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Consumer Perceptions of Drinking Water

in the Kingdom of Saudi Arabia

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Abstract

Purpose

This study examined the quality of tap and bottled drinking water to assess issues related to chemical and microbiological concerns that have been expressed by consumers.

Design

In this study, we examined the tap water in a total of thirty-six different homes from three different regions in Saudi Arabia (Jeddah, Dammam and Riyadh), and compared this with bottled water samples from six manufacturing plants in each of the three regions for three months (n = 54). In addition, we conducted a cross-sectional survey (n = 337) in the same regions to determine consumer concerns towards bottled and tap water; this survey was in the form of a questionnaire.

Findings

Low levels of *E. coli* and *P. aeruginosa* were found in Jeddah and Dammam respectively. The results showed that consumers are concerned about the water that they drink. Distrust, income, purity, risk and taste all played a part in water selection. Respondents with high incomes indicated that they were prepared to pay for bottled water to reduce the risks associated with water borne diseases, while low income earners stated that it was expensive to buy bottled water.

Value

These findings have wide ranging implications for both immediate and future programmes aimed at improving water quality and distribution to homes. Arid regions world-wide will benefit from scrutinising the quality of potable water, assessing and mitigating the risks along the distribution channel. A thorough review of the supply of water to homes using a risk-based scheme, such as hazard analysis and critical control point HACCP, is essential. Furthermore, it is essential that infrastructural materials should be replaced through a planned maintenance programme. The need to inform the general populace about potable water quality is necessary.

Introduction

Water quality is of paramount concern for all. In Saudi Arabia, the responsibility for provision of potable water to homes lies with the Ministry of Environment, Water and Agriculture. The sources of water emanate from the sea (thereby requiring desalination), groundwater and surface water from the mountainous regions of the South West. There has been anxiety about the quality of potable water supplied to residencies around the Kingdom of Saudi Arabia (Hussein and Magram, 2012). These authors have indicated that underground water tanks are prone to contamination from leakage of polluted waters, the shortage of sewerage systems, irregular water supplies and high-water tables that increase the burden on the piped water system. This study investigated the microbiological and chemical quality of drinking water as laid down in the GCC Standardization Organization (GSO) (2014), and consumer perceptions of drinking water quality; this is because a high volume of bottled water is consumed.

The World Health Organization (WHO) considers that "drinking water" should be "suitable for human consumption and for all usual domestic purposes as well as personal hygiene" (Bartram et al., 2004). Guidelines set by WHO and the GSO (2014) for drinking water, including treated water entering public distribution systems, clearly stipulates a zero value for *Escherichia coli* (*E. coli*) or thermotolerant coliforms in any 100ml sample of drinking water. Drinking water containing *E. coli* is an indication of recent faecal contamination from human or warm-blooded animals (WHO, 1993). Lee and Schwab (2005) described the difficulties associated with water distribution systems and, although the existence of a public water distribution system is often considered a gauge of improved water supply in an emerging market economy, it should not be presumed that the resulting water quality is always potable. They ascribed negative hydraulic pressure as a factor that may draw pathogens from faecal contaminated material surrounding water pipes into the water supply through leakages in the network, improper or insufficient disinfection, residual as well as aging, and decomposition of infrastructure to produce favourable conditions for bacterial growth.

The demand for bottled water has grown rapidly around the globe (Bong et al., 2009) and many reasons have been cited for this. Ross et al. (2014) and Parag and Roberts (2009) argue that a significant determinant for the rise in bottled water consumption is a lack of trust in the authorities providing tap water, exemplified by the *Cryptosporidium* and *Giardia* outbreak in Sydney, Australia in 1988. Bottled water is perceived by many to taste better, have fewer impurities and confer an elevated social status to the consumer compared to tap water (Tobin, 1984; Alabdula'aly and Khan, 1999). More recently, Etale et al. (2018) discussed the factors influencing bottled water consumption and found that affect, norms and image can be significant predictors of choice. Environmental concerns also played a role in the consumption of bottled water. Negative reactions to tap water stem from safety and taste (Doria, 2006; Gleick, 2010; Harmon et al., 2018) to distrust (Salzman, 2012) and disgust (Harmon et al., 2018).

Demand for bottled water in Saudi Arabia is extremely high (Grefat, 2013; Al-Sulaiman, 2016). Despite the price of bottled water being three times that of petrol at the pump in Saudi Arabia, bottled water consumption continues to grow. Intrigued by this information, the authors attempted to find out why bottled water consumption was so high compared to tap water. To the best of our knowledge, there is a lack of information regarding consumer concerns about domestic tap water consumption, if any, in Saudi Arabia. Therefore, the purpose of this study was to determine these concerns in comparison to bottled water. Findings may have important implications for future programmes aimed at improving consumer confidence about water safety.

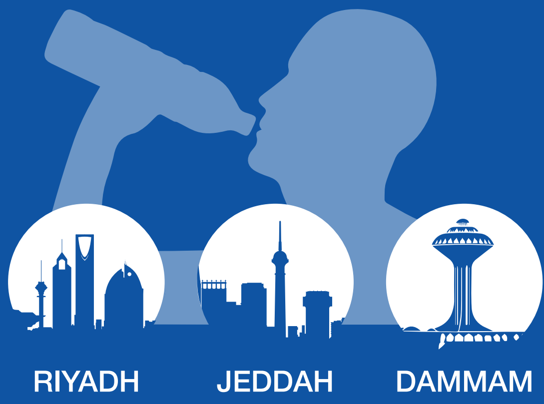
Keywords

Bottled water, tap water, consumer concerns, Saudi Arabia, risk perception

Materials and Methods

Research design and study area

A cross-sectional study was conducted to analyse consumers' concerns regarding drinking water. Three regions were selected, Riyadh, Jeddah and Dammam, as they represent the highest population regions and income diversity.



Methodology

A written questionnaire, in both English and Arabic, was designed and pre-tested in a pilot study consisting of 12 participants. After the pilot study, the questionnaire was revised using appropriate comments from feedback received. Results from the pilot study have not been included in this paper. After approval from the owners, questionnaires were placed in cafes for one week; the price of food in the cafes was considered high, medium and low. A cover note was provided explaining the objective of the survey, and that it was purely voluntary with participants being free to withdraw at any point.

The questions asked individuals to provide information regarding bottled and tap water consumption including usage, opinions about drinking water risks, safety and taste. The survey consisted of 16 questions. Once the questionnaires were completed, they were placed in a sealed box for collection.

Water sampling

Tap water samples were obtained voluntarily from food inspectors' homes from each of the three regions. Aseptic techniques were used to collect five litres per household after running the kitchen tap for one minute. A total of 126 samples were provided, of which 12 samples from each region were randomly selected. Samples of bottled water were acquired from routine inspections of the bottling plant. Every month, for three months, six litres of bottled water (10 x 0.6l) from six plants in each of the three regions was collected for the analysis. This process took place between October and December 2018.

Microbiological Analysis

Total coliforms and *E. coli* was determined by the Most Probable Number (MPN) method (5 tube-test) (BAM, 2002; Stoler et al., 2015). Lactose broth medium was used for inoculation, and 10, 1 and 0.1ml of samples, respectively, and were inoculated in 10ml of medium; double-strength medium was used for the 10ml sample. Three replicates of mediums for each dilution were prepared and incubated at 35°C for 24 hours; these were later observed for any gas production in the Durham-tubes. Coliforms were detected by inoculation of samples into tubes of Lactose Broth (LB) and incubated at 37±1°C for 48 hours.

The positive tubes were sub-cultured into Brilliant Green Lactose Broth (BGLB) and *E. coli* Broth (EC), and were incubated at 35±1 and 44.5±1°C, respectively. Gas production in BGLB and EC broth at 35°C was used for the detection of total coliform and *E. coli* after 48 hours incubation. A loopful of broth from each gassing EC tube was streaked onto a Levine Eosin Methylene Blue (L-EMB) agar plate for 18-24 hours at 35°C for confirmation use in further biochemical testing, as described in *Bergey's Manual of Determinative Bacteriology* (Buchanan and Gibbons, 1974).

Enumeration of *P. aeroginosa* was carried out as described by Al-Qadiri et al. (2006) for each sample in duplicate using a membrane filtration technique. Under aseptic conditions, 100ml of drinking water sample was filtered through a gridded sterile cellulose-nitrate membrane filter (0.45ím pore size, 47mm diameter, Sartorius type filters) under partial vacuum. The membrane filters were immediately removed with sterile forceps and placed on Hifluoro *Pseudomonas* Agar (Grigoryan et al., 2014). Petri dishes were incubated at 37°C for 48 hours. All microbiological culture media were obtained from Sigma-Aldrich (UK).

Chemical Analysis

Nitrate, nitrite, chlorine and fluoride determinations were carried out as per Pfaff et al. (1999) method number 300.1. Bromate was analysed using the ISO (2001) 15061 method. Total dissolved solids (TDS) and pH was measured using an HI 98129 combo meter from Thermo Scientific (Waltham, MA, USA)

Statistical Analysis

All statistical analyses of the data were performed using SPSS software, version 19.0 (IBM Corporation, Armonk, NY). Descriptive statistics were used to summarise the variables of interest and determine relationships between them. Cross-tabulations were performed using Chi-Square tests and the statistical significance was determined using $P < 0.05$.

Ethical Considerations

An application was initially lodged in March 2017 through the Research Ethics Committee in Riyadh to conduct this research. In June 2017, further information was sought and supplied to the Research Ethics Committee. This included the questionnaire as well as the cover note stating the following:

(i) The objective of this study.
(ii) Participation was purely voluntary and that there was no pressure to complete any questions.
(iii) That individuals were free to withdraw at any time.
(iv) Anonymity would be maintained at all times.

A signed consent was also requested showing that they had read and understood the information in the cover note. Approval was gained in October 2017.

Results

Demographic profile of respondents

Respondents' demographic profiles are shown in Table 1. Over 70% of responses were from Riyadh, followed by Dammam, 10.4% and Jeddah, 5.6%. Individuals visiting from other areas constituted 13.4%.

Distribution of income among the participants showed that 47.1% earned more than SAR10,000, 23.9% between SAR5,001-10,000, and 29% less than SAR5,000 (1 US$ = 3.75 SAR). Up to 64.3% received tertiary education, 29.8% secondary or diploma, and 5.9% elementary and intermediate levels of attainment.

Table 1: Demographic information of respondents (n=337)

Variable		Frequency (%)
District	Riyadh	238 (70.6)
	Jeddah	19 (5.6)
	Dammam	35 (10.4)
	Other	45 (13.4)
Education	Elementary	3 (0.9)
	Intermediate	17 (5.0)
	Secondary	77 (22.7)
	Diploma	24 (7.1)
	Four year College degree	167 (48.4)
	Postgraduate	54 (15.9)
Income per month	Less than SAR 5,000	95 (29.0)
	SAR 5,001 – 10,000	78 (23.9)
	More than SAR 10,000	154 (47.1)

Source: Yunus Khatri

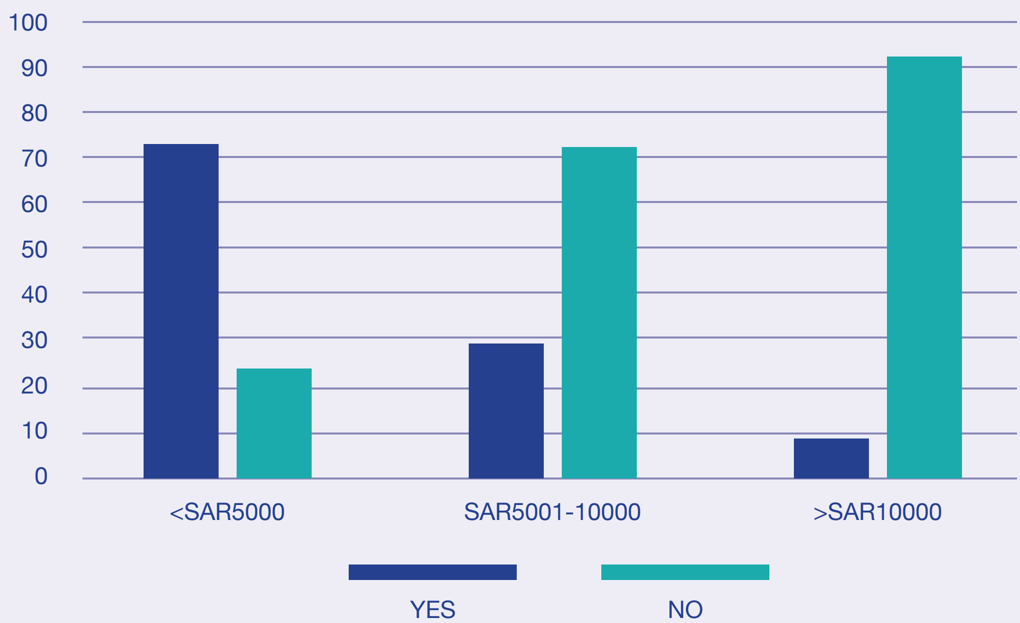
Purchase of bottled water

Figure 1 shows the percentage of individuals purchasing bottled water based on income.
Results revealed that
74.7% (n = 65) earning less than SAR 5,000,
28.6% (n = 20) earning SAR 5,001-10,000
and 8.2% (n = 12) earning more than SAR 10,000 did not purchase bottled water.

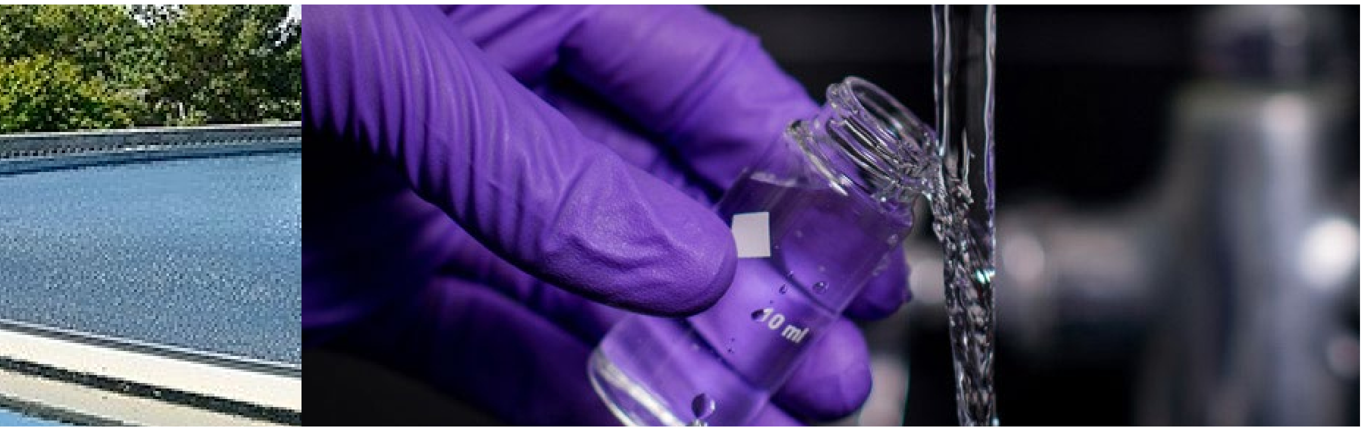
The remainder purchased bottled water. Thirty-four individuals did not answer this question.
Consumer comments included:

- "Very risky to drink tap water"
- "I am not sure if they test the water properly"
- "You'll get diarrhoea"
- "I don't trust the authorities. It's been years and no one provides information that it is safe to drink"
- "The label on my water bottle says it's pure premium water. That's it"

Figure 1: Percentage of individuals purchasing bottled water



Source: Yunus Khatri

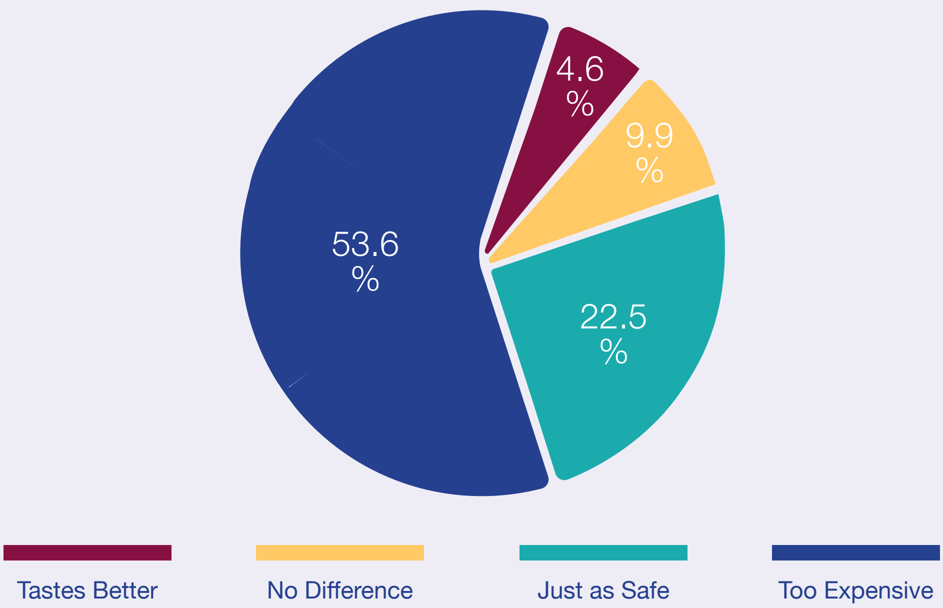


Reasons for not purchasing bottled water

Over 53% of responses reported that bottled water was too expensive to purchase, while 22.5% stated that tap water was just as safe.
No difference in the two types of water was reported by 9.9%, and 4.6% indicated that it tasted better.
Comments regarding purchase behaviour also included:

- "Nothing has ever happened to me"
- "Waste of money"
- "I use tap water for everything, cooking, drinking, bathing, gargling and wadhu[1]".

Figure 2: Reasons for not purchasing bottled water



Source: Yunus Khatri

1 Wadhu is a cleansing process that usually takes place prior to prayer whereby hands, arms, face, nostrils, ears, mouth gargling and feet are washed with water.

Attitudes towards drinking bottled water

All variables tested were significant (P<0.05), except for bottled water containing valuable salts (P = 0.108) and bottled water that did not contain bacteria (P = 0.212).
The style of reporting the degree of agreement or disagreement is consistent with Gkana and Nychas (2018).

About 67% of the respondents agreed (strongly agreed 26.1% or agreed 41.2%) with the statement that bottled water is pure water compared with about 11% who disagreed (strongly disagreed 0.6% or disagreed 10.1%).
Almost 71% agreed (strongly agreed 14.8% or agreed 56.1%) that bottled water has a clean taste.
Similarly, approximately 82% agreed (strongly agreed 19.5% or agreed 62.4%) that bottled water does not contain impurities.
Up to 56% of respondents agreed (strongly agreed 27% or agreed 29%) that bottled water can be trusted and is safer than the municipal water supply compared to 21% who disagreed (strongly disagreed 17% or disagreed 4%).
Almost 70% agreed (strongly agreed 32% or agreed 38%) that hot weather affects the quality of bottled water.
About 38% agreed that bottled water does not contain bacteria.
Approximately half of the responders (49%), strongly agreed (16%) or agreed (33%) that there was no risk to their health when drinking bottled water compared with 10% that either disagreed/strongly disagreed (see Table 2).

Table 2: Attitudes towards drinking bottled water

Attitudes	Level of Agreement					p-Value
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	
Bottled water is pure water	88 (26.1)	139 (41.2)	74 (22.0)	34 (10.1)	2 (0.6)	0.000
Bottled water has a clean taste	50 (14.8)	189 (56.1)	82 (24.3)	15 (4.5)	1 (0.3)	0.000
Bottled water does not contain impurities	66 (19.5)	211 (62.4)	35 (10.4)	24 (7.1)	2 (0.6)	0.038
Bottled water contains valuable salts	40 (11.8)	137 (40.4)	92 (27.1)	53 (15.6)	17 (5.0)	0.108
I trust that it is safer than municipal supply water	93 (27.4)	99 (29.2)	75 (22.1)	57 (16.8)	15 (4.4)	0.000
Bottled water has no smell	72 (21.2)	176 (51.9)	66 (19.5)	24 (7.1)	1 (0.3)	0.000
Hot weather affects the quality of bottled water	110 (32.4)	129 (38.1)	65 (19.2)	28 (8.3)	7 (2.1)	0.000
Bottled water does not contain bacteria	32 (9.4)	99 (29.2)	122 (36.0)	71 (20.9)	15 (4.4)	0.212
There is no risk to my health when drinking bottled water	53 (15.7)	112 (33.2)	138 (40.9)	31 (9.2)	3 (0.9)	0.000
I prefer bottled water to tap water	100 (29.5)	124 (36.6)	77 (22.7)	30 (8.8)	8 (2.4)	0.000

Source: Yunus Khatri

Microbiological and chemical analysis of water

Table 3 shows the microbiological and chemical analysis of water samples.
E coli 150cfu and *P. aeruginosa* 91cfu were found in samples from Jeddah and Dammam respectively. The pH values were in the range of 7.3 to 9.29; 14 samples were outside specification limits.
TDS were within the range; however, four samples were above the limit.
Nitrates and nitrites were all within specified limits.
Ten bromate samples exceeded the limit of 10ppm, ranging from 13.3 to 64.5 ppb.

Table 3: Chemical and microbiological analysis of tap and bottled water

Test	Region (Tap water)			Region (Bottled water)			Limit
	Riyadh (n = 12)	Jeddah (n = 12)	Dammam (n = 12)	Riyadh (n = 12)	Jeddah (n = 12)	Dammam (n = 12)	
Total Coliforms	<1	<1	<1	<1	<1	<1	0/250ml
***Pseudomonas aeruginosa* (cfu)**	<1	<1	91*(1)	<1	<1	<1	0/250ml
Total count (cfu)	<1	<1	<1	40-88 (2)	36-990 (2)	<1	
***E. coli* (cfu)**	<1	<1 150*(1)	<1	<1	<1	<1	0/250ml
Residual Chlorine	N.D	N.D	N.D	N.D	N.D	N.D	5ppm
pH	7.88-7.99 8.01-8.23 *(4)	7.3-9.29 8.54-9.29 *(5)	7.33-7.88 8.18-8.5 *(6)	6.97-7.4	7.02-7.51	6.91-7.24	6.5-8
TDS	185-382	148-570	80-900 1197-3400 *(4)	91-146	88-107	123-252	100-1000ppm
Fluoride	N.D	1.14-1.39 N.D (10)	0.45-0.82 N.D (7)	0.73-1.22	0.8-1.1	0-1.39	1.5ppm
Nitrate	5.34-9.36	3.7-3.77 N.D (10)	11.7-33.1 N.D (6)	0-4.46	1.06-22.53	0-1.3	50ppm
Nitrite	N.D	N.D	N.D	N.D	0-1.2	0-1.15	3ppm
Bromate	N.D	2.2-9.3ppb 13.3-22.5ppb*(5)	3-9.8ppb 16-64.5 *(5)	N.D	0-6.86	0-5.07	10ppb

N.D = Not detected
*Number of samples in parenthesis that were out of specification

Source: Yunus Khatri

Discussion

Demographic profiles

The three regions chosen constitute the highest populated densities in the Kingdom of Saudi Arabia. This study revealed that the majority (70%) of respondents were from Riyadh. Over 60% of respondents possessed a college degree or postgraduate qualification. Interestingly, individuals with a higher education level and literacy took the time and interest to participate in this survey. Those with a lower level of education may have been averse or sceptical to participating (Anuar and Mohamed, 2012). The fact that the majority of respondents had the highest salaries indicates their propensity to frequent cafes as they have more disposable income and can therefore afford to purchase bottled water.

Reasons for not purchasing bottled water

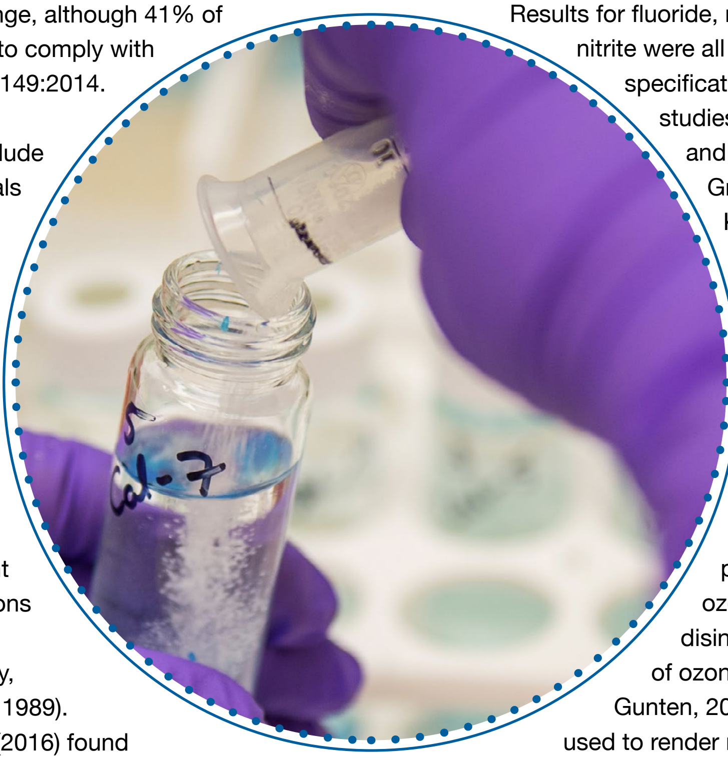
Of the people who did not purchase bottled water, 53% reported that it was too expensive; approximately 75% of these were from the lowest income group. A few comments regarding the non-purchase of bottled water were that there was no difference between bottled and tap water and no ill effects had come from drinking tap water. Some individuals commented that tap water had a better taste. The risk of these consumers contracting any water borne illness as healthy individuals is low (see section below). However, as reported by Trevett et al. (2005), infants are at greatest risk from contracting disease, as well as the elderly and immuno-compromised (Al-Sulaiman, 2016); continuous exposure to possibly low levels of pathogenic organisms is very disconcerting.

Attitudes towards purchase and drinking bottled water

Our findings are contrary to Etale et al. (2018) and Parag and Roberts (2009). The purchase of bottled water is influenced by concerns over tap water quality and distrust of the authorities. The statements made by a few consumers indicate that there is a risk to their health and that this risk relates to food poisoning. Therefore, consumers have resorted to drinking bottled water as a significant number believe that there are no bacteria in bottled water, that there is no risk to their health, it is pure, and that it is safer than the municipal water supply (Table 2). (It is interesting to note that some bottled water labels contain wordings such as 'pure water' and 'premium pure water'.) Higher bottled water consumption has been correlated to higher income, home ownership, presence of children under 5 years of age and convenience (OECD, 2014; Johnstone and Serret, 2012). Occasion, norm effects and image (Etale et al., 2018) also play a role in the consumption of bottled water. Over 90% of individuals in this study earning more than SAR 10,000 purchase bottled water

Microbiological and chemical analysis of water

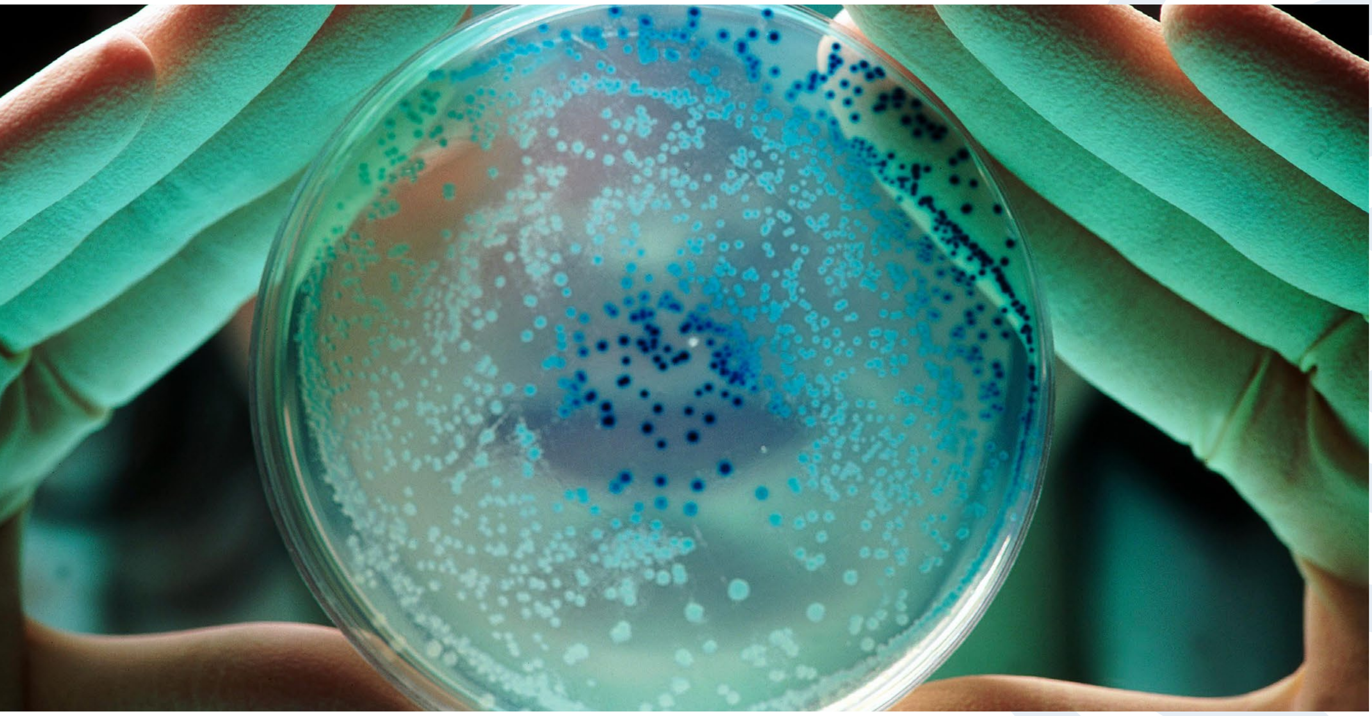
The pH expresses the degree of acidity or alkalinity of the water. It has an influence on taste, odour and appearance of drinking water (Rahman et al., 2017). The WHO has not specified a health-based guidance value but has provided an expected pH range of between 6.5 and 9.5 (WHO, 2007). All the samples analysed here were within the aforementioned range, although 41% of the samples failed to comply with the GSO Standard 149:2014.



TDS essentially include a number of minerals such as Na, K, Mg and Ca and their sulphates, bicarbonates and chlorides. The amount of TDS in natural waters varies between 30-6000 mg/l, depending on their solubility in different environmental regions (geological setting, climate, topography, etc.) (UNEPGEMS, 1989). Vingerhoeds et al. (2016) found the best fresh taste for water to be within a TDS of 190350mg/l. The palatability of drinking water becomes unpleasant in excess of 1000mg/l, and this value has been set by WHO (2008) purely based on taste considerations. Limits set by the Environmental Protection Agency (US EPA, 2016) and the Food and Drug Administration (US FDA, 2010) are at 500mg/l. Four tap water samples had TDS values between 1197-3400mg/l, in excess of the limits set. The palatability of such water remains questionable, and water filters are recommended for these domestic residences. According to Rahman et al. (2017), no recent reports exist about deleterious health effects following the ingestion of TDS in drinking water and no health-based guideline value has been proposed by WHO.

Results for fluoride, nitrates and nitrite were all within the set specifications. Previous studies by Alabdula'aly and Khan (1999), Grefat (2013), and Khater et al. (2014) reported similar results. Bromate is a by-product formed from water containing bromide that has been oxidised during the disinfection process using ozone. The disinfection properties of ozone are excellent (von Gunten, 2003) and can be used to render microorganisms, such as protozoa that exhibit resistance to conventional disinfectants, inactive (Camel and Bermond, 1998). High levels of bromate found in this study (five samples from Jeddah and five samples from Dammam) may have been due to significantly higher doses or extended exposure times for the inactivation of protozoa and resistant bacteria.

The results for the bacteriological quality of tap water revealed the presence of *E. coli* and *P.*



aeruginosa in one sample each from Jeddah and Dammam: *E. coli* is an indicator of faecal contamination. Our findings are consistent with Hussein and Magrab (2012) as they reported detecting *E*. *coli* in domestic water supplies in Jeddah. Finding any domestic supplies that contain *E. coli* is disturbing and a cause for concern. The presence of *E. coli* indicates that there is a likelihood that bacterial pathogens derived from faeces are also present (Food Safety Authority of Ireland, 2009). Our sample size was very small and a greater sample size warrants further investigation across the Jeddah region. Consumers in domestic households must be informed of the risks of drinking tap water, especially when they use it for wadhu (i.e., gargle their mouths as well as wash their face and eyes). Trevett et al. (2005) expressed their concern regarding vulnerable infants and the risk to low doses of pathogens.

The results of our bacteriological findings have been forwarded to the water authority in Jeddah. Bringing water to a rolling boil and cooling before consumption has been recommended by WHO (2008) for dealing with water-borne disease-causing pathogens. In addition, the storage and full supply chain distribution works need to be rigorously tested to assure consumers that the drinking water is potable. The New York State Department of Health (2017) promulgates repairs or modifications of the water system should coliforms be detected. Biofilm formation (Beloin et al., 2008) within pipelines and delivery systems should also form a priority for further investigation. It should be noted that hundreds of thousands of foreign visitors arrive for the Hajj Pilgrimage and Ummrah at Jeddah airport from around the globe every year; therefore there is a pressing need to inform all individuals not to consume water from the tap in this region.

P. aeruginosa is an opportunistic organism (Mena and Gerber, 2009; EAUK, 2002). The detection of *P. aeruginosa* at low levels in a sample from Dammam can only be considered a risk after further extensive sampling and analysis. An oral dose in excess of 1.5 million bacteria of *P*. *aeruginosa* does not infect normal healthy tissue, and only certain hosts are at risk; these include those that are profoundly immuno-compromised, neutropenic, have cystic fibrosis or severe burns (Allen et al., 2004; Buck and Cooke, 1969). Stoler et al. (2015) and the Food Safety Authority of Ireland (2009) confirmed that in the absence of faecal contamination, the presence of *P*. *aeruginosa* is not a significant risk. Their existence may possibly be due to biofilm formation and their persistence in the distribution lines (Saati and Faidah, 2013) rather than the treated water itself after reverse osmosis, microfiltration and ultraviolet light treatment.

Managing risks in the treatment and supply of potable water using a hazard analysis and critical control point (HACCP) based scheme will provide substantially increased protection in the control of water supply to the community. Progress in improved drinking water quality was demonstrated in an article by Ahmad and Bajahlan (2009) in Yanbu (bottled and tap water being comparable) when the whole drinking water network made of asbestos-cemented pipes with glass reinforced plastic to prevent asbestos contamination was replaced.

We did not find any *E. coli*, total coliforms or *P. aeruginosa* in bottled water samples examined in this study. Bottled water samples evaluated by Alabdula'aly and Khan (1999 also confirmed the absence of *E. coli* or heterotrophic bacteria, while results obtained by Al-Sulaiman (2016) revealed approximately 1% of bottled water samples were contaminated with *E. coli*.

Public health significance

E. coli not only includes commensal strains but also pathogenic ones, causing a variety of human diseases that have resulted in more than two million deaths each year worldwide (Jang et al., 2013). Symptoms range from mild gastroenteritis to severe bloody diarrhoea, mostly without fever, through to two serious conditions known as haemolytic uraemic syndrome (HUS) and thrombotic thrombocytopaenic purpura (TTP) that affect the blood, kidneys and, in severe cases, the central nervous system. Pathogenic *E. coli* have been implicated in many waterborne outbreaks around the world and contamination may occur via numerous sources including effluent from wastewater treatment plants, manure and other animal by-products, and wastewater from slaughterhouses (Chandran and Mazumder, 2015). Kaper et al. (2004) reported that the long-term growth and survival of *E. Coli* is a major concern if they carry virulence factors or antibiotic resistance genes. Therefore, *E. Coli* should be considered a potential human health hazard under such circumstances. In addition, antibiotic resistance genes can be transferred among *E. Coli*, including environmental strains that further complicates issues of public health concerns (Wellington et al., 2013).

P. aeruginosa is an opportunistic pathogen and although it rarely affects healthy individuals, it can cause a wide range of infections to those immuno-compromised, newborns, people with severe burns, cystic fibrosis and diabetes mellitus (Food Safety Authority of Ireland, 2009). Regulation for *P. aeruginosa* arises due to protection of the weak and as a quality control measure. In the USA, no such regulations are in place. The reports by Stoler et al. (2015) and the Food Safety Authority of Ireland (2009) confirmed that in the absence of faecal contamination, the presence of *P. aeruginosa* is not a significant risk. However, the at-risk groups mentioned above should be protected and informed of the possible harm involved in drinking tap water.

Conclusions

Our study found low levels of *E. coli* and *P. aeruginosa* in tap water from Jeddah and Dammam respectively. The presence of pathogens signals that tap water should not be drunk without boiling. One of the conclusions of this paper is that there is certainly a need for more research to corroborate and substantiate findings from previous research. The presence of pathogenic bacteria in municipal water supplies in homes must be investigated. The water authority in Jeddah, in particular, and other actors need to form a strategy to raise awareness of the issues of concern, educate the general populace of what it will do to bring safe drinking water to their homes, and tackle all problems and risk associated areas within the supply line using an HACCP-based system. Since Jeddah airport is the arrival point for most pilgrims going to Makkah, information about potable water sources should be publicised and circulated. Signage at airports in different languages is also necessary.

The anxieties or concerns about safe drinking water are entangled with a variety of attitudes and perceptions relating to trust, financial income status, risks and unsafe practices, distribution network, social status and norms. Our findings revealed a disparity in the consumption patterns of tap water due to income. Higher income earners can afford to pay to reduce their risk. Water is an essential commodity as part of an individual's good health and well-being, and can pose a significant problem for public health. Greater measures are needed to provide a reliable source of safe, potable tap water.

Limitations

This preliminary study utilised a small sample size and therefore may not be reflective of the potable tap water quality across the country. Further studies that emphasise greater sampling representative of all homes and the condition of pipework across the Kingdom should be carried out in order to reveal greater insight to quality issues in water distribution to homes. In addition, medical records that relate specific pathogens to water should be investigated by region, district or road and corrective action put into place. Moreover, policy intervention to act swiftly when considering risks to public health will certainly benefit all concerned.

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