Original Research

FACTORS INFLUENCING THE QUALITY OF DRINKING WATER FROM VENDING MACHINES IN THE INNER CITY OF BANGKOK

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ABSTRACT
Objective: To investigate coliform contamination in drinking water from vending machines in the Rajvithi area of Bangkok.
Study Design: Cross-sectional study
Methods: Associated environmental factors were observed and self-administered questionnaires conducted. In total, 123 drinking-water samples were collected to test coliform bacteria contamination.
Results: Coliform bacteria were detected in 28.5% of samples. Links were found between coliform contamination and filter cleaning practices in 57 maintenance persons' responses. Filters cleaned < 3 times per year were at higher risk of coliform contamination (OR 14.49, 95% CI 1.76-125.00). A negative association was found between coliform contamination and vending-machine filters' being cleaned within 100 days (OR 0.21, 95% CI 0.05-0.83).
Conclusion: A negative association was found between coliform contamination and vending-machine filters' being cleaned within 100 days (OR 0.21, 95% CI 0.05-0.83). These results emphasized the importance of effective vending-machine maintenance and monitoring drinking-water quality.

Keywords: drinking water, vending machine, Bangkok, maintenance

INTRODUCTION

Water is essential for human life; people need readily accessible drinking water. World Health Organization and UNICEF (2013) reported 89% of the world's population had access to drinking water in 2011. Up to 768 million people, however, were reliant on substandard sources. Most people living in urban areas do have access to the water supply, and urban drinking water coverage has remained high over the past two decades; currently, only 4% of the world's urban population is reliant on substandard sources. Good quality water – especially for drinking – is key to human health. Various water-borne diseases have been seen in both developed and developing countries, and the quality of drinking water requires greater discussion. For instance, 19.5 million people in the U.S. are estimated to contract water-borne diseases by drinking contaminated water each year (Reynolds, Mena, & Gerba, 2008). In Mexico City, which is one of the world's major urban centers, *Helicobacter pylori* was detected in 10% of tap water sampled, while trihalomethanes measured 40% (Mazari-Hiriart et al., 2005). Also, in Jakarta, Indonesia, fecal coliform contamination was detected in 56% of drinking water (Vollaard et al., 2005).

Bangkok is the capital city of Thailand, and 99% of the population in urban areas of the city has access to drinking water (World Health Organization & UNICEF, 2010). Although previous research has shown, for example, things like the hepatitis A virus and major chemicals are not detected in tap water (Kittigul, Uthaisin, Ekchaloemkiet, Utrarachkij, & Luksamijarulkul, 2006; Kruawal, Sacher, Werner, Muller, & Knepper, 2005), many city dwellers remain concerned about the quality of tap water because of taste, smell, and discoloration (Kruawal et al., 2005). While tap water is a major source for many households, the purchase of drinking water from vending machines is common, especially in the Rajvithi area of central Bangkok, in which there are many apartments, dormitories, and retail shops serving customers, and in which there are many different types of vending machine. A large number of people choose to drink water from these machines rather than purchase bottled water, due to the ease of access and lower price.

Although these vending machines usually come equipped with disinfection and purification systems to produce safe water (WHO, 2004), water quality is not guaranteed. Coliform contamination has been detected in 27.3% of all drinking-water samples from vending machines in Bangkok (Ministry of Public Health, 2006). Also, bacterial growth has been confirmed in biofilm and stored bulk water in reverse-osmosis systems, which many vending machines employ (Park & Hu, 2010).

Hence, the quality of drinking water from vending machines, and especially its biological quality, was investigated in the Rajvithi area. Various factors associated with water quality were assessed by looking at current attitudes and behaviors of persons who take care of vending machines, and the difficulties they encounter as part of their routine maintenance duties.

METHODS

Study Area
This study was conducted in a 1km radius of Victory Monument in the Rajvithi area of Bangkok (Figure 1). The black dots represent distribution points for the 130 vending machines observed as part of this research.
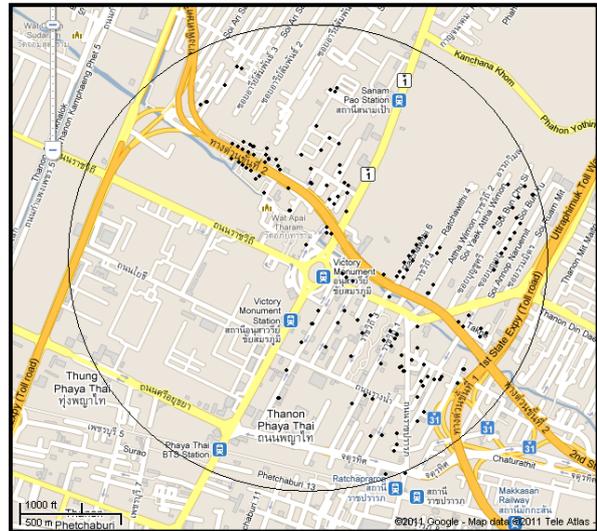
Figure 1: Study site and distribution of vending machines (Photo source: Google.com)

Sampling Procedure
Data were collected from 130 vending machines, where owners were willing to participate in the study. The persons responsible for each vending machine were asked to answer questionnaires. Such people represent the 'maintenance persons' in this study.

Research Instruments
An observation checklist, self-administered questionnaire, and a DOH 11 Medium test (Department of Health, Ministry of Public Health, Thailand) for coliform detection, were used.

Observation checklist - An observation checklist was used to assess the physical condition of each vending machine, consisting of the position, function and hygiene of the vending machine, other general information, and observations about water supply, based on Ministry of Public Health recommendations for vending-machine mainte-nance.

Self-administered questionnaire - The question-naire consisted of five parts: general characteristics of responders, general information about vending-machine maintenance, mainte-nance persons' attitudes towards machine

maintenance, their practices around machine maintenance, and additional information. In Part I of the general characteristics section, respondents were asked about their gender, age, occupation, and education level. In Part II, general information about vending-machine maintenance included the position of responsible persons in relation to each machine, the age of each machine, machine servicing by the company, and problems related to machine users' behaviors. Part III covered the attitudes of the responders, and included 16 items about the importance of maintenance. Answers were chosen from a 5-point Likert scale – 'Low importance', 'Slightly important', 'Somewhat important', 'Moderately important', and 'Very important' (Likert, 1932). Part IV asked about vending-machine maintenance practices, and consisted of 30 questions about general cleaning, maintenance, and monitoring. Part V was concerned with the difficulties of maintaining vending machines, satisfaction levels in relation to maintenance, and in relation to machine-maintenance recommendations by the Ministry of Public Health. Three (3) items asked about the difficulties of machine maintenance, where participants could choose 'Never', 'Sometimes' or 'Every time'. There was also 1 item about satisfaction with the company, where participants could choose 'Dissatisfied', 'Somewhat satisfied', or 'Satisfied'. Regarding questions about attitudes in Part III, reliability testing showed a Cronbach's Alpha of 0.883, using the answers of 7 volunteers in a similar setting.

Test for coliform contamination - The DOH 11 Medium test produced by the Department of Health, Ministry of Public Health, Thailand was used for coliform detection (Ministry of Public Health, 2015). Compared to the standard test procedure using Multiple-Tube Fermentation Technique, accuracy is > 84.5% (16). One (1) drinking-water sample per vending machine was collected. Drinking water was poured directly into a sampling bottle, after flushing for a few seconds to neutralize the water. The outer surfaces of the faucets were not sterilized, in order to maintain the same conditions experienced by other machine users. The collected water samples were incubated for 48 hours at 30°C. The presence of coliform was checked twice, at 24 hours and 48 hours post-incubation. The presence of coliform was recorded when color change and turbidity were observed.

Ethical Consideration
This research was approved by the Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University (COA No.: MUPH 2011-039; Protocol No.: 255/2553).

Data Analysis and Statistics
Nineteen (19) items on the observation checklist, in relation to the position, function, and hygiene of the vending machines, and the supply of water, were scored '1' when they satisfied the criteria and scored '0' when they did not. The scores were then classified by level: poor (< 80%), moderate (80-90%), or good (> 90%), as shown in **Table 1**.

The responder's attitude in the third part of the questionnaire, which asked about the importance of machine maintenance, was scored and recorded by level: low, moderate or high. The answer 'Low importance' was scored as 1, 'Slightly important' was 2, 'Somewhat important' was 3, 'Moderately important' was 4, and 'Very important' was 5. Total attitude scores < 80% were categorized as low, 80-90% moderate, and > 90% high (**Table 1**).

In Part IV, where machine maintenance was performed, the item was scored '1'. When maintenance was not performed or not known, the item was scored '0'. Six (6) items about regular practices of machine maintenance were then classified as being poor, moderate, or good. The maintenance of UV lamps and ozone generators were excluded, since not all machines had this equipment. A total score < 70% was regarded as poor, 70-85% moderate, and > 85% good.

Data were analyzed using SPSS software. For descriptive statistics, data were represented in terms of proportion, median, and range. For inferential statistics, univariate analysis was applied. The Chi-square test was used to verify statistical associations between different factors, and for the presence of coliform contamination. Fisher's exact test was used for the rest of the cases. At the same time, data were assessed by odds ratio (OR) and 95% CI for magnitude.

Mann-Whitney test was used to determine significant differences in medians between coliform-positive and -negative groups. Significance was evaluated by two-sided test, with p-value ≤ 0.05.

Table 1 Grading of Observation, Attitude, and Practice Scores

	Total possible scores	Low/Poor < 80%	Moderate 80-90%	High/Good > 90%
Observation	0-19	0-15	16-17	18-19
Attitude	16-80	16-66	67-73	74-80
		< 70%	70-85%	> 85%
Practice	0-6	0-3	4-5	6

RESULTS

General Characteristics of Vending Machines
Most vending machines (74.8%) utilized a reverse osmosis purification system. Other purification types were ultra-osmosis, ultra-filtration, and nano-filtration. Almost half (43.1%) used UV radiation, while 11.4% used ozonation for disinfection. Half the vending machines (54.5%) were installed in apartment buildings, 22.0% in retail stores, and 18.7% on the street. The price of drinking water in 2011 was 1 Baht (=0.033US$) ([Reuters](#)) per liter.

Environmental Conditions of Vending Machines
For each vending machine, environmental conditions, including position, function, hygiene status, and drinking-water quality, were also observed. Based on our grading, 30.1% of the vending machines had good environmental conditions, while 23.6% were poor. Regarding the position of the vending machines, all were stable and satisfied government criteria. Most (77.2%) machines were protected from sunlight and rain; 69.9% satisfied the government criterion of being 10cm above ground level. Concerning vending-machine functions, such as leakage and dysfunctional drainage, this was not found in most machines. Most machines had a table on which to place containers. Only 14.6%, however, displayed a sticker to certify their maintenance records. Most machines were kept clean, in terms of the hygiene of the faucet, the inside window, outside cleanliness of the machine, and the connecting pipe. Solid waste, dust, wastewater, and vector-borne-like insects were not found in most vending machines. All of the drinking water collected was clear and exhibited no smell.

General Characteristics of the Maintenance Person
The general characteristics of the maintenance persons were analyzed via 57 self-administered questions. Of the 57 maintenance persons, 73.7% were female; the median age was 42.0 years (range 20-72 years). The responders' main occupations were apartment owner, apartment office worker, and shop owner. Vending machines were mostly maintained by apartment office workers, apartment maintenance workers, and shop owners. Over half of the responders had completed either high school, college, university, or graduate school. The median age of the vending machines was 2.9 years (range 0.0-10.0 years).

Machine Maintenance
Of the total 57 maintenance persons, 68.4% answered that maintenance staff regularly come from the company; the median frequency was 12.0 times per year (range 2.0-24.0 times per year). Also, half of the responders (50.9%) answered that machine companies regularly offer drinking-water examinations; however, only 19.3% of responders knew the results of the water examinations (Table 5). The overall attitudinal status of the maintenance persons was classified into three levels, based on the grading of their scores. Around one-third (29.8%) demonstrated a high attitude towards vending-machine maintenance, while over half (52.6%) had a low attitude (**Table 2**).

Table 2 Machine Maintenance and Water Examinations by Vending-Machine Companies, and the Attitude of Vending-Machine Maintenance Persons (*n*=57)

Variable	Number	Percentage
Regular maintenance	39	68.4
Frequency (times/year)		
1-5	17	43.6
6-10	2	5.1
11-15	18	46.2
> 16	2	5.1
Median	12.0 times/year	
Range	2.0-24.0 times/year	
Regular water examination	29	50.9
Report of water examination	11	19.3
Overall attitudinal status of maintenance persons		
Low	30	52.6
Moderate	10	17.5
High	17	29.8

Practices by Maintenance Persons

Regarding the practices and performance of maintenance persons, 21.1% performed at a good level, while 28.1% were poor. As to the cleaning of the area around each vending machine, most maintenance persons (96.5%) answered they cleaned the place regularly. Three-fourths of maintenance persons (78.9%) responded they regularly cleaned inside the vending machine; the median frequency was 4.4 times/month (range 0.1-30.4 times/month), and the most recent day of practice was 20.0 days ago (range 0.0-182.5 days ago). Regarding filter maintenance, two-thirds (64.9%) answered they regularly replaced the filters; the median frequency was 3.0 times/year (range 2.0-12.0 times/year). Those who regularly cleaned the filters represented less than half (38.6%); the median frequency was 7.3 times/year (range 2.0-24.0 times/year) – more than twice compared with filter replacement, as shown in **Table 3**.

Table 3 The Status of Maintenance Practices (*n*=57)

Level	Number	Percentage
Good	12	21.1
Moderate	29	50.9
Poor	16	28.1
Types of practice		
Area cleaning	55	96.5
Frequency of practice (times/month)		
< 10	18	32.7
10-19	10	18.2
20-29	3	5.5
≥ 30	24	43.6
Median	18.7 times/month	
Range	0.2-30.4 times/month	
Recent day of practice (days ago)		
< 1	18	32.7
1-4	23	41.8
5-9	10	18.2
≥ 10	4	7.3
Median	1.0 days ago	
Range	0.0-182.5 days ago	
Inside machine cleaning		45
Frequency of practice (times/month)		
< 1		8
1-4		18
5-9		8
≥ 10		11
Median	4.4 times/month	

Table 3 The Status of Maintenance Practices (*n*=57) (Cont.)

Range	0.1-30.4 times/month	
Recent day of practice (days ago)		
< 1	5	11.1
1-4	9	20.0
5-9	3	6.7
≥ 10	28	62.2
Median	20.0 days ago	
Range	0.0-182.5 days ago	
Filter replacement	37	64.9
Frequency of practice (times/year)		
< 3	13	35.1
3	7	18.9
4	12	32.4
≥ 5	5	13.5
Median	3.0 times/year	
Range	2.0-12.0 times/year	
Recent day of practice (days ago)		
< 30	3	8.1
30-59	11	29.7
60-89	13	35.1
≥ 90	10	27
Median	60.8 days ago	
Range	4.0-273.8 days ago	
Filter cleaning	22	38.6
Frequency of practice (times/year)		
< 3	4	18.2
3-5	6	27.3
6-8	5	22.7
≥ 9	7	31.8
Median	7.3 times/year	
Range	2.0-24.0 times/year	
Recent day of practice (days ago)		
< 30	4	18.2
30-59	10	45.5
60-89	4	18.2
≥ 90	4	18.2
Median	50.3 days ago	
Range	1.0-121.7 days ago	
UV application		
Yes	20	35.1
No/Not know	37	64.9
UV maintenance	6	10.5
Frequency of practice (times/year)		
< 3	2	33.3
3	2	33.3
4	1	16.7
≥ 5	1	16.7
Median	3 times/year	
Range	1.0-12.0 times/year	
Recent day of practice (days ago)		
< 30	0	0.0
30-59	3	50.0
≥ 60	3	50.0
Median	54.8 days ago	
Range	30.4-60.8 days ago	
Ozone application		
Yes	11	19.3
No/Not know	46	80.7
Ozone maintenance	6	10.5
Frequency of practice (times/year)		
< 3	2	33.3

Table 3 The Status of Maintenance Practices (*n*=57) (Cont.)

3	2	33.3
4	1	16.7
≥ 5	1	16.7
Median	3.48 times/year	
Range	1.0-12.0 times/year	
Recent day of practice (days ago)		
< 30	1	16.7
30-59	0	0.0
60-89	3	50.0
≥ 90	2	33.3
Median	64.3 days ago	
Range	4.0-121.7 days ago	
Water examination	25	43.9
Frequency of practice (times/year)		
< 3	6	24.0
3-5	5	20.0
6-8	6	24.0
≥ 9	8	32.0
Median	6.0 times/year	
Range	1.0-52.2 times/year	
Recent day of practice (days ago)		
< 30	3	12.0
30-59	6	24.0
60-89	4	16.0
≥ 90	6	24.0
Median	60.8 days ago	
Range	2.0-365.0 days ago	

Coliform Contamination of Drinking Water from Vending Machines

We collected 123 drinking-water samples from 123 vending machines; we also conducted environmental observations. Water samples were incubated at 30°C, and analyzed for the presence of coliform at 48 hours post-incubation. Of the 123 samples, 35 (28.5%) tested positive.

Correlation of Coliform Contamination and Vending Machine Characteristics

Links between the various factors and coliform bacteria contamination were compared. **Table 4** shows the median frequency between coliform-positive and -negative groups for each maintenance practice item, based on the quantitative data provided by the 57 maintenance persons. A comparison of filter-cleaning medians for these two groups yielded a significant difference, with *p*-value 0.026 by Mann-Whitney test.

Table 4 Factors Associated with Coliform-Bacteria Contamination

Frequency of practice [1]	Total sample	Median	Minimum	Maximum	*p*-value [a]
Filter cleaning (times/year)					0.026
Positive	19	0.0	0.0	12.0	
Negative	38	0.0	0.0	24.0	

[a] by Mann-Whitney test

[1] Responders not performing the practice were recorded as 0 times/month, or 0 times/year

Table 5 shows the results of an analysis of the continuous variables in performance of the maintenance person's practice, by Chi-square test. Cut-off points were based on Ministry recommendations for vending-machine maintenance, covering cleaning of the area around the vending machine, cleaning of the outside, cleaning of the inside, and an examination of the machine's drinking-water quality. Because there was no specific time requirement concerning the replacement or cleaning of filters, maintenance of the UV lamp

or ozone, appropriate cut-off points were set. There were significant associations for frequency and most recent day of filter cleaning. Vending machines where filters were cleaned < 3 times/year were at 14.49 times higher risk of coliform contamination, compared with machines whose filters were cleaned 3 times/year or more (OR 14.49, 95% CI 1.76-125.00, *p*-value 0.003). Also, a negative association was found between vending machines whose filters were cleaned within 100 days and coliform contamination (OR 0.21, 95% CI 0.05-0.83, *p*-value 0.020).

Table 5 Links Between Different Maintenance Practices and Coliform Contamination

	Total sample	Contamination %		OR	95% CI of OR	*p*-value
		Positive	Negative			
Filter cleaning						
Frequency [1] (times/year)						0.003 [a]
<3	39	46.2	53.8	14.49	1.76-125.00	
≥3	18	5.6	94.4	1.00		
Recent day [2] (days ago)						0.020 [a]
≤100	21	14.3	85.7	0.21	0.05-0.83	
>100	36	44.4	55.6	1.00		

[a] by Chi-square test
[1] Responders not performing the practice were recorded as 0 times/month or 0 times/year
[2] Responders not performing the practice were categorized as being above the cut-off point

DISCUSSION

Coliform Contamination of Drinking Water from Vending Machines

The result of this study indicated that 28.5% of collected samples were tested positive. These results were similar to a study by the Ministry of Public Health, Thailand (Ministry of Public Health, 2006), which showed 27.3% coliform contamination among vending machines in Bangkok. While the DOH 11 Medium test for coliform shows only the existence of total coliform and does not reveal the exact genus or species of bacteria, the detection of total coliform is widely accepted as a useful indicator for screening biological water quality (Thai Industrial Standards Institue, 2006; WHO, 1996).

Correlation of Coliform Contamination and Vending Machine Characteristics

This study found that the filter cleaning indicated the different result of coliform contamination in water samples that might be caused by many factors. Montano *et al*. (Montano & Kasprzyk, 2008) stated that there are several inhibitors which hamper people's intentions and behavior, and thus the practice of filter cleaning might not be well performed, regardless of having a high attitude. In fact, no statistical association was found between those who had a high level of concern about filter cleaning and their practice. Many responders in this research also talked about the difficulties of performing maintenance, like the cost and time factors that are involved in vending-machine maintenance.

Judging by the above results and the importance of filter cleaning and replacement, other related factors to coliform contamination may be considered, such as cleanliness of tubes and of equipment connected to the filters and reservoirs. Several studies have pointed out that microorganisms have a tendency to adhere to tube surfaces (Liaqat & Sabri, 2008), and cause bacterial contamination of drinking water (Zanetti, De Luca, & Sacchetti, 2009). Some filters, such as reverse osmosis and nano-filtration, theoretically prevent bacteria passing through, but Park and Hu (Park & Hu, 2010) confirmed the existence and an increase of coliforms in biofilm and permeable-membrane filtered water. Many of the vending machines in this research used the reverse-osmosis system, but it is possible the coliforms passed through the filters and adhered to the tubes and tanks, even though the filters may have been replaced

regularly. That being said, tubes can be washed by filter cleaning, as well, especially by the backwash method; most maintenance persons performing filter cleaning, however, reported being unaware of the accurate names of each of the different methods. Also, it is possible that the source of the water – the water before passing into the vending machine – is an influencing factor for coliform contamination, although the biological quality of the source water was not measured in this study. The outer surfaces of the faucets of vending machines were not disinfected in this study, in order to replicate the conditions experienced by machine users. Therefore, it is possible coliform contamination might be caused by the faucets, which the general public comes into contact with using containers and their fingers. Levesque *et al*. (Levesque et al., 1994) have also stated how levels of water consumption may affect the bacteriological quality of drinking water.

CONCLUSIONS

A cross-sectional study was conducted in the Rajvithi area of Bangkok, to investigate the prevalence of coliform contamination in drinking-water vending machines, and to elucidate factors related to contamination. A total of 123 vending machines were observed, from which drinking-water samples were collected. Of the 123 machines, 57 questionnaires containing information about their maintenance status were obtained from the responsible maintenance persons. The coliform contamination rate was 28.5%, and contamination was significantly linked to both frequency and interval of filter cleaning. However, no links with coliform contamination were found when looking at environmental factors, the attitudes of maintenance persons, practice factors (except filter cleaning), and other aspects concerning vending-machine maintenance. While coliform contamination does not always affect health, a 28.5% contamination rate should not be ignored; it indicates the possibility of continuous fecal contamination into supplies of drinking water. When the hygiene status of the containers for filling drinking water is taken into account, which vending machine users might not always rinse

and disinfect (Luksamijarulkul, Pumsuwan, & Pungchitton, 1994), the opportunity for users to ingest coliform may be higher. In reality, many outbreaks via drinking water have been reported (Leclerc, Schwartzbrod, & Dei-Cas, 2002; Reynolds et al., 2008) and it is possible drinking water from vending machines is causing and contributing to such outbreaks.

In this study, the relationship between filter-cleaning practices and coliform contamination was statistically significant; we are, however, limited in being able to discuss the other contributing factors. Nonetheless, we need to consider the influence of vending-machine maintenance on coliform contamination beyond the statistics. The government should work improve publicity of the recommendations for vending-machine maintenance, besides current monitoring and evaluation exercises, as only 26.3% of maintenance persons knew such recommendations were available.

Declaration of Conflicting Interest
None.

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