JCHR

Journal of Community Health Research 2019; 8(2): 113-120.

A Study of Risk Factors related to Water and Sanitation in Pune, west India

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ARTICLE INFO

Original Article

Received: 23 Feb 2019
Accepted: 19 May 2019

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ABSTRACT

Introduction: Piped water systems are considered to be the gold standard for drinking water according to the Joint Water Monitoring Study. However, poor maintenance of distribution pipes, intermittency of water supply, and sewage water intrusion have contributed to a number of water-borne disease episodes in developed and developing countries.

Methods: This study investigated the risk burden related to drinking water and sanitation in population clusters of Pune, western India that are being served by a piped distribution system through a cross-sectional survey. Two-stage stratified convenience sampling was carried out. The city was divided into administrative wards of which the city center, the neo-urban and the peri-urban settlement were selected. In the second step a higher (HSG) and a lower socioeconomic group (LSG) were selected from each of the three studied wards. A questionnaire including close-ended items was used to conduct the survey.

Results: In 2711 individuals studied, risk burden related to drinking water and sanitation was found to be higher in the LSG; 60% (677 of 1121), 70% (1029 of 1473) , 74% (1325 of 1791) from the LSGs did not have a private water tap and continuous water supply, and did not treat the water at the household level, respectively. 98% (1403 of 1426) had neither a private water tap nor a private sanitary facility. The socioeconomic difference was significant ($p<0.0001$). 51 (3.5%) individuals from the LSGs and 42 (3.49%) ones from HSGs reported having suffered from severe diarrhea in the recall period of 2 years. Although the number of disease cases was lower than the overall risk burden, the potential of the latter to cause a disease outbreak cannot be eliminated.

Conclusion: The study highlights that piped drinking water system which is considered as a safe source can become a source of pathogenic microorganisms if not properly maintained. A holistic approach to risk assessment, i.e., from the catchment and its source water to the consumer, is required.

Keywords: Diarrhea, Risk Factors, Drinking Water, Sanitation

How to cite this paper:

Dutta S, Bharucha E. A Study of Risk Factors related to Water and Sanitation in Pune, west India. Journal of Community Health Research. 2019; 8(2): 113-120.

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[DOI: 10.18502/jchr.v8i2.1181]

Introduction

The World Health Organization defines a risk factor as an attribute or characteristic to which if an individual is exposed, increases the likelihood of incidence of the disease in the individual (1).

Globally, around 2.4 million deaths can be prevented annually if appropriate hygiene, good sanitary practices and adequate treatment of drinking water are carried out (2). Such interventions reduce the risk of contracting gastrointestinal diseases by providing barriers to pathogens and thus preventing them from travelling from feces to fingers/foods, contaminating water and ultimately entering the gastrointestinal system (3). In 2015, globally 2.3 billion people lacked access to basic sanitation and in India, 40% of the national population practiced open defecation (8)

Diarrhea, a gastrointestinal disease, is the third leading cause of mortality in low-income countries, with poor water quality, inadequate sanitation and unhygienic behavior being the most common risk factors (4). According to the definition of the WHO, a diarrheal episode implies three or more loose or fluid stools that take the shape of the container (5). The disease is caused by the consumption of food and water contaminated by fecal microorganisms, like Shigella spp, Aeromonas spp., Clostridium difficile with E. coli being the most common (6). The source of contamination is mainly poor hygiene and lack of adequate sanitation facility. In 2012 diarrhea led to an estimated 1.4 million deaths (7).

In India, even though fatal infections such as typhoid and cholera have drastically reduced since colonial times, diarrhea remains to be systematically controlled. The continuing incidence of the disease imply the presence of its' risk factors, i.e., poor quality water, poor hygiene and inadequate sanitation. In developed countries like USA and UK, the impact of sanitary interventions has greatly led to the elimination of certain infections like diarrhea and cholera. In developing countries (including India) medical interventions are mainly responsible for infection control (9). This is the result of a defective health system that, in turn, is the consequence of a skewed approach, taken towards public health during British rule in India, not allowing public health interventions to receive higher importance than international trade relations (e.g. quarantine during cholera led to interference in trade relations) (10, 11). This historical aspect did not allow the implementation of water, sanitation and hygiene interventions to its full capacity with the underprivileged left at the mercy of the bureaucrats.

With advancements in the field of medicine as well as interventions in public health, India has managed to reduce mortality and morbidity due to cholera, typhoid and other gastrointestinal diseases but their risk factors such as open field defecation are still widespread not only in the rural areas but also in urban under-privileged communities (informal settlements/slums) of India. Low-quality engineering is used to remove piped or open sewage in most urban settings. These factors easily lead to fecal contamination of drinking water supply (12).

If not maintained properly, a building's piped distribution system can also become a source of contamination and may lead to microbial or chemical contamination of drinking water. Gastrointestinal disease outbreaks can also occur through faecal contamination of drinking water within buildings due to poorly maintained roof storage tanks and cross-connections with wastewater pipes.

In a country like India, not only the economically deprived but also those who receive their drinking water supply via a piped distribution system susceptible to this infection. Even though such systems are considered advanced and a safe source by the WHO, JMP and UNICEF, studies have shown that if not maintained properly, they too are easily prone to contamination (13, 14). Rapid deterioration of infrastructure and water distribution systems and other related problems to water supply systems are more frequently observed in developing countries than developed countries (15). Intermittent water supply, insufficient water pressure, disinfectant residual, and cross-

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[DOI: 10.18502/jchr.v8i2.1181]

connection are some of the factors that can lead to contamination of the water distribution system (16). Studies carried out in Indian cities have shown the presence of coliforms in samples collected from intermittent water sources compared to continuous water sources (17-19). Due to supply intermittency, individuals are forced to store drinking water, during which the water may be contaminated if hygiene is not appropriately maintained in the vicinity (14). There is evidence on the presence of high number of coliforms in samples taken from taps at the household level compared to relatively low numbers of or no coliforms when sample is collected immediately after treatment (20-24).

This study investigated the risk burden related to drinking water and sanitation across Pune in higher (HSGs) and lower socioeconomic groups (LSGs) by exploring the distribution of risk factors related to drinking water and sanitation in piped water system of urban and peri-urban Pune, western India.

Methods

Studied Area

The household survey was carried out in Pune, a city in western India located at an altitude of 1800 feet on the Deccan Plateau (25). Pune has grown into a major city by undergoing rapid transformation and industrialization. According to Rode (26), 91% of water in Pune is used for domestic purposes such as drinking, cooking, washing and bathing. The physical, chemical and bacteriological tests of raw and filtered water are carried out in the laboratory on a regular basis. However, the water distribution system of Pune is very old and dates back to the 1960s.

Urbanization in Pune has led to differentiation of the city into distinct regions that are characterized by varying housing typologies. To represent this spatial differentiation in the study population city two wards from within Pune administration Kasbapeth (city center), ward Dhankawadi (neo-urban) and one beyond the administrative boundary Lavale-Pirangut (peri-urban region) were identified for the household survey. Comparative analysis of populations sampled from HSGs and LSGs across was done in three typologically distinct regions of Pune. These three districts vary significantly in population densities and housing. The city center has the highest population density and is also the oldest part of the city. The neo-urban region lies in the peripheral part of the city and is rapidly developing. The peri-urban region is predominantly a rural settlement that has started to show signs of urbanization due to its proximity to Pune. This region has no informal settlements (slums). Therefore, the population of the rural part of the peri-urban region was sampled and categorized as LSG.

Methodology

This study was aimed to explore the differences in risk burden for water-borne disease in urban and peri-urban Pune.

The current study is a cross-sectional study in Pune. This city is undergoing urbanization which has led to division of the city into different typologies which are at different stages of urbanization. Two-stage stratified convenience sampling was carried out so that the studied population substantially represented the whole population of the city. In the first step, the city was divided into administrative wards of which Kasbapeth from city center and Dhankawadi from neo-urban (urban fringe) were selected. Lavale and Pirangut located 20km away from Pune city were selected to represent the peri-urban region. This region is pre-dominantly rural but due to its proximity to the city has started showing signs of urbanization.

In the second step, two socioeconomic groups, namely, HSG and LSG were selected from each of the three studied districts. The socioeconomic characteristics were determined according to the information collected on education. In the districts within the city boundary the LSGs also included the slum settlements. In the peri-urban region the rural part was categorized as LSG (as slum settlements were absent) based on the education level of the studied population.

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A questionnaire of close-ended items was used to collect information related to demography, socioeconomic characteristics, drinking water and sanitation characteristics and disease burden. Informed written consent [in local language (Marathi) and English] to participate in the study was obtained from the household before the interview.

The questionnaire was pre-tested in the peri-urban region. To calculate the disease burden households were asked if any of their members suffered from severe diarrhea in the 2-year recall period.

Paired sample t-test was used to investigate the significance of difference in the risk burden and disease burden between the two socioeconomic groups. Because we compared two percentages obtained from independent samples, paired sample t-test was calculated.

Next, information on drinking water characteristics was collected

(a) Water Source: Private (household) or public
(b) Water Timing: Continuous or intermittent
(c) Water treatment at the household level: Boil/Filter or neither
(d) Sanitation: Private or Communal

The data collected were coded for analysis in Microsoft Excel (2010) and statistical analysis was carried out in the R software.

The ethical approval of the study protocol was obtained from the Interdisciplinary Ethical Committee of BVIEER.

Results

A total of 2711 individuals were studied of whom 1260 and 1451 belonged to HSGs and LSGs, respectively. It was observed during the study that in spite of socioeconomic differences, 100% of the population had access to piped water supply. However, a significant difference was observed in water timing, water source, water treatment at the household level and sanitary status between the two socioeconomic groups. A paired sample t-test was performed to determine whether there was a significant difference between the risk burden and disease burden between the two socioeconomic groups. Results are tabulated below. Risk factors were observed to be higher in the lower socio-economic groups.

Table 1. Age-specific risk burden in the two socioeconomic groups

No private drinking water tap		Intermittent water supply		No treatment at the household level		Sanitation	
LSG	**HSG**	**LSG**	**HSG**	**LSG**	**HSG**	**LSG**	**HSG**
(677 out of 1451) 47%	(444 out of 1260) 35%	(1029 out of 1451) 71%	(444 out of 1260) (35%)	1325 out of 1451 (91%)	466 out of 1260 (37%)	1403 out of 1451 (97%)	23 out of 1260 (1.82%)
Result of 2 sample t-test							
P< 0.0001		P< 0.0001		P< 0.0001		P< 0.0001	

(a) Drinking water source

47% of individuals from the LSG received water from a public tap. A public or a communal tap is one that is distributed among families or sometimes is shared by a whole community. In slum settlements such as those in this study, it is common to see stray animals resting or defecating near such communal sources of water. Because this is common in such environments, it does not raise any concern amongst the inhabitants and therefore they continue to use such water.

(b) *Water supply timing*

The Pune Municipal Corporation supplies water within certain intervals daily depending on the presence of a storage tank that the water is collected in and is then supplied to households throughout the day. During the study, it was found that those living in gated communities had a common water tank due to which the subjects would receive water supply for 24 hours. This was not the case in the LSGs. In the LSGs water would be stored in covered/uncovered barrels outside the

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[DOI: 10.18502/jchr.v8i2.1181]

house, from where it would be used for drinking and other domestic purposes. This was reported to be intermittently supplied. 35% of our studied population in the HSGs did not receive a continuous water supply. This scenario was particularly observed in the peri-urban part of Pune where the main water source is a river and according to the respondents, the water is not treated efficiently due to which sediment can be clearly observed in the water. To overcome this dilemma the inhabitants resort to purchasing bottled drinking water. Hence, even if the inhabitants did have access to piped supply, the water needs to be considerably treated before consumption.

(c) *Drinking water treatment*

Boiling and filtering of drinking water at the point of consumption is a precautionary measure as it has already been treated at the source before being supplied to the whole city. In spite of this prior treatment, there have been instances of intermittent outbreaks that are likely to be due to poor maintenance of the distribution system and pipelines. Minor disease outbreaks that lasted a day or two have also occurred in the past (27).

(d) *Sanitary Facility*

In the urban slums, individuals are forced to use communal sanitary facility that does not have a proper drainage system. In the rural part of the peri-urban system, the households had a private sanitary facility but it was located outdoors. From hygiene perspective, the sanitary facilities were better in the rural part of the peri-urban region than in the urban slums.

(e) Disease Reporting

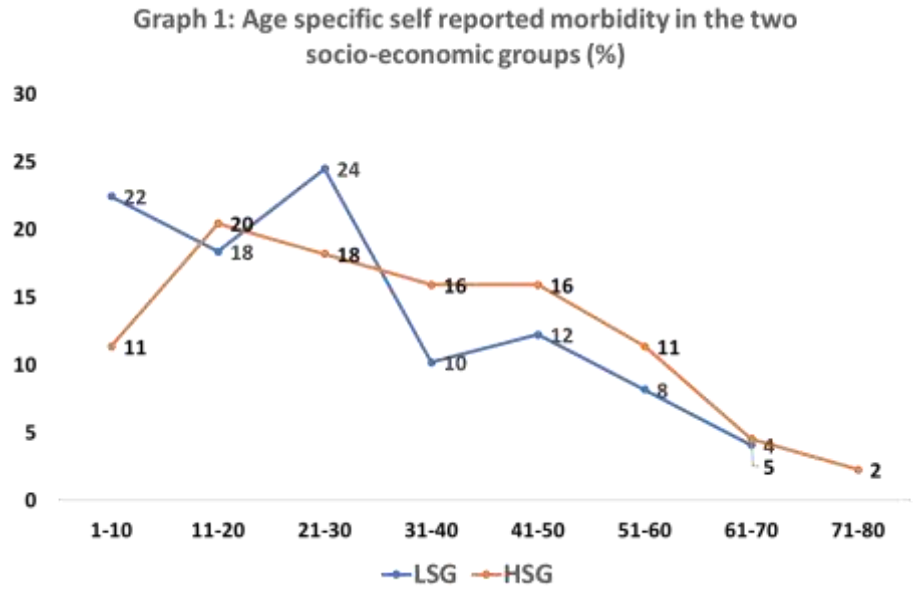


Figure 1. Age specific self-reported morbidity in the two socio-economic groups (%)

Graph 1 The disease burden in the two socioeconomic groups. Overall, 93 (3.6%) individuals reported having severe diarrhoea in the 2-year recall period; 51 (3.5%) from the lower socioeconomic groups and 42 (3.3%) from higher socioeconomic groups. Unlike risk burden, no socioeconomic trend was observed for disease burden.

Discussion

The population investigated in this study had access to piped drinking water supply irrespective of the socioeconomic differences between the two groups. In spite of this common facility, disparity was observed with respect to other aspects of drinking water use and management. The majority of the population belonging to the LSGs did not have a private water tap, had intermittent water supply and did not treat the water before drinking (Table 1). This can be attributed to unaffordability as well as behavioral attributes due to inadequate

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education and awareness.

Good sanitary practices and appropriate methods to dispose of human feces are also critical prerequisites to control water-borne infections. In our study, it was observed that, 77% of the individuals from LSGs used a communal sanitary facility. Inaccessibility to a continuous water supply, along with inadequate infrastructure and poor drainage of the sanitary facilities and unhealthy behavior of those who use the facility increase the risk drastically as it leads to the direct exposure to fecal coliforms. The remaining 9% belong to the rural part of peri-urban region that have private yet outdoor sanitary facilities.

Water treatment at the household level is important even after water has undergone treatment at the treatment plant because of engineering defects in the distribution system. There have recently been reports of outbreaks in the city. In 2017, rusty pipelines and mixing of sewage and drinking water have resulted in many cases of diarrhea and dysentery. Concerns were brought up regarding the age of the distribution system established in the 1960s.

Comparably, the burden of morbidity risk from diarrhea was found to be low. A total of 93 of 2711 (3.6%) cases were reported, without any definite socioeconomic trend.

First, diarrhea as a disease does not elicit a serious response. Public health interventions have been immensely effective in combating many fatal water-borne infections such as cholera and typhoid that decreased life expectancy to 40 years in the 1960s. Diarrhea, which is considered a common disease with a recovery period of a few days, is not regarded as a serious health condition. This leads to negligence of the disease and therefore its risks. Due to failure of the distribution system, 8901 cases of typhoid fever leading to 95 deaths were reported in Tajikistan in 1997 (22). These neglected risks if not dealt with immediately pose serious threats to the population. However, poor drinking water and inadequate sanitation continue to contribute substantially to acquiring other fatal infections like typhoid and cholera. If the present risk burden is not eliminated, the outbreak of other fatal water-borne infections will be likely.

Access to a treated, piped water source has been demonstrated to be crucial in the improvement of public health and the decrease of transmission of infectious water-borne diseases (28). In developed countries distribution system failure (which is relatively rare) has been known to cause 18% of reported disease incidence (29). However, in a developing nation like India, poorly maintained distribution system along with inaccessibility to clean drinking water and inadequate sanitation to certain subpopulations increase the risk to water-borne diseases.

Conclusion

According to the definition of the WHO, a risk factor increases the likelihood of a disease incidence but does not warrant its outcome.

A holistic approach to risk assessment is required throughout a drinking-water supply, i.e., from the catchment and its source water to the consumer to assess and confront risks. This is so because a single flaw does not lead to a distribution failure; instead, a combination of a number of failures in the system results in poor water quality. Inadequate residual disinfection, inadequate pressure, intermittent water supply, leakage, corrosion and old infrastructure are some of the factors that result in a failure in the provision of clean drinking water (16). A reliable water system will not only prevent diarrhea but also other types of water-borne diseases including cholera and typhoid (2).

Acknowledgements

We would like to thank Ms. Masoumeh Esmaeili for her help in translation of the abstract.

Conflict of Interest

The authors declare that they have no competing interests.

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[DOI: 10.18502/jchr.v8i2.1181]

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