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CHEMICAL PROFILING OF GROUND WATER OF AL-KHARJ, SAUDI ARABIA

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Groundwater quality of Al-Kharj, Kingdom of Saudi Arabia, was studied through the analysis of 115 samples for EC, pH, TDS, Ca, Mg, Na, K, B, CO_3, C1, NO_3, PO_4 and SO_4. Correlation of electrical conductivity (EC at 25^{o}mmhos/cm) with total dissolved solids (TDS) for the area was found to be Y=823X-63 (N=115; R=0.968) as compared to the overall formula of the Kingdom, Y=850X-200 and that of the US Salinity Laboratory's formula Y=640X. Correlation of EC with ions like sodium, chloride and sulphate were studied; this shows that sulphate is the most dominant ion in this area (R=0.793).

Frequency distribution of cumulative parameters like TDS showed 80% of sample population in the range of 1000 to 2000 mg/l and above, while pH values ranged from 6.5 to 7.5 for 84% of the population.

Key words: Ground water, Chemical analysis, Correlation of EC.

INTRODUCTION

The quality and quantity of water is a matter of great concern in the arid and semi-arid zones of the world. With the fast development of agricultural activities in the Kingdom of Saudi Arabia, it has become imperative to study the chemical characteristics of groundwater for the purpose of improving land, water and soil conditions and raising productivity.

During our studies of the water quality of the Kingdom of Saudi Arabia over a decade, it has been observed that the chemical constituents of wellwater change with distance, depth, time and other ecological factors within a given area.

Changes in the values of cumulative parameters for total dissolved solids (TDS at 180^{o}C) in irrigation water have been reported to range from 500 to 900 mg/L [5]. This covers a wide range of classification from class I water with no problems for irrigation to class III water associated with serious problems. US Salinity Laboratory has developed a formula to calculate TDS from electrical conductivity based on samples from the US. Due to higher global and regional variations under local conditions it was considered important to amend it for various agricultural areas and compare it to the other two formulae.

Chemical analysis of Riyadh irrigation water has been reported by Naeem *et al* [8]. This paper draws conclusions about a big aquifer like Minjur on the results of two samples that tends to give an erroneous picture. In order to give a broader view a comparison of this data is made with 44 samples from Minjur (Table 9).

Physiological studies of flouride (F) and nitrate (NO_3) contents in Saudi waters have been reported by J.M. Mee [5], its utilization as mineral water [1] and on the trace organics [6] with important information.

In order to make this highly variable data understandable and useful, it was considered important to study the water quality characteristics with a focus on smaller areas and use computerized statistical analysis.

This study is intended to function as data base of the water quality of Al-Kharj area for future comparison of any hydrogeological changes and to help agronomists, soil scientists and irrigation specialists in planning and future extrapolations. It is also intended to help environmentalists and physiologists for study of water related diseases and establishing any possible correlations between water quality and prevalent health disorders.

It is also hoped to serve as a model for water quality study of variable data and to help present a comprehensive study at a later stage by incorporating the comments and input received from the readers of various interacting fields.

An attempt has been made to present the data in an easy and understandable manner, purposely avoiding any rigid conclusions to ensure that other fields of specializations are not overstepped, except where clear references were available.

MATERIALS AND METHODS

Samples were received in clean mineral water bottles from the Al-Kharj area including Kharj, Sahna, Dilem, Sehba, Wadi Nissah. Efforts were made to analyze the samples with minimum time lapse (1-5 days).

EC and pH were determined by dual-ion analyzer after calibration. Ca, Mg, B, C1, NO_3, PO_4 and SO_4 were analyzed by a Technicon Auto Analyzer SMA-9 using colorimetric techniques. Carbonates and bicarbonates were analyzed by a Fischer Autotitralyzer. Determination of Na and K was done by Beckman's Klina flame photometer.

Total dissolved solids were determined by weighing after overnight drying at 180°. The chemicals used for the preparation for standards and working solutions were AR grade. Data processing was conducted by TRS-80 programme for statistical analysis.

RESULTS AND DISCUSSION

The knowledge of total dissolved solids in irrigation and potable water is important to assess its suitability for irrigation and/or drinking purpose. Actual determination of TDS is laborious and time consuming. In order to calculate it approximately, from electrical conductivity, US salinity laboratory has devised a formula, TDS (ppm) = Ec x 640 [10]. The relationship is based on the water samples from the US. Later John Mee *et al.* [7] amended it to TDS ppm =(Ec x 850) −200 for Saudi Arabia on the basis of overall Saudi groundwater samples.

This formula has been further amended to TDS (ppm) = (EC x 823) − 63 with a focus on Al-Kharj area and compared to the above relationships (Fig. 1). The upward shift in the relationship for Saudi groundwater as compared to Al-Kharj and US samples can be attributed to the dominance of ions like sodium, chloride and sulphate in the Saudi groundwater.

Major ions in Saudi ground waters are sodium, chloride, sulphate and bicarbonate. Attempt has been made to derive information about these ions from electrical conductivity (Fig. 2). Sodium, chloride and sulphate showed a positive correlation with electrical conductivity. The value of correlation coefficient (R) equals 0.894, 0.869 and 0.793, respectively. Fig. 2 shows the dominance of these ions in the Al-Kharj waters to be in the order of SO_4, C1 and Na on weight basis. Electrical conductivity and concentration of bicarbonate did not show significant correlation.

Total dissolved solids (TDS) are mainly contributed by ions such as Na, Ca, Mg, HCO_3, C1 and SO_4 and their main effect on irrigation water quality is osmotic. These ions up to a certain limit contribute to plant growth and soil properties, but may adversely affect the productivity of soil and plant growth if present in excessive amounts.

Total dissolved solids in the Al-Kharj waters (Table 1) show a higher tendency in general. There is no sample below 500 mg/l. Only 12% of the samples are less than 1000 mg/l at 180°, which is close to class I irrigation water according to the California State Water Resources Control Board [4]. Majority of the samples (57%) are class II water that demands a careful use of water to avoid problems whereas 30% samples are of class III causing serious problems. Soil solutions may be 3-8 times more concentrated than the replenishing water which will adversely affect plant growth and accentuate soil related problems.

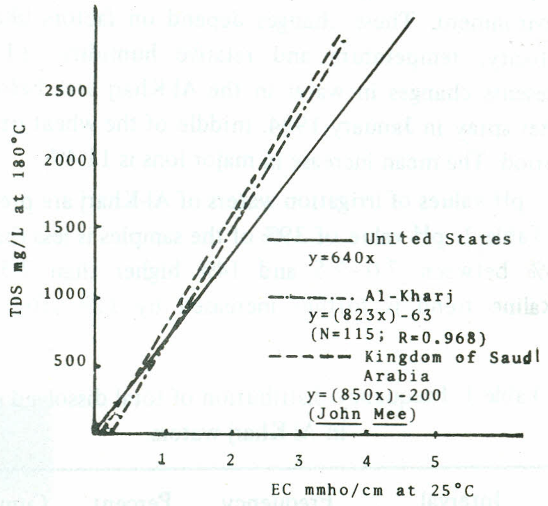

Fig. 1 Relationship of electrical conductivity with total dissolved solids at 180° in Al-Kharj Waters as compared to overall Saudi Waters and US formula.
(RAWRC Water Group 1984)

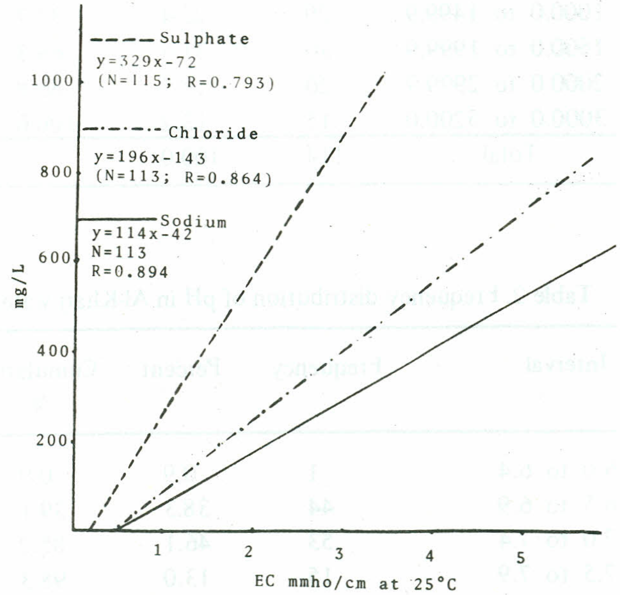

Fig. 2 Relationship of EC with sodium, chloride, and sulphate in Al-Kharj waters.
(RAWRC Water Group KHJ-84)

However, plants vary widely in their tolerance to salinity and specific salt constituents depending on soil type, temperature, rainfall and irrigation practices. Crops like barley, corn, cowpea, rice, sorgum and wheat are most sensitive during early seedling growth and become more tolerant during the later stage of growth and development [3].

The major system of irrigation in this area like elsewhere in the Kingdom of Saudi Arabia is centre pivot irrigation. The water undergoes further changes due to evaporation during spray and its interaction with the environment. These changes depend on factors like wind velocity, temperature and relative humidity. (Table 8) presents changes in water in the Al-Kharj area before and after spray in January-1984, middle of the wheat irrigation period. The mean increase in major ions is 11.4%.

pH values of irrigation waters of Al-Kharj are presented in Table 2. pH value of 39% of the samples is less than 7.0, 46% between 7.0–7.5 and 14% higher than 7.5. This alkaline trend is further increased by 12% after centre pivot spray (Table 8) which is the most common irrigation system of the area.

The alkaline nature of water is likely to raise the soil pH. Efforts should be made to maintain a soil pH of 6.5–7.5 that gives maximum availability of primary nutrients (NPK) and relatively higher degrees of availability of the other nutrient elements (Fe, B, Cu, Zn) [9].

Bicarbonate contents (Table 4) in majority of the samples (86%) are between 150-250 mg/l, which combined with the evaporation effect of 12%, may from white deposits on leaves when applied through the sprinkler [9]. Values of residual sodium carbonate (RSD) (Fig. 2) for water samples of varying electrical conductivity are presented in Fig. 2; they are less than 1.0 and thus are beyond any threat to agriculture development and productivity in this area.

Sodium and chloride contents in the Al-Kharj waters are correlated to electrical conductivity (EC) with R=0.894 and 0.864 and thus correlated to each other. Sodium in the majority of samples (62%) is between 100-300 mg/l and

Table 1. Frequency distribution of total dissolved solids in Al-Kharj waters.

Interval	Frequency	Percent	Cumulative %
0.0 to 499.0	0	0.0	0.0
500.0 to 999.9	14	12.3	12.3
1000.0 to 1499.9	29	25.4	37.7
1500.0 to 1999.9	36	31.6	69.3
2000.0 to 2999.9	20	17.5	86.8
3000.0 to 5200.0	15	13.2	100.0
Total	114	100.0	

Table 2. Frequency distribution of pH in Al-Kharj water

Interval	Frequency	Percent	Cumulative %
6.0 to 6.4	1	0.9	0.9
6.5 to 6.9	44	38.3	39.1
7.0 to 7.4	53	46.1	85.2
7.5 to 7.9	15	13.0	98.3
8.0 to 8.4	2	1.7	100.0
8.5 to 9.0	0	0.0	100.0
Total	115	100.0	

Table 3. Frequency distribution of bicrabonate in Al-Kharj water.

Interval	Frequency	Percent	Cumulative %
0.0 to 49.9	0	0.0	0.0
50.0 to 99.9	3	2.6	2.6
100.0 to 149.9	5	4.4	7.0
150.0 to 199.9	57	50.0	57.0
200.0 to 249.9	41	36.0	93.0
250.0 to 299.9	6	5.3	98.2
300.0 to 349.9	2	1.8	100.0
Total	114	100.0	

Table 4. Frequency distribution of sodium in Al-Kharj water.

Interval	Frequency	Percent	Cumulative %
0.0 to 99.9	12	10.8	10.8
100.0 t0 199.9	37	33.3	44.1
200.0 to 299.9	43	38.7	62.0
300.0 to 399.9	9	8.1	91.0
400.0 to 900.0	10	9.0	100.0
Total	111	100.0	

Table 5. Frequency distribution of chloride in Al-Kharj water.

Interval	Frequency	Percent	Cumulative %
100.0 to 149.9	14	12.6	12.6
150.0 to 199.9	7	6.3	18.9
200.0 to 249.9	32	28.8	47.7
250.0 to 299.9	17	15.3	63.1
300.0 to 349.9	6	5.4	68.5
350.0 to 399.9	15	13.5	82.0
400.0 to 449.9	5	4.5	86.5
450.0 to 499.9	1	0.9	87.4
500.0 to 549.9	0	0.0	87.4
550.0 to 1350.0	14	12.6	100.0
Total	111	100.0	

Table 6. Frequency distribution of sulphate in Al-Kharj water.

Interval	Frequency	Percent	Cumulative %
0.0 to 249.9	16	14.0	14.0
250.0 to 499.9	23	20.2	34.2
500.0 to 749.9	40	35.1	65.0
750.0 to 999.9	11	9.6	78.9
1000.0 to 1249.9	9	7.9	86.8
1250.0 to 1499.9	7	6.1	93.0
1500.0 to 1749.9	5	4.4	97.4
1750.0 to 1999.9	2	1.8	99.1
2000.0 to 2249.9	0	0.0	99.1
2250.0 to 2500.0	1	0.9	100.0
Total	114	100.0	

Table 7. Frequency distribution of boron in Al-Kharj water.

Interval	Frequency	Percent	Cumulative %
0.0 to 0.2	3	6.8	6.8
0.2 to 0.4	18	40.9	47.7
0.5 to 0.7	8	18.2	65.9
0.7 to 0.9	12	27.3	93.2
1.0 to 1.2	3	6.8	100.0
Total	44	100.0	

Table 8. Change in water quality if irrigation water after spray by centre pivot system in Al-Kharj area.

Parameter	Before spray	After spray	% Change
pH	6.81	7.62	11.89
EC (mmho/cm)	1.90	2.09	10.00
Ca (ppm)	205	230	12.19
Mg (")	67	72	7.46
Na (")	207	230	11.11
K (")	12	12	—
HCO_3 (")	212	239	12.76
Cl (")	232	260	12.07
SO_4 (")	600	680	13.33
TDS (")	1579	1757	11.27

$\bar{x}$ = 11.34
CV = 1.75
CV % = 15.41

Table 9. Comparison of chemical characteristics of Minjur water.

Parameter	2 Samples*			44 Samples**			% Diff.
	Min.	Max.	$\bar{x}$	Min.	Max.	$\bar{x}$	
Sp. Cond.	406	943	674.5	500	7000	1560	131.3
pH	7.2	7.7	7.45	–	–	–	–
Na (ppm)	84.2	94.2	89.2	14	1200	204	128.7
Mg "	29.51	59.45	44.48	6	352	60	34.9
Ca "	43.89	106	74.95	14	505	162	116.1
Cl "	117	117	117	14	1670	338	188.9
SO_4 "	185	185	185	14	2300	419	126.5
HCO_3 "	15	18	16.5	43	356	165	900.0
TDS "	284	660	472	360	5860	1390	194.5

* Results based on two samples as reported

** Results based on 44 samples (Ministry of Agriculture and water, (1984)

above. Only 12% of sample population has a chloride level of less than 150 mg/l, whereas 70% samples fall within the 150-400 mg/l range.

Usually there is no problem due to sodium and/or chloride being used through the sprinklers at levels of 70 mg/l of sodium and 106 mg/l of chloride. This means that the majority of the samples may cause leaf burns due to foliar absorption of Na and Cl which may be partly corrected by irrigating at night during hot-dry periods [9].

The effect of sodium on plant growth and yield is both direct and indirect. Direct effects are due to the accumulation of toxic level of sodium and are generally limited to woody species. Indirect effects include both nutritional imbalance and impairment of the physical conditions. The nutritional effect of sodium is not simply related to exchangeable sodium percentage of soils, but depends on the concentration of Na^+, Ca^{++} and Mg^{++} in soil solutions [3].

Higher concentrations of sulphate ions may cause precipitation of calcium and may be toxic in itself to the plant Table 6 shows that 25% of the samples have a sulphate content of less than 500 mg/l which is within permissible levels for irrigation [4]; 44% samples are in doubtful range, while the rest are unsuitable for irrigation purpose.

Boron is an essential element in the nutrition of higher plants, yet concentration of boron in irrigation waters may be deleterious to certain crops in excess of 0.5 mg/l. More than half (54%) of th samples of the area under study fall within this range. The rest of the samples are in the range of 0.5–1.25 mg/l of boron which can be used for irrigating date palm, cabbage, lettuce, alfalfa and wheat [4], the common crops of this area.

Care should be exercised in the irrigation of boron sensitive crops like grapes, oranges, grapefruits and lemons that cannot tolerate levels above 0.5-1.0 mg/l. However, the levels of boron in soil water should be monitored, because of its accumulation in the soil due to resistance to leaching and use of micronutrients.

Majority of the samples (77%) have a calcium content of 100-300 mg/l, 18% above 300 mg/l. Levels of nitrate in 84% of the population are less than 50 mg/l, while potassium is less than 16 mg/l for 95% of the samples. Phosphate is below the detectable level (1 mg/l) in all samples.

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