine the prevalence of contamination of the tube well water and the possible factors associated with it in this area.

Eventually, bearing the facts in mind, the primary goal of the work is to identify the sensitive areas of aquifer contamination in Barasat-I block. This study may also be useful in comparative discussions with other areas of the Lower Gangetic Plains (LGP) in the future. Moreover, this is the first block level in-detail study of ground water quality of north 24 parganas district regarding drinking water.

2. Material and methods

Barasat I is a community development block that forms an administrative division in the Barasat Sadar subdivision of North 24 Parganas district in the Indian state of West Bengal. Barasat I CD Block is bounded by Deganga CD Block in the east, Barrackpore II CD Block in the west, Habra I, Habra II and Amdanga CD Blocks in the north and Barasat II CD Block in the south [17]. As well as, this block is a part of the LGP or north Hooghly flat. Barasat I CD Block has an area of 104.97 km^2. It has 1 panchayat sanity, 9 gram panchayats, 152 gram sansads (village councils), 81 mouzas and 81 inhabited villages [17]. As per 2011 Census of India; Barasat I CD Block had a total population of 294,628, of which 1,75,226 were rural and 1,19,402 were urban [17].

As mentioned above, 20 tube-wells have been chosen from the nine-gram panchayat of this block for this purpose (Fig. 1, Table. 1). All the water samples were collected from the pre-decided tube wells. A short survey was also conducted with the local peoples regarding the installation and maintenance of the following tube wells. Mobile app -Live Mobile Location is used to record the co-ordinates of the tube-wells during sampling.

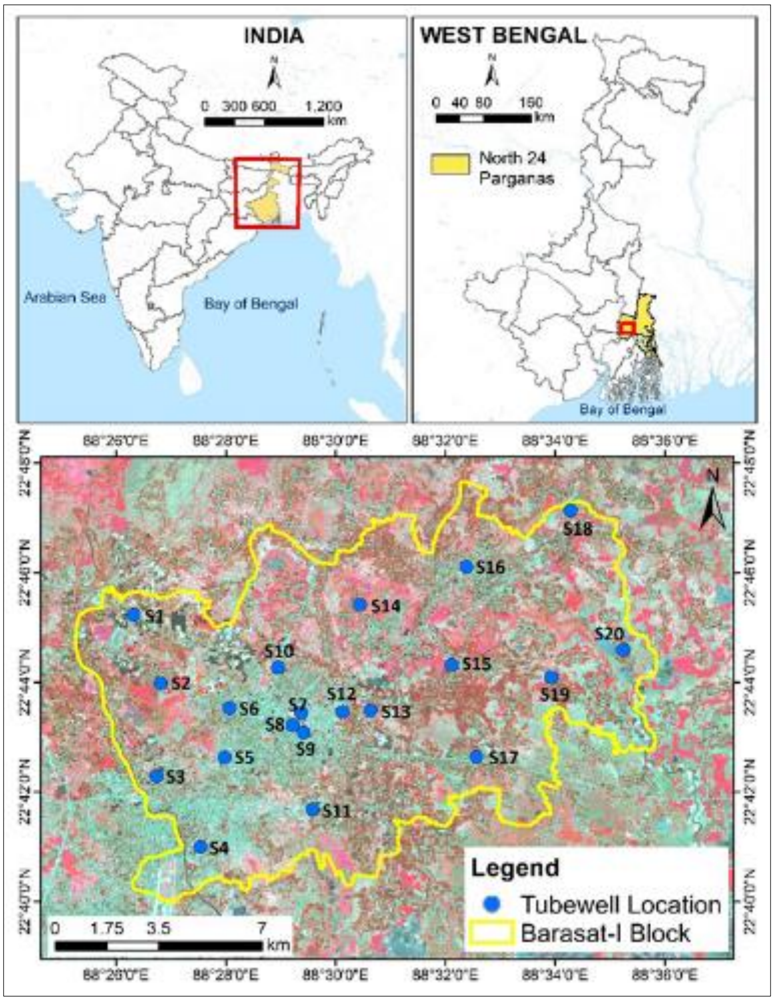

Figure 1 Study area map of Barasat-I showing the sampling points

Tube wells were chosen by random sampling. After proper hand cleaning, pumping out the water from tube well for at least one minute, water from the tube wells were collected and capped in a sterile capped plastic container. A similar process was followed for collecting all water samples. On the same day the samples were brought to the Department of Chemistry laboratory of University for subsequent testing.

Eight water quality parameters (e.g. pH, Total dissolved solid (TDS), Total suspended solid (TSS), Conductivity, Total alkalinity (TA), Hardness, Chloride (Cl) and Arsenic (As) were measured from each water sample.

pH and Conductivity have been measured using digital pH meter (Systronic-335) and digital conductivity meter (Model no. LMCM-2, Made: Lab Man Scientific Instrument). EDTA-Titrimetric method and Argentometric method has been used to analyze and record the hardness and chloride of water, respectively [18]. Similarly, TA and TSS has been measured by using acid-base titration and gravimetric method, respectively [18]. Moreover, TDS have been recorded by using digital conductivity meter (Model no. LMCM-2, Made: Lab Man Scientific Instrument) and optimized leucomalachite green method has been used to measurement arsenic (As) concentration in the water samples [19]. All the GIS maps are prepared using ArcGIS 10.5 software.

Table 1 Details of the sampling points with average ground water level in the Barasat-I block, North (24) Pgs, West Bengal, India.

Sample No.	Lat (N)	Long (E)	App. Depth of tube-well in present study (*MBGL)	Depth of ground water level (m) shown in other recent articles
S1	22.7106	88.5427	10	The average depth of ground water level in Barasat-I and Barasat-II is reported (2-8 m) (Paul and Das, 2021)
S2	22.7349	88.5655	10	
S3	22.7386	88.5352	8	
S4	22.7239	88.4895	8	
S5	22.7378	88.4824	10	
S6	22.7104	88.4662	5	
S7	22.7047	88.4455	10	
S8	22.7180	88.4902	10	
S9	22.7255	88.4677	8	
S10	22.7538	88.4386	8	
S11	22.7569	88.5072	10	
S12	22.7243	88.5021	8	
S13	22.6946	88.4929	8	
S14	22.7684	88.5396	5	
S15	22.7329	88.4468	5	
S16	22.6833	88.4588	8	
S17	22.7432	88.5872	8	
S18	22.7247	88.5105	8	
S19	22.7202	88.4868	5	
S20	22.7856	88.5712	8	

*MBGL stand for Meter Below Ground Level

3. Results and discussion

35% of the tube wells studied were installed by respective panchayats and rests (65%) were installed by the local people (private ownership). Majority (80%, 16 out of 20) of the tube wells installed more than ten years ago required repairing. While most (70%) of the tube wells provide water throughout the year, rests (30%) do get dry during the summer season. Local people are using this water for other household purpose but not for drinking. Table 1 is also showing the average aquifer depth of the sampling sites. We have used the traditional knowledge of the locality to get approximate aquifer depth of the sampling site. We have found minimum three elderly persons on that locality and used a short questionnaire to know the number of pipes bored during the installation of that particular site and calculate the approximate depth of the aquifer. There is no history of inundation as the present block is not flood prone. As told by the user, the water from all the tube wells was used for household purpose except drinking. No tube-well water is used for drinking purpose due to strong bad odor and taste. Fig. 2 shown the land use and land cover (LULC) map of north (24) Pgs district.

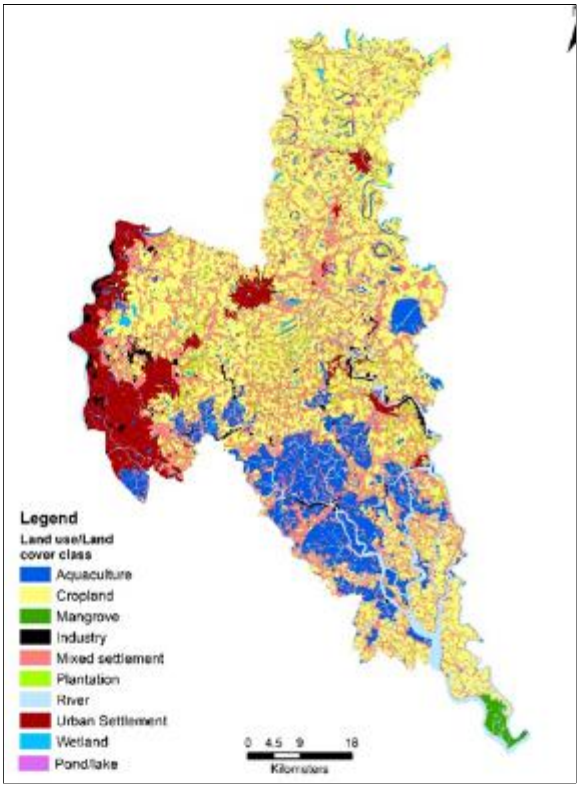

Figure 2 Land use land cover map of north 24 Pgs district, West Bengal, India

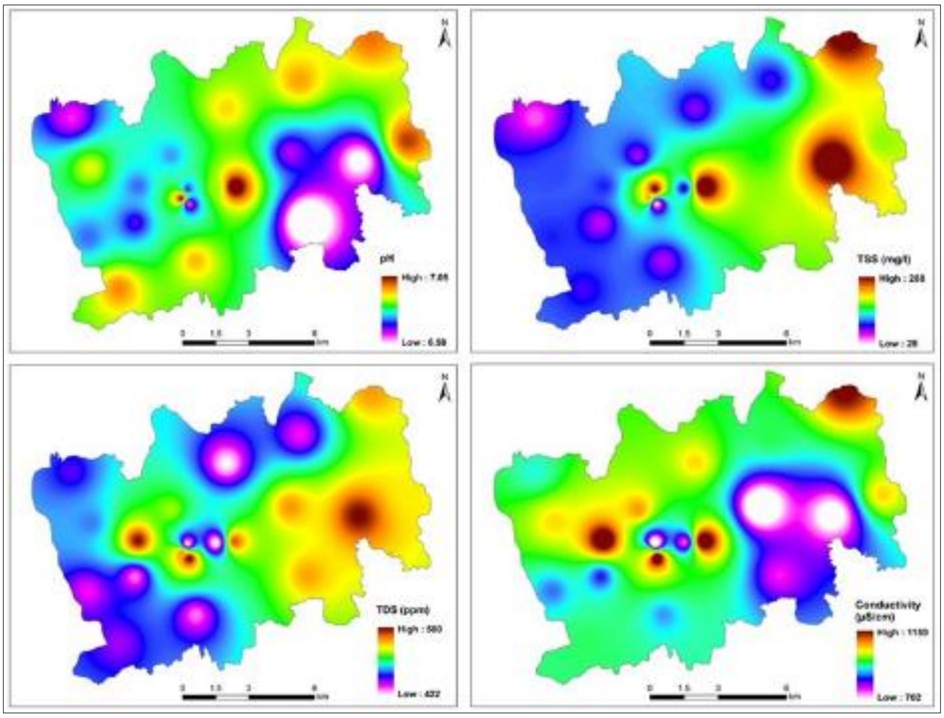

Figure 3 Distribution of pH, total dissolved solid (TDS), total suspended solid (TSS) and conductivity in tube-well water along the Barasat-I block.

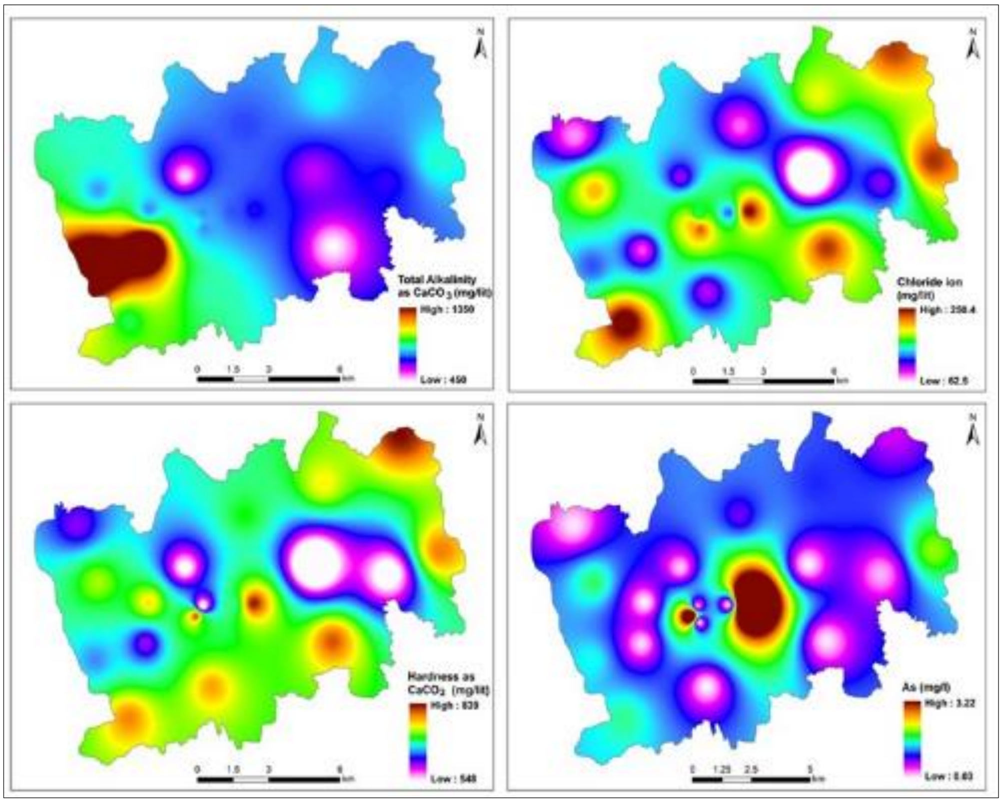

Figure 4 Concentration of total alkalinity (TA), total hardness (TH), chloride (Cl) and arsenic (As) in tube-well water along the Barasat-I block

The result depicted that pH ranged from 7.05 (S18) to 6.58 (S1) at Barasat-I with an average value of 6.85 (Fig. 3). The average TDS is 499.1 ppm, the highest and lowest value shown in S8 (580 ppm) and S12 (422 ppm), respectively (Fig. 3). Similarly, the average TSS value is 132.2 mg/L (range: 288-25 ppm) (Fig. 3). However, the average concentration of conductivity and hardness are 950.6 µS/cm (range: 1159-702 µS/cm) and 741.2 mg/l (range: 839-548 mg/l), respectively (Fig. 3 and Fig. 4). The average TA value of the Barasat-I area is 703 mg/l (range: 1350-450 mg/l) (Fig. 4). The Cl ion concentration was 177.3 mg/l, whereas the maximum and minimum values were 250.4 and 62.5 mg/l, respectively (Fig. 4). Moreover, the result portrayed that As value range from 3.22 mg/l (highest value in S18) to 0.03 mg/l (lowest value in S8) at Barasat-I area with an average value of 0.44 mg/l (Fig. 4). After the segmentation of all sampling points into western (S1-S12) and eastern (S13-S20) side, it is shown that the average value of As of western and eastern sides were 0.11 mg/l and 0.93 mg/l, respectively. Similarly, average value of pH, TDS, TSS, conductivity, Hardness and chloride are 6.76, 497.4 ppm, 116.58 mg/l, 908.33 µS/cm, 696.1 mg/l and 152.3 mg/l in western side (S1-S12) and 6.97, 501.62 ppm, 155.5 mg/l, 1014.0 µS/cm, 808.8 mg/l and 214.7 mg/l in the eastern side (S13-S20) of Barasat-I. Whereas average TA concentration is 718.1 mg/l and 680.3 mg/l in the western and eastern side, respectively. Moreover, As concentration is higher in eastern side (0.93 mg/l) than western part (0.11 mg/l) of the present study area.

This study was conducted in the selected tube wells of Barasat-I block of north 24 Parganas to evaluate the ground water quality. Attempts were also made to identify the factors responsible for ground water quality. In that regard, the tube well and its surrounding environment-related factors as well usage practices were assessed.

The Table 2. shown the year-wise depth of Ground water level at Barasat-I (in MBGL) [20]. These data showed an alarming situation of ground water level of Barasat-I because ground water level decreased 90.62% and 196.76% during pre-monsoon and post-monsoon season during the time period of 2001 to 2013, respectively. The present study has been occurred during pre-monsoon season of 2022 (month of March). Surprisingly, the present study revealed that the avg. MBGL is 8 for the studied 20 sampling tube well during installation timely.

pH is the most important and traditional water parameter from the primitive time scale of water quality measurement. However, several research articles showed that pH values having the capacity to impact on the chemical and biological reactions in the environment. The pH value of the present ground water study was slightly acidic nature (with in the range of 6.58-7.05) in 90% sample waters with the mean value of 6.85 (Fig 2). According to BIS (2012) [21], the standard pH value is 6.5 to 8.5 for drinking (Table 3) water which was not violated by any samples. But 50% of the sample is in the range of 6.5-6.8 which must be scrutinize very carefully in near future. Moreover, the study depicted that pH is lower in value in the western than eastern side. Whereas the Barrackpore industrial area is in the western side of the present study area and the eastern side of Barasat-I is agricultural land. There might be the industrial wastewater effect on the western side lowering the pH slightly.

Table 2 Year-wise depth of Ground water level at Barasat-I (in *MBGL) (Source: District Survey Report, North 24-Parganas District, 2018)

Year	Pre-Monsoon (Ave.)	Post Monsoon (Ave.)
2001	6.4	3.09
2002	7.41	3.4
2003	6.84	3.5
2004	7.45	4.16
2005	7.45	4.3
2006	8.33	4.81
2007	8.09	4.16
2008	7.25	4.24
2009	7.36	4.63
2010	12.09	10.41
2011	12.1	9.2
2012	11.7	9.82
2013	12.2	9.17
Present study	Avg. 8 MBGL for studied 20 sampling tube wells during installation time (traditional knowledge)	

*MBGL stand for Meters below ground level

According to APHA (2005) [18], TDS may have an adverse effect on water quality in several ways. Here the variation of TDS was almost similar to EC. 50% of water samples exceeded the standard for drinking water [21] considering TDS. EC indicated the total concentration of the ionized constituents present in water and it had a positive correlation with TDS. Waghmare et al. (2012) [22] showed that EC is proportional to its dissolved mineral matters in water. Moreover, EC is an indicator of presence of excess ion in polluted water. Several studies described that EC value is lower in the non-polluted water than polluted water sites [23, 24]. The present study also showed the highest value of EC (1159 µS/cm) (Fig. 3) like as TDS value in S8 site which belongs to western side of the present study area near to Barrackpore industrial zone. Their trends also demonstrated that the ion concentrations were higher in the western part of the study area (Fig. 3).

Measuring TA is important in determining the ability of water to neutralize acidic pollution from wastewater. It is considered the sensitivity of the water to acid inputs. 90% of the water samples showed higher than 500 mg/l as $CaCO_3$ (Fig. 3, Table 3) which means ground water of the present study area is good enough to combat with acidic pollution.

If ground water is an industrial or drinking water source, hardness can present problems in the water treatment process. Hardness must be removed before certain industries can use the water. For this reason, the hardness test is one of the most frequent analyses done by facilities that use water. According to BIS (2012) [21] the acceptable limit of Hardness is 300-600 mg/l for drinking water purpose. The present study revealed that 19 water samples out of 20 exceed the acceptable limit of hardness. So that, the tube well water of the present study region is not good enough to use for drinking water purpose regarding hardness.

Table 3 Indian standard specifications for drinking water:10500-2012 (BIS 2012)

Parameters	**Desirable Limit**	**Probable Diseases due to high consume of contaminated water**
pH Value	6.5 to 8.5	One of the main concerns with acidic water is that it often contains high amounts of heavy metal
Total Hardness (as CaCO3) mg/l	300-600	Significant etiological factor around the globe causing many diseases such as cardiovascular problems, diabetes, reproductive failure, neural diseases, and renal dysfunction
Chloride (as Cl), mg/l	250	Hyperchloremia
TDS (ppm)	500	Nausea, lung irritation, rashes, vomiting, dizziness and might be Cancer
Arsenic (As) mg/l, Max.	0.05	Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions (black-foot disease)

The environmental impact of higher chloride not usually directly harmful to human health but higher level of chloride in drinking water give a salty taste, damage household appliances, inhibit the growth of vegetation if used for agricultural field. The acceptable limit of chloride is 250 mg/l. In the present study, the only one water sample (S16) exceed the acceptable limit.

Arsenic (As) is a highly toxic human carcinogen and drinking water contaminant present in many aquifers in north 24 parganas district of West Bengal. Singh et al (2015) [25] identified the major sources of As pollution and NABARD (2016) [26] showed the usage of chemical fertilizer increased dramatically during the time period from 1950 to 2016 in north 24 parganas district. Moreover, Islam and Mostafa (2021) [27] described the higher contribution of As from chemical fertilizer in the Bengal delta plain. The present study showed that 14 sampling point exceed the acceptable limit (according to BIS (2012) [21] 0.05 mg/L, Table 3) of As regarding drinking water purpose. The average As concentration of eastern and western, both side, exceed the acceptable limit, although middle portion to eastern side of the present study area (Fig. 4) having the more higher trend of As concentration. Several researchers worked on the As pollution of the ground water of north 24 district and described the higher rate of As pollution [28, 29, 30, 31, 32, 33]. Paul and Das (2021) [34] also described the same trend (higher in eastern side) of As contamination in the Barasat-I block similar to the present study. As mentioned above, agricultural activities are higher in the eastern part of the present study region. Therefore, agricultural waste might be the probable anthropogenic cause to find higher concentration As in the ground water in the eastern part of the present study area. Moreover, the present study also revealed that avg. MBGL is lower (6.875) at eastern side than western side (8.75). The above-mentioned natural cause might be the effect of getting more As value at Eastern side. A very recent study by Biswas et al (2023) [35] also revealed the range of 0.64-0.01 μg/L and 0.98-0.001 μg/L arsenic concentration while working on the coastal area of GBM India during dry and wet seasons.

The present study depicted the block level (Barasat-I) distribution map of different water quality parameters regarding drinking water purpose (Fig. 3 and Fig. 4). The block level ground water pollution map will be a very good source to find out the drinking water potential zone in the micro level or village level. Moreover, block level ground water quality map will be a unique technique to achieve the sustainable ground water practice by 2030. Finally, the distribution map of different water quality will help us to choose the proper site for tube well installation or digging and which will be sustainable way for good water practice. The present assessment showed a good initiation of microlevel research throughout the LGP and would prepare the block-wise ground water quality map.

4. Conclusion

In the present day, an important chemical hazard in drinking water arise from metals like arsenic and fluoride etc. Several geologic proceedings and anthropogenic activities are the chief cause for high exposure of arsenic and fluoride in the ground water aquifers. The ground water aquifers of LGP are highly vulnerable due to high concentration of trace elements such as arsenic which contaminated the fresh drinking water and adversely impacted on ground water ecology, and finally impact on human health. Hence, the assessment and evaluation of ground water quality should be done to know the overall condition of aquifer. In this study, we have assessed the overall condition of ground water in Barasat-I block of north 24 parganas district.

The present study assessed that As value range from 3.22 to 0.03 mg/l at Barasat-I area with an average value of 0.44 mg/l (Fig. 4). After the segmentation of all sampling points into western (S1-S12) and eastern (S13-S20) side, it is also depicted that the average value of As of western and eastern sides were 0.11 mg/l and 0.93 mg/l, respectively during dry season. The average values shown that ground water of eastern part of the present study area is not safe for drinking during dry season. Lack of proper implementation of government policies, lack of awareness among the local people, and over exploitation of GW unscientifically has been increased the As, contamination rate of groundwater aquifer in LGP. One of the important findings of the present study is lowering the ground water level in Barasat-I block. Our result shown that 30% of the tube well installed during the last ten years do get dry during dry season. The findings of this study will be helpful to the disaster management authorities, environmentalists, policy makers, water scientists and local administrative authorities to take some preventive steps for managing and monitoring the block wise ground water resource in LGP.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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