ORIGINAL ARTICLE

PHYSICO-CHEMICAL QUALITY OF DRINKING WATER AT MUSHAIT, ASEER, SOUTH-WESTERN SAUDI ARABIA.

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Abstract

The physico-chemical quality study of different drinking water sources used in Khamis Mushait, southwestern, Saudi Arabia (SA) has been studied to evaluate their suitability for potable purposes. A total of 62 drinking water samples were collected randomly from bottled, desalinated and groundwater located around the study area. The parameters determined in this study were Turbidity; Conductivity; Total solids; pH; Chlorides; Hardness; Sulphate; Ammonia; Nitrite; Nitrate; Iron; Manganese; Copper and Zinc. Most examined parameters were higher in groundwater, followed by desalinated water except for Manganese and Zinc levels. Manganese level was highest in desalinated, followed by bottled water, while Zinc was higher in groundwater than bottled and desalinated water. Most examined groundwater samples had the highest physico-chemical levels as compared with guideline of international and Saudi standards, followed by desalinated and lastly bottled water. Desalinated water showed the higher Manganese value more than the recommended level followed by bottled water, while all the examined water samples had Zinc content lower than the guideline values of international and Saudi standards. Strict hygienic measures should be applied to improve quality of drinking water and to avoid deleterious effect on human health. This could be achieved by working towards a proper monitoring program of drinking water supply and sources.
Key Words: physico-chemical quality, Drinking Water Quality, Khamis Mushait, Saudi Arabia.

Introduction

Safe and good quality of a drinking water source is the basis for good human health. Water provides essential elements, but when polluted it may become a source of undesirable substances dangerous to human health.

Quality of drinking water is strongly influenced by the quality of the corresponding natural water, from which drinking water derives [1]. There are still water quality problems related mainly to the effective water treatment and defects in the distribution networks of drinking water or during transportation and distribution stages in general, which may expose the consumers to the risk of adverse health effect [2].

Bottled water consumption is widely and rapidly increasing because its accessibility, availability, tastes better, contains fewer impurities and confers a higher social status on consumer than tap water. Poor quality control during production and\or distribution can contaminate this widely consumed water resource [3].

Groundwater is an important resource for human water supply and in Asia alone some one billion people are directly dependent on it. In Saudi Arabia, groundwater is the main source for safe and reliable drinking water consumption particularly in rural areas. Water taken from groundwater (wells) is often of better quality than surface water. This is true only if the soil or rock is fine-grained and does not have cracks, crevices and bedding plants, which permit free and faster passage of pollution such as of polluted surface water [4]. The inorganic chemical quality of these waters is however, rarely adequately tested before the wells are put into production. Due to variation in the regional geology and water/ rock interactions, high concentrations of many chemical

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elements can occur in such water source. During the last 10 years several studies have shown that wells in areas with particular geological features yield water that does not meet established drinking water standards without any influence from anthropogenic contamination [5,6].

For the last four decades, many countries in the arid regions had been depending on desalination of seawater to meet their growing domestic needs. The Kingdom of Saudi Arabia is the biggest producer of freshwater by desalination with an installed capacity of more than 1000 million USGPD accounting for 24.4% of the world desalinated water production [7,8]. Contamination of desalinated water with various chemical parameters may occur and end up in drinking water sources threatening human lives and surrounding environment.

The main objective of this study was to assess physico-chemical parameters of drinking water samples from different sources (bottled water, desalinated water and groundwater) from Khamis Mushait area and to compare these results with the drinking water standards set by Saudi Arabia Standards Organization (SASO) and other international regulatory standards.

Materials and Methods

A total of 62 drinking water samples were collected randomly from bottled water from local stores, desalinated water and groundwater (wells) from Khamis Mushait, area, south western SA. Sixteen brands of bottled water consisting of spring and purified bottled water types were purchased from different supermarket stores at Khamis Mushait governorate. Concerning desalinated water, 31 water samples were obtained from public & regional distributing points known as *Ashiab*, water trailers; houses; water networks; fish markets and slaughterhouse. From groundwater, 15 water samples were taken from different types of wells located at and around Khamis Mushait governorate using point network technique utilizing digital satellite maps of Googlearth engine search to map and sample groundwater network of study area in order to determine and locate sampling points in the field of both houses and wells [9].

All the brands of bottled water samples were in plastic container with capacity of 1.5liter and plastic screw caps except purified water samples, which collected in 1.5liter colorless glass container with metal screw caps. Water samples from desalinated and groundwater were collected in colorless labeled glass bottles provided with glass stopper with capacity of 1.5liter. For physico-chemical examination of desalinated and groundwater, samples were taken after flushing water for at least 5 minutes [10]. All water samples were dispatched to laboratories of Medical Lab. Technology Department, Khamis Mushait Community College, King Khalid University to perform physico-chemical examination for the collected drinking water samples. All the collected drinking water samples were purchased and analyzed between March and June, 2007. All water samples were transported to the laboratory, where most water quality constituents were determined within 2-6 hours after collection. Furthermore, all collected water samples did not contain particulates. Thus, water samples were not filtered prior to analysis for various parameters.

The physico-chemical parameters analyzed in this study were Turbidity (FAU); Conductivity (µS/cm); Total solids (mg/l); pH; Chlorides (mg/l); Hardness as Ca Co_3 (mg/l); Sulphate (mg/l); Ammonia (mg/l); Nitrite (mg/l); Nitrate (mg/l); Iron (mg/l); Manganese (mg/l); Copper (mg/l) and Zinc (mg/l).

Conductivity (µS/cm) was measured by the Dist

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Family II meter (Hana Instrument, An ISO9001 Certified Co., Portugal), after calibration with conductivity standard solutions. pH was measured by using pH meter (HI8014, Hana Instrument, Romania), after calibration with standard pH buffers. Total solids and Chloride contents were determined according to the methods previously described [10].

Turbidity; Hardness as $CaCo_3$ (mg/l); Ammonia (mg/l); Nitrite (mg/l); Nitrate (mg/l); Sulphate (mg/l); Copper (mg/l); Manganese (mg/l); Zinc (mg/l) and Iron (mg/l) were determined by using DR/ 890 Colorimeter (HACH Company, 1997-2004, USA). The procedures used for measuring these parameters were fully described in the procedure manual of DR/ 890 Colorimeter (Table 1).

Statistical analysis of the obtained results was done using a one-way analysis of variance (ANOVA). The one way parametric ANOVA procedure (at 5% level of significance) was adopted since it has been adjudged to be preferred method compared to non-parametric procedures, especially when the percentage of non-detects is less than 15% [11].

Results

Generally, average turbidities (FAU) of all examined water sources were 2.85±0.4 (Table 2). However, the variation of turbidity within each source was large. The highest mean being recorded in groundwater, which had an average of 5.47±0.98, followed by desalinated water (2.23±0.46). The lowest mean turbidity value (0.56±0.18 FAU) was reported in samples taken from bottled water source. The higher turbidity levels recorded in groundwater samples were significantly correlated with bottled and desalinated water samples (p≤ 0.05). There was also a significant correlation at p≤ 0.05 in the turbidity level between desalinated and bottled water (Table 2). Generally, 12 water samples did not meet the international and Saudi standards for turbidity in drinking water, which set

as 5 NTU. Three (9.68%) and 9 (60%) from desalinated and groundwater samples were higher than the maximum limit for turbidity (Table 3). Higher values were previously recorded [12], while a lower turbidity level was also reported [13].

It is evident from Table (2) that the overall range of conductivity (μs/cm) in all collected water samples were 120.00-2460.00 with an average of 296.49±63.20. The highest conductivity value (μs/cm) was detected in groundwater samples (937.67±199.13), followed by those determined in desalinated water (152.90±3.05) and lastly bottled water samples (136.25±12.84). From the result obtained in the present study, conductivity had large variation within the different water sources. The higher turbidity levels recorded in groundwater samples were significantly correlated with bottled and desalinated water samples (p≤ 0.05). Table (3) declared that 10 out of 15 (66.67%) examined groundwater samples had conductivity values exceeding the permissible limit set by international and Saudi standards (400 μs/ cm). On the other hand, all water samples collected from bottled and desalinated water sources were lower than the permissible limit.

Generally total solids (mg/l) in all collected water samples considering range values were found to be 68.00-3640.00 with a mean value of 481+ 98.56 (Table 2). In terms of the mean value obtained in all water samples, the minimum value was 130.31±13.79 mg/l for bottled water, followed by desalinated water 203.48±8.97 mg/l. However, the highest total solids (mg/l) was recorded in samples taken from groundwater with an average of 1373.00±314.51. The higher total solid recorded in groundwater samples were significantly correlated with bottled and desalinated water samples (p≤ 0.05). As presented in Table (3), 66.67% (9 out of 15) groundwater samples exceeded the permissible

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levels (500 mg/ l) set by the international and Saudi standards for total solids. On the other hand, there no water samples collected from bottled and desalinated water exceeding the permissible limit of total solids.

Overall mean pH value was 7.64±0.04 in all investigated water samples (Table 2). The variation of pH values within the examined water sources was small, where the range was between 6.67 and 8.40. The lowest mean pH value (7.28±0.09) was recorded in groundwater, while the highest pH value (7.78±0.09) was found in bottled water followed by desalinated water with a mean value of 7.75±0.04. On the other hand statistical analysis presented in Table (2) revealed a significant correlation between the lowest pH value of underground water and pH value of bottled and desalinated water samples ($p \leq 0.05$). The results of pH value recorded in this study fall within the range of international and Saudi standards for drinking water, where the range lies between 6.5 and 8.5 (Table 3).

The overall mean value of chloride content (mg/l) in all drinking water samples was 64.50+18.07 (Table 2). The chloride ranges (mg/l) were 14.50-40.50; 15.20-34.00 and 11.50-914.80 in the examined bottled, desalinated and groundwater respectively. For comparison, groundwater samples showed the highest chloride value, where mean value was 206.01±63.15 mg/l, followed by bottled water (21.78±1.82 mg/l). On the other hand, desalinated water had the lowest chloride content with a mean of 18.08±0.66. There was a significant variation at $p \leq 0.05$ in the amount of chloride between groundwater and bottled as well as desalinated water (Table 2). Only 40% (6 out of 15) having chlorides exceeding the guideline value (250 mg/l) as recommended by international and Saudi Standards (Table 3).

Total hardness is expression of total Ca and Mg content of water expressed in equivalent of $CaCo_3$. Table (2) shows that overall mean of total hardness as $CaCo_3$ (mg/l) in all investigated drinking water samples was 36.68±7.59. The mean values of total hardness were 36.46±6.19; 4.82±1.58 and 102.75±22.81 in samples taken from bottled, desalinated and groundwater, respectively. It is indicated from Table (2) that total hardness showed a significant higher values at $p \leq 0.05$ in water samples taken from bottled water more than recorded in desalinated water. However, A significant difference was also present in the total hardness level between groundwater and desalinated or bottled water ($p \leq 0.05$). It is clear from Table (3) that out of 15 examined groundwater samples, 7 (46.67%) had higher hardness levels more than the guideline level of hardness (100 mg/l as $CaCo_3$) as recommended by international and Saudi standards.

It is presented from Table (2) that the overall mean value of sulphate (mg/l) in all examined drinking water samples was 158.84±39.76. The highest sulphate concentration was recorded in samples collected from groundwater (524.20±125.59), followed by desalinated water with an average of 55.13±2.84 and bottled water which had a mean value of 21.3±4.73. A statistically significant difference at $p \leq 0.05$ was very clear between the higher sulphate level in groundwater and bottled as well as desalinated water. Of 15 groundwater samples, 9 (60.00% were above permissible limit of sulphate (200 mg/ l) as reported by international and Saudi standards. On the other hand, there was no water samples had sulphate content above the permissible limit (Table 3).

It is shown from Table (2) that the overall mean value of ammonia (mg/l) in all examined water samples was 0.03+0.01. The mean values of

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ammonia (mg/l) in the examined bottled;, desalinated and groundwater samples were 0.002±0.001, 0.02±0.005 and 0.09±0.03, respectively. Ammonia levels were varied significantly between groundwater and bottled or desalinated water (p≤ 0.05), where groundwater had more ammonia levels than recorded in desalinated and bottled water. All examined water samples had ammonia levels below international and Saudi standards of ammonia in drinking water, which should not exceed a level of 0.5 mg/ l (Table 3).

It is obvious from Table (2) that nitrite was non-detectable in all investigated drinking water samples in this study. Regarding nitrate, Table (2) revealed that the average of nitrate (mg/l) in all examined water samples was 16.74±1.78. The highest nitrate value was recorded in samples taken from groundwater with an average of 26.94±5.85 mg/l, followed by desalinated and bottled water, where the respective values were 13.98±1.35 and 12.54±2.11 mg/l. Moreover, nitrate showed significant high levels in groundwater than in desalinated or bottled water samples (p≤ 0.05). Table (3) declared that in comparison the results of nitrate concentrations with the international and Saudi standards, it was found that only one out of 31 (3.23% and 4 out of 15 (27.67%) water samples collected from desalinated and groundwater exceeded the maximum permissible limit for nitrate (45 mg/ l).

The overall mean of iron (mg/l) for all investigated drinking water samples was 0.17±0.05 (Table 2). The iron ranges (mg/l) in the examined bottled, desalinated and groundwater samples were 0.00-0.28; 0.00-0.39 and 0.00-2.20, respectively. On the other hand, the highest mean value of iron (Fe) was recorded in samples taken from groundwater (0.41±0.18 mg/l), followed by desalinated water (0.11±0.02 mg/ l) and bottled water with a mean of 0.07±0.02 mg/l. A statistically significant difference at p≤ 0.05 was very clear between the higher iron levels in groundwater and desalinated as well as bottled water. It was found in Table (3) that 9.69% (3 out of 31) and 26.67% (4 out of 15) of desalinated and groundwater samples present high iron concentrations exceeding the maximum permissible limit set by the international and Saudi standards for iron (0.3 mg/ l).

It is evident from Table (2) that manganese (Mn) value (mg/l) recorded in all examined water samples was 0.29±0.03. The mean Mn values recorded in bottled, desalinated and groundwater samples were 0.16±0.04; 0.39±0.05 and 0.23±0.07, respectively. The recorded Mn level in desalinated water was significantly higher than bottled and groundwater samples (p<0.05). However, there was no significance variation of Mn values between bottled and groundwater samples. As indicated from Table (3) that most examined water samples had higher Mn levels more than the guideline value (0.05 mg/l) as recommended by international and Saudi standards. Water samples exceeding the maximum permissible limit of Mn were obtained from bottled, desalinated and groundwater with frequencies of 68.75% (11 out of 16); 87.10% (27 out of 31) and 53.33% (8 out of 15), respectively.

The overall mean of copper (Cu) concentration (mg/l) in all examined water samples was 0.78±0.22 (Table 2). Higher copper value (mg/l) was recorded in samples taken from groundwater with an average of 2.95±0.68, followed by desalinated water (0.09±0.03) and bottled water, which showed copper levels ranged from 0.00 to 0.7 with an average of 0.08±0.04. It is indicated also from Table (2) that copper levels showed significant higher levels in groundwater than in desalinated or bottled water (p<0.05). However, there was no significant variation in copper levels between desalinated and bottled water. Copper levels

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\hould not exceed 1.0 mg/l in drinking water supplies, as recommended by the international and Saudi standards. As presented in Table (3), water samples exceeding maximum permissible limit were obtained from groundwater with a frequency of 60.00% (9 out of 15).

Zinc (Zn) levels in the examined water from bottled, desalinated and groundwater are presented in Table (2), where ranges (mg/l) were 0.20-0.90; 0.00-0.26 and 0.0-2.42 with mean values of 0.22±0.05; 0.10±0.01 and 0.83±0.16, respectively. Moreover, the overall mean Zn value (mg/l) was 0.31±0.06 for all examined water samples. Zinc values showed significant differences between higher Zn levels in groundwater and Zn levels in bottled and desalinated water. ($p < 0.05$). Table (3) showed that all the examined bottled, desalinated and groundwater samples had Zn content lower than the guideline values as recommended by international and Saudi standards (5.0 mg/ l).

Table 1: Physico-chemical constituent results of drinking water samples

Water source/ Physicochemical parameter	Bottled water (n=16)		Desalinated water (n=31)		Groundwater (n=15)		TOTAL (n=62)	
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE
Turbidity (FAU)	0.00-2.00	0.56± 0.18	0.00-13.00	2.23[a]± 0.46	0.00-10.00	5.47[a b]± 0.98	0.00-13.00	2.85 ± 0.40
Conductivity (µS/cm)	90.00-290.00	136.25± 12.84	110.00-200.00	152.90± 3.05	120.00-2460.0	937.67[a b]± 199.13	120.00-2460.0	296.49± 63.20
Total solids (mg/l)	68.00-270.00	130.31± 13.79	110.00-340.00	230.48± 8.97	150.00-3640.00	1373.0[a b]± 314.51	68.00-3640.0	481.05± 98.56
PH	7.03-8.29	7.78± 0.09	7.40-8.40	7.75± 0.04	6.67-7.90	7.28[a b]± 0.09	6.67-8.40	7.64± 0.04
Chloride (mg/l)	14.50-40.50	21.78± 1.82	15.20-34.00	18.08± 0.66	11.50-914.80	206.01[a b]± 63.15	11.50-914.80	64.50± 18.07
Total hardness as Ca co₃ (mg/l)	3.07-85.40	36.46± 6.19	2.46-52.28	4.82[a]± 1.58	11.52-299.93	102.75[a b]± 22.81	2.46-299.93	36.68± 7.59
Ammonia (mg/l)	0.00-0.02	0.002± 0.001	0.00-0.10	0.02± 0.005	0.00-0.40	0.09[a b]± 0.03	0.00-0.40	0.03± 0.01
Sulphate (mg/l)	3.00-72.00	21.13± 4.73	17.00-82.00	53.13± 2.84	7.00-1400.0	524.20[a b]± 125.59	3.00-1400.0	158.84± 39.76
Nitrite (mg/l)	ND	-	ND	-	ND	-	ND	-
Nitrate (mg/l)	2.66-41.17	12.54± 2.11	3.98-49.13	13.98± 1.35	0.00-64.63	26.94[a b]± 5.83	0.00-64.63	16.74± 1.78
Iron (mg/l)	0.00-0.28	0.07± 0.02	0.00-0.39	0.11± 0.02	0.00-2.20	0.41[a b]± 0.18	0.00-2.20	0.17± 0.05
Manganese (mg/l)	0.00-0.60	0.16± 0.04	0.00-1.00	0.39[a]± 0.05	0.00-0.70	0.23± 0.07	0.00-1.0	0.29± 0.03
Copper (mg/l)	0.00-0.68	0.08± 0.04	0.00-0.70	0.09± 0.03	0.01-6.54	2.95[a b]± 0.68	0.00-6.54	0.78± 0.22
Zinc (mg/l)	0.20-0.90	0.22± 0.05	0.00-0.26	0.10± 0.01	0.00-2.42	0.83[a b]± 0.16	0.00-2.42	0.31± 0.06

(Fieldwork and sample analysis have extended from February-July 2007)

ND= Not Detected.
[a]= Variation against bottled water samples (the mean difference is significant at 0.05 level).
[b]= Variation against desalinated water samples(the mean difference is significant at 0.05 level).

Table 2: Percentage of water samples exceeding the permissible limits of physical, and chemical parameters of the examined drinking water sources

Parameter	Permissible limit	Bottled water (n=16) Over Permissible Limit		Desalinated water (n=31) Over Permissible Limit		Groundwater (wells) (n=15) Over Permissible Limit	
		No.	%	No.	%	No.	%
Turbidity (NTU)	5**	0	0.0	3	9.68	9	60.00
Conductivity µS/ cm	400***	0	0.0	0	0.00	10	66.67
Total solids (mg/l)	500*	0	0.00	0	0.0	9	60.00
Ph	6.5-8.5*	0	0.0	0	0.0	0	0.0
Chloride (mg/l)	250*	0	0.0	0	0.0	6	40.0
Total hardness as Ca co$_3$ (mg/l)	100**	0	0.0	0	0.0	7	46.67
Sulphate (mg/l)	200*	0	0.0	0	0	9	60.0
Ammonia (mg/l)	0.5*	0	0.0	0	0.0	0	0.0
Nitrite (mg/l)	0.2**	0	0.0	0	0.0	0	0.0
Nitrate (mg/l)	45*	0	0.0	1	3.23	4	26.67
Iron (mg/l)	0.3*	0	0.0	3	9.68	4	26.67
Manganese (mg/l)	0.05**	11	68.75	27	87.10	8	53.33
Copper (mg/l)	1*	0	0.0	0	0.0	9	60.0
Zinc (mg/l)	5.0*	0	0.00	0	0.00	0.0	0.00

(fieldwork and sample analysis have extended from February-July 2007)
ND=Not Detected. *=Saudi standards for drinking water.
**=Highest desirable limit for drinking water [33].
***= European Union [35]

Discussion

The main problems related to drinking water quality are associated with the conditions of the water supply networks of the study area. The hygienic condition of the three major water resources (bottled, desalinated and groundwater) used in this study area was assessed.

Turbidity of water less than 5 NTU (FAU) is usually accepted for consumers, although this may vary with local circumstances. From the hygienic point of view, the consumption of high turbid water may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants, and also stimulate the growth of bacteria during storage [20].

The results of conductivity recorded in this study were nearly similar with those of previously reported [2, 7]. lower conductivity values were previously reported [21], while higher levels were also recorded [22]. It was concluded that taste was objectionable and soap consumption deemed high for the water with highest conductivity, while for water with lowest conductivity, taste was satisfactory and soap consumption deemed normal [18].

Regarding total solids, lower figures were previously recorded [23]. From the hygienic aspects, high levels of total solids may affect taste, hardness and corrosion properties of water. On the other hand, water with extremely low levels of total solids may also be unacceptable of its flat and insipid taste [20].

In case of pH, nearly similar results were obtained [18, 19, 22, 23]. Lower pH values were also recorded [7, 21]. It was suggested that low pH results in corrosion and high pH would result taste

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complaints [20].

The chloride levels recorded in our study are supported with those previously recorded [2, 22, 23]. Lower chloride levels were also reported [24]. In previous study carried out in Saudi Arabia on water samples taken from Zamzam well water and Zamzam pipe water, the mean chloride values were 163.3 and 159.7 mg/l, respectively [25]. Bottled and desalinated water samples had chloride levels lower than the maximum permissible limit of chloride. The highest chloride content is related to evaporation process [7], However, enriched water with salt may occur either naturally or due to over pumping, resulting in intrusion of marine waters in groundwater [2]. It should be underlined that the parametric value established especially regarding chloride, are not health related, but set in order to avoid unpleasant taste and corrosion effect in pipes. The high salt content in water supplies is also not suitable for drinking. It may reduce their palatability and can cause distress in livestock [26]. A higher hardness level was previously recorded [23].

Calcium and magnesium are known to occur naturally in water due to its passage through mineral deposits and rock strata and contribute to its total hardness [2]. It has been suspected that there is a causal link between water hardness and cardiovascular disease and mortality [27].

The obtained sulphate results are supported with those previously recorded [2, 22]. Lower sulphate figures were also reported [7, 21, 24, 25]. Sulphate occurs naturally in many water sources coming in contact with particular rock strata and mineral deposits [28]. Moreover, excess in sulphate indicates many causes of pollution either surface or ground water. Considering groundwater in particular, such substance may associated with health risk. Diarrhea may be associated with the consumption of water polluted with sulphate [2].

In comparison the results of ammonia obtained in this study with other previous results, it was found that higher levels were previously recorded [2, 23, 25, 29]. The presence of ammonia at higher levels is an important indicator of recent faecal pollution from sewage, imposing a serious threat against public health. This may be attributed to the fact that ammonia may result also from fertilizers, although in this case it is relatively easily oxidized in soil to nitrite and finally to nitrate [2].

Higher nitrate levels more than the obtained results of this study were previously recorded [2, 21, 22, 23, 24, 29]. However, lower nitrate figure was also reported [7]. Nitrates originate from fertilizers of potassium and/or ammonium nitrate. Since these salts are very soluble and do not bind to soils, nitrates migrate easily to groundwater [30]. The presence of nitrates indicates older events of pollution and excessive nitrate levels in drinking water have caused illness and sometimes death. Nitrate and nitrite at higher levels have an potential to cause the diuresis, increased starchy deposits and haemorrhage of spleen as well as causing infant methaemoglobinaemia like nitrates, a disease characterized by bluish coloration of skin [26].

In previous studies, lower iron figures were reported [7, 19, 22, 24]. Iron is mostly a naturally derived metallic pollutant, which owes its origin in waters mainly to the sources derived from soil and rocks [26]. Iron is essential in low concentration. Moreover, iron poisoning is very clear in children less than 5 years of age. Gastrointestinal tract and liver are the main target iron toxicity. Iron produces coagulative necrosis, bleeding and death [32].

Higher Mn value was previously reported [19], while lower Mn figures were also recorded [7, 21, 22, 24]. Excessive Mn concentration may exist in groundwater from soil and rocks as well as decaying organic matter. Manganese does not

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appear to have any toxicological significance in drinking water at the quantities generally occur in raw waters. In some cases, chronic poisoning by Mn can result by extended exposure to very high levels in drinking water, manifested by progressive deterioration of central nervous system, lethargy and symptoms stimulating Parkinson‚s syndrome [26, 33]. Nearly similar results were previously reported [22]. Lower copper figures were also recorded [2, 7, 21, 24]. The recorded copper levels in desalinated and bottled water were lower than the maximum permissible levels for copper.

The results of copper levels showed significant higher levels in groundwater than in desalinated or bottled water. Copper is essential at low concentration, but it is toxic at high levels in drinking water. Ingestion of water with high copper concentrations may lead to gastrointestinal distress, jaundice and Wilson‚s disease which characterized by destruction of new cells, liver cirrhosis, ascitis, oedema and hemolytic anaemia, cardiovascular collapse and hepatic failure [34].

From the obtained zinc results, the highest value was recorded in samples taken from groundwater, followed by bottled and lastly desalinated water. Zinc is an essential component for at least 8 enzyme systems. Moreover, when Zn ingested in water with high amounts may lead to gastrointestinal irritation with nausea, vomiting and watery diarrhea. Also, it is associated with central nervous system depression and tremors [33, 34].

Conclusion

In conclusion, the physico-chemical analysis of water sources used in Khamis Mushait governorate has allowed determining and characterizing their quality and pointing out its suitability for human consumptions with regards of national and international standards. Water derived from groundwater (wells) showed increases in most of the investigated physico-chemical parameters as compared to bottled and desalinated water. However, this may be attributed to the fact that groundwater is at risk contamination as indicated by the higher levels of these parameters and has to be considered for more of investigations. Moreover, groundwater is exposed to point pollution sources as septic wells, domestic and farming effluents as well as soil of high humus content. The lower physico-chemical characteristics in bottled water samples indicates their satisfactory for human drinking water purposes. Desalinated water is considered also satisfactory at its regional distributing point. However, contamination of desalinated water may occur during transportation or storage in house reservoir. Improving and expanding existing water treatment as well as sanitation system is more likely to provide safe and sustainable sources of water over the long term. However, private drinking water systems are not regulated by local health and environmental agency. So, strict hygienic measures by local authorities of the study area should be applied to improve quality of drinking water and to avoid deleterious effect on human health. This could be achieved by working towards a proper monitoring program of drinking water supply and sources for Aseer province in general. Sanitary criteria and regulations should be also established\to provide necessary protection of drinking water consumption.

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