

The Relationship between Electrical Conductivity and Total Dissolved Salts Estimated by the Gravimetric Method and the Effect of Dilution of Some Groundwater Samples on Electrical Conductivity

العلاقة بين الموصلية الكهربائية والأملاح الذائبة الكلية المقطرة بطريقة الوزن، وتأثير تخفيف بعض عينات المياه الجوفية على الموصلية الكهربائية.

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Abstract

A laboratory experiment was conducted in the Soil Chemistry and Fertility Laboratory at the Faculty of Agriculture - Sebha University, Libya to study the effect of the relationship between electrical conductivity and total dissolved salts estimated by the gravimetric method and the effect of dilution of some groundwater samples on the **electrical conductivity**. To study this relationship,

63 water samples were collected from different groundwater wells from different areas of the Fezzan region, Libya. The electrical conductivity (EC_{25}) of each sample was estimated, and the amount of salts was estimated by the gravimetric method. The amount of salts was calculated with the information about the electrical conductivity by the currently used method using the equation: $mg/l = EC_{25} * 640$ when EC_{25} is less than $5 dSm^{-1}$. If EC_{25} is greater than $5 dSm^{-1}$, to find the amount of total dissolved salts (TDS), we substituted in the following equation: $mg/l = EC_{25} * 800$. When applying these equations, we did not obtain correct results for the amount of total salts, but rather obtained results far from the reality obtained by the gravimetric method. However, when applying the equations that we obtained as a result of this research, which are as follows:

First, when EC_{25} is less than $5 dSm^{-1}$, we arrived at the following equation:

$$mg/l = 705.649EC_{25} dSm^{-1} - 372.282.$$

When substituting in this equation, we obtained results very close to the amount of salts obtained by the gravimetric method.

Secondly, when EC_{25} is greater than $5 dSm^{-1}$, we arrive at the following equation:

$$mg/l = 761.00 EC_{25} dSm^{-1} - 180.316.$$

Also, when we substituting in this equation, we get results very close to the amount of salts obtained by the gravimetric method.

Thirdly, we may sometimes look at the dilution process (two, three or four times), then we estimate the conductivity by multiplying the conductivity by the reciprocal of the dilution to get the original conductivity, but when we apply that, we get a value that was not the same as the value before the dilution. To avoid making mistakes when doing the dilution process and to get a value (EC) closer to the original conductivity, this is done by multiplying the electrical conductivity measured at any dilution * the correction factor calculated at this dilution.

The correction factor obtained for dilutions two, three, four, five, and six times is 0.83, 0.78, 0.69, 0.66, 0.65 respectively.

Keywords: – **Electrical Conductivity, Total dissolved solids, Dilution, water quality. Wells water.**

الملخص

أُجريت تجربة معملية في مختبر كيمياء التربة والخصوبة بكلية الزراعة - جامعة سبها، ليبيا، لدراسة تأثير العلاقة بين الموصلية الكهربائية والأملاح الذائبة الكلية المقدره بطريقة الوزن، وتأثير تخفيف بعض عينات المياه الجوفية على الموصلية الكهربائية. لدراسة هذه العلاقة، جُمعت 63 عينة مياه من آبار جوفية مختلفة من مناطق مختلفة في منطقة فزان، ليبيا. قُدِّرت الموصلية الكهربائية (EC25) لكل عينة، وقُدِّرت كمية الأملاح بالطريقة الوزنية. حُسبت كمية الأملاح بناءً على معلومات الموصلية الكهربائية المستخدمة حاليًا باستخدام المعادلة $mg/l = EC25$: 640 * عندما تكون EC25 أقل من 5 ديسي سيمنز-1. إذا كانت EC25 أكبر من 5 ديسي سيمنز-1، لإيجاد كمية الأملاح الذائبة الكلية (TDS)، عوضنا بالمعادلة التالية. $mg/l = EC25 * 800$: بتطبيق هذه المعادلات، لم نحصل على نتائج صحيحة لكمية الأملاح الكلية، بل حصلنا على نتائج بعيدة كل البعد عن الواقع الذي تم الحصول عليه بالطريقة الوزنية. ومع ذلك، بتطبيق المعادلات التي توصلنا إليها نتيجة هذا البحث، وهي كما يلي:

أولاً، عندما تكون قيمة EC25 أقل من 5 ديسي سم-1، توصلنا إلى المعادلة التالية:
 $mg/l = 705.649EC_{25} dSm^{-1} - 372.282..$

عند التعويض في هذه المعادلة، حصلنا على نتائج قريبة جداً من كمية الأملاح التي تم الحصول عليها بالطريقة الوزنية.

ثانياً، عندما تكون قيمة EC25 أكبر من 5 ديسي سم-1، توصلنا إلى المعادلة التالية:
 $mg/l = 761.00 EC_{25} dSm^{-1} - 180.316.$

أيضاً، عند التعويض في هذه المعادلة، حصلنا على نتائج قريبة جداً من كمية الأملاح التي تم الحصول عليها بالطريقة الوزنية.

ثالثاً، قد ننظر أحياناً إلى عملية التخفيف (مرتين أو ثلاث أو أربع مرات)، ثم نُقدِّر الموصلية بضرب الموصلية في مقلوب التخفيف للحصول على الموصلية الأصلية، ولكن عند تطبيق ذلك، نحصل على قيمة مختلفة عن القيمة قبل التخفيف. لتجنب الأخطاء عند إجراء عملية التخفيف وللحصول على قيمة (EC) أقرب إلى الموصلية الأصلية، يتم ذلك بضرب الموصلية الكهربائية المقاسة عند أي تخفيف في معامل التصحيح المحسوب عند هذا التخفيف.

معامل التصحيح الناتج عن التخفيفات مرتين، ثلاث، أربع، خمس، وست مرات هو 0.69، 0.78، 0.83، 0.66، 0.65 على التوالي.

الكلمات المفتاحية: الموصلية الكهربائية، إجمالي المواد الصلبة الذائبة، التخفيف، جودة المياه. مياه الآبار.

Introduction

Libya is considered one of the countries located in arid and semi-arid regions, with limited water resources, as groundwater in Libya constitutes about 98% of water resources, making it the main source of water used and groundwater is exploited in Libya in three ways: agriculture, industry, and urban use, where the first use consumes more than 85% of the total water withdrawn, while the share of the second and third uses does not exceed 15% (Zaid, 2018) and the average share per person is estimated at about 120 cubic meters per year, according to the World Water Development Report 2015 (Hamidan, 2017) including water used for agricultural purposes. The importance of studying the quality of irrigation water under arid and semi-arid regions lies in its containing different concentrations of dissolved salts, which may result in many problems for irrigation as a direct result of the accumulation of salts in the soil from added water, and the severity of this problem increases with the increase in the degree of salinity of irrigation water, which may negatively affect the productivity of the planted crops. The groundwater areas in Libya are divided into five water basins: The Jaffara Plain Basin, the Green Mountain Basin, the Kufra and Sarir Basin, the Hamada al-Hamra Basin (the central region basin), and the Murzuq Basin (the Fezzan Basin). It is located in southwestern Libya and is the largest groundwater basin in Libya. It is located in the heart of the Sahara Desert, where rainfall is scarce and temperatures are high. With the increase in population growth and technological development, the amount of unregulated water withdrawals has increased. To determine the quality of irrigation water, this is done through chemical analyses in order to avoid the damage that may occur from using water that is not suitable for irrigation (Al-Najm and Hamadi, 1980). Among the criteria used to evaluate irrigation water is knowing the concentration of total dissolved salts and its ionic composition (Fadel et al., 2012). Irrigation water is classified and its suitability for agriculture depends on measuring its electrical conductivity (FAO) Ayers and Westcot, 1985). Water was also classified according to the Food and Agriculture Organization in 1992 based on knowing the concentration of salts in water, which is done by measuring the electrical conductivity of water (Rhodes et al., 1992). (Tchnobanoglous and Kreiti, 2002) defined the electrical conductivity of water as the ability of a water

sample to transmit an electric current, and it is measured by special devices in the laboratory or on site in the field. While the concentration of dissolved salts expresses all the dissolved materials in the water, and is estimated in the laboratory. There is a strong relationship between the electrical conductivity of water and the concentration of dissolved salts in it (Uwidia and Ukulu, 2013). The electrical conductivity of water is a direct function of the total concentration of salts (Total Dissolved Solids, TDS). The electrical conductivity values of water depend on the concentration and quality of salts in it. The reason for the increased salinity of well water is due to the effect of the geological formation of the region, and the salinity of the water seeping into the groundwater through the permeable layers of the earth and what it does to dissolve the salts during its seepage (Sheet, 2004). Some statistical methods can be used to describe the relationship between the concentration of dissolved salts in water and electrical conductivity. For example, the correlation analysis between any two variables of water quality elements gives an idea about the chemical composition of the water source in a given area, according to a study (Sanjay. 1993). The regression equation is useful, especially when experimental data are limited (Gajendran, 2011). Using simple linear regression, the mathematical relationship between the concentration of dissolved salts in water and its electrical conductivity can be found (Uwidia and Ukulu, 2013). Total salts are an important element in water evaluation and refer to the amount of dissolved salts in water and are estimated as a percentage or in milligrams/liter of water. When analyzing water and determining its salt content, the cations that represent the basic part of salts such as calcium, magnesium, sodium and potassium are estimated, as are the anions that represent the acid part of salts such as bicarbonates, carbonates, chlorides and sulfates (Al-Zubaidi, 1989). There are several methods used for measurement, including the electrical conductivity method (EC) and the gravimetric method (drying method), where the total dissolved salts are measured by evaporating a known weight of water until it dries completely. However, this measure is not accurate because there are several forms of salts in one sample, and evaporation may result in the loss of one of these forms (Al-Zubaidi, 1989). The electrical conductivity method is considered one of the best methods for measuring salinity due to its accuracy and speed, in addition to

being inexpensive. The electrical conductivity method depends on the fact that the current flowing in the saline solution increases with the increase in the salinity of the solution under standard conditions (Al-Khatib, 1998). The concentration of salts is considered the first characteristic on which the classification of water quality is based. It has been known for a long time that salty water is harmful to plants. With the progress of studies, a number of important points have become clear regarding the effect of salt concentration in water, including its effect on the structure of the soil in which water is used and the drainage condition of soil irrigated with salty water. Interest in the properties of water and the amount of harmful elements that may be present in it has increased, especially in dry areas. Several attempts have been made to classify water in terms of its quality or suitability for irrigation. These divisions were based on two basic characteristics: the first is the concentration of total salts in the tested water and the second is the specific composition of the salts (Balbaa, 1986). To find the correct relationship between electrical conductivity (EC) and total dissolved salts (TDS), the idea of this research came, which aims to find the relationship between the electrical conductivity of some irrigation water samples in decimens/meter (dSm^{-1}) and the concentration of total dissolved salts (TDS) estimated by the gravimetric method in milligrams/liter (mg/l), Calculating the regression equation for the previous relationships (the relationship between electrical conductivity (in decimens/meter) and total dissolved salts estimated by the gravimetric method (mg/liter)), as well as the effect of dilution on the electrical conductivity of some samples with high salt concentrations.

Materials and research methods:

Sampling is a very important and sensitive process and all necessary precautions must be taken while doing it. 63 samples were collected from wells used for irrigation from several different areas in the Fezzan region. The samples were collected in 0.5 liter bottles after cleaning and drying them. Before collecting the samples, the wells were operated for 15 minutes so that the sample would be representative of the actual water from the well as well as in order to remove the stored groundwater. Before filling, the bottles were washed with the source water. The samples were transferred directly to the laboratory and first the electrical

conductivity reading was taken directly using an (EC meter) device according to what was reported by (Richard, 1954). The samples were kept in the refrigerator until the amount of salts in them was estimated. Secondly, the salts were estimated by the gravimetric method by weighing a clean, dry cup and placing a known amount of water in it and placing it in a water bath until the water evaporated. The dishes were then placed in the oven at a temperature of 105C° for 24 hours to ensure that the sample was completely dry. The cup was weighed again to determine the amount of salts in the sample according to what was stated in (Richard, 1954). Also, the dilution process was carried out for samples with high electrical conductivity and the relationship between electrical conductivity and dilution was studied. Also, statistical work was done to find the regression equation, which enables us to determine the form of the relationship between two random variables, as well as finding the correlation coefficient, by which we can know the degree of strength of the relationship between the two variables.

Results:

First: – The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) for all samples up to the degree of electrical conductivity ($\text{EC } 15.38 \text{ dSm}^{-1}$)

As shown in Table No. (1) which shows the relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method in mg/L for all samples, the table indicates that the lowest value of electrical conductivity was ($\text{dSm}^{-1} 0.478$) and the highest value of electrical conductivity was (15.38 dSm^{-1}) while the weight of salts was the lowest value (298 mg/L) and the highest value (11574 mg/L), the relationship equation for this relationship was reached, which was ($\text{mg/l} = 794.790 \text{ EC}_{25} \text{ dSm}^{-1} - 574.274$). The correlation coefficient was ($R=0.993^{**}$), and it was highly significant. as shown in Figure No. (1)

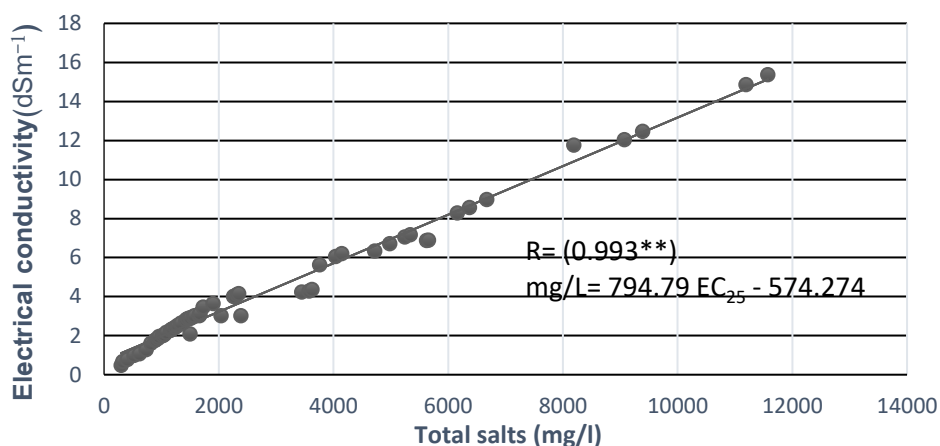


Figure (1) The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) up to an electrical conductivity of (15.38 dSm^{-1}).

Table (1) The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) for all samples up to ($\text{EC } 15.38 \text{ dSm}^{-1}$)

Sample number	Dissolved salts (mg/L)	EC_{25} (dSm^{-1})	Sample number	Dissolved salts (mg/L)	EC_{25} (dSm^{-1})
1	298	0.478	33	1574	3.02
2	326	0.684	34	1660	3.03
3	402	0.771	35	1668	3.05
4	520	0.987	36	1672	3.14
5	618	1.08	37	1726	3.47
6	736	1.29	38	1898	3.64
7	818	1.62	39	2040	3.02
8	888	1.76	40	2258	4.00
9	904	1.79	41	2268	4.02
10	938	1.86	42	2320	4.11
11	956	1.96	43	2346	4.16
12	1018	2.01	44	3446	4.23
13	1022	2.01	45	3572	4.29
14	1050	2.06	46	3626	4.36
15	1496	2.09	47	3760	5.63
16	1088	2.17	48	4040	6.05
17	1162	2.29	49	4144	6.21
18	1164	2.29	50	4716	6.34



19	1178	2.32	51	4982	6.71
20	1194	2.35	52	5622	6.88
21	1242	2.44	53	5654	6.90
22	1274	2.50	54	5246	7.05
23	1288	2.53	55	5336	7.17
24	1334	2.62	56	6160	8.28
25	1340	2.64	57	6370	8.56
26	1446	2.84	58	6672	8.97
27	1428	2.81	59	8188	11.76
28	1460	2.87	60	9070	12.05
29	1500	2.88	61	9390	12.47
30	1504	2.92	62	11190	14.87
31	1552	2.96	63	11574	15.38
32	2388	3.02			

Second: – The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) for samples with electrical conductivity from (0.474 dSm^{-1}) to electrical conductivity (5.63 dSm^{-1}).

To study the relationship between low values of electrical conductivity between $0.474, 5.63 \text{ dSm}^{-1}$ and the corresponding values of total salts between $298, 3760 \text{ mg/l}$ as shown in Table No. (1) and Figure No. (2) Which establishes the relationship between electrical conductivity (dsm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) at an electrical conductivity between ($0.474, 5.63 \text{ dSm}^{-1}$), where the

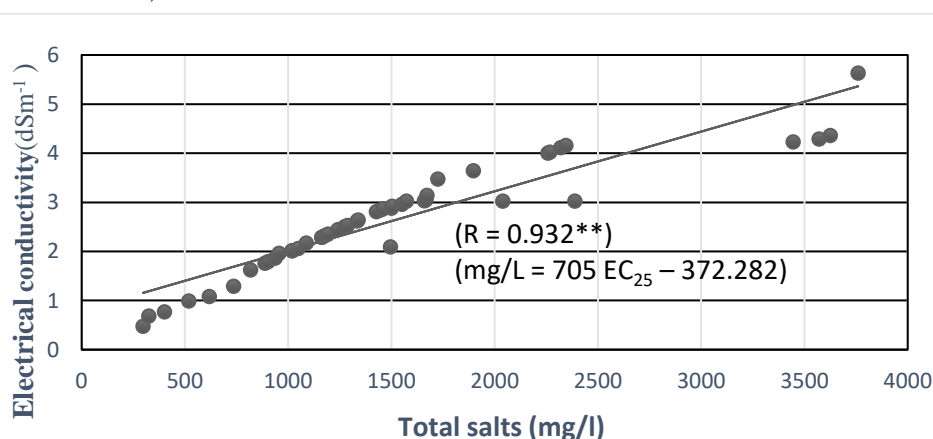
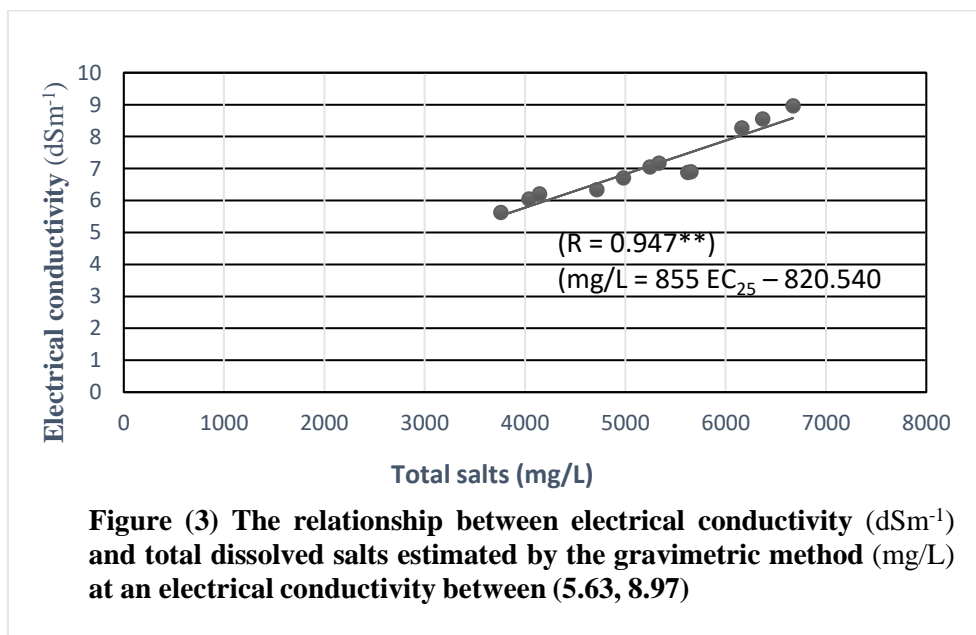


Figure (2) The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) at an electrical conductivity between ($0.474, 5.63$)

results obtained were statistically analyzed to know the regression equation and the correlation coefficient, and the regression equation was reached as follows ($\text{mg/L} = 705 \text{ EC}_{25} \text{ dSm}^{-1} - 372.282$) and the correlation coefficient was as follows ($R = 0.932^{**}$) meaning that it is highly significant.

Third: - The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/l) for samples with electrical conductivity from (5.63 dSm^{-1}) to (8.97 dSm^{-1}).

To study the relationship between the average values of electrical conductivity of $5.63, 8.97 \text{ dSm}^{-1}$ and the corresponding values of total salts between 3760 and 6672 mg/l as shown in Table No. (1) and Figure No. (3) which shows the relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/l) at an electrical conductivity between 5.63 and 8.97 dSm^{-1} , where the results obtained were statistically analyzed to find out the regression equation and the correlation coefficient, and the regression equation was reached as follows ($\text{mg/l} = 855 \text{ EC}_{25} \text{ dSm}^{-1} - 820.540$) The correlation coefficient was as follows ($R = 0.947^{**}$), meaning that it is highly significant.



Fourth: - The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method in mg/L for samples with electrical conductivity from (5.63 dSm^{-1}) to (15.38 dSm^{-1})

To study the relationship between the average values of electrical conductivity of 5.63, 8.97 dSm^{-1} and the corresponding values of total salts between 3760 and 11574 mg/L , as shown in Table No. (1) and Figure No. (4), which shows the relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) at an electrical conductivity between (5.63, 15.38), where the results obtained were statistically analyzed to find out the regression equation and the correlation coefficient, and the regression equation was reached as follows ($\text{mg/l} = 761.00 \text{ EC}_{25} - 180.316$) The correlation coefficient was

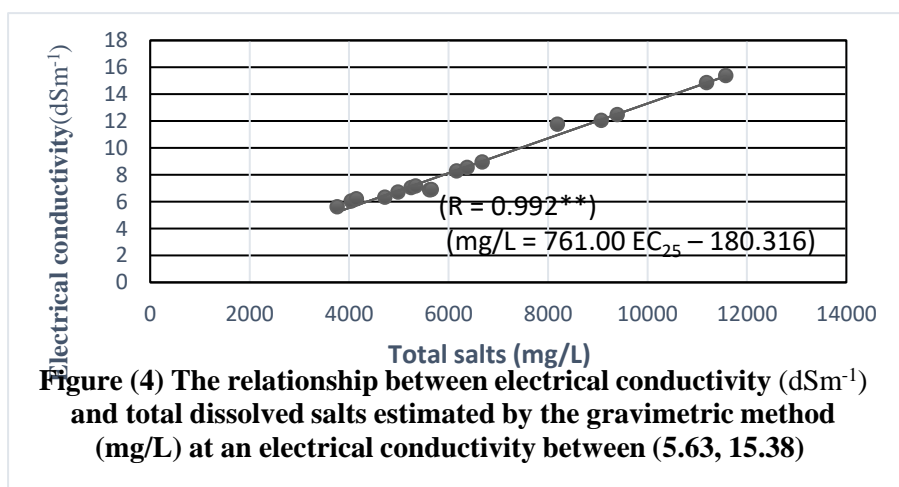
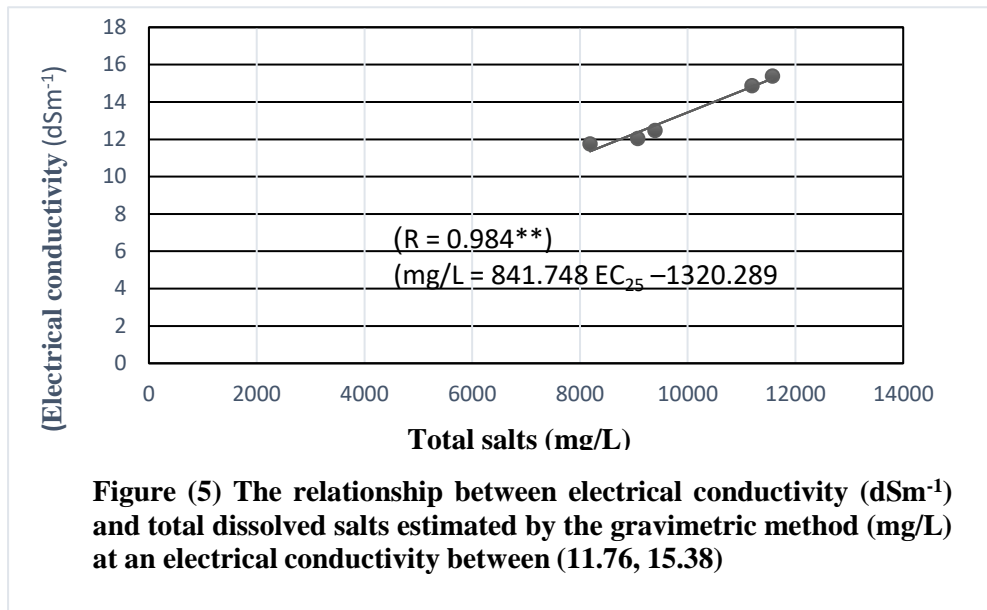


Figure (4) The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) at an electrical conductivity between (5.63, 15.38)

as follows ($R = 0.992^{**}$) i.e. it is highly significant.

Fifth: – The relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/l) for samples with electrical conductivity from (11.76 dSm^{-1}) to electrical conductivity (15.38 dSm^{-1}). To study the relationship between the average values of electrical conductivity of 11.76, 15.38 dSm^{-1} and the corresponding values of total salts between 8188 and 11574 mg/L , as shown in Table No. (1) and Figure No. (5), which shows the relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (mg/L) at an electrical conductivity between 11.76 and 15.38 dSm^{-1} , where the results obtained were statistically analyzed to find out the regression equation and the correlation coefficient, and the regression equation was reached as follows ($\text{mg/L} = 841.748 \text{ EC}_{25} \text{ dSm}^{-1} - 1320.289$) The correlation coefficient was as follows: ($R = 0.984^{**}$) meaning that it is highly significant.



Effect of dilution on electrical conductivity

In this process, a dilution process was carried out for some samples in which the electrical conductivity value exceeds 5 dSm^{-1} , as we may have considered carrying out such a process because the device cannot read samples with high concentrations. As noted in Table No. (2), which shows the effect of dilution on electrical conductivity, in all samples that underwent a dilution process, starting with the sample with electrical conductivity (5.63 dSm^{-1}) and ending with the sample with electrical conductivity (15.38 dSm^{-1}), the sample was diluted 5.63 dSm^{-1} at a ratio of 1:1 and 1:2, i.e. it was diluted twice and three times, and the first and second dilutions were multiplied by the reciprocal of each dilution, so we obtained the following values: $6.70, 6.81 \text{ dSm}^{-1}$, respectively. As noted, we did not obtain the same original electrical conductivity value (5.63 dSm^{-1}), as we were supposed to obtain theoretically, and this is due to the increase in activity Ions in the solution, resulting in an increase in electrical conductivity, and so on for all electrical conductivity values that were determined by the dilution process, as shown in the aforementioned table 2. To restore the values to their original state, we multiply by the correction factor obtained. For example, if we multiply the value obtained after dilution twice for sample 50 (7.44 dSm^{-1}) by the correction factor obtained (0.83), we obtain a value of 6.18, which is closer to reality (6.34 dSm^{-1}) with a difference not exceeding 0.16, while the difference reaches 1.1 dSm^{-1}

¹ if the value is not multiplied by the correction factor obtained. Thus, for all other dilutions, multiply by their corresponding dilution factor (0.78, 0.69, 0.66, 0.65), respectively.

Table No. (2) Effect of dilution on electrical conductivity

Sample No	Electrical conductivity	Electrical conductivity measured after dilution (EC) *				
		Reciprocal of dilution				
		2*	3*	4*	5*	6*
47	5.63	6.70	6.81			
48	6,05	7.56	8.04			
49	6.21	6.90	7.35			
50	6.34	7.44	7.86			
51	6.71	7.58	8.04			
52	6.88	7.90	8.40			
53	6.90	8.06	8.43			
54	7.05	8.08	8.46			
55	7.17	8.10	8.50			
56	8.28	9.62	9.09			
57	8.56	9.94	10.40			
58	8.97	11.31	11`84			
59	11.76	14.84	15.54	16.72	17.71	
60	12.05	15.08	15.78	17.04	17.55	
61	12.47	15.60	17.10	19.25	19.49	
62	14.87	17.92	19.53	20.48	21.50	21.96
63	15.38	20.26	22.71	22.76	24.30	24.90
Correction factor		0.83	0.78	0.69	0.66	0.65

Discussion:

Through the results obtained and explained previously, which show the relationship between electrical conductivity (dSm^{-1}) and total dissolved salts estimated by the gravimetric method (milligrams/liter), first, in the case of EC_{25} less than 5 for the samples, as shown in Table No. (1), and in order to obtain the amount of salts in milligrams/liter with the information of electrical conductivity (EC_{25}), we

substitute in the equation ($\text{mg/L} = \text{EC}_{25} * 640$) (Al-Khatib 1998) and according to this equation, if EC_{25} is less than 5, then if its value is according to Table (1), let it be 2.01 dSm^{-1} , and according to Al-Khatib's equation, the amount of salts is 1286.4 mg/L .

If we apply in the equation we obtained ($\text{mg/L} = 705.649\text{EC}_{25} - 372.282$) when the conductivity is less than 5, the amount of salts equals 1046.07 mg/l and this result is closer to the amount of salts obtained practically 1022 mg/L as shown in Table No. (1) and it is noted that by applying the equation obtained, results are given closer to reality. Secondly, in the case of EC_{25} greater than 5 and let it be (12.05 dSm^{-1}) as shown in Table No. (1) and the amount of salts corresponding to it was 9070 mg/l , and as is known we can know the amount of salts by knowing the electrical conductivity.

By substituting in the equation ($\text{mg/L} = \text{EC}_{25} * 800$) (Al-Khatib 1998), we obtain a quantity of salts equal to 6940 mg/l , and as noted, there is a large difference between it and the quantity of salts obtained practically, this difference is estimated at about 2130 mg/L .

However, if we apply in the equation obtained ($\text{mg/L} = 761.00 \text{EC}_{25} - 180.316$) when the conductivity is greater than 5, and by substituting the value of EC_{25} with its value (12.05 dSm^{-1}), we obtain the value 8989.734 mg/l , and as noted, there is a very small difference, and therefore the result obtained is closer to the practical result obtained (9070 mg/L).

Thirdly, in the case of performing the dilution process for the samples, whether this dilution is two, three, four or more times, we multiply the EC obtained as a result of the dilution by the reciprocal of the dilution. Theoretically, we were supposed to obtain the same value as the original EC, but this did not happen. Rather, we obtained an EC higher than the original EC. Therefore, this must be taken into consideration when performing the dilution process for any solution. To avoid making mistakes when performing the dilution process and to obtain the original (EC) value, multiply the electrical conductivity measured at any dilution * the correction factor calculated at this dilution, as shown in Table No. (2).

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