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INitrate and Nitrite Levels of Drinking Water in Bitlis Province, Turkey

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Abstract: In this study, nitrate and nitrite levels of drinking water in city of Bitlis were investigated. A total of 164 water samples, collected from the tank and tap water in Spring and Autumn were used as material. Analysis performed through spectrometric techniques showed that all samples contained some levels of nitrate and nitrite. The average nitrate and nitrite levels were 5.68±0.31 and 1.32±0.09 mg L^{-1}, respectively. The effects of residential areas and season on the nitrate and nitrite levels were found to be statistically significant ($p<0.05$). Nitrate levels of tank and tap water were in accordance with recommended standards. However, 12 and 100% of tank water samples and 7.02 and 100% of tap water samples collected respectively in Spring and Autumn did not meet the national standards for nitrite levels. In addition, 3.58% of tap water collected in Autumn did not meet the international standards.

Key words: Drinking water, nitrate, nitrite, Bitlis, spectrometric techniques

INTRODUCTION

Nitrate and nitrite are related nitrogen compounds that occur naturally in plants, soil, water and food (Avery, 1999). Principal sources of nitrate or nitrite include; commercial fertilizer, sewage disposal systems, industrial wastes, livestock manure or geological formations containing soluble nitrogen compounds (Adam, 1980; Egboka, 1984; WHO, 1985). Drinking water is contaminated by nitrate run-off from municipal and industrial sites, animal feed lots and septic systems. Nitrates may be carried by during irrigation, heavy rains and snowmelt and is transported in the groundwater to public and private sources of drinking water (Young and Morgan-Jones, 1980; Mancl, 1987).

Nitrate is more commonly found in water than nitrite. Both the nitrate and nitrite forms of nitrogen in drinking water are a health concern, especially for infants, pregnant women, nursing mother and the elderly (Speijers *et al*., 1989; Spalding and Exner, 1993). There are mostly two health concerns when drinking water with high levels of nitrate or nitrite. The first health concern is with infants being at risk for blue-baby syndrome, also called methemoglobinemia. Infants under 3 months of age are more susceptible to nitrate poisoning. Other groups especially, susceptible to methemoglobin (metHb) formation include pregnant women and people deficient in glucose-6-phosphate dehydrogenase or metHb reductase (Speijers *et al*., 1989; Fan and Steinberg, 1996; Avery, 1999). The second health concern regarding nitrate and nitrite is the formation of N-nitrosamines are potent carcinogens (Dutt *et al*., 1987; Cantor, 1997).

Ruminant animals (cattle and sheep) and infant monogastrics (baby pigs and chickens) are also susceptible to nitrate poisoning because of bacteria living in their digestive tracts. Horses, even though they are monogastric are susceptible to nitrate poisoning throughout their lives. Livestock may be exposed to large quantities of nitrate in their feed as well as in contaminated water (Mancl, 1987).

Nitrate accumulation in plants varies widely between species and is influenced by several factors, especially those factors that tend to limit the growth of the plant while, still allowing for the uptake of nitrate. Plants absorb nitrate, which is normally converted to nitrite by the nitrate reductase system and incorporated into amino acids and proteins (Roder, 2001).

Health impacts to humans and animal life occur from drinking water or eating foods high in nitrate such as vegetables and meat (Litovitz *et al*., 1996). Potential health impacts associated with nitrate and nitrite include cardiovascular or blood toxicity, kidney toxicity and reproductive toxicity (Anonymous, 2007).

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Table 1: Distribution of sample sources by cities and provinces

Seasons	Bitlis	Adilcevaz	Ahlat	Guroymak	Hizan	Tatvan	Total
Spring							
Tank	6	3	3	4	3	6	25
Tap	15	9	8	6	5	14	57
Total	21	12	11	10	8	20	82
Autumn							
Tank	7	4	3	4	3	5	26
Tap	14	8	8	6	5	15	56
Total	21	12	11	10	8	20	82
General total	42	24	22	20	16	40	164

Nitrate levels in drinking water can also be an indicator of overall water quality. Elevated nitrate levels may suggest the possible presence of other contaminants such as disease-causing organisms, pesticides or other inorganic and organic compounds that could cause health problems (Robillard *et al*., 2006).

In this study, how the seasonal changes effect nitrate and nitrite level in drinking water, whether, the requirements for national and international standards are met regarding to nitrate and nitrite level and the effects on public health have been studied.

MATERIALS AND METHODS

A total of 164 water samples, collected from the tank (city water supply reservoir) and tap water in spring and autumn in Bitlis and its provinces (Tatvan, Guroymak, Ahlat, Adilcevaz and Hizan) were used as material.

The water samples were collected at regular intervals in November 2006 and May 2007 from the sources and presented in Table 1. All the procedures were carried out according to the standard methods for the examination of water and wastewater (APHA, 1995).

Statistical analysis: A three-way analysis of variance method was used to evaluate the data. Significance of differences among group means was determined by Duncan test. Statistical analysis was performed by SAS program (SAS, 1998).

RESULTS AND DISCUSSION

Seasonal distribution of nitrate and nitrite levels in drinking water is shown in Table 2, while, residential distribution is shown in Table 3 and 4 and frequency distribution of nitrite level is shown in Table 5.

The result of analysis showed that all the tested samples contained some levels of nitrate and nitrite. Nitrate contents ranged between 1.49-5.39 and 6.90-13.41 mg L^{-1} in tank water and 1.49-5.17 and 7.12-17.31 mg L^{-1} in tap water, while, nitrite levels were between 0.07-0.67 and 0.07-1.20 mg L^{-1} in tank water and 2.00-2.87 and 2.07-4.80 mg L^{-1} in tap water in spring and autumn, respectively. The highest nitrite content of tank water found in spring was in Ahlat Province and in autumn it was in Tatvan Province. Additionally, in both seasons, highest nitrite content detected in tap water was in Ahlat and Guroymak Provinces.

Nitrate and nitrite are chemicals that enter water from fertilizer runoff, leaching septic tanks and erosion of natural deposits (Anonymous, 2007). It is known that

Table 2: Seasonal distribution of nitrate and nitrite levels in drinking water

Region	Nitrate (mg L^{-1}) Spring	Nitrate (mg L^{-1}) Autumn	Nitrite (mg L^{-1}) Spring	Nitrite (mg L^{-1}) Autumn
Bitlis				
Tank				
X±SX	2.00±0.42	7.59±0.25	0.20±0.08	2.20±0.03
Min.-Max.	1.49-4.09	6.90-8.86	0.07-0.47	2.00-2.33
Tap				
X±SX	1.89±0.18	8.18±0.34	0.12±0.03	2.20±0.02
Min.-Max.	1.49-3.65	7.12-11.89	0.07-0.47	2.07-2.33
Adilcevaz				
Tank				
X±SX	2.79±1.30	8.53±0.44	0.11±0.04	2.32±0.10
Min.-Max.	1.49-5.39	7.77-9.72	0.07-0.20	2.20-2.60
Tap				
X±SX	1.73±0.10	8.61±0.40	0.09±0.02	2.32±0.03
Min.-Max.	1.49-2.14	7.56-10.59	0.07-0.20	2.20-2.47
Ahlat				
Tank				
X±SX	2.72±0.62	10.52±0.690	0.45±0.19	2.49±0.02
Min.-Max.	1.49-3.44	9.29-11.67	0.07-0.67	2.47-2.53
Tap				
X±SX	2.11±0.43	11.16±1.100	0.13±0.04	2.75±0.29
Min.-Max.	1.49-4.95	8.86-17.31	0.07-0.40	2.40-4.80
Guroymak				
Tank				
X±SX	1.65±0.10	11.13±0.79	0.12±0.03	2.54±0.04
Min.-Max.	1.49-1.92	9.72-13.41	0.07-0.20	2.47-2.60
Tap				
X±SX	2.57±0.55	10.16±0.26	0.40±0.17	2.57±0.06
Min.-Max.	1.49-5.17	9.51-11.24	0.07-1.20	2.40-2.80
Hizan				
Tank				
X±SX	1.49±0.00	7.85±0.19	0.18±0.11	2.47±0.08
Min.-Max.	1.49-1.49	7.56-8.21	0.07-0.40	2.33-2.60
Tap				
X±SX	1.58±0.09	8.42±0.19	0.19±0.12	2.48±0.10
Min.-Max.	1.49-1.92	7.99-9.07	0.07-0.67	2.33-2.87
Tatvan				
Tank				
X±SX	1.71±0.18	10.46±0.46	0.24±0.10	2.68±0.07
Min.-Max.	1.49-2.57	9.51-12.11	0.07-0.67	2.53-2.87
Tap				
X±SX	1.95±0.27	10.42±0.38	0.21±0.08	2.72±0.08
Min.-Max.	1.49-4.95	8.86-13.62	0.07-1.13	2.47-3.73
Total				
Tank				
X±SX	2.06±0.44	9.35±0.47	0.22±0.09	2.45±0.06
Min.-Max.	1.49-5.39	6.90-13.41	0.07-0.67	2.00-2.87
Tap				
X±SX	1.97±0.27	9.49±0.44	0.19±0.08	2.51±0.10
Min.-Max.	1.49-5.17	7.12-17.31	0.07-1.20	2.07-4.80
General total				
X±SX	1.97±0.10a	9.40±0.20b	0.18±0.02a	2.47±0.04a
Min.-Max.	1.49-5.39	6.90 -17.31	0.07-1.20	2.00-4.80

The difference among mean values with different letters in the bottom row is important (p<0.05)

Table 3: Residential distribution of nitrate levels in drinking water (mg L^{-1})

Source	Bitlis	Adilcevaz	Ahlat	Guroymak	Hizan	Tatvan	Total
Tank							
X±SX	5.01±0.84	6.07±1.28	6.62±1.79	6.39±1.83	4.67±1.42	5.68±1.39	5.66±0.54
Min.-Max.	1.49-8.86	1.49-9.72	1.49-11.67	1.49-13.41	1.49-8.21	1.49-12.11	1.49-13.41
Tap							
X±SX	4.92±0.62	4.97±0.88	6.63±1.30	6.36±1.18	5.00±1.14	6.33±0.83	5.69±0.38
Min.-Max.	1.49-11.89	1.49-10.59	1.49-17.31	1.49-11.24	1.49-9.07	1.49-13.62	1.49-17.31
Total							
X±SX	4.95±0.49b	5.29±0.72b	6.33±1.04a	6.37±0.99a	4.87±0.86b	6.15±0.71a	5.68±0.31
Min.-Max.	1.49-11.89	1.49-10.59	1.49-17.31	1.49-13.41	1.49-9.07	1.49-13.62	1.49-17.31

Table 4: Residential distribution of nitrite levels in drinking water (mg L^{-1})

Source	Bitlis	Adilcevaz	Ahlat	Guroymak	Hizan	Tatvan	Total
Tank							
X±SX	1.27±0.29	1.37±0.45	1.47±0.46	1.33±0.46	1.32±0.51	1.35±0.39	1.34±0.16
Min.-Max.	0.07-2.33	0.07-2.60	0.07-2.53	0.07-2.60	0.07-2.60	0.07-2.87	0.07-2.87
Tap							
X±SX	1.12±0.20	1.14±0.28	1.44±0.37	1.48±0.34	1.33±0.39	1.50±0.24	1.32±0.11
Min.-Max.	0.07-2.33	0.07-2.47	0.07-4.80	0.07-2.80	0.07-2.87	0.07-3.73	0.07-4.80
Total							
X±SX	1.17±0.16b	1.21±0.23b	1.45±0.29a	1.42±0.27a	1.33±0.30ba	1.46±0.20a	1.32±0.09
Min.-Max.	0.07-2.33	0.07-2.60	0.07-4.80	0.07-2.80	0.07-2.87	0.07-3.73	0.07-4.80

The difference among mean values with different letters in the bottom row is important ($p<0.05$)

Table 5: Frequency distribution of nitrite levels in drinking water (mg L^{-1})

			0-05		0.6-1		1.1-3		3>	
Region	Source	Season	n	%	n	%	n	%	n	%
Bitlis	Tank	Spring	6	100	-	-	-	-	-	-
		Autumn	-	-	-	-	7	100	-	-
	Tap	Spring	15	100	-	-	-	-	-	-
		Autumn	-	-	-	-	14	100	-	-
Adilcevaz	Tank	Spring	3	100	-	-	-	-	-	-
		Autumn	-	-	-	-	4	100	-	-
	Tap	Spring	9	100	-	-	-	-	-	-
		Autumn	-	-	-	-	8	100	-	-
Ahlat	Tank	Spring	1	33.33	2	66.67	-	-	-	-
		Autumn	-	-	-	-	3	100	-	-
	Tap	Spring	8	100	-	-	-	-	-	-
		Autumn	-	-	-	-	7	87.50	1	12.50
Guroymak	Tank	Spring	4	100	-	-	-	-	-	-
		Autumn	-	-	-	-	4	100	-	-
	Tap	Spring	5	83.33	-	-	1	16.67	-	-
		Autumn	-	-	-	-	6	100	-	-
Hizan	Tank	Spring	3	100	-	-	-	-	-	-
		Autumn	-	-	-	-	3	100	-	-
	Tap	Spring	4	80	1	20	-	-	-	-
		Autumn	-	-	-	-	5	100	-	-
Tatvan	Tank	Spring	5	83.33	1	16.67	-	-	-	-
		Autumn	-	-	-	-	5	100	-	-
	Tap	Spring	12	85.72	1	7.14	1	7.14	-	-
		Autumn	-	-	-	-	14	93.33	1	6.67
Total	Tank	Spring	22	88	3	12	-	-	-	-
		Autumn	-	-	-	-	26	100	-	-
	Tap	Spring	53	92.98	2	3.51	2	3.51	-	-
		Autumn	-	-	-	-	54	96.42	2	3.58

nitrate and nitrite concentrations have gradually increased in many countries (WHO, 2007). For example, concentrations of up to 1500 mg L^{-1} were found in groundwater in an agricultural area of India (Jacks and Sharma, 1983). In Denmark and the Netherlands, nitrate concentrations are increasing by 0.2-1.3 mg/L/year in some areas (WHO, 1985). In the United Kingdom, an average annual increase of 0.7 mg L^{-1} has been observed in some rivers (Young and Morgan-Jones, 1980).

The US Environmental Protection Agency (EPA) has set the Maximum Contaminant Level (MCL) of nitrate as nitrogen (NO_3-N) at 10 mg L^{-1} (equivalent to 45 mg L^{-1} as nitrate) for the safety of drinking water. The MCL for nitrite is 1 mg L^{-1} as nitrite-nitrogen (NO_2-N). In addition, the sum of the amount of nitrate and nitrite in drinking water should not total >10 ppm. The standards for nitrate and nitrite have been set at levels, which should not cause methemoglobinemia in infants. In the EU and

Table 6: Nitrate and nitrite content of different water sources in Turkey

Water sources	No. of samples	Nitrate	Nitrite	References
Drinking water	100	84%	14%	Yalcin *et al.* (1988)
Fountain water	-	-	25%	Ucar (1990)
Well water	-	-	20%	-
Drinking water	250	0-1.0 mg L^{-1}	-	Sonmez (1992)
Fountain water	-	2.2-46.5 mg L^{-1}	-	-
Tap water	-	1.59.3 mg L^{-1}	-	-
Artesian water	-	6.2-81.9 mg L^{-1}	-	Omurtag (1992)
Stream water	-	6.2-81.9 mg L^{-1}	-	-
Well water	-	2.2-305.5 mg L^{-1}	-	-
Drinking water	27	100%	4%	-
Fountain water	36	100%	-	Patir *et al.* (1992)
Well water	23	91%	30%	-
Well water	-	0.4-546 mg L^{-1}	0-16 mg L^{-1}	Yavuz *et al.* (1993)
Well water	-	4.92-196.55 mg L^{-1}	0.14-2.8 mg L^{-1}	Pirincci and Servi (1993)
Fountain water	-	5.41-88.56 mg L^{-1}	-	-
Well water	20	2.30-168 ppm	0-0.40	Yavuz *et al.* (1994)
Well water	-	46% (50 ppm)	55% (<50 ppm)	Dagoglu *et al.* (1995)
	-	6% (<100 ppm)	10% (>101 ppm)	-
Fountain water	-	<50 ppm	<50 ppm	-
Drinking water	3957	13.67 mg L^{-1}	0.1 mg L^{-1}	Anonymus (1996)
Streamlet water	-	83.7-120.9 mg L^{-1}	-	Saatci *et al.* (1998)
Tap water	8	-	12.5%	-
Well water	29	-	65.5%	Peker *et al.* (1998)
Station water	324	-	11.41%	-
Well water	-	52.15 mg L^{-1}	-	Kaplan *et al.* (1999)
Drinking water	203	45.7-58.3 mg L^{-1}	-	Keven (2002)
Streamlet water	-	7.51-14.35 mg L^{-1}	0.10-0.14 mg L^{-1}	Alas and Cil (2002)
Well water	142	243.61 mg L^{-1}	0.63 mg L^{-1}	Ozdemir *et al.* (2004)
Drinking water	-	-	-	Dayioglu *et al.* (2004)
Station water	-	2.96-50.44 mg L^{-1}	0.01-0.80 mg L^{-1}	Kara and Comlekcioglu (2004)
Stream water	-	-	7.30 μg L^{-1}	Verep *et al.* (2005)
Drinking water	154	-	5.8%	Atasoylu *et al.* (2004)
Well water	83	9.18 mg L^{-1}	0.02 mg L^{-1}	Durmaz *et al.* (2007)
Well water	14	0-20 NO_3-N mg L^{-1}	0-0.118 NO_2-N mg L^{-1}	Can and Kali (2008)

Turkey, drinking water may contain up to 0.5 mg of nitrite per liter and 50 mg L^{-1} of nitrate. The World Health Organization guidelines for nitrate and nitrite in drinking water are 50 and 3 mg L^{-1}, respectively (EC, 1998; EPA, 2003; Anonymous, 2005; WHO, 2006).

Numerous reports from all over the world describe water supplies with nitrate concentrations greater than the WHO guideline value of 50 mg L^{-1}. In 15 European countries, the percentage of the population exposed to nitrate levels in drinking water above 50 mg L^{-1} ranges from 0.5-10% (WHO, 2007). One hundred and sixteen thousand Americans in 15 states were served tap water contaminated with nitrate and nitrite at levels above health-based limits between 1998 and 2003 (Anonymous, 2007). Many studies have been conducted in Turkey regarding the subject and the results are shown in Table 6.

As can be shown in Table 6, there is no significant contamination in water supplies except well waters. However, nitrite levels detected in this study are different than the levels in above mentioned studies. This could be due to the long distances between water supplies and residential areas, in addition to different industrial and agricultural practices.

In current study, the nitrate levels in tank and tap water in Bitlis and its provinces were in accordance with national and international standards. However, 12 and 100% tank water and 7.02 and 100% tap water samples collected, respectively in spring and autumn contained higher nitrite levels than the recommended national standards (Table 5). According to WHO (2006), report only 3.58% of tap water in autumn had higher nitrite concentration than recommended level. Moreover, the effects of residential areas (Table 3 and 4) and seasons (Table 2) on nitrate and nitrite levels found to be significant ($p<0.05$). Can and Kali (2008) reported that nitrate and nitrite levels could change depending on seasons and weather conditions.

The hazardous effect of nitrate and nitrite on human health is known, although, nitrate itself is not toxic, nitrite originating from the reduction of nitrate induces methemoglobinemia in infants. Up to 100 mg NO_3/L (as N) can be safely consumed by adults and older children (WHO, 1985; Anonymous, 2004a). The APHA survey noted that most cases of methemoglobinemia studied were related to NO_3-N concentrations >40 mg L^{-1} (Walton, 1951). Avery (1999) and L'hirondel and L'hirondel (2002) have questioned the importance of nitrate in drinking water as a risk factor for methemoglobinemia and have suggested that the current nitrate standard might be safely raised to 65-90 mg L^{-1} nitrate with no increase in methemoglobinemia cases.

Currently, there is no regulatory drinking water quality standard for livestock. Researchers suggest a level of 100 mg L^{-1} of nitrate-nitrogen. In the current study, nitrate levels in Bitlis drinking water did not exceed the above mentioned levels (Table 2 and 3).

Studies from the countries, including China, Botswana, Turkey, Senegal and Mexico, report private well water levels that exceed the WHO (2004) guideline, in some instances at levels >68 mg L^{-1} nitrate-N. Accordingly, the protection of water against agricultural nitrate pollution regulations came into force in Turkey (Anonymous, 2004b).

The risk of methemoglobinemia and cancer depends on many factors other than the ingestion of nitrate in drinking water (Sanchez-Echaniz *et al*., 2001; Ward *et al*., 2005). Some epidemiological studies of human populations have shown a correlation between gastric cancer and nitrate levels in drinking water. However, many similar studies have not found any association between drinking water nitrate and cancer. Therefore, nitrate and nitrite would be classified in group D, inadequate evidence to determine carcinogenicity, under the old US Environmental Protection Agency (EPA) (1990) cancer categorization scheme. Under the new EPA cancer guidelines, it would be appropriate to classify them into the inadequate information to assess carcinogenic potential category.

CONCLUSION

In this study, even though the nitrate level in drinking water does not pose a risk in Bitlis and its provinces, exposure to nitrite from drinking water could be hazardous for the infants under 6 months of age and sensitive individuals. It has been concluded that protection and management of water sources, providing sustainable access to healthy drinking water and education about the subject are the necessary measures to apply taking into consideration the area's conditions. Furthermore distillation, reverse osmosis and ion exchange systems could be useful. Also, bottled water or other alternative water sources should be used in infant feedings.

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