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## **SALINITY FUNCTIONS FOR GROUNDWATER AT SAFWAN, SOUTH IRAQ**

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*Function type between electrical conductivity and total dissolved solids is polynomial and the exponential which are taken according to the water quality classification for irrigation. These functions relate the EC in ds/m to the salinity in term of part per million or to the half salinity in equivalent per million directly or in form of logarithmic transformation. A statistical test for best fit is considered for the selection of the type of a representative function. The irrigation salinity classification is taken as index of grouping extended to moderately sensitive vegetable crop tomato as salinity tolerance rating up to 15 ds/m groundwater salinity used for irrigation at Safwan area of arid climate. All fitted type of functions is programmed within a flow model computer of basic language by which the output from of both methods is an average final value. Thus the coast of analysis is reduced. This type of functions is standard for groundwater and so designed to involve the water type. The involved parameter for Safwan area is 0.5 for more than 5 ds/m in case of ppm half total and it is 1.3 for less than 5ds/m salinity, or using the direct model.*

## INTRODUCTION

All irrigation waters contain at least small amounts of dissolved mineral salts. Any mineral exposed at earth's surface may decompose, and its matter may become dissolved in water by a process known as weathering. One of the principal agents of weathering is water itself (Al Dahan 2015). A way for water does this type of work is by freezing and then melting again, over and over. When that is happened within cracks, the rock eventually will be split apart. At a long time, this action can disintegrate rocks into smaller and smaller fragments. Other way of the water does this kind of work is by reacting chemically with a mineral consisting rock, possibly eventually altering or replacing those minerals. So, during the weathering, water exerts an influence on the geologic materials (Hem, 1989). The net result is that rocks are broken down smaller and smaller and, where water is present, minerals may be dissolved. The minerals and rocks that disintegrate during weathering affect the water that acts on them. Thus, the very act of dissolving imparts to nearby water a mineral content that is at least a little bit different than previously existed at that location. Though weathering wears rocks away over geologic time, matter is not destroyed. What is once solid rock becomes fine sediment and colorless, dissolved mineral matter. At some places, residual or secondary minerals, principally clays, were formed during the weathering. Eventually, all these materials are carried by streams and rivers to the ocean. (Alhumoud, Al-Ruwaih, and Al- Dhafeeri, 2010).

The total dissolved solids content of recycle water is not much different from that of the fresh water. Typically, it is slightly more than for the fresh water (Hem, 1985) (Ayars, Christen, Soppe, and Meyer. 2006). Recycled water is creating by extensively treating for wastewater effluent to remove the chemical and biological contaminants.

Though purring to a high degree, recycled water usually contains a little amount of salt picked up by the water during its previous cycle of using. That's why, for recycled water, the total dissolved solids content typically is exceeded that of original source of water by a little amount. The enrichment of the concentration usually is between 140 to 400 mg/L (Taylor and Stefan, 2009). Minerals of soil like calcite ( $\text{CaCO}_3$ ) and feldspars (calcium-sodium and potassium-rich silicates) are low soluble and contribute to water small increases in salinity. Highly soluble minerals like gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) are high soluble and can contribute significant concentrations of  $\text{Ca}^{2+}$  and  $\text{SO}_4^{2-}$  ions. Gypsum solubility in pure water is about 2600 mg/L; but, the presence of magnesium and sodium ions in the water can increase the solubility even higher (Reluy, Paz-Bécares, Zapata, and Sánchez. 2004). Other highly soluble minerals may be found in many salt-affected soils such as sodium chloride, sodium sulfate, and magnesium sulfate. These salts are readily leached by the rain or water of irrigation, seepage more down in the soil profile. Usually such seepage of salts is beneficial to plants, because the cations and anions end up beneath, and out of reach for roots of plant. There are wide types of plants adversely affected by high concentrations of salt ions (Alsam, Jassim and Hanna, 1990). Many factors depend on the type of salt that forms in a soil, the climate, the chemical composition of the soil and the chemistry of the irrigation water. The rate for any salts accumulate is depending on these same factors. It also depends on the quantity of annually water as irrigation and the total of rain fall with snow (Hassan and Al Dahan, 1988) (Holman, Allen, Cuthbert and Godemiaux, 2012). Parameters of water quality and constituents of interest inorganic ions and compounds usually found in natural water are bicarbonate  $\text{HCO}_3^-$ , Sulfate  $\text{SO}_4^-$ , Chloride  $\text{Cl}^-$ , Nitrate  $\text{NO}_3^-$ , Silica  $\text{Si}(\text{OH})_4$  and many of cations such as  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Fe}^{2+}$ . Regard to surface irrigation, the most important water quality parameters are TDS, EC, known as total dissolved solids and electrical conductivity respectively. Concentrations of specific ions or elements that can be toxic to plants, especially sodium  $\text{Na}^+$ , chloride  $\text{Cl}^-$ , and boron B, plus, bicarbonate  $\text{HCO}_3^-$ , carbonate  $\text{CO}_3^{2-}$ , sodium adsorption ratio SAR and pH, moreover the concentrations

of nitrogen, potassium, phosphorus, residual chlorine, potentially detrimental to the growth of plants, suspended solids, which can lead to clogging for water application systems, and the concentrations for trace elements (Boyed, 2000). (Al Dahaan, 2000). Many other parameters of the biological constituents for water or the effects of the concentration by pathogens and viruses (estimated as number per 100 milliliters of water), dissolved oxygen and the concentrations of organic chemicals which exert an oxygen demand under their decomposition (Ayars, Hutmacher, Schoneman, Soppe, Vail, and Dale. 2000) (WHO, 2007). Study area represents part of southern sector of western desert at Iraq (Budy and Jassim, 1987). It bounded by latitude  $30^{\circ} 05' 00'' - 30^{\circ} 10' 00''$  and longitudes  $47^{\circ} 40' 00'' - 47^{\circ} 47' 00''$  (Figure 1). The upper part of Dibdiba formation is predominating at steady are in the south of Iraq. Dibdiba has a large extension over large area in the southern part of Iraq plus some areas in the middle west of Iraq. It is a part of alluvial fans deposits of the stable shelf at tectonic map in Iraq. Dibdiba formation age is upper Miocene–Pliocene, and it is consisting of sand, gravel with pebbles of igneous rocks and white quarts somewhere cemented into a hard grit (Jassim and Coff, 2006). The studied area is about 75 square kilometers of Dibdiba plain. According to (Al-Naqib, 1967), Dibdiba plain is considered as a part of western desert extended from the south to Middle West of Iraq.

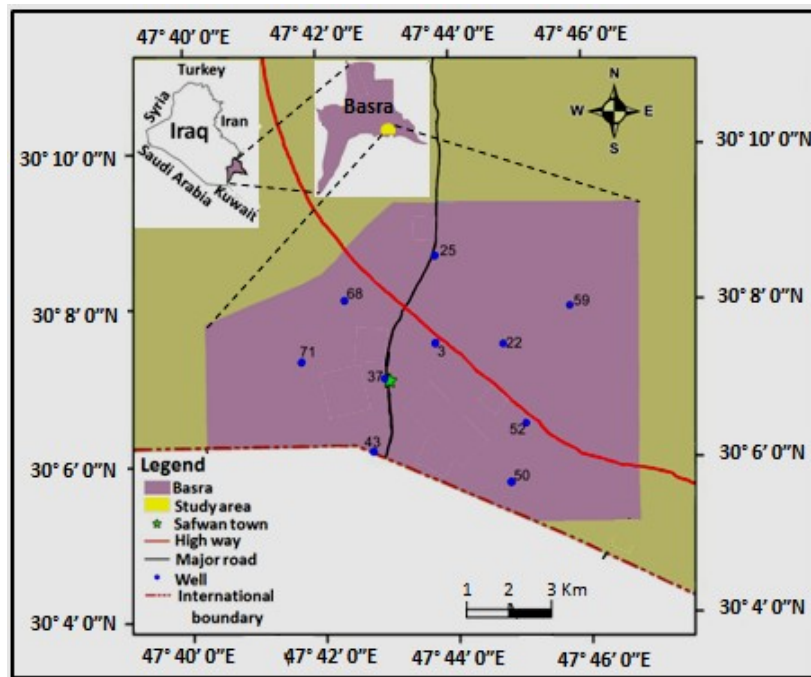


Figure.1. Location map for hand-dug well at study area.

It has sandy surface resulted from the reworking processes of the upper part of Dibdiba (A mountain named Jabal Sanam) as a Hill with elevation about 152 meters above sea level. So there are many shallow wades and many tidal flat at south and south west part (Al- Kubaisi, 1996). It is well known at Iraq as an agricultural area for production of tomato, onion and garlic between the August and March period. Irrigation at this area is from the underground water by way of hand-dug wells of large diameter. The salinity of water is changing locally and through the vertical and horizontal flowing during the pumping. Steady area contains two saline aquifers. First is less than 10 dS/m, and the second is more than 10dS/m. The predominant ions in the two aquifers are the sulphate and sodium. Deposits of Dibdiba formation is the actual open aquifer for water irrigation, so in this steady, is a trial to find the function between total dissolved solids and electrical conductivity of irrigation water by a model for

the studied area and the essential model which reflects the type of groundwater in the whole aquifer (Al-Kubaisi,1999).

## MATERIALS AND METHODS

Ten water samples were collected from the hand-dug wells at the studied area in November, 2014. The collected samples were chemically analyzed for the major cations and Anions. Unstable parameters such as pH and electrical conductivity EC were measured in the field using pH meter and EC meter. Sodium and potassium contents were determined by using Flame photometer. Calcium and magnesium contents were determined by EDTA. Chloride was determined using the (APHA, 1992) procedure. Sulfate concentrations were obtained using Technical ultra violet spectrophotometer U.V. Carbonate and bicarbonate contents were measured by acid-base titration (Adams, 2001). TDS was measured using vaporization at 105 °C (Boyed, 2000). The accuracy of analysis is tested by triple analysis for two random samples, and the results are less than 5% or not significant (Hem, 1991). (Fetter 1980). To get the correlation coefficients for the salinity groups, Laboratory experiments statistical analyses were performed for the variables of electrical conductivity and salinity by computer program depending on suggested limits of irrigation water for tomato as vegetable crops (Davis, 2002). The tomato is medium salt tolerance up to 15ds/m (Al-Janabi, 2008, Qannam, 2003, Don, 1995) and Table 1, shows the salinity boundaries ds/m for irrigation at the study site.

Table1. Salinity boundaries ds/m for irrigation at studied area.

Frequency		Locality	Less than upper limit		More or equal than lower limit		
A model for Whole Area	Zero	Outside of studied area	0.750	>	EC	≥ 0.250	
	Zero		1.500	>	EC	≥ 0.750	
	Zero		2.250	>	EC	≥ 1.500	
	29	A model of study area	Inside of studied area	5.000	>	EC	≥ 2.250
	15			10.000	>	EC	≥ 5.000
	4			15.000	>	EC	≥ 10.000
35							

Correlation coefficient R and Chi square methods are applied to ensure of correlation relation between the measurement of salinity, electrical conductivity and total dissolved solids by two ways:

1-Direct relationship method, it depended on:

a-Find the direct correlation between electrical conductivity and total dissolved solids within three functions, that are exponential and the correlation relationships functions of first and second degrees.

b-The function above is taken as logarithmic transformation, then to find the average for the all constituents.

2- Indirect relationship method: It depended on finding the relation in 1.a, between electrical conductivity and half of total dissolved solids as equivalent per million (Meddis, 1975) (Hassan and Al Dahan. 1988) (Reluy, Paz-Bécares, Zapata, and Sánchez. 2004). Basic language of computer program (Appendix 1) is applied for the hydrochemical model, which represents all relationships as a model for groundwater function (Hassan, and Al Dahan. 1988). It gives the possible lower limit of values and corrects from data of special relation for any region in whole studied area.

Finally, the program finds the constant of correction for Safwan area from the basic model and compares it with upper and lower limit of chemical analysis (Xu and Eckstain, 1997; Davies, 2002).

## **RESULT AND DISCUSSION**

The correlation between electrical conductivity and total dissolved solids is divided into seven ranges:

1-Correlation relations between 0.250 EC 0.750.

Results of computer indicated the value of correlation coefficient R between electrical conductivity and total dissolved solids for this group is more than 97%, and this value is more than R at statistical tables, or the possibility of increment of relationship is not significant. A relative improvement for  $R^2$  in the equation of first and second degree in both case, but the expected increment is not significant. The original function is corresponding more than 95% at match level by Chi square.

2- Correlation relations between 0.750 EC 0.1.500.

Within salinity limits, the correlation degrees have very high significant values in all used functions and the difference between correlation degrees is not significant at 95% level. Also Chi square is explained more than 95% and very high corresponding between the derivative and original function.

3- Correlation relations between 1.500 EC 2.250.

This range represented high degree of correlation within significant level 99% for the test of  $R^2$  and the choose of correlation between derivative and original function by Chi square plus half of equivalent per million.

4- Correlation relations of salinity between 2.250 EC 5.000.

It represent more significant of correlation relationships according to total dissolved solids.

5- Correlation relations of salinity between 5.000 EC 10.000.

This group represent a rebound of correlation relationships because the groundwater is at 95% level has a high corresponding between derivative and original function (Figure 2).

6- Correlation relations of salinity between 10.000 EC 15.000.

There is some of salinity data within this rang. The correlation relationship is significant at 95% level and has high corresponding between derivative and original function.

The samples of studied are standardization by salinity data for non derivative underground wells and the results were high significant with limit difference only +5%. Range of  $5.000 > EC \geq 2.250$  of studied area is used in basic program (Meddis, 1975) (Hassan and Al Dahan. 1988) (Reluy, Paz-Bécares, Zapata, and Sánchez. 2004). The average of general sample is 1.3 EC as ppm and the half of total dissolved solids as equivalent per million is corresponding 100%, while second state of 5000 ds/m is corresponding for total dissolved solids plus 0.5 modification for half of total dissolved solids. The general function for groundwater is very high corresponding with data of correlation relationship for

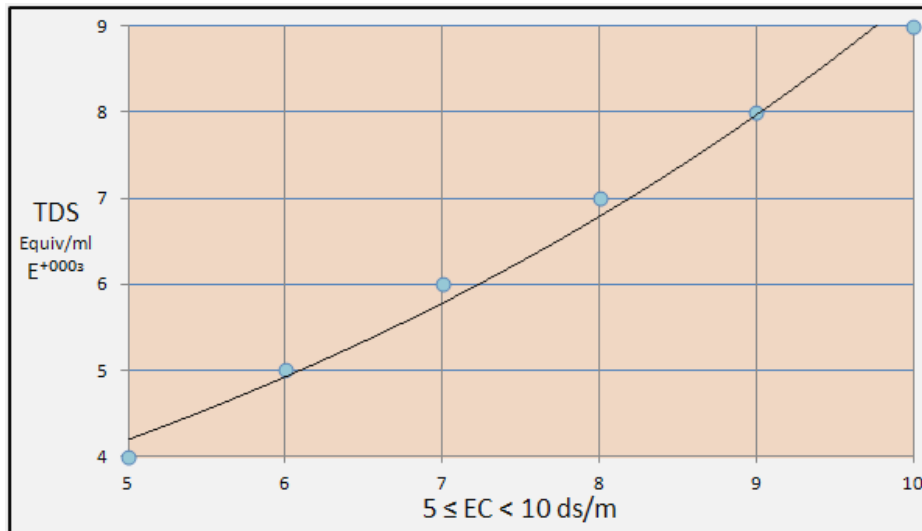


Figure.2. Relationship between total dissolved solids and electrical conductivity.

salinity within 10.5 ds/m, or no deviation of salinity in this value, but the effect of groundwater quality on the relation between salinity and half of total dissolved solids as equivalent per million was 100%, so this variable put in at the computer to give the requirement data. Value of more than 10 ds/m and less than 15ds/m is represent the acceptable salinity value for computer at corresponding 100%.

Also the model is standardization, when the salinity is more than 10 and less than 11ds/m, the significant differences become less than 5%, so when the salinity is more than 11 and less than 15 ds/m, the significant differences is also less than 5%. (Kangas, 1993). (Datta, Sharma and Sharma. 1998). (Lamsal, Guna, Paudyal and Saeed. 1999). (Prendergast, 1993).

## CONCLUSION

1-Range 0.250 EC 0.750: Relationship between EC and TDS is corresponding up  $R^2$ -95.8% and 96.42% for second degree equation. The use of logarithmic transformation gave values of correlation 95.04-97.04 for the first and second functions respectively. Result of half salinity values as equivalent per million is 96.8% higher correlation corresponding and the logarithmic transformation gave correlation corresponding  $R^2$ -97.7%, where it is more accurate for this range of salinity.

2-Range 0.750 EC 0.1.500: 89.3% of EC variation can be explained by TDS according to liner function, while it was 97.7%. The logarithmic liner function was of second order with value more than its logarithmic transformation. The liner function with first order of half TDS as equivalent per million gave 97% correlation and 94% corresponding, while it's logarithmic transformation led to the correlation for liner and second order function up to 97%, other meaning we can use the liner function directly.

3-Range 1.500 EC 2.250: Salinity ppm correlation has 99.94% for liner function, 99.95 for logarithmic. Correlation of function for second order is 99.98%; it's corresponding 99.97, 99.98 respectively and 99.98% correlation by logarithmic transformation of the function for second order at both units. Result of half salinity as equivalent per million gave preference for this unit because it has very high correlation and corresponding up to 100%.

4- Rang 2.250 EC 5.000: The result of correlation and corresponding is 99.98% and 100% respectively for all cases.

5- Range 5.000 EC 10.000: Only 84.7% of result for the variation of EC with TDS can explained for liner function at this rang. It is due to the variation of groundwater.

6- Range 10.000 EC 15.000: Result of correlation and corresponding for the variation of EC with TDS as ppm is 98.6%, while with half TDS as equivalent per million is 100%.

All the data is stored as a hydrochemical program written in the basic computer language, in order to interpret data for other similar aquifers and receive the results (Appendix 1).

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## APPENDIX 1

Electrical conductivity salinity program in Basic computer code

```

10 DISP "APPENDIX : DIRECT MODEL SZ ( TDS PPM = 2250 < = EC < 15000 ) "
20 PRINT
30 FOR 1=1 TO 10
40 BEEP 3*1 , 7*1
50 NEXT 1
60 DISP " RUN PUT YES "
70 INPUT DON$
80 IF DON$ = " YES" THEN GOTO 90 ELSE GOTO 1240
90 DISP " TOTAL DISSOLVED SOLIDS AND ELECTRICAL CONDUCTIVITY "
100 WAIT 2000
110 CLEAR
120 DISP " INPUT EC IN MIC . MHOS/CM 25 DEG. CENTG. "
130 INPUT EC
140 DISP " PRINTING CODE IS 1 OR 10 "
150 INPUT PC
160 PRINTER IS PC
170 CLEAR
180 IF EC < 5000 THEN GOTO FOURTH
190 IF EC < 10000 THEN GOTO FINISH
200 IF EC < 15000 THEN GOTO SEXITH
210 STOP
220 FOURTH:
230 PRINT " 2250 < = EC < 5000 "
240 PRINT

```



```

250 TDS11 = -502.7 + 0.8888*EC
260 TDS12 = -195.4 + 0.7076*EC + 0.0002524*EC^2
270 TDS13 = 0.14722*EC^1.1979
280 TDS21=-0.837+1.198*LGT (EC)
290 TDS22=-0.825+1.194*LGT (EC)-0.0005616*LGT EC^2
300 TDS31=1.942+0.01082*EC
310 TDS32=-19.3+0.02307*EC-0.000001708*EC^2
320 TDS33=0.011475*EC^0.09976
330 TDS41=1.94+0.9975*LGT (EC)
340 TDS42=-16.76+9.405*LGT (EC)-1.192*LGT (EC)^2
350 GOTO OUTPRINT
360 FIFTH:
370 PRINT "5000<=EC < 10000"
380 PRINT
390 TDS11=541.4677+0.798*EC
400 TDS12=-1224.3325+1.3002*EC-0.00003453*EC^2
410 TDS13=1.584*EC^0.9328
420 TDS21=0.19974+0.9328*LGT (EC)
430 TDS22=-13.3761+8.0026*LGT (EC)-0.92*LGT (EC)^2
440 TDS31=6.7154+0.005211*EC
450 TDS32=4.663+0.0058*EC-0.00000004101*EC^2
460 TDS=0.2484*EC^0.8429
470 TDS41=-1.6048+0.8429*LGT (EC)
480 TDS42=-0.0324+0.02362*LGT (EC)+0.1067*LGT (EC)^2
490 GOTO PUTPRINT
500 SEXITH:
510 PRINT "10000<EC<15000"
520 PRINT
530 TDS11=-9757.832+1.6625*EC
540 TDS12=-10161.846+1.7323*EC-0.0000029912*EC^2
550 TDS13=0.0000046735*EC^2.0436
560 TDS21=-4.3304+2.0436*LGT (EC)
570 TDS22=-29.5858+14.477*LGT (EC)-1.5301*LGT (EC)^2
580 TDS31=-9.4434+0.0063257*EC
590 TDS32=-3.8604+0.0053614*EC+0.000000041334*EC^2
600 TDS33=0.0013813*EC 1.1478
610 TDS41=-2.8597+1.1478*LGT (EC)
620 TDS42=-2.7745+1.1058*LGT (EC)+0.0051649*LGT (EC)^2

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```

630 GOTO OUTPRINT
640 REM NO MORE
650 OUTPRINT
660 PRINT "METH00 1 :DIRECT RELATION"
670 PRINT
680 PRINT USING 690 ; TDS11
690 IMAGE "FIRST ORDER TDS (PPM)=" , 10D . 1D
700 PRINT USING 710 ; TDS12
710 IMAGE "SECOND ORDER TDS (PPM)=" , 100 . 10
720 PRINT USING 730 ; TDS13
730 IMAGE " EXPONENTIAL TDS (PPM)= , 10D . 1D
740 TDS14=TDS11/TDS12+(TDS13)/3
750 PRINT USING 760 ; TDS14
760 IMAG "AVERAGE TDS (PPM)=" , 10D . 1D
770 PRINT
780 PRINT "LOG LOG TRANSFORMATION METHOD 1"
790 PRINT
800 TDS21=10^TDS21 @TDS22=10^TDS22
810 PRINT USING 820 ; TDS21
820 IMAGE "ORDER . 1 TDS(PPM)=" ,10D . 1D
830 PRINT USING 840 ; TDS22
840 IMAGE "ORDER . 2 TDS22
850 TDS23=(TDS21/TDS22)/2
860 PRINT USING 870 ; TDS23
870 IMAGE "AVERAGE TDS(PPM)" , 10D . 1D
880 PRINT
890 TOT1=(TDS14+TDS23)/2
900 PRINT USING 910 ; TOT1
910 IMAGE "FINAL AVERAGE METHOD 1 TDS (PPM) = ,10D . 1D
920 PRINT
930 WAIT 3000
940 CLEAR
950 PRINT "METHOD 2: HALF EPM VALUE TO EC"
960 PRINT
970 PRINT USING 980 ; TDS31
980 IMAGE "ORDER . 1 TDS(0.5EPM)=" , 10D . 2D
990 PRINT USING 1000 ; TDS32
1000 IMAGE "ORDER . 2 TDS(0.5EPM)=" , 10D . 2D

```

```
1010 PRINT USING 1020 ; TDS33
1020 IMAGE "EXPONENTIAL TDS10 . (5EPM)=", 10D . 2D
1030 TDS34=(TDS31+TDS32+TDS33)/3
1040 PRINT USING 1050 ; . TDS34
1050 IMAGE "AVERAGE TDS(0.5EPM)=", 10D . 2D
1060 PRINT
1070 PRINT "LOG LOG TRASFORMATION METHOD 2"
1080 PRINT
1090 TDS41=10^TDS41 @ TDS42=10^TDS42
1100 PRINT USING 1110 ; TDS41
```

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