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Assessment of Groundwater Chemical Quality, Using Inverse Distance Weighted Method

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ABSTRACT: An interpolation technique, ordinary Inverse Distance Weighted (IDW), was used to obtain the spatial distribution of groundwater quality parameters in Damghan plain of Iran. According to Scofield guidelines for TDS value, 60% of the water samples were harmful for irrigation purposes. Regarding to EC parameter, more than 60% of studied area was laid in bad range for irrigation purposes. The most dominant anion was Cl^- and 10% of water samples showed a very hazardous class. According to Doneen guidelines for chloride value, 100% of collected water from the aquifer had slight to moderate problems for irrigation water purposes. The predominant cations in Damghan plain aquifer were according to $Na^+ > Ca^{++} > Mg^{++} > K^+$. Sodium ion was the dominant cation and regarding to Na^+ content guidelines, almost all groundwater samples had problem for foliar application. Calcium ion distribution was within usual range. The magnesium ion concentration is generally lower than sodium and calcium. The majority of the samples showed Mg^{++}amount within usual range. Also K^+ value ranged from 0.1 to 0.23 meq/L and all the water samples had potassium values within the permissible limit. Based on SAR criterion 80 % of collected water had slight to moderate problems. The SSP values were found from 2.87 to 6.87%. According to SAR value, thirty percent of ground water samples were doubtful class. The estimated amounts of RSC were ranged from 0.4-2 and based on RSC criterion, twenty percent of groundwater samples had slight to moderate problems.

KEYWORDS: GIS, Spatial analysis, Water Quality, IDW, Groundwater.

INTRODUCTION

In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and other factors are rarely considered important [1]. The chemical composition of water is an important factor for domestic or irrigation purposes.

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Salinity and pollution of well water, either from point or non-point sources, have become subjects of health concern both in urban and rural areas. Groundwater resources are dynamic in nature and are affected by such factors as the expansion of irrigation activities, industrialization and urbanization; hence monitoring and conserving this important resource are essential. The quality of water is defined in terms of its physical, chemical and biological parameters. Ascertaining the quality is crucial before its use for various purposes such as drinking; agricultural, recreational and industrial uses; etc. [2, 3]. Some research findings indicated that parameters of groundwater such as ECw, SARw, chloride, sodium mainly affect on the groundwater quality and crops growth in the studied area [4]. Also, results showed that salinity and Cl^- and $HCO3^-$ were the problems on irrigation water in some studied areas[5]. Recently, groundwater assessment has been based on laboratory investigation, but the advent of Satellite Technology and Geographical Information System (GIS) has made it very easy to integrate various databases.

MATERIALS AND METHODS

Study area

The study area "Damghan plain" between north latitude N36 04 51.4, N36 06 47.5 and east longitude E54 25 20.9, E54 27 20.8 with an area of 10.75 km2. Basic map is selected from topographic map with 1:50,000-scale. The studied map is shown in Figure 1. It falls in drought-prone region of Semnan, Iran.

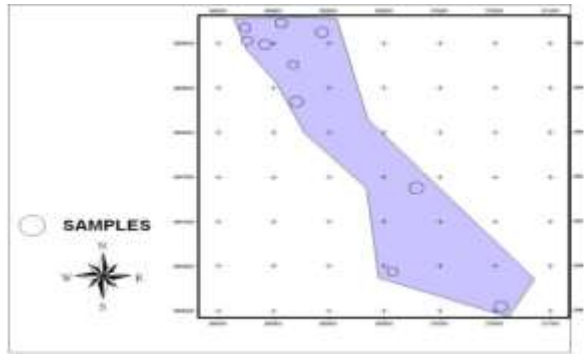

Figure 1. The map of the studied area

Sampling

In order to evaluate the suitability of groundwater quality in Damghan plain for irrigation purpose, Water samples were collected from 10 boreholes capturing the deep aquifer. The water samples in question were collected in clean polyethylene bottles. At the time of sampling, the bottles were thoroughly rinsed two to three times with the groundwater to be sampled. In the case of bore wells and hand pumps, the water samples were collected after pumping for 10mn. This was done in order to remove groundwater stored in the well. In situ, measurements included electrical conductivity (EC).

Include instrumentation section

Total Dissolved Solids (TDS) were measured using a portable field kit, since these parameters changed along the storage time. Preservation and transportation of the water samples to the laboratory were done based on standard methods. The samples collected were brought to the laboratory. For anion analysis, these samples were stored below 4°C. The chemical analyses (Cl^- , HCO_3^{2-} , Ca^{2+}, Mg^{2+}, Na^+ and K^+) were performed at the Laboratory. Chloride was estimated by argent metric titration [6]. Bicarbonate was determined by titration method. The spectrometry of atomic absorption was used to measure the concentrations of calcium, magnesium, sodium and potassium. The accuracy of the chemical analysis was verified by calculating ion- balance errors. The errors were generally around 10%. Each parameter was compared to the desirable standard limit of that parameter stipulated for irrigation purposes.

GIS Analysis

The study was carried out with the help of topographic sheets, Arcview GIS 3.2. The paper map of the city has a 1:50,000 scale and was digitized to the UTM coordinate system by applying the on-screen digitizing method. GPS was used to map the location of each sampling borehole; and finally, the results of each parameters analyzed were added to the concerned boreholes. The various thematic layers were prepared using a spatial interpolation technique through Inverse Distance Weighted (IDW). This method uses a defined or a selected set of sample points for estimating the output grid cell value. It determines the cell values using a linearly weighted combination of a set of sample points; and, it controls the significance of known points upon the interpolated values based upon their distance from the output point, generating thereby a surface grid as well as thematic isolines [7]. Groundwater quality classification maps for EC, SAR, SSP RSC, TDS, Cl^-, HCO_3^{2-}, Ca^{2+}, Mg^{2+}, Na^+ and K^+ from thematic layers have been created for studied area. Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) and Residual Sodium Carbonate (RSC) were calculated on the basis of some standard equations [8].

RESULTS AND DISCUSSION

Understanding the groundwater quality is important that it is the main factor determining its suitability for various usages [9, 10]. Physical and chemical parameters including statistical measures, such as minimum, maximum, mean and standard deviation, are reported in Tables 1 and 2. The water quality parameters were selected and their maps were prepared; using point data spatial analysis of GIS. The water quality parameters included TDS, EC, SAR, SSP, RSC, $Ca^{2+,}$ Mg^{2+}, Na^{2+}, K^{2+}, HCO_3^{2-} and Cl^-. TDS are compound of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides) and of small amounts of organic matter that are dissolved in water. Concentrations of TDS in water vary considerably due to differences in the solubility of minerals [1]. The TDS amount ranged from 1152mg/l to 4591.36mg/L to with an average of 2836.09mg/l (Figure 2). According to Scofield guidelines [11], for TDS value 60% of the sample locations were harmful for irrigation purposes. As shown in Figure 3, the TDS amount increased from the south to the north-east.

Table 1. Chemical analysis of Water Quality based on different criteria for irrigation

Sample	HCO_3^-	Cl^-	Mg^{2+}	Na^+	K^+	Ca^{2+}
N1	7.5	10	1.5	10.5	0.21	5.5
N2	8	7.8	1	10	0.15	5
N3	7.9	6.1	1.5	8	0.23	4.5
N4	6	6.8	0.5	8	0.18	4.5
N5	4	5.3	1	5	0.1	3.5
N6	7.9	12.1	1.2	13	0.14	6
N7	7.8	8	1.1	9	0.2	5.9
N8	6.5	4.2	1.5	5	0.17	4.4
N9	6.5	4.5	1.6	5	0.13	4.5
N10	4	4.3	1.2	5	0.19	2.1
max	8	12.1	1.6	13	0.23	6
min	4	4.2	0.5	5	0.1	2.1
mean	6.61	6.91	1.21	7.85	0.17	4.59
SD	1.54	2.61	0.33	2.82	0.04	1.16

Table 2. Different parameters of Water Quality based on different criteria for irrigation

Sample	SAR	EC	SSP	RSC	TDS
N1	5.61	4400	59.28	0.5	2816
N2	5.78	7174	61.9	2	4591.36
N3	4.62	7000	56.21	1.9	4480
N4	5.1	6100	60.69	1	3904
N5	3.33	1800	52.1	0.8	1152
N6	6.87	6200	63.9	0.7	3968
N7	4.81	1820	55.55	0.8	1164.8
N8	2.92	2720	45.17	0.6	1740.8
N9	2.87	4210	44.52	0.4	2694.4
N10	3.9	2890	59.2	0.7	1849.6
max	6.87	7174	63.9	2	4591.36
min	2.87	1800	44.52	0.4	1152
mean	4.65	4431.4	55.85	0.94	2836.09
SD	1.32	2085.13	6.7	0.55	1334.48

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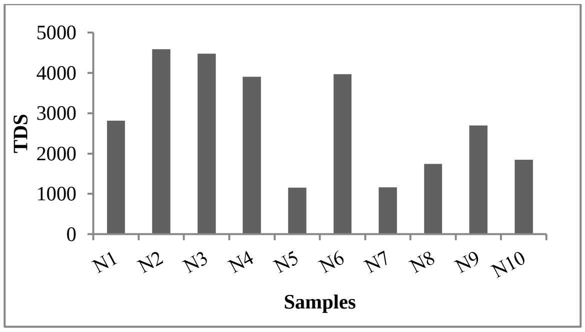

Figure 2.The amount of TDS in samples

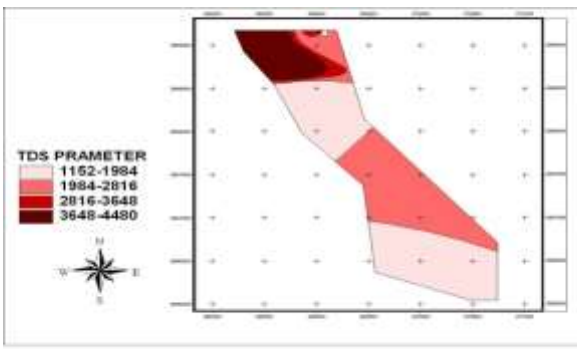

Figure 3. Spatial distribution of TDS_w

The Electrical Conductivity (EC) of water at 25°C is due to the presence of various dissolved salts. The electrical conductivity varies widely and ranges between 1800µS/cm and 7174 µS/cm at 25°C with a mean of 4431.4 µS/cm. Water quality with respect to EC indicates that more than 60% of the study area groundwater lies in bad range for irrigation water purposes (Figures 4 and 5).

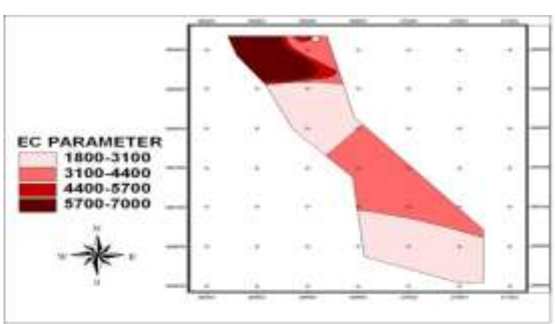

Figure 4. Spatial distribution of EC_w(µs cm-1)

The most dominant anion is chloride with a concentration ranging from 4.2 mg/L to 12.31 and with an average value of 6.91 mg/L (Figure 6). According to Doneen guidelines [12], for chloride value 10 % the chloride ion concentration in groundwater of the study area was very hazardous for irrigation water purposes. The bicarbonate ion concentration (Figure 7) is relatively lower than chloride concentrations (range: 8-4mg/L).

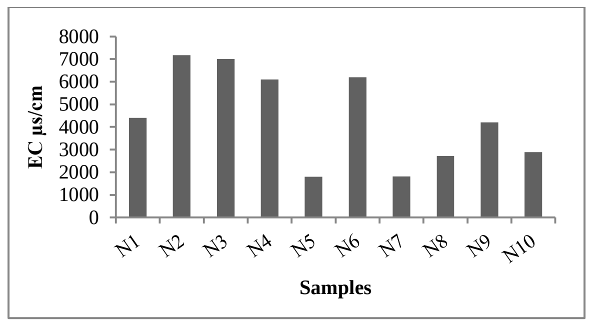

Figure 5.The amount of EC in samples

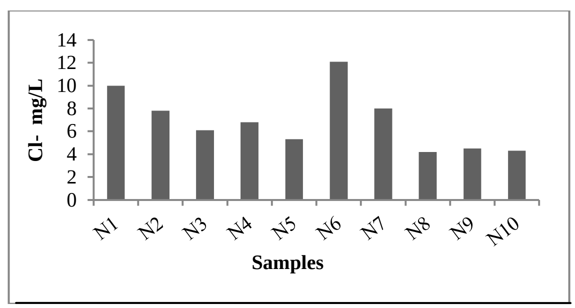

Figure 6. The amount of Chloride ion in samples

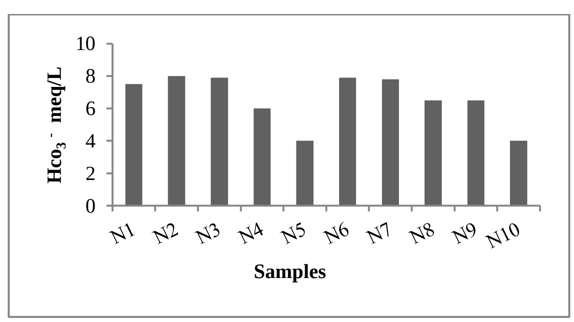

Figure 7.The amount of Bicarbonate ion in samples

According to Ayers guidelines [13], for bicarbonate value 100% of collected water from the aquifer had slight to moderate problems for irrigation purpose. The predominant cation trend in Damghan plain aquifer is $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$. Sodium is the dominant cation in Damghan plain aquifer. Its concentration ranges between 13 and 5 meq/L with an average value of 7.85 meq/L (Figure 8). Regarding to Ayers guidelines [13], for sodium value almost all groundwater samples had increased problem for foliar application. Calcium is the second most dominant cation; and its concentration was ranged from 2.1 to 6 meq/L with an average value of 4.59 meq/L. Calcium ion distribution is within usual range in irrigation water (Figure.9). The magnesium ion concentration is generally low compared to those of sodium and calcium; and it also falls in the range of 0.5 meq/L to 1.6 with a mean value of 1.21meq/L (Figure 10). The majority of the samples showed a magnesium amount within usual range in irrigation water. In the area of investigation, the potassium amounts were ranged from 0.1 to 0.23 meq/L with an average value of 0.17meq/L (Figure 11); and, it was found that all the samples had potassium values within the permissible limit.

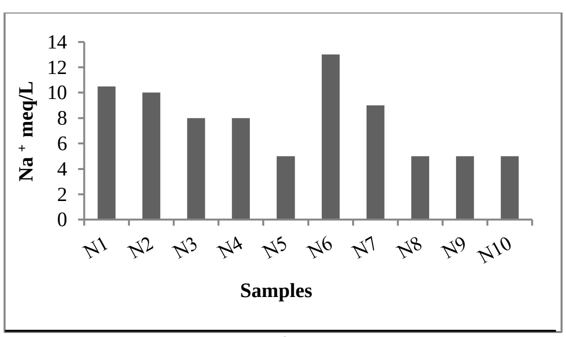

Figure 8.The amount of sodium ion in samples

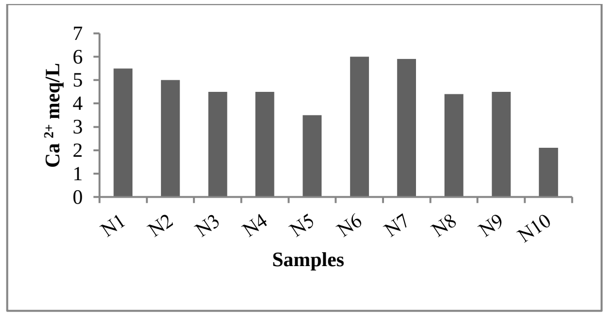

Figure 9.The amount of Calcium ion in samples

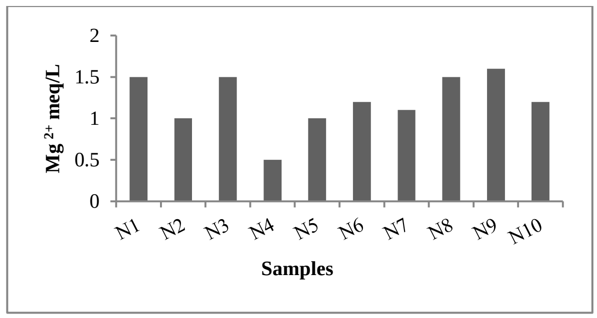

Figure 10.The amount of Magnesium ion in samples

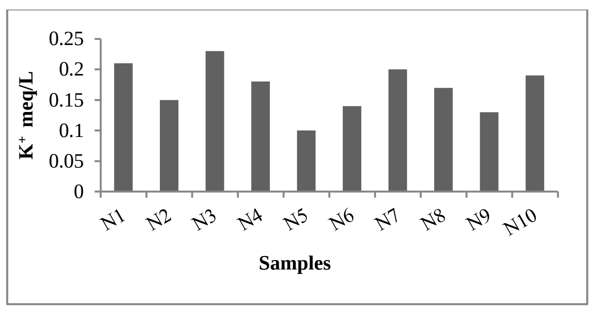

Figure11.The amount of Potassium ion in samples

Based on SAR criterion 80 % of collected water had slight to moderate problems for irrigation proposes (Figures 12). The SSP values were found from 2.87 to 6.87 (Figures 13 and 14). According to SAR value [14], 30 % of ground water samples were doubtful class for irrigation proposes (Figure 15).

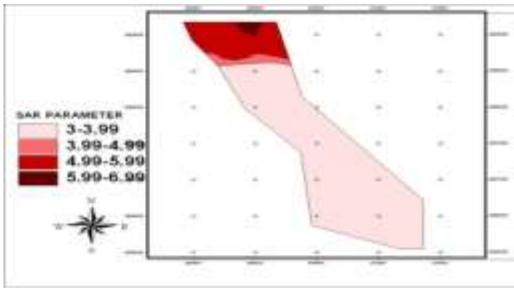

Figure 12. Spatia

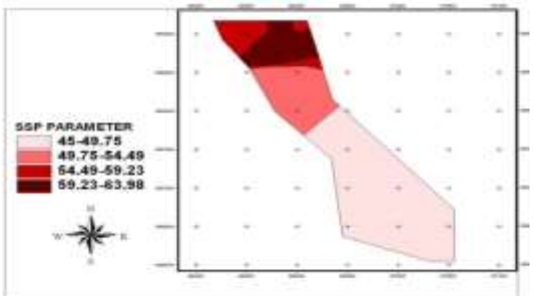

Figure 13. Spatial distribution of SSP_w distribution of SAR_w

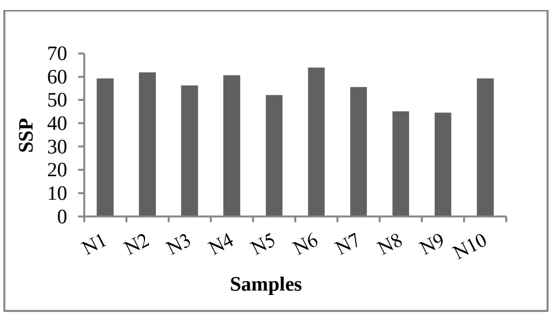

Figure 14.The amount ofSSP in samples

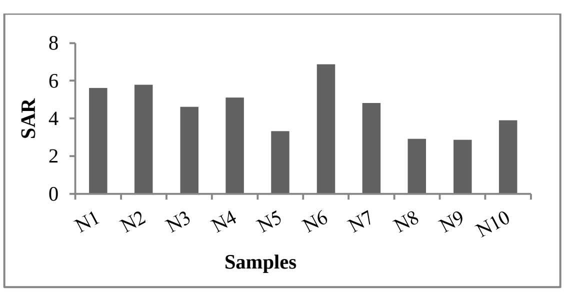

Figure 15.The amount of SAR insamples

The estimated amounts of RSC ranged from 0.4-2 and based on RSC criterion 20% of groundwater samples had slight to moderate problems for irrigation proposes (Figures 16 and 17). According to Clesceri findings, the differences between sum total of cations and anions were not exceeding 10% [6].

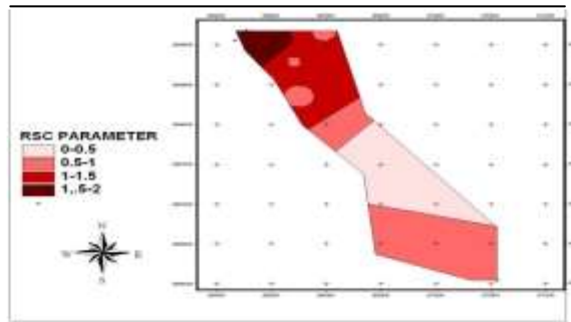

Figure 16.Spatial distribution of RSC_w

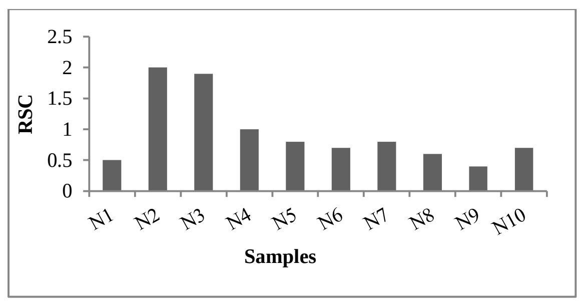

Figure 17.The amount of RSC in samples

CONCLUSION

In the present investigation, an attempt was made to evaluate and map the groundwater quality of Damghan plain aquifer. Spatial distributions of groundwater quality parameters were carried out through GIS. The analysis of the results drawn from the work revealed that GIS is an effective tool for the preparation of various digital thematic layers and maps showing the spatial distribution of various water quality parameters. Moreover, GIS makes the groundwater quality maps in an easily understood format. The interpreted water quality with respect to EC indicates that more than 60%

of the study area groundwater lies in bad range for irrigation purpose. The TDS value increased from the South to the North-east. The predominant cation trend in Damghan plain aquifer is Na^{+}> Ca^{2+}> Mg^{2+}> K^{+}. Almost all groundwater samples exceed the maximum permissible limit of sodium. Calcium ion distribution is within usual range in irrigation water. The spatial distribution maps of Mg and K concentrations illustrates that the majority of the samples were within the usual. The abundance of the major anions in Damghan plain aquifer was in the following order: Cl^{-} > HCO_3^{2-} . This study demonstrates that the use of GIS methods could provide useful information for water quality assessment.

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