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Dissolved Nitrogen Survey in Groundwater Resources in Al-Ula village, Madina El Monawara, Saudi Arabia

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ABSTRACT

Nitrogen contents contamination of groundwater is the subject of interest because of their hazard potential to human health. A water quality study was carried out on groundwater wells, which serves as drinking water sources in rural communities, in Al-Ula village of Madina El Monawara region, Kingdom of Saudi Arabia. The ammonia (NH_3), nitrate (NO_3^-) and nitrite (NO_2^-) contents of water samples collected from 10 wells and 3 water sources were estimated using spectrophotometric techniques. Water samples were collected monthly from April 2012 to March 2013 and analyzed for different forms of nitrogen in water samples. Results showed that the mean concentration of ammonia, nitrate, and nitrite ranged from 0.042 to 0.0 mg/l, 2.6 to 0.6 mg/l, and 0.23 to 0.003 mg/l, respectively. The concentrations of nitrogen contents in the water samples were within the permissible limits of the World Health Organization (WHO) drinking water quality guidelines and Saudi Arabia Standards Organization (SASO). Therefore, our conclusion showed that these water resources are safe for human use.
Key words: Al Ula, Ammonia, Groundwater, Nitrate, Nitrite, Saudi Arabia.

INTRODUCTION

The high quality of drinking water is the fundamental unit of 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 (Nash and McCall, 1995). Water quality problems related mainly to the effective water treatment and defect in the distribution networks of drinking water or during transportation and distribution stages in general, may expose the consumers to the risk of adverse health effect (Karavoltsos *et al*., 2008).

In Saudi Arabia, groundwater is the only main source for safe and reliable drinking water in rural areas (Al-Abdula'aly, 1997). The most regions in Saudi Arabia do not face serious problems regarding drinking water as other parts of the world (Moghazi and A1-Shoshan, 1999). However, groundwater can have some dissolved forms of chemicals, which may cause very serious health problems, whether the chemicals are naturally occurring or derived from source of pollution. These include intensive application of organic and inorganic fertilizers, pesticides, and animal wastes (Zubari, *et al*., 1994; Al-Turki *et al*., 2003; Camargo *et al*., 2005).

Recent studies show that an increasing rate of concentration of nitrogen content in the groundwater has been observed as a common problem in many parts of the world arising from diffuse reasons. Agricultural activities, poor sewer systems, wastewater, industrial activities, chemical fertilizers, uncontrolled animal feeding operations, and pesticides are the main sources for groundwater contamination with nitrogen content (Bogardi *et al*., 1991; Oldham *et al*., 1996; Alabdula'aly *et al*., 2010). Nitrogen in the aquatic environment occurs in four forms: ammonia (NH_3), nitrate (NO_3^-), nitrite (NO_2^-) and ammonium ion (NH_4^+). The most toxic nitrogen is ammonia, followed by nitrite and nitrate (Rouse *et al*., 1999). Nitrate is the final oxidation product of the nitrogen cycle in natural waters and is considered to be the only thermodynamically stable nitrogen compound in aerobic waters. The heavy use of nitrogenous fertilizers in cropping system is the largest contributor to anthropogenic nitrogen in groundwater worldwide. Nitrate and nitrite are soluble and negatively charged and thus have a high mobility and potential for loss from the unsaturated zone by leaching below the root zone to underground water (Hallberg and Keeney, 1993; DeSimone and Howes, 1998; Chowdary *et al*., 2005). The study in 1992 revealed that approximately three million people, including 43,500 infants, have been drinking groundwater that contains nitrate over the acceptable level (Canter, 1997). Infants who drink water containing nitrate in excess could develop blue-baby syndrome (methemoglobinemia) (Spalding and Exner, 1993; Hudak, 1999; EPA, 2002).

Nitrate is reduced to nitrite in the saliva, which has the tendency to oxidize the hemoglobin in blood cells to methemoglobin, thereby the transporting oxygen to the body tissues is not occurred. Severe methemoglobin can result in brain damage and death. High levels of nitrate in drinking water can also cause cancer when it reacts with protein compounds in the body to form nitrosamine, a well-documented and cancer causing agent (Tricker and Preussmann, 1991; Van Leeuwen *et al*., 1999). Nitrate and nitrite are detectable in water only by chemical testing. It is colourless, odourless and tasteless. Most laboratories usually report nitrate content in parts per million (ppm) of nitrate-nitrogen (NO_3^-N). Ammonia is an important indicator of water quality. It can indicate the possible bacterial, sewage and animal faces pollutions (WHO, 2003).

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The World Health Organization indicates that the threshold odour concentration of ammonia at alkaline pH is approximately 1.5 mg/l, while the taste threshold is 35 mg/l. The guideline for ammonia concentration is 0.5 mg/l for drinking water in European Union (1998). According to the US Environmental Protection Agency (EPA) health risk assessment model, human health risk caused by ammonia content in drinking water is very low (Qin *et al*., 2011).

Although agriculture is the main economic activity in Al Ula city, there is no information on effects of farming activities on quality of ground water which serves as drinking water sources. Such information is vital for policy makers who should in turn give a proper advice to farm owners and surrounding communities to alleviate potential health concerns.

This Water source is not treated before it is consumed; therefore the type and levels of pollutants are unknown. The main objective of this study was to determine concentration of different forms of nitrogen in drinking water samples and evaluate the results with the national standard of Saudi Arabia Standards Organization (SASO, 1984) and other international regulatory standards.

MATERIALS AND METHODS

Site and sampling

Al Ula is located at the north-western part of the Kingdom between latitude 26°37′ and 26.617° to the North and longitude 37°55′ to 37.917° to the East.

It has an area of 29,261 km^2 and an estimated population of 200,127. This mountainous village extends on about 300 km North of Madinah EL Monawara province (Figure. 1).

These stations include ten wells water and three water sources. These selected sites are considered as representative of the main consumed water used in the region.

Water samples were collected from these sites monthly from April 2012 to March 2013. A total of hundred fifty-six samples were collected. Water samples were collected in clean high-density polyethylene bottles and stored in an icebox at 4°C. The bottles were earlier washed with detergent, rinsed with deionized water. Prior to collection, the screw caped bottles were rinsed three times with water sample. Samples were analyzed within 24 h.

Analytical Method

Analytical grade BDH products (BDH Chemicals Ltd, Poole, England) were used to prepare both reagents and calibration standards. Deionized water was used to prepare all reagents and dilution standards.

Dissolved nitrogen in forms of Ammonia (NH_3), Nitrite (NO_2^-), and Nitrate (NO_3^-) were determined by using DR/ 800 Colorimeter (HACH Company, 1997 - 2004, USA) following the spectrophotometric method (Manivasakam, 2011).

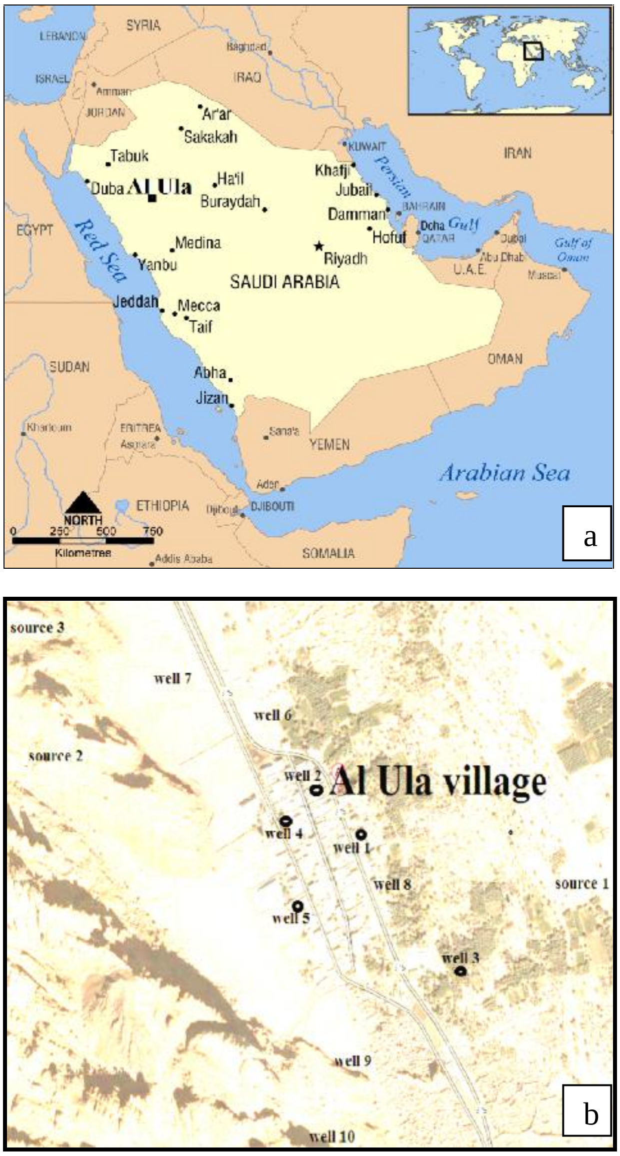

Figure (1): Location of Al Ula city, West of Saudi Arabia (**a**) and the sampling sites (**b**). Thirteen ground water sampling sites were fixed.

RESULTS

Nitrogen content in the selected ground water resources is provided in figures (2) and (3). The maximum nitrate levels of examined ground water was monitored at February and followed by July. The nitrate concentrations were found to be highest in water sampled of well 7 and well 8 that recorded 5 and 4.4 mg/l, respectively. The average monthly distribution of nitrate concentrations was displayed in figure (3a). The average value of nitrate was ranged from 2.1 to 0.6 mg/l. Average nitrate concentrations were highly variable among individual wells and sources (Figure 3a) sampled between April 2012 and March 2013. Monthly nitrite concentrations in individual well and sources of ground water during the study period have been measured and depicted in figure (2c, 2d). During this period, nitrite concentrations in the 156 samples collected from the 10 wells and 3 sources ranged from 0.9 mg/l to note detect (ND). The highest nitrite concentrations were found to be 0.9 mg/l at Well 6. The ammonia concentrations of selected ground water samples have been measured monthly during the study period. The results have been displayed in figure (2e, 2f). The maximum ammonia concentration was found to be 2.1 and 2 mg/l in source 2 and Well 7, respectively.

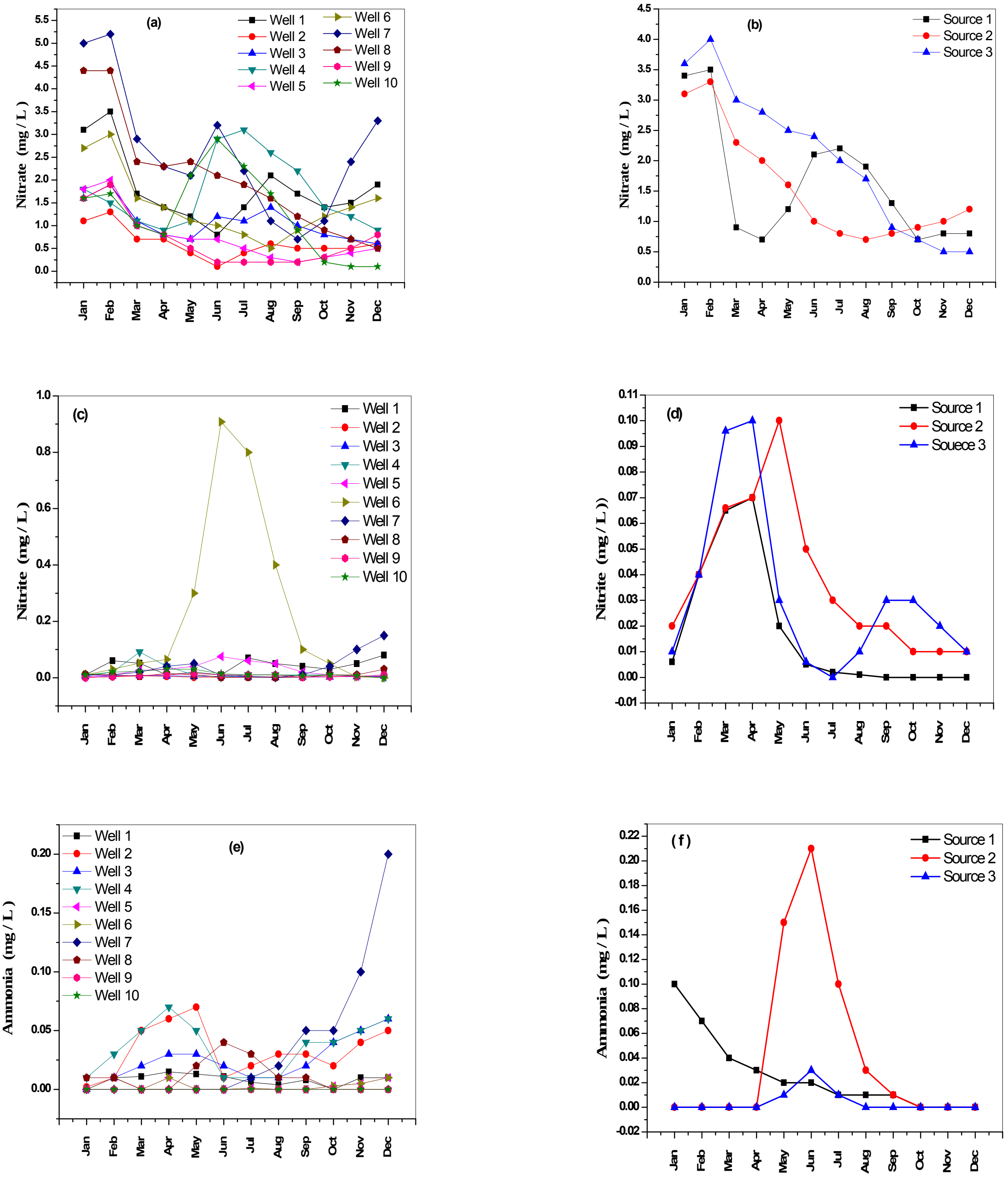

Figure (2): Monthly concentrations of nitrate (a, b), nitrite (c, d), and ammonia (e, f) in water samples

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DISCUSSION

The main problems related to drinking water quality are associated with the conditions of the water supply networks of the study area. The wide variation of the nitrogen content among the studied well water samples examined could be attributed to the extent of depth of wells examined as well as human activity, specially the irrational use of nitrogenous fertilizers (El-Garawany and Al-eed, 1997; Al-Hindi, 1997).

All tested water samples have nitrate with different values throughout the 2012 and 2013. The average nitrate concentration was found to be 1.5 mg/l. The highest and the lowest values were estimated to 5.4 and o.1 mg/l, respectively. Relatively higher concentrations of nitrate were observed in samples from the wells in agricultural areas. There were significant variations ($P< 0.05$) in NO_3^-N concentrations in ground water throughout the period. Higher levels were observed during the February and July after massive farming period. This may be the result of leaching from fertilizer use and human waste.

Most international standards organizations state a maximum value of 50 mg/l for NO_3- whereas it is 0.5-3 mg/l for NO_2^- in drinking water. It indicates that all collected samples comprised the best quality water with respect to NO_3^- and NO_2^- level as recommended by WHO and SASO. These low levels may not affect the health of the aquatic ecosystems of the investigated water bodies. However, it is suggested that regular monitoring of these water resources should be encouraged. Results have also shown that there was an increase in the concentration of nitrates during the rainy season. From the results, nitrate occurred in much larger amounts than nitrite, which is consistent with the relative stability of these ions.

The ground water wells and sources contained NH_3^-N concentrations (Figure 3c) were low in all samples. Values of NH_3^-N ranged from the mean average of 0.008 mg/l (well No. 2) to 0.35 mg/l (well No. 1). All examined water samples had ammonia levels below international (WHO, 2003) and Saudi standards (SASO, 1984) of ammonia in drinking water, which should not exceed a level of 0.5 mg/l. Ammonia is usually present in aquatic systems as dissociates ammonium ion, which is therefore present at very low quantities (Horne and Goldman, 1994).

CONCLUSION

In general, groundwater is exposed to point pollution sources as septic wells, domestic and farming effluents. Evaluation of nitrogen content in Al Ula groundwater showed that these water sources are suitable for human consumptions with regards of national and international standards. However, the monitoring of the water samples should be done regularly. Further research works are needed mainly about groundwater heavy metals and bacterial properties to ensure the safe state of these water bodies and to prevent inhabitants from chronic health problems. This research may serve as a reference data for future studies on the assessment of well water quality in the study area which depends heavily on these groundwater sources as a means of their portable water supply.

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النيتروجين الذائب في المياه الجوفية بمحافظة العلا، المدينة المنورة، المملكة العربية السعودية

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الملخص العربـــــى

تعتبر التركيبة النيتروجينية للمياه من أهم الخصائص الكيميائية المحددة لجودة المياه وبالتالي مدى جاهزيتها للاستهلاك البشري. تمت دراسة الخصائص النيتروجينية (أمونيا NH_3، نترات NO_3^- ونتريت NO_2^-) للمياه الجوفية بمحافظة العلا، المدينة المنورة، المملكة العربية السعودية، وذلك لأجل التعرف على مدى ملائمة هذه المياه للشرب ومن خلال هذه الورقة البحثية قمنا بدراسة مجموع عشرة آبار و ثلاثة عيون وذلك باستعمال تقنية الطيف المرئي سبيكتروفوتومتر.
تم جمع العينات شهريا ابتداء من شهر أبريل ٢٠١٢ إلى شهر مارس ٢٠١٣ كما وقع تحليل أشكال النيتروجين الثلاثة في عينات الماء. أبرزت النتائج أن متوسط تركيز هذه العناصر يتراوح بين صفر و ٠.٠٤٢ ملغرام بالنسبة للأمونيا ، بين ٠.٦ و ٢.٦ ملغرام بالنسبة لنترات وبين ٠.٠٠٣ و ٠.٢٣ بالنسبة للنتريت وذلك بالنسبة لكل لتر من الماء. من خلال هذه الدراسة التي تم فيها فحص ١٥٦ عينة، تبين أن تركيز النيتروجين الذائب بالمياه الجوفية لمحافظة العلا فى مستوى المعدلات المسموح بها طبقا لمقاييس منظمة الصحة العالمية (WHO) لمياة الشرب أو المقاييس والمعايير السعودية(SASO) وبالتالي تبقى المياه الجوفية بمحافظة العلا من ناحية المحتوى النيتروجينى صالحة للإستهلاك البشري.