

Social-epidemiological study for evaluation of water supply and sanitation systems of low-income urban community in Dhaka, Bangladesh

Kabirul A. Mollah and Toshiya Aramaki

ABSTRACT

This study aims at quantification of health losses, considering social and environmental factors. Morbidity and mortality cases of diarrhoea for children under five years old were used to estimate the disability adjusted life years (DALYs) lost for the target households in low-income communities in Dhaka, Bangladesh. Water supply facilities and sanitation systems, along with hygiene practices and their health outcomes, were studied at community level. Demographic, socio-economic and socio-cultural aspects were also studied to support the research findings and give a better understanding of the local conditions. The four selected communities, Ward 60 (W60), Ward 61 (W61), Ward 62 (W62) and Ward 65 (W65), all had different existing urban services such as water supply, sanitation, garbage management and drainage facilities. All of these services existed in W62, but W60 did not have any of the services; W61 had sanitation and drainage coverage, whereas W65 had only a water supply facility. The results conclusively showed that, compared with the null (absence of services) scenario (W60), the other three scenarios (W61, W62 and W65) showed a substantial decrease of diarrhoea (1.219, 1.284 and 2.052 DALYs/household/year, respectively) reported for children under five years old. Besides urban services, other socio-economic characteristics might also influence the prevalence of diseases.

Key words | diarrhoea, disability adjusted life years, health implications, low-income urban community, sanitation, water supply

Kabirul A. Mollah (corresponding author)
Natural, Biotic and Social Environmental
Engineering,
Interdisciplinary Graduate School of Medicine
and Engineering,
University of Yamanashi,
4-3-11 Takeda,
Kofu Yamanashi 400-8511,
Japan
Tel./Fax: +81-55-220-8592
E-mail: kabirulmolla@yahoo.com

Toshiya Aramaki
Department of Regional Development Studies,
Toyo University,
1-1-1 Izumino, Itakura,
Oura Gunma 374-0193,
Japan

INTRODUCTION

Cholera outbreaks in Bangladesh are a reflection of the poor state of water and sanitation in the affected areas. In fact, 2.2 million people in developing countries, most of them children; die every year from diseases associated with a lack of safe drinking water, inadequate sanitation and poor hygiene (WHO/UNICEF 2000). About one-third of the populations of developing countries do not have safe drinking water (Wegelin *et al.* 1994). Acute diarrhoeal diseases are the major causes of morbidity and mortality in the developing world such as Bangladesh, where one in ten children die before their fifth birthday (Bern *et al.* 1992; Petri *et al.* 2000). Dhaka city had huge outbreaks of *Escherichia coli* and *Vibrio cholera O1* following the severe flood in

2004 (Qadri *et al.* 2004). Diarrhoea is a disease of the gastrointestinal tract caused by the ingestion of bacteria, and by viruses that are spread via contaminated water and/or food. The faeces of an infected person may carry large quantities of these bacteria and viruses, and when shed they contaminate the water supply. Waterborne diseases are those for which water is the agent of transmission, particularly pathogens transmitted from excreta to humans through water, such as cholera and diarrhoea (Thielman & Guerrant 1996). The occurrence of waterborne diseases can be reduced by improving water quality and preventing casual use of other unimproved sources of water (Gleick 1999).

doi: 10.2166/wh.2009.201

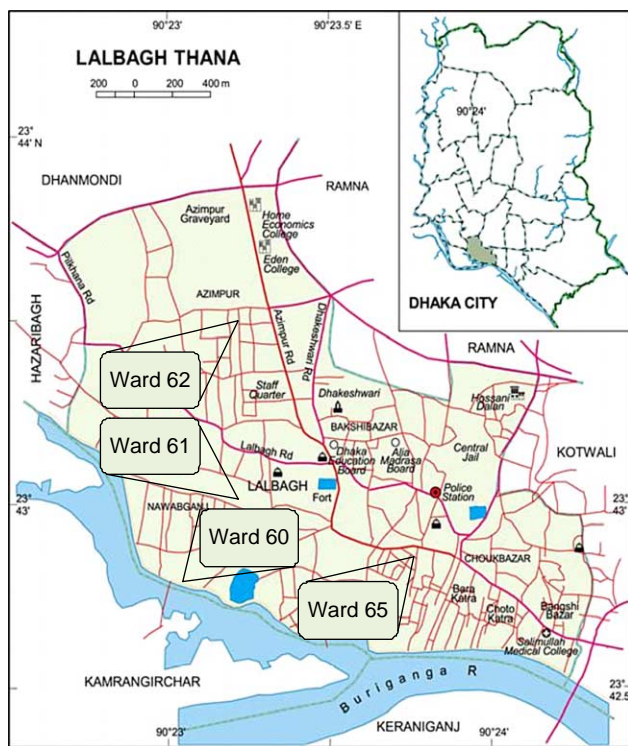


Figure 1 | Location of study area Lalbagh and Dhaka city map (source: <http://www.banglapedia.search.com>).

A randomized prospective epidemiological study was conducted over a period of 16 months in a middle-class suburban community, served by a single water filtration plant. The results suggested that 14–40% of gastrointestinal illnesses were attributable to tap water; meeting the current standards of North America while the water distribution system appeared to be partly responsible for these illnesses (Payment *et al.* 1997). An epidemiologic study of an infectious disease in a community is an initial step toward the introduction of the proper interventions for controlling the disease because the features and the patterns of isolation of etiologic agents of the disease vary from place to place depending on the local meteorology, geography and

socio-economic elements (Ferrecio *et al.* 1991; Yamashiro *et al.* 1998). We have reported in an earlier paper that disability adjusted life years (DALYs) lost by diarrhoea seem to be correlated to sanitation practices, water supply conditions and sanitation facilities and there is a difference in the number of DALYs among the communities of varied social status in the Lalbagh area of Dhaka, Bangladesh (Mollah & Aramaki 2006; Figure 1). In this paper, we emphasize how water collection, storage facilities and types of latrines influence the significant reduction of the DALYs lost by diarrhoea. Understanding the relationship between community health and the environment is essential in combating the vulnerability of poor communities to disease. This study aims to analyse and evaluate whether the different situations in communities, including water supply and sanitation practices, are responsible for the health problems in a specific group of people, and also to quantify the health implications for four communities in the Lalbagh area.

MATERIALS AND METHODS

Lalbagh is the most problematic area in Dhaka city regarding water supply, sanitation, drainage and solid waste management. The sanitation systems installed in this area are only on-site systems such as pour-flush toilets, septic tanks, cesspools, etc. The sludge in these systems is typically collected by a private company and dumped into unused land without treatment or control, or discharged into drainage systems. In the rainy season, flooding frequently occurs in some areas, and many diseases prevail in these areas. Among other problems, the water supply is critical due to the poor distribution and maintenance of the system. Drinking water pipes often leak, and are installed in close proximity to the sewerage and drainage pipes.

Table 1 | Satisfaction levels of the urban service provisions in each selected community

Urban services	W62	W65	W61	W60
Water supply	Satisfactory	Satisfactory	Unsatisfactory	Unsatisfactory
Sanitation system	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory
Solid waste management	Satisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory
Drainage coverage	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory

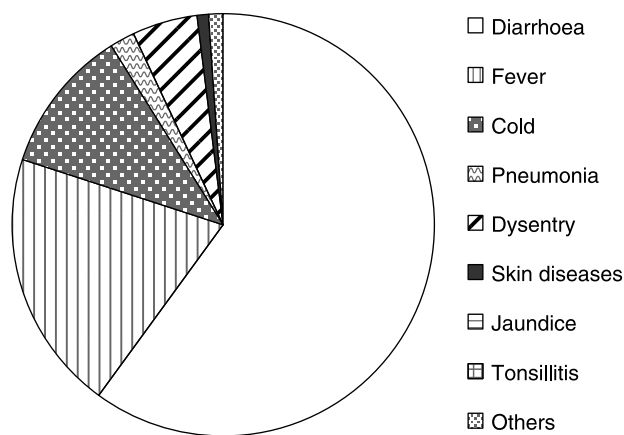


Figure 2 | Morbidity among children under five years.

The Dhaka Water Supply and Sewerage Authority (DWASA) is responsible for providing pure and safe drinking water to city dwellers on a regular and continuous basis, and for regularly disposing of sewerage. However, the city dwellers often find that the water is contaminated and needs boiling at home before drinking. Because of leaks in the pipelines, imperfect water taps and misuse, DWASA incurs a system loss estimated at around 40% (DWASA 2005). Also, the water supply falls short of demand in the dry months because of a decline in the groundwater level. Most of the areas had inadequate water supply, poor sewerage and drainage facilities and irregular clearance of garbage. They were usually submerged in filth and dirt without any modern utility services. Educational facilities and health services were absent; diseases are common and regular features of the targeted areas.

Out of nine wards in Lalbagh, Ward 62 (W62), Ward 65 (W65), Ward 61 (W61) and Ward 60 (W60) were selected as shown in Table 1. These were different in urban services

provisioning for water supply, sanitation, drainage and solid waste management. The satisfaction levels of the service provision in Table 1 were determined by integrated opinions such as interviews with the concerned authority and dwellers as well as field investigation during selection of communities as study sites, prior to the social-epidemiological survey.

The modified home-based epidemiological procedure (Ferrecchio *et al.* 1991; Payment *et al.* 1997; Yamashiro *et al.* 1998) combined with a surveillance system was used to conduct this small-scale household-level survey. Among 530 households that were visited, 50 households of each ward (total of 200 households) were selected. The selected families met predefined criteria, such as low family income, a child under five years old in residence, consumers of unsafe water, had been defecating in open or unhygienic latrines, *etc.* The mother of each household agreed and replied to the questionnaire, and also co-operated with the follow-up on the subjected child during the study period. Informed consent was obtained from the parents or guardians, and the study protocol was reviewed by the concerned committee of research supervisors, Environmental Engineering and Management programme of Asian Institute of Technology (AIT), Thailand, and their advice was followed in conducting this research.

Morbidity and mortality cases from diseases, hygienic practices, water supply and sanitation situations, income and education level, as well as other general information about the household, were asked in the questionnaire and interview survey. The duration of diarrhoea morbidity was also considered in this survey. The survey was carried out from July to September in 2005. Among waterborne diseases, diarrhoea is relatively easy to monitor, because it

Table 2 | Diarrhoea morbidity and mortality cases among children under five years old in different communities

Children Age/sex	W62		W65		W61		W60	
	Death	Diseases	Death	Diseases	Death	Diseases	Death	Diseases
0–1 years	0	2	2	16	0	10	1	18
1–5 years	0	7	1	42	1	22	3	67
Male	0	5	2	20	1	19	3	17
Female	0	4	1	38	0	13	1	68
Total	0	9	3	58	1	32	4	85
Total children	60		97		78		125	

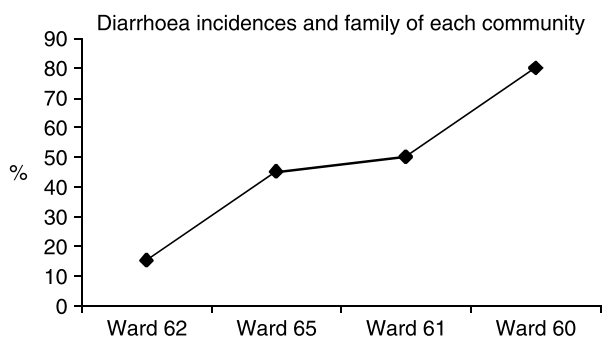


Figure 3 | Status of diarrhoea-affected families in each community.

occurs rather frequently and the respondent mothers easily understand its definition; the occurrence more than three times of loose, watery or mucous stools in the last 24 hours (WHO 1994). The Child Health Epidemiology Reference Group of WHO (CHERG 2004) summarized a table for the definition of diarrhoeal deaths that was used in this survey for verbal autopsy. It was demonstrated to responding mothers by the investigator and the assisting team how to recall/keep records of when and how diarrhoea would be indicated and that they should inform in the next visit, which was within the following two weeks. A series of household-level questionnaires was developed by authors according to the UN and the WHO guidelines. These questionnaires were pre-tested during a preliminary study and some words and ways of asking question were modified, to make them suitable for the targeted population.

Calculations of DALYs were done by the methods described by Murray (1994), and modified for a single

disease at the family and population level by Clark *et al.* (2005) and Anderson *et al.* (2007). The morbidity and mortality cases of diarrhoea for children under five years old and their significance were used to estimate DALYs by diarrhoea in the target households in each ward. DALYs are one of the indicators for measuring aggregated health losses, and combine years of life lost with years lived with a disability that is standardized by means of severity weights (Murray & Lopez 1996; Anderson *et al.* 2007). DALYs due to premature mortality were calculated using standard expected years of life lost with model life-tables. DALYs due to the disability from age *a* to the age (*a* + *L*) were calculated using the following equation, shown by Murray (1994) and Homedes (2000),

$$DALYs = - \left[\frac{(D)(Ce^{-\beta a})}{(\beta + r)^2} \right] [e^{-(\beta+r)L} \{1 + (\beta + r)(L + a)\} - \{1 + (\beta + r)a\}] \tag{1}$$

where *D* is the disability weight (1 for the case of death, 0.5 for the case of diarrhoea) (Murray & Lopez 1996), *C* and β are constants (0.16243 and 0.04, respectively) and *r* is the discount rate (assumed to be 0.03).

Demographic, economic and habitual aspects were also studied during the community survey to support the research findings and provide a better understanding of the local conditions. Moreover, different scenarios were set up on the basis of existing situations and their performance, including improved sanitation systems with or without improved water supply options.

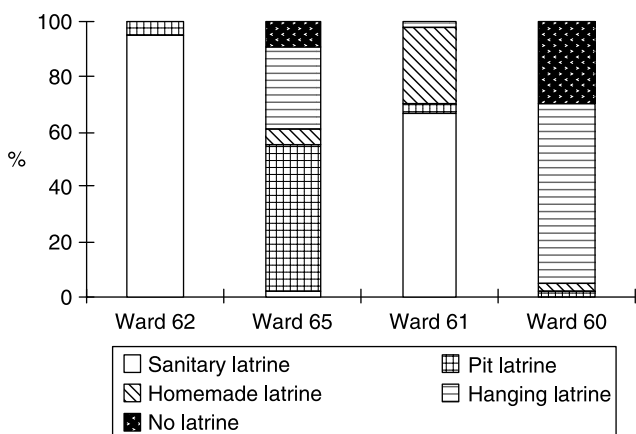


Figure 4 | Types of latrine used by families.

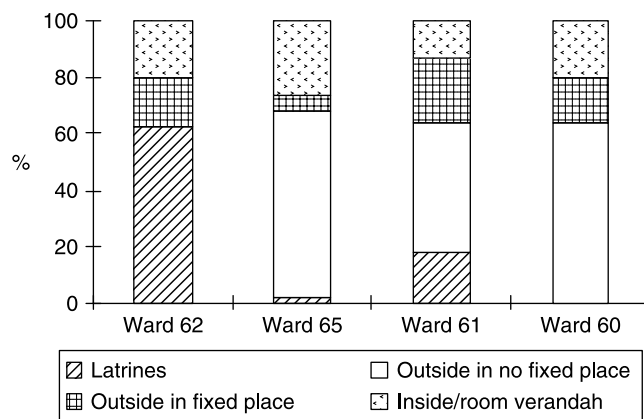


Figure 5 | Defecation habits in children under five years old.

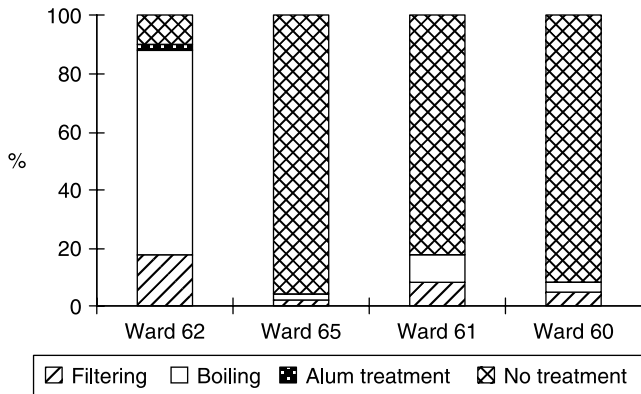


Figure 6 | Household level water-treatment conditions of different communities.

RESULTS AND DISCUSSION

All of the mothers of the children in the 200 households responded and cooperated during this survey; as a result the reply and response rate of this survey was 100%. Figure 2 shows the composition of diseases which prevailed among the children under five years old for the two months prior to the survey period in four communities during preliminary data collection. Diarrhoea was found to be the most prevalent disease in the study area, and it was considered as an indicator disease for estimating the health implications of the poor urban dwellers in this area.

Table 2 shows community-wise distribution of the total numbers of death and disease cases of diarrhoea. In W60 and W65, there were more cases than in W61 for both morbidity and mortality. No death case was reported for

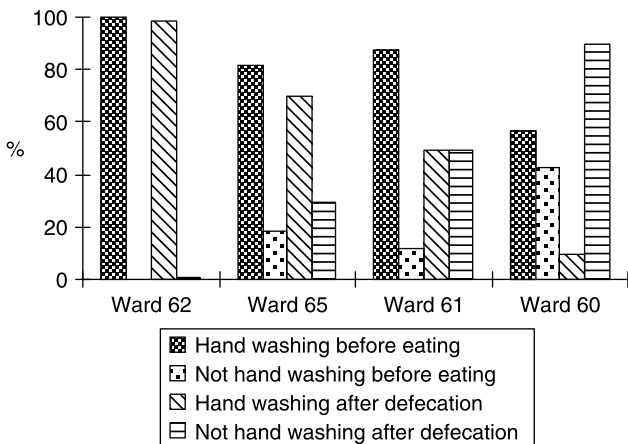


Figure 7 | Hygiene practice of households.

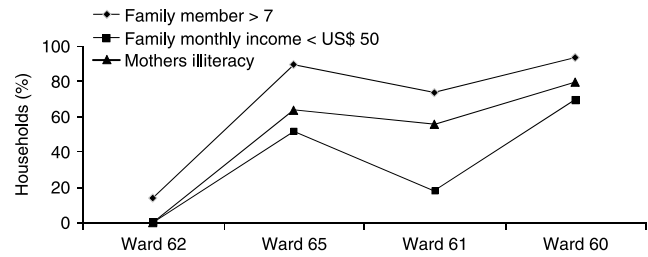


Figure 8 | Family characteristics trend in surveyed communities.

W62. Moreover, Figure 3 shows the percentage of families whose children were affected by diarrhoea in each ward. Ward 62 had the best situation, whereas Ward 60 had the worst situation, and the other two communities were in between these two extreme situations in terms of diarrhoeal incidence. The families affected by diarrhoea in W61 were mostly cases of a single child suffering the disease, but in W65 multiple children suffered from diarrhoea, which constituted a comparatively higher percentage in terms of families affected, although W61 had fewer individual cases than W65.

Diseases and symptoms assessed and reported by the inhabitants shows uncertainty to some extent and high reliability depends on shorter recall periods (Byass & Hanlon 1994). We assumed that symptom and recall bias were not particularly large in our survey, as we took some precautionary initiatives. In our study we asked the mother to follow her child for the following two weeks from recruitment and demonstrated to them during the preliminary visit how to confirm diarrhoea as the occurrence more than three times of loose stools or watery faeces within the last 24 hours etc., marking the day that symptom first started and the last day of suffering, using local available

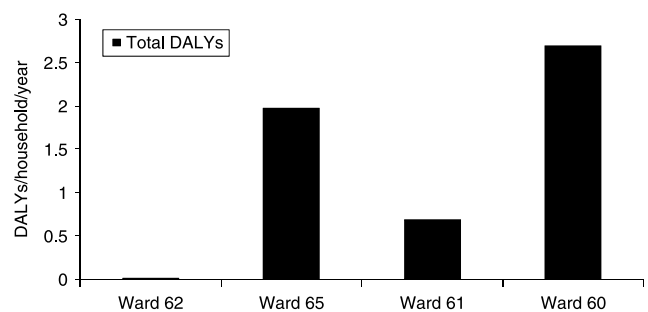


Figure 9 | Total DALYs lost among children in surveyed households of different communities (wards).

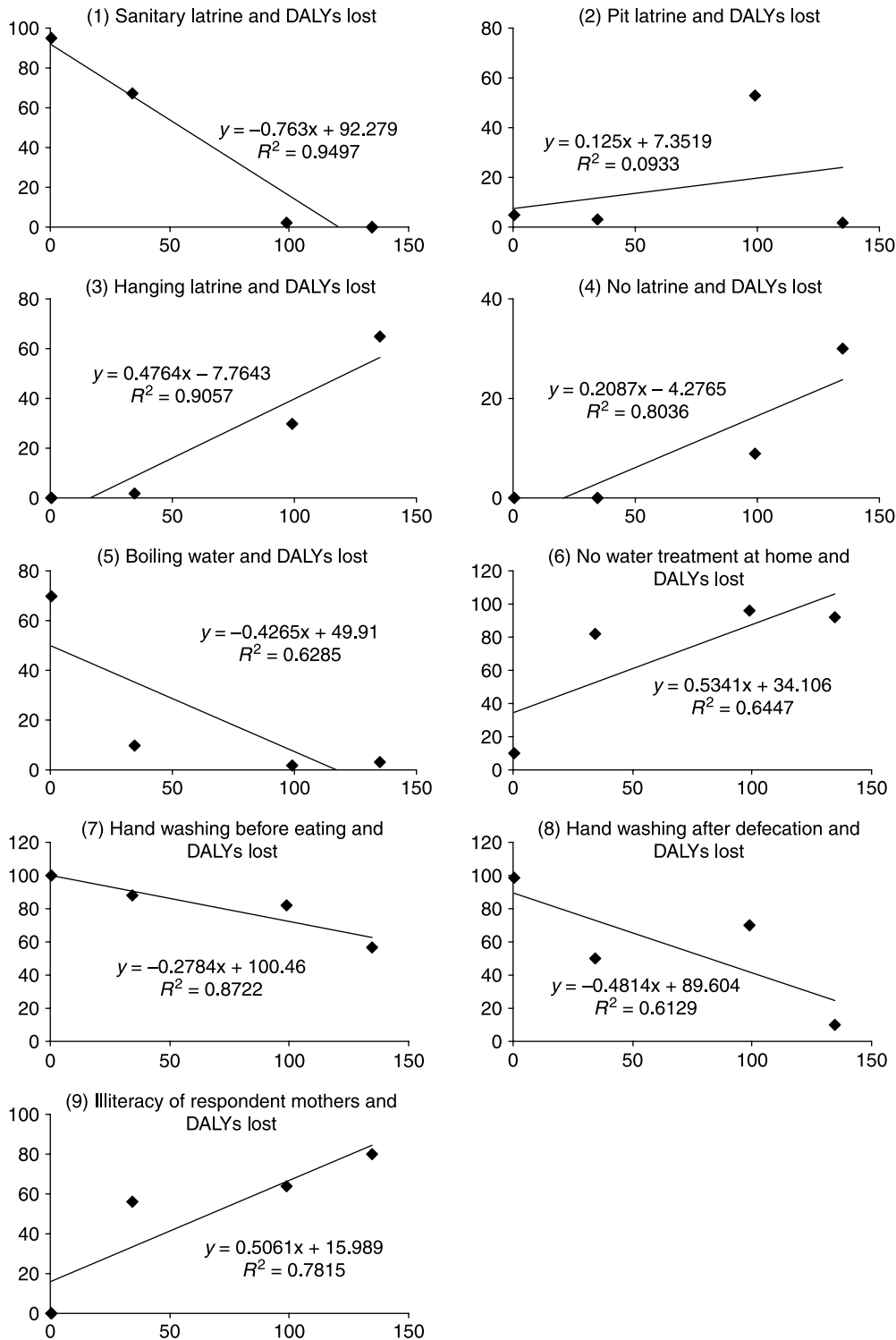


Figure 10 | Relationship trend with significant coefficient between each of some selected determinants and DALYs lost by diarrhoea among children under five years old in four communities (the x-axis shows the number of DALYs/year and the y-axis shows the percentage of each of the determinants).

counting materials. Lastly, final data input was done only if the mother's performance level for defining the symptoms and counting the suffering days (as per the pre-trained method) during the follow-up visit was satisfactory.

Figure 4 shows the latrine types and their use by respondents. A septic tank and pour-flush connected with a sewer system was considered as a sanitary latrine in this study. A hanging latrine is also known as an open latrine. These latrines are usually flimsy structures built on stilts over rivers or small streams, which usually provide very little or no privacy. These latrines are very smelly and unpleasant. Ward 60 had the worst situation with either hanging latrines or no latrines in 95% of households, whereas in Ward 62 95% of households had access to a sanitary latrine. It was also asked, besides the latrine, what places for defecation were used by children. In the cases of W60 and W65, almost all the children defecated in open fields and inside rooms or on verandahs but in the case of W62 most of the children used latrines (Figure 5).

Water treatment at home may be one of the contributing factors for diarrhoea. It was found that household level water treatment was not well known or practised in all communities, except W62, where boiling was practised as a major treatment followed by filtering by cloths (Figure 6). Practice of hygiene largely depends on literacy and it was found that hand washing before eating and after defecation were significantly lower where the education level of the respondent mothers were also lower, such as for the cases of W60 and W65. Moreover, the percentage of families who did not wash their hands after defecation was comparatively higher than those who did not wash their hands before eating in W60, possibly due to social beliefs and culture (Figure 7). Affordability was also incorporated with the family characteristics, such as family income, family size and literacy rate of mothers for maintaining the family health-caring practices. A clear trend was found among family characteristics, and W60 and W65 had the lowest level of family characteristics, shown in Figure 8. This might result in less hygiene practice.

Thus, the total DALYs were calculated from the contribution of years lost through disability and years of life lost due to diarrhoea, regardless of age and sex; for the sub-group of children under five years for the 50 households surveyed in each community, these were 0.55, 98.92, 34.56

and 134.79 DALYs/year in W62, W65, W61 and W60, respectively. DALYs lost per household are also shown in Figure 9.

Compared with the null scenario (W60), the three other scenarios (W61, W62 and W65) showed a substantial decrease of diarrhoea (1.219, 1.284 and 2.052 DALYs/household/year, respectively) reported for children under five years old. Figure 10 shows the results of correlation analysis among some selected indicators: (a) different types of latrine such as 1) sanitary, 2) pit, 3) hanging, 4) no latrine; (b) different types of household level water treatment while source water was from a tap supply such as 1) boiling, 2) no treatment; (c) Hygiene practices such as 1) hand washing before eating, 2) hand washing after defecation and (d) level of education such as illiteracy of respondent mothers. From this analysis it was found that strongly correlated indicators with DALYs lost were sanitary latrine, hanging latrine, no latrine and hand-washing practices before eating. Indicators for household level water treatment did not show a strong correlation because of possible partial correlation with secondary contamination through hand washing before eating, which might be with contaminated water for washing and cooking purposes. However, DALYs lost had a more significant relationship with illiteracy than the household level water treatment, which might imply the importance of social factors such as cultural background.

CONCLUSIONS

The results conclusively showed that comparing with the null (absence of services) scenario (W60), the three scenarios (W61, W62 and W65) showed a substantial decrease of diarrhoea (1.219, 1.284 and 2.052 DALYs/household/year, respectively) reported for children under five years old. Besides the level of water supply and sanitation facilities, other socio-economic characteristics were different in these four wards, which might also influence the prevalence of diseases. Households in W62 had high education levels and hygienic awareness, which also contributed to the low disease prevalence within the ward. Low education levels and lower hygienic awareness probably resulted in the higher disease prevalence in W60.

ACKNOWLEDGEMENTS

Funding for the work reported in this paper by the AIT fellowship and the CREST program in Japan Science and Technology Agency is gratefully acknowledged. We thank Rezina Ashraf, physician, and Neelima Afroz Mollah for field assistance. Constructive comments provided by two anonymous referees on an earlier draft of this paper are gratefully acknowledged.

REFERENCES

- Anderson, K. B., Chunsuttiwat, S., Nisalak, A., Mammen, P. M., Libraty, H. D., Rothman, L. A., Green, S., Vaughn, W. D., Ennis, A. F. & Endy, P. T. 2007 Burden of symptomatic dengue infection in children at primary school in Thailand: a prospective study. *The Lancet* **369**(9571), 1452–1459.
- Bern, C., Martinez, J., de Zoysa, I. & Glass, R. I. 1992 The magnitude of the global problem of diarrhoeal disease: a ten-year update. *Bull. World Health Organ.* **70**, 705–714.
- Byass, P. & Hanlon, P. W. 1994 Daily morbidity records: recall and reliability. *Int. J. Epidemiol.* **23**, 757–763.
- CHERG 2004 Child Health Epidemiology Reference Group of World Health Organization. CHERG methods and assumptions for diarrhoea mortality estimates. World Health Organization, Geneva, Switzerland.
- Clark, D. V., Mammen, M. P. J., Nisalak, A., Pathimethee, V. & Endy, T. P. 2005 Economic impact of dengue fever/dengue hemorrhagic fever in Thailand at the family and population levels. *Am. J. Trop. Med. Hyg.* **72**, 786–791.
- DWASA 2005 WASA Management Information Report for the month of September 2005, Dhaka Water Supply and Sewerage Authority, WASA Bhaban, 98, Kazi Nazrul Islam Avenue, Dhaka-1215.
- Ferreccio, C., Prado, V., Ojeda, A., Cayyazo, M., Abrego, P., Guers, L. & Levine, M. M. 1991 Epidemiologic patterns of acute diarrhea and endemic *Shigella* infections in children in a poor periurban setting in Santiago. *Chile. Am. J. Epidemiol.* **134**, 614–627.
- Gleick, H. P. 1999 *The World's Water 1998–1999: the Biennial Report on Freshwater Resources*. Island Press, Washington, DC.
- Homedes, N. 2000 *The Disability-Adjusted Life Year (DALY)–Definition, Measurement and Potential Use*. Human Capital Development and Operations Policy, Working paper, World Bank.
- Mollah, K. A. & Aramaki, T. 2006 *Contribution to Environmental Burdens from Sanitation Systems in Abatement of Health Impacts–Case Study in Low-income Community of Dhaka, Bangladesh*. Proceedings of the Fourth International Symposium on Southeast Asian Water Environment, University of Tokyo, AIT, Thailand, December 6–8, 2006, Vol. 4, pp. 41–48.
- Murray, C. J. L. 1994 Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bull. World Health Organ.* **72**, 429–445.
- Murray, C. J. L. & Lopez, A. D (eds) 1996 *The Global Burden of Disease; a Comprehensive Assessment of Mortality and Disability from Disease, Injury, and Risk Factors in 1990 and Projected to 2020*. Global Burden of Disease and Injury Series, Vol. I, WHO/Harvard University Press.
- Payment, P., Siemiatycki, J., Richardson, L., Renaud, G., Franco, E. & Prevost, M. 1997 A prospective epidemiological study of gastrointestinal health effects due to the consumption of drinking water. *Int. J. Environ. Health Res.* **7**(1), 5–31.
- Petri, W. A., Jr, Haque, R., Lyerly, D. & Vines, R. R. 2000 Estimating the impact of amebiasis on health. *Parasitol. Today* **16**, 320–321.
- Qadri, F., Khan, A., Faruque, A., Khan, A. I., Faruque, A. S., Begum, Y. A., Chowdhury, F., Nasir, G. B., Salam, M. A., Sack, D. A. & Svennerholm, A. M. 2004 Enterotoxigenic *Escherichia coli* and *Vibrio cholera* diarrhea, Bangladesh. *Emerg. Infect. Dis.* **11**(7), 1104–1107.
- Thielman, N. M. & Guerrant, R. L. 1996 From Rwanda to Wisconsin: the global relevance of diarrhoeal diseases. *J. Med. Microbiol.* **4**(3), 155–156.
- Wegelin, M., Canonica, S., Mechsner, K., Fleischmann, T., Pesaro, F. & Metzler, A. 1994 Solar water disinfection: scope of the process and analysis of radiation experiments. *AQUA* **43**(2), 154–169.
- WHO 1994 *Household Survey Manual: Diarrhoea and Acute Respiratory Infections*. WHO/CDR/94.8. Geneva: World Health Organization.
- WHO/UNICEF 2000 *United Nations Children's Fund, and Water Supply and Sanitation Collaborative Council, Global Water Supply and Sanitation Assessment 2000 Report*.
- Yamashiro, T., Nakasone, N., Higa, N., Iwanaga, M., Insisiengmay, S., Phounane, T., Munnalath, K., Sithivong, N., Sisavath, L., Phanthauamath, B., Chomlasak, K., Sisulath, P. & Vongsanith, P. 1998 Etiologic study of diarrheal patients in Vientiane, Lao People's Democratic Republic. *J. Clin. Microbiol.* **36**, 2195–2199.

First received 30 December 2008; accepted in revised form 17 July 2009. Available online 9 November 2009