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Quality awareness of tap drinking water among Bangkok city residents and implications for sustainable supply management

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ABSTRACT

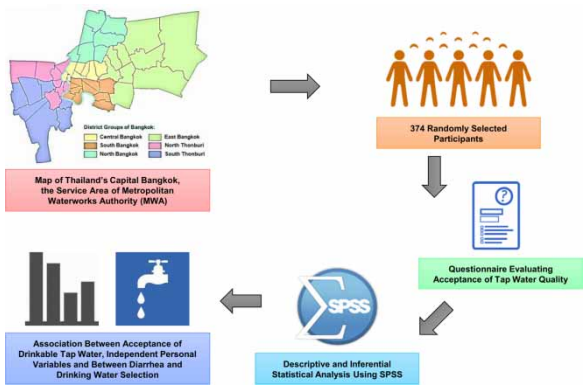
Although tap water in Bangkok has met international standards, some consumers do not trust that it is safe to drink. The demand for bottled water is still increasing. This may result in infrastructure investments and the production of waste. This study aimed to explore factors that influence the acceptance of drinkable tap water among Bangkok residents. Data for this cross-sectional study were collected via an interview of 374 participants using a structured questionnaire. There was a significant prevalence (51.87%) of the acceptance of drinkable tap water among Bangkok residents. Among them, 82.99% selected tap water to drink and 9.79% drank water directly from the tap. Factors that affected the acceptance of drinkable tap water were occupation, monthly income, campaign perception, personal belief, unacceptable sensory appearance, risk perception, knowledge, and attitude. This study found that drinking water selection was not associated with self-reported diarrhea. While we recognize that the cross-sectional study has some limitations, our data may provide additional insight into factors which affect consumers' behavior and may offer several benefits for water suppliers and public health decision-makers. This would eventually increase public awareness for economic benefits associated with the use of tap water and finally would reduce pollution by plastic waste.

Key words: acceptance, diarrhea, drinking water, perception, plastic bottles, tap water

HIGHLIGHTS

- The manuscript presents recent surveillance data for the acceptance of drinking water by end-consumers in relation to water quality and supply.
- The results of water quality monitoring are discussed with a view to socio-demographic and sanitary factors.
- We present the most obvious conclusions derived from this analysis and their possible implications for water quality maintenance.

GRAPHICAL ABSTRACT



INTRODUCTION

Water is a fundamental need for all life and access to safe water is a human right (Hall *et al.* 2014). The quality of water supply is important for the health of individuals and entire communities as evidenced by frequent health problems such as diarrhea caused by poor water quality (Yongsi 2010; Chen *et al.* 2012; Shrestha *et al.* 2013; Francis *et al.* 2015). According to global trends, future water demand will increase depending on urbanization and the growth of populations in large cities (McDonald *et al.* 2014). Bangkok, Thailand's capital, is a large city where extensive urbanization has occurred. Between 2000 and from 2010 to 2020, the population of this city grew from 7.8 million people to 9.6 and to 10.7 million people, respectively (World Bank Group 2015; Losiri *et al.* 2016; National Statistical Office 2020). Qualitative interviews conducted in earlier studies revealed that drinking water choices can be influenced by several factors (Prempong 2005; Ward *et al.* 2009; Hu *et al.* 2011; Chen *et al.* 2012) such as age, income, housing conditions, education and health awareness.

In Bangkok, the Metropolitan Waterworks Authority (MWA) is responsible for the public water supply. The quality of its tap water meets World Health Organization (WHO) criteria and standards for drinking water and is safe to drink in all serviced areas (Metropolitan Waterworks Authority 2010). In 2001 the MWA established a monitoring system for water quality in the distribution system (Metropolitan Waterworks Authority 2008). This information was published via advertisement campaigns and on the MWA website. Nearly 100% of Bangkok's population presently has access to reliable and safe tap water (Babel *et al.* 2010), a situation that complies with the Millennium Development Goals (MDGs) for population access to safe water (United Nations 2015; World Health Organization 2018). Previous studies showed that most Bangkok residents did not trust that tap water was clean and safe to drink and preferred to consume bottled water instead (Kuawiriyapan 2008). Therefore, the worldwide demand for bottled water is increasing despite higher costs than those for tap water (Ward *et al.* 2009; Hu *et al.* 2011; Güngör-Demirci *et al.* 2016). According to the MWA, this could result in investments for the public which may lead to higher prices per m^3 of tap water for the end-consumer (Kooy & Walter 2019).

Several studies suggest that acceptance of tap drinking water is governed by factors such as gender, age, education, attitude, economic status including income and housing conditions, risk perception, and health awareness. However, very few studies addressing this issue have been carried out in Thailand (Prempong 2005). Therefore, the authors designed a cross-sectional study to explore factors that influence the acceptance of drinkable tap water and its possible link to the development of diarrhea among Bangkok inhabitants.

METHODS

Study area and participants

A cross-sectional study among Bangkok residents was conducted and data were collected via an interview questionnaire. Participants were at least 18 years old and had lived in Bangkok for more than one year. In addition, in-depth interviewing was used to collect further details from participants who drank water from the tap. The initial sample size of 500 participants was chosen to ensure a 95% confidence level with a precision of $\pm 5\%$ (Cochran 1963).

The area encompassing Bangkok was divided into six regions consisting of Central Bangkok, South Bangkok, North Bangkok, East Bangkok, North Thonburi, and South Thonburi (Figure 1). The sample sizes for these regions were 57, 78, 96, 110, 76 and 83 participants, respectively. For each region, a multistage sampling method was used (Balakrishnan *et al.* 2014). In the first stage, four districts were selected by using probability proportional to size (PPS) sampling. In the second stage, households in these districts and consequently participants were randomly selected. Households in which members could not be contacted by the interviewers were replaced by adjacent households. Since some participants refused to participate, there were finally 374 participants interviewed who lived in 12 service areas of the MWA.

This study was approved by the committee for ethical human research of Mahidol University, Bangkok, Thailand (reference number COA MUPH 2016-070). Written informed consent was obtained from every participant prior to the interview. The study was entirely risk-free for the participants and participants' answers were kept confidential.

Questionnaire

A pilot study with 30 volunteers was carried out to evaluate the feasibility and reliability of the structured questionnaire. Imprecise questions were removed, and the sequence of questions was adapted where appropriate.

Independent variables included were: (1) social and demographic factors such as sex, age, education, occupation and monthly income; (2) campaign perception (personal perception of the drinkable tap water project as published by the

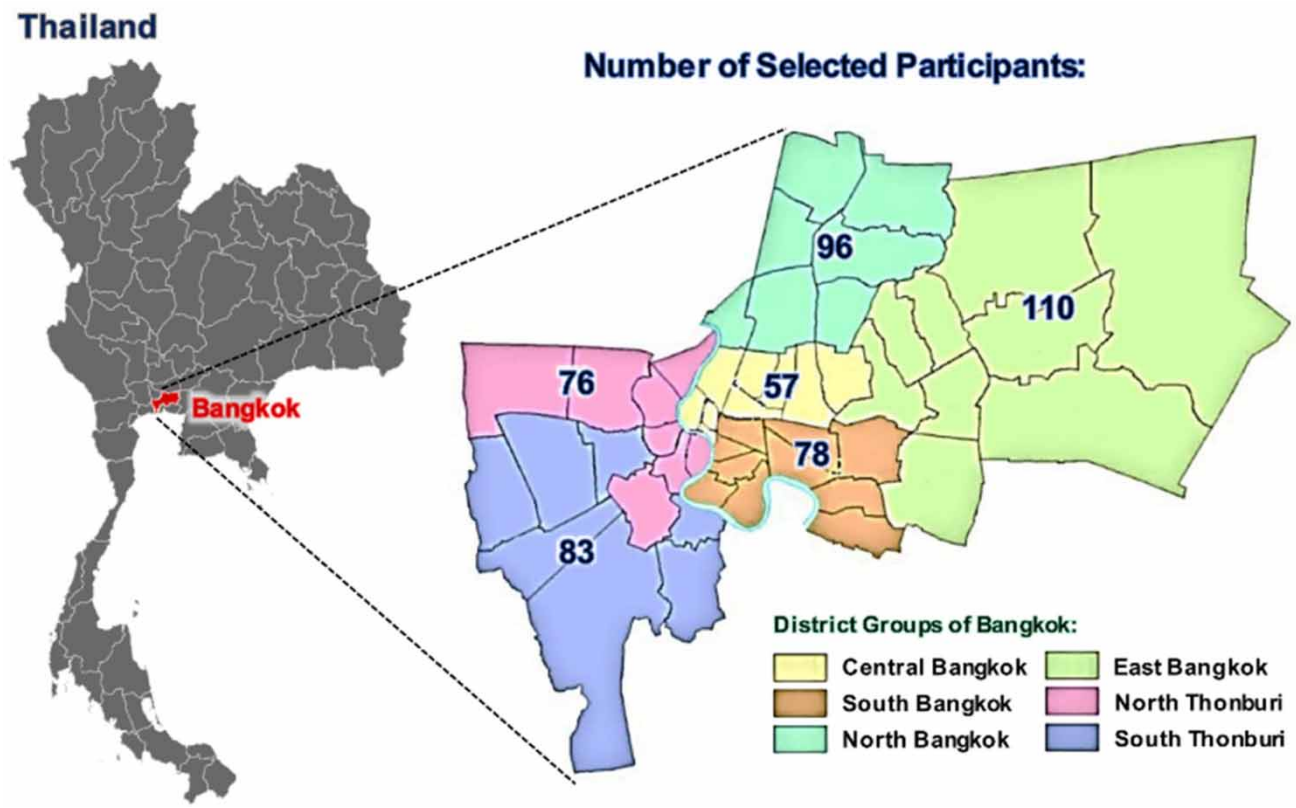


Figure 1 | Map of Bangkok, Thailand, indicating the location of the investigated districts as well as the number of selected participants.

MWA); (3) personal faith that drinking water is safe and clean; (4) unacceptable personal perception of sensory reactions to color, smell, turbidity, taste and larvae or worms; (5) personal perception of risks originating from tap water drinking; (6) knowledge (participant's understanding about the drinkable tap water project) and (7) attitude (settled way of personal thinking about drinkable tap water).

Participants were divided into a working-age group (15–59 years) and old-age group (> 60 years), following the age classification criteria of the National Statistical Office of Thailand (NSO). The monthly income of participants was classified into five groups: fewer than 5,000 baht/month, between 5,000 and 10,000 baht/month, between 10,000 and 20,000 baht/month, between 20,000 and 30,000 baht/month and higher than 30,000 baht/month. Three levels of knowledge were evaluated by ten questions: poor, fair, and good knowledge. Attitude was measured by eight items that had 5-Likert-scale choices (Likert 1932). Scores of 1–5 were assigned by the participant ranging from 'strongly disagree' to 'strongly agree'. The total score was divided into three groups: poor, fair, and good attitude, respectively.

To investigate the question of whether a link possibly existed between the preferred choice of drinking water and the occurrence of diarrhea, sources of drinking water were divided into two groups: tap water and processed tap water (boiled and filtered tap water, water from vending machines, bottled water). Herein, we defined diarrhea as the passage of three or more loose or liquid stools per day (World Health Organization 2017). Participants were asked to recall their experience with diarrhea during the last year.

Data analysis

Descriptive and inferential statistics were used to analyze the data and statistical analysis was performed with Statistical Package for the Social Sciences V.18 (SPSS Inc, Chicago, IL, USA). Chi-square test and Fisher's exact test were used to evaluate the association between acceptance of drinkable tap water, independent personal variables and between diarrhea and drinking water selection (Kim 2017). To estimate the degree of association for different service areas of the MWA, the generalized estimating equation (GEE) was used (Hardin & Hilbe 2013).

RESULTS

A total of 264 females (70.59%) and 110 male subjects (29.41%) participated in this study and their average age was 52.96 years (mean = 52.96, SD ±14.77, min = 18, max = 86); 62.73% of the individuals were in the working-age group and 31.28% in the senior-age group; 32.62% were self-employed, followed by housewives (19.52%) and work for hire (15.51%). The average monthly income was 10,000 baht (range: 700–20,000); 35.29% of participants received incomes of less than 5,000 baht per month; and 41.71% of the participants graduated in primary school (Table 1).

A majority of participants (78.34%) were aware of the drinkable tap water campaign of the MWA. Almost half of the participants had good knowledge (47.06%) and a good attitude (40.64%) whereas only a few participants (4.55%) had a poor attitude. Of the participants, 42.51% answered that tap water drinking would harm their health due to the presence of chemical contaminations, pathogenic microorganisms, and industrial waste, and 71.12% of participants found that tap water was

Table 1 | Socio-demographic parameters of the study population

Parameter	Study population, *n* (%) (total = 374)	Bangkok population, *n* (%) (total = 7,245,150)
Gender		
Female	264 (70.59)	3,758,059 (51.87)
Male	110 (29.41)	3,487,091 (48.13)
Age Group		
(Mean = 52.96 years, SD = 14.77, Min = 18, Max = 86)		
Working-Age	257 (62.73)	6,445,110 (88.96)
Senior-Age	117 (31.28)	800,040 (11.04)
Education		
Uneducated	11 (2.94)	–
Primary School	156 (41.71)	–
Middle School	60 (16.04)	–
High School	41 (10.96)	–
High Vocational Certificate/Diploma	44 (11.76)	–
Bachelor's Degree or Equivalent	54 (14.44)	–
Master's Degree of Higher	8 (2.14)	–
Occupation		
Self-Employed	122 (32.62)	–
Government Employee	40 (10.70)	–
Private Employee	17 (4.55)	–
Work for Hire	58 (15.51)	–
Housewife	73 (19.52)	–
Student	9 (2.41)	–
Unemployed	42 (11.23)	–
Others	13 (3.48)	–
Monthly Income (THB)		
(Median = 10,000 [Range: 700–20,000])	(average = 30,103.58 baht)	
<5,000	132 (35.29)	–
5,000–10,000	76 (20.32)	–
10,001–20,000	90 (24.06)	–
20,001–30,000	46 (23)	–
>30,000	30 (8.02)	–

Note: Data for the Bangkok population was obtained from the 2010 Population and Housing Census (National Statistical Office 2010). Unavailable data are indicated by dashed lines.

unacceptable ($n = 180/374$, 48.13%) with regards to smell, color, turbidity, and taste. It should be noted that 71% of the participants found water quality unsatisfactory, while the MWA claimed that their tap water is 100% safe for consumers.

Although there was a high prevalence (51.87%; 95% CI 46.81% to 56.89%) for common acceptance of drinkable tap water among Bangkok residents, only a few (5.35%) participants drank water directly from the tap. Most participants (62.30%) selected filtered tap water for their day-to-day supply. If all sources of tap water are taken into account (tap water, boiled tap water, filtered water and water from vending machines), 299 participants (79.95%) used tap water for their daily intake (Table 2).

Among the participants who accepted drinkable tap water ($n = 194$), 82.99% selected tap water to drink (all sources from tap water), and 9.79% of them drank water directly from the tap. The most preferred source was filtered tap water (56.19%) as shown in Figure 2.

The GEE analysis with fixed service areas of the MWA revealed that participants with good attitude had the highest likelihood to accept drinkable tap water (OR 55.53; 95% CI 7.58 to 406.94), followed by participants with good knowledge (OR 12.76; 95% CI 8.39 to 19.40) and participants who believed that drinking water from any source exhibits no difference (OR 7.11; 95% CI 5.34 to 9.45). Participants with a monthly income of fewer than 5,000 baht had a higher probability to consume water directly from the tap (OR 6.56; 95% CI 3.21 to 13.39). Other factors associated with the acceptance of drinkable tap water include age, occupation, campaign perception, unacceptable sensory quality, and risk perception (Table 2).

To assess the health impact of drinking water behaviors, residents were asked about their recently experienced health problems. There were 126 participants (33.69%) who reported diarrhea in the year 2019 to 2020. However, we observed no significant differences between the selection of drinking water and diarrhea (Table 3).

DISCUSSION

Influential factors for the acceptance of drinkable tap water were explored using data from a cross-sectional study among 374 participants. The sample size was slightly smaller than the optimal number required for the study since participants were excluded who could not be contacted or refused to participate. It should be noted that some of the demographic indicators of the participants differ from those commonly observed for Bangkok residents (Table 1) (National Statistical Office 2010). Since the interviews were conducted during the daytime, female and old-age participants with lower monthly incomes were more likely to be interviewed. This eventually could have resulted in biased answers and as such could be seen as a limitation of our poll. Descriptive analysis revealed a high prevalence for the acceptance of drinkable tap water among Bangkok residents, as 51.87% of participants accepted drinkable tap water. These findings correspond well to the results of prior studies (Saengaram 1999; Prempong 2005; Babel *et al.* 2010).

Attitude appears to be a highly influential factor for the acceptance of drinkable tap water, followed by knowledge (Table 2). These findings may be explained by a recently published knowledge–attitude–practice (KAP) model which assumes that knowledge, attitude and practice are interrelated (Bano *et al.* 2013). Our results are consistent with a prior report that found: (1) knowledge about drinkable tap water had a positive correlation with attitude toward tap water drinking; (2) attitude toward tap water drinking had a positive correlation with water drinking behavior; and (3) attitude toward tap water drinking was the best variable to explain water drinking behavior (Saengaram 1999). It is worth mentioning that water quality is mostly assessed by odor or taste (chlorine content), while insoluble material (sediment) or turbidity could be factors contributing to pathogen growth.

We found that senior-age participants were more likely to accept drinkable tap water than working-age participants (Table 2). As previous studies suggested, elder participants were often used to drinking rainwater and water from wells, fountains, and rivers (Saengaram 1999; Kuawiriyapan 2008; Rufener *et al.* 2010; Yongsi 2010). A previous study conducted in Canada found a positive perception of private water supply as long as the sensory properties of the water provided were deemed acceptable (Jones *et al.* 2005). In comparison with self-employed participants, unemployed and work–for–hire participants were more likely to accept drinkable tap water as the use of tap water could reduce expenses.

Earlier studies in the literature had established a role for health awareness and we found that acceptance of drinkable tap water correlated with perception and belief (Jones *et al.* 2005; Chen *et al.* 2012; Kim *et al.* 2012). Participants who perceived campaign information and felt that tap water lacks undesirable sensory properties were more likely to accept drinkable tap water than those who thought tap water is safe and clean and does not affect their health. It is interesting to note that a study

Table 2 | Odd ratio (OR) for acceptance of drinkable tap water among participants according to independent variables: results of the generalized estimating equation (GEE)

Variables	Study population, *n* (%) (total = 374)	Accepted drinkable tap water among participants, *n* (%) (total = 194)	OR	95% CI
Age Group				
Working-Age	257 (62.73)	124 (63.92)		
Old-Age	117 (31.28)	70 (36.08)		
Occupation				
Self-Employed	122 (32.62)	52 (26.80)	1.00	
Government Employee	40 (10.70)	15 (7.73)	0.81	0.35–1.87
Private Employee	17 (4.55)	6 (3.09)	0.73	0.28–1.91
Work for Hire	58 (15.51)	37 (19.07)	2.37*	1.23–4.57
Housewife	73 (19.52)	40 (20.62)	1.63	0.81–3.29
Student	9 (2.41)	5 (2.58)	1.68	0.56–5.03
Unemployed	42 (11.23)	30 (15.46)	3.37***	1.89–5.98
Others	13 (3.48)	9 (4.64)	3.03*	1.24–7.42
Monthly Income (THB)				
<5,000	132 (35.29)	82 (42.27)	6.56***	3.21–13.39
5,000–10,000	76 (20.32)	41 (21.13)	4.69***	2.39–9.20
10,001–20,000	90 (24.06)	42 (21.65)	3.50***	1.57–7.79
20,001–30,000	46 (23)	23 (11.86)	4.00**	1.31–12.18
>30,000	30 (8.02)	6 (3.09)	1.00	
Campaign Perception				
Yes	293 (78.34)	160 (82.47)	1.66**	1.17–2.36
No	81 (21.66)	34 (17.53)	1.00	
Personal Belief				
Bottled Water	108 (28.88)	38 (19.59)	1.00	
Tap Water	5 (1.34)	4 (2.06)	7.37	0.82–66.34
Filtered Water	140 (37.43)	63 (32.47)	1.51	0.95–2.39
Water from Vending Machine	3 (0.80)	1 (0.52)	0.92	0.24–3.57
No Difference	102 (27.27)	81 (41.75)	7.11***	5.34–9.45
Others	16 (4.28)	7 (3.61)	1.43	0.55–3.72
Unacceptable Appearance in Tap Water Perception				
Yes	266 (71.12)	122 (62.89)	1.00	
No	108 (28.88)	72 (37.11)	2.36**	1.33–4.19
Risk Perception				
Yes	159 (42.51)	149 (76.80)	1.00	
No	215 (57.49)	45 (23.20)	5.72***	3.70–8.84
Knowledge				
Poor	88 (23.53)	19 (9.79)	1.00	
Fair	110 (29.41)	38 (19.59)	1.92	0.86–4.28
Good	176 (47.06)	137 (70.62)	12.76***	8.39–19.40
Attitude				
Poor	17 (4.55)	1 (0.52)	1.00	
Fair	205 (54.81)	75 (38.66)	9.23*	1.13–75.37
Good	152 (40.64)	118 (60.82)	55.53***	7.58–406.94

Note: *, *p*-value <0.05; **, *p*-value <0.01; ***, *p*-value <0.001.

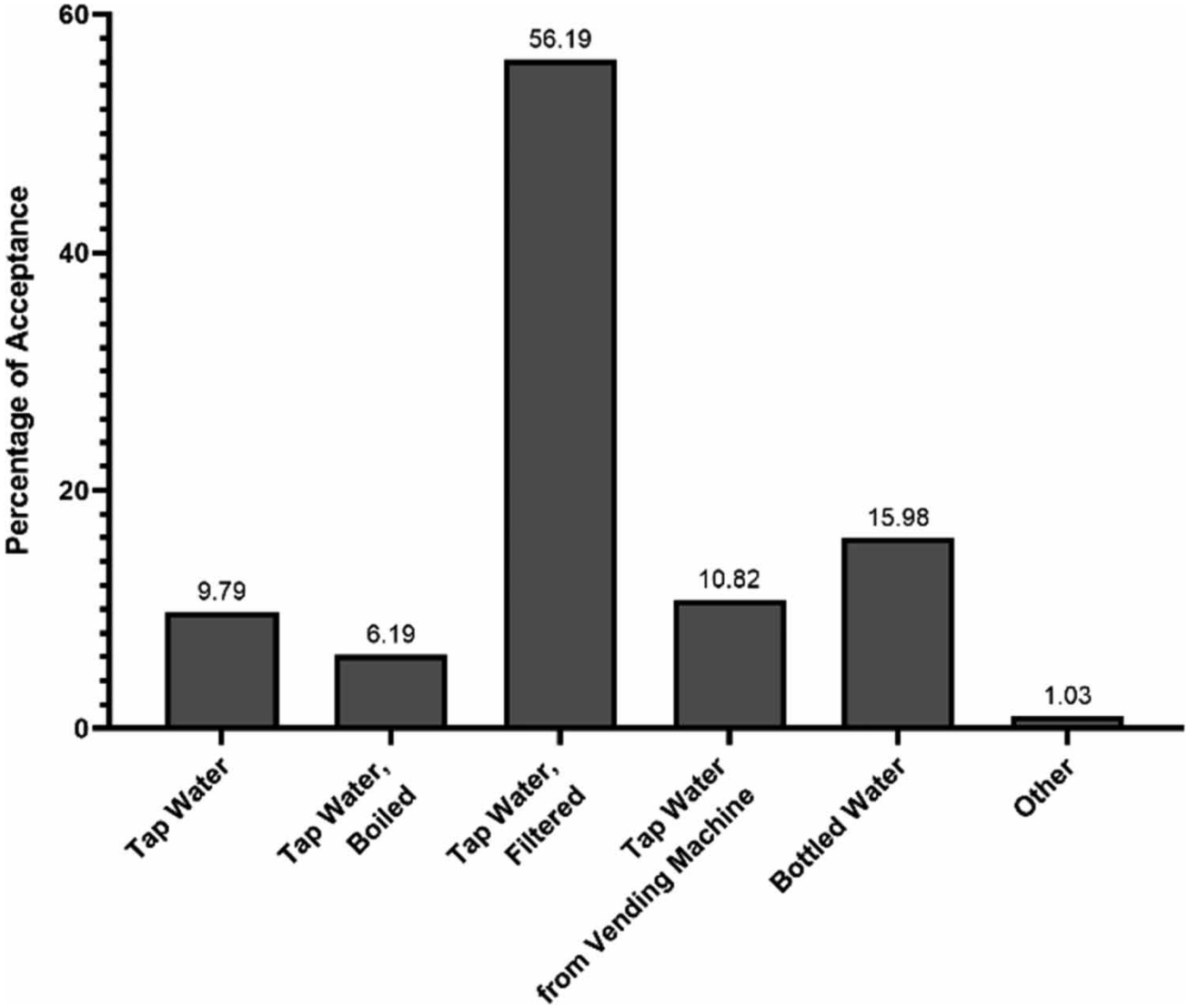


Figure 2 | Drinking water selection among participants who accepted drinkable tap water.

Table 3 | Odd ratio (OR) for diarrhea among participants according to drinking water selection: results of the generalized estimating equation (GEE)

Variables	Study population, *n* (%) (total = 374)	Diarrhea among participants, *n* (%) (total = 126)	OR	95% CI
Drinking Water Selection				
Tap Water, Directly	20 (5.35)	4 (3.17)	0.48	0.16–1.42
Others	354 (94.65)	122 (96.83)	1.00	

conducted in the UK revealed that most participants did not believe that bottled water conferred significant health benefits over tap water (Ward *et al.* 2009).

Few participants (9.79%) drank water directly from the tap while half of them (56.19%) accepted drinking tap water that was treated by filtration. This finding is comparable to the drinking behavior of Bangkok residents reported in a previous study (Kuawiriyapan 2008). Among the consumers drinking tap water, a majority accepted drinking tap water that passed through sediment or activated charcoal filter systems. Participants mentioned two important reasons: (1) water can be purified to high quality; and (2) water filters are relatively inexpensive and can be replaced frequently. Nevertheless, it should be noted that carbon filtration may not be sufficient to remove all pathogenic bacteria and compounds (nitrate) completely.

A high proportion (62.89%) of participants perceived unacceptable manifestations like smell, color, turbidity, and taste following the filtration process, thus indicating limiting efficiency of the purification step. The reasons comprise rust formation (Rajasärkkä *et al.* 2016; Schnoor 2016), leakage of pipes (Fox *et al.* 2016), odor from chlorine used for disinfection (Zhang *et al.* 2013), storage methods (Rufener *et al.* 2010) and seawater seeping into the water supply (Metropolitan Waterworks Authority 2014). Nevertheless, consumers appear to perceive filtration-treated water as quality-improved and superior when compared with untreated tap water.

Bottled water was identified as the second-best choice among participants who accepted drinkable tap water (28.88%). For them, bottled water was convenient to obtain, safe and better tasting. This finding is corroborated by results from earlier studies (Ward *et al.* 2009; Cunningham *et al.* 2010; Hu *et al.* 2011; Thomas 2015). A negative perception of tap water quality also affects the decision to purchase bottled water (Johnstone & Serret 2011). These observations may also explain why participants who accepted drinkable tap water did not drink it directly from the tap. In summary, our data support the notion that while public water supply generally claims a high standard of safety, closer inspections reveal some limitations for consumer safety and overall acceptance.

CONCLUSIONS

We found a high prevalence of the acceptance of drinkable tap water among Bangkok residents. Influential factors were identified as age, occupation, monthly income, campaign perception, personal belief, sensory appearance, risk perception, knowledge, and attitude. Attitude appeared to be a significant influential factor for the acceptance of drinkable tap water. A majority of participants accepted drinkable tap water, but few participants drank water directly from the tap. Approximately 50% of them accepted drinking tap water that was treated by filtration. Moreover, our study demonstrated that drinking water selection was not associated with self-reported diarrhea.

Our results offer several clues that benefit water suppliers and public health decision-makers in improving public perception of drinking tap water. This study supports the use of water that is consistent with the expansion of urban and industrial sectors, and this will have an impact on the maintenance of sustained quality water supply, credibility to investors and tourists, and compliance with international regulations.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Babel, M. S., Rivas, A. A. & Kallidaikurichi, S. 2010 Municipal water supply management in Bangkok: achievements and lessons. *Int. J. Water Resour. Dev.* **26** (2), 193–217.

Balakrishnan, N., Colton, T., Everitt, B., Piegorsch, W. W., Ruggeri, F. & Teugels, J. L. 2014 *Wiley StatsRef: Statistics Reference Online*. John Wiley and Sons, New York, NY, USA.

Bano, R., Alshammari, E., Fatima, S. B. & Al-Shammari, N. A. 2013 A comparative study of knowledge, attitude, practice of nutrition and non-nutrition student towards a balanced diet in Hail University. *IOSR J. Nurs. Health Sci.* **2** (3), 29–36.

Chen, H., Zhang, Y., Ma, L., Liu, F., Zheng, W., Shen, Q., Zhang, H., Wei, X., Tian, D., He, G. & Qu, W. 2012 Change of water consumption and its potential influential factors in Shanghai: a cross-sectional study. *BMC Public Health* **12**, 450.

Cochran, W. G. 1963 *Sampling Technique*. John Wiley and Sons, New York, NY, USA.

Cunningham, J., Honeyman, C., Prygoski, A., Opatowski, A. & Wang, Y. 2010 *Options for Reducing Bottled Water Use in the Michigan Union and on Campus*. University of Michigan, Michigan, MI, USA.

Fox, S., Shepherd, W., Collins, R. & Boxall, J. 2016 Experimental quantification of contaminant ingress into a buried leaking pipe during transient events. *J. Hydraulic Eng.* **142** (1), 04015036.

Francis, M. R., Nagarajan, G., Sarkar, R., Mohan, V. R., Kang, G. & Balraj, V. 2015 Perception of drinking water safety and factors influencing acceptance and sustainability of a water quality intervention in rural southern India. *BMC Public Health* **15**, 731.

Güngör-Demirci, G., Lee, J., Mirzaei, M. & Younos, T. 2016 How do people make a decision on bottled or tap water? Preference elicitation with nonparametric bootstrap simulations. *Water Environ. J.* **30** (3–4), 243–252.

Hall, R. P., Van Koppen, B. & Van Houweling, E. 2014 The human right to water: the importance of domestic *and* productive water rights. *Sci. Eng. Ethics* **20** (4), 849–868.

Hardin, J. W. & Hilbe, J. M. 2013 *Generalized Estimating Equations*. Chapman and Hall/CRC, New York, NY, USA.

Hu, Z., Morton, L. W. & Mahler, R. L. 2011 Bottled water: United States consumers and their perceptions of water quality. *Int. J. Environ. Res. Public Health* **8** (2), 565–578.

Johnstone, N. & Serret, Y. 2011 Determinants of bottled and purified water consumption: results based on an OECD survey. *Water Policy* **14** (4), 668–679.

Jones, A. Q., Dewey, C. E., Doré, K., Majowicz, S. E., McEwen, S. A., Waltner-Toews, D., Henson, S. J. & Mathews, E. 2005 Public perception of drinking water from private water supplies: focus group analyses. *BMC Public Health* **5**, 129.

Kim, H.-Y. 2017 Statistical notes for clinical researchers: chi-squared test and Fisher's exact test. *Restor. Dent. Endod.* **42** (2), 152–155.

Kim, H.-S., Ahn, J. & No, J.-K. 2012 Applying the Health Belief Model to college students' health behavior. *Nutr. Res. Pract.* **6** (6), 551–558.

Kooy, M. & Walter, C. T. 2019 Towards a situated urban political ecology analysis of packaged drinking water supply. *Water* **11** (2), 225.

Kuawiriyapan, S. 2008 *Adoption of Consumers toward the Drinkable Tap Water Supply in Bangkok*. King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.

Likert, R. 1932 A technique for the measurement of attitudes. *Arch. Psychol.* **22** (140), 5–55.

Losiri, C., Nagai, M., Ninsawat, S. & Shrestha, R. P. 2016 Modeling urban expansion in Bangkok metropolitan region using demographic–economic data through cellular automata–Markov chain and multi-layer perceptron–Markov chain models. *Sustainability* **8** (7), 686.

McDonald, R. I., Weber, K., Padowski, J., Flörke, M., Schneider, C., Green, P. A., Gleeson, T., Eckman, S., Lehner, B., Balk, D., Boucher, T., Grill, G. & Montgomery, M. 2014 Water on an urban planet: urbanization and the reach of urban water infrastructure. *Glob. Environ. Change* **27**, 96–105.

Metropolitan Waterworks Authority 2008 *Drinkable Tap Water: MWA Annual Report 2007*. Metropolitan Waterworks Authority, Bangkok, Thailand.

Metropolitan Waterworks Authority 2010 *Real-Time Tap Water Quality Monitoring System: MWA Annual Report 2009*. Metropolitan Waterworks Authority, Bangkok, Thailand.

Metropolitan Waterworks Authority 2014 *The Taste of Tap Water Might Be Changed from Sea Water Seeping: MWA Annual Report 2013*. Metropolitan Waterworks Authority, Bangkok, Thailand.

National Statistical Office 2010 *The 2010 Population and Housing Census*. National Statistical Office, Bangkok, Thailand.

National Statistical Office 2020 *The 2020 Population and Housing Census*. National Statistical Office, Bangkok, Thailand.

Prempong, B. 2005 *The Acceptance of the People to the Drinkable Tap Water Project in Service Providing Areas of Metropolitan Waterworks Authority*. Chandrakasem Rajabhat University, Bangkok, Thailand.

Rajasärkkä, J., Pernica, M., Kuta, J., Lašňák, J., Šimek, Z. & Bláha, L. 2016 Drinking water contaminants from epoxy resin-coated pipes: a field study. *Water Res.* **103**, 133–140.

Rufener, S., Mäusezahl, D., Mosler, H.-J. & Weingartner, R. 2010 Quality of drinking-water at source and point-of-consumption – drinking cup as a high potential recontamination risk: a field study in Bolivia. *J. Health Popul. Nutr.* **28** (1), 34–41.

Saengaram, T. 1999 *Media Exposure, Knowledge, Attitude toward the 'Drinkable Water Supply Project' and Water Drinking Behavior of Population in Bangkok Metropolitan Area*. Chulalongkorn University, Bangkok, Thailand.

Schnoor, J. L. 2016 Recognizing drinking water pipes as community health hazards. *J. Chem. Educ.* **93** (4), 581–582.

Shrestha, S., Aihara, Y., Yoden, K., Yamagata, Z., Nishida, K. & Kondo, N. 2013 Access to improved water and its relationship with diarrhoea in Kathmandu Valley, Nepal: a cross-sectional study. *BMJ Open* **3** (6), e002264.

Thomas, P. M. 2015 Do they drink our water? Attitudes about tap water and the impact on our industry. *Proc. Water Environ. Fed.* **2015** (4). doi:10.2175/193864715819556453.

United Nations 2015 Millennium Development Goals. United Nations, New York, NY, USA.

Ward, L. A., Cain, O. L., Mullally, R. A., Holliday, K. S., Wernham, A. G. H., Baillie, P. D. & Greenfield, S. M. 2009 Health beliefs about bottled water: a qualitative study. *BMC Public Health* **9**, 196.

World Bank Group 2015 *East Asia's Changing Urban Landscape: Measuring a Decade of Spatial Growth*. World Bank Group, Washington, DC, USA.

World Health Organization 2017 Diarrhoeal disease. World Health Organization, Geneva, Switzerland. https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease.

World Health Organization 2018 Millennium Development Goals. World Health Organization, Geneva, Switzerland. https://www.who.int/news-room/fact-sheets/detail/millennium-development-goals-(mdgs).

Yongsi, H. B. N. 2010 Suffering for water, suffering from water: access to drinking-water and associated health risks in Cameroon. *J. Health Popul. Nutr.* **28** (5), 424–435.

Zhang, Y., Ye, H., Zhou, L. & Hu, L. 2013 Influence of chlorine-to-nitrogen ratio on the inactivation of heterotrophic bacteria in bulk water during chloramination. *Water Environ. Res.* **85** (6), 568–573.

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