C5) An investigation of microbiological potable water quality in high-rise residential buildings of Hong Kong

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Abstract

In Hong Kong, the potable water in residential buildings is generally supplied through water pipes and available at water taps in washrooms and kitchens. It is known that microbial growths in water supply systems are highly associated with enteric diseases. However, the information and guideline on the microbiological potable water qualities in Hong Kong is limited. This study aimed to investigate the microbiological potable water qualities in high-rise residential buildings. Tap water samples (100 mL) were collected at the water supply systems from residential buildings during summer of Hong Kong. The age of buildings of the sampling sites ranged from 5 to 48 years and located at both rural and urban areas. The results showed that the heterotrophic plate counts (HPC) bacteria ranged from 0 CFU mL$^{-1}$ to 1.60 CFU mL$^{-1}$. The identified bacterial genera in water were Acinetobacter, Aeromonas, Bacillus, Escherichia coli, Micrococcus, Pseudomonas, Staphylococcus and Streptococcus. And the fungal count ranged from 0 CFU mL$^{-1}$ to 0.20 CFU mL$^{-1}$. The identified fungal genera were Aspergillus, Penicillium and non-sporulating fungi. Future investigations regarding the possible association between the environmental factors and microorganisms in the potable water of high-rise residential buildings in sub-tropical climate as well as their health effects were recommended.

Keywords

Bacteria; fungi; high-rise residential buildings; water quality; water supply.
1. Introduction

In Hong Kong, water is supplied from rainfall collected from natural catchments and the East River (Dongjiang) of China. Water is disinfected in the treatment plants to an acceptable level and then supplied to the buildings by gravity via extensive networks of water mains. The pressure in the system is generally sufficient to provide a direct supply to six or seven storeys above street level and the upper floors of tall buildings are supplied from their own roof tanks, filled by their own pumping systems (WSD, 2008). Storage tanks would be constructed by reinforced concrete with access cover and periodic cleaning every three months is recommended (WSD, 2008).

During 2006 and 2007, domestic freshwater consumption contributed to 53.3% of total water consumption and the per capita domestic fresh water consumption was 127.6 L day\(^{-1}\) (WSD, 2008). As a major concern in drinking water safety, microbiological water quality has been identified as one of the key issues in reducing the risk of transmissions of waterborne diseases. It is well known that microorganisms in water systems would degrade the water quality by depletion of dissolved oxygen (O\(_2\)), reduction of hydrogen sulfate to hydrogen sulfide, corrosion of pipes, and occurrence of bad taste and color (van der Wende and Characklis, 1990). Therefore, microbiological water quality is an indicator of the performance of building’s drinking water distribution system.

The most common method to assess the microbiological water quality is to measure the amount of heterotrophic plate count (HPC) bacteria (Edberg and Allen, 2004). Under the Safe Drinking Water Act, the United States Environmental Protection Agency (USEPA), has set a standard for drinking and recreational water at 500 colony forming units per milliliter (CFU mL\(^{-1}\)) for HPC bacteria (USEPA, 2003). Most of commonly recorded HPC bacteria are not human pathogens, but some of them are considered to be opportunistic pathogens, included *Acinetobacter*, *Aeromonas*, *Flavobacterium*, *Klebsiella*, *Legionella*, *Moraxella*, *Mycobacterium*, *Serratia*, *Pseudomonas* and *Xanthomonas* (WHO, 2004; Edberg and Allen, 2004). It is also reported that the waterborne fungi may caused infections to the immunocompromised patients (Anaissie and Costa, 2001). However, to our knowledge, there is no report on the exposure level of fungi in drinking water of domestic buildings in Hong Kong. This study aimed to investigate the microbiological potable water qualities in high-rise residential buildings.

2. Methodology

Water samples were collected from the water tap of a washbasin of restroom of in-use, high-rise residential buildings (N=63) of Hong Kong during June 2007 to November 2007. All samples were taken on daytime of weekdays. Upon each measurement, a water sample of 100 mL was collected by using a 250 mL sterilized bottle which containing sodium thiosulfate (1 mL 10% w/v solution). The water samples were diluted and 0.1 ml of samples were spreaded on triplicate plates of R2A (Oxoid) and Malt Extract Agar (MEA) (Oxiod) for isolation of heterotrophic plate count (HPC) bacteria and fungi respectively. The plates were incubated at 35°C for 48 hours and 25 °C for 1 week. After incubation, the number of colonies (colony forming unit, CFU) was counted, and the bacteria and fungi were isolated and identified.
3. Results and Discussions

3.1 Bacterial and fungal levels

The microbiological quality monitoring results of drinking water of high-rise residential buildings of Hong Kong are shown in Table 1. A total of 63 water samples were collected from different locations of Hong Kong. None of the sampling location installed with the household water disinfection or filtration machine. The temperature of water samples varied from 18.6°C to 28.3°C.

It is found that the HPC bacteria levels are below the USEPA HPC limit (USEPA, 2003). The present study supported previous findings in Hong Kong that the chlorination process for drinking water in Hong Kong were reported satisfactory (Chan et al., 2007; Ho et al., 2003). The HPC bacteria were detected in 68% of water samples with levels varied from 0 CFU mL⁻¹ to 1.60 CFU mL⁻¹. The average level was 0.52±0.53 CFU mL⁻¹ which was higher than the previous findings in the office building reported in Hong Kong, which was 0.26±0.23 CFU mL⁻¹. However, levels were comparatively low when compared with some problematic cases of HPC ranged from <0.10 CFU mL⁻¹ to 20,000 CFU mL⁻¹ (Reasoner, 1990; Edberg et al., 1996; Cloete et al., 2003; Allen et al., 2004).

The results also showed that fungi were detected in 35% of water samples. The fungi levels varied from 0 CFU mL⁻¹ to 0.20 CFU mL⁻¹ and average level was 0.05±0.08 CFU mL⁻¹. The fungi levels were comparatively low when compared with studies ranged from 0 CFU mL⁻¹ to 30 CFU mL⁻¹ (Augustinos et al., 1995; Gottlich et al. 2002; Goncalves et al., 2006; Kanzler et al., 2008). However, there is no fungi detected in the water samples collected in office buildings previously (Chan et al., 2007).

The relatively higher microbial levels in drinking water of residential buildings when compared with the office buildings of Hong Kong may probably due to different cleaning practices, occupancy load, degree of water consumption and the environmental conditions (Chan, et al., 2007; Wong and Mui, 2008).

Table 1 – The HPC bacterial and fungal levels of drinking water in high-rise residential buildings of Hong Kong (N=63)

<table>
<thead>
<tr>
<th></th>
<th>Range (CFU mL⁻¹)</th>
<th>Average ± Standard derivation (CFU mL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPC bacterial level</td>
<td>0-1.60</td>
<td>0.52±0.53</td>
</tr>
<tr>
<td>Fungal level</td>
<td>0-0.20</td>
<td>0.05±0.08</td>
</tr>
</tbody>
</table>

3.2 Bacterial and fungal composition

A total of 8 bacterial genera and 2 fungal genera were detected in the water samples and the compositions are presented in Table 2. It is reported that 57.3% are belonged to gram positive bacteria and 42.7% of isolates are belonged gram negative bacteria. None of the water samples contained pathogenic bacteria except that Escherichia coli was
detected in 11.1% of samples. The *E. coli* levels varied from 0 CFU mL\(^{-1}\) to 0.8 CFU mL\(^{-1}\) with average level of 0.03±0.11 CFU mL\(^{-1}\). This exceeds the WHO guideline for drinking water quality of “zero” *E. coli* per 100 ml water (WHO, 2004). The presence of *E. coli* indicated that the water was contaminated by human or animal wastes and would cause problems of probable infections. It may also due to improper cleaning practices of water taps. And some species were considered to be opportunistic pathogen from oral ingestion for immunocompromised patients, such as *Pseudomonas* (Rusin *et al*., 1997).

In general, *Micrococcus* was the most dominant genera, presented in 28.6% of samples, with relative abundance of 29.2%. The other isolated gram positive bacteria genera were *Bacillus* (with relative abundance of 6.5%), *Staphylococcus* (2.8%), *Streptococcus* (0.6%) and others (18.2%). The isolated gram negative bacterial genera were *Acinetobacter* (2.5%), *Aeromonas* (3.1%), *Escherichia coli* (5.2%), *Pseudomonas* (10.5%) and other (21.5%). These HPC genera were reported common bacteria in drinking water in Hong Kong and other countries (Allen *et al*., 2004; Chan *et al*., 2007).

**Table 2 – The composition of HPC bacteria and fungi of drinking water in high-rise residential buildings of Hong Kong (N=63)**

<table>
<thead>
<tr>
<th>Composition (%)</th>
<th>Occurrence frequency</th>
<th>Relative abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HPC bacterial genera</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acinetobacter</td>
<td>9.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Aeromonas</td>
<td>9.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Bacillus</td>
<td>12.7</td>
<td>6.5</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>11.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Micrococcus</td>
<td>28.6</td>
<td>29.2</td>
</tr>
<tr>
<td>Pseudomonas</td>
<td>19.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Staphylococcus</td>
<td>6.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Streptococcus</td>
<td>1.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Other gram +ve HPC bacteria</td>
<td>30.2</td>
<td>18.2</td>
</tr>
<tr>
<td>Other gram –ve HPC bacteria</td>
<td>38.1</td>
<td>21.5</td>
</tr>
<tr>
<td><strong>Fungal genera</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspergillus</td>
<td>15.9</td>
<td>53.1</td>
</tr>
<tr>
<td>Penicillum</td>
<td>14.3</td>
<td>31.3</td>
</tr>
<tr>
<td>Non-sporulating fungi</td>
<td>6.3</td>
<td>15.6</td>
</tr>
</tbody>
</table>

The fungal genera were detected in the water samples were *Aspergillus*, *Penicillium* and non-sporulating fungi, which were recorded in 15.9%, 14.3% and 6.3% of water samples respectively. The relative abundance of *Aspergillus*, *Penicillium* and non-sporulating fungi were 53.1%, 31.3% and 15.6% respectively. *Penicillium* and non-sporulating fungi are also found to be common in drinking water reported by other studies (Gottlich *et al*., 2002; Kanzler *et al*., 2008). *Penicillium* spp. are recorded in 40.6% to 48.7% of the samples (Goncalves *et al*., 2006; Kanzler *et al*., 2008).

Although these isolates are not considered as pathogenic fungi, *Aspergillus* spp. are considered to be predominantly opportunistic fungi (Anaissie and Costa, 2001). It is reported that *Aspergillus* spp. are not isolated frequently from water but in our study, it
contributed to 15.9% of samples (Goncalves et al., 2006; Kanzler et al., 2008). Fungi in drinking water may lead to a health risk for infections, however, the critical concentration for people is not known so far, more investigation on the health impacts of these fungal isolates are needed.

4. Conclusions

Monitoring of microbiological water quality of drinking water collected from the water supply system of in-use, high-rise residential buildings of Hong Kong showed that the HPC bacteria and fungi were detected in 68% and 35% of samples. The bacterial genera in the samples were identified; 57.3% were gram-positive bacteria genera composed of Bacillus (6.5%), Micrococcus (29.2%), Staphylococcus (2.8%), Streptococcus (0.6%) and other isolates (18.2%), and 42.7% were gram-negative bacteria genera including Acinetobacter (2.5%), Aeromonas (3.1%), Escherichia coli (5.2%), and other isolates (27%). Faecal indicating bacteria, E. coli, was detected in 11.1% of samples. The presence of E. coli was probably due to an inappropriate cleaning practice. The fungal genera in the samples were identified and belonged to Aspergillus (53.1%), Penicillium (31.3%) and non-sporulating fungi (15.6%). Although no pathogenic microorganism was detected in the samples, but some genera isolated are considered to be opportunistic pathogen for immunocompromised patients. Investigation regarding the probable transmission through a water supply system in buildings was recommended.

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5. References

6. Presentation of Authors

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