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Evaluating groundwater contamination of Urmia plain by using GIS

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Abstract

The purpose of this study is to update the information and determining the chemical quality of ground water in Urmia plain in order to control the contamination and optimal utilization of these resources. In this research, to evaluate chemical parameters of water quality (Sodium, hardness, bicarbonate, calcium, sulfate, chloride, electrical conductivity and pH and total soluble salts) 70 wells were selected. Then maximum, minimum, average, standard deviation and coefficient of variation were determined by using GIS package and Excel software. The average of each parameter was analyzed during 2001-2011 and compared with international standards. The results demonstrate that average of sodium and electrical conductivity in drinking water is close to Europe standards and average of pH and chloride is less than mentioned standards. Based on the chemical composition of water and zoning maps, it seems that agricultural activities (excessive use of chemical fertilizers, pesticides and agricultural waste) and Urmia saline lake were effective in contaminating eastern parts of the plain.

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Introduction

Along with the development of civilization the use of water changed as it is used in many fields, from agriculture to industry and above all in energy production. Nowadays access to adequate water with high quality in appropriate time and place is significant and any deficiency of water hinders the sustainable development. Groundwater is the only source of water for millions of people throughout the world and its Contamination has profound impact on human health, industries, agriculture, environment and society (Josuma *et al*, 1987). Rapid population growth and increasing demand for water leads to excessive utilization of ground water that causes a disturbance in their balance. So levels of aquifers in many parts of the world are negative. This is result from improper management of plains and non-optimal use of these resources. By applying the proper management in use of available water resources not only we can reduce the costs of development and exploitation but also we can optimize the use of these resources (Nakhaee, 2012). Water contamination can occur by several mechanisms, in some cases natural processes cause serious water pollution. Most human concerns about groundwater pollution are due to human activities. Domestic and industrial sewage discharge, urban runoff, saline water into the aquifer, mining activities, chemical compounds produced by factories and their Storage and transportation and insanitary burying of solid wastes can contaminate groundwater (Laws, 2000). Groundwater decontamination is very costly and long process. In many cases, when the infection was diagnosed, the aquifer purification is almost impossible (Khodaee *et al*, 2006). Banezhad and Moheb zadeh in 2012 in an investigation entitled assessment of water quality in Rosen and Qahavand plains, while evaluating the electrical conductivity, total dissolved solids, pH, chloride, sodium and sodium adsorption ratio mentioned that 43.7 percent of the area has a inappropriate concentration of sodium ion and in terms of statistical analysis a positive correlation between EC and SAR, and a linear relationship between EC and TDS have been determined. (Mohammadi *et al* 2011) by studying the temporal and spatial variations of water quality in the Qazvin plain and investigation on 50 wells in 2003-2007 concluded that 10% of groundwater is suitable for drinking and agriculture. By examining studies, groundwater provides about 50 percent of Urmia Lake Basin consumption. Urmia Lake aquifers discharge by wells and springs. Drought in recent years and declining groundwater levels in some of the major aquifers contribution of springs greatly reduce in exploitation of groundwater and more than 90% of groundwater discharges occur through wells. Exploitation of wells during past two decades has been increased rapidly. Therefore continuous drop in groundwater levels in some aquifers has been created. The main objective of this research was to analyze and evaluate the parameters (Sodium, hardness, bicarbonate, sulfate, conductivity, chloride, calcium, PH and total soluble salts in groundwater of Urmia plain by using GIS package to identify contaminated areas.

Methods and materials

Geographical location of studying area

Urmia plain with 1043 km² area is geographically located in 44˚ 55´ to 44˚ 18´ east longitude and 37˚ 20´ to 37˚ 49´ north latitude. Length of the plain along the north - south, is about 55 kilometers and along the East - West, is about 22 kilometers. The altitude of plain is 1320 meters above sea levels. Dip direction is from west to east (Jonoubi *et al*, 2012). Groundwater recharge and discharge rates of Urmia in 1385 are according to table 1. (Ministry of Energy, 2010)

Table 1. Entrance and discharge volume of Urmia plain.

Selected area	Extent of area (km²)	Total entrance (M.M.C)	Total discharge (M.M.C)	Drop (m)	Reservoir volume changes
Urmia plain	1043	533.3	540.67	- 0.18	- 7.38

Evaluating of used statistics

According to the flow direction of groundwater in Urmia plain which are predominantly from the West to the east, among the pumping wells in upstream, downstream and existing wells within the city limits, 70 wells for sampling were selected (fig.. 1). Information about the quality of these wells was collected from West Azerbaijan Regional Water Statistics. To study groundwater contamination of Urmia plain location of all wells were prepared by using the GIS and Excel softwares. These softwares were also used to calculate the average, standard deviation and coefficient of variation, lower and higher limits. Then zoning maps of chemical parameters were prepared. After studying the zoning maps and statistical calculations, conclusion, discussion and recommendations were presented. Attention to the type of consumption, physical, chemical and bacteriological properties is important as much as exploitation of groundwater resources. Sometimes geological conditions and climatic changes, contamination in entrance regions to aquifer, saline water and fresh water interactions in coastal aquifers, municipal and industrial wastes and fertilizers used in agriculture Which penetrate into the earth due to rainfall or irrigation cause chemical changes in the groundwater in large quantities. Based on the statistical data of chemical parameters of 70 wells, the results are provided in Table 2. Then zoning maps were prepared by using GIS package.

Fig. 1. Location of the study area.

Table 2. Results of statistical values of Urmia plain.

Parameter		pH mg/lit	Na mg/lit	Ca mg/lit	HCO3 mg/lit	Cl mg/lit	TH mg/lit	EC µmhos/cm	SO4 mg/lit	TDS mg/lit
Maximum		8.47	6.45	6.50	9.14	6.08	663.57	1638.57	6.74	1065.07
minimum		7.10	0.50	1.55	3.23	0.40	160.00	437.27	0.65	284.23
mean		7.80	1.99	3.52	5.13	1.57	340.01	826.68	2.19	531.79
standard deviation		0.26	1.46	1.08	1.08	1.33	96.43	293.48	1.25	186.55
Coefficient of Variation		3.38	73.51	30.82	21.12	84.62	28.36	35.50	56.93	35.08
standard	EU	6.5-9.5	2	-	-	2.5	-	2500	2.5	-
	WHO	6.5-9.5	-	-	-	-	-	-	-	1000
	EPA	6.5-9.5	-	-	-	2.5	-	-	2.5	500

Changes of Sodium, Calcium and Chloride

Despite being one of the most abundant elements, it is found in most water resources due to its high solubility. Standard concentration of taste for NaCl is 350 mg/lit (Taghizadeh and Mohammadi, 2005). The mean values of these parameters are within the standard range. Calcium and magnesium represent hardness of water. Chloride was evaluated and based on standards placed in group of suitable water. Zoning maps are shown in fig. 2.

Changes of hardness and total dissolved solids

Water hardness is related to the presence of solutes in water. Total hardness includes: carbonate hardness or temporary hardness and permanent hardness or non-carbonate hardness. Permanent hardness occurs because of elements such as magnesium, calcium and sulfates which don not settle by boiling (Taghizadeh and Mohammadi, 2005). Average hardness of sampled wells is 340 mg/lit which Place in group of suitable drinking water according to fig. 3.

TDS, including total solids that are dissolved in water but does not include suspended sediments, colloids and dissolved gases. If all dissolved solids in water determine by exact chemical analysis, the total numerical of them is equal to the TDS (Moghimi, 1385). Average TDS in sampled wells is more than standard limits according to EPA standard and place in group of suitable drinking water according to WHO standard. Related map is shown fig. 3.

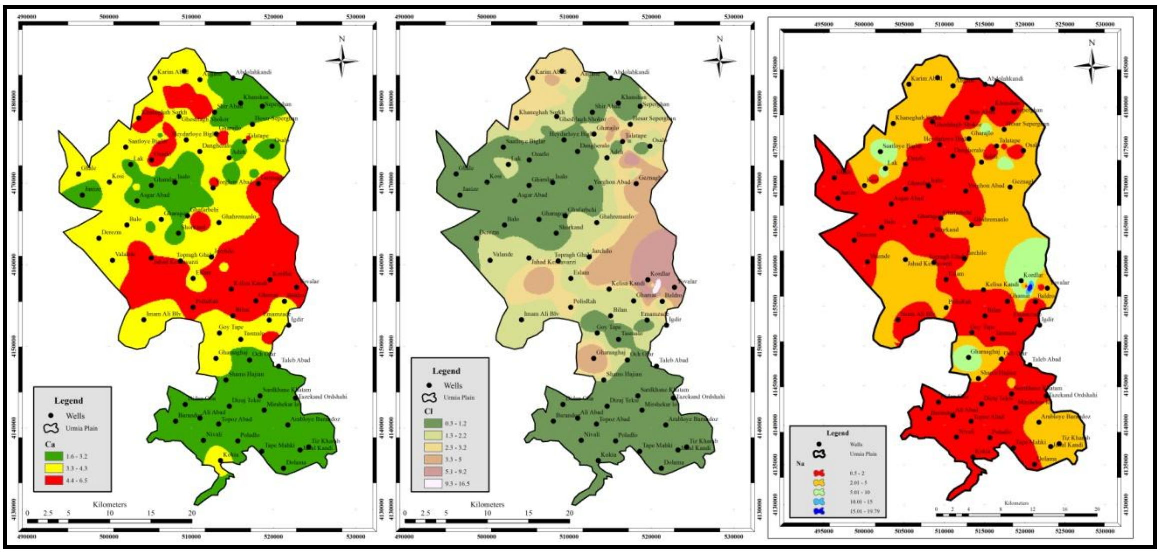

Fig.2. zoning maps of Calcium, Chloride and Sodium.

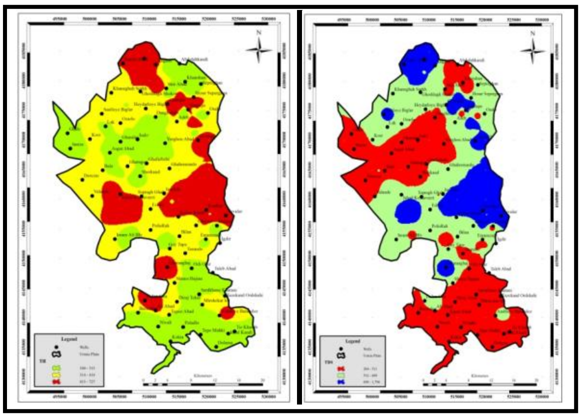

Fig.3. zoning maps of hardness and total dissolved solids.

Changes of bicarbonate and sulfate

While carbon anhydride dissolved in water, combines with other factors in the water or some water turns to carbonic acid and some water turns to carbonate and bicarbonate. In natural water with pH about 8 there is equilibrium between carbonate and bicarbonate due to presence of Co_2 that prevents deposition of calcium (Taghizadeh and Mohammadi, 2005).

Sulfate exists naturally in many minerals and in business, especially in the chemical industry is used. Sulfate discharges to the water from industrial wastewater and rainfall. However the maximum amounts are usually in ground water and derived from natural sources. Average of this parameter has suitable status according to the standards. In some samples values of sulfate are higher than standard limits, so decrement of this parameter is necessary. Zoning maps are shown in fig. 4.

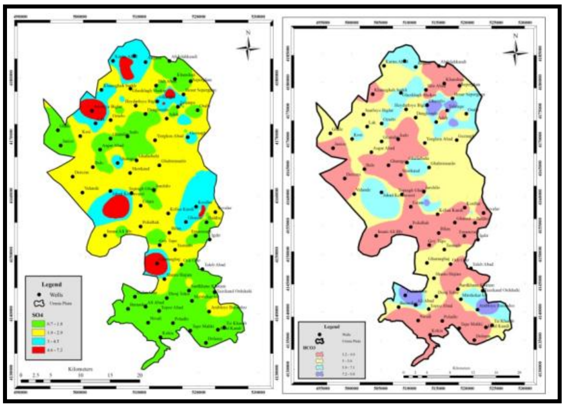

Fig. 4. zoning maps of bicarbonate and sulfate.

Changes of pH and electrical conductivity

PH refers to acidic (below 7) and alkaline (above 7). It means, if hydrogen ions increase in the water, water becomes acidic and these ions decrease, water become alkaline. Water with pH 7 means it is neutral. According to the analysis, certain restrictions is not found at sampled wells and place in group of suitable water.

EC represents the conductive elements in water. Unit of electrical conductivity is Ohm^{-1} or mho. EC has a direct relationship with TDS and dissolved salts in the water. So its measurement in order to control water quality is important. Based on sampled wells and Europe standard it has an acceptable status. Zoning maps of theses parameters are shown in fig. 5.

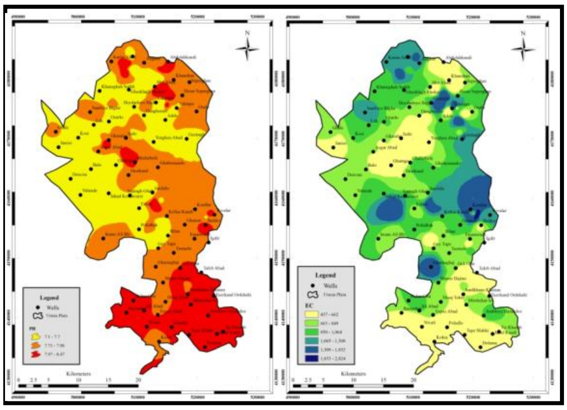

Fig.5. zoning maps of pH and electrical conductivity.

Results and discussion

Each country according to water resources and climatic conditions has its own drinking water characteristics. It is a fact that drinking water standards in an arid country will vary with the country with high rainfall (Moghimi, 2006). Parameters of sodium, hardness, calcium, sulfate, chloride, total dissolved solids, conductivity, pH and bicarbonate were analyzed by using data from 70 wells during 2001-2011. The results of zoning maps of drinking water quality in selected area and compare them with international standards, aside from precise accuracy demonstrate that most of the parameters placed in the ideal situation and their values are less than standard limits. In terms of bicarbonate, there is no problem for drinking and groundwater for drinking is suitable with considering the other issues. Average sodium of 70 wells has the capability for consumption. According to low rainfall in recent years, negligible effects on quality of groundwater in studying area, intensity of evaporation and excessive pumping from wells cause an increment of soluble salts concentration and hardness in some areas of plain. Also chemical fertilizers, pesticides and agricultural wastes are also important factors for increasing the hardness and dissolved minerals in Urmia groundwater. According to the zoning maps, parameters of sodium, dissolved salts and hardness increased from west to east because plain is located nearby Urmia saline lake. In these areas, plants with high resistant to salinity should be planted and reducing salinity of water should be considered. The best way to preserve the quality of groundwater is identification of contaminant sources. Creating a database for groundwater and required data and using this information to identify vulnerable areas can help economic savings in operational monitoring and increasing efficiency in the management of groundwater resources. Balamurugan and Dheenadayalan (2012) in their study on groundwater quality in Madurai district in Tamil Nadu, India concluded that pH, electrical conductivity, hardness, alkalinity, calcium, fluoride, Do and COD values are in permitted range and TDS is above acceptable range. So they suggested that water quality is unsuitable for industrial and domestic purposes. Zakarya *et al* (2012) after sampling of 25 groundwater wells from various sites around the Rivers Aynsu and analysis of physical and chemical parameters: pH, EC, TDS, Ca, Mg, Na, K, HCo_3, Cl, $SO4^-$, and NO_3 stated that 80% of EC samples placed within WHO standard, water have been acidic. Ion concentrations were generally low except for Na, Cl and HCo_3. Also Aly *et al* (2013) after assessment and analysis of chemical parameters of Riyadh and Alahsa Regions and their comparison concluded that salinity in both areas is in high level. Also chloride was effective on making the water unsuitable and affected agricultural activities.

According to the research, Urmia Plain, based on the parameters is in good condition. In some wells, some parameters values were higher than standard limit which should be tried to reduce values of contaminant parameters. In order to prevent the contamination suggested that:

- Prevent interference of saline and freshwater aquifers.
- Reduce groundwater exploitation.
- Barriers or stacks instead of Reservoir dams.
- Use modern methods of irrigation (Trickle, sprinkler, etc.).
- Use halophyte plants in areas near Urmia lake.

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