Health risk of children caused by waterborne infectious disease in Baseco slums of Manila, Philippines

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Introduction

There is seldom adequate sewer drainage or access to sanitary latrines in urban slums. The hygiene and sanitation problems raise health risks of people living there. Whenever there is a rainfall or flood, pathogen contaminated water will stay on the ground for a long time, which would cause infectious diseases to human through direct and indirect ingestion. It has become a significant public health concern for slum dwellers, especially for children. The study was conducted in a typical slum in Baseco Compound, Manila. The main objective was to analyze microbial level in water sources and to quantify risk of children caused by waterborne infectious disease. A quantitative microbial risk assessment was performed and both daily and annual risks were calculated, under circumstances of both direct and indirect ingestions

Materials and methods

Baseco was officially declared as Barangay 649 with an area of 54 hectares, which locates in the South Harbor of the Port Area of Tondo, western Manila. It is built on an area that grew from wastes and mud swept in from Pasig River and became a resettlement place for informal settlers. Most of houses are made of junk wood and waste materials. Approximately 50,918 urban poor people live in the compound as of May 1, 2010. There are approximately 10,712 families, of which over half population (30,588 people) are below age 18. These families struggle to survive from poor sanitation, fires, frequent flooding and typhoons. Residents in slum areas obtain water from several deep wells until 2008, when the Maynilad Water Service Inc. started of its mainline extension project to supply drinking water through pipelines in Baseco slum area. However, the lack of sanitation still affects the well-being of the most vulnerable group in the compound: the poorest children.

Forty-two water samples were taken from Baseco slum areas in Manila, for microbial analysis, including drinking water, ice, seawater, rainwater, groundwater, road water and toilet-flushing water. Water samples were added to the sterile phosphate buffer. Dilution series of the mixture are made and one milliliter of the mixture at each dilution level is applied to the test kit for total coliforms and E.coli. Oral exposure per event is calculated based on *E. coli* concentrations in water and water intake.

The Beta Poisson dose-response models used are as follows.

For single infection risk: $$P(D) = 1 - \left[1 + \frac{D}{N_{50}}(2^{1/\alpha} - 1)\right]^{-\alpha} \quad (1)$$

For annual infection risk: $$P_{annual} = 1 - [1 - P(D)]^n \quad (2)$$

In Equations (1) and (2), *P(D)* is the daily infectious probability; P_{annual} is yearly infection; *D* is the dose of pathogen (CFU/day), here 0.30 of *E. coli* dose was used, α is slope parameter, α=0.1778; N_{50} is medium infectious dose, $N_{50}=8.6*10^7$ (Haas, 1999); *n* is number of exposure times per year.

Incorporating events into overall probability of infection

$$P_{\inf} = \sum_{i=1}^{n} P_{event_i} \times P_{\inf_i} + (1 - \sum_{i=1}^{n} P_{event_i}) \times P_{\inf_{nominal}} \quad (3)$$

Incorporating the impact of events into the annual probability of infections

$$P_{ann} = 1 - (1 - P_{\inf_{nominal}})^{t_{nominal}} \prod_{n=1}^{i} (1 - P_{\inf_n})^{t_n} \quad (4)$$

In Equations (3) and (4), P_{inf} is the overall probability of infection; n is the total number of event conditions to be included; P_{eventi} is the probability of event i occurring; P_{infi} is the probability of infection given that event i has occurred; $P_{infnominal}$ is the probability of infection under baseline or nominal conditions.

Results and Discussions

The drinking water was supplied with simple pipes which were exposed on road with leakage, running through road water, muds and wastes. Most people in slums stored drinking water in containers. Drinking water in Baseco slum areas includes pipe water,

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tank-stored water, ground water and ice water. As shown in Table 1, drinking water was found to be highly contaminated with fecal matter. There is a high possibility of existence of pathogenic bacteria in drinking water. Furthermore, while children play in puddles or rains, oral exposure may occur via hand-mouth transfer or via direct ingesting of contaminated water. The E. coli concentration in road water, sea water and rain water implied a high health risk to children who play in the water.

Table 1 Maximum microbial concentrations detected in waters of Baseco slum areas

Water sample	Maximum microbial concentrations (CFU/100 mL)		Ingestion pathway
	E. coli	Total coliforms	
Pipe water	1.0×10^2	2.1×10^3	Drinking
Tank-stored water	50	2.4×10^3	
Ground water	4.5×10^2	7.5×10^3	
Water from melt ice	48	4.0×10^2	
rainwater	1.4×10^3	2.5×10^4	Playing, swimming
Seawater	5.0×10^3	1.1×10^4	
Puddle water on road	5.6×10^5	1.2×10^6	

Table 2 Parameters used for calculation of risk of infection

Water Exposure	Volume swallowed (mL/day)	*E. coli* Concentration (CFU/100 mL)	Frequency (days/yr)
Drinking water	$V_{DW} = 580$	$C_{DW} = 4.5 \times 10^2$	365
Swimming in the sea	$V_{SW} = 31$	$C_{SW} = 5.0 \times 10^3$	365
Wading in the puddle	$V_{PW} = 1$	$C_{PW} = 5.6 \times 10^5$	176
Playing with rainwater	$V_{RW} = 8.25$	$C_{RW} = 1.4 \times 10^3$	176

The exposure routes leading to oral ingestion could be different. In this study, direct ingestion through drinking water, indirect ingestion while swimming in sea, wading in puddles and playing with rainwater were considered for children. According to Dufour *et al*. (2006), the mean water ingestion rate during swimming activities is 50 mL/hr for children ages from 6 to 15 years old. This is a high estimation of the amount of water to which a typical child in slums could be exposed. The ingestion rate when playing in the rain was estimated to be 1/2 the amount of water ingested by a child while swimming. Nett *et al.* (2010) reported that children place open mouth to splash park water, with a mean of 9.9 min per hour observation, which is used for children's ingestion of rainwater in this study. Daily ingestion of water through playing in rain (V_{RW}) was calculated based on the assumption that children play in rain for 2 hours daily in rainy days. For annual risk estimation, a historic number (176) of rainy days in the year 2014 was used for yearly frequency of children playing with rainwater. As shown in Table 2, the annual frequencies of drinking water, swimming in the sea and wading in puddles were assumed to be 365, 365 and 176 days, respectively.

Table 3 Numbers of slum children getting infected

Water Source	Daily ($/10^6$)	Annual ($/10^4$)	Overall Daily ($/10^6$)	Overall Annual ($/10^4$)
Drinking water	78	281	206	725
Swimming in seawater	46	168		
Playing in Puddles	168	291		
Playing with rainwater	3	6		

Daily and annual infectious risks were simulated and results are shown in Table 3. The number of infection through drinking was 281 per 10,000 children annually. The USEPA has proposed an acceptable standard of 1 infection per 10,000 exposed annual risk of infection from drinking water. This limit has been debated and some researchers consider it should be lowered to 1:1000 per year. The overall risk of infection, while children in slum areas intake polluted water from drinking water, swimming in seawater, playing in puddles or rain, reached as high as 725:10000. It should be noticed that here the risks of infection through intake of contaminated water were studied based on the maximum E. coli concentrations. And the lowest drinking water intake of Manila was used during calculation. Those together with various assumptions in this research could cause an overestimation or underestimation of the real risks for children in slum areas. However, it could give some useful information about health risks that could be caused to children in slum areas involved in multiple daily events. Further research is needed on relationships between common water bacteria and pathogens in water, in order to, on one hand, to better understand the ecology of these microorganisms in water, on the other hand, perform a better health risk analysis for pathogens in water.

References

Haas, C. N., Rose, J. B., Gerba, C. P. (1999) Quantitative Microbial Risk Assessment. Wiley, New York.

Dufour A. P., Evans O., Behymer T. D., Cantu R. (2006) Water ingestion during swimming activities in a pool: A pilot study. Journal of Water and Health 4: 425-430.

Yason J. A. D. L., Rivera W. L. (2007) Genotyping of Giardia duodenalis isolates among residents of slum area in Manila, Philippines. Parasitol Res 101: 681-687.

Nett R. J., Toblin R., Sheehan A., Huang W. T., Baughman A., Carter K. (2010) Nonhygienic Behavior, Knowledge, and Attitudes Among Interactive Splash Park Visitors. J Environ Health 73(4): 8-14.