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Original Research Paper

Comparative Study of the Quality of Bottled Drinking Water Called Kawthar from Some Commercial Treatment Plants in Taiz City, Yemen

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ABSTRACT

Water supply in Taiz city contains high concentration of different elements so it is not suitable for drinking purpose, therefore, the people in the city depend upon commercial water from different units of water treatment. This type of water is commonly called Kawthar. Water quality with regards to pH, Cl_2, HCO_3, hardness, Ca, Mg, NO_3, TS, TASA (total anions of strong acids), coliform group and *E. coli* was tested. There were variations in some physico-chemical characteristics in the samples but the concentration of these parameters was within the permissible limit of WHO. The reason for this is that all waters used for the treatment were brought from groundwater of good quality from outside the city. Bacterial parameters did not show any growth in coliform group and *E. coli* and in MPN test show results within the permissible limit, except in K7 and K8 samples. Relation among water quality parameters reveals a significant positive correlation between pH and TASA, TS, SO_4 and hardness. Total hardness shows a positive correlation with TS. SO_4 shows a positive correlation with TASA.

INTRODUCTION

Yemen is among the ten countries experiencing water scarcity in the world and the poorest in terms of resources in the Middle East. Water crisis has become a real threat to human life of Yemeni due to the increase in population and the widespread cultivation of khat to which Yemenis are addicted who chew its leaves. Cultivation of khat consumes more than 60% of the groundwater which is the major source of water in Yemen.

It has become more and more difficult to meet human needs with sufficient quantities of safe and clean water of acceptable quality (Gleick 1993,1996, Postel 2000, WWC 2000).

Taiz is one of the first Yemeni provinces which suffers from water crisis as up water distribution cycle in the provincial capital city of Taiz is sometimes nearly of two months. The biggest problem that these waters are not of drinking quality because they contain a high proportion of salts which makes people in the city to buy water from treatment plants distributed across the city and called Kawthar water.

There are many chemicals that may occur in drinking water; however, only a few are of immediate health concern in any given circumstances.

The use of biological indicators is perhaps even more time consuming than chemical analyses. Biological indicators can serve as effective tools for identifying areas generally impacted by pollution loading and groundwater and surface water exchange. Bacteria exist in groundwater thousands of feet below the land surface (Frederickson et al. 1991). However, invertebrates are typically found within the shallow groundwater zone, many macroscopic invertebrates have been identified. Furthermore, the species richness and community structure of these organisms have been shown to change with alterations in groundwater quality. Therefore, the relative presence or absence of different communities or populations of organisms may reflect the impact of changes in regional groundwater quality. As a result, the organisms living within the shallow groundwater zone can serve as indicators of the quality of groundwater resource (Job & Simons 1994).

To now suitability of Kawthar water for drinking purposes, we have analysed physico-chemical and biological quality of water samples.

MATERIALS AND METHODS

Sampling: Water samples were taken randomly from 9 plastic bottles, each sample belonging to a unit of water treatment. A bottle each with a capacity of 1.8 litres from the stores of the commercial treatment units in Taiz city was taken and closed and sealed.

Physico-chemical and bacterial parameters: Physico-chemical and three bacterial parameters were analysed by following standard methods given in Trivedy & Goel (1986) and APHA (1992). The analyses of these samples were done in laboratories of Yemen Standardization, Metrology and Quality Control Organization, Sana'a, Yemen.

RESULTS AND DISCUSSION

Taste and odour: Taste and odour can originate from natural inorganic and organic chemical constituents and biological sources and processes, from contamination by synthetic chemicals from corrosion or as result of water treatment (e.g. chlorination). Taste and odour may also develop during storage and distribution due to microbial activity (WHO 2004).

The chlorine added for disinfection of water reacts sometimes with organic matter to form chlorophenol which is highly odorous. Some organic substances imparting odours are toxic (Trivedy & Goel (1986). All water samples studied were unpalatable in taste, but odourless (Table 1).

pH: pH is considered as an important factor and is the result of the interactions of various substances in solution in the water and also of numerous biological phenomena. It is an important parameter in water quality assessment as it influences many biological and chemical processes within aquatic habitat. The pH varied from the lowest value of 6.99 from K8 sample to the highest value of 7.88 in the K3 sample. The pH values were around neutral in most water samples. Natural water with pH value of 6.0 to 8.0 can be considered as neutral water and majority of potable water fall within this category (Bulushu 1987). In this study, mean values of pH were circumneutral and well within the permissible limits of 6.5 to 8.5 (WHO 1993, EPA 1985, APHA 1992 and YSMO 1999).

Chloride: Chloride occurs naturally in all types of water. Most chlorine occurs as chloride (Cl^-) in solution. It enters surface waters with the atmospheric deposition of oceanic aerosols, with the weathering of some sedimentary rocks (mostly rock salt deposits), from industrial and sewage effluents, and agricultural and road run-off. The Cl^- in groundwater may be contributed from minerals like mica, apatite and hornblende and also from the liquid inclusions in the igneous rocks (Das & Malik 1988). The lowest value of Cl^- content was 18.4 mg/L recorded in K1 water sample and the highest of 29.78 mg/L recorded in K5 water sample. The Cl^- content in the present study was within the permissible limit of 250 mg/L prescribed by WHO (1993) and 300 mg/L by YSMO (1999).

HCO_3: Bicarbonate ions are the principal alkaline constituent in almost all water supplies. Bicarbonate water alkalinity is introduced into the water by CO_2 dissolving carbonate-containing minerals. Alkalinity control in water is important in boiler feed water, cooling tower water, and in the beverage industry. The HCO_3 recorded varied from the lowest value of 4.88 mg/L from K4, K6, K7 and K9 samples to the highest value 7.32 mg/L in the K2, K5 and K8 samples. The HCO_3 content in the present study samples was within the permissible limit of 350 mg/L prescribed by YSMO (1999).

Hardness: The hardness is mainly caused by the multivalent metallic ions like calcium and magnesium present in the water. Polyvalent ions of some other metals like strontium, iron, aluminium, zinc and manganese etc. are also capable of precipitating the soap and thus contribute to the hardness. However, the concentration of these ions is very low in natural water, therefore, the hardness is generally measured as concentration of only calcium and magnesium (as calcium carbonate), which are higher in quantities over other hardness producing ions. The lowest hardness concentration in the study samples was 92 mg/L in K9 sample, and the highest of 180 mg/L in K7 sample (Table 1). The concentration of hardness in all samples analysed in the present investigation was within the permissible limits of 300 mg/L (WHO 1991 and YSMO 1999).

Calcium (Ca): It is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in Ca minerals, particularly as carbonate and sulphate, especially limestone and gypsum. High concentration of Ca is due to its presence in rocks and from where it has leached to groundwater. Ca as such has no hazardous effect on human health. It is one of the important nutrients required by all the organisms. High concentration of Ca is not desirable in washing, laundering and bathing owing to its suppression of formation of leather with soap, scale formation in utensils and boilers. It coagulates with soap and makes dirty layers on sinks, wash basin and tubs (Motir Sharma 2004). The lowest Ca content was 18.43 mg/L in K9 sample, and the highest of 48 mg/L recorded in K1 sample (Table 1). Calcium in all the samples was within the permissible limit of 100 mg/L by WHO (1984) and YSMO (1999).

Magnesium (Mg): It is common in natural waters as Mg^{2+} and along with Ca^{+2}, is a main contributor to water hardness. Mg arises principally from the weathering of rocks containing ferro-magnesium minerals and from some carbonate rocks. Mg occurs in many organo-metallic compounds and in organic matter, since it is an essential element for living organisms. Natural concentrations of Mg in freshwaters may range from 1 to > 100 mg/L, depending on the rock types within the catchment. The lowest mean concentration of Mg was 4.8 mg/L recorded in K1 sample, and the highest of 21.4 mg/L recorded in K7 sample (Table 1). All the groundwater samples had Mg values more than the permissible limit of 30 mg/L (WHO 1984 and YSMO 1999).

Nitrate: The nitrate ion (NO_3^-) is the common form of combined nitrogen found in natural waters. It may be biochemically reduced to nitrite (NO_2^-) by denitrification processes, usually under anaerobic conditions. The nitrite ion is rapidly oxidised to nitrate. Natural sources of nitrate to surface waters is from igneous rocks, land drainage and plant and animal debris. The potential for pollution of agricultural areas varies depending on land use and fertilization history, position relative to the stream or water table, underlying geology, hydrological, chemical and physical soil properties and the climatic conditions in the area (Rogowski 1990). Many sources contribute to the nitrate content in the groundwaters like leaching of fertilizers, salts from agriculture (Lerner 1986, Mull et al. 1992, Bajwa et al. 1993, Ynag et al. 1999, Eiswirth et al. 2000), and from sewerage and water supply networks from residential areas (Anderson 1993, Vijay Kumar 1994, Eckhardt & Stackelberg 1995), and also from commercial and industrial areas (Prasad & Ramchandra 1997. A high nitrate level in groundwater (above 45 mg/L WHO 1984) and its consumption can lead to methaemoglobinaemia and human cancer through the formation of N-nitrosamines and nitrosoamides (Fraser et al. 1980). The lowest nitrate content was 8.99 mg/L recorded in K9 water sample, and the highest of 20.55 mg/L recorded in K6 water sample (Table 1). The nitrate content in the present investigation was well below the highest desirable limit of 45 mg/L as prescribed by WHO (1993) and YSMO (1999).

Sulphate (SO_4): Natural water has of SO_4 in varying amount. Gypsum and anhydrite are important sources of sulphate in water. The SO_4 is necessary for plant nutrition. High concentration of SO_4 increases salinity in soil. Water containing more than 1000 ppm of sulphate has a disadvantage for plant with respect to absorbing of Ca. If SO_4 concentration in water is above 1000 ppm, this water is called corrosive water. It is noteworthy that the lowest value of SO_4 content was 8.85 mg/L in K5 water sample, and the highest of 62.7 mg/L in K3 water sample (Table 1). The SO_4 content in the present study was within the permissible limit of 250 mg/L as prescribed by WHO (1993) and 300 mg/L by YSMO (1999).

Total solids (TS): TS is the sum of all dissolved and suspended solids in water. TS could consists of organic and inorganic substances, microorganisms and larger particles such as sand and clay. The lowest total solids (TS) was 130 mg/L in the K9 sample, and the highest of 220 mg/L in the K7 sample. TS content of the studied samples was within the permissible limit of 1500 mg/L as prescribed by (WHO 1984).

Total anions of strong acids (TASA): These are sum total of chloride, sulphate and nitrate ions. TASA varied from a low concentration of 48.48 mg/L recorded in K8 water to a high concentration of 102.48 mg/L recorded in K3 water (Table 1).

MPN of coliforms: It was determined by the method of multiple fermentation tubes as given in (APHA 1985) and (WHO 1998). MPN test showed varied coliform bacterial growth from a low of 2/100 mL recorded in K1, K2, K3, K4, K5 and K9 water to a high number of 13/100 mL recorded in K8 water sample. The coliform group using MPN method was within the permissible limit in the present investigation as prescribed by YSMO (1999) except K7 and K8 samples which was higher than the permissible limit. So we must make sure that the disinfection process during the packing process has correctly been done for K7 and K8 samples.

Total coliform (per 100mL): Total coliform bacteria was determined using membrane filter technique as described by APHA (1992). 100mL of water sample was filtered under vacuum, through a bacteriological cellulose acetate membrane. Bacteria were retained on the surface of the membrane which is placed on M-Endo Agar selective media in sterilised plates and incubated at a temperature of 35-37°C for 24 hours. The colonies with a metallic sheen are the colonies of the coliform bacteria. The metallic sheen was seen covering the entire colony or it appeared only in the central area or the periphery, which could be counted directly. Coliform bacteria did not show any growth on the media in all the water samples (Table 1).

***E coli*:** The *E. coli* test is recommended as a measure of ambient recreational freshwater quality. Epidemiological studies have led to the development of criteria which can be used to promulgate recreational water standards based on established relationships between health effects and water quality (Dufour 1984). The results did not show any growth of this type of bacteria on the selective media for all the water samples studied (Table 1).

Correlations: The correlation of environmental (physico-chemical) parameters in all the water samples are given in Table 2. Nearly similar correlations were reported by Bahura (1998) who studied physico-chemical characteristics of a highly eutrophic temple tank at Bikaner, Rajasthan; Mayur et al. (2006), who studied the assessment of drinking water quality of various railway stations at Ahmadabad to Khedbrahma Train Route in Gujarat, India; Baruah (1996) who studied the effect of paper mill effluent on the water quality of receiving wetland; Gupta et al. (1996) who studied the evaluation of groundwater pollution potential of Agra, India; Lingeswara et al. (2005), who studied the groundwater quality of Nellore coast; Arunkumar & Sabu Joseph (2006) who studied the environmental degradation of coastal ecosystems, southern Kerala; Purandara et al. (2003) who studied the impact of sewage on groundwater quality; and Sudhir

Table 1: Summary of physico-chemical and bacterial parameters in water samples.

Sl No.	Parameters	Water samples K1	K2	K3	K4	K5	K6	K7	K8	K9
1	Taste	Unpalatable	Unpalatable	Unpalatable	Unpalatable	Unpalatable	Unpalatable	Unpalatable	Unpalatable	Unpalatable
2	Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless
3	pH	7.74	7.63	7.86	7.25	7.36	7.60	7.80	6.99	7.06
4	Chloride	18.4	19.8	19.85	19.85	29.78	19.85	25.5	26.95	22.69
5	HCO_3	7.30	7.32	6.1	4.88	7.32	4.88	4.88	7.32	4.88
6	Hardness	140	140	148	124	152	142	180	116	92
7	Ca	48	35.2	25.6	27.25	29.66	28.86	36.8	24.05	18.43
8	Mg	4.8	12.6	20.4	13.62	18.97	17.02	21.4	13.62	11.19
9	NO_3	17.72	16.39	19.93	18.6	15.75	20.55	12.4	11.65	8.99
10	SO_4	56.9	55.7	62.7	10.69	8.85	9.26	34.15	9.88	17.9
11	TS	184.9	195.8	207	182	212	189.6	220	165.8	130
12	TASA	93.02	91.89	102.48	49.14	54.38	49.66	72.05	48.48	49.58
13	MPN	2/100mL	2/100mL	2/100mL	2/100mL	2/100mL	2/100mL	8/100mL	13/100mL	2/100mL
14	Coliforms	Negative	Negative	negative	Negative	Negative	negative	Negative	negative	Negative
15	*E. coli*	Negative	Negative	negative	Negative	Negative	negative	Negative	negative	Negative

Note: The units are in mg/L except pH, taste and odour, otherwise stated.

Table 2: Relationship between physico-chemical parameters in water samples.

Parameters	pH	Cl_2	$CaCO_3$	TH	Ca	Mg	NO_3	SO_4	TS	TASA
TASA	0.788*	NS	NS	NS	NS	NS	NS	0.987**	NS	
TS	0.736*	NS	NS	0.953**	NS	NS	NS	NS		
SO_4	0.737*	NS	NS	NS	NS	NS	NS			
NO_3	NS	NS	NS	NS	NS	NS				
Mg	NS	NS	NS	NS	NS					
Ca	NS	NS	NS	NS						
TH	0.786*	NS	NS							
HCO_3	NS	NS								
Cl^-	NS									
pH										

1. Values are Pearson's correlation coefficient, a 2- tailed test was applied and calculated after $\log_{10}$ transformation of all variables after scaling so that all values were > 1, n= 24, * Correlation is significant at 0.05 level, ** Correlation is significant at 0.01 level and NS = Non Significant.
2. Cl^- = Chloride, HCO_3 = Bicarbonate, HD = Hardness, Ca = Calcium, Mg = Magnesium, NO_3 = Nitrate, TS = Total solids, TASA = Total anions of strong acids.

et al. (2000) who studied the quantification of fluoride in groundwater in rural area of Tosham Subdivision, District Vhiwani, Haryana, India. It was found that there are six positive correlations in all the water samples studied (Table 2).

CONCLUSION

The results of the analysis of bottled drinking water (Kawthar) showed variations in some physico-chemical parameters, but the concentrations were within the permissible limit of WHO. Similarly, the bacterial parameters did not show any growth in coliforms and *E. coli* except a few colonies indicating no major pollution hazard. The bacterial test of the samples was within the permissible limit, except in K7 and K8 samples, where the MPN of coliforms was little higher than the permissible limit, so we must make sure that the disinfection process during the packing process has been properly made. The correlation among water quality parameters reveals a significant positive correlation between pH and TASA, TS, SO_4 and hardness. Total hardness shows a positive correlation with TS. Sulphate shows a positive correlation with TASA.

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