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Prevalence of household drinking-water contamination and of acute diarrhoeal illness in a periurban community in Myanmar

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ABSTRACT

Background: A major health consequence of rapid population growth in urban areas is the increased pressure on existing overstretched water and sanitation services. This study of an expanding periurban neighbourhood of Yangon Region, Myanmar, aimed to ascertain the prevalence of acute diarrhoea in children under 5 years; to identify household sources of drinking-water; to describe purification and storage practices; and to assess drinking-water contamination at point-of-use.

Methods: A survey of the prevalence of acute diarrhoea in children under 5 years was done in 211 households in February 2013; demographic data were also collected, along with data and details of sources of drinking water, water purification, storage practices and waste disposal. During March–August, a subset of 112 households was revisited to collect drinking water samples. The samples were analysed by the multiple tube fermentation method to count thermotolerant (faecal) coliforms and there was a qualitative determination of the presence of *Escherichia coli*.

Results: Acute diarrhoea in children under 5 years was reported in 4.74% (10/211, 95% CI: 3.0–9.0) of households within the past two weeks. More than half of the households used insanitary pit latrines and 36% disposed of their waste into nearby streams and ponds. Improved sources of drinking water were used, mainly the unchlorinated ward reservoir, a chlorinated tube well or purified bottled water. Nearly a quarter of households never used any method for drinking-water purification. Ninety-four per cent (105/112) of water samples were contaminated with thermotolerant (faecal) coliforms, ranging from 2.2 colony-forming units (CFU)/100 mL (21.4%) to more than 1000 CFU/100 mL (60.7%). Of faecal (thermotolerant)-coliform-positive water samples, 70% (47/68) grew *E. coli*.

Conclusion: The prevalence of acute diarrhoea reported for children under 5 years was high and a high level of drinking-water contamination was detected, though it was unclear whether this was due to contamination at source or at point-of-use. Maintenance of drinking-water quality in study households is complex. Further research is crucial to prove the cost effectiveness in quality improvement of drinking water at point-of-use in resource-limited settings. In addition, empowerment of householders to use measures of treating water by boiling, filtration or chlorination, and safe storage with proper handling is essential.

Key words: Acute diarrhoea, drinking-water quality, periurban neighbourhood, children under 5 years, water purification

INTRODUCTION

The Millennium Development Goal target 7C was to "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation". By 2010, the world had met the target of halving the proportion of people without access to improved sources of water, five years ahead of schedule. Nevertheless, in 2011, an estimated 768 million people did not use an improved source for drinking water and 2.5 billion lacked access to an improved sanitation facility.[1]

Population density, climate change and water scarcity situations are the main factors influencing sources of drinking water and likely contamination. The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation drinking-water ladder defines the continuum of sources of drinking-water from unimproved to improved (that is protected from outside contamination) *(See Box 1)*.[1] Globally, consumers from poor households rarely use household water-treatment products such as chlorine or a water filter on a sustained basis,[2,3] and a better understanding of the factors that promote or inhibit use of these products is needed.[4] Along with poor sanitation and hand hygiene, drinking-water contamination is one of the routes by which there can be transmission of the bacterial, viral or protozoal pathogens responsible for diarrhoea.[5,6]

There is a need to examine three interrelated factors that contribute to the sources of microbiological risk among households with access to improved water sources: water storage, risks specific to piped water supplies and household water management practices. It is essential to focus on the provision of microbiologically safe water at both community and household levels. Even when water sources are improved, water-quality risks may still exist at the point of consumption, and this has implications in the use of international targets for safe drinking-water access.[7]

Low-income countries such as Myanmar are particularly affected by deficient water systems and services, and poor sanitation and hygiene. The objectives of this study were: (i) to ascertain the two-week and one-year prevalences of acute diarrhoea in children under 5 years; (ii) to identify the sources of drinking water, water purification and storage practices; and (iii) to assess the bacteriological contamination of household drinking water at point-of-use.

METHODS

The setting for this study was North Dagon Township, an expanding periurban neighbourhood of the Yangon Region, Myanmar. North Dagon comprises 27 wards; two of these wards were purposely selected for this study since our previous survey had identified high levels of acute diarrhoea in children aged 5 years or younger.[8] These wards have a higher proportion of lower-income households than other wards in the township.

This study comprised a household survey to collect recall data on diarrhoea in children under 5 years, followed by analysis of drinking water from a subset of households. The first survey was carried out during February–March 2013, at the beginning of the hot, dry season, which is a period when the area typically experiences water shortages. In the previous study done in 2012, we surveyed 575 households that included children younger than 5 years. The sample size for the current survey was calculated as 211, based on an estimated diarrhoea prevalence of 10% in the hot, dry season, with an acceptable accuracy of 5% at the 95% confidence level inclusive of 5% nonresponse rate, assuming a design effect of 1.5.

A total of 211 of the 575 households were selected at random. Every second household in the list was included. All selected households who were approached by the survey team participated in the study and none refused. At each selected household, after obtaining written informed consent, trained interviewers administered a pretested, structured questionnaire to the mothers or carers of children under 5 years. Issues of privacy, anonymity and confidentiality were observed. This study was approved by the Ethics Review Committee of the Department of Medical Research. The structured questionnaire allowed collection of household demographic data and details of sources of drinking-water, water purification and storage practices, and waste disposal. Interviewers recorded mothers'/carers' recall of diarrhoea in their children during the past two weeks, past month and past year. For the purpose of this study, acute diarrhoea was defined as: passage of three or more loose watery motions, more than usual loose watery motion, a single large watery motion in a day, or a mother's assessment that her child passed more-frequent liquid stools.

Box 1:
Drinking-water ladder

Unimproved drinking water		**Improved drinking water**	
Surface drinking-water sources: river, dam, lake, pond, stream, canal, irrigation channels	**Unimproved drinking-water sources:** unprotected dug well, unprotected spring, cart with small tank/drum, bottled water	**Other improved drinking-water sources:** public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, rainwater collection	**Piped water on premises:** piped household water connection located inside the user's dwelling, plot or yard

Source: World Health Organization and United Nations Children's Emergency Fund.[1]

The second survey of drinking water was done between March and August 2013. Owing to funding constraints, it was not possible to revisit all of the 211 households, thus a subsample of 112 was purposely selected by prioritizing households with poor sanitation facilities. The number was based on feasible laboratory facilities to analyse water quality. No household refused to have their drinking-water examined. Samples were taken from a cup used by the family to drink water, and collected in sterile glass bottles and transported in ice-cooler boxes to the laboratory of the Bacteriology Research Division, Department of Medical Research, for processing within six hours of collection.

For microbial water quality, verification is usually based on the analysis of faecal indicator microorganisms, with the organism of choice being *Escherichia coli* or, alternatively, thermotolerant (faecal) coliforms.[9] Guideline values for verification of microbial quality according to the WHO guidelines for drinking-water quality are shown in Table 1. Water samples were analysed by the multiple tube fermentation method to detect total faecal coliforms and *E. coli.* Quantitative assessment to detect faecal coliforms was by enumeration of CFU and this was classified into five categories of <1 CFU/100 mL, 1–10 CFU/100 mL, 11–100 CFU/100 mL, 101–1000 CFU/100 mL and >1000 CFU/100 mL. *E.coli* was detected qualitatively.

Quantitative data were entered into the EpiData software application after thorough checks. Episodes of acute diarrhoea at different periods within the past two-week period, and over the past two weeks within a one-year follow-up period were computed, along with the 95% confidence interval (CI). Frequency distributions were carried out for variables of interest. SPSS version 17.0 was used for univariate analysis, and the chi-squared test was used to determine associations. Spearman's rank correlation coefficient was computed to identify the relation between faecal coliform contamination and the presence of *E.coli* in drinking-water samples.

RESULTS

In this study, 25% (53/211) of the household heads had primary school level education. The age of the respondents ranged from 18 to 74 years (mean age 37.5 ± 12.6 years) and 83% (175/211) were women. Around 63% (133/211) of the study population were families of five or more members and the total number of children under 5 years was 262 (mean age 1.2 ± 0.5 years) ranging from age 1 to 3 years. There were no children older than 3 years of age or younger than 1 year of age in the surveyed households. Nearly half of the households (102/211) were made of bamboo. About half of households had insanitary pit latrines (111/211); other households used sanitary fly-proof latrines. There were no community block toilets and 36% (77/211) of householders disposed of their waste in nearby surface water-bodies (for example, stream and ponds).

Reported acute diarrhoea in children under 5 years

Ten of the 211 (4.74%; CI: 3.0–9.0%) households reported acute diarrhoea in children under 5 years within the past two weeks. Further, within the past four weeks, 18 households (8.53%; CI: 5.0–13.0%) had reported acute diarrhoea, and 33 households (15.64%; CI: 1.0–21.0%) cumulatively reported acute diarrhoea in children under 5 years within a one-year period.

Sources of domestic water and drinking-water, storage and purification

Nearly 42% (88/211) of households obtained their water for domestic use from the improved-source ward reservoir. Of these, approximately 77% (68/88) of households had a piped-in supply and the remaining households carried the water manually from the reservoir. In 74/211 (35.1%) households, the nonchlorinated ward reservoir was also used for drinking

Table 1: Guideline values for verification of microbial quality[a]

Organisms	Guideline value
All water directly intended for drinking: *E. coli* or thermotolerant coliform bacteria[b,c]	Must not be detectable in any 100 mL sample
Treated water entering the distribution system: *E. coli* or thermotolerant coliform bacteria[b]	Must not be detectable in any 100 mL sample
Treated water in the distribution system: *E. coli* or thermotolerant coliform bacteria[b]	Must not be detectable in any 100 mL sample

[a] Immediate investigative action must be taken if *E. coli* are detected.

[b] Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable as an indicator of the sanitary quality of water supplies, particularly in tropical areas, where many bacteria of no sanitary significance occur in almost all untreated supplies.

[c] It is recognized that in the great majority of rural water supplies, especially in developing countries, faecal contamination is widespread. Especially under these conditions, medium-term targets for the progressive improvement of water supplies should be set.

Source: World Health Organization.[9]

water; most households (137/211; 64.9%), sourced drinking water from improved sources other than the reservoir, that is, from a chlorinated tube well or purified bottled drinking-water *(See Table 2)*.

Nearly a quarter of households (52/211; 24.6%) used no method of drinking-water purification. Among households using drinking-water purification, 82% (131/159) reported use of a cloth filter (which could easily be contaminated), and 33.3% reported boiling the water (53/159). Use of chlorine tablets and liquid chlorine for drinking-water purification was rare (2.5%; 4/159) *(See Table 2)*.

Observations revealed the storage of drinking-water in clay pots (59/211, 28%), plastic bottles of 20-litre capacity that had previously been filled with purified water (93/211, 44.1%), and ceramic jars (50/211, 23.7%); *(See Table 2)*. Only 20% of drinking-water containers were fully covered.

As shown in Table 3, 2.7% of households (2/74) with drinking-water sourced from the reservoir reported acute diarrhoea in children under 5 years within past two weeks compared with 5.8% (8/137) of households using other improved drinking-water sources. Likewise, reported acute diarrhoea within a 1-year period was lower in households using the reservoir for drinking-water than in those using other improved sources. The differences were not statistically significant.

Table 2: Drinking-water management in study households

Characteristic	Number	Percentage
Source of drinking water	(*n* = 211)	
Reservoir	74	35
Tube well only	58	27.5
Purified bottled water only	78	37.0
Tube well and bottled water	1	0.5
Storage of drinking water[a]	(*n* = 211)	
Clay pots	59	28.0
Large plastic bottles (20 litre)	93	44.1
Ceramic jars	50	23.7
Small plastic bottles (1 litre)	17	8.1
Steel pots	2	0.9
Drinking-water purification	(*n* = 211)	
No	52	24.6
Yes	159	75.4
Households with drinking-water purification	(*n* = 159)	
Cloth filter	131	82.4
Boiling	53	33.3
Ceramic filter	24	15.0
Sedimentation	26	16.4
Chlorine products	4	2.5

[a] Some households used more than one type of storage vessel.

Table 3: Relationship between source of drinking water and reported acute diarrhoea in children under 5 years

Household source of drinking water	Reported acute diarrhoea in children under 5 years (per household)							
	Never		Within past two weeks		Within one year		Total	
	n	%	*n*	%	*n*	%	*n*	%
Reservoir	61	82.4	2	2.7	11	14.9	74	100.0
Tube well and/or bottled water	107	78.1	8	5.8	22	16.1	137	100.0
Statistical significance	Chi squared = 1.2; *P* = 0.56							

Table 4: Relationship between presence of faecal coliform bacteria and *E.coli* in drinking-water samples

Thermotolerant (faecal) coliform count[a]	*E. coli* detection				Total number with faecal coliforms	
	No		Yes			
	n	%	*N*	%	*n*	%
<1	7	11.9	0	0.0	7	6.2
1–10	23	39.0	1	1.9	24	21.4
11–100	8	13.6	5	9.4	13	11.6
101–1000	0.0	0.0	0.0	0.0	0.0	0.0
>1000	21	35.6	47	88.7	68	60.7
Total count	59	100.0	53	100.0	112	100.0

[a] Colony-forming units per 100 mL (CFU/100 mL).

Bacteriological contamination of household drinking water

When analysing water samples obtained from serving cups, 94% (105/112) were contaminated with thermotolerant (faecal) coliforms, that is, had a coliform count of one or more. The range varied from 2.2 CFU/100 mL to over >1000 CFU/100 mL *(See Table 4)*. Of faecal-coliform-positive water samples, 50% (53/105) grew *E. coli*, indicating faecal contamination probably from hands, drinking cups or storage vessels. In addition, one could not rule out postsource contamination. As expected, the presence or absence of *E. coli* was a fairly good marker, indicating that about 70% (47/68) of water samples had gross contamination (>1000 CFU/100 mL) with faecal coliforms. The rank correlation value of 0.6 was highly significant (P = 0.0005) indicating a high level of contamination that required attention. *(See Table 4)*

DISCUSSION

Vulnerability to diarrhoea in children increases in the presence of environmental contaminants and is a significant challenge in a resource-limited context. Acute diarrhoea in children under 5 years reported within the past two-week period in this study is higher than that reported in the previous study conducted in the same area at the end of rainy season (4.74% vs 1%).[8] This might be due to the effect of seasonality. In the study area, the hot season is usually linked to water shortages, intermittent pipe water supply, increased storage and increased likelihood of contamination of drinking water from an unsanitary environment, which may all cause acute diarrhoea in children under 5 years. Approximately 88% of diarrhoeal diseases are attributable to unsafe drinking-water apart from poor environmental conditions including household-water insecurity[10] and there is recent evidence that the incidence of acute diarrhoea in children under 5 years is reduced by expanding access to household-water chlorination.[11] A modelling study estimated that the proportion of the population using drinking water sourced from protected groundwater in 2012 was only 11.9% of the urban population and 12.6% of the rural population of South-East Asia.[12] In the present study, only 32% of households had a piped-in unchlorinated water supply from the private reservoir in the ward. However, there is an attempt by the local municipal service to increase the coverage of piped water from the public reservoir, with central chlorination in the area in 2016.

Rapid population growth in urban areas puts increased pressure on existing overstretched essential services such as water supplies, sewage and sanitation and collection, and disposal of solid waste. This is consistent with the findings of the present study, which was conducted in low-income households of an expanding periurban settlement with unsatisfactory environmental conditions. A report from India also supported the argument that high population density, coupled with poor sanitation facilities, were found to worsen living conditions and affect the quality of water.[13] There is a growing body of evidence that safe, clean, accessible and affordable drinking-water and sanitation is linked to reduction of childhood diarrhoea. In study households, people were able to obtain drinking-water from improved sources, but this study and others are a reminder that use of an improved water source does not mean that the water is safe.[14]

Water with an initially acceptable microbial quality often becomes contaminated with pathogens during transport and storage.[15] Especially during storage, contamination can occur if the water containers are not fully covered, as found in this study. Safe storage and household water treatment interventions may improve water quality in slums. Simple reports of water purification practices are unreliable metrics for understanding the complexities of purification practices. People might report that they treat their water, but may not do so in reality.

For drinking-water purification, very few study households reported boiling and use of chlorine products (2.5%); most used cloth filters. This finding is similar to an Indian study in which 568 (59.2%) households in a slum did not use any method of water purification, 25.8% used a cloth filter and 17.2% boiled their drinking-water prior to consumption.[16] Boiling fails to ensure drinking water safety at the point of consumption because of contamination during subsequent storage and poor domestic hygiene.[17] In this study, there was an inconsistency of reported acute diarrhoea between households with either an improved or an unimproved water supply. This finding indicated that water was likely to be contaminated at point-of-use, in addition to at source, and this may contribute towards the acute diarrhoea burden in this environment.

There are complex microbiological processes occurring within the transport and storage vessels, indicating the interaction of the biota in the collected water with biofilms in the containers and/or recontamination through dipping hands and cups into water-holding containers at point-of-use.[18] Bacteriological parameters, especially *E.coli*, have been found to be the most specific indicator of faecal contamination in drinking water.[19] In study households, the concentration levels of total and faecal coliforms and *E. coli* in collected water samples were above the permissible limits of the WHO guidelines for drinking-water quality, which note that, "immediate investigative action must be taken if *E. coli* are detected".[9] Inadequate water quality is associated with outbreaks and endemic disease. Dirty hands contaminate drinking water at point-of-use, adding to microbial contamination.[20–22] In this study it was unclear whether the very high prevalence of faecal coliform contamination (more than 1000 CFU/100 mL) in drinking water was due to contamination at source or at point-of-use.

Further attempts to differentiate between contamination of drinking water at source or at point-of-use are essential. Epidemiological surveillance of household drinking water quality plays a pivotal role in minimizing health risks caused by contamination from an insanitary environment. This requires capacity building in the community and close monitoring of drinking-water quality at the local service level through practical and cost-effective methods, in addition to strengthening the enforcement of environmental regulations.[23] One recent study in Myanmar revealed various water-quality assessments in urban areas of Yangon Region and Nay Pyi Taw by examining river, dam, lake and well-water sources, and found them to be of generally good quality. However, measures need to be taken to improve low-quality water in pots and nonpiped tap waters.[24] In addition, household water-quality improvement by promoting household water treatment is necessary to prevent diarrhoeal diseases,[25,26] as well as improved hand hygiene and addressing contamination of drinking-water cups at point-of-use.

Regarding limitations, this cross-sectional study did not cover the effect of seasonality and was unable to prove associations between drinking-water quality and the occurrence of acute diarrhoea and other water-quality risks. Due to limited funding and time constraints, the degree of contamination of drinking water could not be assessed, beginning with examination of the water source, transport and storage.

CONCLUSIONS

The maintenance of drinking-water quality in study households is a complex subject, although water-quality risks are minimized partially by improved water sources. Drinking-water samples were highly contaminated and unfit to drink, with limited or no use of point-of-use purification technologies. Strengthening household drinking-water treatment and safe storage requires attention through public and private sector involvement in study sites. There is an urgent need to promote portable field laboratory systems and kits for either routine or ad hoc water-quality monitoring and surveillance of acute diarrhoea, which is a challenging task for resource-limited settings. Further research is crucial to capture the composite index of water-quality risks in vulnerable sites as a signal of outbreaks.

This study confirms that improved water sources are not always safe, as there are many factors that can change the quality of water between the point of source and the home. Unless water source and distribution systems are intact, with no chance of contamination, additional measures at home are essential, such as treating water by boiling, filtration or chlorination, and safe storage with proper handling. Therefore, a key factor is empowering household members to employ these interventions.

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