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Investigating Groundwater Pollution using GIS for Sustainable Development: Case Study on Plains of Sarvestan, Iran

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ABSTRACT

The purpose of this study is to update the information and determine the chemical quality of the underground water of plains of Sarvestan, Fars, Iran, to control water pollution and optimal utilization of resources for sustainable development. In this research chemical parameters of water quality (sodium, hardness, bicarbonate, soluble salts) were studied in 28 deep wells/half deep:1 well in the residential area, 8 wells, 19 wells with capped pasture and agricultural land use in plains of Sarvestan, using Excel, Arc GIS and version 3/9 of Surfer to map and calculate the coefficient of variation, mean, standard deviation, maximum and minimum cytotoxicity. Then by studying and investigation of the geological maps, land use, aerial photographs and considering the national-international drinking water standards and Schuler diagram, the mean of each parameter during 2005-11 were analyzed and interpreted. The results of this study showed that the mean of 27 drinking water wells with good quality of Schuler diagrams, Piezometric well No. 5 with 15/401 mg of sodium per liter has the maximum amount of sodium, average hardness of 28 wells more than the national standards is classified in poor to non-potable, average bicarbonate of 28 wells is classified in good drinking water and average water-soluble salt , 27 wells were classified in poor to non-potable water according to Schuler diagram more than WHO and EPA standards and Shurijeh well by 471/3 mg per liter was less than the above mentioned standards with the availability of good drinking water. According to the chemical composition of water and study of the above mentioned maps, it seems that the hardness and soluble salts of water, agricultural activities (excessive use of the chemical fertilizers, agricultural runoff, pesticides and agricultural waste) constructor types of the surroundings, plain's substrate, movement of the ground water were the most important pollutants and pollution source in the catchment. In addition to identifying the polluted ground water, zone mapping provide us with the quality parameters of the water in sustainable development and also appropriate comprehensive management and using them in process of decision making and selecting systems and provide technologies related to the building treatment plan of the refineries for the experts.

KEYWORDS*:* agricultural activities, GIS water quality standards, sustainable development, and underground water.

1. INTRODUCTION

Along with the advance of civilization, usage of the water took a new form, so that in many areas, from agriculture to industry, and the most important of all energy production, access to water with the appropriate quality in right time and space is very important and any water shortage is considered as an obstacle in regard to sustainable development. Rapid population growth and its correspondence with the increasing needs of water resources leads to excessive exploitation of ground water and thus the natural balance and it has caused many groundwater level in many aquifers around the world to be negative. Due to inappropriate or unsuitable management in plains, it has caused water loss or effects of non-optimal usage of these sources. With proper management methods in usage of existing water resources, not only we can reduce the heavy expenses of development and exploit of these resources, but also we can optimize their usage. In many cases, groundwater pollution is identified after the contamination of the drinking water wells. Decontamination of the drinking water is very expensive and lengthy activity and after that the pollution is diagnosed, it is almost impossible to decontaminate the aquifer (Khodaei, 2006). Many researches about groundwater pollution have been presented in different parts of the world. In terms of literature review, Banejad and Mohebzadeh (2013) in a study titled "Evaluation of groundwater quality in Razan and Qahavand plains" in addition to evaluating the electrical conductivity, total dissolved solids, ph, chloride; sodium adsorption ratio stated that 7/43 percent of the region has high concentration of sodium ions, and due to inappropriate statistical

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analysis there is positive correlation between EC and SAR and linear correlation between EC and TDS. Mohammadi and Ebrahimi (2011) studied the spatial and temporal variation in groundwater quality of plains of Qazvin and 50 irrigation wells in a period of 2003-07 and stated that 10 percent of the total groundwater in plains of Qazvin is suitable to be used for drinking and agriculture and 6 percent is unfavorable. The overall goal of this research is to evaluate and analyze the parameters of sodium concentration, hardness, bicarbonate and soluble salts in ground waters of Sarvestan plains associated with effective factors using geographic information system (GIS) and determination of the correlation between these parameters with the kind of geological formations, atmospheric participation, climatic conditions of the dessert, excessive pumping of the groundwater and land use and designing informational layers using GIS in order to provide us with the contaminated areas which finally leads to achieve practical purpose including pollution distribution of the area, suitable sites for water extraction with less pollution and provide practical solutions for the management and improvement of the groundwater.

2. MATERIALS AND METHODS

2.1: geographic location of the area under study:

Plain of Sarvestan is located in southern Chastain of Tashk and Bakhtegan lakes, 80 km west of Shiraz (Fars province). The area of this range is 1641 square km the longitude north side is Goshnegan Marvdasht Kharameh and from the south to the city of Jahrom and from North Westto Shiraz and from west it is limited to the city of Fasa. Average temperature, rainfall and evaporation rates 1/17 centigrade, 8/379 mm, 8/2222 mm and according to the classification of Dumbarton it has a dry climate. With regard to the Indian Agriculture Forum, it is estimated that the average annual discharge is 7/59 million cubic meters per year. Direction of the groundwater movement is from the highlands of east and south-east to the west plains (Maharlou Lake). The depth of the groundwater level at the edge of the southern highlands and northern plains was high and toward the center and west of plains (near Maharlou Lake) was reduced. Most of the negative changes and decline of the groundwater levels in the central plains were 19 meter and according to the balance sheet of the aquifers, the volume of the ground water were 39/6 million cubic meters. From the adjacent area, there is no flow from the surface and groundwater and there are no permanent rivers in this area. In fig. 1 location of the study area and wells of the above mentioned parameter measurements is specified in the country's map. In this area, there is one well in the residential area, 8 wells coated with pasture and 19 wells with agricultural use were located.

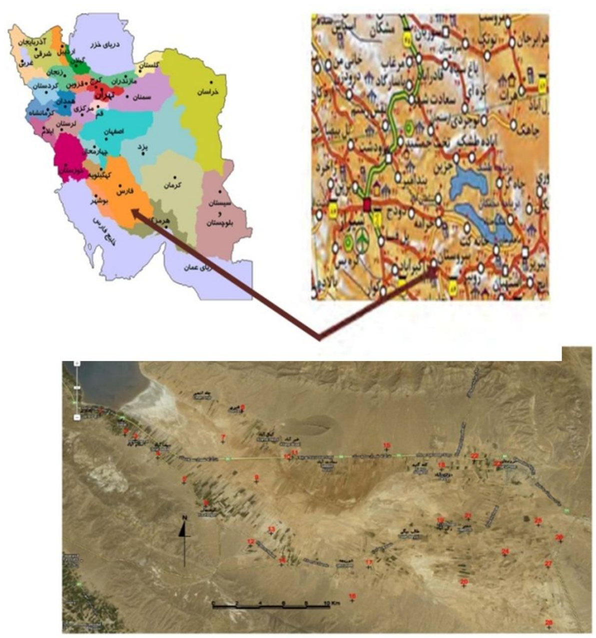

Fig.1: position of the wells of Sarvestan Plains in country map.

2.2: material formation of the area:

According to the studies and regarding the Fig. 2 (geological map of the plain) in the mentioned range, specific units which is consisted of Asmari- Jahrom formation (delomit, marl and limestone), hop (layers of gypsum and limestone- gypsum-bearing marl) pabdeh- gurpi (limestone, clay, shale and marl) and sachun (hard layers and compounds of gypsum, shale and marl)e surrounding the place and Aghajari formation (gypsum, limestone and layer of marl) are in the context of the plain. Hormoz formation consisted of evaporated deposits (gypsum and sult) are located in the North West and North East of the plain.

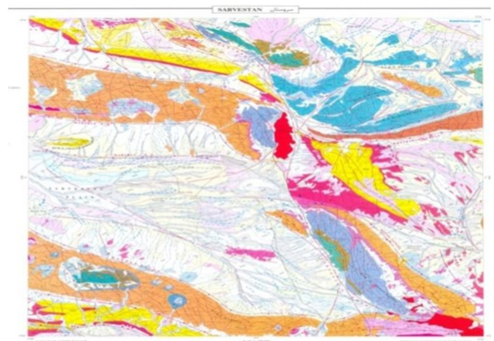

Fig. 2: geological map of the Sarvestan plain

In order to study the contamination of the groundwater of the Sarvestan plain, at first it was attempted to provide a vegetation map and topography of the area and adapted these 2 maps, by using UTM (x,y) of each well, the location of each well was specified on the land use map using the GIS software, and a map of each well's location using Google earth software in order to demonstrate agriculture lands, pasture and residential area was provided. By using the GIS software and Excel, zoning maps, average of each parameter, plot graphs drawing of each graph, graph of periodic change of 4 chemical factors of water; calculation of the mean, standard deviation, and coefficient of variation of maximum and minimum was calculated.

After studying the zoning maps, geology, land use, excel charts, statistical calculation, the underground water level, rainfall data and information obtained from visiting the region, average of the parameters were interpreted and conclusions, discussion and recommendations were made. Measurement of HCO^{-3} was done using spectrophometer and photometer model 7000 with palintest and with the precision of 01/0 unit made in England

2. RESULTS AND DISCUSSION

Rate of exploitation of material from the underground water resources is equally important, according to the type of use, physical and chemical and bacteriological characteristic is also important. Sometimes geological and climate change, pollution in nutrition sites, interference of fresh and saline water in coastal aquifers, urban and industrial waste and fertilizers used in agriculture which penetrates into the ground due to precipitation and irrigation; cause chemical characteristic of the underground water to change. In studying the chemical characteristics of water samples, chemical analysis is required.

Changes in sodium:

In addition to being one of the most abundant elements in the nature, due to its high solubility, sodium is found in most natural water sources. Threshold taste concentration of chloro sodium is 350 mg per liter (Taghizadeh & Mohammadi, 2005). According to the zoning map in Fig. 3 and scholar diagram, the mean of sodium is 27 wells in group of drinking water wells with good quality is less than the national standard and Pizometeric well with the 15/401 mg of sodium per liter has the highest level of sodium and is categorized as unpleasant drinking water with unpleasant taste and it is more than the national standards.

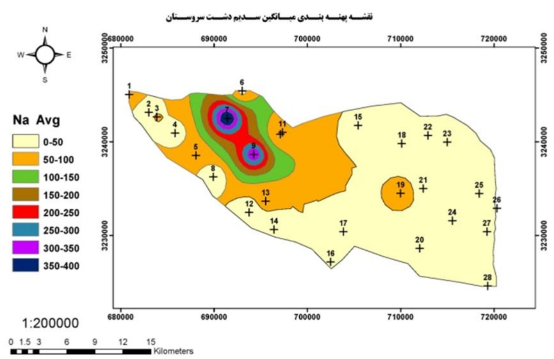

Fig.3: sodium's mean zone mapping

Hardness change:

Water hardness is related to the presence of salt in water. Total hardness includes temporary hardness or carbonate hardness plus permanent hardness or non-carbonated hardness. Permanent hardness emerges due to the presence of elements such as sulfate, magnesium and calcium chloro which are not precipitated by boiling (Taghizadeh & Mohammadi, 2005). The average hardness of 28 wells in group of non-potable to poor is more than the national standard (in WHO standard it has hardly been mentioned) and Pizometric well number 5 by having 9320 mg per liter has the maximum of the above mentioned parameter,according to the national standard average hardness of the 26 wells are more, Shurijeh wells (316/6 mg per liter) and north Kuhanjan (362/9 mg per liter) are less than national standard, the result of which is demonstrated in the Fig. 4 of the zone mapping.

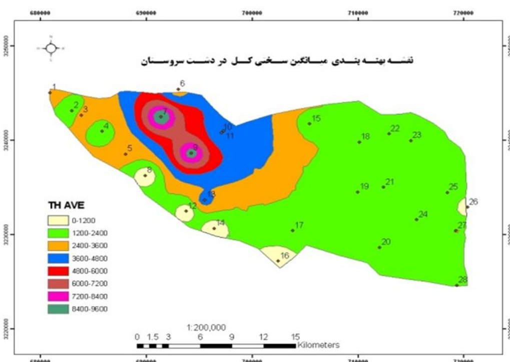

Fig. 4: zone mapping of the average hardness

Bicarbonate variation:

While dissolving in the water, anydrid carbonic is combined with the existing agents or some portion of it becomes acid carbonic and the other portion becomes bicarbonate ions or bicarbonate. In natural water in which PH is in range of 8, because of existence of CO_2, among carbonate and bicarbonate balance occurs and prevents sedimentation of calcium (Taghizadeh & Mohammadi, 2005). Figure 5 indicates that the average of bicarbonate of 28 wells were in the group of drinking water in Schuler diagram.

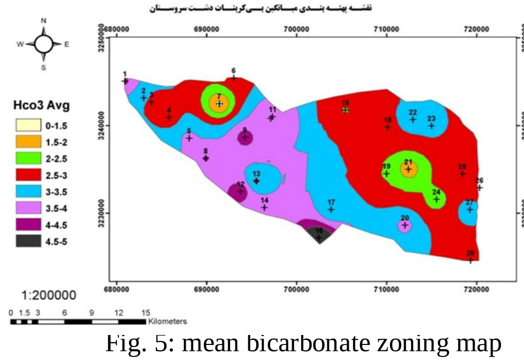

Fig. 5: mean bicarbonate zoning map

Changes in total soluble salts: total dissolved solids (T.D.S) are consist of solids which are dissolved in water but contain suspended sediments, colloids and dissolved gases are not included. If all the dissolved solids in water cannot be determined with chemical testing, the total number of them will be equal to T.D.S (Moghimi, 2005). Average of the water-soluble salts of 27 wells (figure 6 mean of the soluble salts zone mapping) are classified in not non-potable in Schuler diagram, more than WHO and EPA standards and south Shurijeh well with 471/3 mg per liter less than national standards of WHO and EPA are classified in good potable water in Schuler diagram and 24 wells are more than national standard and south shurijeh , north Kuhanjan ,bottleneck of Hashi and Nazarabad Puzzeh are respectively 1209- 936/8- 680/1- 471/3 mg per liter less than national standard.

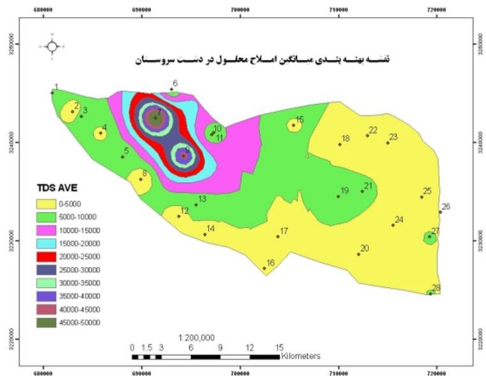

Fig. 6: Soluble salt zone mapping

3. CONCLUSION

Regarding the water resources and climatic conditions, any country has its own water characteristics. This is a fact that drinking water standards of a country located in a dried and arid desert is varied with a country with high rainfall (Moghimi, 2005). In this study, parameters variations of sodium, hardness, bicarbonate and soluble salts were studied using data from 28 wells with residential purposes, pasture and agriculture during 2005-2011. Results of the water quality zoning in the study area and comparing them with national and international standards shows that considering the fact that mean bicarbonate of 28 wells are less than the above mentioned standards; therefore, there is no problem with drinking water and considering other parameters groundwater is suitable for drinking. The average sodium of 27 drinking wells are below the national and international standards and Pizeometer well number 5 with the 15/401 mg per liter is grouped as inappropriate drinking water. The average hardness of 28 wells are grouped in poor to non-potable and Pizeometer well number 5 with 9320 mg per liter has the maximum amount of the above mentioned parameter, the average amount of soluble salts in 27 wells are bad drinking water and pizeometer well number 5 with 51311 mg per liter has the maximum amount and south Shurijeh well with 471/3 has the minimum amount of the soluble salt. Loss of rainfall and its little effect on the quality of the water in study area, unfavorable climatic conditions such as low rainfall high temperature and intensity of evaporation and excessive pumping of wells has increased the degree of concentration of dissolved salts and its hardness. Thus, considering the dryness of the area, the situation is provided for increase of the soluble salts. Existence of evaporate minerals and Chile marl in evaporate units (formation of the surrounding dessert and floor of the plain and formation of Hormoz in the North West of the plains) has caused hardness increase, dissolved salts, decrease of water quality). Also, chemical fertilizers, pesticides and agricultural waste appear to be the most important factors which increase the soluble salts and hardness of the groundwater in plains of Sarvestan. According to the drawn maps, as it goes from east to west, 3 parameters of sodium, dissolved salts and hardness increase. If the water quality in Lake Maharlou reaches the minimum amount, as we go from north to south, parameters of hardness, sodium, bicarbonate, soluble salts and bicarbonate will decrease. Probably due to agricultural land use in these plains sodium absorption by plants such as celery, lettuce and etc., regarded as useful but not required element, has caused sodium reduction. During2005-2011, groundwater levels shows significant decline which is consistent with relative increase in soluble salts and hardness and concentration of these parameters in ground water direction (from the East to the North West and North East) shows increase. The best way to preserve the quality of the groundwater resources is to identify pollution sources and prevent water pollution. Creation of a database for ground water and spatial data required and applying this information to identify the vulnerable areas can cause economic savings in monitoring operations and increase efficiency in management of groundwater resources. Balmorgan and Dayalan (Balamurgan & Dheenadayalan, 2012) conducted study on the quality of groundwater in Madurai, Tamil Nadu and concluded that

PH, electrical conductivity, hardness, alkalinity, calcium, fluoride, DO and COD values are within normal limit and TDS, S_3, S_7, S_8, S_9, S_{10} are well above the optimal range, so they proposed that the water quality is not suitable for industrial and domestic use. After taking 25 samples of groundwater from different parts of the Insu and analyzing chemical and physical parameters like PH, EC, TDS, CA2+, Mg^{2+}, Na^{2+}, K^+, HCo_{3-}, CL^-, SO_4^{2-}, NO_{3-}, in an article entitled Hydro geochemical of the groundwater Zakaria et al. declared that 80% of EC samples were in WHO, water had acidic and slightly PH feature, soluble salts of groundwater were generally low except sodium, bicarbonate, choloride. After analyzing the chemical parameters of two areas of Riaz and Alahsa and comparing them, Ali et al. concluded that there is high level of salinity in both regions. Except salinity, choloride has caused the water to be unsuitable for irrigation and has affected the agricultural activities. Comparing to Riaz, groundwater of Alahsa is generally higher in the amount of salinity, choloride and volume of sodium. Graphs indicate that most of the studied water types in Alahsa were sodium choloride-solfate while in Riaz the majority of them were calcium, magnesium, sulfate and choloride. The results of study are expressed and entitled as hydro geochemical and qualitative of groundwater resources in region of Alahsa in Saudi Arabia.

4. Suggestions

- Preventing the passage of fresh water from saline geologic formation
- Reducing withdrawals from groundwater
- Constructing stacks or barriers of artificial groundwater
- Using modern methods of irrigation (drip, rain or magnetic and etc.)
- Cultivation of halophyte plants (halophytic)

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