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Assessment of Factors Affecting Drinking Water Quality from Free Water Dispensers in the Higher Education Institution

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ABSTRACT

Water dispensers are popularly used in public areas and workplaces. Assessment of factors that affect the drinking water quality in water dispensers is important for the prevention of water-related diseases and other health risks. The aim of this study was to assess the bacteriological, physicochemical and sanitary parameters of drinking water in free water dispensers at Mahidol University, Thailand. Two models, namely, the bottled water dispensers (BWDs) and the bottle-less water dispensers (BLWDs), were used. The bacteriological results revealed a widespread of the coliform bacteria group in the BWDs while none were found in the BLWDs. Even so, the physicochemical results showed that 56.4% of the water samples from the BLWDs possessed the hardness value that exceeded the reference values of the drinking water regulation. For the assessment of the factors affecting drinking water quality, the number of faucets have an effect on the drinking water quality in the BWDs, of which the difference was statistically significant at *p*-value = 0.003 while the BLWDs have 3 factors that directly impacted the drinking water quality, namely, the location of water dispenser (*p*-value = 0.001), the drip tray water drainage system (*p*-value = 0.026), and the pathogen source around the water dispenser (*p*-value = 0.022). Ultimately, the primary source of this problem may be due to a lack of routine maintenance and cleaning, some water dispensers could be considered unfit for use.

KEYWORDS
Drinking water, free water dispensers, factors affecting drinking water quality, the higher education institution

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Introduction

Throughout the world, water is a very important resource needed to sustain all forms of life (Moosa et al., 2015). Globally, consumption of contaminated drinking water was associated with 80 percent of disease

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(Fiebelkorn et al., 2012; World Health Organization, 1996). There are more than 1.1 billion people around the world who drink unsafe water. This accounts for the vast majority of diarrheal diseases in the world (88%) as a result of poor sanitation and hygiene (World Health Organization, 2003). Hence, a basic requirement for human health protection is to provide the public with adequate supply of drinking water that is safe (World Health Organization, 2011). Nowadays, there has been an increase in the consumption of drinking water derived from different sources, e.g. water dispenser and bottled water (Liguori et al., 2010).

Drinking water from water dispensers is a popular source of water in public places and workplaces. The increased popularity is a result of people in workplaces having an easy access to clean water. However, the structure of water dispenser could affect the quality of drinking water (Farhadkhani et al., 2014). Bacterial contamination in drinking water consists of both pathogenic origin and non – pathogenic origin. In the instance of chemical contamination, dissolved organic compounds in drinking water are responsible for the growth of bacteria and the colorization of water surfaces (Bitton, 2005). Hence, the drinking water already contained in water dispensers was found to be more contaminated than the water newly supplied to the dispensers.

In many countries, drinking water quality monitoring programs have been established in order to prevent or to reduce the risk of contracting water related infections. For Thailand, the drinking water coming from dispensers is required by law to be free from any pathogenic microorganism as well as chemical contaminations (Thai Industrial Standards Institute, 2006). Given the importance of drinking water safety, this study was conducted to assess the factors affecting drinking water quality in water dispensers. Therefore, the objective of this study was to investigate the bacteriological, physicochemical quality of drinking water and assess the sanitation practices of both the bottled water dispensers (BWDs) and the bottle-less water dispensers (BLWDs).

Materials and methods

Water dispenser sample selection

The data in this study were collected during the period between October 2015 and March 2016, from 9 faculties, 4 colleges, 8 institutes and 5 centers located in the area of the Mahidol University, Salaya Campus, Thailand. From 26 workplaces, the calculation of sample size was determined using the formula for calculating a sample for proportions (Cochran, 1963).

$$n = (P(1-P)Z^2)/e^2 \quad (1)$$

Where n is the sample size, e is the desired level of precision at 0.05, P is the estimated proportion of an attribute that is present in the population at 90% and Z is the 95% confidence level at 1.96.

Before studying, the notification letter was sent to all the selected workplaces to inform the personnel concerned of the research project as well as other details of the study. Participation in this study was voluntary with the assurance of privacy and anonymity as part of the informed consent process. A total of 138 water samples, consisting of 83 samples from BWDs and 55 samples from BLWDs were analyzed. The two types of water dispenser are shown in Fig. 1.

Photograph by Chitsanuphong pratum; Left-hand side is BWDs (a) and Right-hand side is BLWDs (b).

Figure 1. A type of water dispenser was used in the area of the Mahidol University, Salaya Campus, Thailand.

Technically, the BLWDs must filter water coming from the tap water faucet. The filtered water is then stored inside of the water dispenser's tank. BWDs are made to use filtered water into a sealed container, which is supplied by a drinking water provider. This water does not need a filtering process. A twenty liter water bottle is placed upside down in the water dispenser's tank. Usually, the BWDs may require more maintenance than the BLWDs because the drinking water provider must ensure enough water is always available. The BWDs only delivers water from the water bottle source, so if there are no water bottles available, there is no water left in the water dispenser. Additionally, the BWDs work the same way as the BLWDs. The user presses a button or turns a knob to release the water into the faucet. Moreover, according to the Food Regulations and Enforcement in Thailand, water from the BWDs and the BLWDs is defined as special control food offered for sale in a sealed container (Thai Industrial Standards Institute, 2006).

Photograph by Chitsanuphong pratum. Left-hand side is BWDs (a) and Right-hand side is BLWDs (b).

Water sample collection

To make sure that the sample was representative of the drinking water consumed all the drinking water samples were taken from the most-often-used water dispenser. Each drinking water sample was collected without flushing and/or sterilizing the outer surfaces of the faucets before sampling (Liguori et al., 2010; da Silva et al., 2008). For the bacteriological analysis, the water samples were collected in 100 mL – sterile glass bottles containing sodium thiosulfate (10 % w/v) to neutralize any residual disinfectant or halogen (American Public Health Association, 2012). For the physicochemical analysis, the water samples were collected in 1 L – sterile glass bottles. The water containers were kept in airtight plastic ice-cold containers and were transported to laboratory within 4 hours of their collection for the further processing. To prevent cross contamination, the sample glass bottles were not allowed direct contact with ice cube and wrapped with plastic bags.

Parameters analysis

In this study, the parameter analysis for the quality of drinking water from the dispensers was divided into 3 parts, all of which were used to assess the factors impacting the drinking water quality.

Part 1: the bacteriological parameter.

The analysis was conducted as follows: a detection of total coliform bacteria (TCB), fecal coliform bacteria (FCB) and *Escherichia coli (E. coli)* was conducted. TCB and FCB were quantified by multiple-tube fermentation technique while a specific EC medium containing 4-methylumbelliferyl-ß-D-galacuronidas (MUG) is used to detect E. coli in the drinking water sample. All of the bacteriological parameters were performed according to the Standard Methods for the Examination of Water and Wastewater 22nd Edition (American Public Health Association, 2012).

Part 2: the physicochemical parameter.

The analysis was conducted as follows: pH, turbidity and hardness are quantified by Electrometric measurement method, Nephelometric method and EDTA titrimetric method respectively. All of the physicochemical parameters were performed according to the Standard Methods for the Examination of Water and Wastewater 22nd Edition (American Public Health Association, 2012).

Part 3: the sanitary parameter.

The analysis was conducted using self - administered questionnaire. Five and eight sanitary questionnaires were used for BWDs and PWDs, respectively. A structured questionnaire form was adapted from Liguori et al., 2010; Ravadchai and Sungsitthisawad, 2012.

Statistical analysis

Descriptive analysis was used to describe measures of tendencies and dispersion of the water dispenser quality. Additionally, the Chi square (x^2) test was used for the assessment of factors affecting the drinking water quality in the water dispensers. The statistical significance was assessed using two-sided tests with *p*-value of ≤ 0.05.

Results

Raw water quality

Raw water samples were analyzed for both bacteriological and physicochemical qualities. 20 L – bottle of drinking water and tap water were used in the BWDs and the BLWDs respectively. For the BWDs, all the water quality parameters measured show zero percent of contamination. Thus, under the Thai regulations, the 20 L – bottle of drinking water is satisfactory for human consumption. For the BLWDs, a total of 38 tap water samples were collected and analyzed for TCB, FCB, E. coli, pH, turbidity and hardness. The overall results showed that 18 out of 38 samples (47.3%) were unsatisfactory and exceeded the limit prescribed by the Thai regulations (see Table 1).

Table 1. Number (%) of raw water sample unsatisfactory

Water quality parameters	**20 L – bottle of drinking water (*n* = 83)**	**Tap water (*n* = 38)**
Total coliform bacteria	0 (0.0)	7 (18.4)
Fecal coliform bacteria	0 (0.0)	3 (7.9)
Escherichia coli	0 (0.0)	0 (0.0)
pH	0 (0.0)	7 (18.4)
Turbidity	0 (0.0)	0 (0.0)
Hardness	0 (0.0)	1 (2.6)

Table 2. Bacteriological and physicochemical analytical results of raw water

Water quality parameters	**20 L – bottle of drinking water (*n* = 83)**	**Drinking water quality Std. [1]**	**Tap water (*n* = 38)**	**Tap water quality Std. [2]**
Total coliform bacteria (MPN/100mL)	nd	< 2.2	< 2.2 – 27	nd
Fecal coliform bacteria (MPN/100mL)	nd	< 2.2	< 2.2 – 17	nd
Escherichia coli	nd	nd	nd	ns
pH	6.7 – 8.4	6.5 – 8.5	5.3 – 7.8	6.5 – 8.5
Turbidity (NTU)	0.0 – 0.7	≤ 5	0.0 – 1.6	≤ 5
Hardness (mg/L as $CaCO_3$)	1 – 171	≤ 100	0.0 – 252	≤ 250

[1] Reference from Thai Industrial Standards Institute (2006)
[2] Reference from Department of Health (2010)
nd = Non detected in 100 mL of water samples
ns = Not stated

18.4 %, 7.9%, 18.4% and 2.6% of the tap water samples possessed the number of TCB, FCB, pH and hardness that exceeded the limit imposed by Department of Health, Thailand (0.0 – 27.0 MPN/100mL, 0.0 – 17 MPN/100mL, 5.3 – 7.8 and 0.0 – 252 mg/L as $CaCO_3$, respectively). A description of the data regarding bacteriological and physicochemical analytical results of tap water according to the Department of Health, Thailand: drinkable tap water (Department of Health, 2010) is provided in Table 2.

Drinking water quality

The drinking water samples were taken from the most-often-used water dispenser. For the BWDs, the 83 water samples were collected and analyzed for TCB, FCB, E. coli, pH, turbidity and hardness respectively. The bacteriological analytical results indicated that TCB and FCB were 18.1% (15 out of 83) and 14% (14 out of 83) higher than the stated TCB and FCB limits (< 2.2 MPN/100mL) in drinking water (Thai Industrial Standards Institute, 2006). Meanwhile, the physicochemical analytical results showed that the hardness was found in only 4.8% (4 out of 83) of the water samples taken from the BWDs. The number of TCB, FCB and hardness fall between < 2.2 – 900 MPN/100mL, < 2.2 – 900 MPN/100mL and 0.0 – 171 mg/L as $CaCO_3$ respectively. Thus, 39.8% (33 out of 83) of the water samples from the BWDs were unsatisfactory. Table 3 showed that 98.1% (49 out of 55) of the water samples taken from the BLWDs were unsatisfactory.

Table 3. Number (%) of drinking water sample unsatisfactory

Water quality parameters	The BWDs (*n* = 83)	The BLWDs (*n* = 55)
Total coliform bacteria	15 (18.1)	6 (10.9)
Fecal coliform bacteria	14 (16.9)	6 (10.9)
Escherichia coli	0 (0.0)	0 (0.0)
pH	0 (0.0)	6 (10.9)
Turbidity	0 (0.0)	0 (0.0)
Hardness	4 (4.8)	31 (56.4)

Table 4. Bacteriological and physicochemical analytical results of drinking water

Water quality parameters	The BWDs (*n* = 83)	The BLWDs (*n* = 55)	Drinking water quality Std. [1]
Total coliform bacteria (MPN/100mL)	< 2.2 – 900	< 2.2 – 13	< 2.2
Fecal coliform bacteria (MPN/100mL)	< 2.2 – 900	< 2.2 – 13	< 2.2
Escherichia coli	nd	nd	nd
pH	6.7 – 8.4	5.8 – 8.0	6.5 – 8.5
Turbidity (NTU)	0.0 – 0.7	0.0 – 1.6	≤ 5
Hardness (mg/L as $CaCO_3$)	1 – 171	0 – 491	≤ 100

[1] Reference from Thai Industrial Standards Institute (2006)
nd = Non detected in 100 mL of water samples

The number of TCB, FCB, pH and hardness also exceeded the regulations of the Thai industrial standards which fall between < 2.2 – 13 MPN/100mL (10.9%), < 2.2 – 13 MPN/100mL (10.9%), 5.8 – 8.0 (10.9%) and 0.0 – 491 mg/L as

$CaCO_3$ (10.9%), respectively. A description of the data regarding bacteriological and physicochemical analytical results of drinking water according to the Thai industrial drinking water standard (Thai Industrial Standards Institute, 2006) is provided in Table 4.

Assessment of factors affecting of drinking water quality

The relationship between the sanitary parameters and the bacteriological – physicochemical levels was used to assess the factors affecting the drinking water quality in the water dispensers. For the BWDs, five sanitary parameters were used for the assessment, namely, the number of faucets, the types of faucet, the pathogen source around the water dispenser, the cleanliness of the water dispenser location and the cleanliness of the water dispenser. The results of the statistical analysis indicated that the number of faucets had a significant effect on the drinking water quality in the BWDs at the previously mentioned significance level (see Table 5). Meanwhile, the other parameters assessed did not have any impact on the drinking water quality of the BWDs.

Table 5. Assessment of factors affecting of drinking water quality from the BWDs

Factors	Drinking water quality Std. [1]		x^2	*p*-value
	Pass Std.	Not pass Std.		
The number of faucet				
- Single faucet	62 (74.70)	13 (15.66)	8.683	0.003*
- More than one faucet	3 (3.61)	5 (6.02)		
The type of faucet				
- Plastic	53 (63.86)	15 (18.07)	0.031	0.861
- Metal	12 (14.46)	3 (3.61)		
The pathogen source around water dispenser				
- More than 1 meter	56 (67.47)	18 (21.69)	2.795	0.095
- Less than 1 meter	9 (10.84)	0 (0.00)		
The cleanliness of water dispenser location				
- Clean	62 (74.70)	18 (21.69)	0.862	0.353
- Dirty	3 (3.61)	0 (0.00)		
The cleanliness of water dispenser				
- Clean	63 (75.90)	18 (21.69)	0.568	0.451
- Dirty	2 (2.41)	0 (0.00)		

[1] Reference from Thai Industrial Standards Institute (2006)
* Significant p-value < 0.05

Eight sanitary parameters were used to assess the quality of the drinking water from the BLWDs, namely, the tap water filtration system, the location of water dispenser, the drip tray water drainage system, the number of faucets, the types of faucet, the pathogen source around the water dispenser, the cleanliness of the water dispenser location and the cleanliness of the water dispenser. The results of the statistical analysis indicated that the 3 factors namely; the location of the water dispenser, the drip tray water drainage system and the pathogen source around the water dispenser had a significant impact on the quality of drinking water, respectively (see Table 6). Meanwhile, the rest of the parameters did not have any impact on the drinking water quality in the BLWDs.

Table 6. Assessment of factors affecting of drinking water quality from the BLWDs

Factors	Drinking water quality Std. [1]		x^2	*p*-value
	Pass Std.	Not pass Std.		
Tap water filtration system				
- Membrane system	17 (30.91)	24 (43.64)	3.409	0.065
- Reverse osmosis system	2 (3.64)	12 (21.82)		
The location of water dispenser				
- Outdoors	12 (21.82)	35 (63.64)	11.610	0.001*
- Indoors	7 (12.73)	1 (1.82)		
Drip tray water drainage system				
- Using drainage system	19 (34.55)	28 (50.91)	4.941	0.026*
- None	0 (0.00)	8 (14.55)		
The number of faucet				
- Single faucet	5 (9.09)	4 (7.27)	2.101	0.147
- More than one faucet	14 (25.45)	32 (68.18)		
The type of faucet				
- Plastic	3 (5.45)	12 (21.82)	1.930	0.165
- Metal	16 (29.09)	24 (43.64)		
The source of the pathogen around water dispenser				
- More than 1 meter	9 (16.36)	28 (50.91)	5.223	0.022*
- Less than 1 meter	10 (18.18)	8 (14.55)		
The cleanliness of water dispenser location				
- Clean	17 (30.91)	30 (54.44)	0.377	0.539
- Dirty	2 (3.64)	6 (10.91)		
The cleanliness of water dispenser				
- Clean	17 (30.91)	51 (61.81)	0.456	0.500
- Dirty	2 (3.64)	2 (3.64)		

[1] Reference from Thai Industrial Standards Institute (2006)

* Significant p-value < 0.05

Discussion

An overview of the raw water quality analysis indicated that the 20 L – bottle of drinking water was superior when compared with the tap water collected from the water dispensers. It is recommended to perform *E. coli,* enumeration periodically on the tap water systems, in addition to the routine data collected by most systems. In water, *E. coli* is an indicator of fecal contamination which implies that pathogenic bacteria, viruses, and protozoa may also be present. The coliform bacteria group analysis has long been recognized as a suitable microbial indicator of drinking-water quality (World Health Organization, 2011; Tantawiwat et al., 2005). The coliform bacteria group, total coliform bacteria (TCB) and fecal coliform bacteria (FCB), are the only bacteriological contamination to be regulated by Thai legislation for both tap water and 20 L – bottle of drinking water. Among physicochemical parameters, water hardness has always been investigated as an important factor that causes clogging of membrane filter (Malakootian et al., 2010).

The bacteriological results indicated that TCB count in the water sample from the BWDs was 8% higher than that in the BLWDs, plus, FCB count in the water sample from the BWDs was 7% higher than that of the BLWDs. Table 3 indicates that the surfaces of the 20 L plastic bottles had the excessive growth of TCB and FCB in in the water sample taken from the BWDs (Farhadkhani et al., 2014). The possible reason for this was that the rough surfaces of 20 L – plastic bottles could support the adherence of bacteria. The bottleneck could also provide a suitable surface for adhesion of the bacteria (Flemming, 2002; Sacchetti et al., 2014). It is suspected that the BLWDs bacteriological contamination may have been caused by the accumulation of small number of bacteria from the faucet's surface. These surfaces are generally not regularly cleaned (Liguori et al., 2010). It is concerning that a large number of drinking water dispensers, both the BWDs and the BLWDs, revealed bacterial counts higher than the TCB imposed limits. However, contamination from *E. coli* was not observed in any of the raw water and the drinking water.

In addition, the physicochemical parameters (such as temperature, pH and dissolved organic compounds) can influence the growth of bacteria in surfaces of water dispensers (Gibert et al., 2013). Fiebelkorn et al (2012) reported that higher temperature of drinking water could lead to an increase rate of bacterial growth. The amount of turbidity in drinking water, as an indirect indicator of dissolved organic compounds (DOC), suggests there is migration of DOC from raw water to drinking water. For the assessment of the factors impacting drinking water quality, the statistical analysis revealed that the number of faucets has a correlation to the quality of drinking water for the BWDs. The lack of regular maintenance and cleaning leads to possible higher levels of bacterial contamination associated with the faucets, especially from the coliform bacteria. Coliform bacteria were reported as the predominant species in water from bottled drinking water (Jeena et al., 2006). In case of the BLWDs, the statistical analysis revealed that the main factors impacting the contamination were the location of the water dispenser, the drip tray water drainage system, and the pathogen source around the water dispenser. The three factors had a direct impact on drinking water quality. Additionally, the pathogen source near the water dispenser may have been due to cross-contamination. It is suspected that the identification of bacteria is ultimately due to a lack of cleaning and maintenance. Drinking water is required by law to be free from any pathogenic bacteria as it poses a threat to human health. Although coliform bacteria may not always be related to the presence of fecal contamination, the presence of coliform bacteria in drinking water suggests the potential presence of pathogenic enteric bacteria, such as *Salmonella* spp., *Shigella* spp., and *Vibrio* spp. (da Silva et al., 2008; de Victorica & Galvan, 2001).

Conclusions

Through the water quality parameter tests, it was found that the major contaminants in drinking water were total coliform bacteria and fecal coliform bacteria, followed by hardness, which indicated that the drinking water in Mahidol University, Salaya Campus, Thailand has been subject to different levels of pollution. Therefore, the related departments need to strictly implement drinking water disinfection measures and regularly monitor drinking water quality, so that full compliance with the Sanitary Standards for Drinking Water issued by University will be realized. Although in most area of the Mahidol University raw water supply is also adopted, but the management system is still not perfect, and most departments do not conduct water quality testing.

For factors affecting of drinking water quality, the results presented in this research raise concern regarding the water quality and hygiene of water distributed from dispensers. These factors impacting the quality of water included the number of faucets in the BWDs and three factors from the BLWDs namely, the location of water dispenser, the drip tray water drainage system and the pathogen source around the water dispenser. The largest contributor to this continued problem is based on the lack of routine maintenance and cleaning. The results suggest that water distribution systems of higher education institution present a risk to human health. Regular maintenance and cleaning would greatly reduce this threat.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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