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Water Quality of water coolers and dispensing machines in AlQurayyat, Al-Jouf Region, KSA: current status and future aspirations

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ABSTRACT

The present study aims to evaluate the quality of selected samples of AlSabeel water, which has been widely spread in AlQurayyat, northern KSA in recent years. The present study aims also to throw light on the precautions that must be followed in order to maintain human health and public safety. Moreover, the present study aims to describe the risk factors affecting such great humanitarian service. Field trips in the streets and visits to governmental institutions and public organizations of AlQurayyat revealed that there are 230 large coolers and 70 small ones. About 95% of the large coolers are located on the side of the main streets. These coolers are abundant in the car repair workshop region. The majority (70%) of AlSabeel water units in AlQurayyat was connected to iron tanks, while the remainder (30%) was connected to plastic or polyethylene tanks. The carrying capacity of the storage tanks of the bottled dispensers was up to 20 L, while that of the large coolers was up to two cubic meters. A total of 46 (20%) of the large coolers show sources of contamination, with approximately one third of these coolers were out of service. In contrast, all the small cooler are working in a proper manner. The sanitary conditions of the street coolers were poor. The pH values were located on the weak alkaline scale and the total dissolved solids comply with the recommendations of WHO and SASO organizations. Out of 9 examined water samples, only one sample was contaminated with bacteria.

INTRODUCTION

Water is the focus of political geography on the planet, particularly in the Middle-East region (Sultana and Loftus, 2011). It is the fundamental leading factor of conflicts and disturbances (Roa and The Value of Water Coalition, 2014). Water security is the most important challenge facing the Arabian world. Water becomes a central issue in the economy, policy, and development. Furthermore, water mining and management is an issue of global concern and broad public debate. The kingdom of Saudi Arabia is classified as one of the most arid countries. The rainfall rate ranges between 50 and 100 mm based on annual estimations. In addition, the evaporation rate is approximately 3000 mm per annum (Sharaf and Hussein, 1996). The water demands of Al-Jouf Region, northern KSA is fulfilled by the Saq aquifer that accommodates more than 280000 million cubic meters of clean, freshwater readily available for consumption (see Edgell, 1987; Lloyd and Pim, 1990). Sharaf and Hussein (1996) reported that the recharge rate of the aquifer is about 310 million cubic meters. Abderrahman (2006) reported that a total of more than US$100bn has been invested in water supply and sanitation between 1975 and 2000, and that a further US$130bn will be needed between 2002 and 2022 to meet the water demand of the growing population in Saudi Arabia.

Humanitarian work has been intensified in recent years to meet the basic needs of poor people in AlQurayyat city that showed a marked population growth. Among these efforts, AlSabeel water service is the most apparent. A total of 300 coolers and dispensing machines for free drinking water are held in different districts of AlQurayyat. These free drinking water units serve thousands of people, particularly during hot summer months that showed marked elevation in the air temperature and relative humidity. Access to safe drinking water is costly in AlQurayyat as well as other Saudi regions. The daily water consumption per capita ranges between three and four liters per day during summer (personal communication). The price of such amount of water is about 5 SR for local bottled drinking water. The monthly cost of bottled water is about 150 SR per capita (about 750 SR for a family of 5 members). Recently, there has been a growing interest with respect the use of the street coolers and dispensing devices in the workplace and public institutions. Although these coolers provide a considerable amount of drinking water, the safety condition of the supply and the sanitary status of the equipment is a subject of debate. In many cases, the perception of need for these drinking units is misguided. Such water supplies may cause many health problems to the consumers (O'Reilly *et al*., 2004; Marshall *et al*., 2006).

According to medical experts, an adult needs to drink at least 2 liters of water daily for sustaining life (de Kok *et al*., 2001). The quality of drinking water can be tested by its colour, transparency, taste, and odor (de Kok *et al*., 2001). The authors suggested the bacterium *E. coli* as a major indicator in drinking water. Drinking water standards specified by the World Health Organization ensured that the potable water must be free from *E. coli* (de Kok *et al*., 2001). Water released from the coolers may cause public health concerns. Unlike hot water, cold water exhibits a pleasant taste. Although the water coolers do not provide the consumers a feeling of safety, poor people are obliged to accept drinking water derived from the street coolers irrespective of its taste or safety. Furthermore, irregular cleaning and testing render these machines readily susceptible to the incidence and probable invasion of potential pathogens and communicable diseases. Preliminary inspection indicated the outbreak of stomach upset and abdominal pain in groups of workers or staff members in some higher education institutions belonging to Al-Jouf University at particular times. These groups shared water dispensers in the workplace.

The objective of the present study is to analyze the physical, chemical and bacteriological properties of the drinking water plumbed in a variety of public coolers in order to reveal its compliance with the guidelines of the World Health Organization (WHO) and the Saudi Standards, Metrology and Quality Organization (SASO). Moreover, it was decided to compute the potential health risks delivered from drinking water in street coolers, a great humanitarian service that have been widely spread throughout AlQurayyat. Furthermore, the present study aims to throw light on the precautions that should be followed in order to maintain human health and public safety.

MATERIALS AND METHODS

Sterile, sealed 50 ml bottles, provided by the laboratory of the water purification station, were adopted. The hands of the researcher collecting water samples were washed carefully with soap and water before water sampling. Water was allowed to run for two minutes before sampling. The cap of the bottle was taken off and held in one hand and the bottle in the other hand. The bottle was emptied off a tablet that neutralizes any chlorine. The bottle never rinsed. The bottle was carefully filled within 6-7 mm of the top. The cap of the bottle was replaced, however neither the mouth of the bottle nor the inner side (inside) of the cap was touched. Water samples were cooled, but not frozen, and sent to the lab within 24 hours. Information about sampling location and time of collection were printed on the bottles. The bottles of water samples subjected to the chemical analysis were completely filled and metal-lined caps were overlooked or avoided. Samples were tested within the holding time, the time from sampling to analysis. It reflects the time during which the properties of water will not change. Three samples of each water type were analyzed and the mean values were documented.

Total dissolved solids in each water sample was determined with the aid of a HQ 14d conductivity meter (HACH). TDS values are expressed as mg/L or ppm units. The total dissolved solids refer to the total amount of organic and inorganic compounds, comprising metals, salts and minerals dissolved in a sample of water. TDS is measured as milligrams of metals, salts, cations or anions existing in water other than total suspended solids, which are non-filterable residues. TDS meter is a reflection of the electrical conductivity of water (EC). TDS is estimated by converting EC by a factor of 0.5 to 1.0 times the EC, relying on the levels. Organic sources of TDS include dead plants and animals, slit, water products and industrial effluents. On the other hand, inorganic sources of TDS comprise rocks and air that are loaded with calcium bicarbonate, iron, nitrogen, phosphorous, silica, etc. Organic and inorganic compounds are water soluble and form cations (positive charge) or anions (negative charge). TDS levels above 1000 mg/L is unfit for human consumption. High TDS levels are attributed to elevated concentrations of potassium, chlorides and sodium.

The hydrogen ion concentration (pH) in the water samples was measured using HQlld pH meter (HACH). Total chlorine, fluorine, iron, sulfate, phosphate, nitrate and nitrite were measured using DR5000 spectrophotometer (HACH). To demonstrate the contamination of water samples with bacteria, 100 ml water were mixed with Colitag (an indicator medium for the growth of bacteria) and incubated at 37 ºC for 24 hrs. Then, bacterial growth was illustrated by inspecting the change of colour from yellow at the initial stage to deep yellow or orange at the terminal stage (24 hours post treatment).

RESULTS

Field trips in the streets and visits to governmental institutions and public organizations of AlQurayyat revealed that there are 230 large water coolers and 70 bottled dispensers. About 95% of the large coolers are located on the side of the main streets. These coolers are abundant in the car repair workshop region. The majority (70%) of AlSabeel water units in AlQurayyat is connected to iron tanks, while the remainder (30%) is connected to plastic or polyethylene tanks. The carrying capacity of the storage tank of bottled dispensers is up to 25 L, while that of the large coolers is up to two cubic meters. A total of 46 (20%) of the large coolers showed sources of contamination (Figures 1, 2, 3 and 4), with approximately one third of these coolers were found to be out of service. In contrast, all the small coolers were working in a proper manner. The sanitary conditions of the street coolers were poor.

Field trips in the streets also demonstrated that hundreds of people share in the drinking from a single steel or plastic cup. In only one occasion, an advanced street water cooler was provided with polyethylene storage tank, disposable paper cubs (Figure 5) and a powerful filter (Figure 6). Close inspection of the street water coolers indicated that they suffer from negligence and being in poor sanitary conditions. They undergo water cessation, dust accumulation and/or filter contamination. This indicates the lack of maintenance and regular monitoring of such important water sources that serve thousands of low income persons. The metallic taste is characteristic of all the large coolers connected to iron tanks. In several occasions, the existence of smells and undesirable odour was evident in the vicinity of unmaintained street water coolers. Moreover, the cups are fixed to the body of the cooler with the aid of steel robe that was found to be covered by rust material (Figures 3 and 4). In only one case, used overflowing car oil tanks were recognized in the close proximity of a street water cooler (Figure 1).

Street coolers are exposed to car exhausts and welding emissions, particularly in the car repair workshop region. A considerable proportion of the vehicles driving down streets of AlQurayyat are operated by diesel engines. Moreover, heavy-duty trucks are abundant in AlQurayyat. They create huge amounts of diesel-related emissions, particularly oxides of nitrogen and particulate matter, which rise up to the atmosphere or accumulate on the road sides, indicating possible health concerns. A total of 70 bottled dispensers were found at governmental organizations, public institutions and private workplaces in AlQurayyat during the first quarter of 2015. Two types of the bottled dispensers were recognized: the first exhibiting a carrying capacity of 15 L of water, whereas the second showing a carrying capacity of 20 L. Close inspection on the operation of these machines revealed some important practices. To affix the bottle to the dispenser the bottle was lifted from the floor to a position higher than the waist, gently dropped and then turned through 180º immediately after setting. In many occasions, the water was left for long periods between uses. Such out of service times varied from days to weeks or months, particularly in higher education institutions during summer vacations. Generally, there was an improper maintenance and cleaning of the street water coolers and bottled dispensers.

Data describing the chemistry of the studied samples are recorded in Table 2. It can be noticed that the pH values are located on the weak alkaline scale and the total dissolved solids in the studied water samples comply with the recommendations of the World Health Organization (WHO) and Saudi Standards, Metrology and Quality Organization (SASO) (Table 1). Out of 9 examined water samples, only one sample was contaminated with bacteria. All AlSabeel water samples were weakly chlorinated and fluorinated. Total chlorine in AlSabeel water ranged from 0.04 to 0.10 mg/L. On the other hand, fluoride level varied between 0.9 and 1.3 mg/L. Turbidity levels varied markedly among the studied water samples. About 90% of the coolers accommodated water with turbidity levels below 1 NTU colour units. The remainder of the water samples exhibited turbidity levels over 1 NTU colour units. The turbidity values ranged between 0.38 and 1.3 NTU colour units.

AlSabeel water samples showed slightly alkaline pH that scaled between 7.10 and 7.42. Data from Table 2 reveal that the amount of nitrites in AlSabeel water is safe, where it ranged between 0.012 and 0.018 mg/L. AlSabeel water has a considerable amount of nitrate salts. The latter ranged between 2.1 and 3.8 mg/L. Sulphate content of the studied water samples is shown in Table 2. It could be noticed that the level of sulphate salts varies greatly from 3 to 90 mg/L. 50% of the studied water samples attained adequate amount of sulphate (from 40 to 90 mg/L), while the remainder water samples showed obviously low sulphate (from 3 to 15 mg/L). Phosphate level of the studied water samples is shown in Table 2. It is obvious that the level of phosphate salts in AlSabeel water is relatively low. The maximum value is 5.7 mg/L, while the minimum value is 1.06 mg/L. Iron level in the water coolers is safe. However, iron gradient differed greatly in the drinking water coolers. It varied from markedly low values (less than 0.01 mg/L) to relatively high levels (up to 0.13 mg/L).

DISCUSSION

Water is regarded as the most important and the most abundant nutrient in the human body. Water makes up the majority of our body weight. Chronic water shortage can cause adverse impacts and even death of the living organisms. The human brain is made up of 95% water, blood 83%, skin 70%, liver 86%, kidney 83%, bone 22%, muscles 76% and lungs 90% (Fox, 2008; Sherwood, 2013; Hall, 2015). Over 2% drop in the water content of the human body can switch on signs of dehydration such as vague memory, confusion with simple mathematical problems, and difficulty focusing on smaller print. All the cell and organ functions rely on water for normal performance (Ahmed, 2010). Water plays a key role as a lubricant in digestion and almost all other body processes (Fox, 2008; Sherwood, 2013; Hall, 2015). The water abundant in saliva (95%) helps facilitate mastication and swallowing. Water also lubricates and cushions human eyeballs, joints and cartilages and facilitates their movement. However, the lubrication is diminished during dehydration and the friction becomes greater. The friction can cause joint, knee and back pain, inducing injuries and arthritis. Water is also important to fitness and fat loss (Hall, 2015).

Physicochemical analysis of AlSabeel water showed that the vast majority of the constituents of water comply with the specifications of the World Health Organization (WHO) and the Saudi Standards, Metrology and Quality Organization (SASO). However, bacteriological analysis of the water under investigation revealed about 10% of the cooler-derived drinking water is polluted with bacteria. The pH values of the cooler water were found to range between 6.5 and 7.5 and were in accordance with the guideline (between 6.5 and 8) suggested by Hrudey and Hrudey (2007). Turbidity levels were found to fluctuate between 0.38 and 1.30

NTU colour units. In turbid water (over 1 NTU colour units), microorganisms could be wrapped in the particles and being secured from the effect of the disinfectant. For this reason, the United States Environmental Protection Agency (USEPA) placed a maximum contaminant level of 0.5–1 NTU for public water supplies (Marshall, 2006). Except for only one water cooler, the remainder units dispensing water had less than 0.1 mg/l total chlorine values. Total chlorine was ranged from 0.04 to 0.1 mg/l in the studied water samples, reflecting the presence of impurities and increased opportunities for the microorganisms to flourish whenever occurred in the coolers.

AlQurayyat streets are a stage for many types of contaminants, for example vehicle exhausts, workshops emissions, sandstorms and grey water resulting from street and house washing and cleaning. About 33% of the air pollution comes from dust kicked by vehicles dwelling the streets. Road dust is formed of deposition of vehicles exhausts, tire and brake wear, dust from paved roads or potholes, and dust from construction sites. Emissions from stainless steel welding are a source of concern because of the potential health impacts from hexavalent chromium (Cr^{+6}), which is regarded as a pollutant of concern. Warmer weather helps create more gasoline vapors. Exhaust emissions comprise volatile organic compounds, namely hydrocarbons. Carbon monoxide is one of the most effective byproducts of the common engine exhausts. The environmental protection agency warned people suffering from heart diseases about this toxic gas. EPA (2000) reported that carbon monoxide interferes with convenient amounts of oxygen flowing into the bloodstream. Carbon dioxide contributes primarily to the greenhouse effect and the global warming crisis. According to the EPA (2002), nitrous oxides lead to ozone depletion and smog violence and help precipitating acid rains.

Emissions from diesel engines include carbon monoxide, hydrocarbons, and aldehydes (MECA, 2007). A significant portion of the hydrocarbons is derived from old engines exhausts and have adverse environmental impacts as they are an important component of the smog. Emissions incorporating nitrogen oxides are of great environmental concern as they participate in the formation of smog. Sulfur dioxide is a toxic gas and has an irritating odor (MECA, 2007). Oxidation of sulfur dioxide results in the production of sulfur trioxide, the precursor of sulfuric acid. The latter is contributes to the emissions of sulfate particulate matter. Sulfur oxides exert profound impacts on the environment, where they are the major cause of acid rains.

Vehicle exhausts, particularly those propelled by diesel engines contribute to many public health problems, for example premature mortality, aggravation of respiratory and cardiovascular disease, aggravation of existing asthma, acute respiratory symptoms, chronic bronchitis, and decreased lung function (EPA, 2002). Diesel exhaust is a mixture of thousands of toxic gases and harmful molecules. Diesel particles are formed of small carbon particles that are coated with a composite of compounds released during the fuel combustion down into the exhaust stream. Some diesel constituents are cancer-causing, for example benzene, formaldehyde and nitrogen oxides (EPA, 2002).

AlSabeel water has a considerable amount of nitrate salts. The latter ranged between 2.1 and 3.8 mg/L. Fortunately, nitrite content of the studied water samples was safe, where it ranged from 0.012 to 0.018 mg/L. Environmental Protection Agency (2011) suggested a maximum contaminant level of 45 mg/L of nitrate for the safety of drinking water. Nitrates in water exceeding this level could lead to a common disease, namely methemoglobinemia (the blue-baby syndrome characterized by blue colouration of the lips, nose, ears, and late in peripheral tissues), which is believed to be fatal in childhood (infants and children). The nitrate sources include human and animal wastes and could infiltrate into ground water reserves. Oxygen-deprived children suffer likely suffer from coma and death (U.S. Agency for Toxic Substances and Diseases Registry, 2001).

Lack of maintenance and monitoring is a common feature of AlSabeel water units in AlQurayyat. This negligence can lead to a series of long-term health problems and adverse environmental impacts. Stagnant water accumulated in the vicinity of the coolers may represent a nursing ground for mosquitoes and a favourable medium for bacterial and algal growth that could in turn cause a variety of diseases. It is highly recommended that a maintenance agreement is involved into the supplier of the water coolers and dispensing machines. Such agreement must include regular perfect cleaning of the components of such water suppliers and periodic testing of the water quality. Moreover, regular external user cleaning of the machine is considered either at every bottle change or every one month. A broad-spectrum cleaner sanitizer should be employed. Furthermore, the dispensing machines must be tested for electrical safety before first use.

Contamination of the dispensing machines and street water coolers could be contributed to human contact (i.e. poor personal hygiene aspects) whilst taking a drink, changing and replacing bottles, internal maintenance or touching with dirty hands after toilet breaks. Many infection control and deterioration prevention precautions should be followed to maintain a safe water source. Water bottles must be kept in a cool dark area and should not be stored for more than one month. Bottled water is known to accommodate small number of harmless bacteria as well as other microorganisms whilst processed by the bottling company. Unfortunately, during storage of bottled water ate room temperatures for long periods, bacterial colonies are rapidly developed and outbreak of infection becomes evident. It is suggested that bottled dispensers should not be adopted in the absence of significant usage and regular turnover of bottles. Dispensed water is replaced by atmospheric air that is loaded with a variety of contaminants. In this respect, it is advised that once the bottle is fixed on the dispensing machine, the water should be consumed within a few days.

Hussein *et al*. (2009) assessed the quality of water from some public coolers in Alexandria, Egypt and suggested the following recommendations: (1) the components of water coolers and associated facilities should be made from lead-free materials, (2) water coolers must not be installed in areas where they have the potential to become contaminated, (3) a maintenance agreement should be carried out with the supplier and should include regular comprehensive cleaning of the outer and inner parts of the cooler, (4) regular external cleaning of the cooler, should be performed every three/four weeks using a broad-spectrum cleaner sanitizer, (5) quality of water delivered from the coolers is to be tested at regular intervals, (6) one should leave water to flow from the faucets for 5 minutes before drinking in the early morning in order to get rid of nocturnal bacterial regrowth and (7) a complete system of water purification should be established with the new setting of the coolers.

The studied water samples were not subjected to heavy metals analysis. Data concerning metal analysis in drinking and household water in AlQurayyat are well documented by El-Naggar *et al*. (2104 a, b, and c). The output of these studies indicates that water sources in AlQurayyat is safe with respect to the essential minerals and metals. However, many pollutants could leak into the cooler systems established on the sides of the streets. Al-Saleh (1996) determined trace elements in drinking water coolers collected from 32 primary schools in Riyadh, Saudi Arabia. The analysis showed high concentrations of metals that exceeded the guideline limits recommended by World Health Organization (WHO). AbdulRahman *et al*. (2008) analyzed water samples collected from 400 coolers in Riyadh area for trace metals like Al, Cr, Cu, Fe, Mn, Ni, Pb, and Zn and reported that water from 382 (95.50%) were found to meet World Health Organization (WHO), Saudi Arabian Standards Organization (SASO), and EPA drinking water standards whereas water from 18 coolers (4.50%) were found to have elevated levels of Fe, Pb, and Ni.

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Table (1). Specifications of the World Health Organization (WHO) and the Saudi Standards, Metrology and Quality Organization (SASO) for drinking water.

Components	Measuring Units	SASO	WHO
pH		6.50 –8.50	6.00 –8.50
Total Dissolved Solids	mg/l	1500	1000
Colour	True Colour Units TCU	50.00 TCU	15.00 TCU
Turbidity	Nephrometre Turbidity Units NTU	25.00 NTU	5.00 NTU
Taste		acceptable	acceptable
Smell		acceptable	acceptable
Calcium	Ca mg/l	200	
Magnesium	Mg mg/l	30 – 150	
Total Hardness	mg/l CaCo3	500	500
Manganese	Mn mg/l	0.05	0.1
Sodium	Na mg/l		200
Chloride	Cl mg/l	600	250
Fluoride	Fl mg/l	0.7 – 1.50	1.50
Sulphate	mg/l	400	400

Iron	Fe mg/l	1.00	0.3
Free Chlorine	mg/l	0.2 – 1.00	
Bacteria	no./100 ml	–	–

Table (2). Physicochemical parameters of the AlSabeel water samples which are abundant in AlQurayyat.

Location	pH	TDS	Sulphate	Nitrate	Nitrite	Phosphate	Chloride	Turbidity
A	7.15	226	51	3.7	0.014	1.87	0.07	0.73
B	7.42	603	90	6.3	0.018	2.17	0.05	0.43
C	7.29	142	15	2.3	0.016	1.26	0.08	0.76
D	7.31	207	48	3.8	0.016	1.35	0.08	0.56
E	7.22	185	43	3.5	0.015	1.06	0.04	0.43
F	7.22	186	50	3.1	0.015	1.55	0.09	0.38
G	7.10	87	3	2.4	0.015	5.70	0.09	0.85
H	7.21	18	50	2.2	0.013	1.43	0.06	0.91
I	7.10	98	10	2.1	0.012	3.09	0.10	1.3

Fig. (1). The poor sanitary condition of a street cooler in AlQurayyat.

Fig. (2). The filter of a street cooler accommodating a variety of impurities and contaminants.

Fig. (3). A steel cup held by steel robe. Rust could be seen in the vicinity of the drinking zone.

Fig. (4).). Highly contaminated water cooler, with much rust.

Fig. (5). A new street cooler provided with disposable paper.

Fig. (6). A powerful filter of a newly operated cooler (one month after setting).