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Using Geographic Information Systems (GIS) Program and Water Quality Index (WQI) to Assess and Manage Groundwater Quality in the City of Baghdad

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ABSTRACT

Groundwater is an essential source because of its high quality and continuous availability characterize this water resource. Therefore, the study of groundwater has required more attention. The present study aims to assess and manage groundwater quality's suitability for various purposes through the Geographical Information System GIS and the Water Quality Index WQI. The study area is located in the city of Baghdad in central Iraq, with an approximate area of 900 km², data were collected from the relevant official departments representing the locations of 97 wells of groundwater in the study area for the year 2019, as it included physicochemical parameters such as pH, EC, TDS, Na, K, Mg, Ca, Cl, HCO₃, SO₄ and NO₃. It used (kriging method) in the geographic information system to generate the groundwater physical and chemical parameters' spatial distribution and the water quality index map. To estimate the water quality index, ten parameters were considered pH, TDS, Na, K, Mg, Ca, Cl, HCO₃, SO₄, and NO₃. The estimated WQI value for groundwater samples in the study area ranges from 50 to 300. Based on the analysis, most of the area under study falls approximately 70% in poor water class and 30% in good water class, where the distribution of the groundwater samples with respect to their quality classes such as excellent, good, poor, very poor and unfit for human drinking purpose, was found to be 3%, 30%, 33%, 12%, and 20%, respectively.

Keywords: GIS, Groundwater Wells, spatial distribution, Baghdad City, groundwater quality.

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استخدام برنامج نظم المعلومات الجغرافية (GIS) لتقسيم وإدارة جودة المياه الجوفية في مدينة بغداد

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الخلاصة

تعتبر المياه الجوفية مصدراً حيويًا لسداد احتياجات المدينة العالية وتؤثر المستمر لذلك تتطلب دراسة المياه الجوفية مزيداً من الاهتمام. تهدف الدراسة إلى تقييم وإدارة جودة المياه الجوفية اللافتة لأغراض مختلفة من خلال نظام المعلومات الجغرافية (GIS) (WQI) لمشفر جودة المياه). تقع منطقة الدراسة في مدينة بغداد وسط العراق بمساحة تقريبية 900 كيلومتر مربع، وتتم جمع البيانات من الدوائر الرسمية ذات العلاقة التي تمثل مواقع 97 بئرًا للمياه الجوفية في منطقة الدراسة لعام 2019، حيث اعتمدت على متغيرات كيميائية كيميائية مثل (PH, EC, TDS, Na, K, Mg, Ca, Cl, HCO3, SO4, NO3) في برنامج نظم المعلومات الجغرافية لإنشاء التوزيع المكاني للمياه الجوفية وعرضة مؤشر جودة المياه وتقدير مؤشر جودة المياه الجوفية في النطاق في عشر محددات (مقياس المياه الجوفية في منطقة الدراسة تتراوح من 50 إلى 300). وبناءً على التحليل تقع معظم المنطقة في الدراسة 70٪ منها تقريباً في فئة المياه المتدنية و30٪ في فئة المياه الجيدة حيث تم توزيع عينات المياه الجوفية فيما يتعلق بفئات مؤشر الجودة ممتاز، جيد، ضعيف، ضعيف جداً وغير صالح لشرب الإنسان وكانت النتائج 3٪، 33٪، 12٪، 20٪ على التوالي.

الكلمات الرئيسية: نظم المعلومات الجغرافية، مؤشر نوعية المياه، أبار المياه الجوفية، التوزيع المكاني، مدينة بغداد

1. INTRODUCTION

Groundwater is generally reliable and high-quality resources if the appropriate conditions are available, so care must be taken to prevent contamination. At the same time, maintaining its quality and characteristics represented the problem for evaluation GW at a time were faces major population growth and the urgent requirements for various development activities in light of the water war climate change and unguided use in various purposes, in addition to environmental or economic, legal and political factors that are important to take into account. Also, groundwater is a valuable resource due to its constant quality and availability, which requires minimal storage and transportation infrastructure requirements (Ahmed, N. et al., 2014). GIS is a computer-based program that can collect, store, analyze, distribute, and output spatial data information. It is particularly important for presenting spatial data and baseline values, and spatial analysis results (Bolstad, P., 2016). Then GIS diagrams extracted from this program led to the investigation of natural and human systems and the modeling and prediction of their behaviors over time, and since that time lead a lot of research efforts in all societies to push researchers in new technology instead of by use GIS. So there has been a significant increase in the use of the evolving capability of GIS over the past three to four-decade (Weng, Q., 2010). GIS can be a powerful tool for developing solutions to water resource problems, assessing water quality, determining water availability to understand the natural environment, and managing water resources at an accurate level and according to the required specifications. It is also a very powerful tool for processing, analyzing, and integrating spatial data sets. In a very broad sense, a geographic information system may mean data need identification, information acquisition, efficient management, processing, analysis, and
Successful water management needs to follow a scientifically coordinated approach to provide water management site officials with information about the decision. Therefore, to meet the needs of accumulated data for water management and water resources research, there is a great need for effective modeling techniques that have high power for long and short-term evaluation in order to be able to reach correct decisions (Arafat, A., 2007). For any city, a groundwater quality map is important for determining its use; the water quality index WQI method for groundwater quality assessment is widely used worldwide due to the capability of the full expression of the water quality information. It is one of the most effective tools and important parameters for evaluating and managing groundwater quality. WQI is defined as a rating reflecting the composite influence of different water quality parameters (Wu Jianhau, et al., 2011). WQI is defined as a classification that reflects the combined effect of water quality indicators. WQI is calculated through the suitability of groundwater for human consumption. Its primary objective is to discuss groundwater suitability for use based on the calculated water quality index values (Ramakrishnaiah, C., et al., 2009). Thus, the study was conducted to assess groundwater quality's suitability for various purposes through the Geographical Information System GIS and the Water Quality Index WQI.

2. MATERIALS AND METHODS
2.1 Study case description
Baghdad is the largest and most populous city in Iraq, with an estimated population of 8 million. Rapid and continuous population growth, accompanied by an increase in municipal, industrial, agricultural and other activities, in addition to changes in the climate, has led to changes in the quality requirements of water resources, including groundwater (Ali, S. M., 2012). According to statistical studies, the city of Baghdad is confined to latitude 36º 30 - 37º 34 north and longitude 39º 20 - 49º 45 east. According to statistical studies, the percentage of urban, agricultural, and industrial areas is 72.69%, 25%, and 2.31%, respectively. These percentages show increased pollution expectations due to the increase in these percentages outside of urban planning (Al-Jiburi, H. and Al-Basrawi, N., 2013). The salinity of groundwater in Baghdad varies from water (fresh to salty) with the water chloride form spread. Groundwater movement in the direction east, north, and southeast, and the transmutability factor ranges between 50-350 m²/day in total, but the susceptibility factor decreases towards the east. The results showed that the groundwater depth for the study area ranges between 2 - 50 m (Al–Basrawi, N., et al., 2011). The study area in WGS 1984- UTM-Zone 38 ° N of the Universal Transverse Mercator – UTM coordinate system structure. As shown in Fig.1.

2.2 Data Collection and Analysis
The research included a study of wells data, numbering 97 wells distributed randomly over the city of Baghdad are approximate coverage, collected from government departments related to groundwater studies, and these parameters include: hydrogen ion concentration pH, electrical conductivity EC, Total Dissolved Solids TDS, Calcium Ca²⁺, Magnesium Mg²⁺, Sodium Na⁺, Potassium K⁺, Chloride Cl⁻, Bicarbonate HCO₃⁻, sulfate SO₄²⁻, nitrate NO₃⁻. The statistical analyses of obtained data were carried out using Microsoft offices excel and the SPSS
program. Wells distribution on the study area, as shown in Fig. 2, data geographical for wells, as shown in Table No.1, and Table No.2 Descriptive statistics for all studied wells.

Figure 1. Location of the Study Area (Researcher's work by GIS).

Figure 2. Wells Distribution on Study Area (Researcher's work by GIS).
Table 1. Wells Data Geographical for Study Area.

| Wells No. | district      | Longitude | Latitude |
|-----------|---------------|-----------|----------|
| W1        | Mahmoudia     | 44 23     | 33 2     | 31.08    |
| W2        | Almadaeen     | 44 37     | 33 4     | 33       |
| W3        | Almadaeen     | 44 38     | 33 2     | 28.4     |
| W4        | Almadaeen     | 44 39     | 33 3     | 30.4     |
| W5        | Almadaeen     | 44 34     | 33 8     | 6.8      |
| W6        | Almadaeen     | 44 34     | 33 8     | 5.22     |
| W7        | Almadaeen     | 44 34     | 33 8     | 9.9      |
| W8        | Almadaeen     | 44 38     | 33 1     | 47.1     |
| W9        | Almadaeen     | 44 41     | 33 0     | 52.6     |
| W10       | Almadaeen     | 44 41     | 33 7     | 22       |
| W11       | Almadaeen     | 44 36     | 33 13    | 1        |
| W12       | Almadaeen     | 44 41     | 33 6     | 4        |
| W13       | Almadaeen     | 44 42     | 33 1     | 42       |
| W14       | Almadaeen     | 44 38     | 33 9     | 12       |
| W15       | Almadaeen     | 44 41     | 33 9     | 18       |
| W16       | Almadaeen     | 44 41     | 33 2     | 33       |
| W17       | Almadaeen     | 44 38     | 33 8     | 23       |
| W18       | Almadaeen     | 44 40     | 33 10    | 10       |
| W19       | Almadaeen     | 44 37     | 33 7     | 19       |
| W20       | Almadaeen     | 44 38     | 33 4     | 58.5     |
| W21       | Karkh         | 44 21     | 33 17    | 26.76    |
| W22       | Rusafa        | 44 25     | 33 19    | 54.1     |
| W23       | Abu Ghraib    | 44 8      | 33 16    | 11       |
| W24       | Karkh         | 44 10     | 33 18    | 3        |
| W25       | Abu Ghraib    | 44 7      | 33 16    | 33       |
| W26       | Adhamiya      | 44 24     | 33 22    | 36.2     |
| W27       | Karkh         | 44 11     | 33 18    | 23       |
| W28       | Kadhimiyat    | 44 17     | 33 31    | 22       |
| W29       | Rusafa        | 44 26     | 33 20    | 28       |
| W30       | Karkh         | 44 26     | 33 16    | 58.9     |
| W31       | Karkh         | 44 22     | 33 18    | 50.1     |
| W32       | Rusafa        | 44 24     | 33 19    | 12.4     |
| W33       | Rusafa        | 44 28     | 33 14    | 9.7      |
| W34       | Adhamiya      | 44 25     | 33 23    | 34       |
| W35       | Rusafa        | 44 23     | 33 21    | 40       |
| W36       | Alssadr       | 44 27     | 33 21    | 27.5     |
| W37       | Rusafa        | 44 30     | 33 21    | 3.5      |
|   |   |   |   |   |
|---|---|---|---|---|
| W38 | Rusafa | 44 | 32 | 12.2 | 33 | 23 | 23.4 |
| W39 | Rusafa | 44 | 31 | 30.2 | 33 | 25 | 40.8 |
| W40 | Alssadr | 44 | 28 | 51.6 | 33 | 23 | 29.4 |
| W41 | Karkh | 44 | 24 | 55.6 | 33 | 16 | 20 |
| W42 | Karkh | 44 | 23 | 15 | 33 | 12 | 31.2 |
| W43 | Rusafa | 44 | 30 | 7.7 | 33 | 14 | 8.7 |
| W44 | Rusafa | 44 | 30 | 35.7 | 33 | 23 | 41.2 |
| W45 | Rusafa | 44 | 27 | 39.9 | 33 | 20 | 45.4 |
| W46 | Kadhimiya | 44 | 21 | 8.6 | 33 | 21 | 41.3 |
| W47 | Kadhimiya | 44 | 19 | 50.6 | 33 | 24 | 33.9 |
| W48 | Adhamiya | 44 | 19 | 50.6 | 33 | 27 | 48.4 |
| W49 | Adhamiya | 44 | 23 | 55.3 | 33 | 27 | 50 |
| W50 | Karkh | 44 | 23 | 27.2 | 33 | 18 | 56.1 |
| W51 | Karkh | 44 | 16 | 2.8 | 33 | 18 | 30 |
| W52 | Karkh | 44 | 14 | 8.3 | 33 | 19 | 20.7 |
| W53 | Karkh | 44 | 16 | 37.7 | 33 | 16 | 37.5 |
| W54 | Karkh | 44 | 21 | 11.4 | 33 | 16 | 10.9 |
| W55 | Karkh | 44 | 18 | 14.2 | 33 | 14 | 2 |
| W56 | almaidsan | 44 | 31 | 56 | 33 | 10 | 40 |
| W57 | almaidsan | 44 | 30 | 52 | 33 | 12 | 17 |
| W58 | Rusafa | 44 | 31 | 9 | 33 | 16 | 37.1 |
| W59 | Rusafa | 44 | 31 | 15.5 | 33 | 19 | 4 |
| W60 | Rusafa | 44 | 23 | 9.3 | 33 | 16 | 43.5 |
| W61 | Kadhimiya | 44 | 17 | 27 | 33 | 22 | 19.24 |
| W62 | Karkh | 44 | 13 | 38 | 33 | 21 | 45.2 |
| W63 | Kadhimiya | 44 | 19 | 58.5 | 33 | 22 | 0.9 |
| W64 | Kadhimiya | 44 | 15 | 48 | 33 | 28 | 1.7 |
| W65 | Karkh | 44 | 22 | 23.7 | 33 | 19 | 53.2 |
| W66 | Rusafa | 44 | 32 | 37.3 | 33 | 24 | 31.5 |
| W67 | Alssadr | 44 | 29 | 22.5 | 33 | 25 | 41.2 |
| W68 | Karkh | 44 | 26 | 47.6 | 33 | 16 | 48.8 |
| W69 | Kadhimiya | 44 | 17 | 1.8 | 33 | 26 | 1.1 |
| W70 | Mahmoudia | 44 | 10 | 43 | 33 | 10 | 4 |
| W71 | Mahmoudia | 44 | 22 | 56 | 33 | 1 | 22 |
| W72 | Kadhimiya | 44 | 12 | 0 | 33 | 30 | 0 |
| W73 | Mahmoudia | 44 | 13 | 20 | 33 | 12 | 10 |
| W74 | Kadhimiya | 44 | 13 | 20 | 33 | 28 | 40 |
| W75 | Mahmoudia | 44 | 25 | 5 | 33 | 10 | 40 |
| W76 | Adhamiya | 44 | 22 | 40 | 33 | 29 | 30 |
| W77 | Almaidsan | 44 | 48 | 55 | 33 | 15 | 20 |
| W78 | Abu Ghraib | 44 | 7 | 15 | 33 | 17 | 20 |
Table 2. Descriptive Statistics for all Studied Wells.

|         | pHc  | EC     | T.D.S | Ca$^{2+}$ | Mg$^{2+}$ | Na$^+$ |
|---------|------|--------|-------|-----------|-----------|--------|
| **Mean** | 7.44 | 6976.64 | 5287.31 | 340.25    | 264.66    | 548.5  |
| **Std. Deviation** | 0.34 | 7666.98 | 6439.57 | 348.84    | 308.81    | 750.63 |
| **Minimum** | 7.01 | 780.63 | 661    | 48.1      | 26.6      | 75     |
| **Maximum** | 8.12 | 38400  | 39016.67 | 2164     | 1490.64   | 3818   |

|         | K + mg/L | Cl$^-$ mg/L | HCO$_3^-$ mg/L | SO$_4^{2-}$ mg/L | NO$_3^-$ mg/L |
|---------|-----------|-------------|----------------|-----------------|---------------|
| **Mean** | 63.93     | 1238.14     | 421.27         | 1696.72         | 2.32          |
| **Std. Deviation** | 137.58    | 1866.23     | 512.45         | 1874.93         | 4.57          |
| **Minimum** | 2        | 71.34       | 23              | 139.78          | 0.11          |
| **Maximum** | 706.38   | 11916.83    | 2562           | 9100            | 30.61         |
3. METHODOLOGY
The objectives of the research are achieved through adopting a data integration strategy, as the study relied on the spatial analysis approach of groundwater parameters by the GIS program to find out the feature by which the data will be integrated with WQI distribution results in the study area, to be an effective tool for planning and decision-making in relation to the protection of groundwater and managing them, the objectives of achieving the study can be generally summarized as follows:

3.1 Geographic Information Systems GIS
Many GIS techniques have been developed for spatial interpolation in various disciplines, with a number of different terms used to distinguish between them (Al-Musawi, N. and Al-Rubaie, F., 2019). The method kriging has been used in this research for the spatial distribution of the determinants of groundwater data in the study area, in addition to representing or identifying appropriate places for different uses of groundwater through maps generated from the GIS after entering data to represent it through the program.

3.2 Ground Water Quality Index (GWQI)
In the research, the water quality index WQI for groundwater wells in the study area for the available data represented for all parameters, the calculation of Groundwater Quality Index GWQI was done by Weighted Arithmetic Index method (Ramakrishnaiah, C., et al., 2009). This method was chosen among other methods for its accuracy and adoption within the researches. Although this method was used in studies of surface water, its application within groundwater studies has succeeded in most studies on the different conditions between surface water and groundwater.

4. RESULTS AND DISCUSSION
4.1 GW Quality Assessment
It is important to assess groundwater quality to ensure the safe and sustainable use of these resources. However, it is difficult to describe the general condition of water quality due to the spatial diversity of multiple pollutants and a wide range of indicators chemical, physical, and biological that can be measured. The chemical constituency of soil water is an indicator of its suitability for irrigation and industrial use and other water supply for human and animal consumption. Thus, the concept of water quality is not empirical, somewhat socially dependent on the desired water use (Babiker, I. S., et al., 2007). By comparing the mean for parameters with the limits of the specifications shown in Table No.3 wells under study, we see that most of the above elements are not within the permissible limits except pH, NO₃ therefore all the wells in the study area, which was mentioned, are not suitable for drinking. The mean pH, NO₃ results are 7.44, 2.32 respectively. This shows that groundwater in the study area did not exceed the permissible limits in Iraq for pH, NO₃. The standard drinking water specifications are not classified by the deterioration standards responsible for water quality. They indicated that the water samples were semi-neutral to alkaline in nature. The results showed that EC's total mean values reached 6976.64 μS / cm, indicating that most EC values were above the maximum permissible level recommended by (IQS, 2009) for drinking water not exceeding 1500 μS / cm. This increase indicates the relationship between EC and TDS in groundwater. High conductivity in groundwater may arise through natural weathering of some sedimentary rocks or an anthropogenic origin. High electrical conductivity was associated with higher dissolved solids, which indicated the presence of
dissolved salinity, significantly in study areas that suffered high levels of TDS and EC contents. The mean of TDS was 5287.31 mg/L, indicating that annual values of TDS were often above the (IQS, 2009) permissible level for drinking water 1000 mg/L. The high concentration of dissolved solids in many wells' models was an indication that there are intense human activities that greatly affect the quality of the groundwater in the study area. The general mean for all stations was 340.25 mg/L. Most of the calcium values exceeded the permissible limits in the Iraqi specifications for drinking water not more than 150 mg/L. The data showed that there are readings within the permissible limits. High concentrations of calcium may indicate the land's geological composition in the groundwater sampling area. When some soil types have increased, the calcium content can be dissolved in the groundwater through recharge areas. The general mean of magnesium for all the stations examined was 264.66 mg/L. Most of the calcium values exceeded the permissible limits in the Iraqi specifications for drinking water not more than 150 mg/L. The data showed that there are readings within the permissible limits. The annual values were also higher than the level permitted by (IQS, 2009) for drinking water 100 mg/L at different locations. During the study period, this rise may be due to the nature of the lands adjacent to the well sites, which directly affect groundwater recharge places. The results of Na for the general average of all stations was 548.5 mg/L. This indicates that most of the values of sodium has exceeded the permissible limits of the Iraqi standards for drinking water not exceeding 200 mg/L and was classified within the standards responsible for the deterioration of water quality in general, significantly high sodium in the groundwater during the study period, the result of the increase in the presence of sodium salts in the feeding areas and in the rocks. The results of potassium concentrations through the data were from the general mean for all wells was 63.93 mg/L. Through the data, it is clear that most of the K values have exceeded the permissible limits according to (IQS, 2009) not exceeding 12 mg/L, potassium in groundwater is due to the land's nature in the feeding areas, especially in agricultural areas. The results of chlorine concentrations through the data were from the general mean for all wells were 1238.14 mg/L. Through the data, it is clear that most of the Cl values have exceeded the permissible limits according to (IQS, 2009) not exceeding 350 mg/L, and this thus greatly affects the deterioration of the quality of groundwater chloride in groundwater is evidence of sedimentary rocks rich in chloride. It can be seen through the salty taste of groundwater, which indicates an increase in chloride salts in it. The general mean HCO₃ it 421.27 mg/L, which is higher than the maximum permissible level in drinking water 350mg/L, the high concentration of HCO₃ it comes from the action of water containing carbon dioxide on limestone, marble, and other minerals containing calcium and magnesium carbonate in the ground that can add large quantities to the groundwater. And the general mean for SO₄ was 1696.72 mg/L, which is higher than the maximum permissible level in drinking water 400 mg/L. This large increase above the permissible level may be due to man-made activities and natural resources as rocks and stones in the ground can add large quantities of sulfates to the groundwater.

Table 3. Water Iraq Quality Specification Standard.

| Parameters                     | Symbol | Unit   | Mean      | IOS/417, 2009 |
|--------------------------------|--------|--------|-----------|---------------|
| Hydrogen Ion Concentration     | pH     | ــــــــ  | 7.44      | 6.5 - 8.5     |
| Electrical Conductivity        | EC     | µS/cm  | 6976.64   | 1500          |
| Total Dissolved Solids         | TDS    | mg/L   | 5287.31   | 1000          |
| Calcium                        | Ca     | mg/L   | 340.25    | 150           |
| Magnesium                      | Mg     | mg/L   | 264.66    | 100           |
4.2 GWQI
The water quality index was applied with the help of GIS technology in this study to assess the appropriateness of the groundwater quality and to calculate the water quality index WQI. Ninety-seven 97 samples of groundwater were collected from the study area, as shown in Table No. 1. Descriptive statistics and Iraqi drinking water standards (IOS/417, 2009) were taken into account for calculating the WQI as shown in Table No. 2. The first step to computing a water quality index is to determine specific weights of chemical parameters and their relative importance in drinking water. The highest weight was given to the nitrite coefficient $NO_3$ due to the importance of the role played by the water quality, more than others were. A lower weight is assigned to Na, Mg, and Ca because it is not harmful to the groundwater quality (Ramakrishnaiah, C., et al., 2009), and the rest of the weights as shown in Table No. 4. In the second step, the relative weight $Wi$ is calculated using equation number one given below:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi}$$  \hspace{1cm} (1)

Where $Wi$ relative weight, $wi$ the weight of each parameter, and $n$ is the number of parameters. The quality rating scale $qi$ was calculated in the third step by dividing each chemical parameter concentration $Ci$ by its respective Iraqi standards for drinking $Si$ as shown in Table No. 4. The result is multiplied by 100 using the following equation.

$$qi = \left[ \frac{Ci}{Si} \times 100 \right]$$ \hspace{1cm} (2)

In the fourth step, $Sli$ is calculated for each chemical parameter using the following relationship

$$Sli = Wi \times qi$$ \hspace{1cm} (3)

Finally, the Water Quality Index WQI was calculated using the following equation:

$$WQI = \sum Sli$$ \hspace{1cm} (4)
Table 4. The calculated relative weight Wi values of each parameter.

| Parameters                        | Sl  | Weight wi | Relative weight Wi |
|-----------------------------------|-----|-----------|--------------------|
| Hydrogen Ion Concentration       | 6.5 | 4         | 0.125              |
| Total Dissolved Solids           | 1000| 4         | 0.125              |
| Calcium                          | 150 | 2         | 0.0625             |
| Magnesium                        | 100 | 2         | 0.0625             |
| Sodium                           | 200 | 2         | 0.0625             |
| Potassium                        | 12  | 3         | 0.09375            |
| Chloride                         | 350 | 3         | 0.09375            |
| Bicarbonate                      | 350 | 3         | 0.09375            |
| Sulfate                          | 400 | 4         | 0.125              |
| Nitrate                          | 50  | 5         | 0.15625            |
| **Σ**                            | **32**|         | **1**              |

The water quality index WQI values were classified into five types (Ramakrishnaiah, C., et al., 2009), as shown in Table 5. Comparing the results of the calculated water quality index classification shows that 3% of water samples in class I (type of water excellent), and shows that 30% of the water samples fall in the second category II, which represents the quality of good water and 33% of the water available well falls under the third category III, representing of poor water quality, 12% percent of the water sample falls in category IV which indicates that the water quality is very poor and 22% percent of water samples fall in category V indicating unsuitable water for drinking purposes.

The WQI is a valuable assessment of the state of total water quality in a single term and helps choose the appropriate treatment method to meet the requirements. However, WQI portrays the combined effect of water quality standards and their variations and conveys information on water quality standards to the user and decision-makers. The WQI aims to give a single value to the quality of groundwater and reduce the number of indicators to a greater extent in easy expression leading to a possible interpretation of the data for monitoring water quality standards. Besides, this is an effort to review important groundwater indicators used in the assessment, and it also provides information on the formation of mathematical indicators and figures (Tyagi, S., et al., 2013). It can also be summed up by showing the variation between wells for water quality index WQI in the study area through Fig. 14, Fig. 15, and Fig. 16. Therefore, it is necessary for the researchers to have a complete perception of the distribution of the water quality index in the study area. And this is done through Integration spatial analysis by geographic information systems GIS program with of the data extracted through the calculations of WQI, as shown in Fig. 17 where the distribution of water quality areas can be used in studies as well as uses the different groundwater that gives an idea of the area to be invested groundwater in it.
Table 5. Result percentage of studied water samples in the study area based on WQI value.

| WQI Value | Class | Water quality | WQI for Wells | Well Number | % studied sample |
|-----------|-------|---------------|---------------|-------------|------------------|
| < 50      | I     | Excellent     | 43,27,42      | 50, 85, 94  | 3 %              |
| 50-100    | II    | Good          | 68,69,100,75,88,72, 69,67,85,94,87,53, 74,78,93,80,87,52, 60,78,62,100,66,67, 69,90,67,99,64 | 8, 11, 12, 14, 20, 23, 24, 25, 26, 29, 31, 33, 34, 37, 38, 39, 40, 42, 45, 51, 59, 61, 62, 63, 64, 65, 66, 82, 93 | 30 % |
| 100-200   | III   | Poor          | 143,115,122,102,131, 150,123,115,126,105, 132,117,108,183,161, 165,183,111,165,175, 105,181,121,197,189, 197,150 | 1, 2, 3, 5, 7, 10, 16, 27, 28, 30, 32, 35, 36, 41, 49, 52, 55, 56, 57, 58, 60, 67, 68, 69, 70, 75, 80, 83, 87, 89, 96, 97 | 33 % |
| 200-300   | IV    | Very Poor     | 286,299,290,298,248, 201,250,249,284,288, 295,218 | 6, 9, 17, 18, 48, 54, 73, 78, 79, 88, 92, 95 | 12 % |
| >300      | V     | Un suitable   | 309,1573,972,1241, 1166,850,331,307,643, 467,464,678, 314, 666, 877,1136,401,515,316, 815,534 | 4, 13, 15, 19, 21, 22, 43, 44, 46, 47, 53, 71, 72, 74, 76, 77, 81, 84, 86, 90, 91, 92, 93, 95 | 22 % |

4.3 GIS
The GIS program is considered an ideal display interface in managing and auditing water resources data, including groundwater, as it has been used in the research by entering groundwater data available for 97 wells sites in the study area, organizing and analyzing and display the program, through maps that are displayed with high accuracy showing the spatial distribution. After obtaining the final information based on spatial analysis through the program, GIS is done taking the appropriate decision regarding it that by choosing the right place for drilling wells to obtain the groundwater necessary for the various industrial, agricultural, constructional and other thus the successful management of this important resource and to be use in the right place according to the global and local specifications and determinants. (Jha, M., et al., 2007)
Where it was done and through the results of examining water models for the wells under study by the competent departments, which were within the boundaries of the city of Baghdad and as shown in the statistical description in Table No.2 and distribution results appeared after entering these data into the program, as it was noticed through Fig. 3. The value of pH ranges between 8.6 - 8.5 in most wells in the study area and its distribution within the permitted Iraqi specifications, as shown in Table No.3. From Fig. 4, it is shown that the value of EC in the study area was the lowest value 2600 mg/L, which is a result outside the permissible limits, and it is also seen from Fig. 5 that the most readings TDS at the study area ranges between 1200-6000 mg/L and the rest of the sites ranges between 6000-25000 mg/L and therefore its value is outside the limits. For the
permissible standard, it is also clear to us that the value of Ca, Na as shown in Fig. 6 and Fig. 8 there are few places where readings are within the limits of the Iraqi standard and the rest of the distribution, which represents most of the study area, was not within the standard. Through the results of the GIS program drawing with values of Mg, K as shown Fig. 7 and Fig. 9, it becomes clear to us that most of the study area have high values less than the required levels in addition to SO$_4$ as shown in Fig. 12, and also with a value see CL as shown in Fig. 10 it is noticed that most of its results in the study area are less than the Iraqi specification, which is 350 mg/L, and the program map resulting from HCO$_3$ data, as shown in Fig. 11, indicating that the western regions up to the north and part of the central regions For the study area is within the limits of the Iraqi standard and its values increase in other regions, and finally the area of data, distribution NO$_3$ as shown in Fig. 13, clarifies that the whole study area is within the standard. Generally, soluble ions and salts are the main components of groundwater. Calcium, magnesium, sodium, bicarbonate, sulfate, and chloride are major ions in drinking water. Potassium, carbonate, and nitrate are beneficial, but it may cause severe problems for humans when increased.

From the above, a complete and clear perception of the values of groundwater data for the wells of the study area can be seen, through which and through the GIS program, it is easier for researchers to have a lot of effort time and research in the event that there are areas where data and information are not available to them and the difficulty of obtaining it due to the lack of time and effort.

(Researcher's work by GIS)
Figure 5. Distribution TDS - mg/L.

Figure 6. Distribution Ca - mg/L.

(Researcher's work by GIS).

Figure 7. Distribution Mg - mg/L.

Figure 8. Distribution Na - mg/L.

(Researcher's work by GIS)
Figure 9. Distribution K- mg/L.

Figure 10. Distribution CL- mg/L.

(Researcher's work by GIS)

Figure 11. Distribution HCO$_3$ mg/L.

Figure 12. Distribution SO$_4$ mg/L.

(Researcher’s work by GIS)
Figure 13. Distribution $\text{NO}_3\text{mg/L}$.  
(Researcher's work by GIS)

Figure 14. Showing the amount of variation in the WQI between wells for W1 to W34.
**Figure 15.** Showing the amount of variation in the WQI between wells for W35 to W68.

**Figure 16.** Showing the amount of variation in the WQI between wells for W69 to W97.
Figure 17. Spatial Analysis for WQI in Study Area (Researcher’s work by GIS).
5. CONCLUSIONS

1- Spatial analysis of groundwater quality has been carried out through GIS and WQI techniques that can provide highly useful and effective tools for summarizing monitoring data for decision-makers to understand better the state of groundwater quality and the opportunity for its better use in the future.

2- The differences between WQI index values for wells in Baghdad city due to water leakage from sewage networks and partial treatment of sewage discharge in the Tigris River.

3- The spatial distribution results comparing with (IQS, 2009) showed that the groundwater water quality in most of the study area is not suitable for drinking, but use for other as industrial, agricultural and other.

4- The WQI results maps in the study area confirm that the groundwater in the study area suitable for drinking purposes after treatment in the western regions and part of the central and eastern regions towards the southwest, where the ground level rise and the level of deep groundwater. The north and southeast direction towards the south is the opposite due to the low ground level and shallow groundwater level. In general, the study area’s groundwater needs a certain degree of treatment before consumption and must be protected from pollution.

5- In general, the main water parameters EC, TDS, Ca, Mg, K, Cl, Na, HCO₃ and SO₄ not within the limits of the specification (IQS, 2009). On the other hand, concentrations were PH, NO₃ within the limits.

6- It is possible, through the maps of spatial analysis by GIS of the physical and chemical parameters of groundwater, to be adopted as a strategy in the event of digging new wells and to be the basis for the management and planning of the drilling process to obtain near-identical results for the old drilled wells as they save time, effort and cost through that to obtain high-accuracy results.

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