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ORIGINAL ARTICLE

Water-borne disease: Link between human health and water use in the Mithepur and Jaitpur area of the NCT of Delhi

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Abstract
Aim Delhi, the capital of India, is experiencing rapid population growth resulting in insufficient sanitation and drinking water facilities. Water-borne diseases are caused by substandard drinking water quality as well as poor sanitation facilities. Mithepur and Jaitpur, located in the south-east district of Delhi, were selected as the study area to identify the links among human health, water use and sanitation.
Subjects and methods A primary survey was carried out based on the random sampling method. Binary logistic regression was used to show the factors related to the incidence of water-borne diseases. Water samples of five different sources were tested to assess the drinking water quality.
Results The results revealed that about 28% of the household were affected by water-borne diseases. Having a bore well, private water supplier and household income less than 15,000 rupees per month were the variables that showed a relationship with water-borne diseases.
Conclusion This article examines the prevalence of water-borne diseases in relation to the behavioural habits of the households utilising different water sources. A vital relationship exists between logical factors and water-borne diseases. Having a bore well and private water supplier appears to be exceptionally influential.

Keywords Water-borne diseases · Drinking water · Human health · Logical factors · Contamination

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Introduction

Clean and safe water plays an important role in all kinds of life on earth (Jena et al. 2012; Patil et al. 2012; Soni and Bhatia 2015; Khatib et al. 2003 and CDC 2007). The quality of drinking water influences health and productivity. The body utilises water to manage its temperature and furthermore water acts as a basis for all nutrients to travel through the body. It successfully transports oxygen to every cell and removes poisonous waste from the body to protect the organs and to maintain health. Therefore, good quality water needs to be consumed in the required quantity. Apart from the quality of drinking water, the availability, storage, distribution and usage of water have profound effects on health, the environment, ecosystems and the economic well-being of individuals and entire areas. Therefore, proper planning and management of water resources are necessary, especially now as the world is experiencing rapid population growth. Over thousands of years of human civilisation, many significant advances have been made in water planning and management, including construction of large-scale water infrastructures. However, such efforts to provide clean water have also been generally inadequate or even misdirected (Gleick 1993). Part of the problem is the population explosion, high standards of living and increasing water demands. These problems increase the contaminants from biological and chemical wastes in rivers, lakes, groundwater aquifers and other water sources, which leads to an increase in prevalent water-borne diseases worldwide (Gleick 2002; Moe and Rheingans 2006; Saravanan 2013b; Mor 2011 and Qureshi et al. 2011). The Millennium Development Goals (MDGs) targeted halving the proportion of the population living without sustainable access to safe and clean water and the required basic sanitation by 2015, but despite the progress made by the MDGs, 2.4 billion people still rely on contaminated drinking-water supplies and remain without improved sanitation facilities. Primarily because of this situation and other associated factors, millions of people die every year from water-borne diseases (MDG 2015; WHO 2000; UNICEF and WHO 2015).

Delhi is the world's second largest megacity after Tokyo (United Nations 2014) and is also called a city of migrants because every year thousands of people migrate to Delhi in search of employment opportunities, better health and education facilities and a high standard of living (Delhi Human Development Report 2013; Directorate of Census Operations 2011 and Ahmad et al. 2012). It is one of the rapidly urbanising cities in India, where almost all of the households have access to a piped water supply and sanitation (Economic Survey of Delhi 2014). Despite this, the incidence of preventable water-borne diseases has not been reduced because of the lack of availability of safe drinking water (Mor 2011; Agresti 1996; McCullagh and Nelder 1989; Dobson 2011; Plewis 1997). According to the Medical Certification of Causes of Deaths in Delhi (MCCD 2015), which reports the total registered deaths from different causes in Delhi, institutional deaths due to infectious and parasitic diseases account for about 15% (NCT of Delhi, MCCD 2015). The selected areas, Mithepur and Jaitpur, are part of the suburbs of Delhi. Tremendous pressure from the influx of immigrants has resulted in unplanned growth of the infrastructure and also worsened the already existing lack of safe drinking water. These negative effects of unplanned growth can be directly seen in selected areas where most of the people belong to the economically weaker level of society. Delhi's groundwater as well as surface water quality is completely unfit for direct consumption and needs further treatment at the household level, which is not possible for residents in the study areas because of financial constraints. Therefore, it is the poverty of the residents in the selected areas that makes them more vulnerable and puts them at a greater risk of water-borne diseases. At present, migration data are not available at the sub-district/ward level in the NCT (National Capital Territory) of Delhi. According to the primary survey, the people in about 33% of the households in the Mithepur and Jaitpur area migrated from different parts of the country, especially from the states of West Bengal and Bihar. These migrants reside in rented houses where water is provided by a piped water supply and by the Delhi Jal Board water tanker service. The water available in the study area is grossly inadequate for meeting the increasing demands for fresh drinking water, and as a result households are dependent on other sources such as bore wells and hand pumps. The water from these sources is not safe for direct consumption. Therefore, households in the study area have experienced an increasing incidence of water-borne diseases. The present study examines the prevalence of water-borne diseases, i.e. diarrhoea and gastrointestinal disorders, due to the water quality of the different water sources.

There are eight types of housing settlements for the residents of Delhi: bunches, slum-designated areas, unapproved colonies, resettlement colonies, regularised unapproved colonies, rural villages, urban villages and planned colonies. Of the eight, only a single type is called 'planned' and the other seven are 'unplanned'. Unplanned settlements are characterised by low-quality houses having inadequate infrastructure and community services. The pattern of different settlement types has an impact on the access to quality water (Haider 2016). More than 50% of the residents in the Mithepur and Jaitpur area live in informal/unplanned types of settlements (Directorate of Census Operation, Delhi 2011).

Quantification of the prevalence of water-borne diseases is a complex task because there are numerous pathways for the transmission of water-borne diseases (Bhattacharya et al. 2011 and Hunter et al. 2011). Water quality analysis is a pre-requisite for studying the incidence of water-borne diseases in any region and the ways in which the transmission of water-borne diseases can be prevented include the effective collection, treatment and disposal of sewage and the provision of safe drinking water supplies. Remote sensing and geographical information systems (GISs) have become very useful tools for the planning and management of water quality systems, making it possible to locate the regions where consumers are drinking contaminated water and suffering from water-borne diseases and to address the lack of sewage systems (Higgs 2004; Gondhalekar et al. 2013 and Musa et al. 2013). This article attempted to examine the prevalence of water-borne diseases in relation to the behavioural habits of the households using different water sources.

Study area

Mithepur and Jaitpur are a part of the south-eastern district of the NCT of Delhi. It is located between 28°28'0" and 28°33'0" north latitude and 77°17'0" and 77°21'30" east longitude along the right bank of the Yamuna River (Fig. 1). The Yamuna River is the main source of water for the study area. The different water sources include hand pumps, tube wells, the Delhi Jal Board and private water supplies.

The total number of households in the study area is 25,230 (Census of India 2011). The total geographical area accounts for 6022860 sq. mt. The average annual temperature is 25 °C and the average annual rainfall is 693 mm. The supply of good quality water in the study area is limited because of the high demand from households of all income groups.

Database and methodology

The Mithepur and Jaitpur areas in the south-eastern district of the NCT of Delhi were chosen as the study area. Both of these areas are located on the right bank of the Yamuna River. A total of 140 households were randomly selected and the members interviewed. The organised questionnaire was partitioned

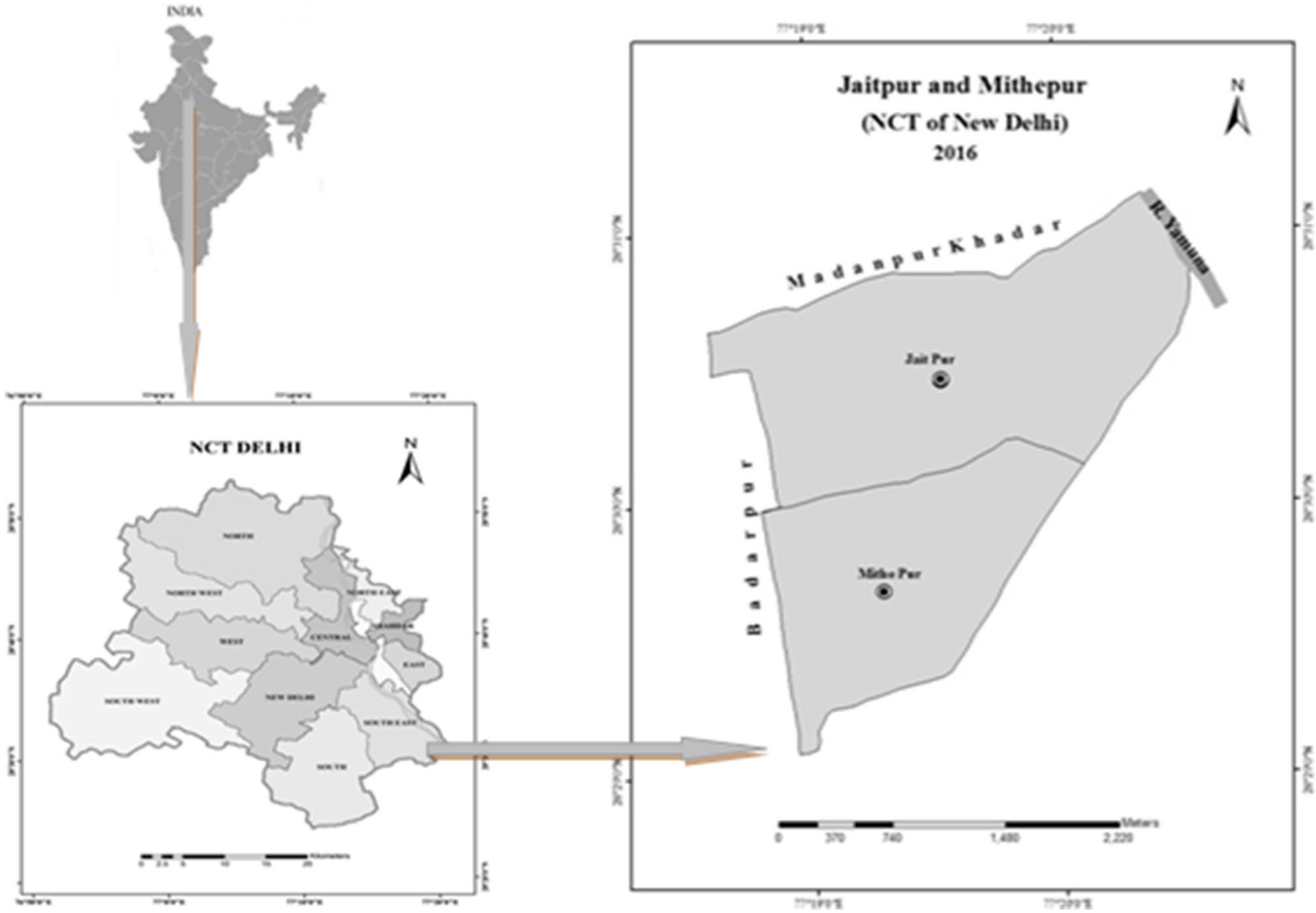

Fig. 1 Location map of study area

into three sections. The first segment contained questions on the demographic attributes of the household members to obtain a social profile of the respondents. The second segment contained questions about the sources of water used by the households for drinking and domestic purposes. The third section included all the information on the incidence of water-borne diseases experienced by the household members. Data were collected by interviewing either the head of the household or an adult over 18 years of age.

The Statistical Package for Social Sciences (SPSS) software was utilised to record and dissect the gathered information. The calculated logistic regression analysis was used to determine the connections with water-borne disease events and determine the significant factors involved in the occurrence of water-borne diseases. Several studies have recognised the significance of logistic models to deal with the specific reasons behind the incidence of water-borne diseases (Field 2005; Hamner et al. 2006; Qureshi et al. 2011 and Sia Su 2005). The link was assessed between the incidence of water-borne disease and explanatory variables (age, gender, income level, different sources of water used by households for drinking purposes). The logistic regression equation given by Burns and Burns gives a coefficient 'b', which measures every independent factor's fractional contribution to variations in the dependent factors. The model accurately anticipates the class of results for individual cases, which is expressed as follows:

Logit(*p*) is the log (to base *e*) of the odds ratio or likelihood ratio that the dependent variable is 1. In an equation it is defined as

$$\log(p) = \log\left(\frac{p}{1-p}\right) = ln\left(\frac{p}{1-p}\right)$$

However, p can only range between 0 to 1.

The form of the logistic regression equation is:

$$\mathrm{log}it(p(x)) = \log\left(\frac{p(x)}{1-p(x)}\right) = a + b_1x_1 + b_2x_2 + \ldots..b_nx_n$$

p can be calculated with the following formula:

$$p = \frac{e^{a+b_1x_1+b_2x_2+\ldots.b_n x_n}}{1+e^{a+b_1x_1+b_2x_2+\ldots.b_nx_n}}$$

Here, p is the probability that a case is in a particular category, e is the base of natural logarithms, a is the constant of the equation, and b is the coefficient of the predictor variables.

Water sample quality testing

A total of five water samples were collected from different water sources such as hand pumps, piped water, bore wells, the Delhi *Jal* board and private water suppliers. The location of the water sample collection point was taken using a global positioning system. Parameters measured by Quality Lab-Defining Quality Analytically included the pH value, total dissolved solids (TDS), alkalinity, and fluoride, nitrate and chlorine levels. Water samples were generally collected in the morning. The Bureau of Indian Standards (BIS) using test method IS 3025 and WHO procedures were followed for the analysis of water samples. All the results of the water samples tested by Quality Lab were entered into a Microsoft Office Excel Worksheet for graphic presentation and for analysis.

Results and discussion

A total of 140 households from Mithepur and Jaitpur were included in the survey. In most cases the respondents were female (80%) as women have to stay at home to look after it. All surveyed respondents were above 18 years of age with a mean age of 30 years old for both sexes. Table 1 shows that in the study area, of the total surveyed population, approximately 51% were male and 48% female. About 60% of the households have four to eight members in their respective family. Forty-eight per cent of the householders worked in private services followed by self-employment, government service and labourers. In terms of education level, about 90% of household members were educated and only 9.76% had no formal education. The education status of the household was examined because the education level increases the level of the households, facilitating achieving a completely hygienic environment; 42.14% of the households have a mean monthly income of less than 15,000 rupees, 40.71% have incomes ranging between 15,000 and 30,000 rupees, and only 17.14% of the households earn more than 30,000 rupees per month.

As shown in Table 2, all the households in the study area use different sources of water for drinking purposes, such as hand pumps, bore wells, private water supplies and piped water supplies from the MCD and DJB (Delhi Jal Board). Due to the inadequate drinking water supply, the private water suppliers provide water in plastic bottles in the Mithepur and Jaitpur area. Private water suppliers provide water in plastic bottles in the Mithepur and Jaitpur area. These suppliers are local in origin and used to treat bore well water for their supplies. Water from bore wells and hand pumps is commonly available in the area, but bore well water is not fit for drinking or cooking purposes. Some of the households use bore well water as they cannot afford to purchase the private water supply all of the time, and the DJB tanker water sometimes arrives at inconvenient times, compelling household members to stay awake to collect the water, and at times the water collection causes social conflicts and struggles between people. To observe the household's behaviour regarding their practices before consuming the water, we analysed how they treat their water before drinking it and for other domestic purposes such as cooking. Of the households, 50.71% said that they did not use any treatment before drinking the water and consumed it as is, while 38.57% used filters to filter the water and only 10.71% used chlorine tablets in their water before drinking it. Boiling water was not followed by any of the households as this method is very expensive.

Of the total households surveyed, 67.85% used handled jugs to take water from vessels and 32.14% took water directly by

Table 1 Socio-economic characteristics of households in the Mithepur and Jaitpur areas of the NCT of Delhi (2016)

Variables	Total no. of households
Sex	
1. Male	348 (51.47)
2. Female	328 (48.52)
Total	676 (100)
Household size	
1. 0–4	51 (36.42)
2. 4–8	84 (60)
3. 8 and above	5 (3.57)
Total	140 (100)
Employment status	
1. Govt. service	13 (9.28)
2. Private service	68 (48.57)
3. Self-employed	44 (31.42)
4. Labourer	15 (10.71)
Total	140 (99.98)
Education status	
1. Illiterate	66 (9.76)
2. Primary	122 (18.04)
3. Secondary	172 (25.44)
4. Senior secondary	165 (24.40)
v. Graduate and other	151 (22.33)
Total	676 (100)
Income level	
1. Below 15,000	59 (42.14)
2. 15,000–30,000	57 (40.71)
3. 30,000 and above	24 (17.14)
Total	140 (100)

*Figures in parentheses represent percentage

Table 2 Use of different water sources and sanitation facilities in Mithepur and Jaitpur in the NCT of Delhi (2016)

Variables	No. of households
Sources of drinking water	
1. Hand pump	21 (4.41)
2. Bore well	90 (33.08)
3. Private water supply	73 (26.83)
4. Piped water supply	52 (19.11)
5. DJB	36 (13.23)
Ways of treating water	
1. Filtering with filter	54 (38.57)
2. Boiling	0
3. Using chlorine	15 (10.71)
4. No treatment	71 (50.71)
Source of water for cooking	
1. Hand pump	10 (6.17)
2. Bore well	87 (53.70)
3. Piped water	52 (32.09)
4. DJB	13 (8.02)
Ways of using water from vessels	
1. Using a handle jug	95 (67.85)
2. Directly dipping hands	45 (32.14)
Toilet facility	
1. Yes	121 (86.42)
2. No	19 (13.57)

*Figures in parentheses represent percentage

Note: DJB is the Delhi Jal Board, which is the government agency responsible for the supply of potable water and also is in charge of sewerage and drainage within the National Capital Territory of Delhi

dipping glasses held in their hands. Such behavioural practices of the household members increase the risk of microbial contamination of water by direct contact with contaminated hands. Concerning sanitation conditions, the household members were asked about the availability of toilet facilities within their home and most had such a facility within their houses, but still 13.57% used public toilets. Of the surveyed households, the majority disposed of their waste in septic tanks as there were no sewage systems in that area, and some households also disposed of their waste in the open drains flowing in front of their houses, which creates breeding grounds for mosquitoes.

The distribution of water-borne diseases among the different age groups is shown in Fig. 2. Children between the ages of 0–5 years were the most vulnerable to water-borne diseases, followed by those older than 30 years. Figure 2 shows that persons between 6–15 and 16–30 years old were less vulnerable to water-borne disease. Hence, the results indicate that children below the age of 5 years are more likely to be affected by water-borne disease. Higher occurrence of water-borne disease among children under 5 years is associated with their increased susceptibility to infections and lower immunity.

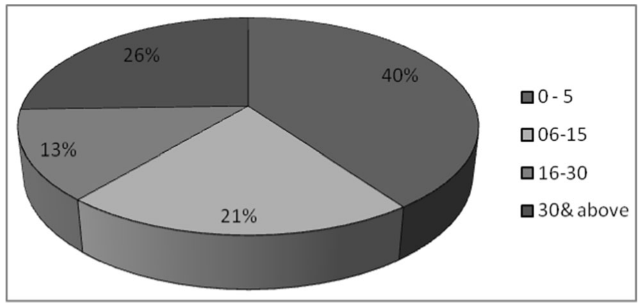

Fig. 2 Distribution of water-borne diseases among the different age groups in the Mithepur and Jaitpur area of the NCT of Delhi (2016)

Table 3 shows the incidence of selected water-borne diseases among the households. Using the formula for calculating the incidence rate for the last year, of the total population of the surveyed households, approximately 22.78% were affected by water-borne disease. The incidence rate was higher for females (28.35%) than males (14.65%). This indicates that females are more prone to water-borne diseases.

Regression results

A logistic regression analysis was conducted to establish the relationship of water-borne disease in 140 households with income, gender, sources of drinking water and age of the affected person as the logical variables. The outcome of the calculated logistic model is present in Table 4. The probability proportion test shows the regression model's significance; the chi-square estimation of 52.509 indicates that a significant relationship exists between logical factors and water-borne diseases. The logit displays the anticipated water-borne diseases with 85.7% accuracy. In this way, about 14.3 % of the values digressed from the dissemination. Income, i.e., less than 15,000 rupees, bore well and private water supplies demonstrated the expected results in relation to water-borne diseases, as all these logical values have p-values less than $\alpha = 0.05$. The other factors did not demonstrate any noteworthy association with any water-borne disease. The bore well water source was the most persuasive logical variable since it is used by the majority of the households for drinking purposes. It has a positive association with water-borne diseases (implying that the greater the consumption of bore well water, the greater the incidence of water-borne diseases). Households are dependent on bore well water sources because of the shortage of the DJB water supply. Furthermore, low-income households cannot afford to purchase water from private water suppliers. The private water supply was additionally evaluated critically and had a negative association with water-borne infection within the model, which suggests that those households using a private water supply source for drinking purposes tend to be less prone to water-borne diseases. Households earning less than 15,000 rupees per month tend to be more prone to water-borne

Table 3 Incidence of selected water-borne diseases in the Mithepur and Jaitpur area of the NCT of Delhi (2015 to 2016)

Variable	Incidence rate
For the entire population	22.781
For males	14.655
For females	28.353

*Incidence rate (IR) = (total number of cases/total population surveyed)*100

diseases compared to those whose monthly income is more than 15,000 rupees.

Table 5 shows the results for drinking water quality from the different sources used by the households. Furthermore, the water quality was tested by following the Bureau of Indian Standards (BIS) IS 3025 test method and also was compared with the IS drinking water standards to reach conclusions.

1. pH: The pH value is the measure of the relative acidity and alkalinity. The pH of water mainly depends on the temperature, nature of the water and relative concentration of acids and bases. The BIS standards reveal that the pH values for drinking water sources should range between 6.5 and 8.5. The pH values measured in all the drinking water sources were within the permissible limit.
2. Total dissolved solids: The total dissolved solids value indicates the total concentration of all constituents dissolved in the water and influences its colour, odour and taste. A high TDS value of water has a direct effect on the human digestive system. The Bureau of Indian Standards has set the required limit for drinking water at 500 mg/l, but in the absence of another drinking water supply, this limit is extended to a permissible limit of 2000 mg/l. The highest concentration of total dissolved solids was measured in the bore wells, hand pumps and piped water supply. Therefore, water from these sources is not suitable for drinking purposes, while the remaining sources have total dissolved solids values within the required limits.
3. Total alkalinity: The alkalinity in water has the capacity to neutralise strong acids. This is mainly due to the presence of carbonate, bicarbonate and hydroxide compounds of calcium and magnesium. In the study area the total alkalinity ranged from 10.0 to 409 mg/l. The maximum concentration above the BIS limit (200 mg/l) was found in the bore well, hand pump and pipe water supplies and the minimum concentration in the DJB and private water supply sources.
4. Total hardness: The total hardness of water is caused by sedimentary rocks and seepage and runoff from soil. Areas with thick topsoil and limestone have hard water. Groundwater is generally harder than surface water. Calcium and magnesium are important parameters for calculating the total hardness of drinking water. The total hardness value was also found to be above the prescribed limit of the Bureau of Indian Standards (BIS) in bore well, hand pump and piped water (300 mg/l). The total hardness of the two sources (DJB and private water suppliers) was within the required limit.
5. Chloride: Chloride is an important parameter for assessing water quality. A high concentration of chlorides indicates a high level of organic pollutants present in the drinking water. These pollutants usually originate from sources such as domestic waste, fertilisers, septic tanks, etc. Water from hand pumps was measured to have a chloride concentration 245 mg/l above the Indian Standard limit (250 mg/l) and hence is unfit for drinking purposes. The chloride concentrations of the remaining sources were within the required limit.
6. Nitrate: Generally in water sources nitrate may be present because of domestic sewage and runoff from agricultural fields. Nitrate in the study area was found within the prescribed limit. It was measured in the range of 0.28 to 34.4 mg/l as shown in Table 5.
7. Fluoride: Fluoride in water sources may be attributed to the effects of natural factors such as climate. A high concentration of fluoride in water causes health hazards such as tooth decay. The water supplied by the Delhi Government through pipe sources has a fluoride concentration above the Bureau of Indian Standards' limit of 1.0 mg/l. Other sources have fluoride levels within the prescribed limit.

Table 4 Logistic regression model estimates of the factors affecting the occurrence of water-borne disease among the households of the Mithepur and Jaitpur area of the NCT of Delhi, 2016

Variables	B	SE	Wald	*Df*	Sig.	Exp(B)
Male	1.930	1.157	2.786	1	0.095	6.892
Female	2.051	1.234	2.765	1	0.096	7.777
Age group (years)						
1–5	0.113	0.987	0.013	1	0.909	1.119
6–15	1.406	1.116	1.586	1	0.208	4.078
16–30	0.910	1.231	0.547	1	0.460	2.485
30–above	0.083	0.986	0.007	1	0.933	1.087
Income (<15,000 rupees)	−0.881	0.374	5.547	1	0.019*	0.414
Water sources						
Hand pump	1.322	0.863	2.346	1	0.126	3.751
Bore well	1.282	0.608	4.446	1	0.035*	3.602
Private water supply	1.669	0.578	8.344	1	0.004*	5.307
Piped water	0.744	0.553	1.810	1	0.178	2.104
Delhi Jal Board	0.105	0.596	0.031	1	0.860	1.110
Constant	−1.404	1.141	1.514	1	0.219	0.246

*Significance at $\alpha = 0.01$

Table 5 Water quality analysis report on different water sources in the Mithepur and Jaitpur area of the NCT of Delhi (2016)

Property	Parameter	Unit	BIS limits	WHO standard	Results					Test method
					Bore well	Hand pump	Piped water	DJB	Pvt. water supply	
Physical	pH	No unit	6.5–8.5	6.5–9.5	7.70	7.60	7.65	7.94	7.2	IS 3025 Part 11
	Total dissolved solids (TDS)	mg/l	500	500	1082*	1286*	757*	299	250	IS 3025 Part 16
Chemical	M. alkalinity as CaCO3	mg/l	200	200	369.7*	409*	257*	11.3	10.0	IS 3025 Part 23
	Total hardness as CaCO3	mg/l	300	200	556*	608*	321*	157	150	IS 3025 Part 21
	Chloride as Cl	mg/l	250	250	223	245	195	55.9	60	IS 3025 Part 32
	Nitrates as NO3	mg/l	45	45	34.4	28.7	0.28	1.1	0.32	IS 3025 Part 34
	Fluoride as F	mg/l	1.0	1.5	0.95	0.10	1.3*	0.11	0.1	IS 3025 Part 23

Source: Laboratory test result, 2016

*Water sample result above the prescribed limit of the Bureau of Indian Standards (BIS)

Conclusions and recommendations

This article shows that the prevalence of water-borne disease is significant because of an inadequate clean drinking water supply and the water sources at the household level. Evidence from the primary survey shows that of the total households surveyed, 28% were affected by water-borne disease in the study area. The finding was further strengthened by the tests carried out on the drinking water. From the foregoing observation of the physical and chemical parameters, it can be concluded that water from bore well and hand pump sources was unfit for drinking as these sources could not meet the BIS standards for drinking water. The logistic regression showed that bore well and private water supplies were significantly associated with water-borne disease. No association could be established between the different age groups of the population because of the variation in the total number of people. Households with incomes less than 15,000 rupees had increased risk compared to those with incomes of more than 15,000 rupees per month as they were dependent on bore well water and were not willing to pay private water suppliers. On the other hand, high-income households can afford to install water purification/filtration systems in their houses, which enables them to have drinking water of standardised quality and live healthy lives. To reduce water-borne diseases in the study area, improvement in the quality of the bore well and piped water supply appears to be significant as it is easily available to the households.

The observations made during the collection of household information through the primary survey and analysis of water samples in the selected study area indicate a direct interaction between people's health and the water used in the study area. Based on this information, the following recommendations can be made:

1. It is highly recommended that efforts should be made to improve the quality of water available in the area to reduce the prevalence of water-borne diseases as well as to reduce the burden of economic costs to purchase water from private water suppliers.
2. A proper sewage system should be built to avoid the overflow of sewage water onto the streets.
3. The MCD pipelines carrying potable water should be regularly checked to detect leaks and should be replaced before the water becomes contaminated.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and/or animal study No human and/or animal participation was involved in the study.

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