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Chemical Analyses of Water from the Riyadh Area Used in Agriculture

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ABSTRACT. A study of underground water with regard to its use in agriculture is presented. The water samples were collected from the Riyadh region. The sources of these waters are Jubaila and Minjur aquifers. A hydrochemical study of these waters indicates that water from Minjur aquifer is more suitable for agricultural purposes, in terms of its salinity and alkali hazard, than the water from Jubaila aquifer. The boron concentration in these waters is less than 1 ppm, making it suitable for some sensitive crops, and all semi-sensitive and tolerant crops. The residual sodium carbonate (R.S.C.) is <1, making it suitable for irrigation.

Water exploration in Saudi Arabia began in 1940 with survey studies made by various organizations (mostly from the U.S.A.) in different parts of the Kingdom to evaluate agricultural potentialities. But, there is a lack of studies for hydrogeological or hydrochemical studies on waters from the region of Riyadh (Fig. 1), the capital of the Kingdom of Saudi Arabia. To characterize the Riyadh waters for agricultural uses, four water samples were collected from different sources in Riyadh and its outskirts. The region is covered by Quaternary superficial deposits and Mesozoic sedimentary rocks. Exposed rocks are dominantly limestones interbedded with some shales and lesser amounts of sandstone.

There are three main water-bearing horizons (Powers *et al.* 1966) in the Riyadh Region: Alluvial Deposits, Jubaila Formation and Minjur Formation. Water from Minjur sandstone aquifer is good for drinking and household uses, while water from Jubaila limestone aquifer is mainly used for irrigation. The wells in the Jubaila formation are about 300 meters deep, whereas the wells in Minjur formation are deeper, about 1300 meters in depth. The present study includes four water samples

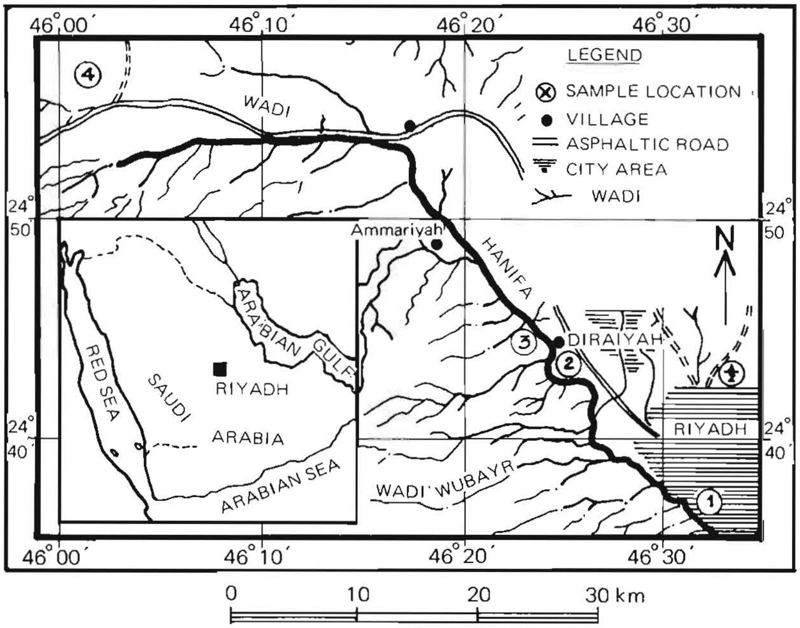

Fig. 1. Map showing water sample locations in Riyadh and its outskirts.

representing waters from the two aquifers. The data for Minjur and Jubaila water samples are presented in Table 1.

Material and Methods

The water samples from four different sources from Riyadh region were collected and carefully stored in clean plastic bottles. The four water samples and their collection sites are summarized in Table 1. These water samples were analyzed

Table 1. Riyadh water samples from four different sources.

Sample No.	Sample Location	Well Depth (m)	Static Water Level (m)	Water Bearing Zones
1	Shamaysi	1307	88	Minjur (sandstone)
2	Al-Twela	260	–	Jubaila (limestone)
3	Diraiyah Dam	300	–	Jubaila (limestone)
4	Salboukh	1342	180	Minjur (sandstone)

using different experimental techniques (Moselhy *et al.* 1974), at the facilities of Technical Service Laboratories (TSL) in Mississauga (Canada). Table 2 represents chemical data and the concentration of toxic and trace elements in the Riyadh waters together with their maximum limits in ppm as recommended by the National Academy of Sciences (1972).

Table 2. Chemical Composition (ppm) of Riyadh Waters.

Element	Upper limit (N.A. Science)	Sample N0. 1	Sample No. 2	Sample No. 3	Sample No. 4
Aluminum	5	1.56	5.75	4.80	0.52
Arsenic	0.1	<0.01	<0.01	<0.01	<0.01
Boron					
(Sensitive crops)	0.75				
(Semitolerant crops)	1	0.77	0.99	0.71	0.41
(Tolerant crops)	2				
Cadmium	0.01	<0.01	<0.01	<0.01	<0.01
Chromium	0.1	<0.01	0.03	0.01	<0.01
Cobalt	0.05	0.04	<0.01	<0.01	<0.01
Copper	0.2	<0.01	<0.01	<0.01	<0.01
Iron	5	<0.01	<0.07	<0.01	<0.01
Lead	5	<0.01	<0.01	<0.01	<0.01
Manganese	0.2	0.015	<0.01	<0.01	<0.01
Nickel	0.2	<0.01	<0.01	<0.01	<0.01
Selenium	0.02	<0.01	<0.01	<0.01	<0.01
Zinc	2	0.15	0.14	0.29	0.17
K^+		<0.01	<0.01	<0.01	8.8
Na^+		84.2	287	140	94.2
Mg^{++}		59.45	185	120	29.51
Ca^{++}		106	400	315	43.89
Cl^-		117	630	553	117
SO_4^{--}		185	816	419	185
HCO_3^-		15	37	15	18
S.A.R.		1.3	3.0	1.7	1.77
E.C. (μmhos/cm)		406	4166	3908	943
T.D.S.		284	2916	2825	660
T.H.($CaCO_3$)		353	1430	977	171
pH		7.2	7.5	7.4	7.7

Results and Discussion

A) Suitability of Riyadh Waters for Irrigation

According to Wilcox (1955), the factors determining the suitability of water for irrigation are salinity, alkali hazards, concentration of boron, toxic elements, bicarbonates, climate, salt tolerant crops, drainage system, soil characteristics and water management. Table 2 presents the concentration of major cations, K^+, Na^+, Mg^{++} and $Ca^{++}$and anions Cl^-, SO_4^{--} and HCO_3^-, together with electrical conductivity (E.C), total dissolved solids (T.D.S.), total hardness (T.H. as $CaCO_3$), pH-value, and sodium-adsorption-ratio (S.A.R.) of the Riyadh waters. A comparison is also presented in Table 2 for boron, toxic elements, and some trace element concentrations in Riyadh waters against the recommended upper limits prescribed by the National Academy of Science for irrigation purposes. The classification of Riyadh waters for irrigation purposes is presented in Fig. 2, based on Wilcox's

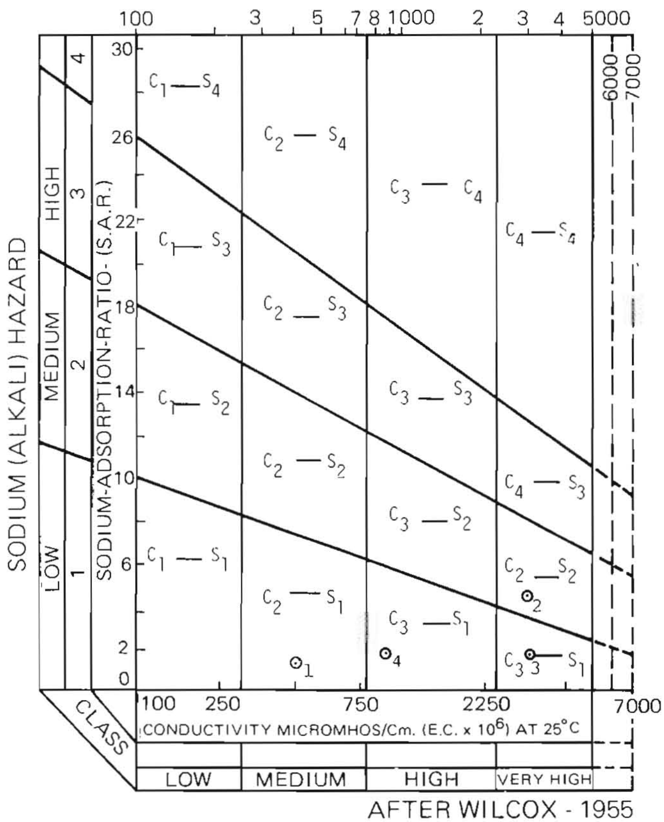

Fig. 2. Diagram for the classification for irrigation water.

classification method. The water sample # 1 is in class $C_2 - S_1$ *i.e.* this water is good for irrigation. Water of sample # 4 belongs to $C_3 - S_1$ class indicating that this water is permissible for irrigation. Both the sample # 2 & 3 belong to $C_2 - S_2$ and $C_3 - S_1$ classes respectively, are doubtful for their use in irrigation.

B) Boron, Toxic and Trace Elements

Concentration of boron is one of the more important factors for the classification of irrigation water. Boron is an important micronutrient but must be in low concentrations (<4 ppm) otherwise boron becomes toxic to plants (Camp and Meserve 1974). Plant species differ markedly in their tolerance to boron. Table 3 shows the permissible boron limits for the sensitive, semisensitive, and tolerant crops. In Riyadh waters, the concentration of boron ranges between 0.41 ppm to 0.99 ppm (Table 2), suggesting that Riyadh waters could be used to irrigate sensitive crops.

The concentration of the toxic elements such as As, Cd, Pb and Se in the Riyadh water samples have been found to be less than 0.01 ppm, so the effect of these elements is not hazardeous for irrigation purposes. Only eight trace elements were found in these water samples. The concentration of most of the trace elements is quite low (less than 1 ppm), the concentration of aluminum varies from 0.52 to 5.75 ppm.

C) Effect of Bicarbonates

The residual sodium carbonate (R.S.C.) in waters to be used for irrigation is also an important factor. If the R.S.C. is more than 2.5 ppm, the water is not recommended for irrigation purposes. The waters with R.S.C. between 2.5 to 1.25 ppm are marginal; those with R.S.C. less than 1.25 ppm are probably safe. It is believed that good management practices and proper use of amendments might make it possible to successfully use some marginal waters for irrigation. The R.S.C.

Table 3. Crops Classification for Boron in Water (Wilcox 1955, Camp and Meserve 1974).

Boron Classification	Sensitive Crops	Semisensitive Crops	Tolerant Crops
1	<0.33	<0.67	<1.00
2	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
3	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	<1.25	<2.50	<3.75

for Riyadh waters is found to be about 1.0 ppm. *i.e.* these waters are suitable for irrigation and should pose no deterimental R.S.C. effects.

D) Climate and Salt Tolerant Crops

Riyadh is located nearly in the center of the Arabian Peninsula. The area is quite arid, with a very small amount of rainfall in winter, and the temperature during the summer reaches above 40°C. Owing to small rainfall and high temperature the humidity is quite low and evaporation is high. Under such conditions, dry (or may be normal) farming is difficult, and hot and temporate region crops can be grown successfully only if proper irrigation techniques are employed.

Salinity, alkalinity and toxic elements in the irrigation water or in the soil are the main factors to consider in plant growth. Plants differ considerably in their tolerance to irrigation water and to soil-water chemical composition. According to the United States Department of Agriculture specifications (U.S. Salinity Laboratory, 1954), water samples No. 1 and 4 with E.C. 406 & 943 µmhos/cm can be used for irrigation for all kinds of crops, because the salinity effect is negligible, while water of sample 2 and 3 with high value of E.C. could be used only for certain types of crops. Climate and water quality in Riyadh region is suitable for certain sensitive crops, like grapes, cucumber, onions, carrots, pepper and potatoes. The more tolerant crops include figs, cabbages, tomatoes, wheat and dates.

E) Drainage and Soil

There is no drainage system in Riyadh area. The irrigation water drains down to water table underlying the cultivated land which contributes to ground water recharge while affecting considerably the chemical composition of the ground water. The water table, under the widely spaced farms, is about 50 m deep, the aquifer contains fissures and joints and the soil is moderately to highly permeable. Consequently, the irrigation water soaks quickly downward to recharge the aquifer and the water table does not rise to the root zone.

Five representative soil samples from the Riyadh area (Wadi Hanifa, Fig. 1) were analyzed (Mechanical Analysis). Table 4 shows the statistical constants and Fig. 3(a) and 3(b) show the histograms and cumulative curves for these five soil samples. These samples were sandy or silty calcareous soils, coarse to medium textured with high to medium infiltration capacity. Because of continuous leaching by run-off water the infiltration rate of the soil is high, and water soaks down rapidly, the soils are devoid of harmful salts. Therefore, enrichment of salts in root zone by evaporation does not occur. In addition, because of the leaching process, the soil becomes poor in nutrients and large quantities of fertilizers, especially organic ones, are needed to replace the leached soil nutrients.

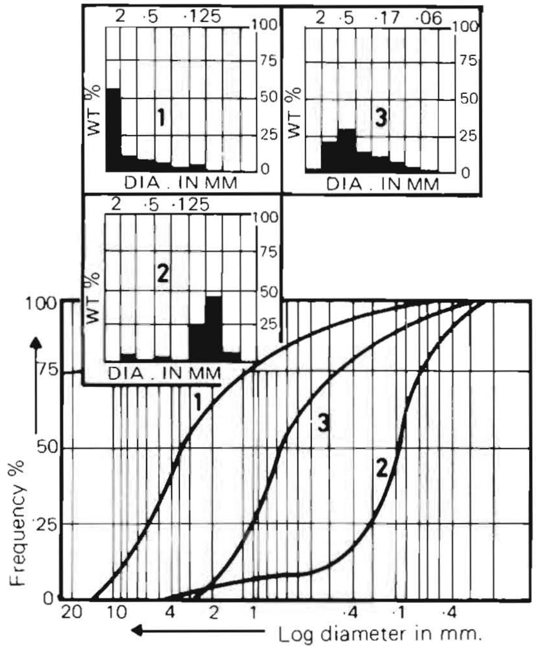

Fig. 3(a). Histograms and cumulative curves for the soil samples 1, 2 and 3.

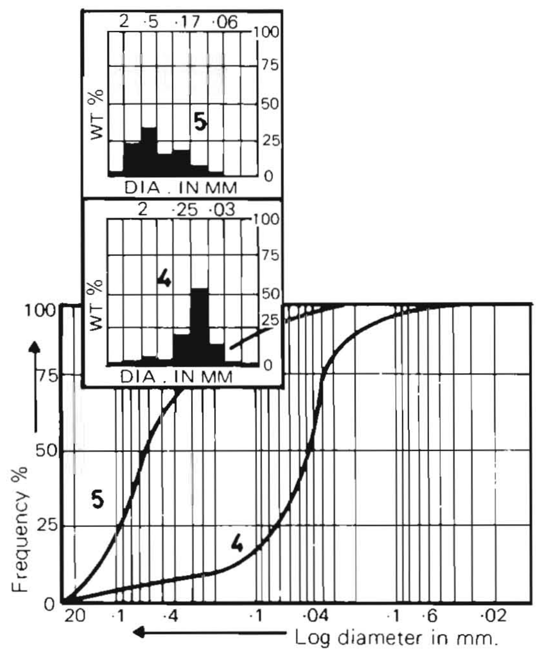

Fig. 3(b). Histograms and cumulative curves for the soil samples 4 and 5.

Table 4. Mechanical analysis of soil samples from Riyadh region.

Sample No.	SO	SK	Unif.CO	Kurt.CO
1	2.15	0.57	0.26	0.28
2	1.55	1.10	0.26	0.06
3	1.86	0.69	0.31	0.23
4	1.39	1.14	0.22	0.10
5	1.95	0.62	0.32	0.24

SO = Coefficient of Sorting
SK = Coefficient of Skewness
Unif.CO = Coefficient of Uniformity
Kurt.CO = Coefficient of Kelley's quartile Kurtesis.

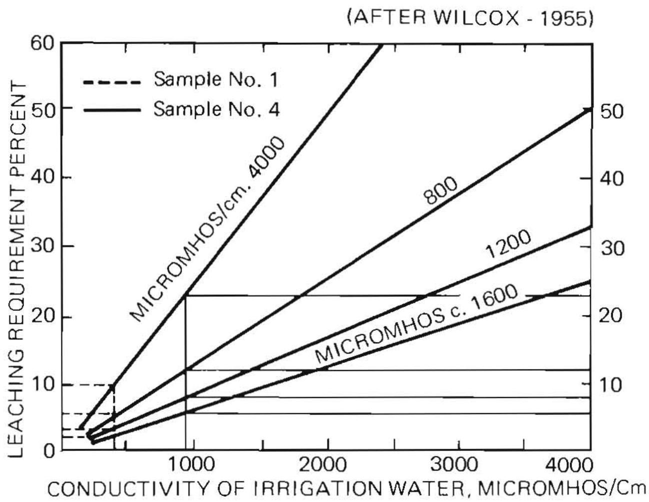

Fig. 4. Graphic estimation of leaching requirement for an irrigation water of known conductivity.

F) Salinity Control

Irrigation with insufficient amount of water in areas of hot climatic conditions, as in the case of the area under study, can lead to undesirable salt accumulation in the root zone which has an adverse effect on plant growth. In such a case, leaching is necessary to maintain a favourable salt balance; leaching requirement as a function of conductivity of water is shown in Fig. 4 for water sample No. 1 and 4. In order to conserve both water and soil (in particular to ensure that the soil does not deteriorate in the long run), suitable irrigation techniques should be employed. In the Riyadh region, a drip or trickle irrigation technique seems to be one of the best techniques to achieve this purpose. The great advantage in this system is in reducing evaporation because only a small area of the soil is wetted and the water is not sprayed into the air. Injecting fertilizers directly into the irrigation water is more effective and it also reduces the cost.

Conclusion

Water represented by samples No. 1 and 4 from the Minjur aquifer are suitable for irrigation in Riyadh and its outskirts. The two other samples, samples No. 2 and 3, from Jubaila aquifer are more doubtful for their use in irrigation, because of their high E.C., and could be used to irrigate only certain types of crops. All other factors such as boron, toxic, and trace element concentrations together with R.S.C. are within permissible limits of irrigation water. Because Wadi Hanifa (Fig. 1) soils are sandy or silty calcareous alluvial deposits, coarse to medium textured with high to medium infiltration capacity, water sample No. 2 and 3 could be used to irrigate salt tolerant crops under special water management in certain hot and temperate regions.

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التحليل الكيميائى للماء المستخدم فى الزراعة فى منطقة الرياض

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يقدم هذا البحث دراسة لأربع عينات ماء ، تُستخدم للزراعة فى الرياض ؛ مصادر هذه المياه هى الطبقات الحاملة للماء فى مُتكونىّ الجبيلة والمنجور. وتدل الدراسة الهيدروكيميائية لهذه المياه على أن مياه مُتكـون المنجور أكثر صلاحية للأغراض الـزراعية من ناحية أخـطار الملوحـة والقلوية . ويقل تركيز البورون فى هذه المياه عن جزء واحد من المليون ، وهذا يجعلها مناسبة لبعض المحاصيل الحساسة للبورون وجميع المحاصيل الأقـل حسـاسية للبـورون . إن تركيز كربـونات الصوديوم المتبقى هو أقل من الواحد الصحيح مما يجعل هذه المياه صالحة للرى .