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Hydrochemical Co-parameters of Groundwaters in the Arabian Shield, Saudi Arabia

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ABSTRACT. The groundwater resources of Saudi Arabia are of great importance, specially in the Arabian Shield where the quantity of water is only limited for local use. Five important wadis within the Shield were assessed in terms of hydrochemistry. The purpose was to find out the compatibility of properties and its utilities.

Statistical and standard methods were used to evaluate the representative water samples of groundwater in each wadi. The results exposed the dominancy values of the parameters. However, bar graphs were used for values comparison. Moderated parameters values were calculated to have a general view of the Shield waters properties and for utilities assessment. In addition, equations of linear relationships (T.D.S. With E.C) for each wadi and for groundwaters within the Shield were obtained for future salinity examination.

Introduction

Saudi Arabia is one of the dry category areas in the world. Due to this, it is characterized by unpredictable and irregular rainfall. The intensity of rainfall during heavy rains is far in excess of the capacity of the land to absorb it. In addition, the area is devoid of perennial streams. Thus, it makes the ground water resources of Saudi Arabia as of great importance.

The major ground water in Saudi Arabia is available as a primary source in the sedimentary part (or in the Arabian Shelf which it's total area is of ⅔ of Saudi Arabia). The secondary source (local amount) of the crystalline part (Arabian Shield, ½ of the total area of Saudi Arabia) is in the alluvium and weathered rocks.

This paper concerns with the hydrochemical evaluation of the ground water of five wadis, located in the middle of the western part of the Arabian Shield (Wadi As Safra, Wadi Nahdah, Wadi Al-Yamaniyah, Wadi Uoranah and Wadi Wajj) (Fig. 1).

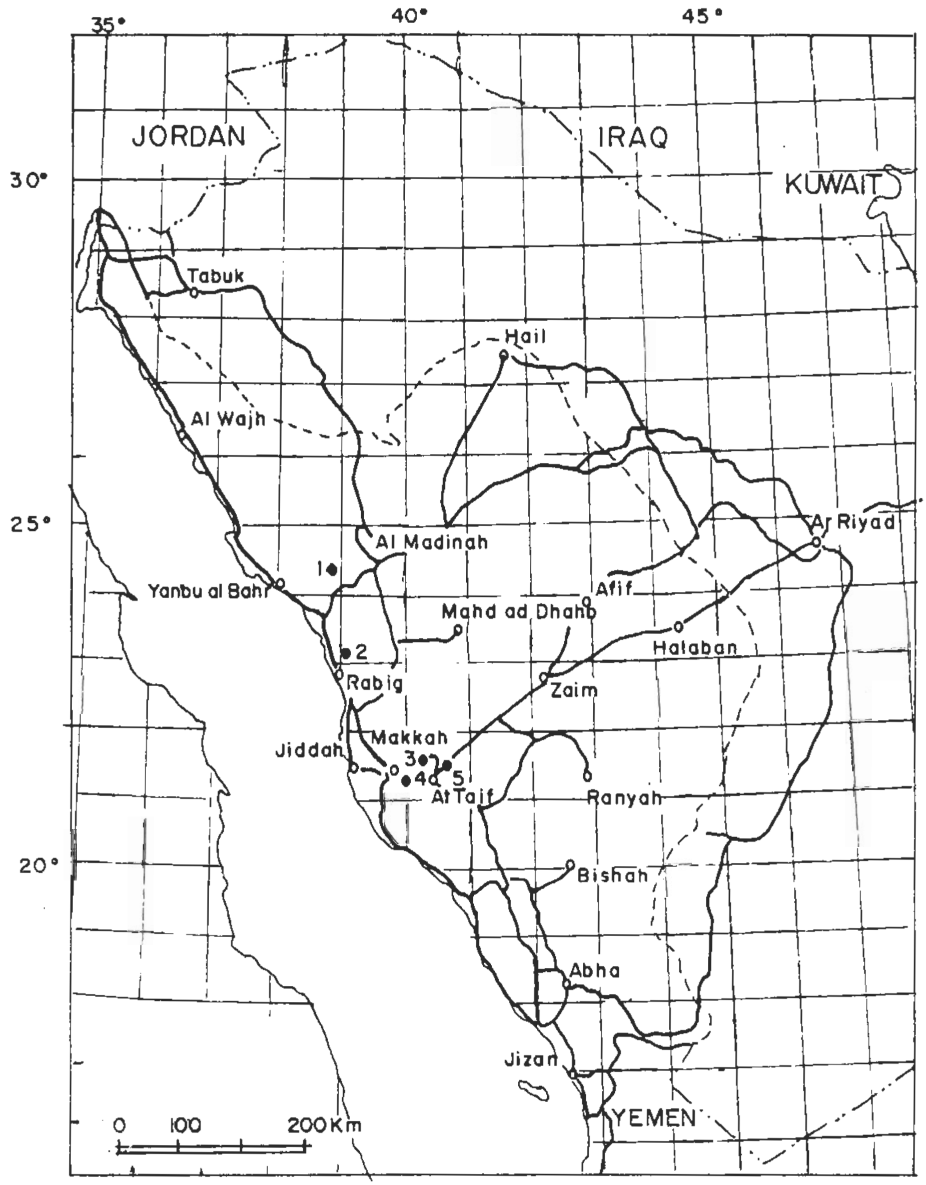

FIG. 1. Location map for studied areas.

1. Wadi As-Safra; 2. Wadi Nahdah; 3. Wadi Al-Yamaniyah; 4. Wadi Uoranah; 5. Wadi Wajj.

Paved Roads

Boundary between the Hard and Soft Rocks

The present work deals with the ion dominancy as well as its general suitability for the current main utilities in the Arabian Shield.

The five wadis were studied individually by other researchers such as Al Ahmadi (1984), Al-Yamani (1983), Bazuhair (1981), Sharaf (1984) and Ghurm (1980). These studies dealt with the situation of the regional hydrogeological situation.

Ranges and Dominancy of Data

The total number of representative water samples were 156, including 30 samples from Wadi As Safra, 40 samples from Wadi Nahdah, 30 samples from Wadi Al-Yamaniyah, 38 samples from Wadi Uoranah and 18 samples from Wadi Wajj. The compiled data of the five areas contained the analyses of the main constituents (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{--}, Cl^{-}) as well as the parameters, total dissolved solids (TDS), electrical conductivity (E.C.), total hardness (TH) and sodium adsorption ratio (SAR).

The dominant ions concentration in each water area is obtained through statistical relationship of the samples frequency and the concentration range values. The obtained ions dominant concentrations are plotted together with concentration range in comparison bar graph forms (Figs. 2 to 7). Similarly was done for T.D.S., TH and SAR. (Figs. 8 to 10).

Dominant concentration ranges
1 – Wadi As-Safra
2 – Wadi Nahdah
3 – Wadi Al-Yamaniyah
4 – Wadi Uoranah
5 – Wadi Wajj

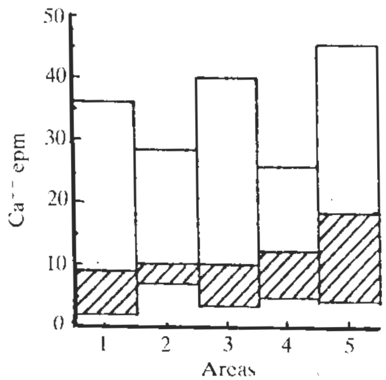

FIG. 2. Range of Ca^{++} values.

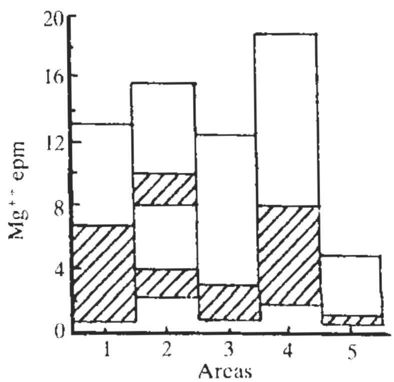

FIG. 3. Range of Mg^{++} values.

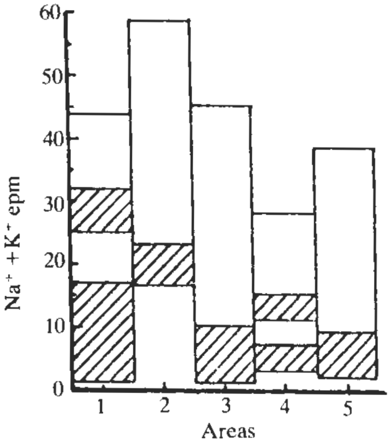

FIG. 4. Range of $Na^+ + K^+$ values.

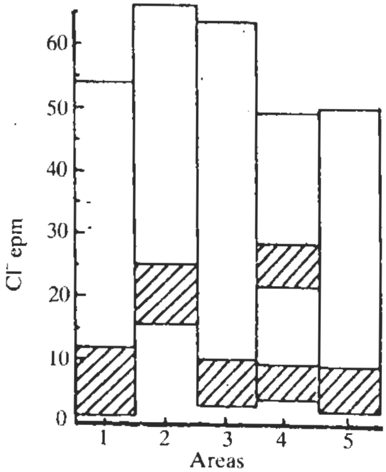

FIG. 5. Range of Cl^- values.

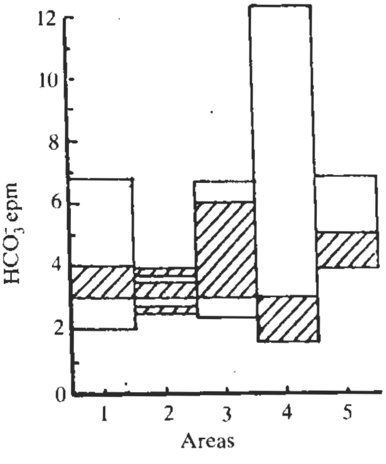

FIG. 6. Range of HCO_3^- values.

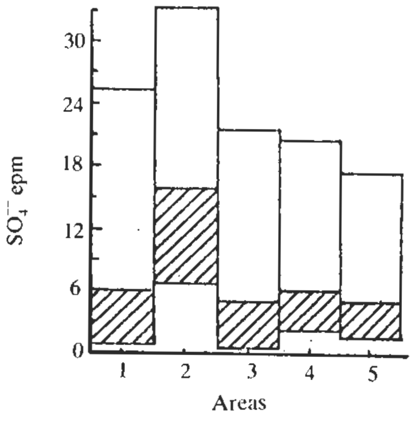

FIG. 7. Range of SO_4^{--} values.

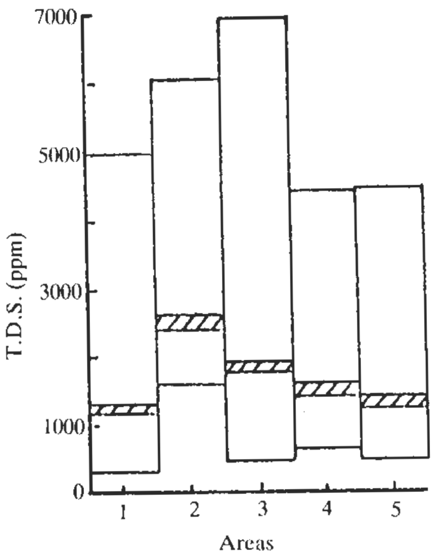

FIG. 8. Range of T.D.S. values.

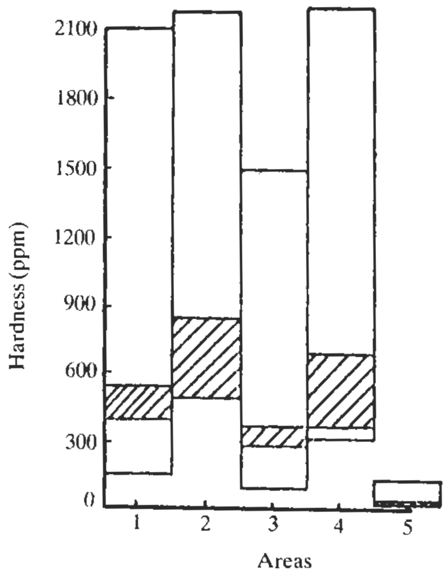

FIG. 9. Range of hardness values.

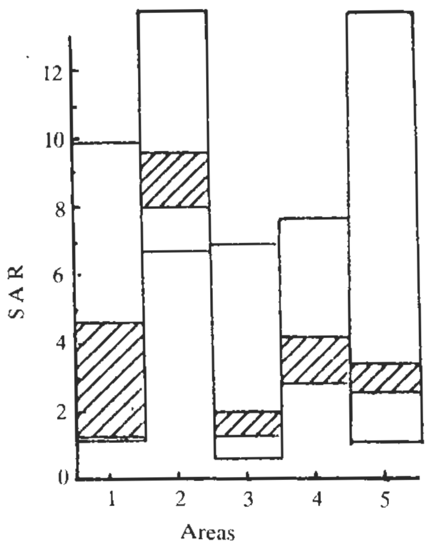

FIG. 10. Range of sodium adsorption ratio.

The ions Mg, Na, K, K, Cl and HCO_3 show two prevailing ranges (Figs. 3 to 6). This means that, there are two major water types having different concentrations but of the same constituents. The reasons behind, are local variation factors, such as surrounding geology, well location, agricultural activities and aquifer lithology.

However, the arithmetic mean for the dominant ranges of the different parameters in the waters of the five areas is summarized below :

Wadi Name	TH (ppm)	SAR	pH	T.D.S ppm	Ca epm	Mg epm	Na+K epm	Cl epm	SO_4 epm	HCO_3 epm
As-Safra	450	3	–	1824	5	3.5	10,27	6	3	3.5
Al-Nahdah	700	2,9	7.4	3444	8	8.5 , 2.5	20	20	11	3
Al-Yamaniyah	350	2	7.1	1764	5	2.5	6	6	3	4.5
Uoranah	550	3.5	7.1	1422	5.5	4	5,11	6,25	3.5	2
Wajj	75	3	7.6	1280	10	1	5	5	3	4.5

The previous table shows that there is a compatibility in the intermediate values of the aquifers water parameters. However, there is an exceptional difference in Al-Nahdah aquifer which is due to solutions of metamorphic rocks mainly chloride and amphibolite schists. The ground water flow through these types of rocks is rich in sulphate and sodium salts, whereas in the other areas, water flow is through rock of granite and diorite.

Therefore, for the assessment purpose the aforementoined table of the dominant values is moderated to the following values :

TH ppm	SAR	pH	T.D.S ppm	Ca epm	Mg epm	Na+K epm	Cl epm	SO_4 epm	HCO_3 epm
450	4.1	7.3	2018	6.7	3.3	12	6.3	4.7	3.5

Results Evaluation

The moderated values of the five aquifers waters of the Arabian Shield were compared with the Saudi Arabian Standards (1984) for potability of unbottled drinking water, it show that it have the intermediate values of the acceptable limits. In addition, for the household cleaning purposes and according to Sawyer and McCarty (1976) standards of the average T.H. values, the waters have been classified as a very hard type. However, for ordinary water supply uses, the waters range from soft to slightly brackish (Davis and De Wiest 1966). The SAR explicits that the waters are good for agricultural supply (Richards 1974).

The linear relationships of the T.D.S. and the E.C. is constructed for each of the five groundwaters (Figs. 11 to 15) and also for the moderated values (Shield data) (Fig. 16). The obtained equations from the best-fit lines are as below :

Wadi	**Equation**
W. As Safra	$Y = 808.7 + 0.43X$
W. Nahdah	$Y = -1572.1 + 0.95X$
W. Al-Yamaniyah	$Y = 770.1 + 0.56X$
W. Uoranah	$Y = 765.4 + 0.47X$
W. Wajj	$Y = 552.6 + 0.52X$
Shield	$Y = 637 + 0.51X$

where Y = T.D.S. in ppm and X : = E.C. (μS/cm)

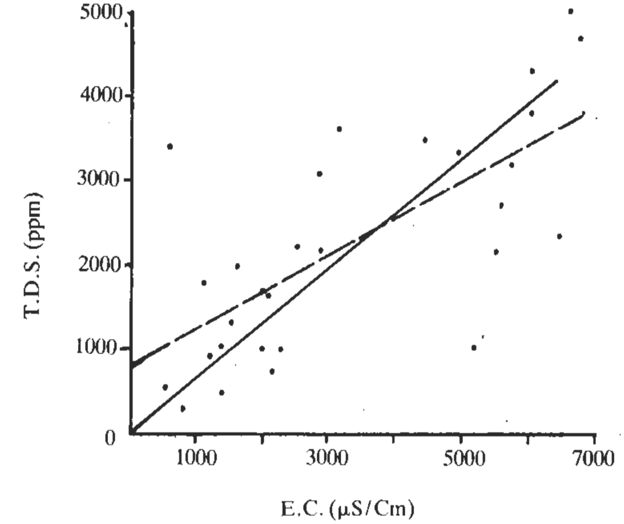

FIG. 11. Wadi As-Safra.

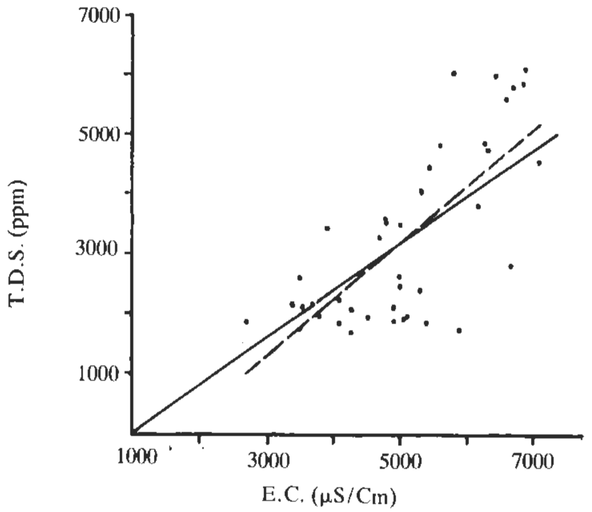

FIG. 12. Wadi Nahdah.

—— Physical–fit line

– – – Best–fit line

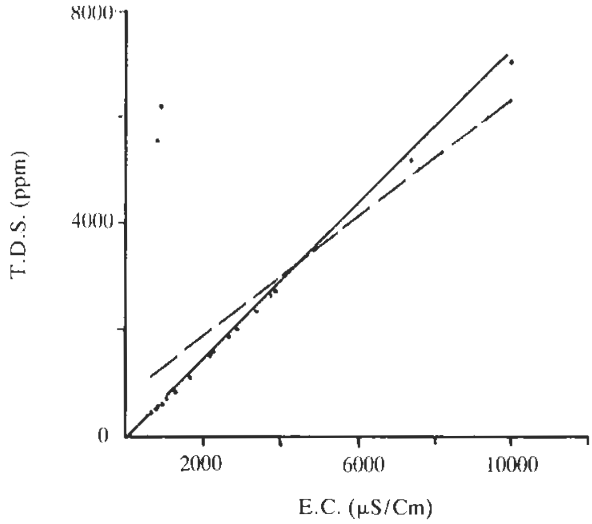

FIG. 13. Wadi Al-Yamaniyah.

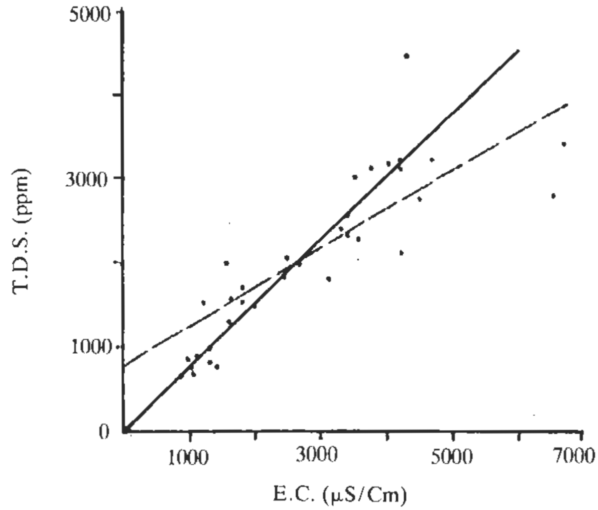

FIG. 14. Wadi Uoranah.

—— Physical–fit line
– – – Best–fit line

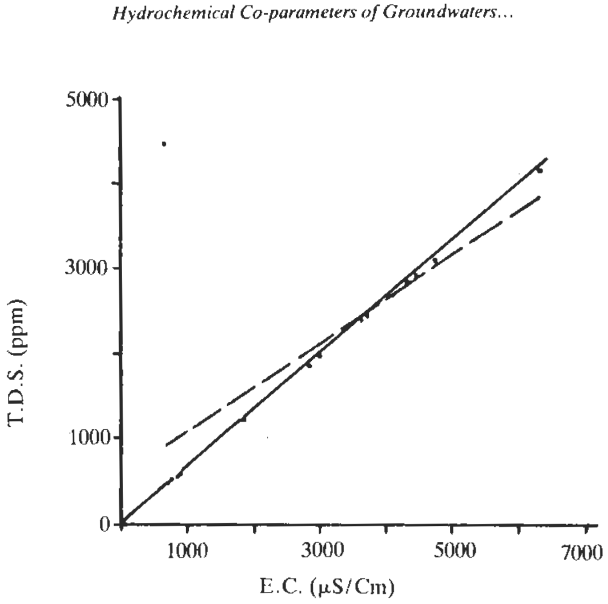

FIG. 15. Wadi Wajj.

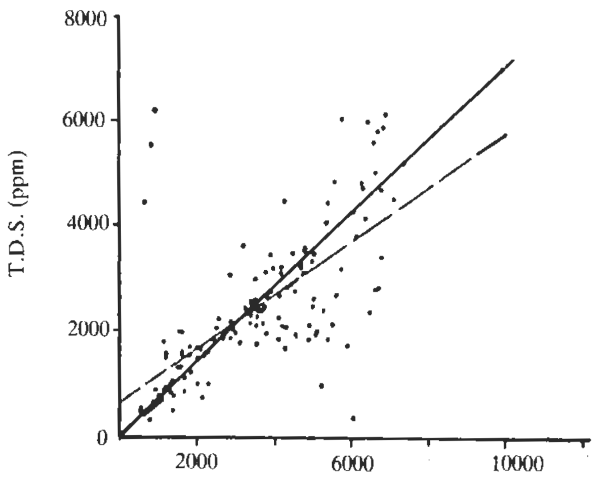

FIG. 16. Shield aquifers.

—— Physical–fit line
– – – Best–fit line

It is clear from the above equations that, there is a compatibility which confirmed the previously mentioned conclusion and the only deviation noticed was in Wadi Nahdah data which is due to the factors mentioned earlier. The equation of the mixed data obtained from the best-fit line is (Y = 637 + 0.51 X). But the best-fit lines did not pass through the origin and therefore a physical-fit line was made by taking the average T.D.S. and average E.C. point and joining it to the origin. The line passing through the origin and the average point is the physical-fit line. Thus the relationship between the T.D.S. and E.C. in the five wadis is obtained as follows:

Wadi	**Equation**
W. As Safra	T.D.S. = E.C. X 0.61
W. Nahdah	T.D.S. = E.C. X 0.60
W. Al-Yamaniyah	T.D.S. = E.C. X 0.69
W. Uoranah	T.D.S. = E.C. X 0.76
W. Wajj	T.D.S. = E.C. X 0.66
Shield	T.D.S. = E.C. X 0.66

This relationship can be safely used for the wadis of the Arabian Shield.

Conclusion

The ground water of the Arabian Shield was evaluated in five wadis close to the Red Sea. Statistical methods show that, these waters, in general, are compatible in hydrochemistry properties. However, the moderated values of the different parameters explain that, the waters have the medium value of the acceptable limits for drinking purpose. However, it is very high in the total hardness as well as slightly brackish. On the other hand, the waters are good for agriculture utilities. The relation T.D.S. = E.C. $\times$ 0.66 is useful to view general salinity in the studied areas.

Acknowledgement

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الخصائص المشــتركة في كيمياء المــاء للميــاه الجوفيــة في الدرع العربي ، المملكة العربية السعودية

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كلية علوم الأرض ، جامعة الملك عبد العزيز ، جــدة ، المملكة العربية السعودية

المستخلص . مصادر المياه الجوفية في المملكة العربية السعودية ذات أهمية كبرى وبالذات في منـطقة الدرع العربي حيث كمية المياه محدودة للاستعمال المحلي . تقيم هذه الدراسة كيمياء المـاء في خمسة أودية مهمة في الدرع العربي والغرض هو معرفة مدى توافق خواص المياه واستعمالاتها .

استخدمت طرق إحصائية وقياسية لتقييم عينات المياه الجوفية الممثلة لكل واد . كما استخدم التمثيل العمودي للمقارنة . وتم حساب القيم المتوسطة لإعطاء فكرة عامة عن نوعية المياه الجـوفية في الدرع العربي ولتقييم صلاحيتها للاستعمال . بالإضافة إلى ذلك تحصلت الدراسة على معادلات لعلاقات خطية (مجموع المواد الصلبة المذابة مع الموصلية الكهربائية) لكل واد يمكن استخدامها لاختبار الملوحة مستقبلا .