Groundwater Quality and Land Use Change
(A Case Study: Shahrekord Aquifer, Iran)

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ABSTRACT
More than 98 percent of the earth’s drinking water supply comes from groundwater. It needs protection from possible contamination, especially in urban areas where wastewater production is high. Most area of Shahrekord plain is under the cultivation and irrigation water comes from the groundwater. Furthermore, urban sewage discharges to the groundwater, in some parts of the Shahrekord plain. In this study, 18 wells were selected for water sampling. The effects of landuse were evaluated on Total Dissolved Solids (TDS), Total Hardness (TH), Electrical Conductivity (EC), Nitrate (NO$_3^-$), Nitrite (NO$_2^-$) and Sulfate (SO$_4^{2-}$). The samples were selected in different seasons; spring, summer and autumn 2004. A Nested Complete Randomized Design (NCRD) was used for statistical analysis with 18 samples per plot. The results show that there were significant differences ($P<0.05$) between value of NO$_3^-$, NH$_4^+$ concentration and EC in farmlands and urban areas. There was no observed any significant difference on the NO$_2^-$, pH and TH value. It was higher in farmlands than in urban areas. The result shows that there are a significant difference ($P<0.01$) on NO$_3^-$ concentration in different seasons.

Keywords: Groundwater contamination, Urban and agricultural landuse

INTRODUCTION

Freshwater scarcity is recently affecting arid and semi-arid regions condition and it is reasonably expected that in the next few decades a larger part of the world’s population will experience this problem, because of the combination of climate change, industrial development and population growth. Groundwater is the most important drinking water resource in many areas of the world and its protection is fundamentally important. Groundwater pollution in urban area is inextricably linked to patterns of landuse. Recharged waters originating from different landuse and application periods have different effect on groundwater contaminations (Abedi and Bagheri, 2001).

Today, nitrate contamination of groundwater resources is one of the most important problems of the biological environment. The water quality in a region depends on the nature and extent of the industrial, agricultural and other activities in the catchments. Nitrate (NO$_3^-$) is the most common contaminant in groundwater (Spalding and Exner, 1993). Identification of sources of NO$_3^-$, as well as other nitrogen (N) species, has received a tremendous amount of attention, due in part to health concerns regarding NO$_3^-$.
ingestion (World Health Organization, 1996) and to potential ecosystem effects of N loading (Howarth and Marino, 2006). For example, the history and fate of NO₃⁻ contamination have been carefully evaluated in multidisciplinary local transect studies in areas with agricultural sources (Bohlke and Denver, 1995; Tesoriero et al., 2000) and septic tank sources (Robertson et al., 1996). Decomposed plant, N-fertilizer, urban sewage, industrial activities enter a large amount of nitrate and nitrite in groundwater (Abedi and Bagheri 2001). Transport of nitrate and chloride tends to be conservative in the groundwater of the investigated area. Therefore, the elevated concentrations of these anions are suitable as indicators of anthropogenic impact on the groundwater (Zhan and Grim 1993). N-fertilizer release NO₃⁻, NO₂⁻ and NH₄⁺. The NO₃⁻ is immediately leached from the topsoil and entered to the groundwater. The NO₂⁻ is a poison anion that exists in the environment. The NH₄⁺ is absorbed by the surface soil and entered into the environment gradually (Pirnia et al. 1996). Rauret et al. (1990) evaluated the effective factors on groundwater contamination in Catalonia, Spain. They found that sewages gradually transport in to the groundwater and cause water pollution. The study was carried out with forty-five samples collected in three different periods, and eleven parameters were considered. Ibe et al. (1999) showed that groundwater in an alluvial aquifer in the Warri River plain has been polluted by municipal and industrial wastewater and agricultural activities. Hydrochemical analysis carried out for a two-year sampling and analysis program indicate that the highest concentration of groundwater pollution occurred in the industrial areas. The concentrations of ammonia and nitrate of the surveyed wells range from 0.06-0.1 ppm and 0.64-1.20 ppm respectively.

Potential for groundwater contamination is high where soils of low water holding capacity occur above a shallow aquifer. Careful management of nitrogen becomes more critical as soil water storage capacity decreases. The amount of water remained in the soil after gravity drainage is controlled by soil pore size. Soils composed of predominately large particles, like sand and gravel, have relatively large pores that hold much less water against gravity compared to fine-textured soils with smaller pores. Therefore, low storage capacity sands and gravel have greater potential for water percolation and nitrate loss (Dale and Bruce 1994).

Ahn and Chon (1999) reported the significant seasonal variation of SiO₂, HCO₃⁻, and Ca²⁺ contents. Seasonal variation of pollutants such as Cl⁻, NO₃⁻ and SO₄²⁻ was not observed in either area. Zanfang et al (2004) investigated the sources of nitrate in the shallow groundwater at urban area, Hangzhou City, China using chemical and isotopic techniques. Electrical conductivity (EC) of groundwater was high in the study area and ranged 369-1544 µS/cm. There was a high frequency of groundwater (43% of total) with nitrate above the World Health Organization’s standards of 10 mg NO₃/L. The different landuse areas had different nitrate concentrations. Domestic wastewater was the major nitrate source of shallow groundwater in the urban area, and the point source (septic tank) still exists in residential settings. Choi et al. (2005) showed a special variation of ions according to the type of landuse. The ion concentration tends to increase with anthropogenic contamination, due to the local pollutants recharge. The total dissolved solids (TDS) appears to be a useful contamination indicator, as it generally increases by the order of forest green zone, agricultural area, residential area, traffic area, and industrial area. Increasing anthropogenic contamination,
the groundwater chemistry changes from a Ca-HCO$_3$ type into a Ca–Cl (+NO$_3^-$) type. The source and behavior of major ions are discussed and the hydrochemical backgrounds are proposed as the basis of a groundwater management plan. Yongjun et al. (2006) show that the concentrations of NH$_4^+$, SO$_4^{2-}$, NO$_3^-$, NO$_2^-$, Cl$^-$ and the pH level, total hardness, total alkali increase significantly, in which NH$_4^+$, NO$_3^-$, and NO$_2^-$ of groundwater exceeded the drinking water standards as a result of non-point pollution caused by the expansion of cultivated land and mass use of the fertilizer and pesticide. Also Ca$^{2+}$ and HCO$_3^-$ showed an obvious decline trend due to forest reduction and degradation and stony desertification. Obeidat et al. (2007) showed that nitrate concentration increased in some of the selected wells during 2001 to 2006 between 10 to 330 mg/lit with average 77 mg/L. This study indicated that nitrate concentration in 92% of samples is more than 20 mg/L and human activities have an influence on it. Also it shows that there is close correlation between nitrate concentration and wastewater as a contaminant source.

Tabatabaei and Lalehzari (2009) studied the chemical contaminants in Shahrekord aquifer, Iran. They show that total hardness, TDS and nitrate concentration in the southern parts of the Shahrekord plain are higher than northern parts of it. They concluded that flow direction from the north to the south of the aquifer and recharging by rural and urban wastewater in the main reason of these change. Developing agricultural lands and high use of N-fertilizer and supplying urban water from this resource, makes it crucial to consider the pollution of water resources. The main objective of this research was evaluation of the effects of agricultural and urban areas on groundwater quality in different seasons.

**Materials and Methods**

Shahrekord aquifer is located in the Chaharmahal and Bakhtiari Province (latitude 32° 07” N to 32° 35” N, longitude 50° 38”E to 51° 10”E) with a total area of 551 Km$^2$. Location of the Shahrekord plain is shown in Figure 1. More than 85 percent of the plain is under cultivation and 15 percent constitutes the urban and industrial lands (Figure 2). There are 814 wells in the Shahrekord plain. The wells were divided into two parts based on landuse map (Figure 2): agricultural and urban area. Table 1 shows the groundwater consumption in Shahrekord aquifer in 2004. Among the wells, 18 wells in the agricultural area and 18 wells in the urban area were selected for water sampling with regard to good distribution in the plain. Figure 3 indicates position of the selected wells.

Total 108 water samples (18 wells$x$2 area$x$3 season=108) were collected during spring, summer and autumn in 2004 from the wells (Figure 3). Electrical conductivity (EC$_w$), Total Dissolved Solids (TDS), Total Hardness (TH), Nitrate (NO$_3^-$), Nitrite (NO$_2^-$), Sulfate (SO$_4^{2-}$) and ammonium (NH$_4^+$) were measured according to standard method (AHPA, 2005).

Because of the importance and effect of nitrate, 10 more groundwater samples were collected from the wells influenced by the urban wastewater and 10 more groundwater samples were collected in agricultural wells (Figure 4). Total 60 groundwater samples (10 wells$x$2 area$x$3 season=60) were collected during spring, summer and autumn in 2004 and then analyzed for NO$_3^-$, NO$_2^-$ and NH$_4^+$ according to standard method (AHPA, 2005).

A Nested Complete Randomized Design (NCRD) with two factors was employed for statistical analysis. The first factor included three seasons (spring, summer and autumn) and the second factor included two landuses (urban and
agriculture area). The data were analyzed by SAS software version 8.2 (SAS Institute, 2007).

Figure 1. The position of Shahrekord aquifer in Iran

Figure 2. Urban and agricultural areas in Shahrekord aquifer
Figure 3. Position of 36 wells for chemical analyses (EC, TDS, TH, SO$_4^{2-}$, NO$_3^-$, NO$_2^-$ and NH$_4^+$) in Shahrekord aquifer.

Figure 4. Position of 20 wells for chemical analyses for (NO$_3^-$, NO$_2^-$ and NH$_4^+$) in Shahrekord aquifer.

Table 1. Groundwater consumption in Shahrekord aquifer (Isfahan regional water company 2000)

<table>
<thead>
<tr>
<th>Total depletion of groundwater (MCM)</th>
<th>Amount and type of consumption (MCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shahrekord</td>
<td>383.11</td>
</tr>
<tr>
<td></td>
<td>agricultural 215.000</td>
</tr>
<tr>
<td></td>
<td>industrial 8.500</td>
</tr>
<tr>
<td></td>
<td>urban 32.200</td>
</tr>
</tbody>
</table>

*1 MCM=10$^6$ m$^3$
RESULTS AND DISCUSSION

Nitrate

The results show that the average of nitrate concentration was 6.6 mg/L in spring, more than 20 mg/L in summer and 7.5 mg/L in autumn (Figure 5). Concentration of the nitrate in autumn is lower than summer and spring because the agricultural activities are finished in this season. Some of the N-fertilizer was absorbed by crops and soil whereas the others were infiltrated and changed during denitrification and nitrification reactions of the material. It seems that in this region nitrate contamination are generally increased because of the more agricultural activities and the more N-fertilizer usages. These results are in conformity with the study of Zanfang et al. (2004). They reported that different landuse areas had different nitrate concentrations. The applied statistical analysis shows that in spring the nitrate contamination of groundwater in urban areas is higher than agricultural areas \((P < 0.01)\), but in summer and autumn water contamination in agricultural lands is significantly higher than water contamination in urban areas (respectively \(P < 0.05\), \(P < 0.01\) in summer and autumn).

Results are presented in Table 2. Furthermore comparison between different seasons (Table 3), indicated that the different seasons have significant effect on NO\(_3^-\) contamination \((P < 0.01)\). The difference between the nitrate concentration in two areas was significant \((P < 0.05)\) (Table 4). Ahn and Chon (1999) reported pollution of groundwater by NO\(_3^-\), SO\(_4^{2-}\) and Zn\(^{2+}\) in the groundwater from the agricultural district.

![Figure 5. Variations of nitrate concentration vs. different seasons](image-url)

Table 2. Comparison of nitrate concentration in spring, summer and autumn between two regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Autumn**</th>
<th>Summer*</th>
<th>Spring**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>6.6b</td>
<td>19.09b</td>
<td>7.41a</td>
</tr>
<tr>
<td>Agriculture</td>
<td>8.55a</td>
<td>22.72a</td>
<td>5.86b</td>
</tr>
</tbody>
</table>

a,b: means values in the same column, followed by a different letter are significantly different at Fisher LSD test.

* Significant at 0.05 probability level. ** Significant at 0.01 probability level.

Table 3. Comparison of nitrate concentration in different seasons

<table>
<thead>
<tr>
<th>Region</th>
<th>autumn</th>
<th>summer</th>
<th>spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of regions</td>
<td>7.6b</td>
<td>20.9a</td>
<td>6.6b</td>
</tr>
</tbody>
</table>

a,b: means values followed by a different letter are significantly different at Fisher LSD test \((P < 0.01)\).
Table 4. Statistical analysis of contamination in urban and agricultural wells

<table>
<thead>
<tr>
<th>Landuse</th>
<th>NH$_4^+$</th>
<th>NO$_2^-$</th>
<th>NO$_3^-$</th>
<th>SO$_4^{2-}$</th>
<th>EC*</th>
<th>TDS**</th>
<th>pH</th>
<th>TH</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban</td>
<td>0.023b</td>
<td>0.0226a</td>
<td>11.03b</td>
<td>18.09b</td>
<td>452.5b</td>
<td>277.27b</td>
<td>7.78a</td>
<td>227.55a</td>
</tr>
<tr>
<td>agriculture</td>
<td>0.0336a</td>
<td>0.0213a</td>
<td>12.38a</td>
<td>36.8a</td>
<td>525.72a</td>
<td>341.03a</td>
<td>7.86a</td>
<td>238.42a</td>
</tr>
</tbody>
</table>

a,b: means values in the same column, followed by a different letter are significantly different at Fisher LSD test.

* Significant at 0.05 probability level. ** Significant at 0.01 probability level.

**Ammonium**

The concentration of ammonium in different seasons was significantly different ($P<0.01$). Moreover, it was higher in agricultural regions than in urban areas ($P<0.05$). The increase of ammonium is justifiable like the increase of nitrate (Tables 4, 5).

**Nitrite**

There were no significant differences in NO$_2^-$ contamination between groundwater of agricultural land and urban area (Table 4). This shows that the nitrogen cycle reactions produces nitrate more than nitrite. Furthermore, according to the table 5 there was a significant difference ($P<0.01$) among the seasons.

**EC**

In the plain, excessive water is often applied for irrigation in agricultural lands whereas water use efficiency is low. Shamaei (1996) reported a 25.7 percent for the efficiency in Shahrekord plain. Submerged irrigation causes that a large amount of water infiltrates to the groundwater and leaches salts and solutes them. Hence, the EC increases (Figure 6). Statistical analysis confirms these results, (Table 4). The EC of groundwater in agricultural land is more than urban area. But comparison of the amount of EC in the different seasons doesn’t show significant difference.

**pH**

The pH is the most important parameter for test of water quality and useful tool for interpretation of water chemistry. There were no significant differences in pH in aspect of landuse but there were significant difference in pH among the seasons. The pH of samples was 7.7 – 7.9 (Figure 7 and Table 4 and 5).

![Figure 6. The variation of EC vs. different seasons](image-url)

![Figure 7. The variation of pH vs. different seasons](image-url)
**Sulfate**

Sulfate fertilizers increase the sulfate contamination of groundwater. The sulfate concentration in summer was more than in spring but it was not significantly affected by season (Figure 8). Sulfate contamination of groundwater in agricultural lands was more than urban areas. The result shows that the sulfate concentration is significantly influenced by landuse ($P<0.01$).

![Figure 8. The variation of sulfate concentration vs. different seasons](image)

**TDS**

Comparison between EC and TDS reveals the obvious correlation between EC and TDS. The maximum allowable of TDS in drinking water is 500 mg/L (WHO, 1996) and the groundwater has no limitation for drinking-water. The results of the variance analysis of TDS indicated that no significant difference was found among the seasons whereas the TDS of groundwater was significantly different between agricultural land and urban area ($P<0.01$). Figure 9 shows that it is higher in agricultural land than urban area (Table 4 and 5).

![Figure 9. The variation of TDS vs. different seasons](image)

**Total Hardness**

Figure 10 indicates that the average of TH has different in the seasons and regions. The TH ranges between 150 to 300 mg/L so that this water classified into the hard class. Comparison between the TH demonstrates difference in the area and seasons (Table 4 and 5).

![Figure 10. The variation of total hardness (TH) vs. different seasons](image)

**Table 5. Mean square of the parameters for different seasons**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Agriculture area</th>
<th>Urban area</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.O.V</td>
<td>2.09**</td>
<td>0.42**</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>2339**</td>
<td>225 n.s</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>3.06×10⁻³ n.s</td>
<td>21×10⁻³ n.s</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>0.156**</td>
<td>1234 n.s</td>
</tr>
</tbody>
</table>

n.s not significant

** Significant at 0.01 probability level.
CONCLUSION

The following result has been drawn based on this research:
- N-fertilizer increases the nitrate concentration especially is in the summer, whereas it is not considerable.
- The effect of sulfate on quality of groundwater is lower than the effect of nitrate.
- Total Hardness, Total Dissolved Solids, Electrical Conductivity and Sulfate within the different seasons are approximately constant.
- Nitrate is changeable during a year. Although increasing of nitrate is more serious than TH, but its oscillation happened in a short time.
- It is necessary to consider all factors related to the quality of water.

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REFERENCES


