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NITRATE CONTENT OF DRINKING AND IRRIGATION WELL WATER IN AL-QASSIM REGION – CENTRAL SAUDI ARABIA.

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ABSTRACT

Nitrate (NO_3^-) level of drinking and irrigation water sources in Al-Qassim Region-Central Saudi Arabia was investigated. The obtained analytical results indicate that there is a considerable variation in NO_3^- level between the municipal network water supply and domestically produced bottled water on one hand and well water on the other hand. The mean of NO_3^- level of the latter (69.7mgL^{-1}) is above the maximum permissible level (45 mg L^{-1}) set by the local and international standards and guidelines. Of the 40 well water samples examined only 23 (57%) comply with the guidelines set for the maximum permissible level set by most of the standards. Statistical analysis (Correlation) revealed a significant reciprocal relationship between depth of well and NO_3- level ($P < .01$, $R^2=0.293$).
Keywords: Nitrate content, Irrigation, Al-Qassim region

INTRODUCTION

Groundwater is the main source of drinking and irrigation water supply for an overwhelming majority of the population of the kingdom of Saudi Arabia. The purity of this water for drinking has become a controversial issue, because certain health concerns may result when potentially toxic substances are consumed with water (Chettri and Smith, 1995: Ahmed *et al.* 2001, and Al-Redhaiman and AbdelMagid, 2002). Many of these substances are naturally occurring substances that have always been present in the environment.

One of the most common pollutants is nitrate (NO_3^-). Although NO_3^- occurs naturally in drinking and irrigation water, elevated levels in groundwater usually result from human activities such as overuse of both chemical and organic fertilizers and improper disposal of human and animal wastes (Payne, 1993; El-Garawany and Aleed, 1997; Davis and Champan, 2000 and Bhumbla, 2002).

These fertilizers and wastes are potential sources of nitrogen-containing compounds, which are converted to NO_3^- in soil. Nitrates are extremely soluble in water and can move through the soil into the drinking water supply (Ahmed *et al.*, 1996, 2001; Al-Hindi, 1997). High levels can build up over time as NO_3^- accumulates in water but even at elevated levels, they are not likely to pose serious health hazards for most adults. The main concern with high levels of NO_3^- in water is the increased incidence of methemoglobinemia in infants of less than six months of age. Moreover, ingestion of excessive amounts of NO_3^- can cause diverse health effects in very young infants and susceptible adults (USEPA, 1976; WHO, 1993; EEC, 1992; Kross *et al.*, 1993). The critical level of NO_3-N in drinking water is 10

mgL^{-1} which is equivalent to 45 mg L^{-1} NO_3- (SASO, 1984; Kamrin, 1987; EEC, 1992; WHO, 1993).

In Saudi Arabia, comprehensive studies on nitrate levels in groundwater are meager or limited.

The aim of the present study is to report results on NO_3^- content of some wells used for both drinking and agricultural irrigation in al-Qassim Region of Central Saudi Arabia. For purpose of comparison, the paper also discusses NO_3^- concentration in municipal network water supply and in 22 domestically bottled drinking water brand.

MATERIALS AND METHODS

Samples collection: Well water (W.W) samples were mainly collected from wells distributed in farms and towns and villages throughout Al-Qassim Region-Central Saudi Arabia. Many of these wells water is used for drinking, domestic as well as agricultural purposes. Groundwater in many farms is used as potable water especially by expatriate farm workers. Municipal network water (MNW) samples were obtained from water coolers used for drinking in mosques and public places. Domestically produced bottled water (DBW) samples were obtained from local supermarkets.
Water samples were collected in polyethylene bottles. The samples were taken to the laboratory (Ambient temperature 25°C) and stored in a refrigerator at 4°C. Analyses were then carried out promptly.

Analyses: The analyses were carried out according to the standard methods for the examination of water and wastewater (APHA, 1992). Nitrate was determined using spectronic 2000 Spectrophotometer, KNO_3 was used to prepare the standard NO_3 solution. Statistic analyses were performed by using Microsoft Office Excel Version 2000 Program. The mean values were evaluated according to the current Saudi Arabian Standards Organiazation (SASO, 1984), World Health Organization (WHO, 1993), Economic European Community (EEC, 1992), and United States Environment Protection Agency (USEPA, 1976) of drinking water standards and guidelines.

RESULTS AND DISCUSSION

The results of the present investigation are summarized in Tables 1, 2 and 3 which provide a comprehensive picture on the level of NO_3^- in well water used for drinking and agricultural purposes, municipal network and domestically produced bottled water in AL-Qassim region of Central Saudi Arabia.

Table 1 presents the summary of NO_3^- levels in the various water types studied.

In view of the SASO (1984), WHO (1993), EEC (1992) and USEPA (1976) drinking water standards which set the limit of 45 mgL^{-1}(EEC 50mgL^{-1}) nitrates as the highest tolerable NO_3^- level in drinking water, Table 2 shows

that many of the wells studied suffer from high NO_3^- contamination , only 57.5 % of the well water samples are within the 45mgL^{-1} limit specified by most of the standards used in this study. 42.5% of the wells (25-200m in depth) exceeded the 45 mgL^{-1} threshold (Kross *et al*, 1993). Well water quality, generally, improves with depth i.e. there is a reciprocal relationship between NO_3^- level and depth of well ($P< 0.01$, $R^2 = 0.293$). It may be inferred from figure 1 that beyond a depth of about 1140 m, NO_3^- level declines sharply for the group of wells studied. Kross *et al.*(1993) indicated that contamination of shallow wells is much more prevalent than contamination of deep wells. Nevertheless, most of the NO_3^- values < 45 mgL^{-1} are still high even not above the health advisory limit, and should be of great concern. It is well known that NO_3^- is toxic when present in excessive concentrations in drinking water and can cause methaemoglobenemia in infants under 6 months of age (Comly, 1987; Kamrin, 1987; Van Dijk-Looyaard and Montizaan, 1990).

Although the maximum contaminant limit for NO_3^- was set at 45mgL^{-1}, in 1976 the USEPA suggested that water having concentrations above 1mgL^{-1} should not be used for infant feeding (Rail, 1989). The problem of elevated nitrate level is currently considered a serious problem in many countries. For example, in the United Kingdom, Forman *et al.* (1985) and Payne (1993) linked stomach and gasterointestinal cancer to nitrate intake. Scientists claim that nitrate represents a potential risk because of nitrosation reactions which are precursor for N-nitroso compounds that are strongly carcinogenic in animals (Shank, 1975; Forman *et al.*, 1985) . Moreover, in USA scientists indicated that NO_3^- in drinking water increases the risk for bladder cancer. They suggested that NO_3^- levels much less than 45 mgL^{-1} could be of a serious health concern (UICHEEC, 2001). Other claims indicated that intake of NO_3^- contaminated groundwater is linked to birth defects, hypertension and high blood pressure in adults (Magee, 1971; Shank, 1975; Crosby and Sawyer, 1976; NRC, 1987; Lamb, 1985).

Table 1: Summary of NO_3^- level in the various water samples studied

Origin of sample	No. of samples	NO_3^- level (mgL^{-1})			
		Mean	SD	Minimum	Maximum
WW	40	69.7	92.2	4.0	429
MNW	67	1.7	4.0	0.0	23
DBW	22	5.3	4.1	0.1	16.7

Table 2: Distribution of 40 well water samples in Al-Qassim region according to their content of nitrate.

NO_3^- (mgL^{-1})	Number of samples	% of total	Depth range (m)
0-45	23	57.5	45-1791
46-90	5	12.5	120-200
91-135	3	7.5	200 each
>135	9	22.5	25-120
Total	40	100	-

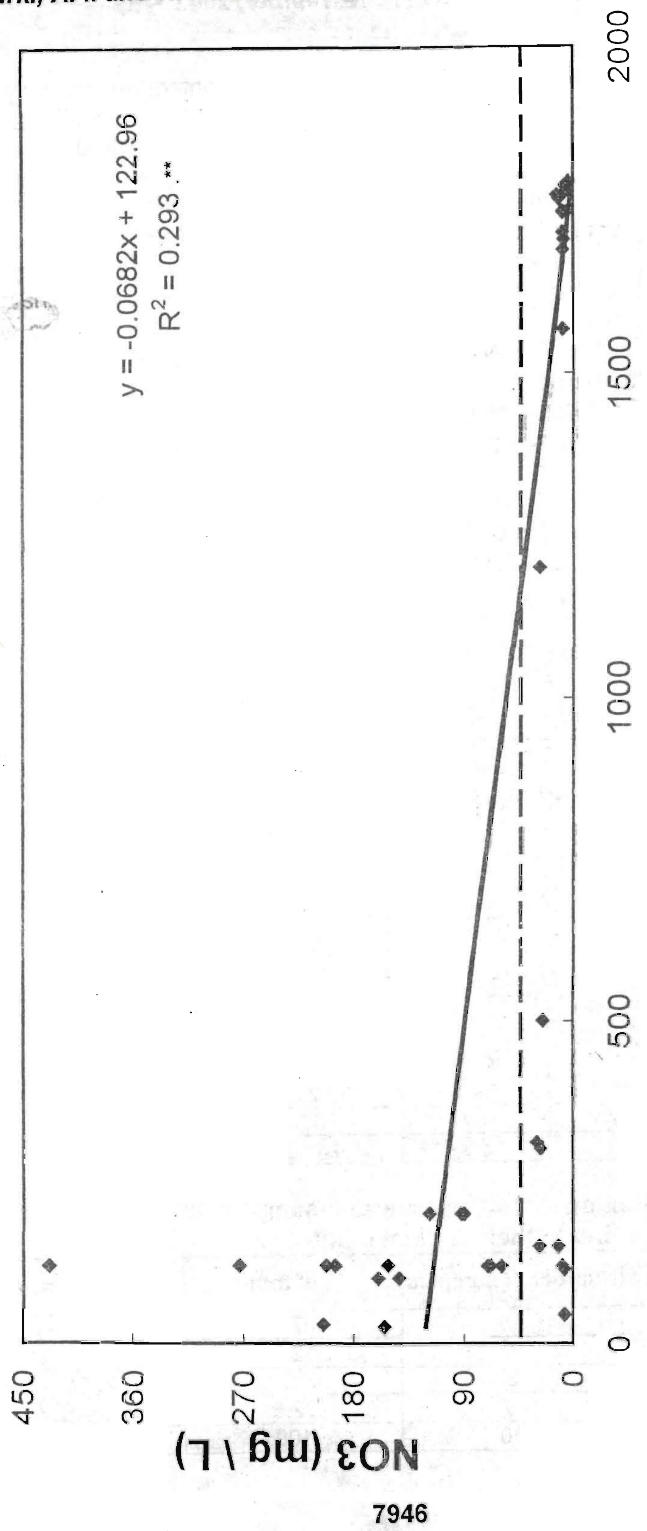

Fig. 1: Depth Vs. nitrate level relationship.

In comparison with well water, the NO_3^- level of municipal network water supply and domestically produced bottled water samples (Table 3) falls within or below the SASO, WHO, EEC, and USEPA standard limits and, therefore, pose no health concern with respect to higher NO_3^- content at the present time. Well water, as shown in Table 3, violated the limits of the above mentioned standards by 42.5% (SASO and WHO standard), 53% (desirable EEC standard limit) and 40% (maximum EEC standard limit). Previous results (AbdelMagid, 1997 and AL-Redhaiman and AbdelMagid, 2002) indicated little or no NO_3^- content in municipal network water supply, and mineral bottled waters.

There are several sources which might have contributed to the comparatively elevated level of NO_3^- in well water (mean 69.7 mgL^{-1}, Table 1), including agricultural sources such as nitrogen rich fertilizers and manuers applied at libral rates by farmers in the region (Amr, 2000, Al-Redhaiman and AbdelMagid, 2002). Conversely, Sowayan and Allayla (1989) tentatively attributed the high NO_3^- levels in Al-Qassim region to nitrogen fixation by blue green algae which have been observed in many places in the upper drainage basins of wadis rather than to human activities such as agriculture.

Table 3. Comparison of NO_3 level of the water sources investigated with the local and international standards

Sample origin	No. of samples	% of samples within the limits of each standard*				
				EEC		
		SASO (45)	WHO (45)	Desirable (25)	Maximum (50)	USEPA (45)
WW	40	57.5	57.5	53	40	57.5
MNW	67	100	100	100	100	100
DBW	23	100	100	100	100	100

* Standards guidelines limit (NO_3 mgL^{-1}) in parenthesis.

CONCLUSIONS

Nitrate content of drinking water sources in Al-Qassim Region of Saudi Arbia was investigated. The results obtained indicated that there are significant variations among the sources with respect to their NO_3^- level. Well water NO_3^- level was found to be in the range of 4-429 mgL^{-1} with an average of 69.7 mgL^{-1} which is well above the maximum permissible level of 45 mgL^{-1} set by the local and international drinking water standards and guidelines, whereas the municipal distribution network and the domestically produced bottled water supplies conform to or even lie below the maximum permissible level. Moreover, statistical analysis of the results revealed that there is a significant inverse relationship between well water nitrate level and depth of well.

Based on this study, it may be stated that the municipal distribution network water and the domestically produced bottled water supply pose no threat to human health with respect to their NO_3^- content. However, utilization

of well water for drinking, specially by expatriate workers in farms, warrants some attention due to high NO_3^- level in shallow bores.

Regarding the NO_3^- problem, the best suggestions to avoid health risks are to have wells checked frequently, deepening wells, and reduce and control fertilization of farms which may reduce NO_3^- leaching from surface soil to groundwater.

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محتوي النترات في مياه الشرب ومياه الري في إقليم القصيم بالمنطقة الوسطى من المملكة العربية السعودية

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يعتبر تركيز النترات (NO_3^{-1}) في المياه أحد المعايير المهمة في جميع الموصفات العالمية والتي تحدد صلاحية المياه للاستهلاك الآدمي والري الزراعي. في هذه الدراسة تم تقدير تركيز النترات في عينات مياه مأخوذة من بعض الآبار في إقليم القصيم في المنطقة الوسطى من المملكة العربية السعودية. كذلك قدر تركيز النترات في عينات من مياه شبكة توزيع البلدية في المنطقة نفسها وفي مياه معبأة بواسطة شركات المياه لغرض المقارنة. أشارت النتائج المتحصل عليها إلى وجود اختلافات كبيرة في مستويات النترات بين شبكة توزيع مياه البلدية والمياه المعبأة بواسطة شركة المياه من جهة وبين مياه الآبار من جهة أخرى. لقد كان متوسط النترات في مياه الآبار (والذي بلغ $69.7 mgL^{-1}$) يفوق الحد الأعلى المسموح به ($45 mgL^{-1}$) في الموصفات المحلية والعالمية. كما وجد أن ٥٧,٥% من عينات الآبار فقط تقع تحت الحد الأعلى لمستوى النترات المسموح به في معظم المواصفات القياسية للنترات. هذا وقد لوحظ وجود علاقة عكسية بين عمق البئر ومستوى النترات في عينات مياه الآبار.