Quality Assessment of Drinking Water from Vending Machines for a Healthier Life

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KEYWORDS

Drinking water, Vending machines, Physiochemical analysis, Quality assessment

ABSTRACT:

Commercial water vending machines in urban communities are important for consumers because of their convenience and affordability. Therefore, this study investigated the environmental conditions, maintenance, and quality of drinking water distributed through vending machines in an urban community in Thailand. The research sampled 101 drinking water machines in Buriram Municipality, Buriram Province. These machines were assessed for physical characteristics and the surrounding environment and were conducted according to an evaluation form provided by the Ministry of Public Health, Thailand. The findings revealed that 93.07% of the machines had auto coin failures; did not record the date, month, and year of filter changes; and did not display the business license on the cabinet. Additionally, 89.1% of the cabinets had thick dust, 57.43% had damaged or rusted handles on the water inlet door, and 56.44% had algae or rust stains on the water dispenser head. A physiochemical analysis revealed that 83.2% of the machines did not detect the pH levels. Total coliform bacteria and *E. coli* were not detected in 39.6% and 12.9% of samples, respectively. This study was conducted to develop an application for monitoring the quality of drinking water from vending machines to ensure that standards are met and up-to-date information is provided to help consumers make informed decisions about using clean and safe drinking water from vending machines.

1. Introduction

Sustainable Development Goals are a collection of 17 interconnected global objectives designed to serve as blueprints for peace and prosperity. One of these goals focuses on health and well-being; specifically, Goal 6 ensures the availability and sustainable management of water and sanitation for everyone [1]. A significant portion of the world's population lacks access to safe drinking water, which is fundamental for sustainable development [2]. Drinking water is in increasing demand and is key factor in life and health. However, the global economic situation has adversely affected the quality of life. In urban communities, drinking water from vending machines is an option. The convenience and affordability of commercial water vending machines have made them popular among urban populations. They are easy to access and inexpensive, but water quality from these vending machines has raised health concerns due to contamination and a lack of continuous maintenance. Research has identified microorganisms related to the surrounding environment and maintenance practices [3-5]. The maintenance and quality of water separators, causes of inadequate maintenance, and poor hygiene are often related to the growth of different organisms in water. Physicochemical parameters such as temperature and pH influence bacteria growth on vending machines' surfaces [6]. Waterborne diseases, such as gastrointestinal diseases, inflammatory bowel diseases, and cholera, may occur if consumers drink contaminated water [7]. Previous research found that water quality from automatic coin-operated machines did not meet standards but has not yet been adequately communicated to consumers. Therefore, this study aimed to inform officials about the need for annual inspections of these machines in Buriram Municipality twice a year, including inspections by the Public Health Division of Buriram Municipality once and joint inspections with the Department of Health, Ministry of Public Health once. This research examines drinking water quality results to develop further applications for drinking water vending machines in Buriram Municipality, aiming to increase access to clean and safe drinking water.

This research aimed to assess the quality of drinking water from vending machines and determine their environmental surroundings and conditions to estimate their physical characteristics. By identifying and addressing potential health risks, this study sought to promote a healthier life for consumers who rely on these machines for daily water intake.

2. Methods

2.1 Drinking water location and sampling

This study involved sampling drinking water from vending machines in Buriram Municipality, Buriram Province (Figure 1). In total, 101 water vending machines were identified based on information received from the Buriram Provincial Public Health Office.

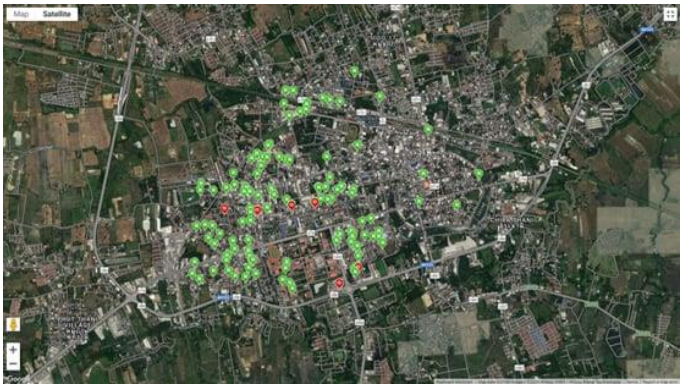

Figure 1. Location of drinking water from vending machines in Buriram Municipality.

(Green = location of available) Reference: Application D-drink

2.2 Questionnaire analysis of environmental conditions

The survey on drinking water from vending machines included an assessment of the physical characteristics and the surrounding environment, conducted according to an evaluation form provided by the Ministry of Public Health, Thailand (Environmental Health Accreditation 2003).

2.3 Water quality analysis

Drinking water was determined using pH, total dissolved solids (TDS), salinity, conductivity, (pH-conductivity, ProLine plus V6), and turbidity (HACH: 2100N Turbidimeter) [8]. A microbiological analysis was conducted using a test kit for coliform bacteria and *E. coli* in the water from the Department of Medical Sciences, Ministry of Public Health, Thailand. All samples were analyzed in triplicates.

2.4 Statistical analysis

The physical characteristics of the drinking water from the vending machines were analyzed using percentages. The relationship between these physical characteristics and coliform bacterial contamination of drinking water was analyzed using binary logistic regression.

2.5 Development of an application for drinking water from vending machines

The application was created using the System Development Life Cycle concept [9] with the following details:

2.5.1 Problem Recognition

The initial phase involved studying regulations and laws and interviewing Buriram Municipality's Public Health and Environment Division officials responsible for overseeing automatic coin-operated water dispensers. The identified problems were prioritized as follows:

2.5.1.1 Currently, there is a need for a centralized database of automatic coin-operated water dispensers in the Buriram Municipality, resulting in a deficit of actionable information for officials.

2.5.1.2 Insufficient funding hinders comprehensive inspections of water quality from these dispensers.

2.5.1.3 Consumers and entrepreneurs in Buriram Municipality are not informed about the quality of drinking water from these dispensers.

2.5.1.4 Several dispensers operate without proper licenses in Buriram Municipality.

2.5.1.5 No established channels exist for consumers to register complaints concerning these dispensers.

2.5.2 Feasibility Study

This phase evaluated the feasibility of transitioning from an existing surveillance system to one incorporating an application. The study involved consultations with officials from Buriram Municipality's Public Health and Environment Division and environmental health officers from the Provincial Public Health Office. All stakeholders concurred with the establishment of a database and an accessible information system for monitoring dispenser water quality. The proposed system is user-friendly and cost-effective.

2.5.3 Analysis

Information gathered from interviews with officials, entrepreneurs, and consumers influenced the design process. This comparative analysis assessed the current operational system (as is) against the requirements of the proposed system (to be).

2.5.4 Design

Essential to the analysis, conceptual (Logical Design) solutions were devised to address identified issues. These concepts were refined into detailed technical specifications (System Design), equipment requirements, technological integration, database architecture, network capabilities, data import protocols, and report formats.

2.5.5 Development and Testing

The researcher performed programming (coding) to develop the system from the designed application format using the Appsheet program, together with Google Sheets to develop the application. Subsequently, experts evaluated their performance.

3. Results

3.1 Environmental assessment

The survey data on water filtration and disinfection systems in coin-operated water dispensers revealed significant findings. The researchers obtained information from the water dispensers; however, the water filter systems inside the cabinets could not be accessed. The 101 cabinets surveyed, 48 (47.52%) were equipped with reverse osmosis (RO) water-filtration systems. This system effectively filters fine sand, iron particles, dust, and microorganisms. It removes heavy metals, such as lead, mercury, and cadmium, as well as various germs, odors, and gases from water [10-12]. Additionally, 53 cabinets (52.48%) were equipped with a combination of RO and ultraviolet (UV) water-filtration systems. This combined system filters fine sand, iron, and microbial particles and removes chemicals and heavy metals such as lead, mercury, and cadmium, along with various germs, odors, and gases [14-15]. The survey also indicated that the water sources used in these dispensers produce high-quality drinking water with low risk when filtered, thereby enhancing the treatment efficiency [15], as shown in Figure 2. The regular maintenance and proper cleaning of water dispensers are critical for providing safe and high-quality drinking water. The maintenance of RO and UV filtration systems reduces the risk of

contamination, thereby protecting public health. The details of the environmental assessment of the vending machines are presented in Table 1.

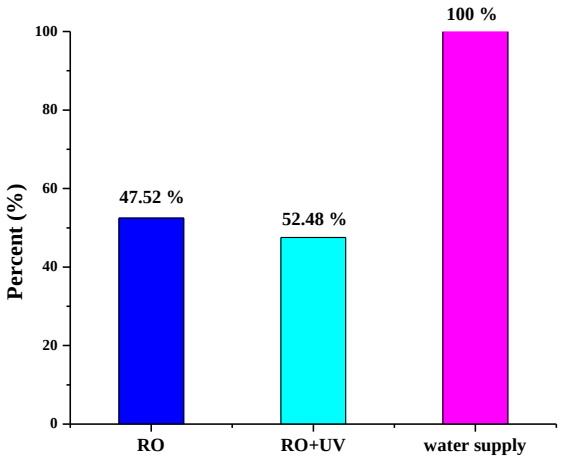

Figure 2. Filtration system and source water

Table 1. Environmental conditions and maintenance machine (N = 101)

Items	Total number (%)		Health impacts
	Good/satisfactory (%)	Poor/ inappropriate (%)	Evaluation level
Location (drinking water vending machine)			
1. 30 meters away from the sewage pipe	87 (86.14)	14 (13.86)	Good
2. 30 meters away from the garbage source	91 (90.10)	10 (9.90)	Excellent
3. Raised at least 10 cm from the floor	91 (90.10)	10 (9.90)	Excellent
4. Not wet or waterlogged	92 (91.09)	9 (8.91)	Good
Maintenances and servicing record (drinking water vending machine)			
1. Shows the date the filter was changed	7 (6.93)	94 (93.07)	Poor
2. Recommendations for changing the filter	11 (10.89)	90 (89.11)	Poor
3. Displays a record of the day, month, and year filter change	11 (10.89)	90 (89.11)	Poor
4. Displays the business license clearly	12 (11.88)	89 (88.12)	Poor
Dispenser nozzle and surrounding (drinking water vending machine)			
1. Did not detect algae stains and rust.	44 (43.56)	57 (56.44)	Should improve
2. The condition of the water inlet opening and closing cover was not damaged.	84 (83.17)	17 (17.83)	Good
3. Dispenser section or dispenser nozzle was not corrosion resistant and had rust.	93 (92.08)	8 (7.92)	Good

Items	Total number (%)		Health impacts
	Good/satisfactory (%)	Poor/ inappropriate (%)	Evaluation level
4. The handle for opening and closing the water intake hole was not damaged.	43 (42.57)	58 (57.43)	Should improve
5. Clean and sanitary loading platform.	93 (92.08)	8 (7.92)	Good
6. The condition of the drinking water dispenser's filling station is not damaged.	95 (94.06)	6 (5.94)	Good

The physical characteristics of the coin-operated drinking water vending machines in the Buriram Municipality showed significant noncompliance with health standards. Specifically, 90 machines (89.11%) did not display the date or year of the most recent filter change; 57 machines (56.44%) did not have algae stains or rust around the dispenser nozzle or the surrounding areas and 58 machines (57.43%) had handles for opening and closing the water intake holes that were neither damaged nor rusty. All samples were within the permissible limits, as shown in Table 1. Maintaining safe drinking water quality and minimizing the risk of contamination by harmful microorganisms necessitates the regular maintenance and cleaning of water dispensers. Research has highlighted the critical importance of maintaining and cleaning water distribution systems to ensure the quality and safety of drinking water. Proper maintenance significantly reduces microbial contamination, thereby protecting public health [4-6]. The relationship between the physical characteristics of coin-operated drinking water dispensers and bacterial contamination of drinking water was studied using a W110 test kit from the Department of Health, Ministry of Public Health, Thailand and then the Table 2 shows the relationship between the physical factors and coliform bacterial contamination in drinking water. Corroded or rusty automatic drinking water dispensers are 8.42 times more likely to be contaminated with coliform bacteria than dispensers in normal condition ($p = 0.046$, 95% CI = 1.03–68.55). Binary logistic regression based on the data attributes and investigation was used to select the relationship between the physical characteristics described above. This research aligns with a study on water samples from 53 water dispensers in 13 student dormitory rooms, which found that the most common hygiene issues were maintenance, cleaning, and monitoring. Coliform bacteria were found in 10 of the 53 water dispenser samples (18.87%), and *E. coli* was found in three samples (1.59%) [6]. Moreover, this research was consistent with a univariate analysis to assess the relationship between the outcome variable and each explanatory variable to identify risk factors that predict *Salmonella spp.* and *E. coli* contamination at the farm and slaughterhouse level [16].

Table 2. Relationship of physical characteristics of coin-operated drinking water dispensers with microbial contamination.

Categories variable	Total of number (N) and coliform bacteria (%)		p-value	OR	95% CI of OR
	Not detected (%)	detected (%)			
1. Filtration system			0.736	1.19	0.44–3.22
RO+UV	31 (58.5)	22 (41.5)			
RO	30 (62.5)	18 (37.5)			
2. Display of date of last filter change			0.400	0.42	0.06–3.16
Shown	5 (71.4)	2 (28.6)			
Not shown	56 (59.6)	38 (40.4)			

Categories variable	Total of number (N) and coliform bacteria (%)		p-value	OR	95% CI of OR
	Not detected (%)	detected (%)			
3. Recommendations on how long to change filters			0.438	1.99	0.35–11.47
Shown	54 (60.0)	36 (40.0)			
Not shown	7 (63.6)	4 (36.4)			
4. Clearly displaying the business license on the cabinet.			0.825	0.85	0.19–3.69
Shown	7 (58.3)	5 (41.7)			
Not shown	54 (60.7)	35 (39.3)			
5. Displaying filter replacement history			0.050	11.06	0.99–122.84
Shown	10 (90.9)	1 (9.1)			
Not shown	51 (56.7)	39 (43.3)			
6. The location is at least 30 meters away from the sewer pipe.			0.599	0.68	0.16–2.92
Passed	52 (59.8)	35 (40.2)			
Did not pass	9 (64.3)	5 (35.7)			
7. The location is at least 30 meters away from the garbage disposal site.			0.900	1.11	0.23–5.39
Passed	55 (60.4)	36 (39.6)			
Did not pass	6 (60.0)	4 (40.0)			
8. The automatic drinking water dispenser is raised at least 10 centimeters from the floor.			0.405	2.02	0.39–10.58
Passed	56 (61.5)	35 (38.5)			
Did not pass	5 (50.0)	5 (50.0)			
9. Water dispenser of automatic clean drinking water dispenser There are no algae stains or rust.			0.152	0.49	0.18–1.30
Passed	23 (52.3)	21 (47.7)			
Did not pass	38 (66.7)	19 (33.3)			
10. The condition of the automatic drinking water dispenser is clean. There is no thick dust.			0.903	0.91	0.19–4.37
Passed	5 (45.5)	6 (54.5)			
Did not pass	56 (62.2)	34 (37.8)			
11. The condition of the automatic drinking water dispenser is not corroded or rusted.			0.046	8.42	1.03–68.55
Passed	59 (63.4)	34 (36.6)			
Did not pass	2 (25.0)	6 (75.0)			
12. The condition of the water inlet opening and closing cover is not damaged.			0.974	1.02	0.25–4.13
Passed	51 (60.7)	33 (39.3)			
Did not pass	10 (58.8)	7 (41.2)			
13. The handle for opening and closing the water intake hole is not damaged. and does not rust			0.061	0.39	0.15–1.04
Passed	21 (48.8)	22 (51.2)			
Did not pass	40 (69.0)	18 (31.0)			
14. Filling platform of automatic clean drinking water dispenser There are no algae stains or rust.			0.224	0.24	0.02–2.41

Categories variable	Total of number (N) and coliform bacteria (%)		p-value	OR	95% CI of OR
	Not detected (%)	detected (%)			
Passed	54 (58.1)	39 (41.9)			
Did not pass	7 (87.5)	1 (12.5)			
15. The condition of the automatic drinking water dispenser's filling station is not damaged.			0.811	1.30	0.16–10.77
Passed	58 (61.1)	37 (38.9)			
Did not pass	3 (50.0)	3 (50.0)			
16. The area where the automatic drinking water dispenser is located is not wet or has standing water.			0.397	2.19	0.36–13.40
Passed	56 (60.9)	36 (39.1)			
Did not pass	5 (55.6)	4 (44.4)			
17. Standard criteria for acidity and alkalinity			0.192	0.43	0.12–1.52
Passed	8 (47.1)	9 (52.9)			
Did not pass	53 (63.1)	31 (36.9)			

3.2 Physiochemical properties

As shown in Table 3, the pH is an important factor affecting the quality of filtered or treated drinking water. Eighty-six cabinets did not meet the Department of Health criteria, which set an acceptable pH range between 6.5 and 8.5, representing 86.15% of the total cabinets. The analysis revealed that the lowest pH value was 3.24, and the highest was 6.99. Specifically, 82 cabinets (81.19%) had pH values below 6.5, ranging from 3.24 to 6.40%. In addition, four cabinets could not be analyzed. The pH value of the water sample is the negative logarithm of the hydrogen ion concentration, or pH = -log [H^+]. The value indicating acidity is the concentration of hydrogen ions H^+ [18]. This affects the taste of the drinking water, making it weakly acidic and causing an unpleasant odor. This result was related to the failure to change the filter according to the recommended period, as listed in Table 1. A survey of water dispensers found that the filter systems, as shown in Figure 2, included RO systems in 48 cabinets (47.52%), which filtered fine sand, iron particles, dust particles, and microorganisms and removed heavy metal chemicals such as lead, mercury, and cadmium, eliminating up to 95% of various germs and odors or gases [10-12]. Combined RO and UV water filtration systems in 53 cabinets (57.48%) can filter fine sand, iron, dust particles, and microorganisms and remove heavy metal chemicals such as lead, mercury, and cadmium, eliminating up to 99% of various germs, odors, and gases [13-14]. The maintenance and service records of the drinking water vending machines are listed in Table 1. Our findings are consistent with those of a study on the effect of pH on taste and odor production and control of drinking water [19]. This report highlights that pH is critical in many drinking water treatment and control processes, particularly for taste and odor control. Despite its importance, pH is often overlooked in favor of other treatment issues. The permeate from RO membranes requires post-treatment for remineralization (e.g., adding calcium and magnesium) and reconditioning (e.g., adjusting pH and chemical stability) to meet drinking water regulations and improve taste [20]. Moreover, the turbidity and TDS factors passed the standards set by the WHO. However, a microbiological analysis revealed that the presence of coliform bacteria and *E. coli* is an important factor affecting the quality of filtered or treated drinking water. Despite the WHO criteria, coliform bacteria were detected in 40 cabinets (39.6%), whereas *E. coli* was found in approximately 13 cabinets (12.9%), failing to meet the criteria. A previous study found that positive coliform detection indicates that the water dispenser is not clean and that the sanitation system is inadequate,

leading to the growth of coliforms [21]. This contamination is also caused by poor-quality membranes and unmaintained filtration systems, which contribute to microbial contamination [7, 22-23].

Table 3. Water sampling results according to the World Health Organization, WHO).

Parameter (Unit)	WHO reference value [17]	Total of Number (N)	
		Passed (%)	Did not pass (%)
Color	15 or less	101 (100.0)	-
pH	6.5–8.5	17 (16.8)	84 (83.2)
Turbidity (NTU)	≤ 5	101 (100.0)	-
Total dissolved solids (TDS) (mg/l)	≤ 500	101 (100.0)	-
Microbiological analysis			
Coliform Bacteria	Not detected	61 (60.4)	40 (39.6)
E. coli	Not detected	88 (87.1)	13 (12.9)

4. Development of a management application for drinking water vending machines

The implementation phase of a fully developed system involves installation and real-world deployment to facilitate effective utilization, as shown in Figure 3. In addition to mere installation, a robust support framework is necessary to ensure comprehensive utilization. This includes developing user-training courses, system documentation, and service plans to sustain continuous system operations. Experts evaluate system efficiency through rigorous assessments and performance evaluations. In Buriram Municipality, Buriram Province, experts conducted a performance evaluation of a drinking water vending machine, yielding an overall high rating of 4.19 ± 0.71. The detailed findings are presented in Table 4.

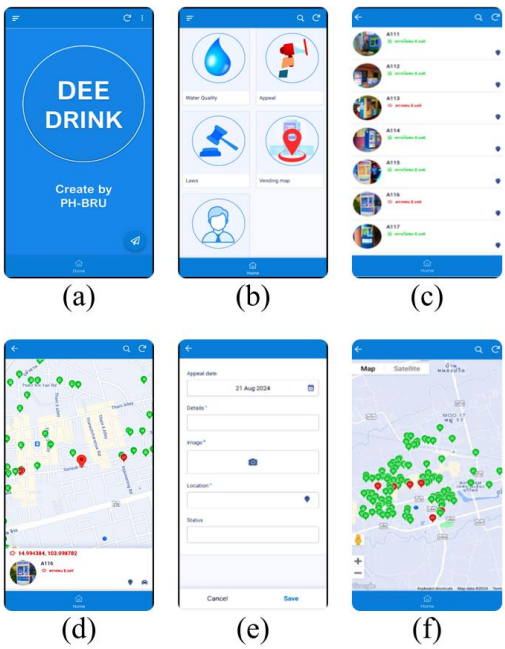

Figure 3. Drinking water application (a) home page (b) home menu (c) cabinet code and water quality menu (d), (e) Complaint location notification menu and (f) Location**.**

Table 4. Efficiency application of drinking water from vending machines (n = 3)

Database evaluation	Application performance level		
	$\bar{x}$	S.D.	Interpretation
1. Screen layout			
1.1 Physical characteristics of the designed screen, aesthetic, and appropriate.	4.00	1.00	High efficiency
1.2 Used easily	4.33	0.58	Highest efficiency
1.3 Interesting	3.67	0.58	High efficiency
Summary of screen formats	4.00	0.72	High efficiency
2. Graphic images			
2.1 Sharpness	4.67	0.58	Highest efficiency
2.2 Meaningful, easy to understand	4.00	1.00	High efficiency
2.3 Suitable size	4.67	0.58	Highest efficiency
Summary of graphic images	4.45	0.72	Highest efficiency
3. Database system			
3.1 Data storage system	4.33	1.15	Highest efficiency
3.2 Convenience of searching	4.00	1.00	High efficiency
3.3 Data relationship	4.33	0.58	Highest efficiency
3.4 Information systems design	4.00	1.00	High efficiency
Summary of database system	4.17	0.93	High efficiency
4. Application characteristics			
4.1 Convenience of accessing website	4.00	1.00	High efficiency
4.2 Data download speed	4.33	0.58	Highest efficiency
4.3 Resolution and clarity of images used	4.00	1.00	High efficiency
4.4 Image proportions are correct	4.33	0.58	Highest efficiency
Summary of application characteristics	4.16	0.71	High efficiency
Total of overview	4.19	0.71	High efficiency

5. Conclusion

Drinking water from vending machines did not meet the pH standards in 83.2% of cases, with values ranging from 3.24 6.49. Acidic pH affects taste and odor, mainly because of neglected filter changes. RO systems were used in 47.52% of the machines and 52.48% used a combination of RO and UV systems. Microbial contamination was found in many cabinets, with 39.6% revealing coliform bacteria and 12.9% harboring *E. coli*, which did not meet WHO standards. The physical characteristics of the Buriram Municipality coin-operated drinking water vending machines showed significant noncompliance with health standards, with 89.11% of missing data for filter changes. However, 56.44% had no traces of algae or rust and 57.43% had intact handles. Regular maintenance and proper post-treatment are essential for ensuring water quality and safety. The Buriram Municipality should continuously monitor the quality of drinking water from vending machines obtained from the DRINK application. Emphasis is placed on controlling business operators to ensure that they are hygienic, clean, and dust- and rust-free and to promote consumers' ability to choose drinking water from a clean and hygienic dispenser.

6. Funding

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7. Declaration of Competing interests

There are no conflicts of interest to declare.

8. Author contributions

Pattaranun Thuadaij: Writing original draft, Methodology, Investigation, Formal analysis, data curation.

Sakesit Duangkham: Writing, review, and editing; writing original draft; Methodology, Investigation, Funding acquisition; formal analysis; data curation; conceptualization.

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