Assessment of Groundwater Quality Using Correlation Matrix in Humaydat- Region, Mosul, Iraq

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Abstract: The current study deals with analyzing samples of 29 groundwater samples collected from 29 wells which are used in the Humaydat-Mosul region for irrigation, home use, and sometimes for drinking purposes. Standard water tests were carried out over the course of a year, all of which were in use. The tests included HCO$_3^-$, CL$^-$, Mg$^{+2}$, Na$^+$, NO$_3^-$, Ca$^{+2}$, SO$_4^{+2}$, TDS, EC and the well depth with the symbol D and conducting statistical analysis method (Main Components) for the tests. The correlation matrix showed that the significant levels between the components of the study, as a result, the TDS, EC and SO$_4^{+2}$ distinct roots are known for the regression equation that will connect the distinctive roots with the other components. Thus these water wells are not valid for human and domestic use and were outside the permissible limits and the viability of those wells water for agricultural use after treatment on water.

Keyword: Water Quality, Correlation matrix, Humaydat Mosul, Iraq

1. Introduction
The increasing need to consume water as a result of population growth and agricultural and industrial activities, dependence on well water has become an imperative for watering crops and drinking sheep and cows, especially for areas not serviced by good water networks and far from the surface water source. The drilling of wells increased in a random manner and without prior study of the reality of the situation, the geography of the region, the type and composition of the soil, with no knowledge of the environmental determinants of this work. Rain water is the main source of natural groundwater in those areas and it is suitable for drinking except if it is close to a source of surface water where its quality will be affected, as well as the human activity will affect the quality of this water in one way or another. According to the type of soil and the difference in the melting of the salts in which the groundwater moves, so that such movement can be controlled only with narrow limits, so it was necessary to know its suitability for all uses.

This study was conducted to know and define tests for components and compare them with international classifications and to use statistical methods to determine the distinct roots of components and find a regression equation that links roots to reducing tests and reach easily judgment to suitability water. AinSubashi water in Tal Afar within the Nineveh governorate has been studied which are using for drinking purposes for lack of surface water in this region [1]. The study demonstrated that the inability of groundwater for drink due to its hardness and also the presence of heavy metals in toxic proportions. The following study [2] was for well water the study confirmed that the wells are not fit for domestic use, drinking, and industry, in order to increase the concentrations of soluble salts, hardness, sulfate ions, and bicarbonate. While the researcher in the research [3] studied the qualitative distribution of the properties of existing wells, it has proven invalid for Use. He conducted [4] a study for the area of the church container inside Mosul, and it proved bad water due to
hardness, calcium, magnesium and sulfate increase, some of which are valid for irrigation only. The researchers [5] proved the validity of the well water for cows and livestock within the concept and determinants of WQI. Whereas the Elsa wells from the right solution of Mosul dug within the residential area were invalid and poor in research [6].

2. Area of study
The study area (Al-Humaydat) is located in the northwest of al-Mosul city, Iraq (Figure.1). It is a large village located between 36°12' and 36°33' north and 42°38' and 43°02' east. The climate of this area is semi-arid area characterized by hot dry summer and cold dry winter.

3. Materials and method
Twenty-nine samples of well water in the study area were collected over the course of 2018 in clean plastic bottles with a capacity of one liter after washing with distilled water. The openings of these bottles were tightly closed and the NO₃⁻, HCO₃⁻, CL⁻, Mg⁺², Na⁺, Ca²⁺, SO₄²⁻, TDS, EC tests were performed. Physical and chemical analyzes were conducted in the laboratories of the University of Mosul, where a certain amount of groundwater was vaporized to obtain total TDS. Conductivity measurements were performed using the estimated conductivity meter and sodium ion by Digital Flame Analysis Gallen Kamp. The chlorides were measured by correction, nitrate and sulfate by the flash spectrum apparatus and the total hardness was measured by correcting Na₂EDTA and finding both magnesium and calcium [7] [8]. The results were entered into the SPSS statistical program by adopting the main components method [9] in finding the importance level through the correlation matrix

4. Results and Discussions
Table 1 shows physical and chemical characteristics of studied wells during 2018 of the Al-Humaydat-Mosul area
There is a clear increase in the conductivity values in all studied samples and its values ranged between (7570-670) µm/cm as shown in Table 1. The apparent increase is due to an increase in the concentration of the dissolved solids, which either dissolve from soil salts or wastewater near the wells. Table 1 shows the important level of relationship between Na\(^+\), SO\(_4\)\(^{2-}\), Cl\(^-\), Mg\(^{2+}\), and Ca\(^{2+}\) with EC and correlation coefficients respectively were 0.895, 0.859, 0.835, 0.612, 0.575. The acceptable level of drinking water conductivity is 1000 µm / cm. Consequently if the conductivity is 2500 µm/cm, the water is unpalatable [10]. For the standard of irrigation wells, all wells are either a suitable for some crops or need to be treated (Table 3).

4.2 Total Dissolved Solids TDS:
There is also clear increase in the TDS values in all studied samples and its values ranged between from 1562-6090 mg / l except for one site (well No. 24) as shown in Table 1. This is normal because most of the lands of Mosul within their geological composition contain rocks rich in salts with high solubility in addition to the effect of wastewater to the residential area [11][3]. This makes it invalid according to the European drinking water standards and the WHO (Table 2). The statistical Table 1 shows the correlation coefficients of the total dissolved solids with Cl\(^-\), SO\(_4\)\(^{2-}\), Mg\(^{2+}\), Na\(^+\), Ca\(^{2+}\), EC and the highest correlation coefficients with Na\(^+\) which is 0.891. When compared to Table (4), it is restricted to acceptable and not suitable for home use.
4.3 Bicarbonate (HCO₃⁻)

Bicarbonate showed wide variation in its values ranged from 15-794 mg / l as shown in Table 1. If the bicarbonate exceeds 500 mg / l for the Iraqi specification and WHO the water is hard. Consequently all wells in this area are soft, except for one site. It has been noticed that the correlation coefficient does not exist with any of the components in the Statistical Table (1).

Table 2. Standard Specifications for Drinking Water [13] [12] [2]

| Specifications | WHO    | Iraqi | European |
|----------------|--------|-------|----------|
| SO₄²⁻         | 400-200| 400   | 250-25   |
| CL⁻           | 600-200| 250   | 200-25   |
| Na⁺¹          |        | -     | 175-20   |
| Ca²⁺         | 200-75 | 200   | -        |
| Mg²⁺         | 150-30 | 150   | 50-30    |
| TDS          | 1500-500| -  | 1500    |
| HCO₃⁻        | 100-500| 500   | -        |
| NO₃⁻         | 6-11   | 20    | -        |

Statistical table 1. Correlation Matrix

|          | HCO₃⁻ | CL⁻ | SO₄²⁻ | Mg²⁺ | Na⁺¹ | Ca²⁺ | NO₃⁻ | TDS | EC | D |
|----------|-------|-----|-------|------|------|------|------|-----|----|---|
| HCO₃⁻    | 1     |     |       |      |      |      |      |     |    |   |
| CL⁻      | -0.05 | 1   |       |      |      |      |      |     |    |   |
| SO₄²⁻    | -0.232| 0.332| 1     |      |      |      |      |     |    |   |
| Mg²⁺     | -0.156| 0.234| 0.614 | 1    |      |      |      |     |    |   |
| Na⁺¹     | 0.009 | 0.630| 0.545 | 0.508| 1    |      |      |     |    |   |
| Ca²⁺     | 0.146 | 0.270| 0.631 | 0.023| 0.31 | 1    |      |     |    |   |
| NO₃⁻     | 0.038 | 0.039| 0.038 | -0.125| -0.141| 0.061| 1    |     |    |   |
| TDS      | -0.119| 0.529| 0.788 | 0.819| 0.891| 0.533| -0.144| 1  |    |   |
| EC       | -0.177| 0.581| 0.727 | 0.582| 0.819| 0.598| -0.023| 0.885| 1  |   |
| D        | 0.287 | -0.061| 0.102 | 0.296| 0.345| 0.129| -0.128| 0.293| 0.271| 1 |

Table 3. Irrigation Standards water [14] [2]

| E.C (μm/cm) | Water Quality                  |
|-------------|--------------------------------|
| 1000        | Good water quality             |
| 2000-1000   | Suitable water for sensitive crops |
| 7000-2000   | Suitable water under high clearance and discharge condition |

Table 4. Middle Asia Classification for home use [13]

| Water quality | TDS | Ca²⁺ | Mg²⁺ | Cl⁻ | Na⁺ | SO₄²⁻ |
|---------------|-----|------|------|-----|-----|-------|
| Good          | 1500| 150  | 75   | 600 | 600 | 400   |
| Acceptable    | 2000| 250  | 100  | 700 | 800 | 500   |
| Permitted     | 2500| 300  | 125  | 800 | 900 | 700   |
| Unsuitable    | 3000| 350  | 150  | 900 | 1000| 800   |

4.4 Sulfate (SO₄²⁻)

Table 1 show that the sulfate values exceed the permissible limits for all standard specifications of drinking and irrigation water as well as. The presence of sulfates significantly due to the geological formation of this region as well as from the decomposition of organic materials of all kinds and added to them the increased use of chemical fertilizers. As shown in Statistical table 1, there was a high correlation coefficient for Sulfate (SO₄²⁻) with EC, TDS and low coefficients with Ca²⁺, Na⁺, and
Mg$^{+2}$, with no correlation coefficients for the remaining components.

### 4.5 Chlorides (Cl$^-$)

The values of chlorides varied (11-1296) mg / l, shows that 62% of wells was within the specifications of Iraqi drinking water and WHO, and 90% was good to the permitted as shown in Table 4. The main source of chlorides is the salts of chlorides present in the soil which are characterized by their high solubility with their presence in rainwater or by human activity. The correlation coefficients were clear for chlorides with Na, TDS, and EC, as shown in the Statistical Table 1.

### 4.6 Magnesium (Mg$^{+2}$)

The amount of Magnesium ions is ranges for 34 to 301 mg / l in the studied samples and the correlation coefficients of Mg with Ca$^{+2}$, Na$^+$, TDS, SO$_4^{2-}$. Consequently, most of the wells were outside the specifications for drinking water, while 49%, of the wells water was not suitable for home use according to Table 4. The positive magnesium ion is present with water tests because of its presence in the soil components of the study area.

### 4.7 Sodium (Na$^+$)

The concentrations of sodium ion vary between (21) to (897) mg / l in the studied samples. It is one of the rapidly soluble ions and the effluent through the soil is a source of this ion, with correlation coefficients of (Na$^{+2}$) was CL$^-$, TDS, EC, and it was within the European standard (table 2), where it reached 66%, while most well sites are good and acceptable for home use.

### 4.8 Calcium (Ca$^{+2}$)

Most studied wells are not suitable for drinking because they exceed the limitations and showed the correlation coefficients of calcium ion with SO$_4^{2-}$, EC, and TDS and 79% of wells accepted for home use as shown in Table 4. The presence of calcium ion with magnesium ion caused chalky deposits on pots, tubes and heaters.

### 4.9 Water depth (D)

The depth of the well was indicated in relation to the unit of measurement in meters. The depths of the wells in the study area varied between 11.3 m to 21.2 m as they were excavated by primitive methods. The statistical table 1 did not show that there correlation coefficients with any of the components.

### 4.11 Nitrate (NO$_3^-$)

Table 1 showed the limits of nitrates in well water (0.5-14.5) mg / l, thus would be suitable for drinking and home use purposes; also note that there is no correlation coefficient with other components. The presence of the nitrate ion is not related to the geological formations of the soil and its presence in the water depends on the quality of the source.

### 5. Statistical analysis:

The statistical table number 2 is a statistical description of the basic water components, which are the examined elements, and showed the mean and standard deviation to reduce the dispersion in the data. The statistical table 3 showed that the greatest variance of the main components. The greatest variance was for three components, respectively, 45.73%, 14.342%, and 11.178%. the statistical Diagram (1) shows the distinctive roots of the components that achieve a value greater than one (1), which are three (Eigen value) that go into the regression equation and the remaining components are excluded. For the Statistical table 4 gives the value and name of the main components that has distinctive roots, and the values of these roots are considered independent values in the regression equation while the excluded components have their values based on the distinctive roots which are EC, TDS, and SO$_4^{2-}$. 


### Statistical table 2. Mean and standard deviation

| Parameters | Mean    | Std. Deviation | Analysis N |
|------------|---------|----------------|------------|
| HCO₃⁻      | 229.9286| 152.75129      | 28         |
| Cl         | 241.5357| 241.18557      | 28         |
| SO₄²⁻      | 1707.9286| 643.46475     | 28         |
| Mg²⁺       | 166.0714| 90.63436       | 28         |
| Na⁺²       | 265.9643| 232.36840      | 28         |
| Ca²⁺       | 496.4286| 169.18594      | 28         |
| NO₃⁻       | 8.9393  | 9.11537        | 28         |
| TDS        | 3146.4286| 1192.53649    | 28         |
| EC         | 3644.8571| 1516.07245    | 28         |
| D          | 16.7857 | 3.15486        | 28         |

### Statistical table 3. Most influential components in variance

| component | Initial Eigenvalue | Extraction Sum Squared load | Rotation Sum Squared load |
|-----------|--------------------|-----------------------------|---------------------------|
|           | Total (%)var | Cum% | Total (%)var | Cum% | Total (%)var | Cum% |
| 1         | 4.573  | 45.73 | 45.73 | 45.73 | 4.403 | 44.03 | 44.03 |
| 2         | 1.434  | 14.34 | 60.07 | 14.34 | 1.363 | 13.62 | 57.66 |
| 3         | 1.118  | 11.17 | 71.25 | 11.17 | 1.359 | 13.59 | 71.25 |
| 4         | .963   | 9.63  | 80.87 | 9.63  | 1.359 | 13.59 | 71.25 |
| 5         | .857   | 8.57  | 89.45 | 8.57  | 1.359 | 13.59 | 71.25 |
| 6         | .526   | 5.26  | 94.71 | 5.26  | 1.359 | 13.59 | 71.25 |
| 7         | .277   | 2.77  | 97.48 | 2.77  | 1.359 | 13.59 | 71.25 |
| 8         | .148   | 1.49  | 98.96 | 1.49  | 1.359 | 13.59 | 71.25 |
| 9         | .070   | .69   | 99.66 | .69   | 1.359 | 13.59 | 71.25 |
| 10        | .034   | .34   | 100.00| .34   | 1.359 | 13.59 | 71.25 |

### Statistical table 4. The values of the components, including the three distinct roots

| Parameters | Component | 1 | 2 | 3 |
|------------|-----------|---|---|---|
| EC         | 0.942     | 0.041 | .130 |
| TDS        | .921      | .93 | .263 |
| SO₄²⁻      | .837      | -.173 | .099 |
| Na⁺²       | .823      | .263 | .252 |
| Ca²⁺       | .684      | -.082 | -.318 |
| Cl⁻        | .661      | -.009 | -.134 |
| HCO₃⁻      | -.175     | .844 | -.211 |
| Depth      | .210      | .731 | .311 |
| NO₃⁻       | .081      | -.013 | -.766 |
| Mg²⁺       | .550      | .016 | .593 |
The regression equation:
\[ Y^* = B_0 + B_1X_1 + B_2X_2 + B_3X_3 \]

Where \( X_1, X_2, \) and \( X_3 \) are the independent coefficients are (distinctive roots EC, TDS, SO4); their values have entered the F or t significance test, \( Y \) are the dependent component \( (Na^+, Ca^{2+}, Mg, Cl^-, NO_3, HCO_3, D, Mg^{2+}) \). For Mg ion explain in the Statistical table No. 5, the first part includes the R2 coefficient of determination, which is a measure of the model’s quality, which is 0.65.

**Statistical Table 5. First part:** Output to complete the regression equation

| Model | R   | R Square | Adjusted R Square | Std. Error of The Estimate |
|-------|-----|----------|-------------------|-----------------------------|
| 1     | .810| .655     | .612              | 56.42939                    |

In Table 5, the second part, the variance analysis table; note the significance of the F test, which is equal to \( \text{Sign} = 0.000 \), and this indicates the significance of the regression coefficient.

**Statistical Table 5. Second part:** Output to complete the regression equation

| Model       | Sum of squares | df | Mean Square | F     | Sig |
|-------------|----------------|----|------------|-------|-----|
| Regression  | 145371.241     | 3  | 48457.080  | 15.218| .000|
| Residual    | 78422.616      | 24 | 3184.276   |       |     |
| Total       | 221793.857     | 27 |            |       |     |

In the third part of Table 5 also, note the significance of the regression coefficients \( B_0, B_1, B_3 \) for the t test at the level of significance of 5%, 1%, and insignificance the regression treatment \( B_2 \) is at the 5% and 1% level of significance.
### Statistical Table 5. Third part: Output to complete the regression equation

| Model                        | Unstandardized coefficients | Standardized coefficients | t  | Sig |
|------------------------------|-----------------------------|----------------------------|----|-----|
|                              | B                           | Std. Error                 | Beta |     |
| Constant                     | 166.071                     | 10.664                     | 15.573 | .000|
| REGR factor score 1 for Analysis 1 | 49.893                     | 10.86                      | .550 | 4.594 | .000|
| REGR factor score 2 for Analysis 1 | 1.461                     | 10.86                      | .016 | .135 | .894|
| REGR factor score 3 for Analysis 1 | 53.784                     | 10.86                      | .593 | 4.953 | .000|

The equation for linear regression is:

\[ Y^\* = B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 \]

\[ Y^\* = 166.071 + 49.893 X_1 + 1.461 X_2 + 53.784 X_3 \]

For example, Mg (Y) dependent component equal \( \text{EC} = X_1 \) (49.893) plus \( \text{TDS} = X_2 \) (1.461) plus \( \text{SO}_4^{2-} = X_3 \) (53.784). The numbers (10.664, 10.860, 10.860 and 10.860) represent the standard error of the regression coefficients.

### 6. Conclusions:

The study demonstrated, through statistical treatment that the EC electrical conductivity, total dissolved solids, TDS and \( \text{SO}_4^{2-} \) sulfate are the distinctive roots in the benign-conductor residences and the independent agent will be within the regression equation and thus the work can be reduced. The study also demonstrated that the groundwater in the study area is not suitable for drinking as well as for home use the water quality was inappropriate due to TDS, \( \text{SO}_4^{2-} \). As for their classification of irrigation, most of studied wells are suitable, and are subject to high conditions of liquidation and disposal.

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