Environ Dev Sustain (2019) 21:2097–2111
https://doi.org/10.1007/s10668-018-0125-z

Drinking water quality problem in Haryana, India: prediction of human health risks, economic burden and assessment of possible intervention options

Ruchi Gupta[1] · **Anil Kumar Misra**[2]

Received: 8 January 2018 / Accepted: 3 March 2018 / Published online: 6 March 2018

Abstract The present study was carried out in Jhajjar district of Haryana state, India, to understand the burden of diseases due to consumption of contaminated drinking water. About 630 respondents in villages, namely Kablana, Talao, Shekhupur Jat, Hassanpur, Babra and Kheri Asra, were interviewed for the quality of water they consumed from different sources such as government supply stations, hand pumps, tube wells, tanks, etc., and its overall impact on their health was analysed. The study considered both geogenic and anthropogenic contamination in drinking water sources and found that nearly 15% of the sampled population suffered with water-related health issues, of which 6% faced frequent episodes of stomach infection, and 9% were detected with mild to moderate dental fluorosis. Several cases of stones, severe joint pain, and backbone pain were also observed. The average medical expenses incurred by the villagers are in the range of Rs. 1000–2000 per month (approximately $17–$34 per month) for treatment owing to drinking of polluted and contaminated groundwater. Overall finding of the study indicates that unavailability of treated water supply, usage of groundwater with high to very high concentration of geogenic contaminants in groundwater such as fluoride and salinity, and use of water from open surface water resources are causing health problems to people in Jhajjar district. Use of contaminated water is causing economic burden to the villagers in terms of expenditure on health or water treatment by various means, which can be addressed by implementing various in situ and ex situ water management and treatment techniques suggested as intervention options, suitable for the study area.

Keywords Drinking water quality · Dental fluorosis · Diarrhoeal diseases · Economic burden · Intervention options

✉ Anil Kumar Misra
anilgeology@gmail.com

[1] Department of Civil and Environmental Engineering, The Northcap University, Gurgaon, Haryana, India

[2] Department of Geology, School of Physical Sciences, Sikkim University (A Central University), 6th Mile, Samdur, P. O. Tadong, Gangtok, Sikkim 737102, India

1 Introduction

The impacts of consuming contaminated water on health are well known but highly ignored by people especially in rural areas. Worldwide, infectious diseases such as waterborne diseases are the number one killer of children under 5 years old and more people die from unsafe water annually than from all forms of violence, including war (WHO 2002). Surface water is highly affected due to change in living styles, urbanisation and misuse of the resources, while groundwater is deteriorating due to the uncontrolled over drafting and natural and anthropogenic contamination. In totality, both surface and groundwater resources are severely contaminated and thus need immediate attention.

In India, majority of the rural population depend on groundwater for drinking purposes, and thus consumption of contaminated groundwater may cause serious health problem. As per Central Ground Water Board (CGWB) report, about half of India's groundwater is contaminated, as many as 276 districts have high levels of fluoride, 387 districts report nitrates above the safe levels and 86 districts have high levels of arsenic (CGWB 2007). Another report of WaterAid indicates that about 37.7 million Indians are affected by waterborne diseases annually, and 66 million Indians are at risk due to excess fluoride and 10 million due to excess arsenic in groundwater (Khurana and Sen 2008).

Jhajjar district of Haryana is part of the Indo-Gangetic Plain; thus, majority of the area of the district is covered by Gangetic alluvial deposits of the quaternary period comprising gravel, sand, silt, clay and kankar in various proportions (Misra and Mishra 2006). The groundwater studies carried out in the district showed the presence of high concentration of contaminants such as fluoride, chloride, salinity, TDS, etc. (Yadav and Lata 2003; Yadav et al. 2009; Gulab 2014; Gupta and Misra 2016). The Haryana Groundwater Yearbook 2016 also mentioned the role of geogenic factors in continuous deterioration in groundwater quality of Jhajjar district and indicated the range of various parameters as, fluoride—0.37–6.86 mg/L, chloride—20–2345 mg/L, nitrate—0.2–876 mg/L, sulphate—14–728 mg/L, hardness—159–2610 mg/L, etc. (CGWB 2016). Studies also show that industrial activities and minerals in sedimentary and crystalline rocks have an important role in escalating groundwater fluoride concentrations; moreover, fluoride occurrence has positive correlation with Na and HCO_3- concentrations and negative correlation with Ca^2+ (Martins et al. 2018). Further granite rocks also play a major role in increasing the fluoride concentration in groundwater owing to the dissolution of minerals (Craig et al. 2018; Abiye et al. 2018). Besides that groundwater–sediment interaction long residence time and changes in facies (Ca–HCO_3 to Na–HCO_3) during groundwater flow regime are also the factors which can increase fluoride concentration in groundwater (Raj and Shaji 2017).

The present study was carried out in Jhajjar district, where groundwater is the main source of water for domestic as well as irrigation purpose that is not suitable for use owing to high to very high concentration of fluoride and salinity. Water is the most important component of life; therefore, protection of water resources is essential for our own protection. In this regards, a study was carried out in Jhajjar district to understand the status of quality of drinking water and awareness amongst the villagers about the quality of water they are consuming. The broad objectives of the present study are to find out (a) health impacts of drinking contaminated groundwater in Jhajjar district, (b) medical expenses borne by people in case of health problems associated with drinking water, (c) methods or products use by people to avoid the drinking water contamination and (d) willingness to pay (WTP) for improved quality of drinking water.

This study will be useful to understand the health problems associated with drinking water quality in the rural areas of the country and will suggest suitable and affordable in situ and ex situ methods to improve the quality of groundwater.

1.1 Hydrogeological conditions of study area

Jhajjar district is the part of eastern Haryana plain, which forms a part of the Indo-Gangetic Plain stretching between 28°22′ and 28°50′ north latitudes and between 76°17′ and 76°58′ east longitudes. Most part of the district is covered by Gangetic alluvial deposits of quaternary period comprising gravel, sand, silt, clay and kankar in various proportions (Misra and Mishra 2006). The geological formations belong to Pleistocene to recent period and represented by major rocks such as boulders, pebbles, different grade of sands, silt–clay. These rocks form the major part of the potential aquifer zones. Based on the formation characteristics and hydraulic properties to store and transmit ground water, Jhajjar district can be considered hydrogeologically an area of unconsolidated formations having the primary porosity (Jha and Sinha 2007).

The study of borehole data generated by the CGWB indicates that the clay group of formations dominates over the sand group in the district. The lithological correlation clearly indicates the presence of clay layer at the top of the surface. Granular zones that occur are interbedded with clays in alluvial formations form the principal ground water reservoir (CGWB 2013).

1.2 Groundwater quality in Jhajjar district

The groundwater quality in entire Jhajjar district varies with aquifer depth. Groundwater salinity and high concentration of fluoride in aquifers is a major problem. For entire district, fluoride and salinity maps for shallow and deep aquifers were developed based on the groundwater quality analysis performed in shallow and deep aquifers during present study and data obtained from CGWB, Agriculture Department, Jhajjar and Public Health Engineering Department. The groundwater quality in shallow and deep aquifers for entire Jhajjar district is shown in Figs. 1, 2, 3 and 4.

Figure 1 shows the concentration of fluoride in shallow aquifers of Jhajjar district. In majority of the area, it is higher than the maximum permissible limit of 1.5 mg/l. There are several reasons for high concentration of groundwater fluoride in this area, like excessive extraction of groundwater for irrigation and domestic use, utilisation of fertilisers, industrial activities and geogenic factors.

Figure 2 shows the fluoride concentration in deep aquifers. The finding of the study has revealed that in shallow aquifers, fluoride concentration is more as compared to the deep aquifers. Since shallow aquifers are the main source of water used for domestic purposes in Jhajjar district, owing to which dental fluorosis and other diseases related with groundwater quality are spreading at fast rate in this area. Further, untreated water and improper practices followed for collection and storage of water at waterworks and household levels are also causing various waterborne diseases in the district. The consumption of such contaminated water is causing various types of health problems in the district.

Figures 3 and 4 show the groundwater salinity status in shallow and deep aquifers. Unlike fluoride, the deep aquifers are more saline as compared to shallow aquifers and the extensive tube well drillings near to wells and hand pumps are most probably affecting the shallow aquifers water quality.

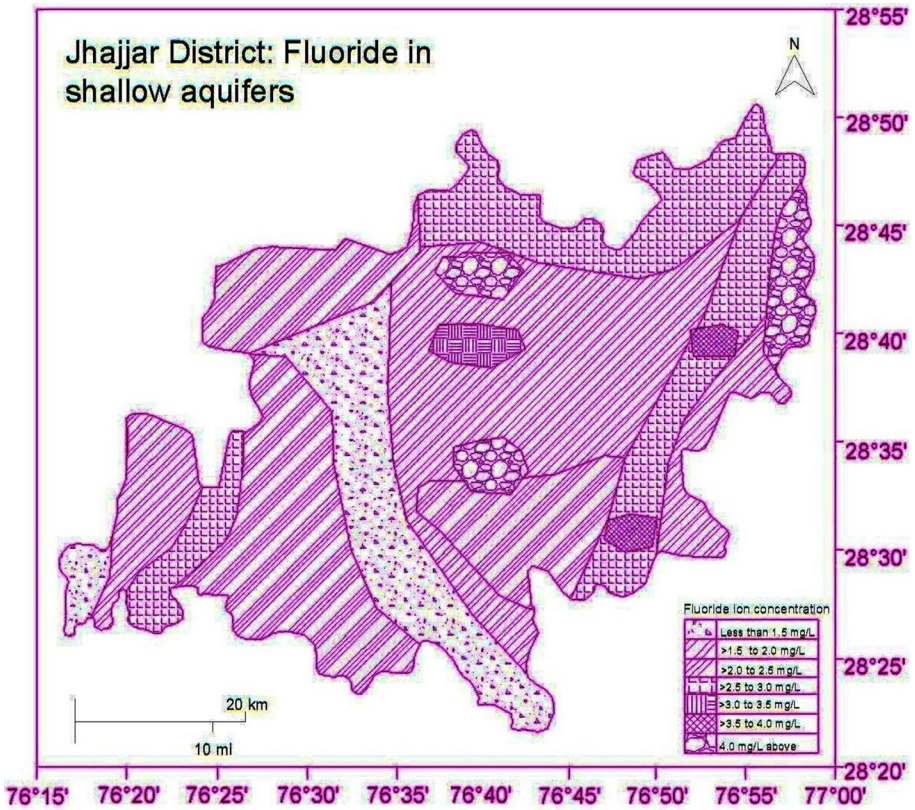

Fig. 1 Fluoride in shallow aquifers of Jhajjar district

2 Methodology

A random sample survey from the identified villages of the district was carried out in 2016. The villages were chosen on the basis of a preliminary assessment of groundwater samples, which indicates high concentration of various water quality parameters above the permissible limits as prescribed by Bureau of Indian Standards (BIS). Figure 5 illustrates the methodology adopted for carrying out the study.

A well-defined questionnaire was used to investigate the key information from the households. Section A of the questionnaire comprised of general questions such as name, age, education and occupation of the respondent, family size, household monthly income, etc. Section B consisted of questions on source of water for drinking and other household usage, availability of water, quality of water, etc. Section C included the questions on health problems faced by the children and adults. Section D was on questions related to medical expenses incurred on health problems including fees of doctor, diagnostic tests and medicine charges. Section E of the questionnaire was on avertive measures taken by the households for obtaining the good quality water for drinking purpose. Section F and G covered the questions on awareness and households willingness to pay if the improved quality water will be provided.

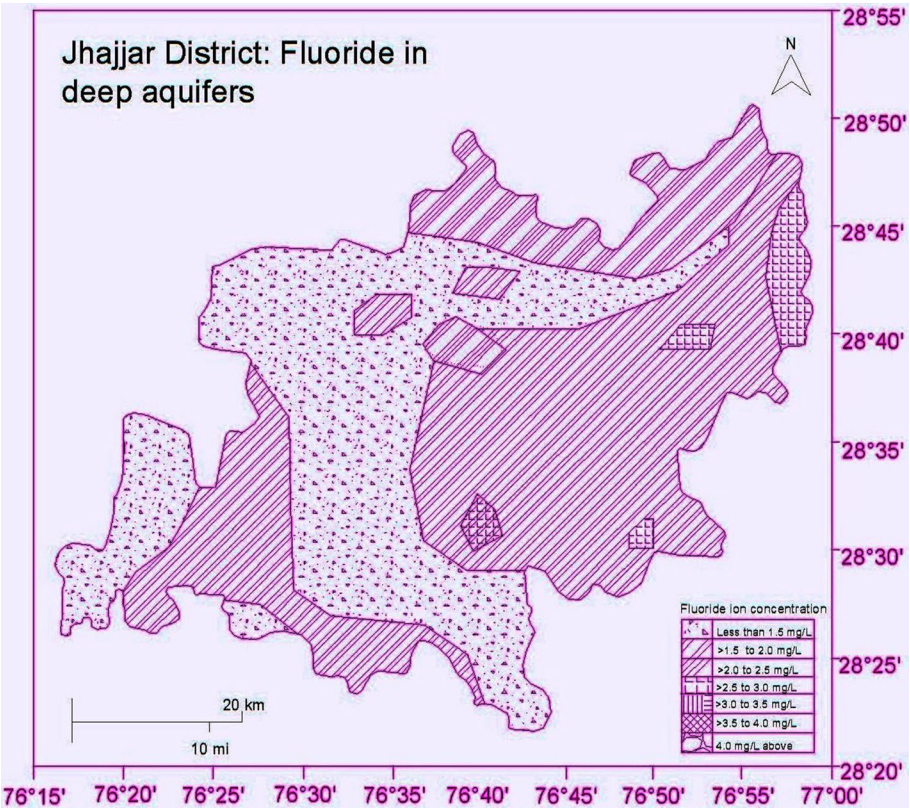

Fig. 2 Fluoride in deep aquifers of Jhajjar district

3 Results and discussion

The household survey was performed in six villages of Jhajjar, namely Kablana, Talao, Shekhupur Jat, Hassanpur, Babra, and Kheri Asra. After the survey, 630-filled questionnaire based on their completeness were screened and used for the further analysis. The number of households surveyed and total number of persons who were included in the analysis across the villages are shown in Table 1.

A detailed analysis of data was done for each question of the survey to understand the problems associated with the drinking water. The outcome is illustrated below:

a. Status of socioeconomic characteristics

A brief overview of socioeconomic characteristics of respondents is presented as a prelude to the analysis. The overall age profile showed that 24.7% of the population is below 18 years, 52.9% of the population was of age group 18–59 years and rest 22.4% of the population belonged to the age group of 60 years and above. There were no major differences across the villages in terms of age group; however, socioeconomic conditions vary from village to village.

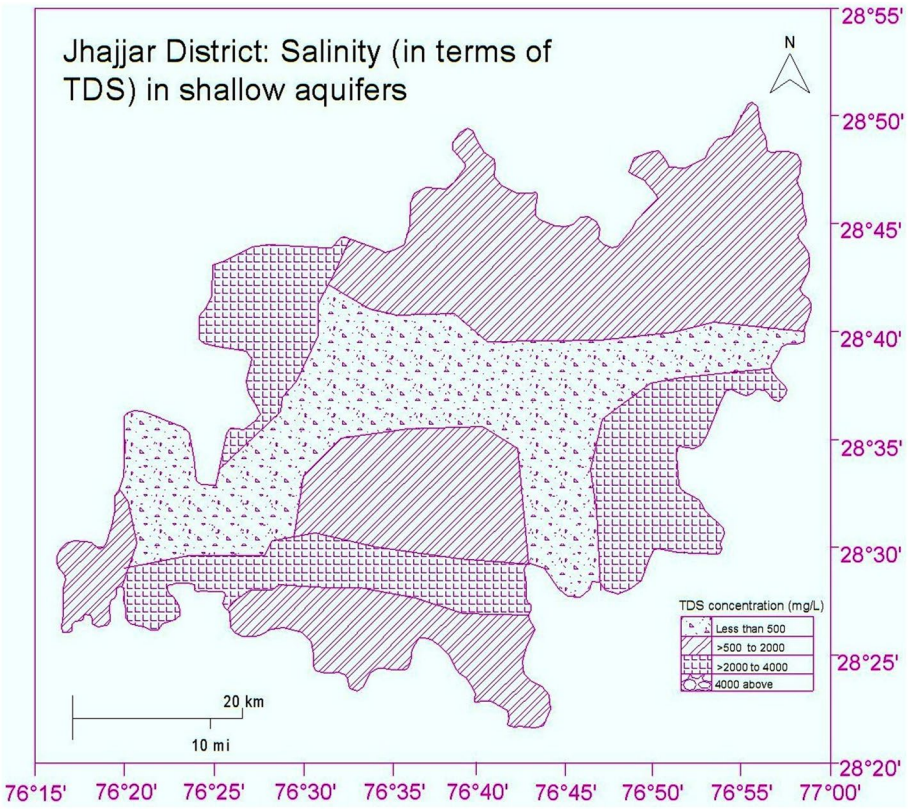

Fig. 3 Salinity in shallow aquifers of Jhajjar district

The education status of the respondents varied from village to village, approximately 21% of the total surveyed respondents were illiterate, 32% have completed their schooling up to VIII class, About 28% have completed schooling up to XII class. The respondents reported their schooling years above the secondary level and up to the graduation (including diploma course) were about 16%. Only 3% of sampled population reported education above the graduation level.

The household income estimated as the sum of earnings from day-to-day occupation/profession (salaries/wages etc.) of all working members of a family during a month. Based on the monthly income, households were categorised into different income groups as shown in Fig. 6. About 3.5% reported their income level below Rs. 5000, while 39% fall in the category of Rs. 5001–10,000 per month. About 35, 11.5 and 7% of the households informed income in the range of Rs. 10,001–15,000 and 15,001–20,000 and 20,001–25,000 per month, respectively. Rest 4% mentioned their income above to 25,001 per month. During the survey, households with very low income group were interviewed. Their main occupation includes rickshaw-pulling, daily wage labour, servants in small shops/dhabas, selling fruits at road side, etc.

The occupation-wise distribution of the respondents showed that 25% of total population were in service, including government sector, private sector, banks, factories,

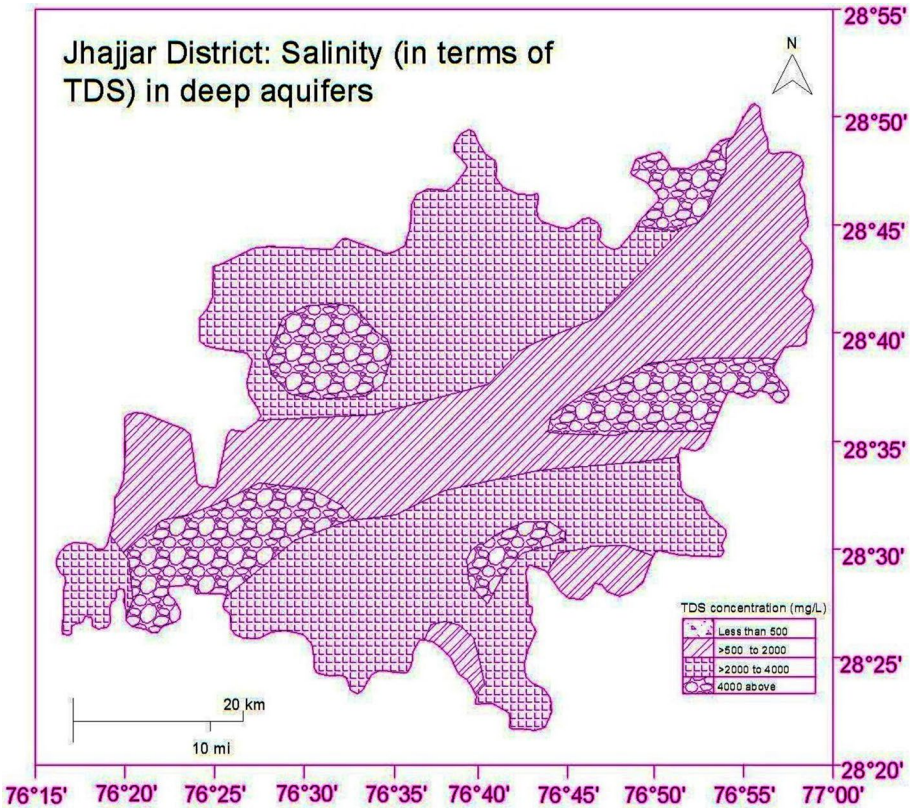

Fig. 4 Salinity in deep aquifers of Jhajjar district

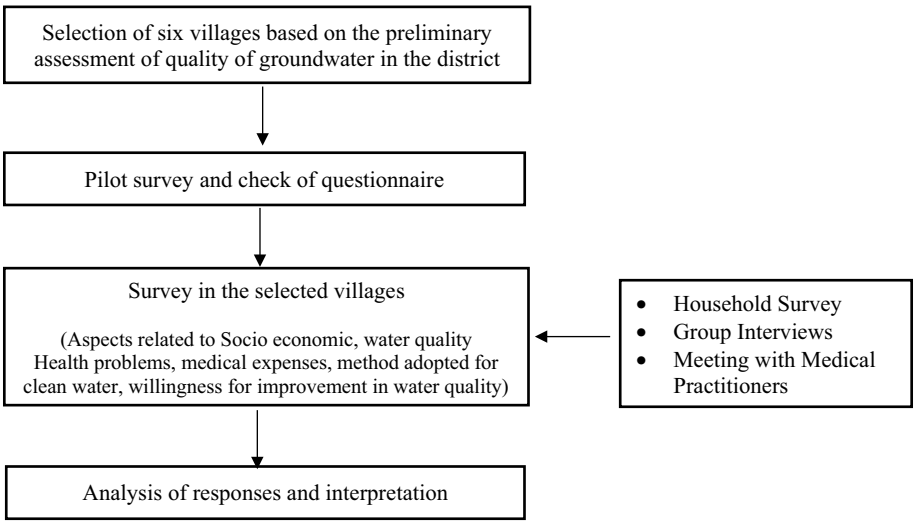

Fig. 5 Methodology adopted for carrying out the survey work

Table 1 Sample distribution. *Source*: Primary Survey conducted in 2016

Variables	Kablana	Talao	Shekhupur Jat	Hassanpur	Babra	Kheri Asra	Total
No. of households surveyed	100	150	80	80	100	120	630
No. of persons	510	561	384	403	430	465	2753

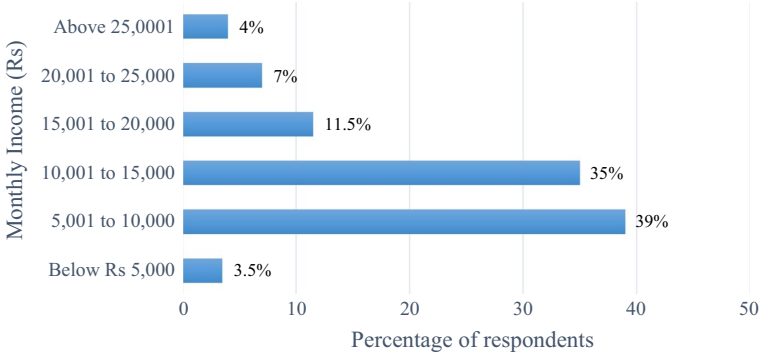

Fig. 6 Status of income level in surveyed villages

doctors and teachers etc. 14.5% of the respondents were engaged in business or self-employed. 13.5% of the respondents were farmers and 9% were involved in labour activities. About 25.5% of the respondents, particularly women were under the category "Housekeeping." All other respondents were considered under "No Job" category which included the dependants, students, minors, etc., and they accounted for 11.5% of total sample surveyed.

b. Status on availability of drinking water

The data were collected about the source and quality of water utilised for drinking and cooking purposes by residents. Most of the population are dependent on groundwater extracted through hand pumps and tube wells for drinking and cooking purposes. Some of the respondents use water supply through private tankers. In many villages, water is supplied from government agencies through network of pipelines, but it is not utilised by respondents for drinking purposes, owing to poor quality of water. The water quality studies showed that supplied water is highly saline in nature, and almost non-potable. Often after drinking supplied water and groundwater, people feel heaviness in the stomach, or suffered with diarrhoea. In Jhajjar district, people intend to adopt various available options for receiving the good quality water, but unable to bear the high cost of water treatment. Out of the total respondents, about 29.5% of the residents purchase water canes, 18% use water from hand pump, 14% use tube wells, 16.5% brought water from nearby government supply scheme, 21% has water from government scheme, and rest 1% has personal supply through tankers. Figure 7 provides the source of water and percentage of households using that source of water for their daily needs in surveyed villages of Jhajjar district.

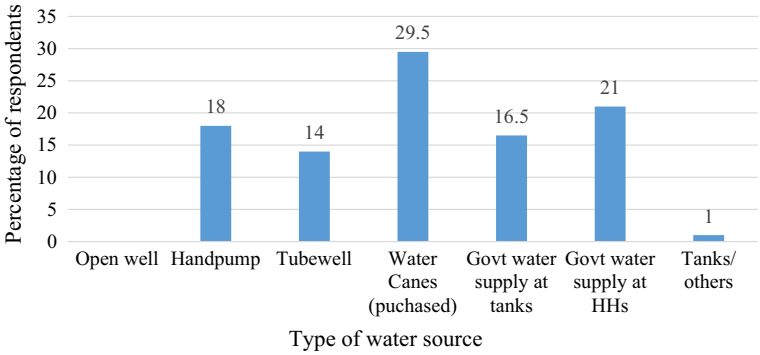

Fig. 7 Sources of water used for drinking purpose

c. Status of prevalence of health problems

A recall period of 2 months was considered in this study for identifying the health problems that occur due to the consumption of contaminated water. It signifies if an individual experienced an episode of water-related disease or symptom-based sickness during the recall period of 2 months preceding the date of survey, the information was included in the survey results. The water-related diseases to both chemical and biological contamination were considered for the study. The health status of all family members was asked during the survey, and the same has been considered (in terms of person observations) for interpretation of results.

It was found that the problems such as diarrhoea, dental fluorosis, pain in joints and backbone and stones are prevalent in the studied area. From the sampled population of 2753 persons, 394 persons were responded for symptom-based sickness. Of which, 108 persons reported the problem of frequent stomach infection, cases of diarrhoea or heaviness in the stomach. A few cases of typhoid were also reported. The problem of stones is also prevalent in Jhajjar district. About 14 persons participated in survey were suffering from stones. A few others also mentioned the problem of stones, but the same was operated and removed, such numbers of individuals were not considered in this study. Besides diarrhoea, the major water-related problem in the district is dental fluorosis. The villages such as Shekhupur Jat, Hassanpur and Talao have high prevalence of dental fluorosis particularly in children. About 140 persons including children and adults were found with mild to moderate dental fluorosis. The joint pain and backbone pain were also common in Jhajjar that may be due to the prolonged consumption of fluoride rich water. Table 2 provides the village-wise assessment of water-related health problems.

d. Status of mitigating expenditure for health problems

Mitigating expenditure are the expenses borne by the persons for mitigating the illness episode. It is calculated as an aggregate of doctor's fee, cost of medicine, cost of diagnostic tests, and travel cost of accessing the medical care. During the survey, it was found that the medical expenditures in the rural areas are attributed to many factors, such that.

- Subsidised government medical care.

Table 2 Symptom distribution for health problems ($N=394$). *Source* Primary Survey conducted in 2016

Diseases	Kablana (*N*)	Talao (*N*)	Shekhupur Jat (*N*)	Hassanpur (*N*)	Babra (*N*)	Kheri Asra (*N*)	Total (*N*)	Total (%)
Diarrhoea/stomach infection	30	22	18	16	13	9	108	27.4
Stones	5	4	1	1	2	1	14	3.6
Dental fluorosis	22	29	31	17	19	22	140	35.5
Joint pain and backbone pain	21	38	18	16	22	17	132	33.5
No. of persons	78	93	68	50	56	49	394	

No. of persons is based on multiple symptom responses, in which a sick person may have experienced more than one symptom

N = No. of persons affected, % = Percentage from total affected person

- People often do home remedies for mild illness episode.
- People usually travel through public transport to the nearest primary centre on civil hospital.

Amongst the 394 respondents who mentioned about their health problems, 45% of the respondents informed their mitigating expenditures against the diseases. The maximum mitigating expenses found was Rs. 8000 for the recall period of 2 month. Village-wise status of mitigation expenditure is provided in Table 3.

e. Status of Averting Expenditure for getting good quality drinking water

Averting activities are expenditure, or the costs incurred by households to avoid exposure to a groundwater contaminant, such as buying of water filtration system, purchasing of filtered water bottles, time spent in travelling to far sites for bringing clean water, boiling of water, or any other treatment method. During the survey, out of 630 households, about 40% households confirmed that they are incurring expenses for getting good quality water.

It was found that about 30% of the respondent families are buying filtered water canes for their drinking needs, 10% of the respondents have installed filtration systems and rest 60% are consuming water as they receive it. No avertive measures are taken care by them for getting good quality of drinking water as shown in Fig. 8.

The village-wise distribution of avertive methods taken by residents is provided in Table 4. Out of 248 respondents, 74% are purchasing water canes from the private suppliers. This practice is very common in Jhajjar district. Not only in the surveyed villages but almost in all villages of Jhajjar district, people are buying water canes for drinking purpose either per day basis or on alternate days depending upon their family size, consumption pattern, and availability of other clean source for drinking purpose.

The avertive expenditure varied in the district depending upon the choice of the treatment. The maximum amount mentioned by the respondents for filtration system was Rs. 12,000 though it does not include the cost of installation. Further, there is an annual maintenance cost for the filter system, which is about Rs. 500–1000. The annual expenditure towards the purchase of water canes was in the range of Rs. 3000–7200 (Rs. 250–600 per month) depending upon the family size, usage and weather conditions.

Table 3 Mitigating expenditure on water-related health problems ($N=176$). *Source* Primary Survey conducted in 2016

Level (Rs.)	Kablana (*N*)	Talao (*N*)	Shekhupur Jat (*N*)	Hassanpur (*N*)	Babra (*N*)	Kheri Asra (*N*)	Total (*N*)
1–500	12	10	13	13	10	8	66
500–1000	12	19	8	7	12	10	68
1500–2000	5	10	2	0	3	4	24
More than 2000	6	6	2	1	1	2	18
No. of persons	35	45	25	21	26	24	176

N=No. of persons

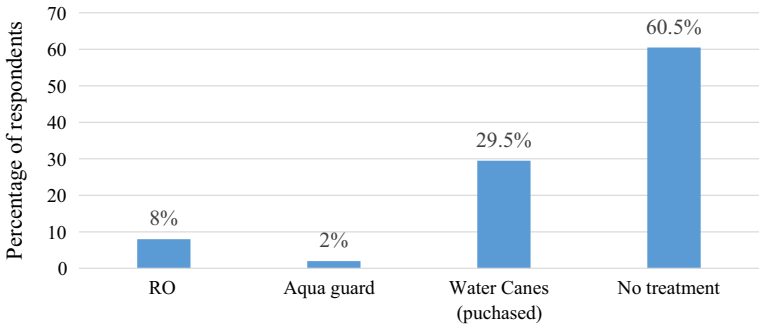

Fig. 8 Methods used as avertive measures in the surveyed villages

Table 4 Avertive measures taken by the respondents ($N=248$). *Source*: Primary Survey conducted in 2016

Avertive method	Kablana (*N*)	Talao (*N*)	Shekhupur Jat (*N*)	Hassanpur (*N*)	Babra (*N*)	Kheri Asra (*N*)	Total (*N*)
Filtration system	11	19	7	5	11	10	63
Purchase of water canes	30	42	30	26	32	25	185
No. of respondents	41	61	37	31	43	35	248

N = Number of respondents

f. Willingness to pay

During the survey, mix responses from respondents on their willingness to pay for better quality of water were received. People would like to spend, as most of the people are unsatisfied with the quality of water they are receiving for drinking purpose. The water supplied in houses is saline in nature, have higher concentration of fluoride and hardness and thus unfit for drinking purpose. In absence of the good quality of drinking water, people are taking water from the various sources as per their awareness, convenience and affordability. They are often spending on procurement of water canes and filtration units. Most of the women in the villages have to walk kilometres to boosting stations or hand pumps to fetch water for their daily needs. Most often, the water taking from various sources are not well treated and thus causing stomach-related ailments to both children and adults. The problem of diarrhoea, stones and joint pain is common, reported by respondents of the district. The occurrence of typhoid is also common. Further, to bacteriological disease outbreaks, the problem of mild to moderate dental fluorosis is prevalent in the villages particularly in children and teenagers. People are mostly referring to government hospital and health services for the remedial measures. It was also observed that to get better quality of water, most of the people relay on the RO water services supplied by the private company; however, there are no records for the quality of supplied water through private suppliers. Considering all these difficulties, people responded to spend for the availability of good quality water in the district though it is difficult to mention expected amount, which people can afford or spend.

4 Conclusions

The study offers the important insights about the quality of drinking water in the Jhajjar district. In the studied area, due to convenience and availability, people are often consuming water from hand pumps and tube wells, which is not filtered and treated. Therefore, drinking water-related health problems are common in the area. The study concludes the followings:

- Groundwater quality in Jhajjar district is highly polluted and contaminated and in the absence of proper treatable supply in domestic areas; people are using contaminated groundwater leading to various types of health problems.
- The groundwater fluoride is one of the major problems caused by both geogenic and anthropogenic factors, and responsible for dental fluorosis, diarrhoea, stomach pain, joint pain, backbone pain and stones to children and adults.
- Despite the subsidised government medical care, people of Jhajjar district is facing an economic burden of Rs. 1000–2000 per month for the treatment related with health problems. Apart from that the average annual expenditure towards the purchase of water canes is around Rs. 3000–7200 per month, which depends upon the family size, usage and weather conditions.
- The willingness to pay is found positive amongst the people as they are highly unsatisfied with the quality and shortage of water they are receiving at present for drinking purpose despite huge economic burden.

4.1 Intervention options

It is important to develop an in situ or ex situ plan for entire treatment and recharge of groundwater for entire Jhajjar district. The ex situ treatment method includes creating facility for water treatment in Jhajjar district.

4.1.1 Ex situ methods

These methods include generation of water treatment facilities within the Jhajjar district, which are easily and economically feasible. There are several such methods which can be used for generating water treatment facilities that include *precipitation–coagulation method*, which is the most widely used process, comprises the addition of prescribed quantities of alum, lime, and bleaching powder to raw water, followed by rapid mixing, flocculation, sedimentation, filtration, and disinfection. After adding alum and lime to the raw water, insoluble aluminium hydroxide flocs are formed; sediment to the bottom and co-precipitate fluoride and bleaching powder ensures disinfection during the process. The Nalgonda process is widely known precipitation–coagulation fluoride removal method. *Adsorption Method* involves passage of water through a contact bed where fluoride is removed by ion exchange or surface chemical reaction with the solid bed matrix. The different adsorbents used for fluoride removal include activated alumina, carbon, bone charcoal, activated alumina coated silica gel, calcite, activated saw dust, magnesia, serpentine, tricalcium phosphate, activated soil sorbents, and other

synthetic ion exchange resins. Most widely used adsorbents are activated alumina and activated carbon.

4.1.2 In situ methods

This method includes the preparation of a comprehensive watershed development and management plan for entire Jhajjar district. Based on watershed map, suitable recharge locations can be identified and various recharge structures, such as check dams, vertical shaft, horizontal shaft, and several recharge pits/ponds, can be constructed. These structures will ensure maximum infiltration of rainwater and help in improving the groundwater quality by dilution and also prevent further depletion of water table.

Further there is need to expand the facility of supply of treated drinking water through pipe systems to all villages, which can be easily managed and monitored regularly at a single point. Most of the residents in the village are incurring expenses on diseases, and few others are spending money to reduce its impacts. In both the cases, people are contributing a portion of their income for attaining the better quality water; this scenario gives a probability of expanding rural drinking programmes in the district with the support from the community. Moreover, there is need to start an awareness programmes in the villages regarding consume safe water and health problems associated with the drinking of polluted or contaminated water.

References

Abiye, T., Bybee, G., & Leshomo, J. (2018). Fluoride concentrations in the arid Namaqualand and the Waterberg groundwater, South Africa: Understanding the controls of mobilization through hydrogeochemical and environmental isotopic approaches. *Groundwater for Sustainable Development, 6,* 112–120.

CGWB. (2007). *Ground water scenario in major cities of India*. Central Ground Water Board, Ministry of Water Resources, Government of India.

CGWB. (2013). *Ground water report Jhajjar District, Haryana*. Central Ground Water Board, Ministry of Water Resources, Government of India.

CGWB. (2016). *Ground water year book of Haryana State*. Central Ground Water Board, Ministry of Water Resources, Government of India.

Craig, L., Thomas, J. M., Lutz, A., & Decker, D. L. (2018). Determining the optimum locations for pumping low-fluoride groundwater to distribute to communities in a fluoridic area in the Upper East Region, Ghana. *Chemical Geology, 476,* 481–492.

Gulab, (2014). Impact of water logging and salinity on agriculture and socio-economic status in Rohtak and Jhajjar district. *International Journal of Resarch Applied Science Engineering Technology, 2*(4), 491–497.

Gupta, R., & Misra, A. K. (2016). Groundwater quality analysis of quaternary aquifers in Jhajjar District, Haryana, India: Focus on groundwater fluoride and health implications. *Alexandria Engineering Journal*. https://doi.org/10.1016/j.aej.2016.08.031.

Jha, B.M., Sinha S.K. (2007). Towards Better Management of Ground Water Resources in India. Central Ground Water Board, Govt. of India.

Khurana I., Sen R. (2008). Drinking water quality in rural India—Issues and Approaches, WaterAid.

Martins, V. T., Pino, D. S., Bertolo, R., Hirata, R., Babinski, M., Pacheco, D. F., et al. (2018). Who to blame for groundwater fluoride anomaly in São Paulo, Brazil? Hydrogeochemistry and isotopic evidence. *Applied Geochemistry, 90,* 25–38.

Misra, A. K., & Mishra, A. (2006). Groundwater quality monitoring in shallow and deep aquifers in Saidabad tahsil area, Mathura district, India. *Environmental Monitoring and Assessment, 117,* 345–355.

Raj, D., & Shaji, E. (2017). Fluoride contamination in groundwater resources of Alleppey, southern India. *Geoscience Frontiers, 8*(1), 117–124.

WHO. (2002). *The World Health Report 2002—Reducing risks, promoting healthy life*. Geneva: World Health Organization.

Yadav, J. P., & Lata, S. (2003). Urinary fluoride levels and prevalence of dental fluorosis in children of Jhajjar district, Haryana. *Indian Journal of Medical Sciences, 57*(9), 394–399.

Yadav, J. P., Lata, S., Kataria, S. K., & Kumar, S. (2009). Fluoride distribution in groundwater and survey of dental fluorosis among school children in the villages of the Jhajjar District of Haryana, India. *Environmental Geochemistry and Health, 31*(4), 431–438.