EVALUATION OF WELL WATER QUALITY IN HAEL REGION OF CENTRAL OF SAUDI ARABIA

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ABSTRACT

The quality of 40 wells water in selected villages in Hael Region North Central of Saudi Arabia used mainly for drinking was examined in respect to total dissolved salts, pH, total hardness, concentrations of calcium, magnesium, potassium, sodium, chloride, fluoride, nitrate, and bicarbonate, beside coliform bacteria as an indicator of faecal contamination. TDS varied widely from 166 to 2400 mgL^{-1} with an average of 557 mgL^{-1}. Of the 40 well water tested, 7.5, 15, 7.5, 15 and 32.5% failed to meet drinking water guidelines of SASO, GC.C.S and WHO, and USEPA respectively. Regarding nitrite concentrations, 36% of the tested water samples were above the limit set by local and international standards and guidelines (50 mgL^{-1}). Fluoride levels were below 0.6 mgL^{-1} in 25% of examined water wells and were above 1 mgL^{-1} in 22.5% of these water samples, thus only 52.5% of tested samples comply with the range of fluoride concentrations set by SASO and G.C.C.S. (0.6-1 mgL^{-1}).Coliform bacteria (mainly *E. coli* and *E. aerogenes*) were detected in 20% of examined well water indicating faecal contamination. Continuous assessment of well water quality on routine basis is imperative to reduce the deterioration of well water quality and eliminate health problems.

Keywords: guidelines, Saudi Arabia, Quality, Faecal coliform, Groundwater

INTRODUCTION

Safe and good quality drinking water is essential for human health. However, when polluted, it may become a source of undesirable substances dangerous to human health. The main source of drinking water in Saudi Arabia is groundwater (Al-Abdula'aly, 1997). Although, most regions in Saudi Arabia do not face serious problems regarding drinking water as other parts of world, there are still water quality problems (Moghazi and A1-Shoshan, 1999). There are several potential sources that may cause chemical and microbial contamination in groundwater. These include intensive application of organic and inorganic fertilizers, pesticides, and animal waste (Zubari et al., 1994). Seepage from septic tanks and wastewater discharged to soil might also in some locations contribute to the deterioration of both chemical and microbial quality of groundwater (Pritchard et al., 2007).

During the past few years, the regulation of water quality has undergone radical changes. Drinking water standards have been developed to define a quality of water that is safe and acceptable to consumers. Therefore, most of these standards set limits for chemicals and organisms that are potentially dangerous, hazardous or obnoxious to consumers (El-Garawany and Aleed, 1997: Pritchard et al., 2007).

In Saudi Arabia, the quality of drinking water is currently receiving some attention from environmentalist and water scientists (Saudi Arabia Standards Organization "SASO", 1984; Hashim, 1990; Garawi and AL-Henidi, 1993; Abdel Majed, 1997; Al-Redhaiman and Abdel Majed, 2002; Al-Turki and Abdel Majed, 2003; Al-Abdula'aly, 1997; Al-Abdul'aly et al., 2002 & 2003).

SASO (1984) developed drinking water standards for both bottled and unbottled 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. A substantial number of these standards are based on the World Health Organization (WHO, 1993) international standards for drinking water.

In Hael, a region located in north central of Saudi Arabia, there are many wells scattered throughout some villages with depth ranged from 15-35 m and used as a source of drinking water by rural residents without receiving any treatment. As a consequence, it is of importance to investigate the state and quality of waters derived from these wells.

The present study was conducted during Winter of 2006 to evaluate the quality of wells water in selected villages of Hael Region, and examine their compliance with local and international standards including SASO, (1984), G.C.C.S (1993), WHO (1993) guidelines and the United States Environment Production Agency (USEPA, 1976) Standards. Water samples were taken from forty wells presented the area, used mainly for drinking. Most of parameters selected for analysis are obligatory from most Drinking Water Directive, comprising physiochemical, chemicals and microbial properties.

MATERIALS AND METHODS

Water samples were obtained during the summer of 2006 from 40 surface water wells scattered throughout some villages in Hael Region, North Central Saudi Arabia. The depth of these wells ranges from 15 to 30 m. Most of these well waters are used for drinking purposes without receiving any treatment.

Prior to sampling, water was allowed to run for several minutes and the water outlet was flamed to avoid external contamination. Water samples for physiochemical and chemical analysis were collected in polyethylene bottles whereas samples for bacteriological analysis were collected in 250 ml sterile glass bottles. The water samples were kept in ice pocket and then shipped to the laboratory and analysis was carried out either immediately or the samples were stored at 4 °C and analysis was conducted within a maximum of 8 hours.

Physical and Chemical Analysis

Both physical and chemical methods of analysis of were employed in this work. Analytical grade BDH products (BDH Chemicals Ltd, Poole, England) unless otherwise stated, were used to prepare reagents and calibration standards. Deionized water was used to prepare all reagents and dilution standards and as diluter water. The determinations were carried out according to the Standard Methods for the Examination of water and Wastewater (APHA, 1985, 1992 and Richards, 1954).

In these determinations, pH was measured by Meterohm pH-meter (Model 632) calibrated against two standard buffer solutions of known pH values (pH 7 and pH 9) produced by Wnlab Ltd. Maidenhead-Berkshire, England. Electric conductivity (EC) (ds/m at 25 °C) was measured by a Beckman solu Bridge type equipment calibrated using anhydrous KCL solution (0.01N) adjusted at 25 °C. Na^+ and K^+ were determined by flame photometer (Corning Model M410 instrument). Ca^{++} and Mg^{++} were determined by titration with ethylenediaminetetraacetic acid (EDTA) disodium salt solution (0.01N). F was determined by the SPADNS [Sodium 2- (parasulphoenylazo) - 1.8 dihydroxy -3.6 naphthalene disalphonate] colorimetric method using NaF for preparation of the standard solution. Iron was determined by the colorimetric phenanthroline method using the Bausch and lomb Spectronie 2000 spectrophotometer. Ferrous ammonium sulfate was used to prepare iron solution. Cl^- was determined by titration using standard silver nitrate solution and potassium chromic (5% solution) as an indicator. Sulfate (SO_4^{--}) was determined turbidimeterically using Model ANA14A turbidimeter (Tokyo Photo-electric Co. Ltd., Japan). Nitrate (No_3^-) was determined by phenodisulphonic acid method using Spectronic 2000 spectrophotometer. Potassium nitrate (KNO_3) was used to prepare the standard (No_3^-) solution. Total hardness was obtained by calculation from Ca^{++} and Mg^{++} concentrations. Total dissolved solids (TDS) were determined by multiplying the conductivity value by 640 according to Rhoades (1982).

Microbiological methods

The three-tube procedure using lactose broth (Difco) was used for estimating the most probable number (MPN) of coliform organisms. Tubes were incubated at 37 °C for 48 h and the MPN was obtained according to the standard Methods for the Examination of Water and Wastewater (APHA 1985; Geldreich 1975). The confirmed coliform test was done by culturing positive tubes into brilliant green bile broth (Difco) and incubating at 37 °C for 48 h.

Statistical analyses were performed using an IPM compatible 486 computer. The means obtained for the various water quality parameter measured were evaluated according to the current local (Saudi Arabian) drinking water quality standards (SASO, 1984), G.SC.C.S., (1993), EEC (1992), WHO (1993) and USEPA, 1976) drinking water standards and guidelines.

RESULTS AND DISCUSSION

Analysis of the 40 water samples for TDS (Table 1) showed a wide variation in concentration. TDS ranged from 166 to 2400 mgL^{-1} with an average value of 557 mgL^{-1} (S.D. = 474). It is clear from the value of standard deviation that there is a wide variation among the samples with respect to their TDS. Comparison with the recommended standards and guidelines for salinity of drinking water (Table 1) revealed that 7.5, 15, 7.5, 15 and 32.5% of the samples studied were above the maximum limits set by SASO, G.C.C.S, E.E.C and WHO and USEPA, respectively. The distribution of the TDS levels in the 40 water samples studied is shown in Table 2, which indicates that 67.5% of the water samples comprised the best quality water (TDS<500, set by USEPA), whereas 25% of the water samples [TDS = 501-1000 mgL^{-1} (17.5%) and TDS = 1001-1500 (7.5%)] comply with the maximum standards and guideline limits set by SASO, G.C.C.S E.E.C and WHO for drinkable water. On the other hand, high salinity water samples (TDS > 2000 mgL^{-1}) comprised only 7.5% of the water samples studied. It is well known that TDS affects taste, and waters above 500 mgL^{-1} can taste poor. Generally, TDS levels less than 500 mgL^{-1} is acceptable to household use (USEPA, 1976, 1986). According to the limits set by the various standards listed in Table 1, water with salinity level beyond 1500 mgL^{-1} is considered unsuitable for dinking but could be used for irrigating crops with good salt tolerance such as date palm trees (Clark et al, 1963; Raveendran and Madany, 1991; Abdel Magid, 1997, Al-Redhaiman and Abdel Magid, 2002) Sources might have contributed to this high salinity include over exploitation, excessive pumping, runoff water, soil weathering and agricultural drainage water (Abdel-Aal et al., 1997; Moghazi and Al-Shoshan, 1999). In general, all of the water samples studied have pH values falling within the limits of the standards (mean = 8.1) and guidelines listed in Table 1 with the exception of the WHO (1993) guideline limit for pH (pH < 8) where 72% of examined samples were above this value.

Table 1. Physical and chemical quality of water samples collected from 40 wells in rural area in Hael region of Saudi Arabia

Parameters	**Mean (n=40)**	**Range**	**SD**	**SASO standards (1984)**	**Percentage of samples above**	**G.C.C.S. standards (1993)**	**Percentage of samples above**	**WHO guidelines (1993)**	**Percentage of samples above**	**USEPA (1976)**	**Percentage of samples above**
TDS mgL^{-1}	557	166.4-2400	474	1500	7.5	1000	15	1000	15	500	32.5
pH	8.1	6.8-8.4	0.28	9.2	0	6.5-8.5	0	<8	72	6.5-8.6	-
Total hardness (as CaCO$_3$)	132	29-348	76	500	0	500	0	NS	-	NS	-
Ca^{++} mgL-	26.6	2.8-78	19.9	200	0	200	0	NS	-	NS	-
Mg^{++} mgL^{-}	15.7	1.2-49	9.2	150	0	150	0	NS	-	NS	-
Na+	90.6	17-455	96.9	NS	-	200	12.5	200	12.5	NS	-
K+	3.6	1.2-12	1.7	NS	-	NS	-	NS	-	NS	-
Cl-	147	28-709	160	600	5	400	12.5	250	17.5	250	17.5
NO3-	44.9	8.7-155	160.6	<45	36	<45	36	50	32.5	45	36
F^{-}	0.83	02-1.9	0.4	0.6-1	22.5	0.6-1	22.5	1.5	8.5	4	-
HCO3^{-}	146	18-244	39.6	NS	-	NS	-	NS	-	NS	-

Table 2. Distribution of 40 water samples in Hail Region of North Saudi Arabia according to their content of total dissolved salts (TDS)

TDS Class (mgl^{-1})	No. samples class within	% of total
< 500	27	67.5
501 - 1000	7	17.5
1001 - 1500	3	7.5
1501 - 2000	——	——
> 2000	3	7.5
Mean	654	
Range	166 - 5005	
SD	845	
CV (%)	129	

Total hardness (as $CaCo_3$) ranged between 29 to 348 mgL^{-1} with 50% of the water samples being above the 100 mgL^{-1} which is the optimum limit recommended by SASO (1984) but none of the water samples studied exceeded the 500 mgL^{-1}, the maximum permissible limit for unbottled water recommended by SASO (1984) and G.C.C.S (1993). Table 3 shows the quantitative classification of drinking water samples studied according to their level of hardness. As stated by many authorities (Techobanoglous and Schroeder 1985; Viessman and Hammer, 1985; Wilson et al., 1999 and Al-Redhaiman and Abdel Magid, 2002) water hardness of levels around or above 300 mgL^{-1} is considered extremely excessive for a public water supply and results in a high soap consumption as well as object ion able scale in heating vessels and pipes. Moreover, many consumers object to water harder than 150 mgL^{-1}, a moderate figure being 60-120 mgL^{-1} (Wilson et al. 1999); thus including the optimum limit of 100 mgL^{-1} recommended by SASO, 1984). Ca^{++}, Mg^{++} and K^{+} concentrations ranged between 2.8% to 78 mgL^{-1}, 1.2 to 49 mgL^{-1} and 1.2 to 12 mgL^{-1}, respectively, thus falling well below the maximum limits set by the respective standards shown in Table 1. Na^{+} concentrations ranged between 17 to 455 mgL^{-1} with 12.5% of the water samples falling above each of the G.C.C.S and WHO standards and guidelines. The USEPA standard did not set any limit for the Na^{+} concentration. Cl^{-1} concentration ranged between 28-709 $mgL^{-1}$with average of 147 mgL^{-1}. According to Raveendran and Madany (1991) the WHO guidelines for Na^{+} (200 mgL^{-1}) and Cl^{-1} (250 mgL^{-1}) are based on taste consideration aesthetic quality rather than the impact of Na^{+} on human health and thus higher values (for example: SASO and G.C.C.S set the maximum limit for Na^{+} at 600 mgL^{-1}).

Table 3. Quantitative classification of 40 samples of water according to level of hardness (Tchobanglous and Schreoder 1988)

Description	Hardness class (mgl^{-1}) as $CaCO_3$	No. samples within class	Percentage of samples within class
Soft	< 50	2	5
Moderately hard	50 - 150	27	67.5
Hard	150 - 300	10	25.0
Very hard	> 300	1	2.5
Mean	132		
Range	29 - 348		
SD	76		
CV (%)	58		

NO^-_3 concentrations as shown in Table 1 ranged between 8.7 to 155 mgL^{-1} (mean 44.9 mgL^{-1}). The distribution of the NO_3^- levels in the 40 water samples studied is shown in Table 4. It indicates that 65% of the samples comprised the best quality water with respect to NO^{-3} level ($NO3^{-1}$ content < 45 mgL^{-1}) as recommended by the respective standards listed in Table 1, whereas 35% of the water samples [NO_3^- level = 45-90 mgL^{-1} (27.5%) and NO_3^-level > 90 mgL^{-1} (7.5%)] thus violating the 45-50 mgL^{-1} maximum recommended by the respective standards listed in Table 1. Previous evidence (Al-Turki and Abdel Magid, 2003, Al-Abdula'aly et al., 2002 & 2003) indicated the presence of high nitrate levels in some well water in Al-Qassim Region which is not in compliance with the standards and guidelines set for the maximum permissible levels for NO_3^- level in drinkable water as recommended by the standards and guidelines listed in Table 1. The wide variation of the NO_3^- levels among the well water samples examined was variously attributed to the depth of wells examined as well as human activity, specially the irrational use of nitrogenous fertilizers (Al-Garawany and AI-eed, 1997; AI-Hindi, 1997). Moreover, AI-Turki and Abdel Magid (2003) indicated that a significant ($P<0.01$, $R^2=0.293$) reciprocal relationship existed between well depth and $N0_3$ level.

Table 4. Distribution of drinking water samples according to their content of NO_3^- (mgl^{-1}): n = 40

NO_3^- (mgl^{-1})	No. of samples within class	% of total within class
< 45	26	65
45 - 90	11	27.5
> 90	3	07.5

F^{-1} concentration in the samples studied ranged between 0.2 and 1.9 mgL^{-1} (Table 1) with only 22.5% of the water samples examined fall above the SASO, 1984) and G.C.C.S. (1993) maximum permissible limit (1 mgL^{-1}). As shown in Table 5, 25% of the water sample examined contain F^- levels below 0.6 mgL^{-1}, while only 52.5% the samples are within the range between 0.6 and 1 mgL^{-1}, SASO, 1984) recommends that the level of F^- in unbolted drinking water shall not be less than 0.6 mgL^{-1} but not greater than 1 mgL^{-1} depending on the average maximum ambient temperature in community area. The WHO guideline for fluoride is 1.5 mgL^{-1} while the maximum USEPA (1976) contamination level for F^- is 4.0 mgL^{-1}. It may, therefore, be inferred from the data presented in Table 5 that 25% of the water samples examined have F^- concentration below the recommended lower permissible level of SASO, 1984) standard (0.6 mgL^{-1}), which means that supplemental fluoride to the optimum level is deemed necessary to avoid dental decay in well water consumers (Al-Khateeb et al. 1991; Abdula'aly, 1997 Al-Redhaiman and Abdel Magid 2002; Van Netten et al. 2002). The USEPA (1986) indicated an aesthetic limit of 2 ppm while Adachi et al., (1991), depending on the regional temperature, estimated the optimal level at 0.7-1.2 mgL^{-1}. The HCO_3^- level ranged between 18-244 mgL^{-1} in examined samples. The respective standards listed in Table 1 have not set any standard or guidelines for the HCO_3 concentration. However, the elevated level of HCO_3 can probably be attributed to the presence of limestone formations in groundwater (Moghazi and AI-Shoshan, 1999).

Table 5. Distribution of 40 water samples in Region of Central Saudi Hail according to their content of fluoride

F^- Class (mgL^{-1})	No. samples within class	Percentage of samples within class
< 0.6	10	25
0.6 - 1	21	52.5
> 1	9	22.5
Mean	0.83	
Range	0.2 - 1.7	
S.D	0.42	
CV(%)	50.8	

Repeated bacteriological analyses of the 40 water samples using the presumptive test indicated the presence of coliform bacteria in 8 of the wells examined, showing that 20% of them failed to meet the guidelines set by SASO, G.C.C.S, WHO and USEPA. Confirmatory and IMViC tests revealed the presence of *Escherichia coli* (fecal coliform) in 3 (7.5%) of the water samples and *Entrobacter aerogenes*_(nonfecal coliform) in 5 (12.5%) of the water samples thus indicating that pollution with human and animal wastes is evident, which may have contributed considerably to the deterioration of well water quality (Pritchard et al., 2007). This is expected since these wells water do not receive any chlorination treatment before consumption in urban areas. The 1984 Saudi standard requires a negative coliform test for every 100 m1 of water examined after treatment with chlorine to kill bacteria. This high count may be attributed to contamination of the hoses used by humans, including farmers and livestock owners, and to the exposure of these delivery hoses to dust and storms (Pritchard et al., 2007). Previous workers indicated that dust storms and livestock activity in the vicinity of surface wells increases microbial levels and bacterial inputs (Stephenson and Street, 1978; Hammad and Dirar, 1982, Abdel Magid, 1997). Moreover, it may be inferred that the high salinity of water in some of the wells examined may have hindered proliferous bacterial growth in spite of the eminent contamination cited above.

CONCLUSIONS

Comprehensive analyses of drinking water samples taken from 40 wells scattered in some villages in Hail Region of North Central Saudi Arabia revealed that there are considerable variations among the examined samples mainly with respect to their TDS, hardness, NO_3^- level, F^- level and coliform load, which mostly fell above the maximum permissible levels set by SASO, G.C.C.S., WHO and USEPA. Nitrate level in well water examined may pose health hazard since 36% of the water samples contain level grater than limits set by all water drinking standards. Fluoride content in 25% of examined well water is blow the lower limits set by SASO and G.C.C.S. guidelines and is above this limit in 22.5% of studied samples. Fluoride assessment in examined water well, therefore, is necessary to determine whether addition or removal of fluoride is needed to meet the range concentration of 0.6-1 mgL^{-1}.

Microbiological water quality results showed that 20% of the samples examined are contaminated with coliform bacteria (mainly *E. coli* and *E. aerogenes*), indicating the necessity of water sanitation prior to use. Continuous assessment of well water quality on routine basis is imperative and a sustainable management is required to reduce the deterioration of well water quality and eliminate health problems.

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