In-house contamination of potable water in urban slum of Kolkata, India: a possible transmission route of diarrhea
Anup Palit, Prasenjit Batabyal, Suman Kanungo and Dipika Sur

ABSTRACT
We have investigated and determined the potentiality of different water sources, both for drinking and domestic purposes, in diarrheal disease transmission in diarrhea endemic foci of urban slums in Kolkata, India in a one and half year prospective study. Out of 517 water samples, collected from different sources, stored water (washing) showed higher prevalence of fecal coliforms (58%) ($p < 0.0001$) in comparison with stored (drinking) samples (28%) and tap/tubewell water (8%) respectively. Among different sources, stored water (washing) samples had the highest non-permissible range of physico-chemical parameters. Fecal coliform levels in household water containers (washing) were comparatively high and almost 2/3 of these samples failed to reach the satisfactory level of residual chlorine. Interestingly, 7% stored water (washing) samples were found to be harboring Vibrio cholerae. Improper usage of stored water and unsafe/poor sanitation practices such as hand washing etc. are highlighted as contributory factors for sustained diarrheal episodes. Vulnerability of stored water for domestic usage, a hitherto unexplored source, at domiciliary level in an urban slum where enteric infections are endemic, is reported for the first time. This attempt highlights the impact of quality of stored water at domiciliary level for fecal–oral contamination vis-à-vis disease transmission.

Key words | chlorination, diarrhea, stored water, transmission

INTRODUCTION
Diarrheal diseases, a major cause of mortality and morbidity in humans, are caused by a variety of micro-organisms including bacteria, viruses and protozoan. It has been estimated that likely 15–20% of community diarrheal disease in developing countries is attributed to unsafe drinking water with recent studies indicating even higher percentages of waterborne diarrheal disease. Even in developed countries, as much as 15–30% of community gastroenteritis (diarrheal illness) has been attributed to municipal drinking water (Sobsey et al. 2002).

Water and sanitation deficiencies represent a growing environmental health challenge in several regions around the globe. Unsafe sewage disposal and fecal–oral transmission of pathogens are responsible for enteric diseases and millions of premature deaths every year. In recent decades, a consensus has been developed that the key factors for the prevention of diarrhea are availability of safe water, adequate sanitation facilities and proper personal hygiene. However, this consensus has recently been disputed by a spate of studies suggesting that home based water treatment can produce substantial reductions in the incidence of endemic diarrhea (Sobsey 2002). There are different schools of opinion addressing the exact source of infection. While Cairncross et al. (1996) observed that two distinct ways of contamination (or pathogen transmission) exist with both the public (outside the household) as well as the domestic (inside the household) domain being the contributors, contrary to this opinion VanDerslice & Briscoe (1995) emphasized that infant diarrhea was associated with water contamination taking place in the public domain solely. Substantiating this fact, in some developing country contexts improvements in source quality may have produced negligible reductions in diarrheal disease (Bennett 2008).

Accordingly several studies have been undertaken to better understand the mechanisms underlying the relationship between source protection and childhood diarrhoea (Jalan & Ravallion 2003; Bennett 2008; Kremer et al. 2009). A study estimating the effects of randomized spring source protection in Kenya found a 62% increase in drinking water quality, increased usage of protected (as...
compared with unprotected) springs and a 33% reduction in childhood diarrhoea after the addition of spring protection (Kremer et al. 2009). However, other studies have found limited or no health benefits from source protection. In India, piped water supplies only benefit high income households, while in the urban Philippines substitution between piped drinking water supplies and sanitation eliminates the health gains from piped water (Jalan & Ravallion 2003; Bennett 2008).

The Kolkata slum dwelling population is considered as diarrhea prone as evidenced from I.D. hospital surveillance data (Mukherjee et al. 2010). Due to high prevalence of the risk factors for diarrhea in Kolkata slum areas (Sur et al. 2004) the incidence of diarrhea and cholera are as high as 57.7 cases per thousand person-years and 2.2 cases per thousand person-years (Sur et al. 2005) respectively. Compared with other slums in Asia, this slum population is stable and relatively homogeneous in nature and in-migration and out-migration is less than 5%. Only 7% of the households use individual flushed latrines and only 11% of families have their own source of drinking water. It is also worthwhile to mention here that in a separate evidence based study, it has been demonstrated that sanitation in terms of hand washing is not a common practice among 34–41% of the population in the target focus and 96% of study population drink water which is neither boiled/nor filtered (Sur et al. 2007).

However, the links between source protections, drinking water quality and childhood diarrhoea remain unclear and less explored at this level of population. Some earlier studies (Nair et al. 2010) pointed out that the major water borne pathogens in this focus are Escherichia coli and Vibrio cholerae, responsible for diarrheal infections. Thereby we attempt to focus on these two diarrheal pathogens along with the presence/absence of coliform.

Accordingly, the present study has been designed to identify factors contributing to the source of contamination in potable water at different levels of usage along with the detection of enteric pathogens attributable to diarrhoeal episodes.

**METHODS**

**Study site**

The study has been carried out in the urban slum population of ward no 28, 29, 33, 34, 66 and 67 of Kolkata Municipal Corporation (KMC) in the city of Kolkata located in the eastern part of India. Kolkata is a densely populated city; the urban area has an estimated population density of 24,718 persons per km² (Census of India 2001).

**Study population**

The study was carried out among 2,09,816 individuals living in 6,949 premises. The families use KMC supplied common tap waters for drinking as well as other household purposes. However, other water sources, such as tube wells, are also in use for carrying out household works. The water lines lie in close proximity with the sewerage and soil water pipes.

**Sample collection**

Samples from all potable water sources (tap/tube well/stored) were collected from randomly selected households where cholera/diarrhea cases were freshly reported between May 2007 to November 2008. Samples were classified into two categories i.e. public domain (outside the household), e.g. main sources such as tap or tube well and domestic (inside the household) domain, e.g. stored water (used either for drinking purposes or for domestic purposes). Collections were made in 200 ml sterile glass bottles and transported to the central laboratory at ambient temperature (Bordner et al. 1978; World Health Organisation 2006; Sobsey & Pfaender 2002).

**Physico-chemical**

Samples were subjected to physico-chemical analysis to measure the sample pH, total dissolved solids (TDS) and residual chlorine following the guidelines of the World Health Organisation (2006).

**Bacterial analysis**

Following the WHO protocol (World Health Organisation 2006), presence–absence of coliform was undertaken to determine the quality of water. Briefly, each sample was subjected to E. coli enumeration. The E. coli levels were determined by using membrane filtration technique (APHA 2001) and modifying the United States Environmental Protection Agency, 2000 protocol (USEPA 2000). Briefly described the samples were passed through a 0.45 μm membrane filter (Millipore, MA, USA) under a vacuum pressure of 10 cmHg. The sample volumes to be filtered were based on a visual inspection of the turbidity of the sample and knowledge of the previous contamination level reported by Sur et al. (2006) and thereby ranged from 1 to 100 ml, yielding approximately 20–80 E. coli
colonies per membrane. After filtration, the membrane was placed on 90 mm Petri dishes containing Chromocult Coliform Agar (Merck, Germany). The E. coli colonies were identified by their blue color. The non-E. coli coliform bacterial colonies appearing red in color were not included in the analysis (Jensen et al. 2004). If the filter yielded 100 or more blue colonies per ml, the sample was enumerated as >100 E. coli per ml filtered.

Simultaneously, the 10 ml sample was enriched in alkaline peptone water for V. cholerae isolation. In culture methods, 5 μl of each of the enriched samples were streaked onto thiosulfate-citrate-bile salts-sucrose (TCBS) (Becton Dickinson) agar and incubated at 37 °C for 18 to 24 h. Sucrose fermenting yellow color suspected V. cholerae colonies was further inoculated in Nutrient agar media to determine the serogroup by slide agglutination test (Difco Laboratories, Detroit, Michigan). For further confirmation a simple PCR technique was used to confirm V. cholerae species using OmpW gene (Nandi et al. 2000).

Statistical analysis

The results have been analyzed statistically applying two different methods viz. 4 × 3 contingency table to compare all the three sources of water samples and its load of E. coli (Table 1). Coefficients of individual variables were exponentiated to estimate the odds ratio of chlorine content in different sources and its relative potential. Depending on presence/absence of E. coli the relative risk of different sources has also been determined. For the continuous variables, the Fisher Exact Probability Test was performed and significance level was fixed at p ≤ 0.05. The analysis was done by using Epi Info (Ver 3.5.1. USA).

RESULTS AND DISCUSSION

A total of 517 water samples, including 117 samples from main sources (tap/tube well), 200 from stored water (drinking purposes) and the remaining 200 from stored water (washing purposes), were collected.

When analyzed, stored water (washing) showed the highest prevalence of fecal coliforms (58%) (116/200). However, 28% (56/200) stored water samples (drinking) and 8% (10/117) main (tap/tube well) water sources were also found to be contaminated with fecal coliform.

Applying the 4 × 3 contingency table for multiple comparison, the differences were statistically significant (p < 0.0001), highlighting a greater chance of contamination probability through usage of stored water (washing).

In the present study, there is evidence to argue and infer that public water supply may not always be the source for diarrheal illness, as has also been evidenced from the earlier works of Jensen et al. (2004). On the other hand, storage of water, subsequent usage pattern, including handling, contributes significantly to possible occurrence of the disease in diarrhea prone areas. As it has been observed that the hand washing practice after defecation is not so common in these settings, chances of fecal contamination in stored water always remains high. Although attention is paid from time to time on the basis of mass awareness only for drinking water storage, the same does not stand true for stored water for household purposes, which is considered as a potential route of transmission of diarrheal diseases. Because at the time of washing hands and mouth, some amount of water is unavoidably ingested.

In contradiction to the view of VanDerslice & Briscoe (1993), our study shows that low levels of fecal pollution in the public domain drinking water sources do not necessarily mean that people are drinking clean water. Heavy fecal contamination can occur when the water is stored inside the household (Jensen et al. 2002), which is evidently proved from our study too.

The number of E. coli found in the stored water (washing) was much higher than the stored (drinking) (RR = 1.71; 1.31 < RR < 2.22) and main (tap/tube well) sources (RR = 2.16; 1.75 < RR < 2.52) (Table 1), suggesting thereby an increase in the risk of diarrhea with increasing E. coli counts in the in-house stored water (kept for washing) containers.

Even though, E. coli is a poor indicator of viral and protozoal pathogens in water, determination of E. coli load is an important tool for water quality monitoring to detect the level of contamination or the effectiveness of the treatment process.

The results of our study lend further support to an earlier view (Jensen et al. 2004) that fecal contamination of water is a less important risk factor for endemic diarrhea in developing countries than access to water in quantity and its use for hygiene.

<table>
<thead>
<tr>
<th>No. of E. coli</th>
<th>Tap/tube well</th>
<th>Stored (drinking)</th>
<th>Stored (washing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘0’ cfu/ml</td>
<td>107 (91%)</td>
<td>144 (72%)</td>
<td>84 (42%)</td>
</tr>
<tr>
<td>1–10 cfu/ml</td>
<td>2 (1.7%)</td>
<td>30 (15%)</td>
<td>8 (4%)</td>
</tr>
<tr>
<td>11–100 cfu/ml</td>
<td>7 (6%)</td>
<td>15 (7.5%)</td>
<td>40 (20%)</td>
</tr>
<tr>
<td>&gt; 100 cfu/ml</td>
<td>1 (0.8%)</td>
<td>11 (5.5%)</td>
<td>68 (34%)</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>
In the past, it has been disagreed (Feachem 1980) that the WHO Guideline value of zero fecal coliforms is too restrictive for untreated water sources in rural communities, as it is not feasible in practice. Our data suggest that such a restrictive standard also lacks adequate justification on epidemiological grounds.

As far as physico-chemical parameters are concerned, most of the stored water (washing) samples failed to reach the satisfactory level of residual chlorine content (57%), TDS (37%) and pH (20%). On the contrary, most (more than 90%) of the samples, collected from the other two sources (viz. stored for drinking and main sources), were within the satisfactory range of pH and TDS value. Seventy per cent of the main sources and stored water used for drinking had satisfactory residual chlorine content. Significant differences (OR = 3.09; 1.72 < OR < 5.53) were found in residual chlorine content between stored (washing) and remaining sources (Table 2) clarifying that majority stored (washing) samples do not have the desired residual chlorine content in them.

Further, all fecal coliform positive stored water samples (182) were analyzed for V. cholerae detection. Altogether 36 water samples (seven from stored water for drinking and 29 from stored water for washing) were found to be contaminated with V. cholerae. Among 36 V. cholerae isolates, 16 (44.4%) were V. cholerae O1 including 12 Ogawa serotypes and four Inaba serotypes (Table 3). The present findings lend support to previous epidemiological findings of Sur et al. (2005), in a cross section of these areas, where the cholera burden has been shown to be of alarming proportions.

Moreover, Sur et al. (2005) reported an extremely high rate of childhood all-cause diarrhoea in a study site in the municipal wards under KMC, which is thereby adequately justified by our present finding of a persistent load of V. cholerae (7%) in its transmission vehicle also, i.e. stored water. Therefore, prevalence of V. cholerae O1 emphasizes the fact that sustained faeco-oral contamination even in stored water is very much prevalent and that too at in-house conditions causing higher risk for disease transmission.

### CONCLUSION

Therefore from this study, two salient factors have been identified which can be addressed to reduce the diarrheal morbidity, i.e. proper chlorination of all potable water sources (including stored water) and necessity of appropriate handling of all types of stored water. It has been reported by Sobsey et al. (2003), that the practice of chlorination at household level and restricted handling have reduced community level diarrheal disease to the extent of 20–50%, which can thereby be reciprocated in the Indian context also.

Hand washing seems to be one of the major behavioral factors attributed to diarrheal endemicity and needs to be considered as a major ‘protection action’ message for arresting further contamination. Accordingly, apart from chlorination, appropriate handling, covering the mouth of the vessel with a proper lid, usage of a spigot valve with the storage container; hand washing is also a very important attribute to reduce the diarrheal episodes.

As in most of the cases, the quality of the potable water is not up to the desired level, it is of primary importance that water users are guaranteed a minimum level of service and it would be more important to secure a supply of at least 100 l of ‘clean’ water per person per day, than to put all resources into achieving the water quality standard of zero E. coli.

Greater efforts to disseminate information about household water treatment and storage technologies and their benefits and advantages are needed at local, national and international levels. For a large part of the world’s population currently lacking access to safe water, the use of an appropriate technology for household water purification such as

### Table 2 | Physico-chemical properties of water samples from different sources

<table>
<thead>
<tr>
<th>Sources</th>
<th>Tap/tube well</th>
<th>Stored (drinking)</th>
<th>Stored (washing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6/117 (5%)</td>
<td>10/200 (5%)</td>
<td>40/200 (20%)</td>
</tr>
<tr>
<td>TDS (mg/l)</td>
<td>29/117 (25%)</td>
<td>18/200 (9%)</td>
<td>74/200 (37%)</td>
</tr>
<tr>
<td>Residual chlorine (mg/l)</td>
<td>55/117 (30%)</td>
<td>60/200 (30%)</td>
<td>114/200 (57%)</td>
</tr>
</tbody>
</table>

*Figures within the parentheses denote percentage of samples failing to reach the required content.

*Limit was calculated according to the guidelines of the World Health Organisation (2006) (Residual chlorine: < 0.5 mg/l; pH: 6.5–8.5; TDS: > 1,200 mg/l).

### Table 3 | Isolation and detection of V. cholerae from stored water samples

<table>
<thead>
<tr>
<th>No. of water samples</th>
<th>No. of water samples contaminated with fecal coliform</th>
<th>No. of V. cholerae contaminated sample</th>
<th>No. of V. cholerae O1 isolates</th>
<th>No. of V. cholerae Non O1 isolates</th>
</tr>
</thead>
<tbody>
<tr>
<td>517</td>
<td>182 (33%)</td>
<td>36 (7%)</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>
chlorination and storage in a valved spigot special vessel, is likely to have beneficial effects in the form of reduced diarrheal disease and greater productivity. Furthermore, improved water treatment vis-à-vis storage at the household level is likely to improve with social awareness and personal knowledge about the importance of water hygiene and sanitation and the benefits that can be derived thereof.

REFERENCES


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