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Research Article

COMMUNITY BASED BACTERIOLOGICAL SURVEILLANCE OF DRINKING WATER QUALITY IN CHANDIGARH, INDIA

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ABSTRACT

The community-based longitudinal study was carried out in Chandigarh city, India from 2014 to 2016 with the objectives: (i) to collect information on bacteriological contamination of drinking water in Chandigarh; and (ii) to determine the pattern of variations in quality of water according to season, area and source. A simple random sampling strategy was used to collect drinking water samples from sources *viz.*hand pumps, tap and overhead tanks from different areas of Chandigarh. The seasonal variations in contamination of water according to area and source were analysed. Out of total 339 samples, only 34 (10.0%) were found to be contaminated. It was found that the contamination of water was higher during the pre-monsoon period although seasonal difference was not found to be significant (p=0.91). There were significant differencesin water contamination according to area (p=0.02) and source (p=0.00). The water being used in slums and rural areas for drinking purposes had higher contamination levels. This study found that drinking water supply in Chandigarh is susceptible to contamination. It has been advocated that an intensive and active interventions should be done by concerned authorities along with raising community's awareness regarding water hygiene to reduce the problem of water contamination.

INTRODUCTION

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Water quality is the measure of how good the water is, in terms of supporting beneficial uses or meeting its environmental standards. Potable water is the water which is suitable for drinking and cooking purposes. Portability considers both the safety of water in terms of health, and its acceptability to the consumer, usually in terms of taste, odor, color, and other sensible qualities (World Bank, 2012).

More than three decades ago, the 34th World Health Assemblyemphasized that safe drinking water is a basic element of 'primary health care'. Later, Millennium Development Goals included safe water and sanitation in the attainable goals. However, climate change as well as demographic change, such as the continuing growth of cities, bring significant challenges for drinking-water supply. Failure to provide adequate protection, effective treatment and disinfection of drinking water will expose the community to risk of outbreaks of water borne diseases. The greatest microbial risks are associated with ingestion of water that is contaminated with faeces from humans or animals.

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The primary bacterial indicator recommended for the purpose is the coliform group of organisms, particularly fecal *E. coli*. The most specific indicator of faecal contamination is *Escherichia coli* (*E. coli*) as mentioned by UNICEF(2008). Securing the microbial safety of drinking-water supplies is based on the use of multiple barriers, from its source to consumer, to prevent the contamination of drinking water. For these reasons, surveillance of drinking water is essentially required as a health measure. Surveillance of drinking water quality can be defined as "the continuous and vigilant public health assessment and review of the safety and acceptability of drinking-water supplies" (WHO, 1976). In India, The National Water Supply and Sanitation Programme was started in 1954 with one of the objective of providing safe water supply for the entire population of India (Park, 2017).Currently, water quality monitoring is done as a part of sentinel surveillance under Integrated Disease Surveillance Project.

One of the most important factors that affect drinking water quality through distribution and with sustainable use of town water supply systems is the quality of water the distribution systems deliver to the users (Brikke, 2002). The public water supply in Chandigarh (India) is managed by a municipal corporation. Majority of the households received individual piped water supplies. However, there are few areas where people fetch drinking water from community taps and handpumps. The water supply in Chandigarh is intermittent like most cities in India i.e. water is delivered during fixed hours (in morning and evening), so majority of households as well as commercial establishments and institutions have built overhead tanks for water storage. There is little to be gained from surveillance of piped water supplies alone if these are available to only a small proportion of the population or if they represent a minority of supplies. Against this background, this study was carried out with following objectives: (i) to collect information on bacteriological contamination of drinking water in Chandigarh; and (ii) to determine the pattern of variations in quality of water according to season, area and source.

METHODS

Study area and study design

The Union Territory of Chandigarh has a total population of 1 055 450 people including 97.25 per cent urban areas (Census, 2011). A community-based longitudinal study was conducted in Chandigarh over a period of three years (from January 2014 to December 2016). The samples were collected as a part of routine water surveillance carried out in different parts of the city by Department of Community Medicine, Government Medical College & Hospital (GMCH), Chandigarh. A simple random sampling strategy was followed to select representative sites from different areas of Chandigarh to represent the different sources of water used by all sections of society residing in urban, rural and slum areas. Thus, the drinking water samples were collected randomly from taps of houses, commercial establishments and institutional settings, hand pumps, community taps and tube wells.

Collection of water samples

A team comprising postgraduate students in Community Medicine, medical officers/demonstrators along with sanitary inspectors and trained health workers collected water samples during early morning hours 0700–0900 hours, in accordance with the methods described in 'International Standards for Drinking Water' (WHO, 2011).Sampling was carried out bimonthly during the months of May to October and once every month during the months of November to April in community. However, weekly surveillance was carried out during the months of May to July to cover the entire hospital, associated rural and urban health centres, and residential campus. Samples were collected in wide-mouthed sterile flasks. Samples were taken to the laboratory for analysis within two hours of collection.

Laboratory analysis of samples

The most probable number (MPN) of coliform organisms in water samples was determined for bacteriological contamination using presumptive coliform count employing the method described by *Mackie and McCartney* (Senior, 1996).

Table 1 Seasonal variations in contamination of water samples according to area and source of collection

Area	Source	Water samples	Pre-monsoon N (%)	Monsoon N (%)	Post-monsoon N (%)	Total N (%)
Rural	Tap	Collected	12	54	34	100
		Contaminated	00	02 (03.7)	02 (05.9)	04 (04.0)
	Hand pump	Collected	04	07	03	14
		Contaminated	02 (50.0)	05 (71.4)	00	07 (50.0)
	Overhead tank	Collected	06	00	00	06
		Contaminated	01 (16.6)	00	00	01 (16.6)
	Total	Collected	22	61	37	120
		Contaminated	03 (13.6)	07 (11.5)	02 (05.4)	12 (10.0)
Urban	Tap	Collected	37	16	02	55
		Contaminated	00	00	00	00
	Hand pump	Collected	01	01	00	02
		Contaminated	00	00	00	00
	Overhead tank	Collected	71	03	08	82
		Contaminated	08 (11.3)	00	00	08 (09.8)
	Total	Collected	109	20	10	139
		Contaminated	08 (07.3)	00	00	08 (05.7)
Slum	Tap	Collected	15	33	21	69
		Contaminated	05 (33.3)	03 (09.1)	04 (19.0)	12 (17.4)
	Hand pump	Collected	02	02	05	09
		Contaminated	00	01 (50.0)	01 (20.0)	02 (22.0)
	Overhead tank	Collected	00	02	00	02
		Contaminated	00	00	00	00
	Total	Collected	17	37	26	80
		Contaminated	05 (29.4)	04 (10.8)	05 (19.2)	14 (17.5)
TOTAL	Tap	Collected	64	103	57	224
		Contaminated	05 (07.8)	05 (04.8)	06 (10.5)	16 (07.1)
	Hand pump	Collected	07	10	08	25
		Contaminated	02 (28.6)	06 (60.0)	01 (12.5)	09 (36.0)
	Overhead tank	Collected	77	05	08	90
		Contaminated	09 (11.7)	00	00	09 (10.0)
	Total	Collected	148	118	73	339
		Contaminated	16 (10.8)	11 (09.3)	07 (09.6)	34 (10.0)

Detection of growth of *Vibrio cholerae* was also done using the concentration technique described by Mackie and McCartney. The samples which were found contaminated (on first visit) were repeated in the next visit.

Data analysis

The data was entered in to EpiData v3.0. Statistical analysis was done with the help of Microsoft Office Excel 2007 and Open Epi 2007. Descriptive statistical analysis was represented through frequency and percentages. Chi square test was used as test of significance, considering $p<0.05$ aslevel of significance. Samples with MPN more than three were considered unfit for drinking purpose i.e. contaminated. Time trend and variations in contamination in different areas were analysed. To explore the seasonal variations in quality of drinking water, the months from March to June, July to October and November to February were considered as pre-monsoon, monsoon and post-monsoon, respectively. On bacteriological examination, if the water sample was found to be contaminated, then appropriate authorities (Director Health Services, Chandigarh Administration and Medical Superintendent, GMCH Chandigarh) were informed, so remedial action could be taken as soon as possible. All the hand pumps which were found to supply contaminated water were either marked unfit for drinking or these hand pumps were removed.

RESULTS

Total of 339 drinking water samples were collected and analysed. Only 34 (10.0%) were found to be not fit for drinking purposes (MPN more than three). None of the water sample was detected to be positive for *Vibrio* cholera during the study period. Table 1 shows the seasonal variations in contamination of water samples according to area and source of collection.The proportion of contaminated samples had significantly reduced from 18.7% in 2014 to 07.4% in 2016 (p=0.00) (Table 2).

Table 2 Association between water contamination and various variables

Variables	Total	Contaminated	Not contaminated	Chi square; p
Season				
Pre-monsson	148	16 (10.8)	132 (89.2)	0.2; 0.91
Monsoon	118	11 (09.3)	107 (90.7)	
Post-monsoon	73	07 (09.6)	66 (90.4)	
Year				
2014	128	24 (18.7)	104 (81.3)	19.6; **0.00**
2015	89	01 (01.1)	88 (98.9)	
2016	122	09 (07.4)	113 (92.6)	
Area				
Urban	139	08 (05.7)	131 (94.3)	7.8; **0.02**
Rural	120	12 (10.0)	108 (90.0)	
Slum	80	14 (17.5)	66 (82.5)	
Source				
Tap	224	16 (07.1)	208 (92.9)	20.7; **0.00**
Hand pump	25	09 (36.0)	16 (64.0)	
Overhead tank	90	09 (10.0)	81 (90.0)	

Figures in parenthesis represents percentages.
Significant results are shown in bold, taking p ≤ 0.05 as level of significance.

Contamination of water from different sources

Maximum 36.0% water samples of the hand pumps were found to be contaminated. None of the water sample from water cooler and only one water sample (out of seven) from tube wells was found to be contaminated. The difference according to source was found to be statistically significant (p=0.00). Due to their small proportions, number of water samples from water coolers and tube wells were merged with water samples from tap for further analysis. The level of contamination of tap water was reduced over the period from 18.1% to 03.7%. Similar observation was recorded in samples collected from overhead tanks (from 13.9% to 8.1%). However, contamination of water samples from hand pumps was 30.0% in 2014, and increased to 60.0% in 2016. The level of contamination of tap water samples remained lower than that of samples collected from other sources throughout the study period (Fig. 1).

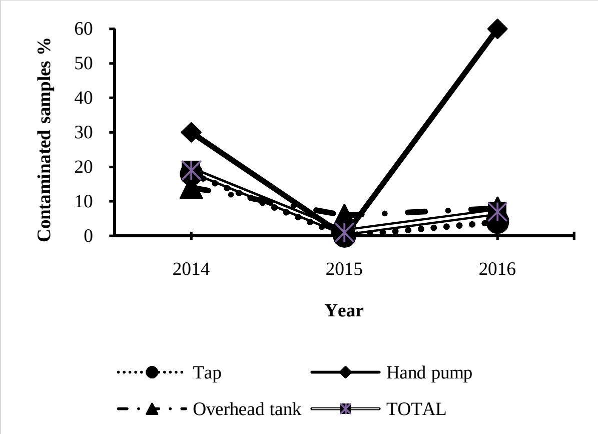

Fig 1 Variations in level of contamination of water samples by source, collected during 2014 – 2016 in Chandigarh (N=339, p=0.00).

Half of the total samples collected from hand pumps in rural areas were found to be contaminated. None of the water sample from tap and overhead tank was found to be contaminated in urban and slum areas, respectively. On the other hand, 17.4% of water samples from tap and 09.8% of water samples from overhead tank were found to be contaminated in slum and urban areas.

Contamination of water from different areas

The prevalence of bacteriological contamination of water was found to be highest in slum areas (17.5%) followed by 10.0% in rural areas and 05.7% in urban (Table 2). The difference was found to be statistically significant (p=0.02). There was a marked reduction in the levels of water contamination in slums over the study period (from 35.5% to 13.0%). Similarly, level of water contamination in urban areas was reduced from 13.2% to 03.3% during study period. However, there was marginal reduction in rural areas (from 13.6% to 10.5%) (Fig. 2).

Seasonal variation in contamination of water samples

It was observed that the level of contamination of water was found to be high in pre-monsoon season (10.8%) although the difference was not found to be significant (p=0.91). There was a marked reduction in the levels of water contamination during pre-monsoon season over the study period (from 24.0% to 04.9%). Similarly, level of water contamination in monsoon season was reduced from 18.0% to 06.2% during study period. However, there was increase in levels of contamination during post-monsoon season (from 10.7% to 14.3%). It was observed that majority of hand pump samples i.e. 60.0% and 28.6% were contaminated during monsoon and pre-monsoon seasons, respectively. During post-monsoon season, 10.5% samples from tap were contaminated.

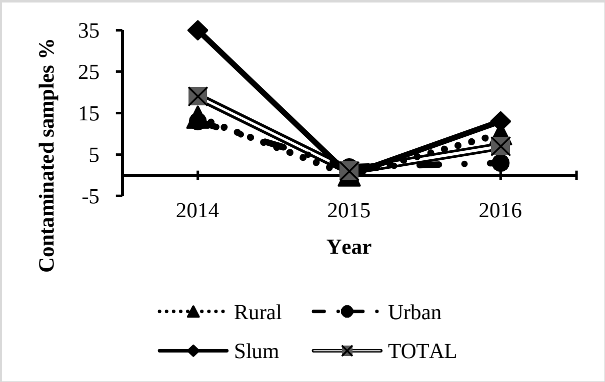

Fig 2 Variations in level of contamination of water samples by area, collected during 2014 – 2016 in Chandigarh (N = 339, p=0.02).

DISCUSSION

Water quality and the risk of water-associated diseases are serious public health concerns. Drinking-water supply arrangements in urban areas of low-middle income countries like India are typically complex. There can be one or more piped supplies with household and public connections, in combination with alternative drinking-water sources, including hand pumps and vended water. In these situations, the surveillance programme should take account of the different sources of drinking-water. In addition, community-managed drinking-water supplies are often found in most countries.

We found that one-tenth of the drinking water samples were contaminated in Chandigarh. This prevalence is much lower compared with study conducted by authors earlier when 29% of the drinking water samples were found to be contaminated (Goel *et al*., 2015). Other studies conducted in Indian cities found higher prevalence of contaminated water samples ranging from 43% to 93% (Mehta *et al*., 1990; Bandopadhyay *et al*., 1992; Brick *et al*., 2004; Rao *et al*., 2006; Shankar *et al*., 2008). However, various authors documented much fewer samples with MPN more than 03 (Manjula *et al*., 1993; Strauss *et al*., 2001; Marisa *et al*., 2005; Tambe *et al*., 2008). In a study by Jain *et al*. (2010) conducted in district Nainital (Uttarakhand, India), bacteriological analysis of samples of groundwater from does not show any sign of bacterial contamination in hand pump and tube-well water samples.

Maximum 36.0% water samples of the hand pumps were found to be contaminated which may indicate contamination of groundwater. The indiscriminate open field defecation and inadequate facilities for human excreta disposal may lead to infiltration of coliforms into the upper level of groundwater. On the other hand, the level of contamination of tap water was reduced over the period from 18.1% to 03.7%. This reduction in contamination in tap water than for hand pumps indicates an improvement in the water distribution system in the areas.

The prevalence of bacteriological contamination of water was found to be highest in slum areas (17.5%) although there was a marked reduction in the levels of water contamination in slums over the study period (from 35.5% to 13.0%). The improvement in water supply to these areas could be responsible for this change. Earlier, the maximum contamination was observed in water samples collected from rural areasin Chandigarh (Goel *et al*., 2015).

In our study, overall the level of contamination of water was found to be high in pre-monsoon season which is contrary to the normal belief that the water sources are maximally infected during monsoon season, although the seasonal difference was not found to be significant (p=0.91). This might be because this time of year (March to June) is the hottest requiring greater consumption (quantity) of water which could be more easily met by hand pumps than tap water in slums and rural areas. In slums and urban areas, the tap water supply is available for a limited period of the day only. Thus, increased demand and short supply of water also forced public to rely on overhead tanks for water. Although these hand pumps were only permitted to be used for purposes other than drinking, the inhabitants were using these for all purposes including drinking. Marisa *et al*. (2005) and Levy *et al*. (2008) in their study also found higher contamination coinciding with the hottest season, which may be indicative of high indoor temperatures promoting bacterial growth in the storage containers. In the dry season, water availability is also lower, particularly in the urban sites, most likely necessitating longer storage times. Longer storage times allow for microbiological water quality changes due to natural growth and attenuation as well as anthropogenic causes (e.g. poor hygiene practices resulting from using insufficient quantities of water).

During monsoon, contamination of water was found in rural & slum areas in our study. A possible explanation for this is that in these area, wet weather conditions lead to higher bacteria concentrations in the water from high outdoor contamination due to open defecation practices and animals being kept near the home. Kattula *et al*. (2015) also found similar observation in their study in south India. Haylamicheal and Moges(2012) assessed rural water supply scheme in Ethiopia and they found majority of the water points (85.7%) had detectable levels of total coliform bacteria and 25% had fecal coliform bacteria. Pritchard *et al*.(2008) in their study in Malawi identified that about 80% of water samples collected from wells fitted with hand-pumps had detectable levels of coliform bacteria.

We found that levels of contamination increased during post-monsoon season (from 10.7% to 14.3%). The rains during monsoon season act to amplify contamination of ground and surface water due to leaching and flushing effects in the insanitary conditions prevailing in the rural and slum areas. Similar observations have been made by several authors (Mehta *et al*., 1990; Bandopadhyay *et al*., 1992; Manjula *et al*., 1993; Strauss *et al*., 2001; Brick *et al*., 2004; Marisa *et al*., 2005; Rao *et al*., 2006; Shankar *et al*., 2008; Tambe *et al*., 2008; Chitanand *et al*., 2008; Levy *et al*., 2009; Kulinkina *et al*., 2016).

Kostyla *et al*. (2015) did a systematic review on seasonal variation of fecal contamination in drinking water sources in developing countries. They reported that in most studies, peaks in indicator bacteria concentrations in drinking water occur during wet weather conditions. When water quality in piped systems specifically was considered, six studies conformed to this trend and two studies found higher contamination levels during dry weather conditions. Bacteria concentrations in piped water are expected to be influenced by infiltration of fecal contamination from the environment during periods of heavy rainfall in case the water systems are in poor structural condition. However, no contaminated water sample was found during monsoon and post-monsoon in urban area in our study which may indicate piped water supply is adequate.

During the study period, the Government of India took the initiative in October 2014 by launching the *Swachh Bharat Abhiyan* (Clean India Mission) all over the country to clean streets, roads and infrastructure of the country, that aims to eradicate open field defecation by year 2019 (Park, 2017).This may be one of the reason for significant reduction in proportion of contaminated water samples from 18.7% in 2014 to 07.4% in 2016 in our study.

CONCLUSION

This study found that drinking water supply in Chandigarh is susceptible to contamination, especially in slums and rural areas, and during pre-monsoon season. A preventive integrated management approach with collaboration from all relevant agencies is the preferred approach to ensuring drinking-water safety. Thus, it has been advocated that an intensive and active interventions should be done by public health engineering and the health department to reduce the problem of water contamination. In addition, the active support and involvement of local communities is also required for effective and sustainable management of community drinking-water quality. Public awareness should be raised about remedial actions for water quality including disinfection and proper storage methods, sanitation and hygiene practices.

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