Estimating the Total Dissolved Salts of Soil from the Grain Size Distribution Curve

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Abstract: ***A procedure is presented to calculate Total Dissolved Salts of Soil. The grain size distribution curve could be uttered as a normal probability distribution cumulative curve and the frequency congruous to Total Dissolved Salts is consequently found. This frequency is adopted as the percent finer congruous to the Total Dissolved Salts .a new relation is found for the Estimate the Total Dissolved Salts by using the final percent finer. A lot of Grain size distribution curves of soil samples are gathered and the value for the Total Dissolved Salts of each soil sample is determined using the final percent finer. The values of the Total Dissolved Salts obtained from these gradation curves are compared with those found using the ordinary test for each soil sample. The results have shown good agreement for using the final percent finer that presented in this paper to determine the total dissolved salt for soils instead of using the usual long test.***

Keywords: Total dissolved salts, Final Percent Finer, Sedimentation, Grain Size Distribution

1. Introduction

The understanding of the soil properties started with what can be observed, for example the particle size distribution could be consider as "a list of values or a mathematical function that defines the relative amounts of particles present, sorted according to size". Particle Size Distribution is also known as grain size distribution [13].

The behavior of most soil physical properties and a lot of chemical properties are affected by the particle size present. [19].

Particle size distribution in soil is one of the more interesting soils physical properties. The information provided by Particle Size Distribution is often used to infer soil functioning and use [16].

The standard analysis of particle size distribution involves the dispersion of mineral particles after destroying the organic matter [21]. Particles of sand size (0.05- 2.00 mm) are usually determined using sieving. The sieve defines a particle diameter as the length of the side of a square hole through which the particle can just pass [2].Finer particles are usually determined by classical sedimentation methods such as hydrometer or pipette [14].

The hydrometer method is "based on the change of density of a soil and water suspension upon the settling of the soil particles". By using Stokes' Law the settling times is predict for different size of particles. Stokes' law states" that the rate which particles fall in a viscous medium (water) is governed by the radius of the particles and the force due to gravity". A special hydrometer, (calibrated in terms of the grams of soil suspended) is used to measure density. The hydrometer is gently placed into the cylinder containing the suspension after periods of time and a reading taken by determining where the meniscus of the suspension strikes the hydrometer [8].

Sieving combined with hydrometer method (SHM) has been adopted as an international standard to determine quantitatively the (PSD) of soils [2], and [11].

However the common source of Particle Size Distribution data is the process of sedimentation of particles in water and the most popular techniques are the hydrometer method, this method is based on the Stoke's law and employs the relationship among time, travel distance, and the diameter of a sphere subject to sedimentation in a viscous liquid [23].

The standard test method for particle-size analysis [4] relies on the well-known Stokes' equation for estimating particle diameters [6], and [1]. The validity of Stokes' equation for fine-grained particle size analysis is based on assumptions "including:

1) Particle-to-particle interference and boundary effects from the walls of the sedimentation column are negligible.
2) Particle sizes are small enough to ensure that the induced fluid flow s well within the laminar flow regime.
3) Actual particle shapes can be approximated by smooth spheres".

For all practical purposes, the first two assumptions are satisfied [18].

The first assumption is validated by limiting the maximum concentration of soil in the suspension. It has been shown that if no more than 50 g of dry soil are used in 1000 cc of suspension, the effects of interference are negligible [27].

2. Water Ratio

The ratio of soil to water influence to the amount of solutes. Therefore, this ratio is standard to obtain results that could be applied and interpreted universally [25]. This ratio is used because "it is the lowest reproducible ratio at which the extract for analysis can be readily removed from the soil with common laboratory equipment", i.e., pressure or vacuum, and because this ratio is often related in a predictable manner to field soil water contents [20]. Soil solutions obtained at lower soil moisture conditions are more labor intensive and require special equipment [19].

3. Definition of the Saline Soils

Soils with high levels of soluble salts are called saline soils. Soils high in sodium are called sodic soils. Saline-sodic soils are high in both soluble salts and sodium [15].

The soluble salt content may be used to correct the index properties of soils (water content, void ratio, specific gravity, degree of saturation, and dry density).ASTM D4542-07.

Total salt concentration in the bulk solution of well-drained soils in humid and temperate regions is generally in the range 0.001 to 0.01 M [7].

4. The Chemical Components of (TDS)

TDS is consist of the following principal cations (or positively charged ions): "Sodium (Na+), Calcium (Ca2+), Potassium (K+), Magnesium (Mg+2), and anions (or negatively charged ions): Chloride (Cl-), Sulfate (SO4 2-), Carbonate (CO3 2-), Bicarbonate (HCO3 -), and, to a lesser extent by Nitrate (NO3 -), Boron (B3+), Iron (Fe3+), Manganese (Mn2+) and Fluoride (F-)" [22].

5. Method of Measuring the Total Dissolved Salts

The total dissolved salts are determined by (two methods) : The evaporation method, made by using evaporation process of a known quantity of water and the quantity then weighted after drying to find the weight of dissolved materials. This method has a number of limitations (9). The electrical conductivity method (EC) is based on the fact that the transmission of electrical currents by a salt solution increases with salt concentration under standard conditions. The (EC) can be measured by placing a solution sample between two electrodes to produce electrical currents under standard conditions and geometry. The resistance of the solution is then measured and converted to equivalent resistance.

6. Previous Studies

In 2003 Zhu et al. presented a relationship between the readings of hydrometer and the total phosphorus which was linear with (R^2=0.97) for a single nursery barn manure source. The study showed that the error in regression equations is larger at lower manure P levels.

Timmerman in 2004 collected 200 samples by a pig industry co-operator from three types of operations: sow, nursery and finisher. The samples were analyzed by using a laboratory hydrometer made to produce a specific gravity reading and a standard laboratory method to determine dry matter and phosphorus (P) concentrations. The readings of the hydrometer were taken after mixing the samples .Linear regression analysis or the obtained data as shown in Figure (1).

This paper aims to predict the total dissolved salts from the final percent finer which was found from the grain size distribution curve.

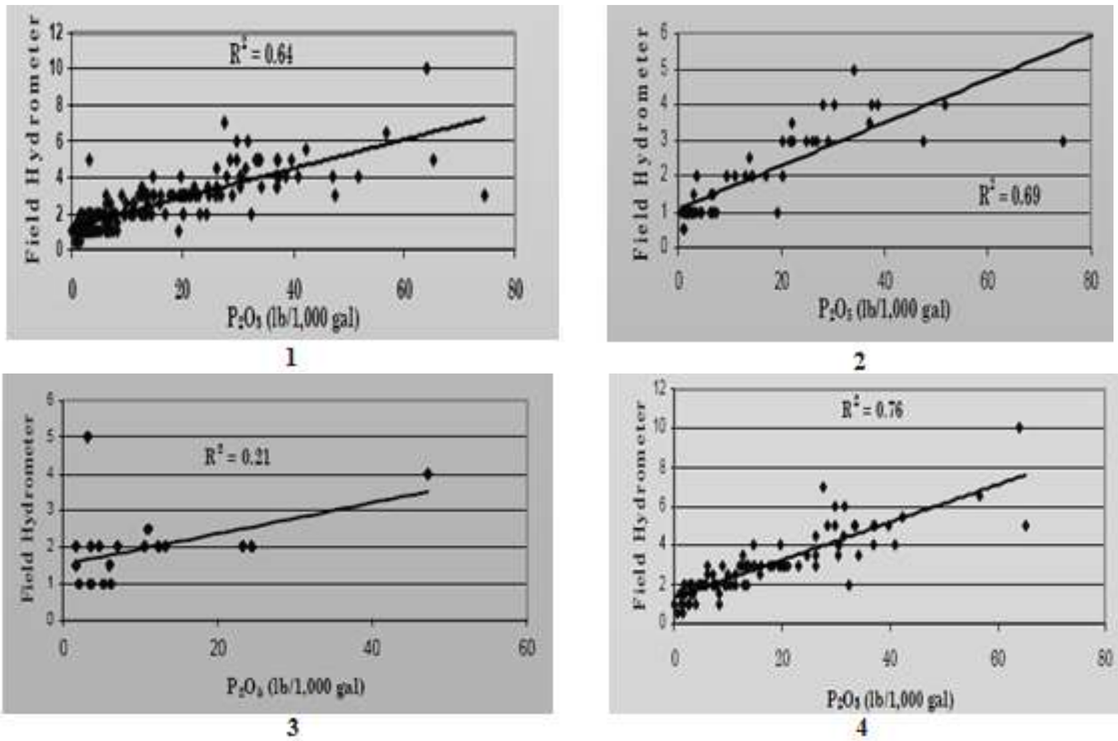


Figure 1: Field hydrometer readings vs. P_2O_5- pooled sow, nursery and finisher data respectively. Timmerman, 2004

7. A Proposed Equation for the Determination of the Total Dissolved Salts

The aforementioned steps were devoted to determine the total dissolved salts. It is well known that the more dissolved solutes, the denser the solution.

The final point of the distribution curve almost represents the salt particle. From this the derivation is start to find the total dissolved salts in soil sample as bellow:

The final reading of the hydrometer= (r - r_w)

To find that final reading (r – r_w) the normal distribution curve divided into a specified number of intervals, this intervals represented the values of the percentage finer (N_f), the (r – r_w) is determined from the Equation (1) taken from lamb and Whitman, 1951.as bellow:

$$N_f = \frac{G}{G-1}\frac{V}{W_s}\gamma_c\left(r - r_w\right)\times 100\% \qquad (1)$$

Where
G = Specific gravity of soil
V = volume of suspension (1000) cm^3
Ws = weight of dry soil
γ_c =unit weight of water at temperature (usually 20^o C)
r =hydrometer reading in suspension
r_w = hydrometer reading in water (at same temperature as suspension)
To put a single equation for simple assessment of (r – r_w), several trials to solve Equation (1) are performed using different number of intervals. The results of these trials are the same results as shown that 200 intervals would be enough to assess properly accurate values for (r – r_w)

Table 1: The percentage finer Nf corresponding to the for the n=100 intervals

n=100									
Nf	r-rw	Nf	r-rw	Nf	r-rw	Nf	r-rw	Nf	r-rw
1	0.031538	21	0.662303	41	1.293068	61	1.923833	81	2.554598
2	0.063077	22	0.693842	42	1.324607	62	1.955372	82	2.586137
3	0.094615	23	0.72538	43	1.356145	63	1.98691	83	2.617675
4	0.126153	24	0.756918	44	1.387683	64	2.018448	84	2.649213
5	0.157691	25	0.788456	45	1.419221	65	2.049986	85	2.680751
6	0.18923	26	0.819995	46	1.45076	66	2.081525	86	2.71229
7	0.220768	27	0.851533	47	1.482298	67	2.113063	87	2.743828
8	0.252306	28	0.883071	48	1.513836	68	2.144601	88	2.775366
9	0.283844	29	0.914609	49	1.545374	69	2.176139	89	2.806904
10	0.315383	30	0.946148	50	1.576913	70	2.207678	90	2.838443
11	0.346921	31	0.977686	51	1.608451	71	2.239216	91	2.869981
12	0.378459	32	1.009224	52	1.639989	72	2.270754	92	2.901519
13	0.409997	33	1.040762	53	1.671527	73	2.302292	93	2.933057
14	0.441536	34	1.072301	54	1.703066	74	2.333831	94	2.964596
15	0.473074	35	1.103839	55	1.734604	75	2.365369	95	2.996134
16	0.504612	36	1.135377	56	1.766142	76	2.396907	96	3.027672
17	0.53615	37	1.166915	57	1.79768	77	2.428445	97	3.05921
18	0.567689	38	1.198454	58	1.829219	78	2.459984	98	3.090749
19	0.599227	39	1.229992	59	1.860757	79	2.491522	99	3.122287
20	0.630765	40	1.26153	60	1.892295	80	2.52306	100	3.153825

These values of the percentage finer are plotted against the (r – r_w) as shown in Figure 2.

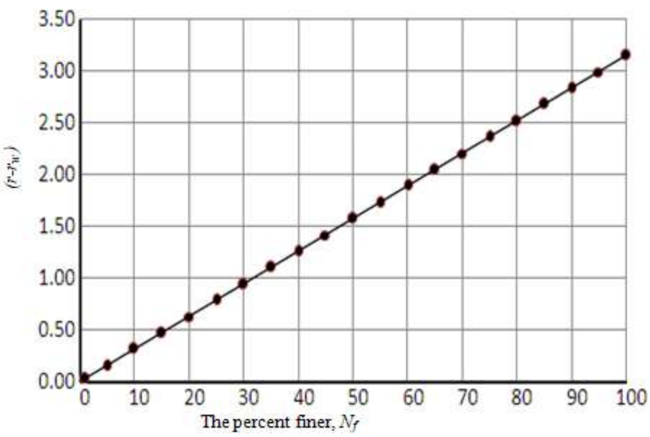


Figure 2: The percent finer corresponding to the for the case of 100 intervals

A regression analysis has been performed and a best-fit curve is found to be the following: -

$$\left(r - r_w\right) = 0.000155 N_f + 0.001 \qquad (2)$$

With N_f in percent. The coefficient of correlation is found to be 0.999999≈1, which is very high indeed. It is obvious now that for a certain soil the (r – r_w) can be easily determined from the grain size distribution curve of that soil. It will be the value corresponding to the(r – r_w) is determined from the Equation. (2). As (r – r_w) is determined; the (R-R_W) in (gm/l) can be calculated using Eq. (3) after lamb and Whitman, 1951.as bellow:

$$\left(R - R_w\right) = \left(r - r_w\right)\times 1000 \qquad (3)$$

The total dissolved salts of the soil can be determining using equation (4) after [26], and [14] as bellow:

$$P = \frac{\left(R - R_w\right)}{C_0}\times 100 \qquad (4)$$

Where:
P = total dissolved salt in percent
C_0 = sample weight = 50 g
In g/l ($R-R_W$)
Equation (4) simplified to be as bellow:

$$P = \frac{\left(\left(r - r_w\right) \times 1000\right)}{50} \times 100 \quad (5)$$

So the total dissolved salts can be calculated directly in equation (6) as below:

$$TSS = \left(0.0031 N_f + 0.02\right) \times 100 \quad (6)$$

An application for this equation is presented in example below.

8. Application Example

In a conventional total dissolved salts (TSS) test carried out for a soil containing a highly soluble salt, and its equal to (3.11)
The ordinary hydrometer test made and the grain size distribution curve drawn and the final passing percent equal to 5% so to find the (TSS) the Equation (6) by Appling as below:

$$TSS = \left(0.0031 \times 5 + 0.02\right) \times 100 = 3.55$$

So the (TSS) found by applying the derived equation equal to (3.55) while the (TSS) found by ordinary method equal to (3.11), and that's give a very good result.

9. Equation Verification

To verify the validity of the derived equation two branch of shoring are made: the first branch represent experimental test made for this research and the second one represent a data collected for this purpose.

9.1 Branch NO. One (experimental test)

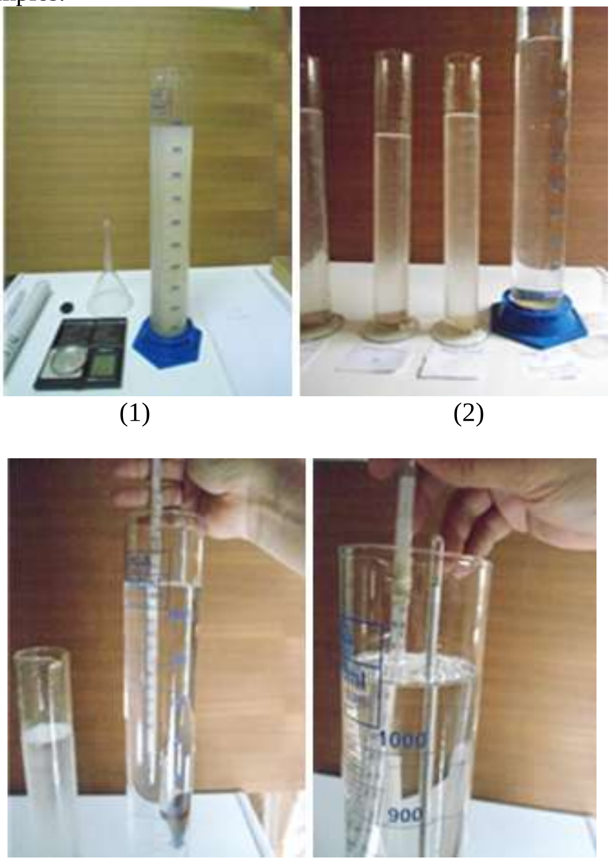
9.1.1 Samples Properties

The soils used in this study are collected from several places in Baghdad for the testing which label as sample 1 to sample 15.

9.1.2. Experimental Procedure

For each sample the following tests are done as bellow to verify the reliability of the equation proposed in this paper:
1) Standard hydrometer test according to [4].
2) The total dissolved salts test as described in [12].
3) The specific gravity test according to ASTM standard no D 854-02.

Figure 3 show recommended hydrometer test for the soil samples.



(1) (2) (3) (4)

Figure 3: Recommended hydrometer test for the soil samples.

Figure 4 show recommended total dissolved salts test for the soil samples

1 2 3

Figure 4: Recommended total dissolved salts test for the soil samples.

The hydrometer tests are shown in Figure 5 and Figure 6 as bellow:

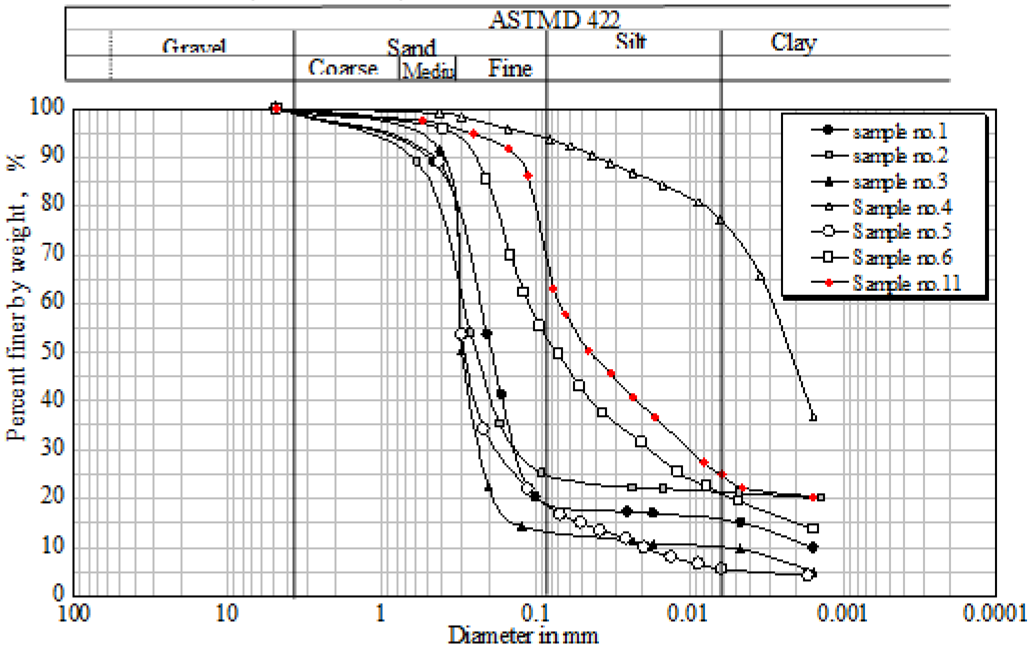


Figure 5: Samples grain size distribution curves.

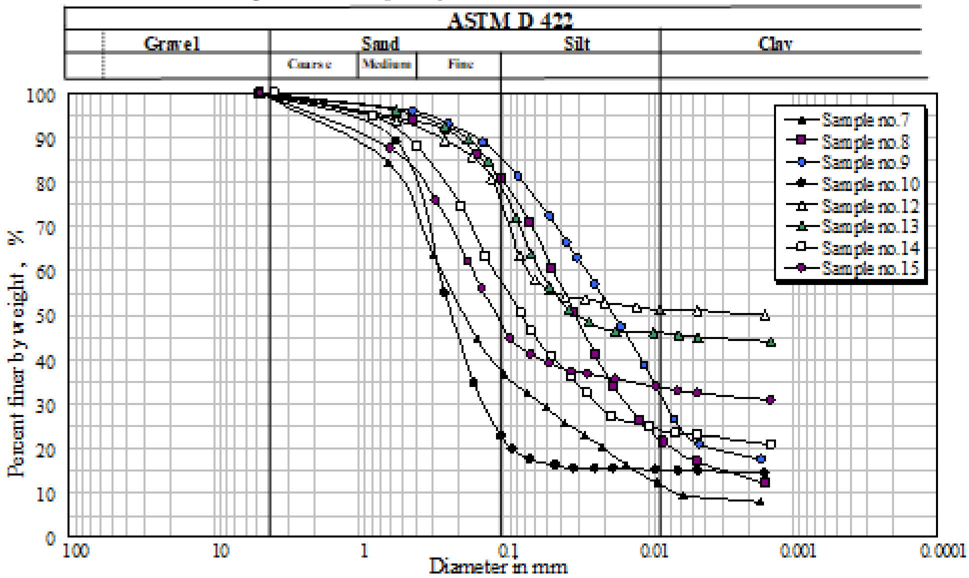


Figure 6: Samples grain size distribution curves.

The results of the tests are shown in table 2 as bellow:

Table 2: The experimental results

Sample no.	TDS by ordinary method %	G_s	N_f %	TDS by eq. 4
1	3.11	2.69	5	3.55
2	8.32	2.68	20	8.2
3	5.22	2.68	10	5.1
4	11.81	2.73	36.7	13.377
5	4.21	2.67	4.19	3.2989
6	5.1	2.73	13.7	6.247
7	4.19	2.69	8.08	4.5048
8	3.82	2.72	12.1	5.751
9	7.53	2.73	17.73	7.4963
10	6.32	2.67	14.5	6.495
11	8.51	2.77	20.4	8.324
12	18.45	2.74	50	17.5
13	15.33	2.78	44	15.64
14	8.61	2.69	21	8.51
15	11.35	2.75	30	11.3

The values of the total dissolved salts obtained by applying the derived equation in this research have been drawn with the total dissolved salts tested by ordinary method as shown in Figure 7.

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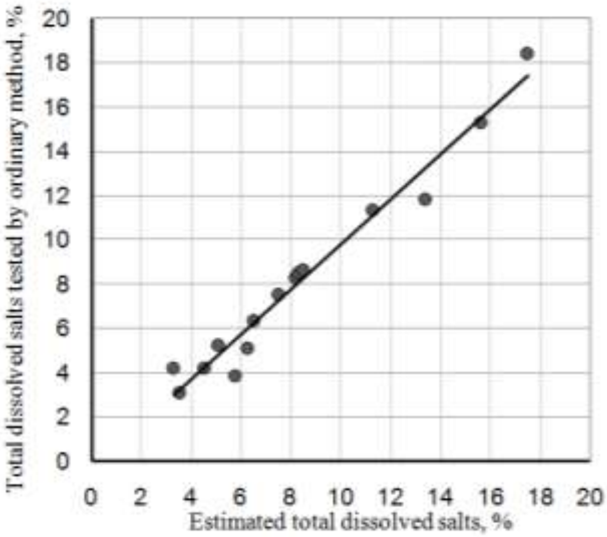

Figure 7: Comparison between values of Total dissolved salts tested by ordinary method and estimated total dissolved salts by the derived Equation (4) for the tested soils samples.

The comparison has proved good agreement and the coefficient of correlation between the results of the total dissolved salts tested by ordinary method and that's estimated by the derived equation, and it is found to be (0.98396), which is very close to (1.0). And the root square equal to (0.9682).

9.2 Branch NO. Two (data collected)

Grain size distribution curves for 40 different soil samples have been analyzed. Table (3) represents the properties and the description of these samples.

The total dissolved salts could be found by applying the derived equation no. (4). which shown in the last column in Table (4).

These results drown in Figure (8) to find the compatibility between the actual and estimated total dissolved salts.

Table 3: The properties and the description of the samples

Sample no.	sample name	depth	Location	Soil Description	Gs	OR %	CL- mg/l	CL- %	SO3 %	gypsum %	TDS %
1	BH 14	1-1.5	Holy Karbala	brown silty sand	2.67	1.9	-	-	0.563	1.21	3.71
2	BH 3	0.5-1.0	Diyala-Al-Lukmaniya	Brown silty clay with fill material	2.75	0.8	100	0.024	3.82	8.31	8.87
3	BH 2	6-6.5	Diyala-Al-mekdadiah	Brown clayey silt with some sand	2.77	1.2	125	0.03	2.24	4.81	6.05
4	BH 3	1.5-3	Diyala-Al-mekdadiah	Dark Brown clayey silt	2.78	1.1	1050	0.252	1.86	3.99	4.84
5	BH 1	1.5-2	Diyala-bakobah	Dark Brown silty clay with gypsum	2.77	1.2	225	0.054	4.98	10.7	9.98
6	BH 1	8-8.5	baghdad-Albaladyat	Grey to yellow to brown silty clay	2.78	3.7	700	0.168	2.62	5.63	6.8
7	BH 1	16.5-17	baghdad-Albaladyat	Yellow to green silty clay	2.71	3.6	400	0.096	1.6	3.44	4.3
8	BH 7	5-5.5	baghdad-Albaladyat	Grey to brown silty clay	2.8	3.2	300	0.072	2.28	4.9	6.3
9	BH 1	16.5-17	Missan-Amarah-alsadda	Green and grey clayey sandy silt	2.74	0.4	5606	1.345	2.17	4.7	6
10	BH 3	9.5-10	Al-Ghazaliyh	Brown to gray clayey sandy silt	2.7	1.6	200	0.048	0	1.29	3.9
11	BH 2	22.5-23	Al-Sa'ediyah	Gray silt	2.76	3.1	3500	0.84	1.37	2.95	4.5
12	BH 3	9.5-10	Baghdad-Dujailah	Brown and green sandy clayey silt	2.79	2.1	300	0.072	1.25	2.69	4.5
13	BH 2	2-2.5	Al-Dewaneyah	Brown silt with clay and salts	2.69	2.1	300	0.072	0.8	1.72	3.25
14	pit 8	0.25	Missan-Amarah	Light brown silty clay to clayey silt	2.72	2.8	-	-	1.45	3.12	4.3
15	pit 10	1.5	Missan-Amarah	Light brown silty clay to clayey silt	2.73	0.5	-	-	1.37	2.95	4.9
16	BH 1	15-15.5	Missan-Amarah	Green sandy silt	2.77	3.6	8000	1.92	2.05	4.41	5.5
17	BH 2	2-2.5	Missan-Amarah	Brown and gray clayey silt	2.71	1.8	9009	2.162	0.58	1.2	4.2
18	BH 6	16-18	Missan-Amarah	Greenish to Bluish river sand	2.72	4.2	-	-	1.25	2.7	5.1
19	BH 1	0-1.5	Babel-Al-Kider	Dark brown sandy silt with clay	2.72	2.3	3700	0.888	2.17	4.67	6.5
20	TMC102	0-0.5	Haditha	Yellow sand with silt and coarse	2.65	0.8	250	0.06	1.53	3.29	6
21	B102	0-0.5	Hit	Yellow to brown siltstone	2.63	0.4	200	0.048	1.06	2.31	4
22	BH 2	4.5-6	Thi-Qar -Nasiriyah	Dark gray silty clay to clayey silt	2.8	1	220	0.053	1.48	3.18	4.52
23	BH 3	0-1.5	Basra	Yellow sand with gravel	2.68	0.7	5500	1.32	5.27	11.33	14
24	BH 3	2-2.5	Basra	Brown clay with silt and with	2.78	0.4	2500	0.6	5.03	10.81	13.5
25	BH 1	9.5-10	Al-Dewaniya	Brown silty clay	2.78	0.3	950	0.228	1.48	3.18	6
26	BH 4	1.5-2	Missan	Graish silty sand	2.67	2.7	6200	1.488	1.67	3.59	4.8
27	pit5	0.25	Missan	Gray to light brown silty clay with	2.74	1.2	-	-	1.95	4.19	6.5
28	pit9	0.25	Missan	Gray to light brown silty clay to	2.76	0.5	-	-	1.25	2.69	4.6
29	pit41	0.25-1	Kerbala	Poorly Graded Sand With Silt Or	2.68	0.9	-	-	2.97	6.39	7.5
30	pit44	0.25-1	Kerbala	YELLOW TO BROWN TO RED	2.7	3.8	-	-	2.17	4.67	7
31	pit56	0.25-1	Kerbala	Poorly Graded Sand With Silt Or	2.67	2	-	-	0.8	1.72	3
32	pit62	0.25-1	Kerbala	Brown To Grey Silmty Sand With	2.69	0.2	-	-	2.05	4.41	6.5
33	pit63	0-0.25	Kerbala	Brown To Grey Silmty Sand With	2.67	1.8	-	-	1.71	3.68	5
34	BH 2	19.5-21	Kut	Light brown clayey silt	2.69	2.3	2000	0.48	1.48	3.18	4
35	BH 2	6.5-7	Missan	Dark brown silty sand	2.69	1.1	375	0.09	1.2	2.58	3.1
36	BH 2	2-2.5	Missan	Brown and gray clayey silt	2.71	1.8	9009	2.162	0.58	1.2	4.2
37	BH 6	16.0-18.(	Missan	Greenish to Bluish river sand	2.72	4.2	-	-	1.25	2.7	5.1
38	BH 2	5.5-7.5	Nasireyah	Gray to green silty clay	2.79	1.5	3850	0.924	2.75	5.91	8.5
39	BH 3	2-2.5	Nasireyah	Brown silty clay	2.64	1.8	1500	0.36	2.51	5.4	5.5
40	BH 16	12.5-15	Baghdad-Rabia and Tunis	brown silty clay to clay with silt	2.78	3.1	150	0.036	0.69	1.48	3.25

Table 4: The results

Sample no.	Sample Name	Depth	Location	TDS % Tested	f final	(r-rw)	TDS % Estimated
1	BH 14	1-1.5	Holy Karbala	3.71	5	0.00100775	**3.55**
2	BH 3	0.5-1.0	Diyala-Al-Lukmaniya	8.87	16	0.0010248	**6.96**
3	BH 2	6.0-6.5	Diyala-Al-mekdadiah	6.05	14	0.0010217	**6.34**
4	BH 3	1.5-3	Diyala-Al-mekdadiah	4.84	5	0.00100775	**3.55**
5	BH 1	1.5-2	Diyala-bakobah	9.98	24	0.0010372	**9.44**
6	BH 1	8-8.5	baghdad-Albaladyat	6.8	15.5	0.001024025	**6.805**
7	BH 1	16.5-17	baghdad-Albaladyat	4.3	4	0.0010062	**3.24**
8	BH 7	5-5.5	baghdad-Albaladyat	6.3	12.5	0.001019375	**5.875**
9	BH 1	16.5-17	Missan-Amarah-alsadda	6	6.5	0.001010075	**4.015**
10	3	9.5-10	Al-Ghazaliyh	3.9	2.5	0.001003875	**2.775**
11	2	22.5-23	Al-Sa’ediyah	4.5	5	0.00100775	**3.55**
12	3	9.5-10	Baghdad-Dujailah	4.5	2.5	0.001003875	**2.775**
13	2	2-2.5	Al-Dewaneyah	3.25	3	0.00100465	**2.93**
14	pit 8	0.25	Missan-Amarah	4.3	4	0.0010062	**3.24**
15	pit 10	1.5	Missan-Amarah	4.9	4.5	0.001006975	**3.395**
16	1	15-15.5	Missan-Amarah	5.5	6	0.0010093	**3.86**
17	2	2-2.5	Missan-Amarah	4.2	4	0.0010062	**3.24**
18	6	16-18	Missan-Amarah	5.1	5	0.00100775	**3.55**
19	1	0-1.5	Babel-Al-Kider	6.5	16	0.0010248	**6.96**
20	TMC102	0-0.5	Haditha	6	5	0.00100775	**3.55**
21	B102	0-0.5	Hit	4	3	0.00100465	**2.93**
22	2	4.5-6	Thi-Qar -Nasiriyah	4.52	8	0.0010124	**4.48**
23	3	0-1.5	Basra	14	36	0.0010558	**13.16**
24	3	2-2.5	Basra	13.5	37	0.00105735	**13.47**
25	1	9.5-10	Al-Dewaniya	6	14	0.0010217	**6.34**
26	4	1.5-2	Missan	4.8	4.5	0.001006975	**3.395**
27	pit5	0.25	Missan	6.5	9	0.00101395	**4.79**
28	pit9	0.25	Missan	4.6	9	0.00101395	**4.79**
29	pit41	0.25-1	Kerbala	7.5	15.5	0.001024025	**6.805**
30	pit44	0.25-1	Kerbala	7	10	0.0010155	**5.1**
31	pit56	0.25-1	Kerbala	3	2	0.0010031	**2.62**
32	pit62	0.25-1	Kerbala	6.5	12	0.0010186	**5.72**
33	pit63	0-0.25	Kerbala	5	7	0.00101085	**4.17**
34	2	19.5-21	Kut	4	6	0.0010093	**3.86**
35	2	6.5-7	Missan	3.1	1	0.00100155	**2.31**
36	2	2-2.5	Missan	4.2	3	0.00100465	**2.93**
37	6	6.0-18.(	Missan	5.1	5	0.00100775	**3.55**
38	2	5.5-7.5	Nasireyah	8.5	18	0.0010279	**7.58**
39	3	2-2.5	Nasireyah	5.5	9	0.00101395	**4.79**
40	16	12.5-15	Baghdad-Rabia and Tunis	3.25	3	0.00100465	**2.93**

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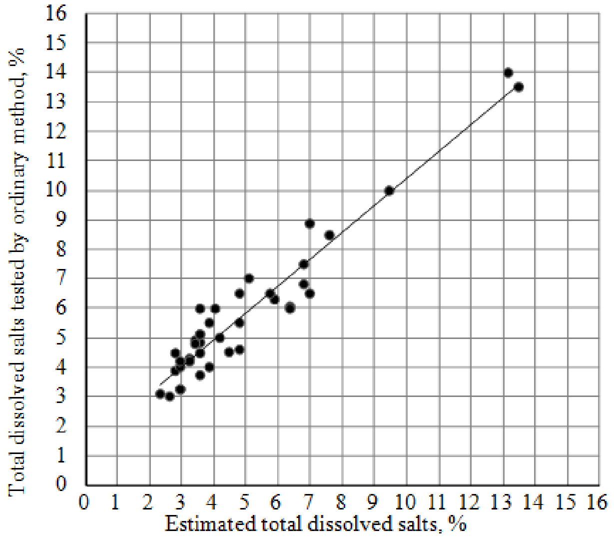

Figure 8: Comparison between values of Total dissolved salts tested by ordinary method and estimated total dissolved salts by the derived Eq. (4) for the analyzed soils

The comparison has proved good agreement and the coefficient of correlation between the results of the total dissolved salts tested by ordinary method and that's estimated by the derived Eq, and it is found to be (0.95962) and the standard deviation is found to be (2.3695).

10. Conclusions

A method is proposed to determine ($r - r_w$) for soil for the purpose of total dissolved salts calculations. The method is based on simulating the grain size distribution curve by the cumulative normal distribution curve. The percent finer at the end of sedimentation correspond the total dissolved salts in soil. Analysis of 40 soil gradation curves has shown good agreement between the total dissolved salts found from the proposed equation depending on the final percent finer in gradation curves and those obtained from the ordinary method.

11. Notations

TSS	Total dissolved salts
SHM	sieve-hydrometer method
PSD	particle-size distribution
Nf	The value in percents representing the final percentage of soil grains by weight passing the corresponding sieve size (diameter) on the gradation curve.
G	The average specific gravity of the soil particles.
ρ_w	The density of water = 1 gm/cm^3
V	volume of suspension (1000) cm3
Ws	weight of dry soil
γ_c	unit weight of water at temperature (usually 20^o C)
(r)	hydrometer reading in suspension
(r_w)	hydrometer reading in water (at same temperature as suspension)
P	total dissolved salt in percent
C_0	sample weight = 50 g

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