Estimation of Human Exposure to Bacterial Pathogens in Drinking Water of Philippine Passenger Ships

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A human exposure estimation to bacterial pathogens in drinking water of Philippine inter-island passenger vessels was done. The calculation of estimated microbial intake per person per voyage was based on the voyage travel time, average water consumption per voyage and estimated microbial contamination level of water consumed. A model that detailed ship drinking water flow diagram and order of change in microbial concentration was used in the estimation of microbial contamination level. Results of the study indicated that possibility of infection relative to established infective doses of Vibrio cholerae, Salmonella typhi and pathogenic strains of Shigella spp. and Escherica coli exist when raw water is loaded to the ship reservoir specially during extended travel time. Review of policy and implementing guidelines related to drinking water management for Philippine inter-island passenger vessels was recommended.

Keywords: bacterial pathogens, human exposure, drinking water

Introduction

Several waterborne disease outbreaks associated with Vibrio cholerae, Salmonella typhi, and pathogenic strains of Escherica coli and Shigella spp. have been reported in the Philippines (Dayrit et al., 1996; Dayrit et al., 1997; Roces et al., 1999; Lopez et al., 2004; Macaraeg, 2004 and Manongdo, 2005). A more recent outbreak of waterborne cholera reported last March 2005 claimed 4 mortalities and 50 morbidities (Crisostomo, 2005). It is undeniable that up to the present time, safety issues related to drinking water supplies is a matter of concern that still need to be addressed and managed appropriately in the Philippines.

The impact of safety in drinking water is further emphasized when consumers are in caught in a situation where supply of water is limited from a controlled source as in the case of passengers in inter-island water vessels. Risks of waterborne disease outbreaks in local inter-island ships is particularly high in the Philippines because of popular patronage due to the fact that this form of transport system remains at present still to be amongst the cheaper means of transporting local human resources and economic goods. The risks associated with drinking water supplies in local vessels are further compounded by the fact that untreated ground or surface water is sometimes loaded to the ship reservoirs.

Mathematical calculations that combine existing laboratory data with previous information related to human infectivity and effects of various treatments to the final microbial profile of drinking water has been widely used for assessing human exposure to waterborne pathogens (Regli et al., 1991; Rose et al., 1991; and Haas, 2000). Such mathematical statements provide practical information related to the chance of illness or other outcomes that may occur after human exposure to certain pathogens (Dennis et al., 2002). However, studies previously utilizing this method of estimation were generally applied to assessment of contamination of community drinking water supplies. There is still a dearth of information related to assessment of drinking water supplies quality, which are institution- or facility-specific provided like in drinking water supplies of inter-island passenger ships. The objective of this study was to develop a means of estimating human exposure to bacterial pathogens in drinking water of Philippine inter-island passenger vessels. Results of this study were envisioned to provide some necessary benchmarks for review of regulatory safety measures for drinking water supplies of Philippine inter-island passenger ships.

Methodology

Exposure estimation to bacterial pathogens An equation to estimate human exposure to bacterial pathogens in drinking water supplies of Philippine inter-island passenger vessels was formulated considering the following factors: (1) voyage travel time of inter-island passenger vessels; (2) average water consumption of a person on a ship per day per voyage; and (3) estimated microbial contamination level of drinking water loaded to the ship. The formulated equation is as shown below:

The working definition used for voyage travel time factor of the equation was a continuous ship voyage travel time without any port stopover. The working val-
ue of 31 average water consumption per person per day (0.1251/l/person) cited in the Sanitation Code of the Philippines (1998) was used as a constant in the equation. Estimated microbial contamination level of drinking water in Philippine inter-island passenger ships was determined by considering the following: type of water loaded (raw or municipal-treated) and effects of various treatments and handling procedures during receipt, transfer, and distribution of ship drinking water. Order of change in microbial contamination level was based on the information obtained from the previously published literatures as shown in Table 1.

**Microbial Contamination Level Model** To estimate microbial contamination level of ship drinking water supplies as affected by the type of water loaded and changes with treatment, storage and distribution until it reaches the end-user, a source-to-passenger exposure model was drawn (Figure 1). This exposure model consisted of: (1) box-line flow diagram of drinking water in inter-island vessel from the source to the end-user; and (2) order of change in microbial contamination level through the various stages of water distribution.

**Survey of ships management protocols** Contacts with local shipping lines with inter-island passenger vessels docking at North and South harbors of Metro Manila, Philippines and their respective water suppliers were done to obtain pertinent information related to management of potable water supply and distribution systems in Philippine inter-island passenger ships. The study was able to document drinking water management of 5 test ships from 3 shipping lines. Information regarding type of water loaded, maximum passenger capacity per ship, maximum water reservoir capacity, and minimum and maximum travel times of ships were obtained.

**Determination of bacterial pathogens infectivity** To determine the possibility of human infection associated with various waterborne bacterial pathogens, the estimated microbial intake per person per voyage calculated in the study was compared to established infective doses of *S. typhi*, *V. cholerae*, or pathogenic strains of *E. coli* and *Shigella* spp. Established minimum infective doses of specific bacterial pathogens were based on USFDA (1992 and 2001) and WHO (2000) published literatures.

**Results and Discussion**

Mathematical statements have been previously drawn to help estimate human exposure to some pathogens in drinking water (Regli *et al.*, 1991; Rose *et al.*, 1991 and Haas, 2000). Essentially, the purpose of exposure estimation is to provide educated estimates of the level of pathogens that may be consumed by a certain target group. The equation that was drawn in this study simply looked into the impact of voyage travel time, average water consumption and estimated microbial contamination level of water supply to assess human exposure to bacterial pathogens of drinking water supplies of local inter-island passenger ships. It had been reported that to determine the estimated microbial contamination level of drinking water, it is necessary to estimate both the initial microbial contamination level of water and the subsequent changes with the contamination level due to treatment, storage and distribution until it reaches the end-user (Regli *et al.*, 1991 and Rose *et al.*, 1991). This approach is the precise mode of assessment that was adapted to evaluate human exposure to bacterial pathogens of drinking water supplies of local inter-island passenger ships.

Figure 1 details the model for estimation of microbial

### Table 1. Effect of different water treatment and handling procedures on microbial quality of drinking water.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Effect on microbial quality</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw water as drinking water (initial microbial contamination)</td>
<td>10⁶ cells/ml</td>
<td>Lozada, 2001</td>
</tr>
<tr>
<td>Municipal treatment</td>
<td>6 log cycle decrease</td>
<td>Geldreich, 1991</td>
</tr>
<tr>
<td>Transfer from pier-water distribution system to barge or truck</td>
<td>1 log cycle increase</td>
<td>Azanza <em>et al.</em>, 2005</td>
</tr>
<tr>
<td>Storage in ship reservoir (24-29 h)</td>
<td>2-log cycle increase</td>
<td>Geldreich, 1972</td>
</tr>
<tr>
<td>Chlorination</td>
<td>3 log cycle decrease</td>
<td>Rice <em>et al.</em>, 1999</td>
</tr>
<tr>
<td>After passing-thru the ship distribution system</td>
<td>1 log cycle increase</td>
<td>Norton and LeChevallier, 2000</td>
</tr>
<tr>
<td>Transfer from ship distribution system to detached water outlets</td>
<td>1 log cycle increase</td>
<td>Azanza <em>et al.</em>, 2005</td>
</tr>
</tbody>
</table>

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1 Estimated microbial voyage travel time (h) X average water consumption (l/h) X estimated microbial intake per person contamination level (cells/l) / person (DOH, 1998).

2 Estimated microbial contamination level as affected by water treatment and other handling procedures in a source-to-passenger exposure model.
contamination level of drinking water supplies in Philippine inter-island passenger ships generated in this present study as affected by the type of water loaded and various stages of its distribution and treatment. This particular model reflects the actual flow of ship drinking water supplies of 5 test ships from 3 participating domestic shipping lines. Two of the participating shipping lines represent major shipping lines in the country whose fleet of vessels per shipping line is not less than 50. The other participating shipping line has currently only 0 ships for its fleet.

Essentially, it was established from the survey that either raw water or municipal-treated water can be loaded in a ship reservoir as potable water, used in part as drinking water supply, via pier-water distribution system, barge or truck. On-ship chlorination is applied to all water supplies that entered the ship reservoir in the country whose fleet of vessels per shipping line is not less than 50. The other participating shipping line has currently only 6 ships for its fleet.

All types of water loaded to the ship reservoir of local vessels should be chlorinated on-board as prescribed by the Philippine BOQ to maintain a residual level of chlo-

rine at 0.20–0.50 ppm (DOH, 1998). Rice et al., (1999) reported that such level of chlorine can effect a 3-log cycle reduction in the microbial concentration of water. Geldreich et al., (1972) reported a 2-log cycle increase in microbial contamination level of drinking water stored for 24 to 29 h without replacement or flushing. LeChevallier (1990) explained that holding of water for a certain duration of time without flushing or replacement may lead to reduction of residual disinfectant level, which may be conducive to proliferation of bacterial pathogens.

It was established in the present study that drinking water supplies from the ship distribution system could be obtained either from a number of attached or detached water outlets. Attached water outlets in the test ships surveyed included drinking fountains, water coolers and water heaters while detached outlets included water dispensers and percolators. Results of the study by Azanza et al., (2005) indicated that potable water supplies may have at least 1-log cycle increase in microbial contamination level the after it had passed thru the ship pipelines. This observation is consistent with the findings of Norton and LeChevallier (2000) that bacterial levels of potable water increased by one-log unit by the time it reaches the outlets after passing thru the water distribution system. Further increased in microbial load of water by another log cycle can be expected from water transferred from the ship distribution lines to detached outlets such as percolators as a result of additional handling (Azanza et al., 2005).

Another factor essential for the estimation of human exposure to waterborne bacterial pathogens is the amount of water ingested per test exposure in a ship voyage (Haas, 2000). Macler and Regli (1993) used as 21/l/person/day value to assess risk to waterborne pathogens. However, Rosebury and Burmaster (1992) mentioned that a value of 21/l/person/day is a rather conservative value for water consumption rate to be used in the assessment of risk to waterborne pathogens in drinking water. This present study utilized a 21/l/person per day value as specified in the Philippine Sanitation Code (DOH, 1998) for estimating microbial intake of each person per voyage.

The estimated microbial intake of person per voyage as a function of travel time, amount of water consumed per voyage and estimated microbial contamination level of water consumed in the 5 test ships surveyed are shown in Tables 1 to 3. Table 2 indicates that when raw water is loaded into the ship reservoir of any of the test ships via barge or truck, the possibility of infection due to V. cholerae, S. typhi, pathogenic Shigella spp., and pathogenic Eschericia coli exists even with the application of the required on-ship chlorination. Possibility of infection is increased as water from attached outlets is transferred to detached outlets, which can be attributed to an additional 1-log cycle increase in microbial load. The negative impact of obtaining raw water as drinking water from detached outlets was further emphasized with increase in voyage travel time as shown in the evaluation of possibility of human infection due to pathogenic E. coli.

### Table 2. Human exposure estimation to bacterial pathogens in ship drinking water using raw water delivered via barge or truck.

<table>
<thead>
<tr>
<th>Drinking Water Flow Diagram</th>
<th>Treatment/Handling Vessel Details</th>
<th>Travel Time (h)</th>
<th>Estimated microbial intake (cells)/person/voyage</th>
<th>Human infection based on minimum infective dose (cells)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Water</td>
<td></td>
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<td></td>
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<tr>
<td>Barge or Truck</td>
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<tr>
<td>Ship Reservoir</td>
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<tr>
<td>On-Ship Chlorination</td>
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<tr>
<td>Ship Distribution Line/Outlet</td>
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<tr>
<td>Detached Water Outlets†</td>
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</tbody>
</table>

†Estimated microbial intake per person per voyage = voyage travel time × average water consumption × estimated microbial contamination level

 motorcycles: 

- ✔️ Possible infection
- X no infection

† Detached water outlets such as percolators and water dispensers

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*Drinking Water Pathogens Human Exposure Estimation*
out any transfer to a detached water outlet, a maximum of 26 h voyage travel time is needed to record possibility of infection due to waterborne pathogenic E. coli. However, for consumption of raw water from detached water outlets such as percolators and water dispensers, this possibility could occur even at a minimum travel time of 2 h.

Tables 3 and 4 show that if municipal-treated water is loaded, whether it is obtained from pier-water distribution system, barge or truck, all possibilities of human infection due to the waterborne bacterial pathogens considered in the study do not exist based on established infective minimum infective doses of these bacterial pathogens and the human exposure model drawn in the study. The municipal treatment, which involves a 0-step treatment, could provide adequate microbial hurdles that could render drinking water on-board safer for human consumption. It is unfortunate, however, that not all the drinking water supplies in the country for ships are subjected to municipal treatment (National Water Information Network, 2003). The impact of on-board handling and travel time on the microbial load of drinking water supplies in ships is fully negated when municipal-treated water is used as drinking water supply.

**Summary and Recommendations**

This study estimated human exposure to bacterial pathogens in drinking water in representative Philippine inter-island passenger vessels. An equation for the estimation of human exposure to V. cholerae, S. typhi, and pathogenic strains of Shigella spp. and E. coli was generated based on the following factors: voyage travel time, average water consumption per person per voyage time, and estimated microbial contamination level as affected by handling and treatment procedures. A model was developed to estimate microbial contamination level of drinking water in ships based on published information related to waterborne pathogen occurrence and effect of disinfection methods. Information regarding type of water supply, maximum passenger capacity per ship, maximum water reservoir capacity, and minimum and maximum travel times of ships were obtained from test inter-island ships. Possibility of infection to some known waterborne bacterial pathogens was determined by comparing estimated microbial intake per person per voyage to established infective doses of these pathogens.

The model used to estimate microbial contamination level of drinking water supplies in Philippine inter-island passenger ships utilized the flow diagram of ship drinking water from the source to the passenger. The order of change in microbial contamination of drinking water supplies as it passed from the source to the end-user was also included in the model. It was shown that the possibility of human infection is higher if raw water is loaded to the ship reservoir. This possibility of human infection is further increased if water is obtained from a ship detached water outlets and with extended travel time of ≥8 h as a result of further handling and storage. It was also shown that municipal water treatment served as a significant barrier against possibility of waterborne bacterial infections. On-ship chlorination to reach a residual of 0.2 to 0.5 ppm was shown to be inadequate to prevent
waterborne infection if raw water is used as drinking water.

This study recommends that water on-board inter-island passenger vessels intended for drinking should preferably be obtained from municipal-treated water sources. However, if there is no recourse but to use raw water, improvement of water disinfection treatment relative to what is being currently used locally should be considered. There should also be a review of protocols of sanitary maintenance of detached water systems by ships to help improve overall drinking water quality in inter-island passenger ships since improper maintenance of such water systems may result in increased possibility of infection due to waterborne bacterial contamination.

References


