Assessment of Drinking Water Quality

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Abstract: It is needless to say that the quality of water is of vital importance to public health. Efficient surveillance and check strategies are important for executing a high quality management of this resource. Fourty eight water samples were collected randomly from different localities within Tabuk in the period between April 2012 and July 2012. Water samples were subjected to Chemical, Bacteriological and Parasitological examination. Drinking water samples taken in the study are almost following the WHO and US-EPA standards with few exceptions in the TOC (41.2%), Fluoride (33%), Hg (17%) , but the alkalinity of water does not make it very harmful. Tap water is more alkaline than other samples with higher salinity than standard, high TDS and hence EC , it also suffer from high presence of TOC, Fluoride, bromide and mercury, so it is least quality to be used as drinking water. Commercial Zamzam water has proven to contain high levels of fluoride, TOC and bromide when compared to drinking water. It also has higher salinity % , TDS and hence higher electrical conductivity than drinking water. For bacteriological examination, 12% of water samples were exceeded the WHO guideline value (>10cfu/100ml), as the total coliform count was determined on each sample through the most probable number of colony forming units method. Parasitological examination revealed that giardia cysts were detected in 25% of water samples and *C. parvi* oocysts were detected in 16.6 % of water samples by both microscopy and ELISA methods.
[Nagwa S.M. Aly, Rabab M. Ali and Hemmat A. El badawy. **Assessment of Drinking Water Quality.** *Life Sci J* 2013;10(1):1795-1803]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 259

Key words: Drinking water-Chemical assessment- *Colifroms- Giardia lamblia-Cryptosporidium parvi*

1. Introduction

It is needless to say that the quality of water is of vital importance to public health. Efficient surveillance and check strategies are important for executing a high quality management of this resource (Alzahrani and. Gherbawy 2011). In Saudi Arabia, there are increasing needs of water as there is rapid growth of population and agricultural activities in increasing around the country (Al-Ahmadi, 2005). Once pollutants enter a groundwater aquifer, the environmental damage can be severe and long lasting, partly because of the very long time needed to flush pollutants out of the aquifer (**Khanfar,** 2008). It can be beneficial to detect deterioration in the quality of water resources and to facilitate appropriate and timely corrective actions with a minimal negative impact on public health (Ikem *et al.,* 2002). It is often assumed that natural, uncontaminated water from deep wells is clean and healthy, and this is usually true with regard to bacteriological composition (AlOtaibi, 2009). However, bacterial pollution of water sources may occur and is mostly derived from watershed corrosion as well as drainage from sewage, swamps, or soil with high humus content. Such suspected water sources cannot be used without caution for human drinking purposes because of the inherent health risks (Kistemann *et al.,* 2002 and Fewtrell and Bartram, 2001). There are bio-indicators of faecal pollution which are non-pathogenic microorganisms including fecal coli, coliform, fecal streptococci and other pathogens (Stevens *et al.,* 2003). Cryptosporidium spp. and *Giardia duodenalis* are two protozoan parasites that are transmitted by water and affect humans (Thompson, 2004). These parasites are a major cause of diarrheal disease in humans and animals worldwide, causing high morbidity in their hosts, and in immunocompromised hosts, they can lead to death.

Giardiasis is the most frequently diagnosed water borne disease and the major public health concern of water utilities in the developed and developing nations, water is an important vehicle for the transmission of giardia to humans (Hogue *et al.,* 2002).

Cryptosporidium causing chronic diarrhea in people with weakened immune systems and is sometimes fatal (Mac Kenzie *et al.,* 1994). Pollution of the rivers and lakes, by oocyst leading to waterborne disease, thus, ultimately the natural transmission cycle is completed (Morgan-Ryan *et al.,* 2002). Infective oocysts are environmentally

resistant, are small enough to penetrate the physical barriers of water treatment, and are resistant to many disinfectants used in the water industry (Moore *et al.,* 1998). In Saudi Arabia, the quality of drinking water is currently receiving some attention from environmentalist and water scientists (Al-Redhaiman and Abdel Magid, 2002 , Al-Turki and Abdel Magid, 2003).

SASO developed drinking water standards for both bottled and un-bottled water to define a quality of water that sustains a healthy population. These standards set limits for the permissible and maximum contaminants level of chemical elements and indicator microorganism that endanger the health of consumers (SASO, 1984). A substantial number of these standards are based on the World Health Organization international standards for drinking water (WHO, 1993). The main objective of this study was to assess the chemical, bacteriological and parasitological water quality for suitability to human health.

2-Material and Methods

2.1- Sample collection:

Forty eight water samples were collected randomly from different localities within Tabuk in the period between April 2012 and July 2012.

Water samples were kept in a screw capped 4.0-litre plastic container. Chemical examination was carried out to 12 water brands. Bacteriological and Parasitological examination was carried out to 36 water samples.

2.2- Sample examination:

Samples was examined individually. Subjected to Chemical, bacteriological and parasitological examination.

2.2.1-Chemical examination

Water samples were collected in polythene bottles, and sent for analyses to *Central Laboratories Unit, National institute of Oceanography and Fisheries, Ministry of Higher Education & Scientific Research, Egypt.*

The following procedures were used for analysis:

1) For determination of; Lead, copper,chromium, cadmium, nickel and manganese by Flame - SHIMADZU atomic absorption spectrophotometer AA – 6800
2) For Mercury determination using HVG-SHIMADZU atomic absorption spectrophotometer AA – 6800
3) For Calcium, Magnesium, sodium and potassium using flame photometry
4) Measuring pH and electrical conductivity

2.2.2- Bacteriological examination:

Coliforms bacteria were determined by incubation of samples into lactose broth as presumptive test. The test tubes are placed in incubator at 35ºC for 24 hours for gas production. To confirm the presence of coliform, gas is also produced in incubation into Brilliant Green Bile broth at 35ºC for 24 hours. Water quality analysis was based on the most probable number of colony forming units (cfu) per 100 ml (Al Sabahi *et al.,* 2009).

2.2.3- Parasitological examination:

A. Sample Processing

Water samples were filtered through a 47 mm diameter, 0.450 µm pore size membrane filter (Bakir *et al.,* 2003).

B. Microscopic examination

Materials retained by filters were examined microscopically as a 0.9% saline smear for parasite cysts, trophozoites and helminthes eggs. A portion of each sample was stained with Lugol iodine on a separate slide. Fresh preparations were examined visually at magnifications of 100X and 40X over approximately 100 fields and then cold acid-fast and a trichrome staining technique were applied for the identification of *C. parvum* and *G. lamblia* (Bakir *et al.,* 2003).

C.Enzyme linked Immunosorbent Assay (ELISA) for *Giardia lamblia and Cryptosporidium parvum* (Siddons *et al.*, 1991)

ELIA was used to analyze the collected environmental water samples. ELISA was performed on filtered materials according to the manufacturer's instructions (Giardia, Cryptosporidium, CELISAPATH, Cellabs Pty Ltd., Australia).

3- Results

3.1- Chemical examination

Table 1 shows Conductivity ,total dissolved salts, salinity and pH of water samples.

Tap water is more alkaline than other samples with higher salinity than standard, high TDS and hence EC , it also suffer from high presence of TOC, Fluoride, bromide and mercury, so it is least quality to be used as drinking water.

Commercial Zamzam water has proven to contain high levels of fluoride, TOC and bromide when compared to drinking water. It also has higher salinity %, TDS and hence higher electrical conductivity than drinking water.

Tables 2 and 3 shows Anions, total organic carbon and metal contents of water samples. Drinking water samples taken in the study are almost following the WHO and US-EPA standards with few exceptions in the TOC (samples 1,2,3,5 and 8), Fluoride (samples 4,5,8and 10), Hg (7 and 8) , but the alkalinity of water does not make it very harmful. High presence of TOC, Fluoride, bromide and

mercury, so it is least quality to be used as drinking water.

3.2- Bacteriological examination

Bacteriological safety of different sources treated water was determined by the total coliform standard of WHO (WHO, 2004). Coliforms were detected in eleven out of thirty six (31%) drinking water brands that were included in this study. It showed growth when inoculated in lactose broth at 35°C for 24 hours. All other samples in the study showed no growth when planted in the same media at 35°C for 24 hours. In this study, 12% of water samples were exceeded the WHO guideline value (>10cfu/100ml), as the total coliform count was determined on each sample through the most probable number of colony forming units method.

3.3- Parasitological examination

Over the course of the 6-months study period, a total of 36 water samples were analyzed for the detection of and *Giardia lamblia* cysts and *Cryptosporidium parvi* oocysts. Initially, 7 of 36 brands were found to be positive for giardia cysts and/or trophozoites by microscopy. Then, 2 of 31 suspect water brands which were negative by microscopic analysis were then found to be positive for *G. lamblia* cyst with ELISA. Thus, giardia cyst was detected in 9/36 (25%) water brands in the study. Similarly, 6/36 (16.7%) of analyzed water brands contain *C. parvi* oocysts by both microscopy and ELISA methods.

Table (1) : Conductivity ,total dissolved salts, salinity and pH of water samples

Sample	Cond. (µ S)	TDS (mg/L)	Salinity‰	pH
1	175	63	0.1	7.55
2	123.8	58	0.1	7.53
3	209	99	0.1	7.57
4	132.6	63	0.1	7.44
5	273	130	0.1	7.44
6	201	96	0.1	7.55
7	124.2	59	0.3	7.82
8	182.8	87	0.1	7.13
9	680	329	0.3	7.99
10	209	99	0.1	7.18
11	336	160	0.2	7.38
12	860	413	0.4	7.09

Table (2) : Analysis of Anions and total organic carbon (mg/L) in Tabuk drinking water samples

Sample	NO_3^-	$*Cl^-$	$*SO_4^{2-}$	TOC	F^-	Br^-	PO_4^{3-}
EPA (mg/L)	10.0	-	200-300*	250*	2.0 in treated water And 4.0 in source	1.5	2.4	0.5*
1	6.34	22.86	66.47	18.15	16.00	ND	0.29	ND
2	4.34	7.14	53.18	25.19	8.00	ND	ND	0.80
3	3.67	5.71	53.18	20.00	12.00	1.70	ND	4.80
4	4.00	10.00	79.76	24.44	ND	6.30	0.19	ND
5	7.67	20.00	86.41	23.33	14.00	6.30	ND	0.004
6	7.34	7.14	66.47	19.63	ND	ND	0.09	0.80
7	8.01	12.86	73.12	20.37	ND	ND	0.20	5.33
8	7.01	4.29	59.82	26.30	20.00	14.40	0.69	0.80
9	8.01	12.86	53.18	25.93	22.00	14.40	0.40	6.40
10	8.34	18.57	46.53	17.41	ND	36.80	ND	1.87
11	7.34	25.71	53.18	20.00	12.00	ND	0.11	7.20
12	8.34	80.00	39.88	66.30	32.00	12.10	0.40	15.19

*No health-based or EPA guideline value has been derived.

May affect acceptability of water, EPA, *Environmental Protection Agency*

Table (3): Analysis of some metals in Tabuk drinking water samples and Commercial Zamzam water

SAMPLE	Pb (µg/l)	Cu (µg/l)	Cr (µg/l)	Cd (µg/l)	Ni (µg/l)	Mn (µg/l)	Hg Conc. (µg/l)	As (µg/l)	Se (µg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)
*EPA	0.05 mg/L	1.3 mg/L	0.1 mg/L	0.005 mg/L	0.05 mg/L	0.4 mg/L	(2.0 µg/l)	0.01	0.05	No maximium limit set by EPA			50 mg/L
1	4.732	3.452	3.342	0.326	0.424	9.63	2.020812	ND	0.56	50	39.9	20	250
2	6.084	4.324	3.02	0.454	0.744	10.462	1.676349	0.03	0.98	130	79.6	20	180
3	5.948	6.856	1.818	0.182	1.22	14.088	2.089761	ND	0.48	120	29.3	20	250
4	5.948	4.39	1.7	0.282	1.726	9.958	1.745298	ND	0.18	140	39.1	25	210
5	10.004	7.482	1.876	0.848	1.354	12.35	2.12501	ND	0.14	130	159.2	30	280
6	4.732	30.81	3.724	0.454	1.248	0.252	1.952004	ND	0.53	120	89.4	25	230
7	4.596	7.662	4.398	0.202	1.328	2.2	2.296467	0.01	0.98	160	29.7	25	190
8	4.596	3.666	1.818	0.214	0.902	8.634	2.526015	0.02	0.03	150	79.1	20	210
9	4.732	7.926	6.186	0.378	1.248	10.136	3.008376	0.03	0.05	110	289.8	25	156
10	4.462	2.532	3.284	0.32	0.982	6.256	2.388258	0.01	1.10	90	39.1	25	130
11	5.408	7.942	10.994	0.256	1.248	14.014	1.699332	0.04	0.72	120	39.2	20	250
12	4.596	3.074	5.014	0.214	1.618	10.642	ND	ND	0.40	190	49.8	100	230

* EPA, *Environmental Protection Agency guide line*

4- Discussion

In the Kingdom of Saudi Arabia, drinking water is obtained from several sources including desalinated seawater, as well as ground water from wells, (Abdulla, 1997) and bottled water.(Paul *et al.,* 1998). According to the World Health Organization, some chemicals in water have no guideline values such as, Bromide which occurs in drinking-water at concentrations well below those of health concern, Chloride and Sulphate because it is not of health concern at levels found in drinking-water, however, Excessive chloride concentrations increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water, Sulfate is one of the least toxic anions. The presence of a high concentration in the drinking water may lead to dehydration, stomach complaints, and possibly diarrhea. In general, the adverse affect on the taste is said to be minimal at levels lower than 250 mg/l for both chloride and sulphate.

Even calcium, magnesium and potassium have no guideline values, inspite of the importance of these elements to the human body where the body needs 2:1 magnesium to calcium ratio otherwise calcium becomes polluting for the body (Remer, 1994) which is the case of all samples except sample 5 and 9 (tap water) as seen in Table (3). The taste limit for calcium is, somewhere, between 100 and 300 mg/L and for magnesium it is probably lower (Al-ahmadi *et al.,* 2009) Whereas some other chemicals have guideline values which should not be exceeded otherwise risk on health takes place (WHO, 1993)

Flouride, is very effective in prevention of dental caries, however the optimum range of fluoride varies according to temperature of the place, for warmer countries the amount should be lowered as people drink more water . Dean et al reported an inverse relationship between caries prevalence and drinking water with different fluoride levels stating that exposure to water containing about 1 ppm fluoride in drinking water reduces caries experience by 50 % whereas fluoride levels higher than 1.5 ppm in temperate countries is known to cause dental fluorosis. (Dean *et al.,* 1942 and Slade *et al.,* 1996).

Bromide , concentrations in seawater range from 65 mg/l to well over 80 mg/l, in fresh water from trace amounts to about 0.5 mg/l and in desalinated waters up to 1 mg/l.

The results of human studies suggest a conservative no-observed-effect level(NOEL) of 4 mg/kg body weight per day, giving an ADI of 0–0.4 mg/kg body weight, including a safety factor of 10 for population diversity.

Arsenic is found widely in Earth's crust in oxidation states of –3, 0, +3 and +5, often as sulfides or metal arsenides or arsenates. In water, it is mostly present as arsenate (+5), but in anaerobic conditions, it is likely to be present as arsenite (+3). It is usually present in natural waters at concentrations of less than 1–2 µg/l. However, in waters, particularly ground waters, where there are sulfide mineral deposits and sedimentary deposits deriving from volcanic rocks, the concentrations can be significantly elevated.

Cadmium and cadmium compounds are classified as carcinogenic through inhalation, but there is no evidence of carcinogenicity by the oral route and no clear evidence for the genotoxicity of cadmium. The kidney is the main target organ for cadmium toxicity.

Lead, Exposure to lead is associated with a wide range of effects, including various neurodevelopment effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes. So

it is very important to decrease the lead level as low as possible. Manganese, It is noted that concentrations below the health-based value (0.4 mg/L) may give rise to black deposits in water mains over an extended period, which is expected in all samples under investigation, table (3). Mercury, the mean dietary intake of mercury in various countries ranges from 2 to 20 µg/day per person. The toxic effects of inorganic mercury compounds are seen mainly in the kidney in both humans and laboratory animals following short-term and long-term exposure. Nickel, The guideline value for nickel in drinking-water is 50- 70 µg/L established after provocation of fasted patients with an empty stomach (Nielsen *et al.,* 1999). Comparison of the concentration of chemical constituents of drinking, tap water in tabuk and commercial zamzam water with respect to the drinking water standards of WHO 1993 and to EPA showed that samples4,5,8,9,10 and commercial zamzam(12) had contents above the limit for fluoride, concentrations of bromide in all samples exceeded the optimum range which are collected in table (2). From table (3) , it is clear that the concentrations of the mercury in samples 5,7,8 and 9 exceeded the acceptable range and for selenium it is found to be more than standard in all samples except 8 and 9 while all tested samples had relatively high concentration of sodium . It is also clear from table (2) that the TOC is greater than the standard limit in all tested samples (Martin, 1994). The results in Table (1) showed that the total dissolved solids (TDS) ranges from 63 to 160 mg/L except for sample 9 (tap water) which showed TDS = 329 ppm and sample 12 (commercial zamzam) which showed TDS = 413mg/L, which make samples 9 and 12 classified as moderate mineral water (Lind, 1979).

The electrical conductivity of drinking water samples collected in Table (1) ranges from (123.8-860) µs which is acceptable for drinking water and results from the total dissolved solids and salts. The values of Electrical conductivity (EC) is almost half the values of TDS as proved in many studies (Argo, 2003) and the relation we have got is; TDS ppm = 0.472 x EC Fig. (1).

The pHs of all water samples are collected in Table (1) showing slightly alkaline behavior in the range (7.09 - 7.99). However, Kellas *et al.,* 1996 stated that alkaline drinking water plays an important role in ridding the body of mercury and other toxins. The more acidic the body is the more it holds onto (heavy) metals. Heavy metals in turn create a high oxidative stress that acidifies the body. Consequently, alkaline water has been used for improving bone density and healing (Wynn *et al.,* 2009).

The WHO has established revised guidelines for drinking water quality that can be applied to national standards and legislation, taking into account the national climatic, geographic socioeconomic and infrastructural characteristics, as well as national health-based targets (WHO, 2004). Total coliform and *E. coli* counts are used worldwide as indicators for faecal contamination of drinking and recreational bathing water (Rompre *et al.,* 2002). Safe drinking water should have nil *E. coli* in 100 ml of water (WHO, 1993). Contamination after collection and during transportation and storage is increasingly being recognized worldwide as an issue of public health importance (Lindskog and Lindskog, 1988). To our knowledge, no specific study has been done to assess microbiological quality of drinking water resources in Tabuk (KSA).

Results obtained in this study show that the bottled water sold in various parts of Tabuk (KSA) exhibited variable characteristics in terms of their microbiological quality. Some brands of bottled drinking water studied were contaminated with coliform bacteria although to varying levels of counts per 100 ml of drinking water. Some of the brands failed to meet the WHO drinking water standard of the presence of coliform per 100 ml water making them unsuitable for human consumption. Our study showed that 31% showed bacterial growth. Erginkaya and Var (1997) in a study on microbial quality of bottled water in Turkey had stated that coliform bacteria were found in 12 of the 130 bottles of water analyzed. According to Edberg (1996), no treatment process or method used in mass production of drinking water yields a sterile product; it only produces a safe product devoid of pathogenic organisms. Appropriate treatment processes should therefore be utilized for production of quality and safe packaged drinking waters. Inadequate sanitation and unhygienic practices account for the major source of microbial contamination of any potable water (Sahota, 2005).

The microbial contaminations of packaged drinking water could be influenced by factors such as their raw water source, treatment process employed and hygienic practices observed in production (Geldreich, 1996). Well water is usually contaminated by surface waters especially during the rainy season and inadequate attention paid to the environmental sanitary qualities of these wells could result in wild animals and birds constituting natural sources of zoonotic pathogens. Once the container is filled and sealed, bottled water may remain on the grocery shelf or stored in the home for weeks or sometimes months (Rosenberg, 2003). It is well known that microorganisms attach on the surface walls of such containers during storage (Momba and Mnqumevu, 2000). Attached bacteria can detach from the surface walls and lead to continuous contamination of the water phase. In a study done by Kivanc *et al.* , he

reported that coliform bacteria was found in 39.2% of 102 samples, and total bacteria was found in 87.25% of 102 samples (Kivanc *et al.,* 1996). Also, the results of a similar study done by Agaoglu *et al.,* in Van (Turkey), stated that 33.3% of drinking water examined had coliform bacteria (Agaoglu *et al.,* 1999). Another study related to the contamination level of drinking water by Avci *et al.,* has shown that 65.35 was total coliform and, 87.3% of water samples were not fit to drink (Avci *et al.,* 2006).

In agreement to our study, Lecierc M. and Moreau, reported that bottled water may have high bacterial counts as a result of natural biological process resulting mainly from multiplication of these bacteria that were present in low numbers in the water sources (Lecierc and Moreau, 2002). Bacterial growth in stored bottles has been reported as a result of specific bottling-materials (Criado *et al.,* 2005) that can release organic matter and provide additional substrates for the microbial growth during storage period (Evandri *et al.,* 2000).

So, it is concluded from the present study, that some samples (12%) taken from bottled containers exceeded the maximum bacteriological limits according to WHO standards brands. This may originate from the water source, sanitation conditions of process, unhygienic and high temperature conditions, defective packaging and lack of protective measures (Kassenga, 2007).Water containing few organisms when bottled may show increase in the numbers of bacteria in a relatively short time (Tamagnini and Gonzalez, 2006).

During the past 15 years, an increasing number of waterborne outbreaks caused by *G. lamblia* and *C.parvi* have been documented worldwide (Lisle and Rose, 1995;Slifko *et al.,* 2000; Craun *et al.,* 2002; Fricker *et al.,* 2002), showing a trend in which protozoa and viruses are replacing bacterial pathogens as agents of primary concern in waterborne disease (Briancesco and Bonadonna, 2005).

The enteric protozoan *G. lamblia* and *C.parvi* are intestinal parasites that can cause gastroenteritis in humans when they are ingested. Giardia is the most common cause of parasitic infections in humans in the United States (Craun, 1988) and can cause a lengthy diarrhea in infected individuals (Wolfe, 1984). Numerous waterborne outbreaks of giardiasis and cryptosporidiosis have been documented worldwide. (Moore *et al.,* 1994). Variable numbers of *G. lamblia* cysts and *C.parvi* oocysts are usually found in water supplies (Craun, 1986).

Cysts and oocysts are the infectious units of the microorganisms, and the development of approaches for the detection of cysts and oocysts in water samples necessitates a simple, efficient and cost effective methods. In addition, since an infection in humans can be initiated by few viable cysts (Akin and Jakubowski, 1986) detection methods and viability assays need to be very sensitive.

The methods for the detection of Giardia and Cryptosporidium in water rely primarily on microscopic observation of water concentrates using microscopy or an immunofluorescent technique , neither of which and also the gene probe technique (Abbaszadeagn *et al.,* 1991) are not able to differentiate between viable and non-viable cysts. Current methods to determine the viability of cysts include infectivity of animal models (Belosevic *et al.,* 1983), and the incorporation of vital dyes (Smith and Smith, 1989). These methods are costly, time consuming and lack sensitivity because they require large numbers of cysts for the results to be statistically accurate. As a result of possible public health threats, it is necessary to develop a rapid and sensitive assay for Giardia cysts and Cryptosporidium oocysts like PCR. In our study, we investigated *G. lamblia* and *C.parvi* contamination of drinking water samples, 25% and 16.6 % of total water samples were contaminated with oocysts respectively.

In studies done around the world, *Giardia was detected* in 31% and Cryptosporidium oocysts were detected in 92% of drinking water sources in Argentina (Abramovich *et al.,* 2001). In 2002, monitoring water for one year in Japan using coagulation-flocculation, sedimentation and rapid filtration, the investigators found Cryptosporidium in all raw water samples and in 35% of filtered samples, while Giardia was found in 92% and 12% of samples, respectively (Hashimoto *et al.,* 2002). In 2003, a UK study done on Cryptosporidium in drinking water, found the parasite in 100% of samples using PCR (Nichols *et al.,* 2003). However, lower detection rates were reported, *e.g.* in the USA in 1991 using immunofluorescence test, the investigators found Giardia in 17% and Cryptosporidium in 27% of filtered water samples (Le Chevallier *et al.,* 1991). Lower rate of parasites detection in water samples was reported in Russia from different water samples collected during 2006. Giardia and Cryptosporidium were found in only 9.6% and 18.1% of these samples using immunofluorescence test (Karanis *et al.,* 2006). This reflects the efficient methods adapted by the water treatment facilities in these countries, for controlling the quality of drinking water. Many countries are routinely monitoring water every year and establishing techniques to identify these parasites, in an attempt to control their existence by using immune-magnetic separation and fluorescent antibody (IMS/FA) (USEPA, 2005).

In contrast to other waterborne pathogens, such as *G. lamblia*, the occurrence of cryptosporidiosis is unknown in many parts of the world; however, the

mean prevalence rate of Cryptosporidium infection is between 1 and 3% in Europe and North America and 5% in Asia (Current, 1994). Moreover, some parasites such as *Giardia, C. parvum and Entamoeba* have been identified as significant waterborne pathogens and have been found responsible for several serious outbreaks worldwide over the past ten years (Marshall *et al.,* 1997, Morris *et al.,* 1998).

A study by Robertson *et al.*(2001) found that 11.5% and 16% of water samples in Norway were positive for *Giardia* and *C. parvum*, respectively. However, in a study of water in western Japan (Ono *et al.,* 2001), 47% of the samples tested were positive for *C. parvum*. Rose et al., 1991 performed a similar study in 17 American States and found *C. parvum* oocysts in 51% of the samples tested. This difference of prevalence may be attributed to different methods used for detection of *G.lamblia* and *Cryptosporedium parvum*.

Based on the above assessments, bottled water in the Tabuk region should be considered for a proper regular monitoring programme to determine the primary sources of contamination and health threat. In addition, we ought to make recommendations to develop appropriate control measures to avoid any sudden public health risk from such a vital water source.

Acknowledgment

Funding was provided by Deanship of Research, Tabuk University, KSA. We thank Deanship of Research staff members for their support to make this project possible.

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1/28/2013