

Saudi Ground Water Chemistry and Significance

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ABSTRACT. The general chemistry of Saudi Ground water is introduced by way of chemical analysis and parameters such as pH, electrical conductivity (E.C.), total dissolved solids (T.D.S.), and major cations and anions which are of significance to water quality. The frequency distribution of E.C. and T.D.S. in a random group water sample (n=530) with respect to water quality is presented. A new association between E.C. and T.D.S. for Saudi ground water is proposed with a modified formula: $T.D.S. = (E.C. \times 850) - 200$, which is subjected to further modification according to each regional ground water characteristics. Range and variation of individual major cations and anions are summarized for comparison via the utilization of RAWRC Water Bank samples which were collected according to E.C. range from 0.8 to 9.0 for the years 1981 and 1982.

The people in the Kingdom of Saudi Arabia are concerned with the qualitative nature of a wide range of Saudi waters which basically include a variety of ground water, desalinated water, municipal city water, potable water, bottled water, the domestic and industrial water and waste water. The information obtained is used to assess the geological, environmental and public health quality and significance which in turn serves for the benefit of overall agriculture and economic development of the Kingdom.

There are a number of approaches to the study of the quality and chemistry of Saudi water for biological, physical, physiological and chemical aspects (Hamza *et al.*

1975a, Hamza *et al.* 1975b, Mee *et al.* 1982a, Mee *et al.* 1982b, Mee *et al.* 1982c, Mee *et al.* 1982d, Mee *et al.* 1982e, Mee *et al.* 1982f, Mee *et al.* 1982g, Mee *et al.* 1983a, 1983b). For the last five years, we have annually investigated thousands of Saudi water samples of various kinds. Our ultimate goal is to provide information and stimulate research on water to provide clean, safe, adequate quality water for every use.

This report is the first article of a series of publications describing our research results and findings on Saudi water with respect to water chemistry and quality in agricultural practice and environmental health. Other reports will feature Potable and Drinking Water; Municipal Water; Bottled Water; Waste Water; and Inorganic and Organic Pollution in Saudi Water.

Ground Water Chemistry

Almost all the water in this Kingdom is derived from underground and generally referred to as ground water or well water. Due to the geological formation, seasonal variations, the depth of each individual well, and the pumping conditions, etc., ground water composition may change its profile with respect to parameters such as pH, electrical conductivity (E.C.), total dissolved solids (T.D.S.), and cations and anions concentrations through the years. A major distinction between Saudi Waters, lies in the inorganic salts contents (Table 1).

Table 1: Total dissolved solids (inorganic salts) of common Saudi waters.

Sea Water	> 40000 ppm
Ground Water	500 - 9000 ppm
Sewage Effluent	1600 - 2000 ppm
City Water (Tap)	500 - 1000 ppm
Potable Water	200 - 500 ppm

Under normal conditions, T.D.S. can be calculated from the E.C. values by using the expression: $T.D.S. \text{ ppm} = 640 \times E.C. \text{ (m Mho/cm at } 25^{\circ}\text{C)}$. However, this formula is derived from findings for surface water in the United States which, in most cases, would not fit Saudi Ground water. The real reason for these changes is not known, but we have noticed that the ground water in the Kingdom randomly changes its E.C. values on storage at laboratory temperature (Table 2).

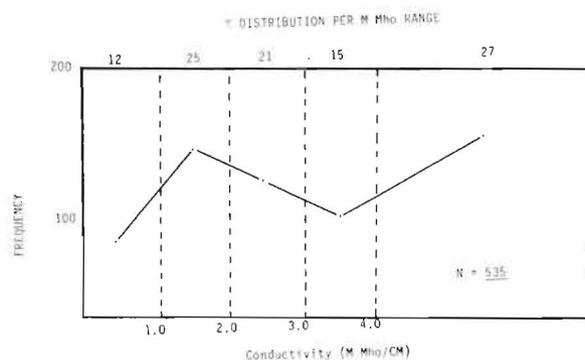
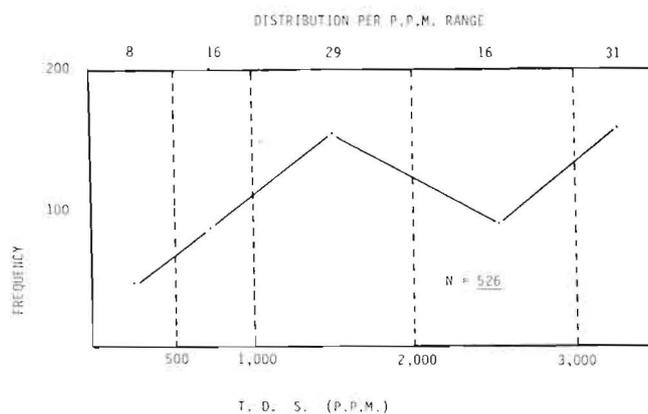
For this survey of Saudi ground water, we have obtained frequency distributions for E.C. and T.D.S. from a random sample of about 530 ground waters. Figures 1 and 2 show a high frequency of E.C. between 1.0-2.0 (25%) and above 4.0 m Mho/cm (27%), likewise the T.D.S. between 1000-2000 (29%) and above 3000 ppm (31%). It is apparent that over 50% of Saudi ground water samples exceeded 3.0 m Mho/cm or yielded above 2500 ppm T.D.S.

Table 2: Changes of E.C. values in ground water during 7 days storage at 25°C.

E. C. (m Mho/cm)	% Change*	Mean RSD**
1.09	0.1+	3.8
1.57	1.3-	2.9
2.75	7.3-	3.2
3.90	12.8+	3.8
3.95	11.3+	2.7
4.30	20.9+	3.0

* $(E.C._7 - E.C._1) / E.C._1 \times 100$

** 4 Analyses

**Fig. 1.** Frequency distribution of a random sample of Saudi Ground Waters with respect to electrical conductivity.**Fig. 2.** Frequency distribution of a random sample of Saudi Ground Waters with respect to total dissolved solids.

New Approach for Quality Assessment

For a better understanding of the various chemical problems, we have further established a "RAWRC WATER BANK" system at the laboratories of Regional Agriculture and Water Research Center (RAWRC) using over 1000 ground water samples selectively banking each water according to their E.C. values ranged from 0.8 to 9.0 m Mho/cm. In addition to our routine instrumental quality control measurements, we have used the RAWRC WATER BANK composite for E.C. and T.D.S. studies. Figure 3 shows the association between T.D.S. being measured after evaporation at 180°C and being calculated from E.C. \times 640 using 52 random ground water samples for the full range of E.C. from 1 to 10. The measured deviation (+38 to -30%) indicates a unique property of Saudi ground water which apparently disqualifies the mentioned formula used for surface water in the U.S.A. and perhaps other parts of the world. To substantiate the variation further, we have used RAWRC WATER BANK samples for testing and the results show a range of deviation between +6.1 to -35%. As a result, we have replotted the T.D.S. against E.C. for the establishment of a new relationship between T.D.S. and E.C. for the Saudi ground water. Figure 4 illustrates the success of a new formula: $Y = 850 X - 200$, where Y is the T.D.S. (in ppm) and X is E.C. (in m Mho/cm). By using this model and formula for RAWRC WATER BANK samples, the deviation is reduced to +7 to 16%.

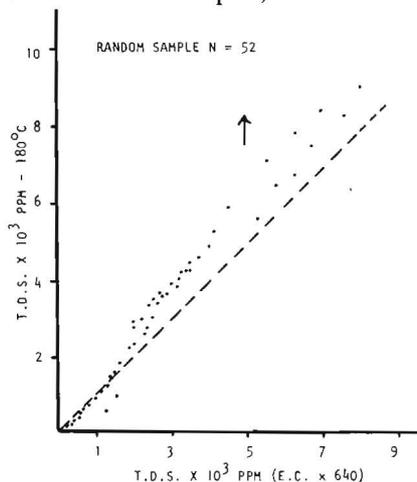


Fig. 3. Total Dissolved Solids - Calculated VS. Tested.

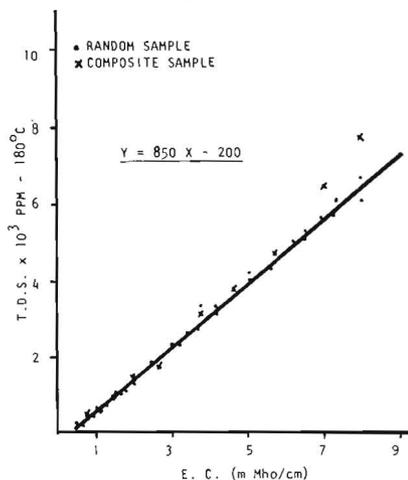


Fig. 4. E.C. VS. T. D. S. in Saudi Groundwaters Based on Composite and Random Samples.

Attempts have been made to re-test the new formula for each regional ground water for further modification, if necessary, and new formula can be derived for each six months or one year period.

The RAWRC WATER BANK has been extensively used for the interpretation of

the characteristics of Saudi ground water. For instance, in our routine water analysis, 17 parameters are now being analyzed. They are three gross analyses (pH, E.C. and T.D.S.), and determinations of 7 cations (Ca^{2+} , Mg^{2+} , K^+ , Na^+ , Fe^{3+} , Al^{3+} , and B^{3+} as borate) and 7 anions (Cl^- , SO_4^{2-} , F^- , HCO_3^- , PO_4^{3-} , CO_3^{2-} and NO_3^-).

The minerals and ions are routinely determined by automated instruments such as the Technicon Autoanalyzer SMA-9 equipped with selective ion probe for F^- and colorimetric systems for Ca^{2+} , Mg^{2+} , Fe^{3+} , Al^{3+} , B^{3+} , Cl^- , NO_3^- , PO_4^{3-} ions; Fisher Autotitrator designed for pH, CO_3^{2-} and HCO_3^- titration potentiometrically; and Beckman Kline Flame unit for the analysis of K^+ and Na^+ based on absorption spectrophotometry method. At the present time, our water analytical capability and technology reach over 80% automation level.

Table 3 summarizes the general inorganic properties of Saudi ground water in which pH, E.C., T.D.S. and major cations and anions are listed. In addition, a new Ion Ratio index (w/w) is provided for the estimation of major cations (Na^+ , K^+ , Ca^{2+} , Mg^{2+}) and anions (SO_4^{2-} , Cl^- , HCO_3^- , NO_3^-) from which it was found quite unique for Saudi ground water at C/A ratio > 0.4 . The C/A ion ratio signifies the proportional levels of minerals (cations) by weight in Saudi ground water. Therefore, C/A ratio reflects the unique water quality in both ground and demineralized potable waters. It is found that sulfate and chloride are two dominant anions while sodium and calcium are the most prominent cations. Bicarbonates become significant contributor for the T.D.S. (10 to 18% T.D.S.) if the E.C. values of the water remains below or at 3.0 m Mho/cm. Carbonates (CO_3^{2-}) are less important for the water quality consideration due to the water pH (pH 7.0-8.4) found only slightly above or below the titratable CO_3^{2-} pH set at endpoint pH 8.3.

Table 3. Inorganic properties of Saudi ground water (RAWRC WATER BANK 81-82)

E.C. (m Mho/cm)	0.8 - 9.0
pH	7.0 - 8.4
T.D.S. (ppm)	550 - 9100
Major Cations (C)	Ca^{2+} , Mg^{2+} , K^+ , Na^+
Major Anion (A)	SO_4^{2-} , Cl^- , HCO_3^- , NO_3^-
Ion Ratio (C)/(A) (By weight)	>0.4

Table 4 gives some quantitative figures and statistics for comparison of the major ions. The variations for each individual ions among different ground waters (E.C. values 0.8 to 9.0) are further expressed in terms of mean relative standard Deviation (RSD%). It is of interest to note that less variations were seen in terms of composition as expressed by % T.D.S. (17-28%). The chloride (Cl^-) level is one of the leading constituents that varies most with respect to E.C. from 0.8-9.0 in the RAWRC water samples.

Ground water contamination and pollution will be discussed in a separate report at a later date.

Table 4. Range and variations of major ions in Saudi ground water*.

(RAWRC WATER BANK 81-82)

Ion	Range (ppm)	Mean RSD %	
		Based on ppm	Based on % TDS
Na ⁺	70 - 2200	67	18
Ca ²⁺	50 - 780	64	17
Mg ²⁺	30 - 270	49	25
Cl ⁻	70 - 3200	70	28
SO ₄ ²⁻	200 - 2100	46	17

* E.C. = 0.8 - 9.0 m Mho/cm, TDS = 550 - 9100 ppm.

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كيمياء المياه الجوفية في المملكة العربية السعودية وأهميتها

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قسم الكيمياء التحليلية، المركز الإقليمي لأبحاث الزراعة والمياه، وزارة
الزراعة والمياه، ص ب ١٧٢٨٥ الرياض، المملكة العربية السعودية

تُعرّف الكيمياء العامة للمياه الجوفية في المملكة العربية
السعودية عن طريق التحليل الكيميائي وخواصها مثل الأس
الهيدروجيني pH، التوصيل الكهربائي E.C، المواد الصلبة
الذائبة الكلية T.D.S، والكاتيونات والأنيونات السائدة التي
لها أهميتها في جودة المياه. ويستعرض هذا البحث التوزيع
التكراري للتوصيل الكهربائي والمواد الصلبة الذائبة الكلية في
مجموعة من العينات العشوائية (٥٣٠ عينة) من حيث جودة
المياه.

ويعرض البحث لعلاقة جديدة بين التوصيل الكهربائي
والمواد الصلبة الذائبة الكلية للمياه الجوفية السعودية مُثلت
بالمعادلة المعدلة التالية:

المواد الصلبة الذائبة الكلية

$$= (\text{التوصيل الكهربائي} \times ٨٥٠) - ٢٠٠.$$

والتي تتعدل - أي المعادلة - حسب صفات مياه كل
منطقة.

ويُلخص البحث التغيير في الكاتيونات والأنيونات السائدة
ومداها بهدف المقارنة باستخدام عينات بنك مياه المركز
الإقليمي لأبحاث الزراعة والمياه التي جمعت حسب مدى
توصيلها الكهربائي من ٨,٠ - ٩,٠ لعامي ١٩٨١ -
١٩٨٢.