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Evaluation of the Pollution Elements at Samara Water Table – Iraq

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Abstract

Underground water is extracted by wells that are connected through underground canals. Thus, the levels of pollutant elements in ground water could be evaluated directly from water samples collected from the wells. This study was conducted in the city of Samara / Salah-Aldeen province – Iraq. The samples were taken from 29 wells within the study area for the period 2012-2014 with a supervision from the General Authority for Groundwater / the Iraqi Ministry of Water Resources. GIS technology was adopted to calculate the pollution elements at Samara water table. The concentrations of chemical elements [K, Na, Mg, Cl, Ca] and compounds [SO_4, HCO_3] were manipulated and calculated for the entire area. The results of laboratory analyses showed that the groundwater in this area is not suitable for use as drinking water for humans, since the concentrations of the chemical elements and the compounds exceeded the permissible limits and are not in accordance with WHO standards. However, the results also indicated that the groundwater in the covered area is suitable for agriculture irrigation.

Keywords: pollution elements, groundwater, Samara city, GIS.

تقييم عناصر التلوث في المياه الجوفية لمنطقة سامراء – العراق

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الخلاصة

المياه الجوفية تستخرج من الابار وان هذه الابار تكون مترابطة بواسطة اقنية جوفية، لذلك يمكن تقييم عناصر التلوث مباشرة من عينات المياه من هذه الابار. تمت هذه الدراسة في منطقة سامراء / محافظة صلاح الدين – العراق. لقد تم جمع العينات من 29 بئر في منطقة الدراسة للفترة 2012–2014 باشراف دائرة المياه الجوفية / وزارة الموارد المائية. لقد تم استخدام تقنيات نظم المعلومات الجغرافية لحساب عناصر التلوث في المياه الجوفية لمنطقة سامراء. ان تراكيز العناصر الكيميائية [K, Na, Mg, Cl, Ca] وتراكيز المركبات [SO_4, HCO_3] تم حسابها لجميع المنطقة. لقد بينت النتائج، بعد التحليلات المختبرية، ان المياه الجوفية لهذه المنطقة غير صالحة للاستخدام البشري كمياه للشرب، لانها تتجاوز الحدود المسموحة استنادا الى معيار WHO ولكنها صالحة للزراعة.

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Introduction

Water is one of the most important means for sustaining life. It is used by all organisms to survive and is also used in agriculture, industry and other areas of life. Water is naturally found in several forms, such as rivers, seas or groundwater. Semi-arid and deserts areas have a specific lack of surface water, where groundwater plays a fundamental role in sustaining life. Groundwater reservoirs are composed of soil, rocks and rainwater that seep into the ground to form groundwater used for drinking, irrigation of crops, industry, poultry farms, etc…[1,2].

Groundwater is generally found in two types; first, natural renewable groundwater that is added to the water stock annually from rain water and, second, non-renewable groundwater which is collected in the ground and has been stored in a previous period of time. Recently, one of the problems that has been increasingly reflecting the quality of groundwater is the pollution with chemical pollutants in well water, in addition to other pollutants such as pesticides, fertilizers and industrial wastes. All these pollutants directly affect the quality of a groundwater, making it unsuitable for use and warranting the need for developing solutions [3-5]. Amomg these solutions is the idea of using the method of spatial interpolation, which involves the prediction of finding an unknown value from two known values. Interpolation includes several methods, which were evaluated to select the best method that matches the data of this study. The evaluation process concluded that the Inverse Distance Weighting (IDW) method is the most compatible with the available data. This method is used when there is an increase or decrease in the number of points, where the nearest points are more influential than distant ones. Using IDW, the interpolation is good when the points in a region are distributed evenly and systematically, which makes it possible to produce maps and prepare a database for that region. The method of IDW is expressed in the following relationship:

$$\lambda_i = \frac{1/d_i^p}{\sum_{i=1}^{n} 1/d_i^p}$$

where di is the distance between x_o and x_i), x_i is the power parameter, n is the number of sample points, p is a power value, and **λ**is the weight of the point.

The pollution problem has been continuously identified by researchers in several previous studies. Nagarajan (2012) investigated the indicators of pollution with Cu, Cr, Cd, Fe, Pb, and Zn in running and groundwater samples the landfill site in the Tamil Nadu region, India. The study reported a significant increase in the amounts of pollutants which highly affected the quality of the groundwater [6, 7]. Groundwater contamination was also identified in the plains area, north of Ibb city, Yemen, where five wells were sampled within the study area during the dry season. The results from that study showed that the ph value of the water was 8.46 and that levels of all chemical elements were unacceptable [8, 9]. Nour (2013) investigated the 26 wells located in Khan Younis governorate, Palestine, for the period of 2011-2012. The results showed that the percentage of nitrates in the wells was 84.6% and that of chloride was 76.9%. Therefore, water was considered unsuitable for use because it did not meet WHO standards [10, 11].

The Study Area and WHO standardization

The city of Samara is an ancient, cultural heritage Iraqi city located at the north of the province of Salah-Aldeen, Northern Iraq. It lies to the east of the Tigris River, 125 Km north of the capital Baghdad (Figure-1) UTM projection was used at zone 38 N. The surveyed region is located between 389123.3-420358.219 East and 377868.83-3799246.483 North with an overall area of 825731000 m^2.

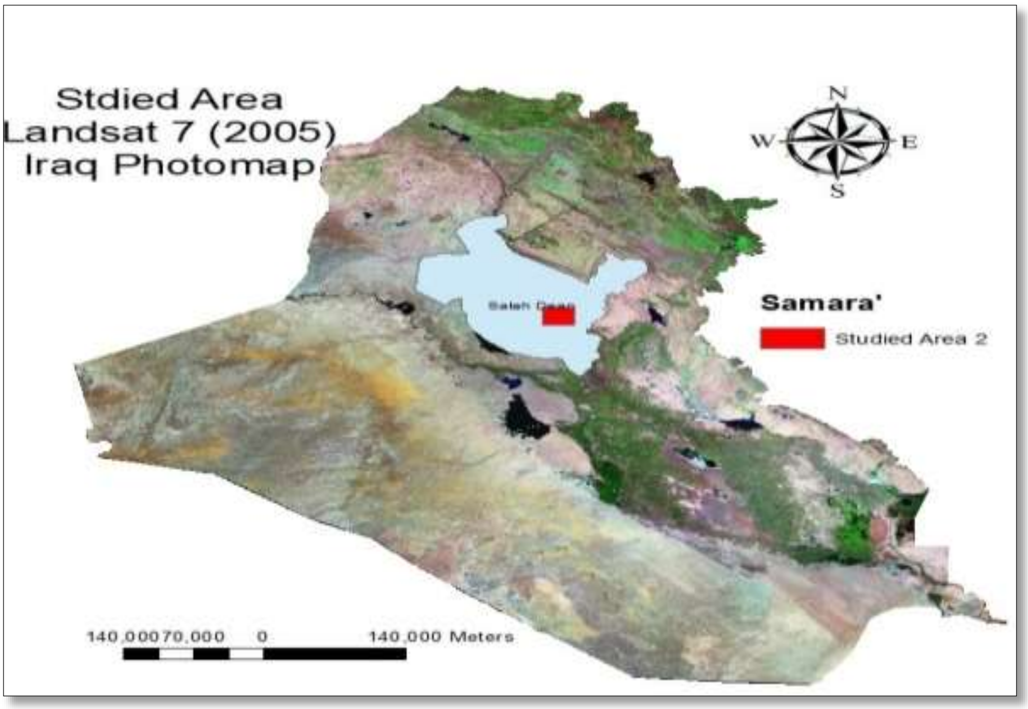

Figure 1-The studied Area at Salah-Aldeen Province – Iraq

The World Health Organization (WHO) is the guiding and coordinating authority within the United Nations System in the field of health. This organization identified 62 criteria, such as physical, chemical and microbiological, for the quality of water. Table-1 presents the standardized limits for human uses, which were adopted in this research.

Table 1-World Health Organization (WHO) standards of water for human use

Symbol	Material	Concentration (ppm)
SO_4	sulfate	400
Cl	Chlorides	250
Mg	Magnesium	150
Ca	Calcium	200
NO_3	Nitrates	45
TDS	Total dissolved solids	1000
Na	Sodium	200
K	Potassium	12
HCO3	Bicarbonate	500

Methodology

The period of data collection for this study was between 2012and 2014, where the necessary data were provided to enable the researchers to assess the current and predict the future situations. The mechanism of work included the aquisition of data obtained from the laboratory analysis by the Iraqi Ministry of Water Resources to prepare a database. The satellite image Landsat 2005 was used as a base map for the Republic of Iraq. A shapefile for the administrative borders was created by using (ArcGIS 10.4) software.

The practical part included several stages. The first stage started by collecting data and relevant information. The second part was the field work phase; Samples were collected from 29 GPS-located wells within the study area. The third stage was the laboratory analysis, at which measurements of concentrations of elements and compounds (K, Na, Mg, Cl, Ca, CO_3, SO4, HCO3, NO3) were performed for each sample. Stage four involved the mapping of the contaminated groundwater sites via the implementation of the Arc GIS 10.4 program and the inclusion of a satellite image of the Republic of Iraq. The study area of Samara- Salah-Aldeen \ was deducted and the results of the samples taken from well water were embedded in the maps.

Results

After the analysis of data, we obtained the results to assess the problem of pollution in the city of Samara. The comparison was made according to the standards of the World Health Organization for water and the use of the tools of the ERP program (GAS) to predict the size of the problem. The results are presented with a table showing the space of each class, as follows below.

Figure-2 shows the height of the wells and the morphology of the area in Samara according to sea level. Well sites are located within the height range of 51-80 m and they were classified as shown in Table-2 to show the morphology roughness.

Figure-3 shows the depth of wells within the studied area. The wells depth was calculated with respect to the ground, and showed a range of 8- 75 m. Table- 3 shows the values of each class of well's depth.

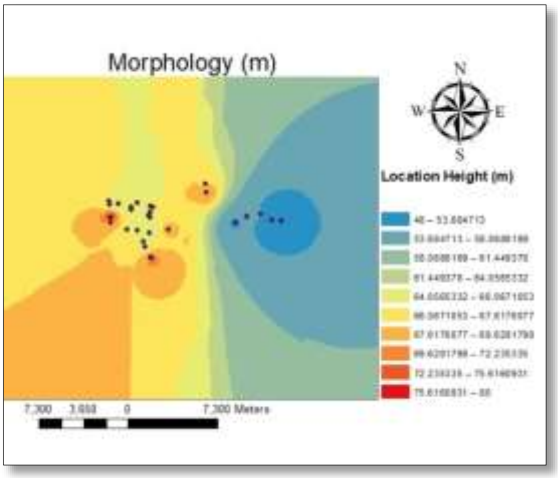

Figure 2-Site Elevations and Morphology

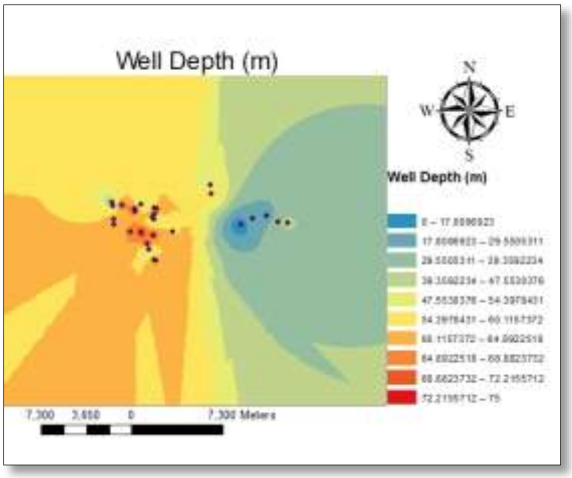

Figure 3-Well Depth

Table 2-The value of morphological height areas

classes	Min_Value of height (m)	Max _Value	Area m^2
1	48.00	53.68	23278000
2	53.68	58.07	184638000
3	58.07	61.45	126814000
4	61.45	64.06	27804600
5	64.06	66.07	69251600
6	66.07	67.62	255423000
7	67.62	69.63	136736000
8	69.63	72.24	1377670
9	72.24	75.62	286818
10	75.62	80.00	121440

Table 3-The value of each well's depth class

Classes	Min_Value of depth(m)	Max _Value	Area(m^2)
1	8	17.80	1366300
2	17.8	29.55	10753100
3	29.55	39.35	206688000
4	39.35	47.55	134280000
5	47.55	54.39	40232700
6	54.39	60.11	233418000
7	60.11	64.89	194254000
8	64.89	68.88	3621630
9	68.88	72.21	961169
10	72.21	75	157038

Figures-(2, 3) demonstrate the results of water table level as calculated with respect to sea level. Figure-4 shows the static water level for the studied wells, which had a range of 3 - 20 m. Table-4 shows the value of each class of static water level. Figure-5 represents the dynamic water level which ranged 6 - 57 m. Table- 5 shows the value of each class of dynamic water level.

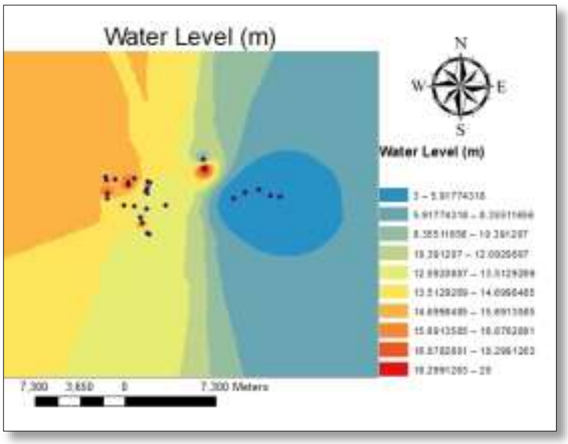

Figure 4-Static water level

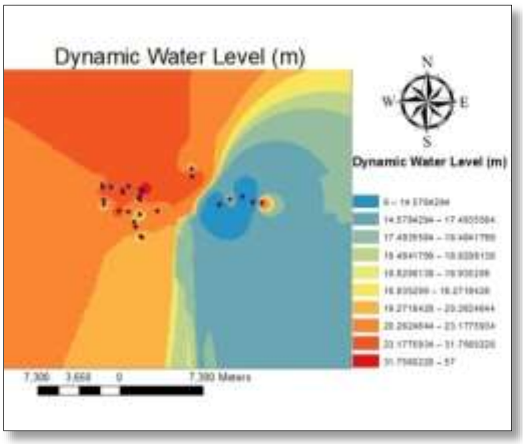

Figure 5-Dynamic water level

Table 4-The value of each water level class

Classes	Value_Min of Water level(m)	Value_Max	Area(m2)
1	3	5.91	66243600
2	5.91	8.35	243841000
3	8.35	10.39	49669700
4	10.39	12.09	39028000
5	12.09	13.51	118475000
6	13.51	14.69	139952000
7	14.69	15.69	165250000
8	15.69	16.87	2424290
9	16.87	18.29	620136
10	18.29	20	227467

Table 5-The value of each dynamic water level class

Classes	Value_Min of dynamic Water level(m)	Value_Max	Area (m2)
1	6	14.57	18018500
2	14.57	17.49	220175000
3	17.49	18.48	61778200
4	18.48	18.82	25572800
5	18.82	18.93	9617330
6	18.93	19.27	15982600
7	19.27	20.26	102559000
8	20.26	23.17	220164000
9	23.177	31.75	151088000
10	31.75	57	775489

TDS is a measure of a group of soluble salts that is used to describe inorganic salts and low amounts of organic matter in water. Figure-6 illustrate TDS concentration ratios for selected wells within the study area, which can reflect such as water interaction with rocks. It is found that the water of most wells has exceeded the TDS limits (550-4250). Table- 6 shows the surface values of each class for TDS.

Figure-7 shows chloride concentrations, where chloride is formed by water due to industrial materials and human waste, WHO has determined that the chloride ratio should not exceed 250 ppm, but our results showed that the range of chloride in the wells was 190 - 715 Permissible Limits. Table-7 shows the values of each class for chloride.

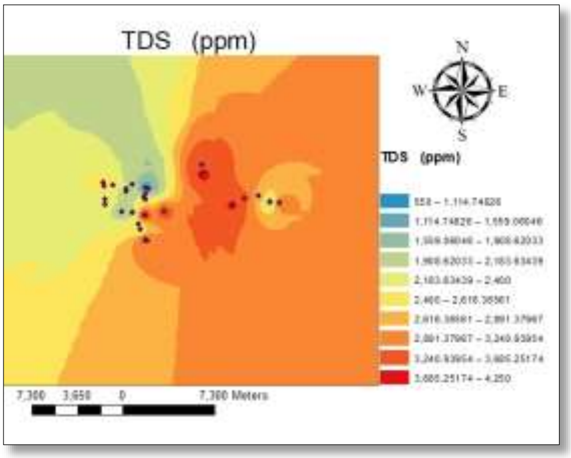

Figure 6-TDS concentrations

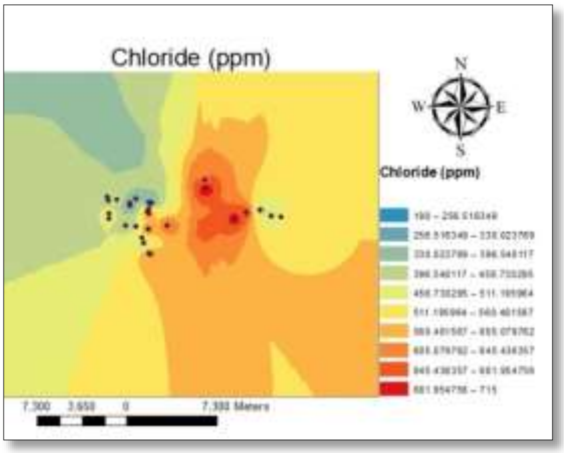

Figure 7-Chloride concentrations

Table 6-The value of each TDS class

Classes	Value_Min of TDS	Value_Max	Area (m2)
1	550	1500	507418
2	1500	1700	626961
3	1700	1908.62	1823870
4	1908	2183.63	87133400
5	2183.63	2400	129470000
6	2400	2616.36	93918900
7	2616.36	2891.37	119393000
8	2891.37	3240.93	357119000
9	3240.93	3685.25	34467000
10	3685.25	4250	1272110

Table 7-The value of each Chloride class

Classes	Value_Min of Cl (ppm)	Value_Max	Area (m2)
1	190	340	363918
2	340	370	1167300
3	370	420	124827000
4	420	456.73	71586700
5	456.73	511.19	114950000
6	511.19	560.48	244188000
7	560.48	605.07	227842000
8	605.07	645.43	26687300
9	645.43	681.95	12575100
10	681.95	715	1544820

Sodium is one of the most abundant chemical elements in nature. It is present in underground water due to the presence of the particles Feldspar minerals. Figure-8 represents the sodium concentrations in the studies area. The World Health Organization (WHO) has set a limit of 200 (ppm) for this element in water. The results demonstrated that sodium levels in the area exceeded the limits, as represented in Table-8 which shows the classes of sodium concentrations. Potassium in groundwater is usually found due to the presence of Feldspar minerals. The limit allowed by the World Health Organization for this element is 12 ppm and our results found that most of the wells of the region were within this limit. Table-9 shows the classes of potassium in the wells of the studied area.

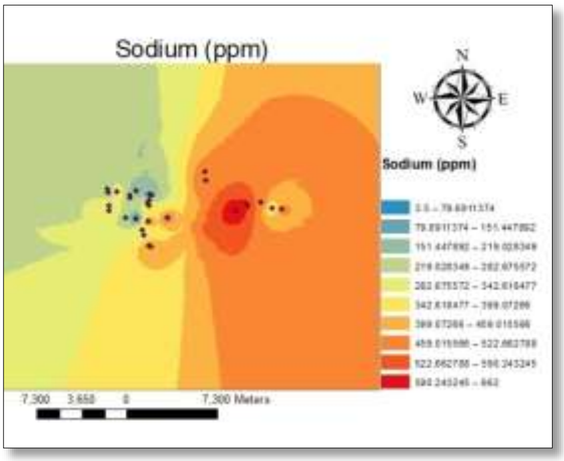

Figure 8-Sodium concentrations

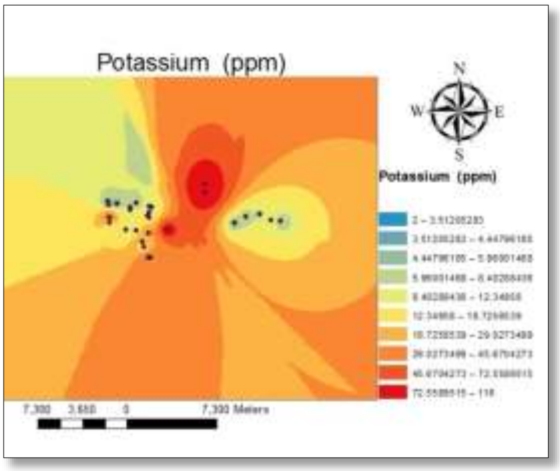

Figure 9-Potassium concentrations

Table 8-The value of each Sodium class

Classes	Value_Min of Na (ppm)	Value_Max	Area (m2)
1	3.5	79.69	118666
2	79.69	151.44	244837
3	151.44	219.02	4469880
4	219.02	282.67	179104000
5	282.67	342.61	124841000
6	342.61	399.07	102069000
7	399.07	459.01	110981000
8	459.01	522.66	285438000
9	522.66	590.24	14901200
10	590.24	662	3563940

Table 9-The value of each Potassium class

Classes	Value_Min of K (ppm)	Value_Max	Area (m2)
1	2	3.51	69788
2	3.51	4.44	94589
3	4.44	5.96	1087160
4	5.96	8.40	15939700
5	8.40	12.34	112097000
6	12.34	18.72	101080000
7	18.72	29.02	267318000
8	29.02	45.67	285315000
9	45.67	72.55	31818300
10	72.55	116	10911500

Magnesium is usually present in the groundwater in few cases, arising from the presence of dolomite rocks surrounding the water. Figure-10 demonstrates the concentration of magnesium according to different classes in the wells. Our results revealed that the well's water within the studied area exceeds the permissible limits. Table-10 shows the classes of magnesium in the studied area.

Calcium is a chemical element that is formed in the groundwater when it is in contact to limestone or dolomite rocks. The results in Figure-11 reveal that the concentrations of calcium in most of the wells exceed the permissible limit. Table-11 presents the areas of each class of calcium.

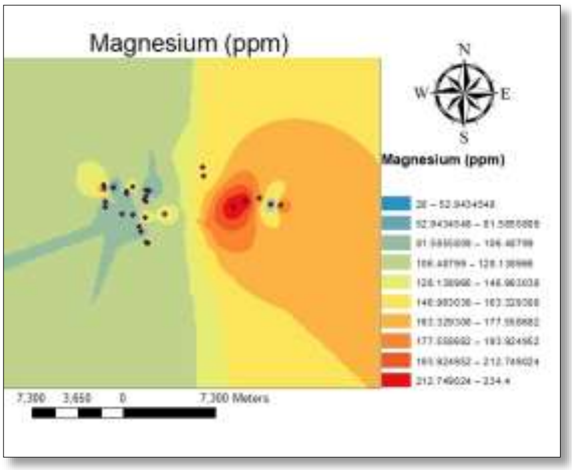

Figure 10-Magnesium concentrations

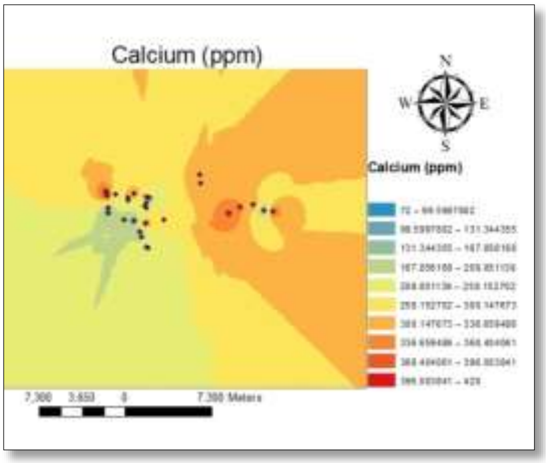

Figure 11-Calcium concentrations

Table 10-The value of each Magnesium class

Classes	Value_Min of Mg (ppm)	Value_Max	Area (m2)
1	20	52.94	125398
2	52.94	81.58	684023
3	81.58	106.48	28992600
4	106.48	128.13	380516000
5	128.13	146.96	48515400
6	146.96	163.32	164524000
7	163.32	177.55	180468000
8	177.55	193.92	13162100
9	193.92	212.74	5508880
10	212.74	234.4	3234700

Table 11-The value of each Calcium class

Classes	Value_Min of Ca (ppm)	Value_Max	Area (m2)
1	72	150	179835
2	150	170	1276140
3	170	190	2654290
4	190	209.851	15511500
5	209.85	258.15	232906000
6	258.15	300.14	324409000
7	300.14	336.65	240957000
8	336.65	368.40	7041090
9	368.40	396.003	660450
10	396.003	420	136683

Sulfates are found in many minerals. Figure-12 presents the concentrations of sulphates in the water of the studied wells. After analyzing the samples, it was found that all the wells in the area exceeded the permissible limit. Table-12 presents the values of each class of Sulfates.

Figure-13 demonstrates the concentration of bicarbonates in the groundwater of the study area, where it was found that all the wells in the region were within the permissible limit. Table-13 presents the areas of each class of bicarbonate.

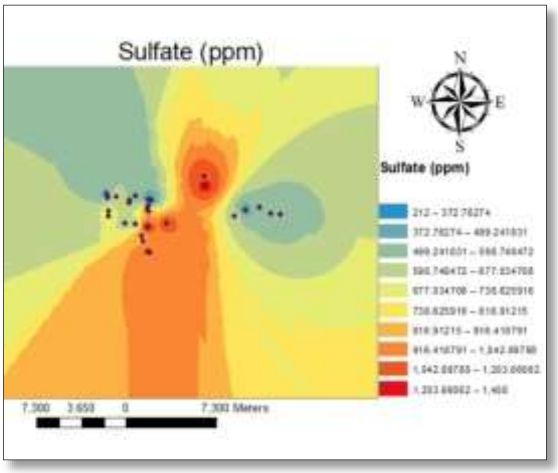

Figure 12-Sulfates concentrations

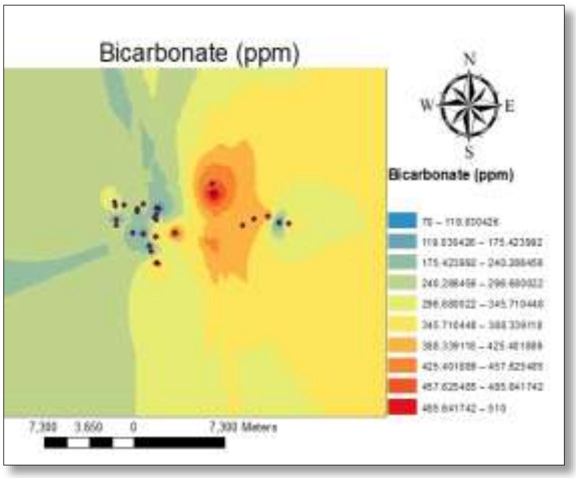

Figure 13-Bicarbonate concentrations

Table 12-The value of each Sulfates class

Classes	Value_Min of SO4 (ppm)	Value_Max	Area (m2)
1	212	372.76	186715
2	372.76	499.24	2003730
3	499.24	598.74	135636000
4	598.74	677.03	177386000
5	677.03	738.62	163181000
6	738.62	816.91	123739000
7	816.91	916.41	116952000
8	916.41	1042.89	97549900
9	1042.89	1203.66	8169950
10	1203.66	1408	926570

Table 13-The value of each bicarbonates class

Classes	Value_Min of HCO3 (ppm)	Value_Max	Area (m2)
1	70	119.03	122385
2	119.03	175.42	1469310
3	175.42	240.28	33553600
4	240.28	296.68	295535000
5	296.68	345.71	167315000
6	345.710	388.33	280814000
7	388.33	425.40	35816600
8	425.40	457.62	8198200
9	457.62	485.64	2263660
10	485.64	510	643103

Conclusions

The results showed that there were many chemical pollutants that affected the quality of water, some of which had concentrations that exceed the permissible limits. The increase of TDS in water affects water taste as well. The results showed that chloride concentration was not in compliance with an international health standard, Chloride in water makes the taste of water salty. Sodium also exceeded the permissible limit, which might raise blood pressure in humans. Therefore, people with blood pressure are advised not to drink water containing large sodium content. Magnesium also shows that the concentration exceeds the permissible limits. The results showed that calcium concentration exceeded the permissible of World Health Standards. The increase in calcium in water causes water hardness. The results also showed that the concentration of sulphates in the groundwater of the studied area had exceeded the permissible limit. The study showed that all wells in the region exceeded the specified values of WHO standards. The increase of sulfates in water makes water bitter. The levels of potassium and bicarbonates were within the permissible limits. The existence of potassium in water is useful for plants.

One possible contamination source in the area is the presence of a pharmaceutical factory in Samara. All of these pollutants directly affected the quality and characteristics of the water, making it unsuitable for human use and causing danger to health> However, the groundwater in the area can be used for irrigating crops and other purposes.

Acknowledgments

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