

## Effectiveness of Groundwater Treatment for Drinking Use and Dairy and Food Processing

Mohamed G El-Ziney<sup>1,3\*</sup>, Abdalla S Ammar<sup>2,3</sup> and Ahmad I Al-Turki<sup>4</sup>

<sup>1</sup>Dairy Science and Technology Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

<sup>2</sup>Food Science and Technology Department, Faculty of Agriculture, Cairo University, Cairo, Egypt

<sup>3</sup>Food Science and Human Nutrition Department, Faculty of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia

<sup>4</sup>Plant Production and Protection Department, Faculty of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia

\*Corresponding author: Mohamed G El-Ziney, Associate Professor of Dairy Science and Technology, Dairy Science and Technology Department, Faculty of Agriculture, Alexandria University, PO Box 21454 Alexandria, Egypt, Tel: +20 3 5921675; E-mail: elziney@yahoo.com

Received date: March 15, 2018; Accepted date: March 30, 2018; Published date: March 31, 2018

Copyright: © 2018 El-Ziney MG, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

### Abstract

Groundwater supplies should undergo comprehensive water quality testing to ensure suitability for drinking water and dairy production purposes. Evaluation of chemical characteristics and microbiological quality as well as treatment processes applied for the removal of contaminants from groundwater extracted from Al-Sag aquifer in Buraydah, Qassim region were investigated. The tested water samples from both well sources and effluents were found to have total dissolved solids, electrical conductivity and turbidity values within the acceptable limits of Saudi standards and WHO guidelines. Of course, the reduction percentages were the same for EC and TDS (58.6-93.6%) while it scored 0.0-100% for turbidity due to the adopted treatment processes. Chemical characteristics such as total alkalinity, chloride, nitrate and hardness were also found to be within the permissible levels of both Saudi standards and WHO guidelines. The effectiveness of the adopted treatment processes led to decrease such chemical parameters percent in the treated groundwater by about 54-82.9, 56.9-82.6, 29.0-95.8 and 7.9-98.2%, respectively. Moreover, mineral contents such as iron and cadmium in both raw and treated groundwater were below the detection limit. Groundwater contained fluorine at low levels than permissible limits set by local and international standards; therefore, fluoridation process must be taken into consideration for drinking use. Zinc content of the treated water was within the allowed concentration required by the Saudi standards and the WHO guidelines. While, nickel and lead contents in three groundwater sources were found to be higher than those postulated and recommended by the Saudi standards and WHO guidelines. However, water treatment at all studied stations was fair enough to remove these hazards and secure water. In regards to microbiological quality, the treated groundwater was found to be totally free from coliform organisms with almost undetectable level of viable count rendering them quite safe for drinking use and dairy-food processing.

**Keywords:** Al-Sag aquifer; Groundwater; Treatment; Drinking water; Dairy process

### Introduction

Treating drinking water to remove toxic chemicals and disease-causing agents and further to improve smell and taste has been necessary throughout human history. Safe and readily available water is important for public health, whether it is used for drinking, domestic use, food production or recreational purposes. Dairy and food facilities and processors work on the premise that incoming public municipal water is safe, and dependably get notice of any oddity so as to secure their procedures in case of contamination. According to EPA regulations, drinking water are cited as the rationale to give municipal water users a safe-harbor-like exemption to bypass water in their written food safety plans and not to evaluate their water integrity risks in a formal, analytical, or scientific way that facilitates planning, prevention, and risk mitigation [1]. The dairy and food plants use water for different activities i.e. washing/cleaning of equipment, transport of product, dissolution of ingredients, water remaining in the final product etc. A characteristic of process water is that it comes into contact with product directly or indirectly. Therefore, process water should meet drinking water quality.

The physical and chemical characteristics as well as microbiological tests are of major importance in evaluating the quality and safety of water source and consequently the applied treatment. Public water supplies must be free from any adverse effects on human health and conform to certain levels of physical, chemical and microbiological quality [2]. The physical and chemical parameter limits suggested by World Health Organization Guidelines [3] and by Saudi mandatory Standards [4] which issued Saudi Standards, Metrology and Quality Organization (SASO) are presented in Table 1.

Literature reveals that the levels of some water quality constituents in drinking waters are in violation of action levels for various parameters, especially some toxic trace metals [5-10]. Groundwater can be contaminated by pathogens, agricultural and industrial chemicals. Water distribution systems may contain living microorganisms due to water treatment failures or deriving from leaks, cross-connections and back-flows. Bacterial growth may also occur at or near the pipe surfaces (biofilms), the interface with suspended particulates and within the water itself. Additionally, inorganic (arsenic, chromium, lead, nickel, etc.) and organic (trihalomethanes and other disinfection byproducts, pesticides and volatile organic chemicals) contamination may occur along water distribution systems [11]. The presence of organics, toxic elements, radionuclides, nitrates and nitrites in drinking water can lead to cancer, other human body

malfunctions and chronic illnesses [12]. Qassim region is the central semi-desert part of the Kingdom of Saudi Arabia (KSA) with population amounted to 1,387,996 in 2106 and eight dairy and food processing plants. The main source for drinking, food processing and irrigation water is the undergroundwater of Al-Sag famous aquifer. The water in this bed varies in its depth between 50 to more than 1000 m [13]. Groundwater contributes to nearly 79% of the total supply, 82% of which is treated [14].

Major constituents	WHO Guidelines limits (ppm)	Saudi Standards (ppm)
EC	-	2300*
TDS	1000	1500
Total hardness	-	500
Cl <sup>-</sup>	-	600
Ca <sup>+2</sup>	-	200
Mg <sup>+2</sup>	-	150
NO <sup>3-</sup>	50	45
Trace metals	WHO Max. permissible limits (ppb)	Saudi Standards (ppm)
Pb	10	0.1
Cd	3	0.01
Ni	70	-
Zn	3000	5-15
Fe	300	0.1-1
Fe <sup>-</sup>	1.5	0.6
*µmhos/cm		

**Table 1:** World Health Organization Guidelines and Saudi standards of drinking water.

The aim of this study was to evaluate the chemical and microbiological characteristics of groundwater and its treatment efficiency in Buraydah, Qassim region and its suitability for drinking use and food processing.

## Materials and Methods

Samples were collected from different water wells before treatment (source water) and after treatment (treated water). Samples were drawn during winter and spring seasons at Buraydah, Qassim region. Water samples were collected according to the WHO recommendations and the Standard Methods for the Examination of Water and Wastewater as reported by APHA, AWWA and WPCF [15].

## Sampling Sites

A total of 32 water samples (from the well source and after treatment) were collected from eight production sites included the main water well stations in Buraydah, Qassim region.

## Handling of Water Samples

Sterile one-liter glass bottles were used to collect water samples. All sample bottles were kept refrigerated (4°C) during transport to the lab inside insulated ice box. Firstly, microbiological samples were withdrawn under sterilized conditions then the rest of sample kept for major constituents and trace elements analysis. Microbial analyses were done at the same day of sampling while chemical analyses were performed during 48 h of sampling.

## Microbiological Analysis

The determination of total viable count in water samples was done according to ISO 6222 [16]. Membrane Filtration Method (MFM) was used to determine total coliforms according to ISO 9308-1 [17]. All used media were purchased from Oxoid (Hampshire, UK) and prepared according to manufacturer instructions.

## Physical and Chemical Analysis

All reagents used throughout study were of analytical grade purity (Sigma, USA). Physical and chemical analyses were carried out according to the Standard Methods for the Examination of Water and Wastewater as reported by APHA, AWWA and WPCF [15] as follows:

### Electrical conductivity (EC) and total dissolved solids (TDS)

Electric conductivity (mmhos/cm at 25°C) was measured by a Beckman Solu-Bridge type SD-178 calibrated using anhydrous KCL solution (0.01N) adjusted at 25°C. Total dissolved solids (TDS) were determined by multiplying the conductivity value by 640 according to Rhoades [18].

### Turbidity

Turbidity of water samples was measured using Tokyo Photoelectric Turbidimeter (Model ANA14A, Japan).

### Total hardness (Ca<sup>++</sup> and Mg<sup>++</sup>) determination

Titration with ethylene diamine tetra acetic acid disodium (Na<sub>2</sub> EDTA) in the presence of eriochrome black T as an indicator was used to measure the total hardness of water samples.

### Total alkalinity

Alkalinity was determined by titration with 0.02 N H<sub>2</sub>SO<sub>4</sub> in the presence of methyl orange as an indicator.

### Chloride determination

Chloride ions of water samples were determined by titration method with 0.0141N silver nitrate in the presence of potassium chromate as an indicator.

### Nitrate determination

Nitrates of water samples were determined calorimetrically by using NED dihydrochloride N-(1-naphthyl)-ethylenediamine dihydrochloride.

## Fluoride

Fluoride of water samples was determined calorimetrically by using SPADNS method [4,5 dihydroxy-3-(p-sulphonylazo)-2,7-naphthalenedisulfonic acid tri-sodium salt] and using NaF for preparation of the standard solution.

## Elements

Elements content included Fe<sup>3+</sup>, Cd, Ni, Pb and Zn were determined by atomic absorption spectrometry (AAS) method (Shimadzu 6800, Japan). Stock solutions for every studied element were prepared and required standards were prepared daily by appropriate dilution of the stock solution (10-2 M).

## Statistical Analysis

Data were subjected to ANOVA analysis to evaluate the effect of well site, station treatment and season on the physical and chemical characteristics among samples. The test of significance was determined on the basis of Duncan's test at p<0.05 probability using the SPSS statistics<sup>®</sup> 13 software.

## Results and Discussion

In the present study, physical, chemical and microbiological characteristics of groundwater whether raw or treated, were determined to evaluate its suitability for drinking and for food industry use. Groundwater either at fresh raw state or after treatment should contain no health hazards as pathogens, toxic chemicals and carcinogenic compounds during their direct consumption as drinking water or as industrial use.

### Physical characteristics of raw and treated groundwater

Physical characteristics of the groundwater in two seasons, i.e. total dissolved solids (TDS), electrical conductivity (EC) and turbidity were determined as presented in Tables 2 and 3. The results indicate that the physical characteristics of the treated groundwater varied according to the treatment plant site and probably to the treatment process itself and to the water quality at well water. The TDS values of raw groundwater ranged between 533.78 (WS7, spring season) and 1817.6 mg/l (WS8, spring season).

Sample*	Physical Parameters					
	TDS (mg/l)	Reduction %	Conductivity (mmhos/cm)	Reduction %	Turbidity (NTU†)	Reduction %
WS1	602.24	86	0.941	86	0.1	100
AT1	83.84		0.131		0	
WS 2	593.92	58.6	0.928	58.6	0.2	100
AT2	245.76		0.384		0	
WS3	586.88	86	0.917	86	0.2	100
AT3	81.92		0.128		0	
WS4	1000.32	87.3	1.563	87.3	0.2	100
AT4	126.72		0.198		0	
WS5	716.8	82.9	1.12	82.9	0	0
AT5	122.24		0.191		0	
WS6	805.76	86.6	1.259	86.6	0.3	83.3
AT6	107.58		0.168		0.05	
WS7	533.76	77.8	0.834	77.8	0.2	100
AT7	118.4		0.185		0	
WS8	1811.2	93.6	2.83	93.6	0.5	40
AT8	115.46		0.18		0.3	

\*WS=Groundwater Source; AT=Source After Treatment.  
†NTU=Nephelometric Turbidity Unit

**Table 2:** Physical characteristics of raw and treated groundwater (winter season).

The TDS of the groundwater due to treatment processing were reduced by 58.6-93.6% during the winter season (Table 2) and 76.8-93.6% in spring season (Table 3).

Sample*	Physical Parameter					
	TDS (mg/l)	Reduction %	Conductivity (mmhos/cm)	Reduction %	Turbidity (NTU†)	Reduction %
WS1	627.2	76.8	0.98	77	1.95	82
AT1	145.6		0.225		0.35	
WS 2	620.8	79.1	0.97	79.2	0.35	0
AT2	129.6		0.202		0.35	
WS3	589.12	86.4	0.92	86.4	0.85	58.8
AT3	80		0.125		0.35	
WS4	937.92	87.2	1.465	87.2	0.2	100
AT4	119.68		0.187		0	
WS5	826.25	88.2	1.291	88.4	0.25	20
AT5	97.28		0.15		0.2	
WS6	816.64	82.9	1.27	82.8	0.65	69.2
AT6	139.52		0.218		0.2	
WS7	543.68	78.8	0.85	78.8	0.55	36.4
AT7	115.52		0.18		0.35	
WS8	1817.6	93.6	2.84	93.6	0.6	50
AT8	115.39		0.18		0.3	

\*WS=Groundwater Source; AT= Source After Treatment.  
† NTU=Nephelometric Turbidity Unit.

**Table 3:** Physical characteristics of raw and treated groundwater (spring season).

However, the obtained TDS values of the treated groundwater as withdrawn from the different sites along the year were within the permissible limits required by the Saudi Standards (1500 mg/l) and the WHO (1000 mg/l) guidelines (Table 1). The results presented in Table 2 also show the electrical conductivity values of raw groundwater occurred between 0.834-2.830 mmhos/cm. The EC values are in agreement with those reported by Al-Oud et al., [13]. The treatment of the groundwater caused a reduction in its EC values being 58.6-93.6% along the year. The obtained EC values of the treated groundwater were within the allowed limits required by the Saudi standards (2.3 mmhos/cm).

Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness. Chemical coagulation by using ferric chloride was very efficient in the removal of turbidity [19]. The turbidity of the groundwater after treatment was also reduced by about 20.0-100% along the different seasons. However, the obtained turbidity values of raw groundwater (0.1-1.95 NTU) were found to be within the permissible limits required by the Saudi standards [4] and the WHO guidelines (5 NTU) [3]. After the treatment processes the treated groundwater of the majority of water plants became totally free of turbidity. Analysis of variance revealed the

presence of significant effects ( $p < 0.05$ ) of groundwater sources, water treatment stations and seasons on water physical properties. In regard to EC and TDS, the highest values were found in well number 8 while the lowest were determined in well number 7 with significant different between wells. The statistical analyses showed that four out of eight water treatment stations (AT 3, 4, 7 and 8), monitored during the present study, had constant TDS values during tested seasons, however as we stated before none of water purification plant exceeds the limits of SASO standards. Similar results are reported of groundwater in central region of Saudi Arabia [20].

### Chemical characteristics of raw and treated groundwater

Chemical characteristics of raw and treated groundwater i.e., total alkalinity, hardness, nitrate, chlorides and metals were evaluated, presented in Tables 4 and 5. The results show that the alkalinity values of raw groundwater ranged from 139.88 (WS8, Table 5) to 240.95 mg/l (WS4, Table 5). The treatment process of groundwater caused a high reduction in alkalinity values by about 54-82.9% during the two seasons. Parker and Litchfield [21] stated that alkalinity might be reduced by treatment with lime or with hydrogen zeolites or cation exchange resins.

Sample *	Chemical Parameters									
	Hardness		Total	Red** %	Chloride	Red %	NO <sup>3-</sup>	Red %	Total alkalinity	Red %
	Ca <sup>+2</sup>	Mg <sup>+2</sup>								
WS1	16.9	15.7	42.25	16.7	4.64	79	6.39	81.2	210	75.7
AT1	14.08	4.22	35.2		0.97		1.2		51.05	
WS 2	29.26	12.56	73.16	98.2	4.33	61.2	0.54	44.4	210.05	59.2
AT2	0.52	0.002	1.31		1.68		0.3		85.6	
WS3	40.7	12.09	103	90.6	4.27	71.7	3	50	200.48	79.4
AT3	3.87	2.27	9.69		1.21		1.5		41.37	
WS4	22.5	11.5	56.25	83.3	12.01	82.6	4.8	95.8	240	82.9
AT4	3.76	0.001	9.41		2.09		0.2		41.03	
WS5	36.86	16.13	92.15	74.4	4.47	77.6	6.2	29	215	80.3
AT5	9.43	0.001	23.57		1		4.4		42.29	
WS6	12.53	38.12	31.34	7.9	6.42	80.7	7.4	47.3	153	54.2
AT6	11.54	0.029	28.85		1.24		3.9		70	
WS7	10.16	14.58	25.41	62.3	3.36	68.2	4.8	47.5	215.5	79.1
AT7	3.83	2.36	9.57		1.07		2.52		45	
WS8	40.78	11.9	101.95	90.2	3.52	67.6	3	52.7	140	69.3
AT8	4	2.48	10		1.14		1.42		43	

\*WS=Groundwater Source; AT=Source After Treatment.  
 \*\* Red%=Reduction percent

Table 4: Chemical characteristic contents (mg/l) of raw and treated groundwater (winter season).

Sample *	Chemical Parameters									
	Hardness		Total	Red** %	Chloride	Red %	NO <sup>3-</sup> mg/l	Red %	Total alkalinity	Red %
	Ca <sup>+2</sup>	Mg <sup>+2</sup>								
WS1	16	14.4	40	50	4.84	77.7	1.3	69.2	209.23	75.8
AT1	8	2.4	20		1.08		0.4		50.63	
WS 2	28	12	70	92.9	4.5	56.9	3.1	45.2	206.79	59
AT2	1	0	5		1.94		1.7		84.79	
WS3	40	12	100	90	4.38	72.1	2.1	66.7	197.64	79.3
AT3	4	2.4	10		1.22		0.7		40.87	
WS4	24	12	60	83.3	12.16	82	1.1	72.7	240.95	82.3
AT4	4	0	10		2.18		0.3		42.7	
WS5	32	14.4	80	62.5	4.66	77.7	6.2	79	215.33	79.9
AT5	12	0	30		1.04		1.3		43.31	
WS6	12	38.4	30	33.3	6.58	78.7	8	67.5	153.72	54

AT6	8	2.4	20		1.4		2.6		70.76	
WS7	10	14.4	50	80	3.4	67	3.2	50	216.55	78.3
AT7	4	2.4	10		1.12		1.6		46.97	
WS8	40.8	11.9	102	90.2	3.48	67.8	2.9	44.8	139.88	69.3
AT8	4	2.5	10		1.12		1.6		42.97	

\*WS=Groundwater Source; AT=Source After Treatment.  
\*\* Red%=Reduction percent

**Table 5:** Chemical characteristics (mg/l) of raw and treated groundwater (spring season).

From the same tables (Tables 4 and 5) it could be noticed that chlorides content of the raw groundwater ranged from 3.40 (WS7, Table 4) to 12.16 mg/l (WS4, Table 5). The chlorides content of the groundwater due to treatment processes adopted were reduced about 56.9-82.0% over the year. However, the obtained chlorides contents of raw groundwater were found to be within the permissible limits required by the SASO (600 mg/l).

Concerning water hardness, Tables 4 and 5 showed that total hardness values in raw groundwater ranged between 25.41 (WS7, Table 4) and 103 mg/l (WS3, Table 4) during the different months of the year. Total hardness was reduced in the groundwater after treatment by about 7.9-98.2% and 33.3-92.9% in winter and spring seasons respectively. Such reduction in hardness is due to the used chemical precipitation treatment [22]. Generally the total hardness of the treated groundwater as withdrawn from the different sites along the year were within the permissible limits required by SASO [4] and the USEPA (500 mg/L) guidelines.

The nitrate content of raw groundwater samples was ranged from 0.54 to 8.0 mg/l (Tables 4 and 5). The nitrate content was reduced in the groundwater after treatment by about 29.0-95.8% during winter season and 45.2-79.0% during spring season. The recorded values of nitrate are, however, within the allowed and recommended levels in accordance to Saudi standards (45 mg/l) and the WHO (50 mg/l) guidelines indicating relevant safety of such treated water as reported by Al-Redhaiman and Abdel Magid, [14]. There were significant differences between treated waters from the water treatment plants inside each season and between winter and spring season ( $p < 0.05$ ). However, all of the produced municipal waters were laid within the SASO guidelines more concerning should be taken into consideration in regrade to hardness and alkalinity of water used for cleaning and disinfection purposes in food plants.

### Mineral content

Besides, it is known that of the water characteristics are mainly related to its minerals content. Therefore, the minerals content, i.e. Fe, Zn, Ni, Cd, pb and Fe- of the raw and treated groundwater in winter season were determined and the obtained results are presented in Table 6. The concentrations of Zn were ranged from 0.00 to 1.57 mg/l in raw groundwater while, it reduced due to water treatment to 0.046-0.55 mg/l. Likewise, nickel content in same groundwater samples ranged from 0.00 to 0.23 mg/l. Concerning lead, raw groundwater samples contained lead up to 1.33 (WS3) while, Pb was not detected in most of raw untreated samples (n=6). In the same manner, iron and cadmium contents in both raw and treated groundwater were below the

detection limit confirmed the validity of water produced by municipalities. Nevertheless, water metal pipelines network found to be responsible for water contamination by Cu, Zn (dissolved from the pipe work) and Cd (entering water from the brass fittings) in Saudi Arabia [6].

Sample*	Fe	Cd	Ni	Pb	Zn	Fe-
WS1	0	0	0.059	0	1.57	0.51
AT1	0	0	0.038	0	0.55	0.22
WS 2	0	0	0.036	0	0.88	0.3
AT2	0	0	0	0	0.25	0.22
WS3	0	0	0	1.33	0.537	0.21
AT3	0	0	0	0	0.22	0.1
WS4	0	0	0	0.228	0.091	0.34
AT4	0	0	0	0	0.08	0.34
WS5	0	0	0	0	0.065	0.34
AT5	0	0	0	0	0.046	0.01
WS6	0	0	0	0	0.063	0.19
AT6	0	0	0	0	0.061	0.14
WS7	0	0	0	0	0.061	0.89
AT7	0	0	0	0	0.057	0.41
WS8	0.0001	0.014	0.23	0.044	0	0.65
AT8	0	0	0.46	0	0	0

\*WS=Groundwater Source; AT=Source After Treatment.

**Table 6:** Mineral content (ppm) of raw and treated groundwater.

In the present study, Zn contents of the treated water were within the allowed concentration required by the Saudi standards (15 mg/l) and the WHO (3 mg/l) guidelines. In the same manner, only one water source (WS8) exceeded Ni recommend limit assessed by the WHO (0.07 mg/l) guidelines. Pb contents in some groundwater sources were higher than those postulated and recommended by Saudi standards (0.1 mg/l) and the WHO (0.01mg/l) guidelines. Meanwhile, water treatment was efficient able to eliminate the trace elements to be below detectable limit (Table 6). Only Zn and Fe- indicated critical

differences ( $p < 0.05$ ) in their level between treated water samples delivered by various water treatment plants. On the other hand, the fluorides content in the treated groundwater (0.01 and 0.41 mg/l) was found to be rather low as compared to its level in fresh raw groundwater (0.19 and 0.89 mg/l) (Table 6). These results are in agreement with those found by AlbdulaAly [23]. In that study the fluoride level in Riyadh drinking water supplies was below the optimum recommended level. Likewise, Al-Redhaiman and Abdel Magid, [14] also found that 88% of municipal water samples were below the lower permissible limit set by Saudi standards [4]. Harrison, [24] stated that in groundwater, fluoride concentrations range from trace quantities to over 25 mg/l. These determined values are lower than those required by the Saudi standards (0.6 mg/l) and the WHO (1.5 mg/l) guidelines for drinking water. Therefore, fluoride has to be added to public water supplies to improve dental health.

### Microbiological evaluation

It is known that the microbiological examination of water is greatly needed to assure its safety for drinking and to avoid cross contamination during dairy and food processing.

Sample*	Total viable count (cfu/ml)		Total Coliforms (cfu/100 ml)	
	Winter	Spring	Winter	Spring
WS1	$0.5 \times 10^2$	$0.9 \times 10^2$	2	nd†
AT1	nd	nd	nd	nd
WS2	$0.44 \times 10^2$	nd	2	nd
AT2	nd	nd	nd	nd
WS3	$0.66 \times 10^2$	$1.5 \times 10^2$	3	nd
AT3	nd	nd	nd	nd
WS4	$0.5 \times 10^2$	nd	1	nd
AT4	nd	nd	nd	nd
WS5	$0.4 \times 10^2$	$0.9 \times 10^2$	1	nd
AT5	nd	nd	nd	nd
WS6	$3.34 \times 10^2$	$0.2 \times 10^2$	2	nd
AT6	$0.4 \times 10^1$	9	nd	nd
WS7	$0.79 \times 10^2$	$0.6 \times 10^2$	1	nd
AT7	$0.2 \times 10^1$	nd	nd	nd
WS8	$0.56 \times 10^2$	$0.61 \times 10^2$	nd	nd
AT8	$0.2 \times 10^1$	2	nd	nd

\*WS=Groundwater Source; AT=Source After Treatment.  
†nd=not detectable.

**Table 7:** Microbiological characteristics of ground drinking water during winter and spring seasons.

Therefore, raw groundwater and treated water were microbiologically examined for its content of total viable count and total coliforms in water samples withdrawn at different sites at two seasons. The obtained results are shown in Table 7 indicated that the

raw groundwater had low bacterial counts ranged between  $0.4 \times 10^2$  and  $3.34 \times 10^2$  cfu/ml during the winter season and  $0.2 \times 10^2$  and  $1.5 \times 10^2$  cfu/ml in spring season. From the same table (Table 7) it could be noticed that the groundwater contained low total coliform counts during both seasons. These results are indicating the absence of mixing between sewage and groundwater [14,25]. On the other hand, the treated groundwater was found to be totally free from the coliform organisms with total count as low as 9 cfu/ml, rendering them quite safe for drinking and other purposes due to the presence of ample residual chlorine. However to assure continuous safety of such water, a constant check on bacterial quality should be carried out at least once a day in large supplies and weekly intervals in small supplies. In previous study 20% of tested groundwater samples ( $n=40$ ) were found to be contaminated by coliforms bacteria [26]. This might be expected since these wells located in urban area (Hael region, KSA) where most of it didn't receive the same protected construction as those reported in the present study (Buraydah, Qassim region).

### Conclusion

The conclusions and recommendations delivered from the present study on Qassim groundwater and its produced treated water could be summarized as follows:

- High content of TDS was removed due to the adopted treatment processes. Further, the groundwater became almost free from turbidities.
- A great removal of total hardness was exhibited in the most of water treatment plant samples however; frequently examination of municipal water supply at food plants is necessary to avoid inconvenient water treatment which could cause a complication during cleaning and disinfection processes.
- Some of water treatment plants reduced nitrate by less than 50% which is requiring more critical treatment review.
- Groundwater exhibited low contents of Fe, Cd and Zn.
- In some groundwater sources, nickel and lead contents were higher than those postulated and recommended by the Saudi standards and WHO guidelines however; water treatment restored it to the safe level.
- Groundwater contained fluoride at levels lower than permissible limits set by national and international standards therefore, fluoridation process must be included in the treatment processes to meet the standards level.
- The treated groundwater was found to be totally free from coliform organisms concurrently with undetectable limit of viable count.
- It is concluded that water treatment of groundwater in Buraydah city is sufficient to render treated water to be quite safe for drinking use and dairy/food processing.

### Acknowledgements

This research work has been financially supported by Deanship of Scientific Research, Qassim University, Saudi Arabia under grant No. SR-D-008-50.

### References

1. EPA (1974) Safe Drinking Water Act.
2. Augoustinos MT, Venter SN, Kfir R (1995) Assessment of water quality problems due to microbial growth in drinking water distribution systems. Environ Toxicol Water Qual 10: 295-299.

3. WHO (2011) Guidelines for Drinking-water Quality (4th ed.), Switzerland, Geneva.
4. Saudi Standards (1984) Saudi Standards for drinking water. Saudi Arabia pp: 408-409.
5. Asubiojo OI, Nkono NA, Ogunsua AO, Oluwole AF, Ward NI, et al. (1997) Trace elements in drinking water and groundwater in Southern Nigeria. *Sci Total Environ* 208:1-8.
6. Al-Saleh I, Al-Doush I (1998) Survey of trace elements in household and bottled drinking water samples collected in Riyadh, Saudi Arabia. *Sci Total Environ* 216:181-192.
7. Misund A, Frengstad B, Siewers U, Reimann C (1999) Variation of 66 elements in European bottled mineral waters. *Sci Total Environ* 243-244:21-41.
8. Reimann C, Siewers U, Skarphagen H, Banks D (1999) Influence of filtration on concentrations of 62 elements analysed on crystalline bedrock groundwater samples by ICP-MS. *Sci Total Environ* 234:155-173.
9. Frengstad B, Skrede AKM, Banks D, Krog JR, Siewers U (2000) The chemistry of Norwegian groundwaters: III. The distribution of trace elements in 476 crystalline bedrock groundwaters, as analysed by ICP-MS techniques. *Sci Total Environ* 246:21-40.
10. Ozturk N, Yilmaz YZ (2000) Trace elements and radioactivity levels in drinking water near Tuncbilek coal-fired power plant in Kutahya, Turkey. *Water Res.* 34:704-708.
11. Ferretti E, Lucentini L, Veschetti E, Bonadonna L, Stamatii A, et al. (2007) Screening and identification of unknown contaminants in water destined to human consumption: A case study. *Microchem J* 85: 57-64.
12. Ikem A, Oduyungbo S, Egiebor NO, Nyavor K (2002) Chemical quality of bottled waters from three cities in eastern Alabama. *The Sci Total Environ* 285: 165-175.
13. Al-Oud SS, El-Nadi AH, Salad S (2000) Detection of organic aromatic polycyclic hydrocarbons in undergroundwater of Al-Qassim region, central of Saudi Arabia. *J Agric Sci Mansoura Univ* 25: 4709-4715.
14. Al-Redhaiman KN, Abdel-Magid HM (2002) The applicability of the local and international water quality guidelines to Al-Gassim region of central Saudi Arabia. *Water Air Soil Poll* 137: 235-246.
15. APHA, AWWA, WPCF (1985) Standard Methods for the Examination of Water and Wastewater. (16th ed.), Port city press, Baltimore, Maryland, USA.
16. ISO (1988) Water Quality C Enumeration of Viable Microorganisms. Colony Count by Inoculation in or on a Solid Medium. International Standard ISO 6222, International Organization for Standardization, Geneva.
17. ISO (1990) Water Quality C Detection and Enumeration of Coliform Organisms, Thermotolerant Coliform Organisms and Presumptive Escherichia coli. Part 1: Membrane Filtration Method. International Standard ISO 9308-1, International Organization for Standardization, Geneva.
18. Rhoades JD (1982) Soluble Salts. In: Page AL, Miller RH, Keeney DR (editors) *Methods of soil Analysis, Part 2: Chemical and Microbiological Properties.* (2nd ed.), American Society of Agronomy, Inc. Madison, Wisconsin, USA, pp: 167-179.
19. Abuzaid, NS, Bukhari AA, Al-Hamouz, ZM (2002) Groundwater coagulation using soluble stainless steel electrodes. *Adv Environ Res* 6: 325-333.
20. Zaidi FK, Mogren S, Mukhopadhyay M, Elkhedr IE (2016) Evaluation of groundwater chemistry and its impact on drinking and irrigation water quality in the eastern part of the Central Arabian graben and trough system, Saudi Arabia. *J African Earth Sci* 120:208-219.
21. Parker ME, Litchfield JH (1962) Food plant sanitation. New York, Reinhold Publishing Corporation, Chapman & Hall, Ltd., London.
22. Gray NF (1994) Drinking water quality: problems and solutions. Published by John Wiley & sons Ltd, Baffins Lane, Chichester, West Sussex, Po. 19, IUD, England.
23. AlbdulaAly AI (1997) Fluoride content in drinking water supplies of Riyadh, Saudi Arabia. *Environ Monit Assess* 48:261-272.
24. Harrison PTC (2005) Fluoride in water: A UK perspective. *J Fluorine Chem* 126:1448-1456.
25. El-Nadi AH, Al-Oud SS (2000) Chemical, physicochemical and biological investigation of groundwater in Al-Qassim region of central Saudi Arabia. *J Agric Sci. Mansoura Univ* 25: 4759-4763.
26. Al Turki AI (2009) Evaluation of well water quality in Hael region of central of Saudi Arabia. In: *Proceeding of 13th International Water Technology Conference, IWTC 13, Hurghada, Egypt.* pp: 1121-1132.