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Spatial Distribution of Groundwater Quality Parameters in Al-Najaf City Using GIS and Geostatistics Techniques

Hadeel A Al Saleh [1, 2], Samir Saify [1] and Nariman Y Othman [1]

1 Civil Eng. Dept. / College of Engineering / University of Babylon / Iraq
E-mail: eng.hadeel.ali@uobabylon.edu.iq

Abstract. The scarcity of water resources in arid areas, as well as the impact of agricultural and human activities on groundwater quantity and quality, need a greater emphasis on these resource quality evaluations. In this study, the groundwater quality in the governorate of Al-Najaf was investigated using geostatistical methods based on the kriging interpolation approach to interpolate values in regions where real data was not available, also groundwater samples were evaluated based on a variety of qualitative parameters. Linear Gaussian, exponential, stable, and quadratic were the semivariogram models the study examined, and archGIS software was extensively utilized to map the investigated data. The study concluded that the groundwater in this area is unsuitable neither for drinking purposes nor in most of the industries according to the Iraqi specifications. Wilcox and United States Salinity Laboratory (USSL) diagrams were used to analyse the accessible water wells in the area. The diagrams depicted that 95.8 percent of the available well water in the research region is unsuitable for irrigation due to the extremely high salinity and continued application of such water may result in the development of salt soils. Spatial examination of groundwater revealed serious problems with almost all groundwater parameters in terms of water appropriateness for drinking, irrigation, and other purposes.

1. Introduction
Groundwater quality is an important environmental issue that must be assessed and maintained based on its spatial distribution. Inadequate management of groundwater resources results in a decline in both quantity and quality of groundwater [1].
In Iraq, river water is the main source for drinking, agriculture or any other purpose, but in recent times, river water faces a lot of problems, particularly the lack of rainfall, industrial and runoff pollution which affect the quality of waters. Hence, there is a need to look for other sources of water or emphasize water assessment of the existing wells. Iraq is confronted with both water quality and quantity challenges, as a significant portion of its water demand is met by surface water.
Groundwater resources have become increasingly significant as the world's population has grown and surface water resources have depleted for a variety of causes. Groundwater resources are extremely important in semi-arid areas of Iraq [2]. The geology of a certain place, seasonal fluctuations, and the composition of dissolved salts may all influence the quality of ground water. Ground water quality is mostly affected by severe pollution activities occurring on surface waterways [3].
Appropriate groundwater quality management measures necessitate the availability of trustworthy quantitative data on groundwater quality behaviour. The spatial behaviour of groundwater quality is urgently needed to be investigated. It is necessary to understand the spatial variation of groundwater quality to establish credible interpretations of groundwater quality and creating accurate estimations of quality at any given position in the aquifer. There are several ways for interpolating data. The samples are studied independently of their geographic position in traditional procedures; however, the samples

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spatial location is also taken into account in geostatistics approaches. In another meaning, we have to be capable of creating a relationship between the distance and direction from one sample to another and the different quantities in samples [4].

Geostatistical analysis offers a collection of statistical models and methods for exploring data spatially and generating groundwater quality surface maps [5, 6]. The Kriging interpolation approach, which is a geostatistical phrase referring to the optimum linear prediction of spatial processes, was used to interpolate values in regions where real data was not available. It is commonly used to interpolate geographical data in geology, hydrology, environmental monitoring, and other fields. ArcGIS assists in the creation of maps that provide the most accurate depiction of the data collection. It allows selecting the semivariogram type, interpolation technique, and mapping type; it makes use of the mathematical as well as statistical characteristics of the observed points [6, 7]. The ArcGIS geostatistical analyst tool is useful for producing a continuous surface map based on sample point measurements saved in a point layer. The data contained in the point layer might represent water quality information, water table elevation, or depth to the water table. Geostatistical Analyst includes a number of tools for creating surfaces. These tools are useful for visualizing, analysing, and understanding spatial phenomena.

Geostatistical approaches were used by many researchers to determine the spatial distribution of groundwater properties. Omran (2012) presented a simple approach for assessing the quality of groundwater and mapping its geographic Variation in irrigation appropriateness in Egypt's South-western Desert's Darb El-Arbaein region. The study reveals GIS's great efficiency in analysing complicated spatial data and mapping groundwater quality [8]. Eslami et al. (2013) employed interpolation techniques (IDW, Kriging, and Co-Kriging approaches) to assess spatial variations and interpolate ground water quality observed in a section of the Mianab plain. The results indicated that the kriging and Co-Kriging approaches outperformed the IDW approach [4]. Narany et al. (2014) create a new method for identifying locations with a high risk of nitrate contamination in Iran's Amol-Babol Plain. Using data from 147 monitoring wells, the indicator kriging approach was used to identify places with a high chance of nitrate contamination [9]. Sharma et al. (2015) applied ArcGIS to create water quality spatial distribution maps in Rajasthan, Tonk district. This appliance was used to analyse exploratory data. selecting the optimum semivariogram model, and cross-validation. The standard kriging interpolation methodology is used to create spatial distribution maps for all of the specified parameters [2].

The objectives of the study were to: (1) offer an overview of current groundwater quality; and (2) establish the spatial distribution of groundwater quality measures such as electrical conductivity EC, Calcium Ca^{+2}, Potassium K^{+}, Magnesium Mg^{+2}, Sulphate SO_4^{-}, Total Dissolved Solids TDS, Chloride Cl^{-}, pH, Sodium Na^{+}, Bicarbonates HCO_3^{-} and (3) to map irrigation water quality in the study area in order to identify places with the best quality for irrigation within the study area by using Geographical Information System GIS and Geostatistics techniques. This study will help engineers, decision-makers, and managers manage groundwater quality control operations.

2. Study area

The governorate of Najaf is located in southern Iraq (The Mid- Euphrates Region), It occupies 6.6 percent of Iraq, with total area of 28824 km2 and is located between latitudes 32°21 N and 29°50 N, longitudes 44°44 E and 42°50 E. Al-Najaf Governorate is divided into three qadhaas for administrative purposes (Al-Najaf, Al-Kufa and Al-Manatheria Qadhaas). Fig. 1 depicts these qadhaas [10]. The research region has a dry continental climate with a long hot dry summer with a substantial change in temperature between day and night and cold winter with little rain; this sort of environment leads to rising salt concentrations in water [11]. To make an evaluation of groundwater, twenty-four groundwater well were tested for chemical and physical parameters.

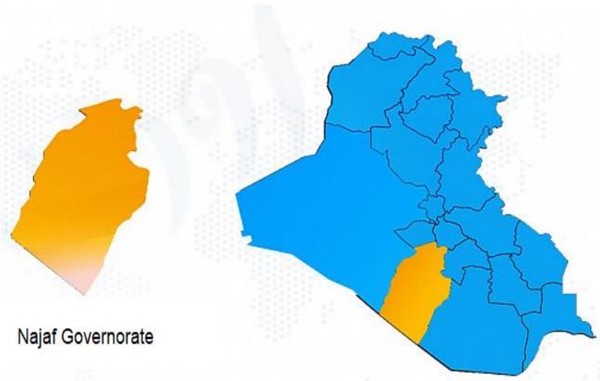

Figure 1. Al-Najaf governorate (study area).

3. Data collection
During the years studied (2016, 2017), samples were gathered from (24) wells in the research region. The samples were analysed for chemical and physical parameters (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, TDS, CL^{-}, pH and the Electrical Conductivity (EC). The gathered samples were analysed by the General Authority for Groundwater using standard Methods procedures. The sampling containers had been washed at least three times with distilled water then sampling water before being used to collect samples. Pumping was performed in the wells until the temperature, conductivity, and pH levels stabilized and to avoid contaminated and stagnant water. For the collection of water samples, clean polyethylene bottles containers were used. Only the average of the measured values for the two years is taken due to lack of significant. A summary of water quality characteristics is presented in Table 1.

4. Methodology

4.1 Phesio-chemechal analysis and water quality indices:
For the purpose of this analysis, a total of 24 groundwater sample were collected from different sites of AL-Najaf governorate. Water samples were analyzed for physical and chemical parameters to evaluate the groundwater quality for drinking, industrial, agricultural and irrigational purposes.

4.2 Geostatistical analysis:
The primary instrument employed to assess groundwater quality was the geostatistical method of analysis. To assess groundwater geographically across the state, the Kriging interpolation technique and the semivariogram modelling methodology were utilized. Initially, a test for the data normality has been done. The GIS program tools as histogram is indicted for this purpose.
The data normality can be checked through the next measurement; if the mean and median are almost equal, skewness coefficient is near to zero and kurtosis is near to three then the distribution become normal distribution. Based on the previous measures none of the parameters showed normal distribution, as a result, the data has undergone a log transformation, as seen in Table 2.
For the selected groundwater quality parameters, exponential, stable, linear Gaussian and quadratic semivariogram models were considered. Each parameter was investigated using all of the four semivariogram models. Following that, the most fitting semivariogram model was chosen by considering the spatial distribution of the data set as well as geostatistical properties as shown in Table 3. The Table shows some of parameters as examples for the work which has been done. The most appropriate model for all parameters was stable model. The Kriging interpolation technique was used to interpolate measurements in regions where real data was not available. In this investigation, the surfaces were interpolated using the software tool Geostatistical Analyst in ArcGIS 10.2. Interpolation techniques are classified into two types by Geostatistical Analyst: deterministic and geostatistical (stochastic). Deterministic approaches do not evaluate errors with predicted values, but stochastic approaches evaluate prediction errors.

IOP Conf. Series: Earth and Environmental Science **952** (2022) 012003 doi:10.1088/1755-1315/952/1/012003

To forecast values at unknown places, both interpolation approaches employ the weights of neighbouring known values. Because stochastic approaches are statistical models, they are more flexible and allow for the investigation of data spatial autocorrelation. If the data is regularly distributed, kriging produces the most efficient results.

There are two stages in kriging process: first, the data spatial structure it computed and then it generates a predicted surface. The Kriging approach uses the fitted model of a semivariogram, the spatial data relationship, and the values of known points surrounding the forecasted point to estimate an unknown value at a specific place [2].

Table 1. Groundwater Parameters Properties

Well no.	**pH**	**EC [µmoh/cm]**	**TDS [mg/l]**	**Ca^{+} [mg/l]**	**Mg^{+} [mg/l]**	**Na^{+} [mg/l]**	**K^{+} [mg/l]**	**Cl^{-} [mg/l]**	**HCO_3^{-} [mg/l]**	**SO_4^{-} [mg/l]**	**NO_3^{-} [mg/l]**	**CO_3^{-} [mg/l]**
S1	7.14	4500	1850	70	34	420	13	337	267	505	1.12	0
S2	7.14	3750	3670	240	103	370	12	484	243	926	2.8	0
S3	7.12	4900	2200	209	106	339	2.5	520	449	572	0.12	0
S4	7.2	4170	2121	170	53	245	4	313	210	530	1.1	0
S5	7.8	3800	1690	160	91	236	7	389	210	572	3	0
S6	7.5	10800	5720	460	250	806	20	1062	549	1754	502	0
S7	7.25	4900	2623	240	130	390	17	550	241	990	-	0
S8	7.4	6760	3510	312	146	572	11	677	482	1204	-	0
S9	7.18	4800	1990	133	91	135	13.5	256	67	565	-	0
S10	7.18	5770	3030	185	80	330	4	310	448	675	-	0
S11	7.12	4560	2316	210	109	322	3	533	448	575	-	0
S12	7.15	4875	1950	129	90	130	13	250	65	558	-	0
S13	7.25	4625	1932	150	88	260	3	319	387	528	-	0
S14	7.14	4575	2350	214	110	325	4	537	448	580	-	0
S15	7	5178	3360	590	145	202	5	550	520	1200	60	0
S16	6.9	4440	2855	521	133	280	4	305	400	850	43	0
S17	7	7400	4810	865	181	845	11	1550	240	1533	20	0
S18	6.9	4000	2780	500	130	150	12	233	260	1700	9	0
S19	7.3	11800	7110	755	200	580	5	1580	380	2350	75	0
S20	6.7	3590	2320	375	150	255	6	650	250	980	4.1	0
S21	7.3	7400	4590	400	215	350	5	1135	230	1300	7.5	0
S22	7.3	5030	3270	645	212	247	4	530	440	1518	61.2	0
S23	7.3	5658	3441	550	81	243	4	387	442	1954	57.9	0
S24	7.16	4047	1680	127	89	136	10	246	62	561	0.1	0

Table 2. Statistical Analysis of the Data

Parameter	**Min**	**Max**	**Mean**	**median**	**Stand. Devi.**	**skewness**	**kurtosis**
pH	6.7	7.8	7.1846	7.17	0.2155	0.4788	4.7754
pH log	1.9021	2.0541	1.9715	1.9699	0.0298	0.3247	3.6078
EC	740	11800	5194.5	4712.5	2243.6	1.4750	5.9718
EC log	6.6067	9.3759	8.4597	8.4578	0.4947	-1.8079	9.8749
TDS	1680	7110	3048.7	2701.5	1354	1.4722	4.7764
TDS log	7.4265	8.8693	7.9445	7.9011	0.3878	0.6876	2.7463
Ca	70	865	342.08	240	220.94	0.8114	2.5970
Ca log	4.2485	6.7627	5.6297	5.4806	0.6682	-0.339	2.0578
Mg	34	250	125.71	109.5	53.802	0.6152	2.7836
Mg log	3.5264	5.5215	4.7414	4.6959	0.4560	-0.5302	3.5724
Na	130	845	340.33	301	190.21	1.3889	4.358
Na log	4.8675	6.7393	5.7006	5.7047	0.5115	0.2428	2.6831
K	2.5	20	8.0417	5.50	4.9671	0.7618	2.516
K log	0.9163	2.9957	1.9011	1.7006	0.6219	0.1618	1.6427
Cl	233	1580	570.96	502	383.42	1.6013	4.5824
Cl log	5.451	7.365	6.1806	6.218	0.5596	0.7048	2.6666
HCO_3	62	549	322.42	323.5	145.35	-0.3148	2.0425
HCO_3 log	4.1271	6.3081	5.6248	5.737	0.6425	-1.3119	2.0332
SO_4	505	2350	2350	1020	536	0.8918	2.7443
SO_4 log	6.2246	7.7622	6.8046	6.7881	0.4981	0.3831	1.7234
CO_3	0	0	0	0	0	0	0
CO_3 log	0	0	0	0	0	0	0

Table 3. Semivariogram Models Type's Characteristics

		Method			
		Exponential	Gaussian	Stable	Quadratic
PH	Mean	-0.0011	-0.0019	-0.0019	-0.0013
	Root Mean Square	0.2381	0.2429	0.243	0.238
	Average Standard Error	0.0013	0.0005	0.0005	0.0009
	Mean standardized	0.9684	0.9904	0.9903	0.9689
	Root Mean Square Standardized	0.2476	0.2457	0.2457	0.2471
EC	Mean	-65.6138	18.5167	18.5167	-65.405
	Root Mean Square	2423.86	2358.44	2358.44	2423.75
	Average Standard Error	-0.0244	0.0102	0.0102	-0.0259
	Mean standardized	1.0833	1.0629	1.0629	1.0841
	Root Mean Square Standardized	2214.93	2192.82	2192.87	2224.47
TDS	Mean	-38.8342	-39.1939	-116.55	-119.65
	Root Mean Square	1506.75	1500.37	1436.77	1425.7
	Average Standard Error	-0.0269	-0.0269	-0.0773	-0.0805
	Mean standardized	1.0412	1.0376	0.9764	0.9654
	Root Mean Square Standardized	1442.749	1441.521	1459.34	1471.42

Water quality maps for various water parameters were created, and the Kriging interpolation technique was used to interpolate surfaces. As a result, the final irrigation groundwater quality maps were created by superimposing the previously indicated grid data. The quality information of water was connected to the sample site (spatial) in ArcGIS, and maps depicting the spatial distribution were created to highlight variations in groundwater parameter concentrations at various places throughout the research region. Various water quality maps were created utilizing point data such as pH, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, TDS, CL^{-}, HCO_3^{-}, SO_4^{-}, by using ArcMap GIS software as shown in the figs. (2 to 11) respectively.

5. Results and discussion

5.1 Groundwater suitability for drinking purposes

Understanding groundwater quality is just as essential as understanding its quantity since it is the primary determinant of its usefulness for drinking, household, agricultural, and industrial applications. The extent of suitability of groundwater for drinking purposes is achieved by comparing the specifications developed by regional and international organizations and agencies. It may be unsafe to consume if it surpasses the allowed limits. The findings of the chemical properties of groundwater samples taken from the research region are shown in Table 1. Chemically, drinking water should be soft, low in dissolved salts, and devoid of harmful components. A comparison of the chemical analysis values of groundwater with the standard guidelines values recommended by (Iraqi specifications IQS 217/ 2009 and World Health Organization, 1996) was made. The pH values of groundwater range from 6.7 to 7.8; this indicates that the research area's groundwater is almost neutral in nature and within both IQS and WHO specifications. In the other hand 100% of the samples were out of specifications due to increasing concentrations of TDS, SO_4^{-} and 95.8%, 83.3% due to total hardness (TH) and Na^{+} respectively. The classification the groundwater quality for drinking is shown in Table 4.

Table 4. Groundwater Quality For Drinking Purposes [12, 13]

Parameter	**Desirable limit**		**Within limits**		**Exceed limits**	
	IQS	**WHO**	**IQS**	**WHO**	**IQS**	**WHO**
pH	6.5-8.5	6.5-8.5	100%		-	
K^{+} (ppm)	10	-	62.5%	-	37.5%	-
TDS (ppm)	1000	1000	-		100%	
TH (ppm)	500	-	4.2%	-	95.8%	-
SO_4^{-} (ppm)	400	250	-	-	100%	
CL^{-} (ppm)	350	250	37.5%	12.5%	62.5%	87.5%
Ca^{+2} (ppm)	150	200	20.8%	33.3%	79.2%	66.7%
Mg^{+2} (ppm)	100	150	37.5%	79.2%	62.5%	20.8%
Na^{+} (ppm)	200	200	16.7%		83.3%	
NO_3^{-} (ppm)	50	50	68.75%		31.25%	

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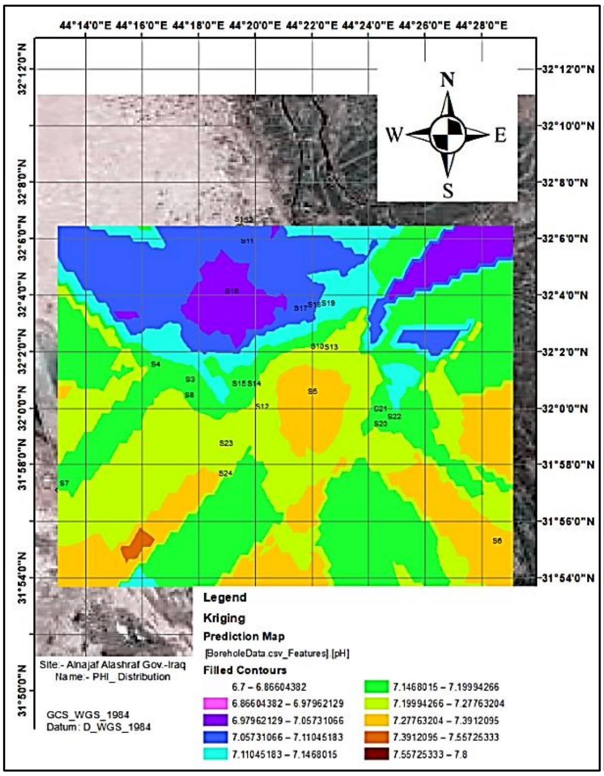


Figure 2. Spatial Distribution of Ph.

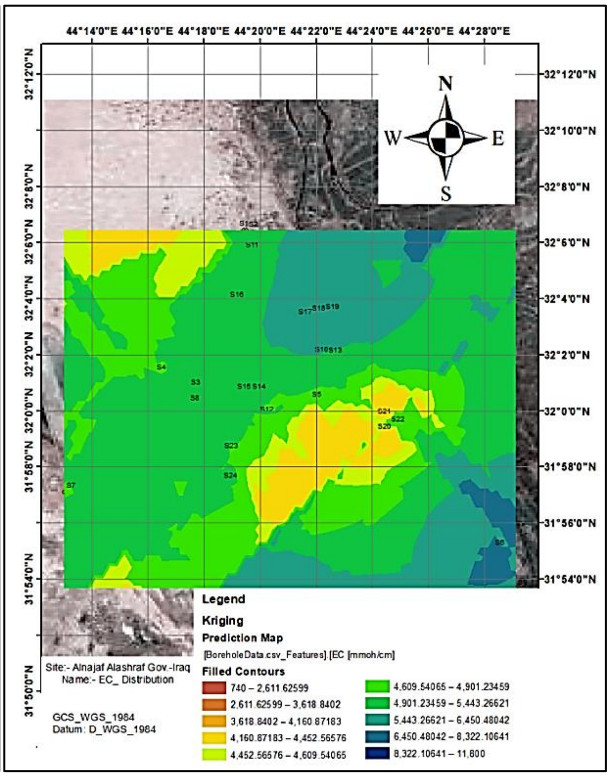


Figure 3. Spatial Distribution of EC.

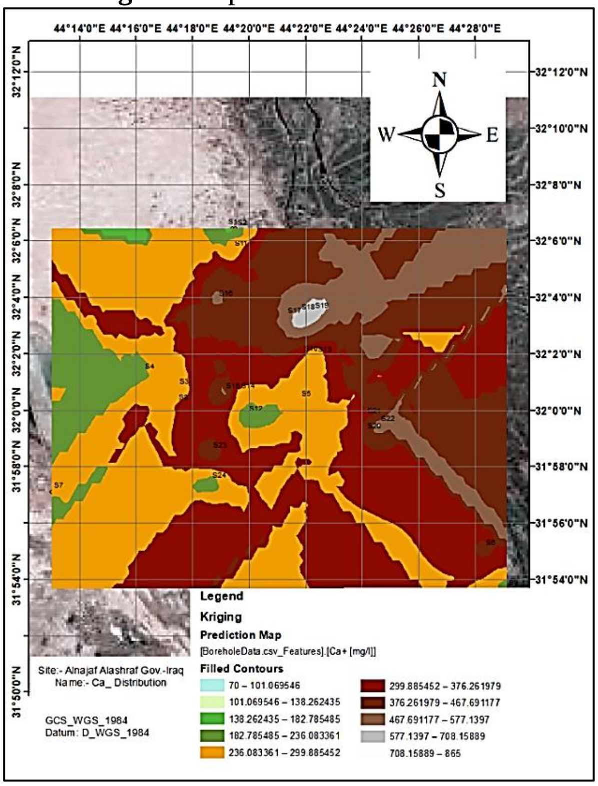


Figure 4. Spatial Distribution of Ca.

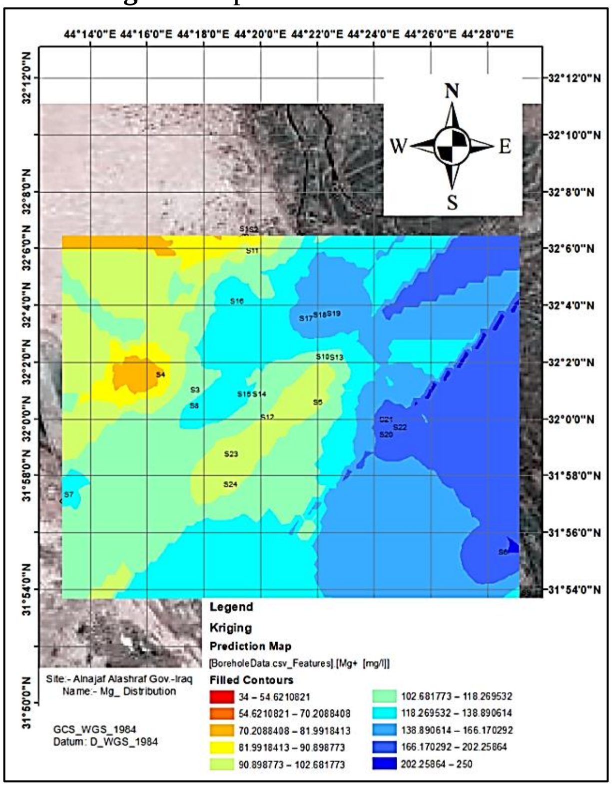


Figure 5. Spatial Distribution of Mg.

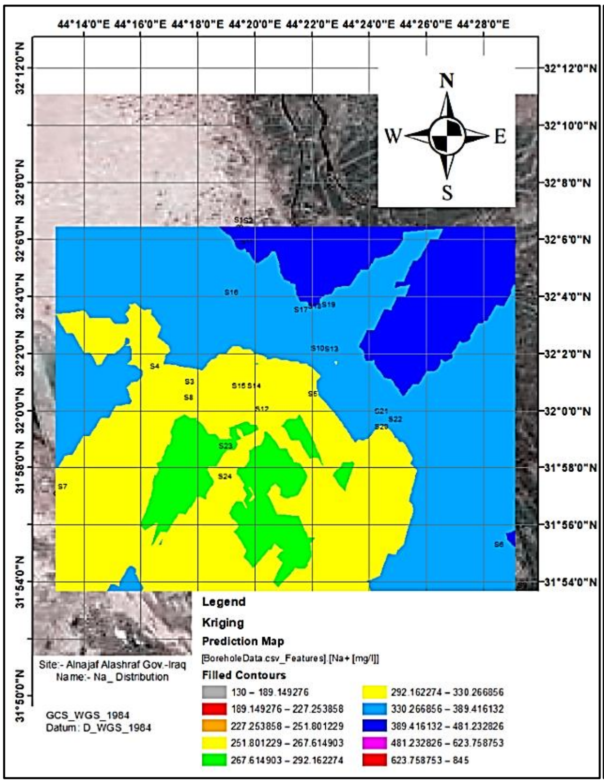


Figure 6. Spatial Distribution of Na.

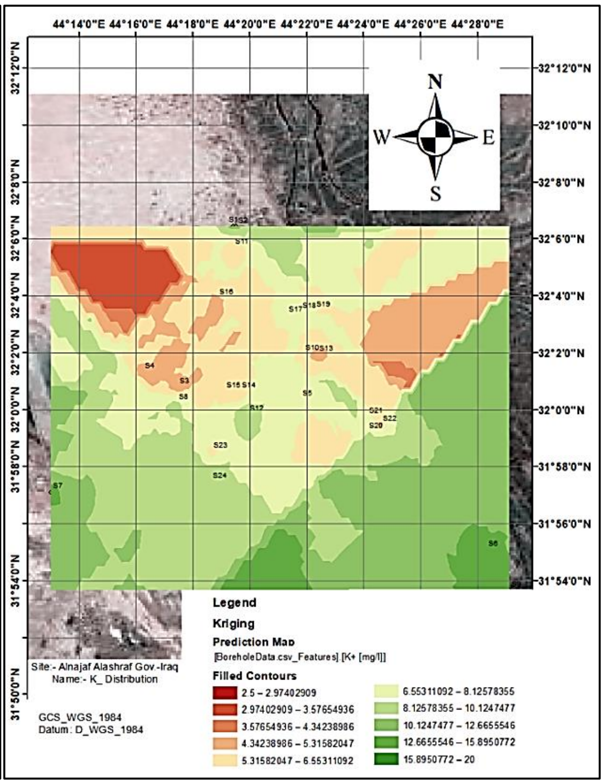


Figure 7. Spatial Distribution of K.

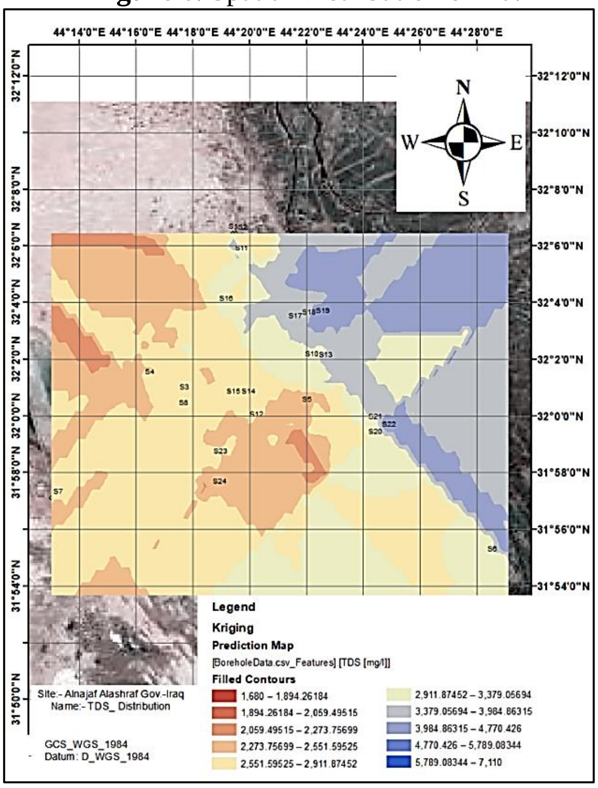


Figure 8. Spatial Distribution of TDS.

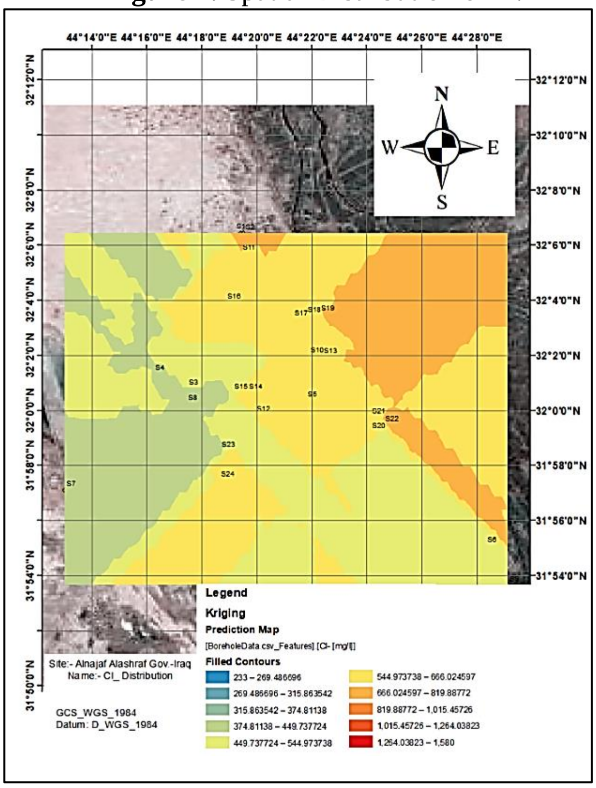
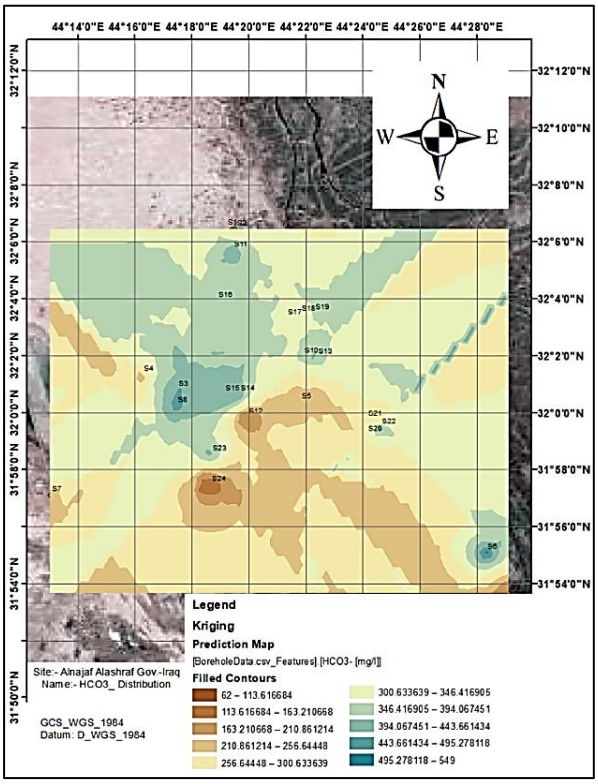


Figure 9. Spatial Distribution of Cl.



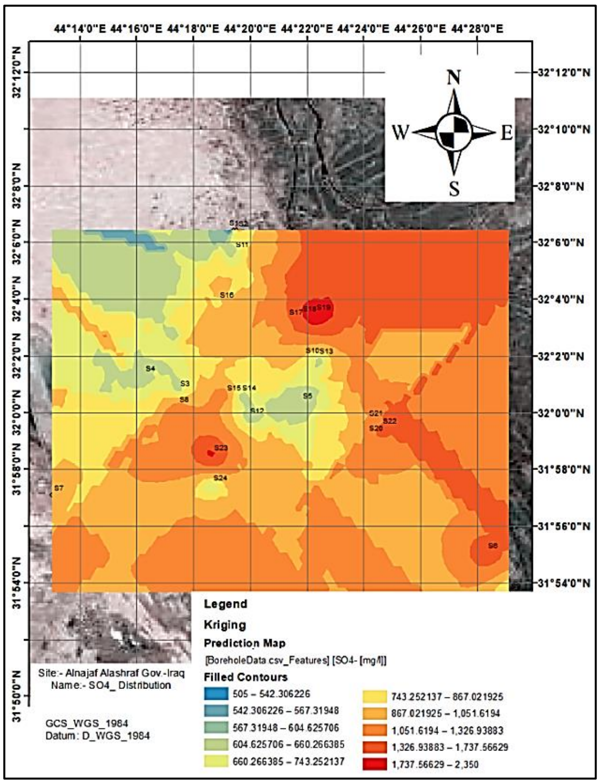


Figure 10. Spatial Distribution of HCO3. **Figure 11.** Spatial Distribution of SO4.

5.2 Groundwater suitability for industrial use

Each industry requires specific quality of water, some industries require water of high quality equals to distilled water in purity like pharmaceutical and paper industry, others can use any type of water. The values of groundwater parameters in the study area were compared to the limits needed for each industry, results shown in Table 5. The comparison revealed that the groundwater quality tested was not suitable for most of the industries, only few wells were suitable for chemical industry and lesser (only two) for refinery industry.

Table 5. Water Quality Specifications for Different Industries [11]

Industry	pH	TH (ppm)	Ca^+ (ppm)	Mg^+ (ppm)	Cl^+ (ppm)	SO_4^- (ppm)	Well no.
Canning food	6.5-8.8	310	120	-	300	250	Nil
Chemical industry	6-9	1000	200	-	500	-	1,4,5,9,10,12,13
Cement	6.5-8.5	-	-	-	250	250	Nil
Refinery	6-9	900	220	85	1600	570	1,4
Paper	6-9	475	20	12	199	-	Nil

5.3 Suitability of Groundwater for Animal Purposes

Almost all animals, unlike humans, can drink low-quality water. Table 6 presents a guideline of water quality characteristics for animal drinking purposes. The quality of groundwater samples from the study region was assessed, and the results demonstrates that water consider suitable for this purpose since nearly all the tested parameters were between the classes very good to good water quality limits in according to Table 6. While by comparing the results with Standard Specifications for Public Health Service in the United States of America shown in Table 7, 100% of wells are suitable for cows and sheep, 95.8% suitable for horses and 58.3% for poultry.

Table 6. Water Quality Specification And Classification For Animal Consumption [11].

Parameter (ppm)	**Limits**	**Water class**	**Samples %**
	800	V. good water	95.8
	1500	Good water	4.2
Na^{+}	2000	Acceptable water	-
	2500	Can be use	-
	4000	Maximum limit	-
	350	V. good water	58.3
	700	Good water	33.3
Ca^{+2}	800	Acceptable water	4.2
	900	Can be use	-
	1000	Maximum limit	-
	150	V. good water	79.2
	350	Good water	20.8
Mg^{+2}	500	Acceptable water	-
	600	Can be use	-
	700	Maximum limit	-
	900	V. good water	83.3
	2000	Good water	16.7
Cl^{-}	3000	Acceptable water	-
	4000	Can be use	-
	6000	Maximum limit	-
	1000	V. good water	62.5
	2500	Good water	37.5
SO_4^{-}	3000	Acceptable water	-
	4000	Can be use	-
	6000	Maximum limit	-
	3000	V. good water	58.3
	5000	Good water	33.3
TDS	7000	Acceptable water	8.4
	10000	Can be use	-
	15000	Maximum limit	-
	1500	V. good water	58.3
	3200	Good water	41.7
TH	4000	Acceptable water	-
	4700	Can be use	-
	5400	Maximum limit	-

Table 7. Standards Of Upper Limits Suitable For Animals Drinking [14, 15].

Animals	**TDS**
Poultry	< 2860
Horses	6435
Cows	10000
Sheep	12900

5.4 Suitability of Groundwater for Irrigation Purposes

Water chemical quality is an important aspect in determining whether or not water is suitable for irrigation. The concentration and content of dissolved chemicals in water determine its appropriateness for agricultural use. Water's suitability for irrigation is determined by the action of various mineral elements, both the soil and the plant are affected by the water.

It is widely acknowledged that the types and intensity of issues caused by poor irrigation water quality varies. However, there is currently a widespread agreement that these issues may be classified into the subsequent primary categories: (a) salinity risk, (b) infiltration and permeability issues, (c) specific ion toxicity, and (d) other issues [16, 17].

5.4.1 Salinity Hazard: Electrical Conductivity (EC) provides adequate estimation of the salinity hazard of irrigation water on agricultural crops because of its reflection on the amount of total concentration of dissolved salts in the water [18]. As it's known, the amount of water that plants can use drops substantially as conductivity rises.
In general, irrigation water with a conductivity of less than 750mhos/cm is satisfactory and causes no threat to most crops. Water with an extent of 750 to 2250mhos/cm is extensively utilized, and excellent crop development is attained under proper management and appropriate drainage conditions, but if leaching and drainage are insufficient, salty conditions will develop, while (EC) greater than 3000μmho/ cm may limit crop growth. In our study, (EC) varied in the range from 3590 to 11800μmho/ cm, Table 1. As a result, 100% of the samples have an EC greater than 2250 mho/cm, and continued application of such water may result in the development of salt soils [19].
In the current study, Wilcox and United States Salinity Laboratory (USSL) diagrams were used to analyse the accessible water wells in the area. The diagrams depicted that 95.8 percent of the available well water in the research region is unsuitable for irrigation due to the very high salinity danger (C4S1). The remaining samples (4.2 percent) are classified as high salinity hazards. In accordance with categorization methodology of USSL and Wilcox irrigation and water, 100 percent of water samples fell into the inappropriate group, the EC values of all studied wells indicate that they are unsuitable for irrigation (3590 to 11800) μS/cm, Table 8 [18, 20].

Table 8. Classification Scheme of USLL And Wilcox [21]

Water class	EC (μm/cm)	Salinity Hazard index
Excellent	100-250	C1: Low
Good	250-750	C2: Medium
Doubtful	750-2250	C3: High
Unsuitable	≥2250	C4: Very high

Groundwater of the low salinity danger class (C1) can be utilized without the need for any specific treatments for salinity management. Samples of water from the high salinity danger class (C3), on the other hand, may have negative impacts on salt-sensitive crops and numerous plants. High salinity regions need cautious management. Under normal settings, very high salinity water (C4) is not appropriate for irrigation, although it can be utilized for salt resistant plants on permeable soils with adequate management procedures [22]. Poor waters should not be utilized on clayey soils with limited permeability because it is typically unsuitable or unwanted for irrigation. However, it can have utilized to water plants with high tolerance to salt cultivated on already salty soils in order to prevent future fertility deterioration. [23, 24].

5.4.2 Permeability and Infiltration Hazard (Sodium Hazard): The sodium adsorption ratio, which is determined by the relative concentrations of sodium, magnesium, and calcium ions in water, is the most frequent water quality parameter that determines the standard rate of penetration of water (SAR) which is recommended by the salinity laboratory of the United States Department of Agriculture due to its direct relationship to soil adsorption. The main issue with excessive sodium levels is the influence on soil permeability and water penetration [11].
When elevated ions of sodium reduce the irrigation water arrival rate to the lowest layers of the soil, a permeability and infiltration hazard arises. When water has no permeability to the crop's roots to the degree that the crop demands, the lowered infiltration rate begins to have negative consequences. As a result, these salts begin to accumulate near the soil's surface. [16, 17].
Water designed for agricultural usage should ideally have lower sodium ions concentrations and a higher percentage of calcium and magnesium ions concentrations [19, 22].

5.4.3 Magnesium Hazard: Soil productivity is also affected by magnesium ion concentration. Higher levels of magnesium in water will have a negative impact on crop yields as soils become more salty [19, 22]. In our study, all of the groundwater samples had no magnesium hazard and these sources of water are appropriate for irrigation.

5.4.4 Residual Sodium Carbonate (RSC), Bicarbonate Hazard: Carbonate and bicarbonate ions are the major component of alkalinity; generally, they are to be in charge for high pH levels (over 8.5) in water. When carbonates levels rise, ions of magnesium and calcium are induced to form insoluble minerals, leaving sodium as the predominate ion in solution [16]. The calcium and magnesium are precipitated as carbonates, and any residual carbonate or bicarbonate is left in solution as residual sodium carbonate (RSC).

5.4.5 Chloride (Toxicity Problem): Chloride is required by plants at extremely low amounts and is usually found in waters that used for irrigation, it is harmful and at high quantities, may be toxic to some sensitive plants. Chlorides are usually soluble and participate to soil salinity (total salts content) [11]. Its harmful effects are instantly visible like burning or dying leaf tissue. Table 9 shows classifications of irrigation waters according to chloride content based on [25]. The chemical analysis of water showed that 37.5% of groundwater samples having chloride content between (141-350 ppm), as a result moderately tolerant plants harmed and 62.5% of samples exceeded the limits (more than 350), moreover, these wells water is unfit for irrigation and can cause severe troubles.

Table 9. Classification of irrigation water due to chloride content [25].

Chloride (ppm)	**Effects on crops**	**samples%**
Below 70	Usually harmless for all plants	Nil
70-140	Sensitive plants show harm	Nil
141-350	Moderately tolerant plants show harm	37.5
Above 350	Can cause severe troubles	62.5

5.4.6 Total Hardness (TH): Total hardness resulted from Calcium and Magnesium Carbonates, Bicarbonates, Chlorides, and Sulphate [24]. In our study total hardness varied from 314.73 to 2904.90 mg/l, so 100% of the groundwater samples considered very hard water.

5.5 Geostatistical Analysis

The spatial distribution of groundwater quality over the research region was examined using four semivariogram models: exponential, linear Gaussian, stable, and quadratic. A visual evaluation of the maps and statistical features such as standard deviation, error percentage, and skewness presented in Table 3 were used to choose the semivariogram. For each of the four semivariograms, every groundwater quality parameter was examined with the kriging interpolation technique. Then the outcomes of the analysis were scrutinized further with the Iraqi and WHO Water Guidelines. The same procedure was conducted for all groundwater quality parameters determining the best semivariogram.
Groundwater quality was spatially analysed for ten groundwater quality parameters. Variation of groundwater quality parameter concentrations was investigated and mapped in (fig. 2 to fig 11). Spatial examination of groundwater revealed serious problems with almost all groundwater parameters in terms of water appropriateness for drinking, irrigation, and other purposes.

6. Conclusion

Groundwater has become a major supply of fresh water for agricultural and drinking uses in recent years, and the importance of groundwater for irrigation is growing by the day as more land is cultivated.
The bulk of groundwater quality parameters have risen due to population increase and industrial expansion.
The quality of groundwater and its appropriateness for drinking and agricultural uses were evaluated using the spatial interpolation techniques and hydro-chemical analysis of the available data.
The results showed that 100% of the samples were out of specifications for drinking due to increasing concentrations of TDS, SO_4^- and 95.8%, 83.3% due to total hardness (TH) and Na^+ respectively, furthermore high concentrations of TDS and large values of EC observed in the study area lead the majority of the well's water properties to be improper and unacceptable for irrigation purposes according to international irrigation criteria, and continued application of such water may result in the development of salt soils if leaching and drainage are insufficient.

The spatial distribution of groundwater quality throughout the examined region revealed that all of the sites showed rising levels of groundwater pollution. It is possible to invest this water in shell and animal husbandry without any treatment, since it falls within the good limits of these requirements.

7. References

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