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Comparative study of the anions content between ground water, treated drinking water and bottled drinking water in the Asir region

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Abstract: This study was performed to investigate the anions content in different water sources in Asir region. A total of 44 water samples were collected from different sources comprising ground water (n = 18) from wells, treated drinking water (n = 18) from stations of water treatment and bottled drinking water (n = 8) from local markets and supermarkets. Anions: chloride (Cl^-), fluoride (F^-), sulfate (SO_4^{2-}) and nitrate (NO_3^-) were determined by Ion Chromatography (IC). Electrical Conductivity (EC) and pH were also measured. Generally ground water samples were recorded higher values compared with the treated drinking water and bottled drinking water samples. All measured parameters in the treated drinking water and bottled drinking water samples were not exceeded the Saudi Arabian Standards Organization (SASO(1984) and World Health Organization (WHO(2008)) recommended guidelines. Ground water samples in the study area were not used for drinking purpose. This study is important to raise the awareness of local community about their drinking water. Further study is needed to cover comprehensive parameters and to analyses more samples, in order to enrich the impact of this pilot study.

Keywords: Heart Disease, FFBP, SVM, RBF, Neural Network

1. INTRODUCTION

High quality drinking water is paramount for human health. Therefore, the regular analysis for drinking water is also very important. Anions source in drinking water from both environment and human activities. Sources of chloride mainly are industrial effluents, seawater intrusion in coastal areas, inorganic fertilizers and irrigation drainage and landfill leachates[1]. Natural source of fluoride in water is the dissolution of mineral content in rocks and soils and interact with water. Fluoride comes from human activities as a result of coal combustion and agricultural fertilizers.

The occurrence of fluoride with high concentration than recommended value could cause skeletal and dental fluorosis[2]. The presence of nitrates in drinking water mainly comes from industrial wastes and discharge of sewage effluent. Animal waste and fertilizers, were also another source, the presence of nitrate in high concentration refers to water pollution[3]. Sources of sulfate in drinking water are natural (breakdown of rocks) and human activities such as fertilizer, paper and textile industries and chemicals used in pesticides. High concentration of sulfate which reaches more than 1000 mg/L in drinking water may cause laxative effect in humans[4].

Anions are considered essential to human health in drinking water. The anions are expected to exist in the following levels: F^- (100-1000 µg/L), Cl^-, NO_3^- and SO_4^{2-} (10-100 mg/L) in drinking water[5]. Therefore, drinking water is the main source of such anions. Many studies were carried out to investigate these anions in drinking water[6-10]. However, it was very rare to find such study[11] in Asir region.

The rapid increase in consumption of bottled drinking water[12] globally has encouraged various studies[13-15]. National and International organizations were already set guideline values for anions levels in drinking water. Some of these organizations are Saudi Arabian Standards Organization (SASO, 1984)[16], World Health Organization (WHO, 2008)[17] and United States Environmental Protection Agency (USEPA, 2009)[18].

Bottled drinking water and treated drinking water are the main types of drinking water available in Asir region for

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drinking purpose. Ground water from wells in Asir region is not commonly used for drinking purpose. Stations for water treatment are distributed over the whole region. Ground water transported from wells to such stations then processed to be suitable for potable purposes. Bottled drinking waters are representing a variety of local and imported brands.

This study basically focused on investigation of chloride (Cl^-), fluoride (F^-), sulfate (SO_4^{2-}) and nitrate (NO_3^-) in different drinking water sources from Asir region. The determined anions levels were compared with national and international guideline levels.

The aim of this study was to determine pH, EC and the levels of anions (fluoride, chloride, nitrate and sulfate) in drinking water. It also aimed to make comparison between anions levels in bottled drinking water, treated drinking water and ground water. In addition, it was also to compare the results with national and international guideline values to ensure their suitability for drinking purpose. The findings

of this research may inspire researchers to do more studies in this field, due to important of drinking water.

2. MATERIALS AND METHODS

Water sample collection

Samples were collected from Asir region including four locations (Fig. 1): Abha, Khamis- Mushayt, Al-Majardah and Muhayil. The following water samples were collected: (i) groundwater samples (n = 18) from different wells, (ii) treated drinking groundwater (n = 18) from commercial stations distributed throughout the area, and (iii) bottled drinking water (n = 8) of different brands, purchased from local markets and supermarkets. Samples were collected in polyethylene bottles which were rinsed several times with the water source to avoid contamination.

Figure 1. Map of Saudi Arabia with Asir region highlighted and detailed Asir region with sources of samples highlighted, the locations are marked with black dots (modified from Google maps and mapsofworld.com).

Analytical methods

pH and EC were measured on samples at room temperature upon arrival at King Khalid University, using a pH meter (HANNA instruments pH 211) and a conductivity meter (Accumet BASIC, AB30).

Anions were measured by Ion Chromatography (IC) at the General Directorate of Water, Ministry of Water and Electricity, Abha, KSA. Anions (F^-, Cl^-, NO_3^- and SO_4^{2-}) were measured with a Metrohm 850 Professional Ion Chromatography (IC). Operating conditions of the IC are described in Table 1.

Table 1. Metrohm 850 Professional (IC) operating conditions

Column	Metrosep A supp7-250/4colum
Eluent	Sodium carbonate (3.6mM)
Flow rate	0.8 mL/min
Injection volume	50 µL
Run time	31 minutes
Software	Mag IC Net software
Temperature	45^0C
Pressure	10.36 Mpa

Statistical Analysis

Excel for Windows was used for statistical analyses regarding descriptive analysis. The statistical analysis for the data was included mean and standard deviation. The processed data are represented in figures (2 - 4).

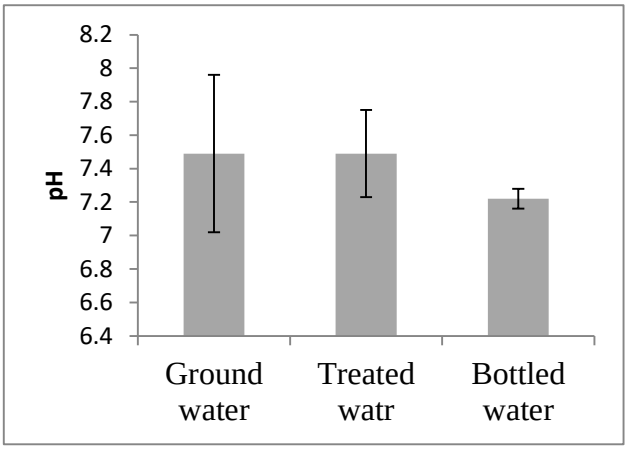


Figure 2. Average values of pH in ground water, treated drinking water and bottled drinking water samples. Error bars represent standard deviations (SD).

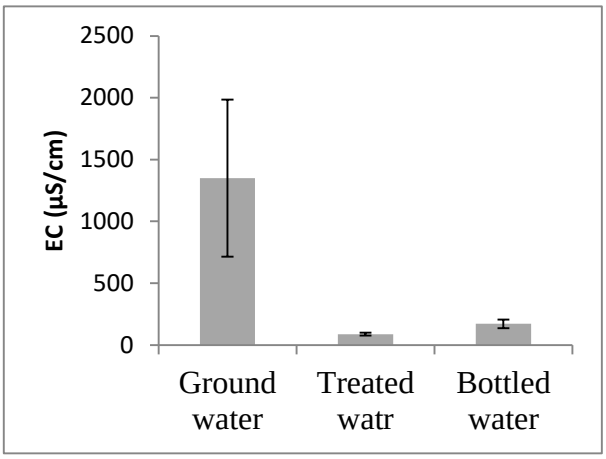
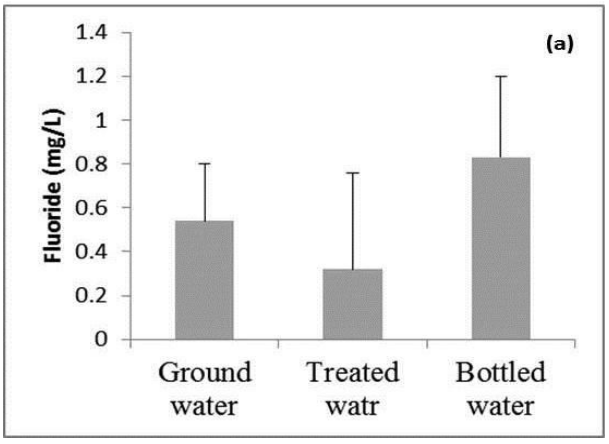
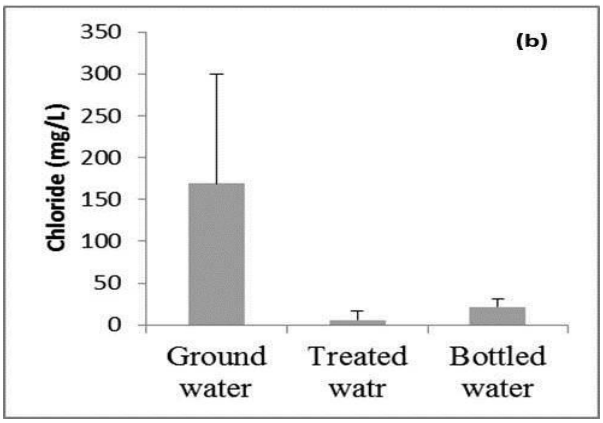
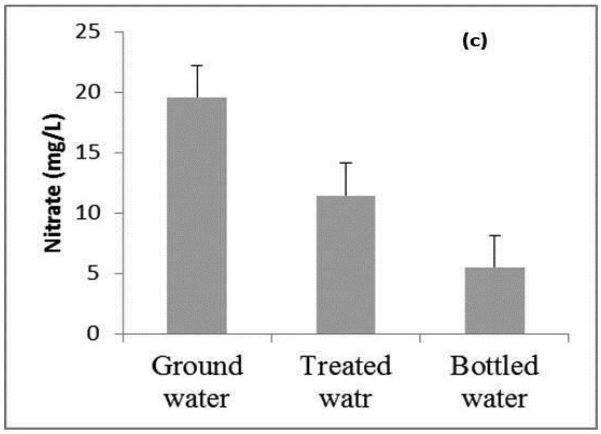


Figure 3. Average values of EC in ground water, treated drinking water and bottled drinking water samples. Error bars represent SD.







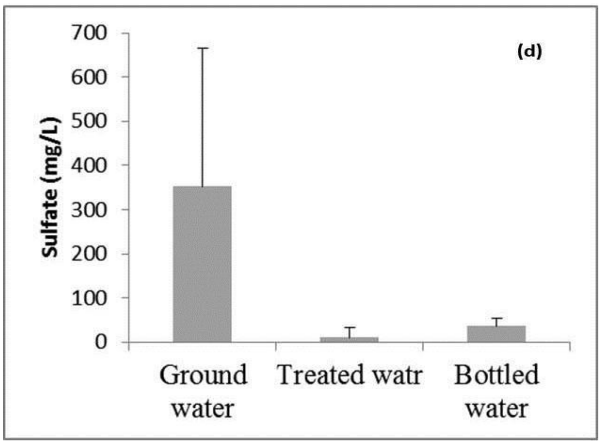


Figure 4. Average values of fluoride (a), chloride (b), nitrate (c) and sulfate (d) in ground water, treated drinking water and bottled drinking water samples. Error bars represent SD.

3. RESULTS AND DISCUSSION

Anions contents, pH and EC in drinking water guideline values set by WHO, USEPA, and SASO[16-18] are presented in Table 2. The measured average values for pH (Fig.2), EC (Fig. 3) and anions contents (fluoride(Fig.4-a), chloride (Fig.4-b), nitrate (Fig.4-c) and sulfate (Fig.4-d)) in ground water, treated drinking

water and bottled drinking water samples are demonstrated in the relevant figures. Values of all parameters are presented in mean and standard deviation (SD).

pH values

The average pH value for ground water samples value was similar to treated drinking water samples and slightly higher than bottled drinking water samples (Fig.2). All measured pH values for all water sources were not exceeded national and international guideline values. Adjusting pH values during water treatment will mitigate corrosion of distribution system and prevent harmful effects to human health[19].

Electrical conductivity (EC) values

The average value of EC in ground water samples was very high compared with those obtained for treated drinking water and bottled drinking water samples (Fig.3). Two values (2580 and 2750 mg/L) of EC in ground water samples were exceeded guideline values. These higher values were from abandoned wells. These results were not surprising as total dissolved solids (TDS) in ground water are generally expected to be higher than those in treated or bottled drinking water. The higher values of EC could also be attributed to the geogenic nature of the locations due to release of ions into water from soil and/or rocks[20]. The mean value of EC in ground water samples is approximately 100-fold compared with both mean values measured for bottled drinking water samples and treated drinking water samples (Fig. 4). The mean value of the EC in treated drinking water samples was the lowest; which may be due to treatment process.

Measured values for Anions

Average values of fluoride, chloride , nitrate and sulfate in ground water, treated drinking water and bottled drinking water samples are shown in Fig. 4-a, Fig.4-b and Fig.4-c, respectively.

Fluoride

Average of fluoride was found to be in the following order bottled water > ground water > treated water (Fig.4a). The lowest average value reported for treated water samples

may be due to depletion of fluoride during treatment process. Normally Reverse osmosis (RO) technology process is used for water purification. The treatment in this technology involves the use of a semipermeable membrane. In this process different types of ions and molecules can be removed to produce drinkable water[21-22]. However, all measured concentrations for fluoride in all samples did not exceed the guideline values. The finding of ground water; mean ± SD (0.54 ± 0.26 mg/L) similar to result of a recent study that reported fluoride concentration, (0.66 ± 0.12 mg/L) in ground water in Asir region[2]. None of the measured value was found to exceed the guideline values in all water samples from the three water sources.

Chloride

The average chloride concentration in ground water samples was very high compared with average values in bottled drinking water and treated drinking water samples (Fig.4b). The average value in ground water samples was almost 28-fold as that in treated drinking water and 8-fold as in bottled drinking water samples. The lower value in treated drinking water sample could be due to depletion of chloride during treatment process. Four samples of ground water had values of (360, 340,335 and 378 mg/L) were exceeded standard values of WHO and USEPA. Only one with a value (794 mg/L) found to be higher than that guideline value of SASO. All measured chloride results in bottled drinking water samples and treated drinking water samples did not exceeding guideline values of national and international organizations.

Nitrate

The measured average concentrations of nitrate in ground water samples was higher than those in bottled drinking water and treated drinking water samples (Fig.4c). USEPA was set guideline value for nitrate in drinking water as 10 mg/L (Table 2). There were six samples had values (13, 12, 16, 12, 18 and 47 mg/L) in treated drinking water exceeded the USEPA guideline value, with only three sample with significant difference from the guideline. The average value (11.44 mg/L) of treated drinking water samples was also exceeded the USEPA value. However, was not a significant difference from the guideline value set by USEPA. In addition, only one sample among ground water samples had a value (52 mg/L) was exceeded the guideline values (50 and 45 mg/L) of WHO and SASO, respectively. In this case the difference was also not significantly higher than the guideline values. Other samples had values were not exceeded the guideline values which was set by those two organizations. High level of nitrate reflects contamination of water sources. The common sources of the contamination by nitrate are included municipal sewage treatment system, animal wastes and decaying plants debris[23]. Fortunately, the highest recorded value, which exceeded WHO and SAO guideline values, was in abandoned well and not in use for agricultural and/or drinking purposes.

Table 2. WHO, USEPA and SASO guideline values for pH, EC and anions in drinking water.

Organization		**WHO (2008)**	**USEPA (2009)**	**SASO (1984/409)**
Parameter	**Unit**	**Guideline**	**Guideline value**	**Guideline value**
pH		**6.5-9.5**	**6.5-8.5**	**6.5-8.5**
EC	**µS/cm**	**-**	**-**	**800-2300**
F^-	**mg/L**	**1.5**	**4**	**0.6-1.0**
Cl^-	**mg/L**	**250**	**250**	**600**
NO^{3-}	**mg/L**	**50**	**10**	**45**
$SO4^{2-}$	**mg/L**	**500**	**250**	**400**

Sulfate

Average value of sulfate in ground water samples were higher than those in bottled drinking water and treated drinking water samples (Fig.4d). The average value of sulfate in ground water samples was almost 35-fold as

that in treated drinking water and 10-fold as in bottled drinking water samples. Only four samples among the ground water samples had high concentrations (1000, 538, 1000 and 770 mg/L), exceeding the recommended values for SASO and WHO organizations. Fortunately, these samples were from wells, which reported as abandoned wells and not in use for agricultural and/or drinking purpose. High concentration (1000–1200 mg/L) of sulfate in drinking water leads to noticeable taste and laxative effect on humans' health[24]. The presence of sulfate in water is due to human activities such as mines, textiles industries and paper mills. The combustion of fossil fuel was also considered as other source of contamination. Atmospheric sulfur dioxide will be oxidized to sulfur trioxide and mixed with water vapour to form diluted sulfuric acid and fall as acid rain[24].

General deduction

Ground water samples from only six wells as mentioned above were reported to have values exceeding the guideline values. These wells were reported as abandoned and not used for agricultural and/or drinking purposes..

It is noteworthy that none of the measured parameters (pH, EC, F^-, Cl^-, NO_3^- and SO_4^{2-}) in bottled drinking water and treated drinking water samples in this study exceeded the national and international guideline values. Therefore, the conclusion that the drinking water quality in Asir region complies with the recommended guidelines values could be claimed.

4. CONCLUSIONS

Ground water collected from Asir region showed higher anions contents compared with bottled drinking water and treated drinking water samples. Only six wells showed some anions content higher than the guidelines values. These wells were reported as abandoned and not used for drinking or agricultural purposes. Commonly ground water in the studied area is not used for drinking purpose. Anions contents in all measured samples, including bottled drinking water and treated drinking water were lower than the standard guidelines values by WHO and SAOS. However, fluoride in treated drinking water samples was showed lower level compared with bottled drinking water. Hence, the level of fluoride in treated drinking water in the region of this study should be considered due to importance of fluoride as essential element for human health. The importance of this study will contribute to public awareness and knowledge about drinking water quality. However, further and regular studies are recommended to expand and enrich the results of this preliminary study.

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