Groundwater quality assessment for drinking and irrigation purposes in Silakhor plain, Iran

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Abstract

This review considered groundwater resources, its characteristics and qualities of Silakhor Plain. Silakhor plain is located in central part of Iran between 25°,50′ to 36° eastern longitude and 36°, 50′ to 37°, 58′ northern latitude. The samples were analyzed for physico-chemical parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids(TDS), chemical parameters like Calcium, Magnesium, Potassium, Sodium, Chloride, Bicarbonate, Sulfate and Nitrate. The results of evaluated parameters were compared against the standard guideline values recommended by the World Health Organization(WHO, 2011) and E.C.O of Iran, 1999 . The concentrations of the cations (Ca, Mg, Na, and K) are all found below the guideline of WHO and E.C.O.I. Sulphate and bicarbonate recorded value range of 0.11 – 2.09 me/L and 1.6 – 7.81 me/L, which are also below the value of set by E.C.O.I and WHO standards. This result indicates that nitrate concentration has positive correlation with the use of fertilizers & negative correlation with depth of water table.

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Introduction

Human activities commonly affect the distribution, quantity and chemical quality of water resources. The increase in groundwater demand for various human activities has placed great importance on water science and management globally (Abdullahi et al., 2011; Ullah et al., 2014). In the last decades, the rapid population growth and urbanization in developing countries have led to the generation of large quantities of wastes (wastewater and solid wastes) and consequential environmental degradation. Perhaps the best-known sources of groundwater contamination are associated with the storage or disposal of liquid and solid wastes. Waste disposal can take a number of forms: septic systems, municipal and industrial landfills, surface impoundments, waste-injection wells, direct application of stabilized wastes to the land. Septic systems are the largest source by volume of waste discharged to the land. These systems are sources of bacteria, viruses, nitrate, phosphorus, chloride and organic substances. Some hazardous waste material may be deposited in municipal landfills and underlying groundwater may become contaminated. Percolation of irrigation water into soils dissolves soil salts and transports them downward (Kampbell et al., 2003). Evapotranspiration of applied water from the root zone concentrates salts in the soil and increases the salt load to the groundwater. Chemigation, the practice of mixing and distributing pesticides and fertilizers with irrigation water, may cause contamination if more chemicals are applied than crops can use. Surface impoundments are used to store, treat or dispose of oil and gas brines, acidic mine wastes, industrial wastes (mainly liquids), animal wastes, municipal treatment plant sludges and cooling water (Pawar, 1993; Ledoux et al., 2007; Longe and Balogun, 2010). Due to industrial, municipal and agricultural waste containing pesticides, insecticides and fertilizer residues with water groundwater has been polluted by leaching process. Ammonium, a major component of fertilizer and manure, is very soluble in water and increased concentrations of nitrate that result from nitrification of ammonium commonly are present in both ground water and surface water associated with agricultural lands (Carey and Lloyd, 1985; Birkinshaw and Ewen, 2000; McLay et al., 2001, Ledoux et al. 2007; Chinedu et al., 2011). Increased concentrations of nitrogen in drinking water can cause methemoglobinemia in infants and stomach cancer in adults (Lee et al. 1991, Wolfe and Patz, 2002; Nolan and Stoner, 2000). Therefore, the set maximum permissible concentration of nitrate in drinking water of 50 mg/L, determined by the World Health Organization (WHO, 2011). Often lack of technical knowledge, financial and human resources coupled with existing policies limit the extent to which landfills can be built, operated and maintained at minimum standards of sanitary practice (Nickson et al., 2005). The environmental problem caused by improper waste management in the expanding cities is one of the most urgent improvement issues for the government of Iran. Silakhor area is experiencing the interplay between natural and human induced factors. These factors in combination have lead to degradation of overall soil and groundwater quality. In this study we consider the ground water quality in Silakhor plain, Boroujerd district of Lorestan state in Iran, using physico-chemical parameters like pH, Electrical conductivity (EC), Total dissolved solids (TDS) and measured the concentrations of anions and cations such as Chloride, Sulphate, Nitrate, Sodium, Magnesium, Potassium and Calcium in the ground water samples.

Materials and methods

Study Area

Silakhor plain is located in the eastern part of the Boroujerd district of Lorestan state in Iran. This plain lays between 36°, 45′ N to 37°, 48′ N latitude and 24°, 58′ E to 34°, 56′ E, longitude. The climate in the area is classified as semi-arid.

Sampling of groundwater

In the present study, 168 ground water samples were collected from 14 different locations of Silakhor. The samples were collected during the September, 2012 to August, 2013 one sample per month from all locations. The latter samples were acidified and their TDS,
EC (Electrical conductivity) and pH was measured at the sampling site.

Also, the sampling polyethylene bottles were first washed up with the sampling water and two samples were taken at each point, one for analyzing major ions (cations: Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$ and anions: Cl$^-$, HCO$_3^-$, SO$_4^{2-}$) and nitrate.

**Samples analysis**

Different test methods and Instruments were used for this study according to the World Health Organization (WHO, 2008) and the Iran Environment Conservation Organization (E.C.O of Iran, 1999). Temperature, pH, TDS (mg/L), EC (µS/cm) was measured by Model HI 991301, Hanna(pH/EC/TDS/Temperature). Total Hardness (mL / L), Ca$^{2+}$ conc. (mL / L) and Sulphate (mL / L) were measured by EDTA titrimetric method, Chloride (mL / L) were examined by gravimetric method, glass filters method and argentometric method respectively. Nitrate (mg/L) was calculated by phenoldisulphonic acid method and Mg$^{2+}$ ion conc. Bicarbonate (HCO$_3^-$) was carried out using acid titration, with methyl orange as indicator. Nitrate (NO$_3^-$), Sulphate (SO$_4^{2-}$) were determined using V$_{2000}$ multi-analyte photometer, Na and K were carried out with flamephotometer 410 after calibrating it with analyte standard while the remaining

**Results and discussion**

The results of the observed physico-chemical parameters showed variations. The description of Physical parameters are given in table 1 respectively.

<table>
<thead>
<tr>
<th>Samples</th>
<th>pH</th>
<th>TDS (mg/L)</th>
<th>EC (µS/cm)</th>
<th>Ca$^{2+}$ (me/L)</th>
<th>Mg$^{2+}$ (me/L)</th>
<th>Na$^+$ (me/L)</th>
<th>K$^+$ (me/L)</th>
<th>Cl$^-$ (me/L)</th>
<th>SO$_4^{2-}$ (me/L)</th>
<th>HCO$_3^-$ (me/L)</th>
<th>NO$_3^-$ (mg/L)</th>
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<td>WW1</td>
<td>7.62</td>
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<td>197</td>
<td>2.12</td>
<td>0.7</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>0.11</td>
<td>1.6</td>
<td>11.8</td>
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<td>602</td>
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<td>1.65</td>
<td>1.18</td>
<td>0.04</td>
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<td>0.48</td>
<td>4.85</td>
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<td>1.1</td>
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<td>0.01</td>
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<td>0.7</td>
<td>0.05</td>
<td>0.6</td>
<td>0.51</td>
<td>4.5</td>
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<td>425</td>
<td>685</td>
<td>0.23</td>
<td>1</td>
<td>0.7</td>
<td>0.03</td>
<td>0.5</td>
<td>1.45</td>
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<td>1.09</td>
<td>0.1</td>
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<td>0.65</td>
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<td>0.74</td>
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<td>1142</td>
<td>1720</td>
<td>8.5</td>
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<tr>
<td>Minimum</td>
<td>7.48</td>
<td>198</td>
<td>197</td>
<td>0.13</td>
<td>0.7</td>
<td>0.05</td>
<td>0.01</td>
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<td>1.6</td>
<td>11.8</td>
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<tr>
<td>Mean</td>
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<td>481.6</td>
<td>744.5</td>
<td>3.18</td>
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<td>0.51</td>
<td>2.35</td>
<td>11.67</td>
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</tbody>
</table>

St. D = Standard Deviation.

**Total dissolved solids (TDS)**

In Table 1 the maximum and minimum values of TDS, EC, pH and ion concentrations of groundwater samples are presented. The dissolved solids originate from the weathering of rocks, soil and dissolving lime, gypsum and other salts sources as water percolates through them. Increase in the concentration of dissolved salts such as sulphate, chlorides, bicarbonates of Ca, Mg and sodium in the groundwater attributable to both natural as well as well as human induced factors, leads to the process of salinisation (Saleem et al; 2012, Subhadra Devi et al; 2003, Hem, 1991). As salinity increases, the proportion of all these salts increases. The total dissolved solids (TDS) are the concentrations of all dissolved minerals in water indicate the general
nature of salinity of water. The TDS value in groundwater ranged between 198(mg/l) to 1142(mg/l), (Table 1). The TDS values are all below the maximum permitted level of 500mg/l set by the World Health Organization (WHO) and the Iran Environment Conservation Organization (E.C.O of Iran, 1999), while values in the wells WW8, WW9, WW10, WW11 and WW13 located in Urban and industrial areas exceeded the set limit.

Electrical Conductivity (EC)
Conductivity is the measure of capacity of a substance to conduct the electric current. Electrical conductivity is an indication of the concentration of total dissolved solids and major ions in a given water body. The electrical conductivity in water samples is an indication of dissolved ions. Thus the higher the EC, the higher the levels of dissolved ions in the water. The electrical conductivity (EC) of groundwater ranged from 197 µs/cm to 1720 µs/cm and a mean of 744.5 µs/cm and a standard deviation of 303.63 permissible limit is <1500 micromohs/cm for domestic use (Table 1). The pH of samples were within the normal range 7.48 to 7.82. The acceptable limit for the drinking water standard is 6.5 – 8.5.

Cations concentration
The calcium concentration varies from 0.13 me/L to 8.5 me/L and the magnesium concentration varies from 0.7 to 4.5 me/L. The desirable limit for calcium is 75 mg/L (3.75 me/L) and the permissible limit in the absence of alternate source is 200 mg/L(5 me/L). The desirable limit for magnesium is 30 mg/L(1 me/L) and the permissible limit in the absence of alternate source is 100 mg/L(3.6 me/L).

Sodium is the sixth most abundant element in The Earth’s crust and sodium stems from rocks and soils. The sodium part of table salt has been linked to heart and kidney disease. Not only seas, but also rivers and lakes contain significant amounts of sodium. Apart from the natural sources, human activities have significant influence on the concentration of sodium in the groundwater (Pawar, 1993). Human activities can have a significant influence on the concentrations of sodium in groundwaters. Also Sodium had a concentration of 0.05 me/L to 2.34 me/L as minimum and maximum with standard 0.17 (table 1).

Potassium is an essential element for humans, plants and animals, and derived in food chain mainly from vegetation and soil. Potassium in the groundwater is derived from rainwater, geological sources, fertilizers and other anthropogenic activities. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The World Health Organization (WHO) has prescribed the guideline level of potassium at 10 mg/L(0.434 me/L) in drinking water. As per World Health Organization (WHO) criteria, none samples exceeding maximum permissible limit.

Anions Concentration
Chloride originates from sodium chloride which gets dissolved in water from rocks and soil. It is good indicator of groundwater quality and its concentration in groundwater will increase if it mixed with sewage or sea water. Concentrations chloride in samples were recorded as 0.1 me/L as minimum and 3.8 me/L as maximum with mean and standard deviation of 1.19. The highest values of chloride are found in the wells (WW1, WW3 and WW13) located in the vicinity of industrial areas.

Sulfate can be found in almost all natural water. The origin of most sulfate compounds is the oxidation of sulfite ores, the presence of shales, or the industrial wastes. Sulfate is one of the major dissolved components of rain. High concentrations of sulfate in the water we drink can have a laxative effect when combined with calcium and magnesium, the two most common constituents of hardness. The sample contains the sulphate concentration in the range of 351 to 487 mg/L. The desirable limit for sulphate is 200 mg/L and the permissible limit in the absence of alternate source is 400 mg/L. The samples WW2 and WW3 are not suitable for drinking.

Bicarbonate alkalinity (HCO$_3^-$) is the measure of the capacity of the water to neutralize a strong acid. The
Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in free state (20). The bicarbonate alkalinity varies from 1.6 to 7.81 me/L (table 1).

Nitrate is one of the most common groundwater contaminants. The excess levels can cause methemoglobinemia disease. Nitrate in groundwater originates primarily from fertilizers, septic systems, and manure storage or spreading operations.

The concentration of nitrate (NO$_3^-$) in groundwater generally is 11.85 mg/L, 43.7 mg/L as the minimum, maximum, and 11.8 as standard deviation. This minimum value of nitrate was recorded in WW1 while the maximum was in WW13. The maximum permitted level of 50mg/L as defined by WHO (2004) and the Iran Environment Conservation Organization (E.C.O of Iran, 1999) guideline for portable water.

Natural levels of nitrate in groundwater may have been enhanced by anthropogenic, municipal, industrial and agricultural wastewaters from waste disposal sites.

All the 19 groundwater samples out of 20 had nitrate values above the stipulated tolerance level of 10mg/l for portable water. The high level of nitrate in groundwater used for human consumption is a serious source of concern to public health. Problems associated with high nitrate concentration in groundwater have become increasingly prevalent in the recent years. High nitrate concentrations have detrimental effect on infants less than six month of age. Nitrate reduces nitrite which can oxidize haemoglobin to methaemoglobin, thereby inhibiting the transport and availability of oxygen around the body or simply causes Cyanosis and asphyxia (blue baby syndrome) (WHO, 1985, Alsabahi et al.; 2009; Abdullahi et al.; 2010, Longe and Balogun; 2010).

Conclusion
The present study was undertaken with an aim to analyze certain physico - chemical parameters in the ground water samples in Silakhor, Lorestan State in Iran. The analytical results shows higher concentration of total dissolved solids (26.66%), electrical conductivity (32.56%) and chloride (32.13%), magnesium (76.46%), sodium (41.2%) which indicates signs of deterioration as per WHO (2011) and E.C.O of Iran, 1999, standards. A few wells of the study area record extraordinary values of conductivity, chloride and nitrate due to the application of fertilizer for agricultural exhibiting and mixing of waste waters effluents the higher concentration of ions contributes to groundwater degradation in varying degrees.

References


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