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Original Article

Effects of Road Deicing Salt on the Quality of Ground Water Resources in Hamadan Province, West of Iran

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ABSTRACT

Background: The aim of this study was to assess the effects of road deicing salt on the quality of the ground water resources in Hamadan Province during winter season.

Methods: Water samples were taken monthly from thirty wells located around the Hamadan-Asadabad highway. The quality of well water was examined by measuring amount of sodium, chloride, total hardness, total dissolved solid, electrical conductivity, total fecal coliform, and total coliform in well water sample. The correlation between mineral deposits in the water samples and the distance of wells from the highway was investigated using Pearson Correlation Coefficient.

Results: It was estimated that nearly 11,000 tons salt were applied annually in this province for deicing roads and streets. There was a statistically significant negative correlation between the quality variables of well water taken from a distance less than 400 meters from highway axis in the southern side except for fecal coliform and total coliform. No statistically significant correlation was seen between the distance from the highway axis and the quality variables of well water taken from the northern side. There was a significant difference between water quality variables of the wells located in a distance less than 200 meters in the northern side of the highway, with that of the wells located in southern side of the highway ($p<0.05$).

Conclusion: A positive correlation between road dicing salt and mineral deposits in the ground water resources was indicated. Therefore, regarding the limited water resources in Hamadan Province, constraining application of road deicing salt is recommended.

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Introduction

Water is the most important factor of life and survival on the earth. Qualitative and quantitative protection of water resources is among major objectives of stable development. Numerous studies have shown the effects of deicing operations and their effects on water bodies [1]. The water containing salt eventually infiltrates to the soil, and reaches the ground water and may increase the salt in the water sources [1].

Hamadan Province, covering 19,493 square kilometers, is located in the west of Iran, 320 km far from Tehran with a population of about 1.7 million [2]. Due to limited access to surface

water resources in Hamadan Province, most of water needs are supplied through ground water resources [3]. Therefore, it is highly important to protect ground water resources in this province.

We studied the area located around of Hamandan-Asadabad high way. The highway length is 45 km and connects Tehran to the west of Iran. Almamablagh Mountains with a height of 2565 meters above sea level is in the north of this highway with many valleys in the south (Figure 1).

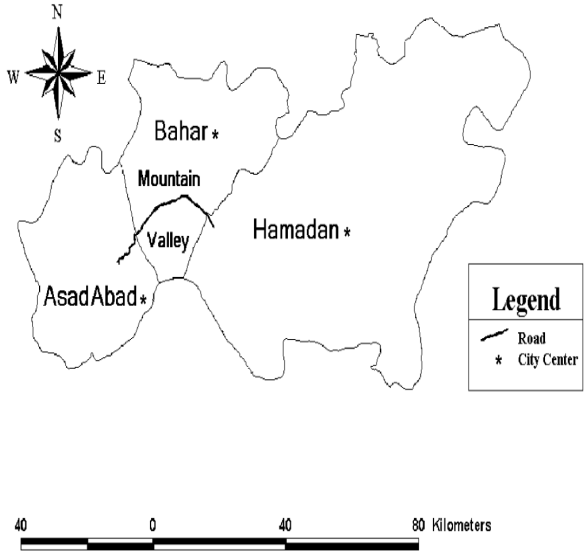

Figure 1: Location of the Hamadan-Asadabad highway

Due to very cold climate during winter in this mountainous area, the precipitations are mainly in the form of snow. Therefore, salt is extensively used to melt the ice in this highway during winter. The presence of brine on the surface will lower down the skidding resistance of the surface considerably [4]. In addition, both adult and larval amphibians were particularly sensitive to changes in osmolarity of their environments [5].

Salt changes the chemical properties of soil [4]. A recent study in Argentina has shown that salinity may affect the soil organic matter component of the soils. The salt-affected soils contained much less organic carbon and nitrogen than the unaffected soils [6]. Salts that are applied for melting the ice on roads disrupt the proportional contributions of nitrate-N and ammonium-N to the mineral inorganic fraction of roadside soils. It is highly probable that the long-term frequently exposure soil to salt controls the rates of key microbial N transformation processes, primarily by increasing soil pH [7].

The aim of this research was to investigate the effects of road deicing salt during winter season on the quality of the regional ground water resources as well as determining the extent of the affected area.

Methods

This research survey was carried out during 2007 to 2008. To identity the amount of salt used to prevent icing of surfaces of roads and streets, enquiry was made from municipalities and General Department of Road And Traffic of the province and the amount of salt used for de-icing of roads was obtained. Then, 17 wells were selected for pre–test evaluation. These wells were located in various distances to Hamadan-Asadabad highway. The well water samples were taken and were transported to the laboratory under standard conditions. The well water samples were inspected for sodium (Na^+), chloride (Cl^-), electrical conductivity (EC), total dissolved solid (TDS), total hardness (TH), total coliform (TC) and fecal coliform (FC). Based on the pre-test results, the minimum sample size was estimated 238. To increase the statistical precision of the study result, the total number of samples was determined 360. Accordingly, 30 dull wells were randomly selected from which a monthly sample was taken. Therefore, sampling was started in June 2007 and continued to May 2008 during which 12 samples were taken from reach of 30 wells. The selected wells located at different distance from either side of the highway axis including 13 wells on the north and 17 wells on the southern side of the highway.

As shown in Figure 2, the locations of the selected wells around the highway were determined using Global Positioning System (GPS) device and then, were implemented in Geographic Information System (GIS). The altitude of the selected wells and their distance from the highway axis are presented in Table 1. The linear relationship between variables was investigated using Pearson correlation coefficient.

The quality variables of the water samples of the wells located in the northern and southern sides of the highway in a distance less than 200 meters form the highway axis were compared using independent *t*-test. All analysis was performed according to the procedures outlined in standard methods [8]. Microsoft Excel and SPSS version13.0 were used for data analysis.

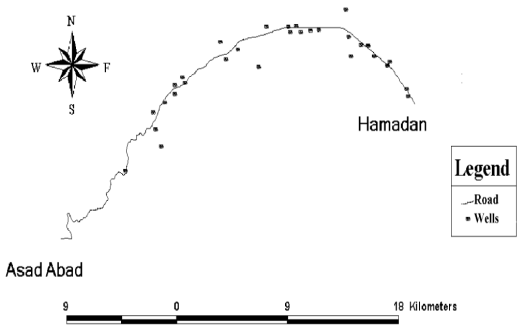

Figure 2: Locations of the selected wells around the Hamadan-Asadabad highway

Table 1: Altitude of the selected wells around the highway and their distance from the highway axis

Selected wells	Altitude (m)	Distance (m)	Side
1	1836	96	North
2	1742	282	North
3	1732	147.8	North
4	1749	1100	North
5	1344	67	North
6	1313	28	North
7	1782	400.4	North
8	1771	811	North
9	1777	13	North
10	1763	131.5	North
11	1845	348	North
12	1893	318	North
13	1449	574	South
14	1875	1500	South
15	1508	121	South
16	1540	285	South
17	1393	260	South
18	1571	337	North
19	1372	109	South
20	1407	2200	South
21	1911	354	South
22	1386	321	South
23	1376	200	South
24	1819	131	South
25	1353	219	South
26	1365	1200	South
27	1401	150	South
28	1652	115	South
29	1355	27	South
30	1366	84	South

Results

The information obtained from municipalities and general department of road and traffic of the province revealed that about 11,000 tons salt were used annually in this province to deicing roads and passages during cold seasons.

There was a statistically significant negative correlation between TH, NA^{+}, CL^{-}, EC, and TDS concentrations of the water samples of the

wells located in a distance less than 400 meters from the highway axis in the southern side. In addition, there was negative correlation between FC and TC concentrations of the well water samples of this area, although the correlation was not statistically significant (Table 2). No statistically significant correlation was seen between these variables and the distance in the northern side of the highway.

There was significant difference between mean titer of NA^+ of the water samples of the wells located in a distance less than 200 meters in the northern side of the highway, with that of the wells located in southern side of the highway ($p<0.01$). However, no significant difference was seen between the mean titer of the other quality including TH, CL^-, EC, and TDS of the water samples of the either sides (Table 3).

Table 2: Pearson correlation coefficients between the quality of water samples and the distance of the selected wells from the highway axis in either sides of the highway

	Southern side		Northern side	
Variables	**r[a]**	***P* value**	**r[a]**	***P* value**
Sodium	-0.194	0.019	0.092	0.300
Chloride	-0.286	0.001	0.050	0.577
Total Hardness	-0.420	0.001	-0.161	0.068
Electrical Conductivity	-0.362	0.001	-0.074	0.403
Total Dissolved Solid	-0.362	0.001	-0.075	0.400
Fecal Coliform	-0.006	0.945	0.110	0.114
Total Coliform	-0.055	0.510	-0.067	0.454

[a] r: Pearson Correlation Coefficient

Table 3: The mean difference of the quality variables of water samples of the selected wells located in the southern and northern sides of the highway

	Southern side			Northern side			
		95% CI			95% CI		
Variables	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**t-test**
Sodium	42.3	37.1	47.6	33.8	29.9	37.7	P<0.01
Chloride	62.3	49.5	75.1	74.8	59.6	90.1	P=0.79
Total Hardness	375.8	351.6	400.0	366.1	341.2	390.9	P=0.15
Electrical Conductivity	858.0	796.1	920.1	808.1	747.1	870.8	P=0.07
Total Dissolved Solid	515.5	478.1	552.9	485.9	448.8	523.0	P=0.07
Fecal Coliform/100 ml	182.4	110.5	254.2	164.7	82.1	242.2	P=0.16
Total Coliform/100 ml	42.7	7.0	78.3	43.2	0.0	86.4	P=0.29

Discussion

The degree of impact of road deicing salt varies from one area to another and due to many variables such as distance from the road, the amount of salt applied and precipitation. Devikarani et al indicated that the impacts of road deicing salt vary because of many factors such as length and type of road draining into the streams, the amount of salt applied prior to thaw periods, road drainage system, topography, discharge of the receiving stream, degree of urbanization of the watershed, temperature, precipitation, dilution, adsorption on to the soil, and microbial degradation in soils. Hence, it can be concluded that road deicing salts affect soil and water quality locally and transiently [1].

The slope of the area around the highway is predominantly from the northern side to the southern side. The results of this research revealed that the quality of water of the wells, located in southern side in a distance less than 400 meters from the highway axis, was influenced by the road deicing salt process. Nonetheless, bacterial contamination (FC and TC) were not affected by this process.

The results of this research showed that deicing process did not affect water quality of the wells located in the northern side of the highway. In other words, the altitude of the northern side of the highway was higher than the highway surface. Therefore, water flows down towards the southern side of the highway. Accordingly, the quality of water of the wells located in the southern side of the highway was influenced significantly compared to that of the northern side.

In the southern side of the highway, the quality of water samples obtained from the wells near the highway was worse than that of wells located in farther distance. These results support the findings of previous studies reported that the influences of road salt on soil and soil solution declined with increasing distance from the road [9]. Nancy et al [10] investigated the impacts of road deicing salts on the fauna of aquatic ecosystems in the northeastern United States and focused on the reproduction of adults and growth and survival of embryonic and larval wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*), that breed in vernal (seasonally inundated) pools. They indicated that conductivity, pH, dissolved oxygen, and water temperature differed between forest and roadside pools. Mean conductivity was nearly 20 times higher in roadside. Conductivity had a strong correlation with both Na^+ and Cl^- concentrations in 30 well water samples. In addition, 61% of roadside pools had higher average conductivity than all forest pools. Conductivity in roadside pools declined exponentially with increasing distance from road. Other water quality variables differed among roadside and forest pools and among years. Mean pH was higher in roadside than forest pools [10].

We revealed that nearly 11,000 tons salt had been applied in this province for deicing roads and passages in 2006. Eric et al examined the water quality of thirteen lakes in Twin Cities Metropolitan Area (TCMA) in the state of Minnesota in USA. They concluded that over 317,000 tones of road salt were used annually for road deicing in the TCMA. Based on the results of this study, sodium and chloride concentrations in urban lakes were 10 and 25 times higher than in other non-urban lakes respectively. Seasonal salinity/chloride cycles in the lakes in the region had a positive correlation with road salt applications. The ionic composition in the lake water samples collected in 2007 differed between the winter (February) after some snowmelt water has entered the lake and the fall (November) after the summer flushing of the lake by rainfall events [11].

The results of this study may be compared with another study conducted in Sweden reported that the contribution of deicing salt is of importance for the chloride concentration on a regional scale. The results of this Swedish study showed that road deicing salt applied by the Swedish National Road Administration accounts for more than half of the total chloride load for the river basin investigated [12].

Water pollution is one of the major threats in many developing countries, including Iran. Furthermore, drinking water supply is one of the most essential components of environmental health. The results of present study showed that if winter road deicing salt continues, salinization of wells water would increase more and more. In this situation, bottled water should be substituted the current drinking water, while, the price of bottled water in Iran is over than 1000 times higher than tap water [13].

Conclusion

A positive correlation between road dicing salt and mineral deposits in the ground water resources was indicated. Hence, regarding the limited water resources in Hamadan Province, replacement of deicing salt with and alternative method is recommended regarding all economic and environmental considerations.

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Conflict of interest statement

The authors declare that there is no conflict of interests.

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