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ON THE APPLICATION OF ARABIAN GULF WATER IN IRRIGATION: A FUTURE POSSIBILITY

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ABSTRACT

Open seas waters have a chlorinity (Cl‰) of 35‰. Chloride and sodium are the dominant ionic species in sea water; where their gravimetric contents are 89.98 and 77.39% of total anions and cations, respectively. Sodium absorption ratio (SAR) is relatively high (59.89). Magnesium is the predominant bivalent cation and its concentration is 5.2 times greater than that of calcium. Therefore, restriction on soil water management should be considered when applying sea water for irrigation. Exchange of water between the Arabian Gulf and the Indian Ocean is restricted through the strait of Hormuz; thus shallow western coasts of the Arabian Gulf can acquire Cl‰ as high as 60−70‰. Therefore, highly salt tolerant crops can only be irrigated by Gulf water using certain application/blending strategies. Barley can tolerate 12 dS m^{-1} water salinity without any apparent yeild decrement. Yield would decrease by 5% per each additional increment in water salinity beyond 12 dS m^{-1} Thus, if Gulf water salinity was treated according to the model of plant response to time weighted salinity, then barley could alternatively be irrigated with fresh/Gulf water in a way that would save a minimum of 16% of the applied water. Different strategies of applying/mixing good quality water with Gulf water are also discussed.

INTRODUCTION

Shortage of good quality water is becoming an increasing problem in many arid and semi−arid regions of the world. As for areas with ground water that is susceptible to contamination by pesticide residues or by deeply percolated

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nitrate, new measures have recently been imposed on excessive application of irrigation water. In other areas, like San Joaquin valley, California and Nile Delta, Egypt, discharging excessive drainage water is rather a technically complicated and environmentally critical problem.

Because of the above factors, interest has recently been focused on minimizing amounts of applied irrrigation water (minimum leaching fraction), reuse of drainage water, or blending drainage water with good quality irrigation. The Arabian Gulf area has been facing a shortage of good quality water. In addition, the limited soil and water resources, joined by the harsh climate, pose a real challenge to the possibility of developing feasible agriculture. The objective of this study was to demonstrate the possibility of applying the Gulf water in irrigating salt–tolerant winter crops, particularly, barley (Hordeum vulgare). Potential problems associated with soil solution chemistry and reduction in crop yield will also be discussed.

Chemistry of Sea Water

The relative composition of the major 11 ionic species in sea water is almost constant. The ion that is usually selected to characterize a given sea water CL expressed gravimetrically as chlorinity is parts per thousand (Cl‰). The chlorinity is determined by titration of sea water with $AgNO_3$, and is defined as the mass in grams of Ag necessary to precipitate the soluble halogens (Cl and Br) in 328.5233 g of sea water. Coefficient of salinity is constant which is equivalent to 1.80655. Therefore, the total mass of sea salt (S‰) is related to the Cl‰ by:

$$S‰ = 1.80655\ Cl‰ \qquad \text{(UNESCO, 1966)}$$

Chlorinity was first determined by the British Chemist Dittmar is his report on the chemistry of 77 sea water samples collected during the expedition of the British warship "Challenger" for the period 1873 – 1876 (Wallace, 1974).

Typical results of a sea water of 35‰ salinity is presented in Table (1). The stoichiometric values of each ionic species is calculated in SI units. These results show that among ionic species, Cl is the most dominant anion (899.8g kg^{-1} sea water); being 566 mol m^{-3} out of 629 mol m^{-3} of the total negative charge. Sodium is the most dominant cation (773.9 g kg^{-3} sea water); being 486 mol m^{-3} out of 628 mol m^{-3} of the total positive charge. Moreover, Na concentration (mol m^{-1}) corresponds to 85.87% of that of Cl.

Table 1

Chemical composition of sea water of 35‰ salinity *

Ionic Species	Concentration	
	$g\,kg^{-1}$ Sea water	$MoL\,m^{-3}$
Cl	19.353	566.04
Na	10.760	486.06
SO_3	2.712	58.55
Mg	1.294	110.36
Ca	0.413	21.38
K	0.387	10.26
HCO_3	0.142	2.41
Br	0.067	0.87
Sr	0.008	0.19
$B(OH)_3$	0.023	1.15

* Concentration ($g\,kg^{-1}$ sea water) were taken from W.J. Wallace (1974). Concentrations ($mol\,m^{-3}$) were calculated from the previous values after correction for water volume.

Gravimetric ratios of each ionic species relative to Cl is represented in Table (2). The results shows that Na represents only 55.56% of the Cl weight. Predominace of Na is best evaluated by sodium absorption ratio (SAR). This parameter is usually used to describe sodicity level of irrigation water and could be determined as:

$$SAR = 1.414\ [Na]\ /\ [Ca+Mg]^{1/2}$$

Where ionic concentration is expressed in mol m^{-3}. The SAR of the above sea water sample is 59.89, which is relatively high and indicates the enrichment of sea water by Na.

Table 2

The ratio of gravimetric ion concentration to that of Cl in 1 kg sea water of various chlorinities *.

Ionic Species	Ion‰/Cl‰	Ionic Species	Ion‰/Cl‰
Na	0.55556	SO_4	0.14000
Hg	0.06680	HCO_3	0.00735
Ca	0.02125	Br	0.00348
K	0.02060	F	0.00006
Sr	0.00041	$B(OH)_3$	0.00132
Cl	0.99894		

* After E.D. Goldberg (ed.) (1974).

Contrary to most irrigation water, Mg concentration in sea water is much higher than that of Ca. The concentration of Mg is about 5.2 times greater than that of Ca. The inbalanced ionic distribution in sea water can aggravate salinity stress for some crops (Pearson, 1960), or induce nutritional difficiences for others (Bernstein and Hayward, 1958).

The results given for HCO_3 are actually values of the carbonate alkalinity expressed as if they were all bicarbonate. At pH 8.0 and 298 K, the carbonate alkalinity is about 91% of the bicarbonate (Edmond, 1970). Moreover, carbonate alkalinity represents only 0.38% of the total anionic charge. Therefore, precipitation of Ca as $CaCO_3$ is not expected to play a dominant role in the chemistry of sea water.

At pH of about 8.2 of the sea water, boron exists primarily as boric acid [$B(OH)_3$ = 80%]; the remaining 20% of total soluble boron is hydrolyzed into $B(OH)_4-$. According to Goldberg and Glaubig (1986) boron absorption is best described by Ligand exchange with hydroxyl groups at the edges of clay particles and Al and Fe oxide minerals. In addition, boron absorption exhibits a peak in the pH range 8.5 to 10; thus using sea water in irrigation might lead to soil enrichment with boron, particularly in soil that are rich in Al and Fe hydroxides.

Characteristics of The Arabian Gulf Water

The Arabian Gulf is a shallow sea oriented in a northwest – southeast direction. The Gulf has an area of about 24000 km^2, an average depth of 31m, and a maximum depth of about 110 m near Strait of Hormuz. The latter depth is relatively shallow compared to 900 m depth of the Gulf of Oman (Al Asfour, 1982).

Most of the Arabian Gulf can be considered partially restricted due to the limited interchange of water with the Indian Ocean through the narrow Strait of Hormuz. Surface salinities in the central parts of the Gulf average 37–40%; while, shallow western coasts of the Arabian Peninsula can acquire salinities of 40–50‰, rising to 60–70‰ in remote lagoons and coastal embayments such as the Gulf of Salwa.

In the axial parts of the Gulf, salinity increases 2–4‰ with depth. Figure 1 shows salinity trends within the Gulf (Purser and Seibold, 1973). Because of the high evaporation rate, loss of water from the surface is not compensated by precipitation and river inflow. Consequently, a slow circulatory surface current flows into the Gulf moving anticlockwise along the Iranian coast. This current plays a dominant role in determining the distribution of salinity, temperature and nutrients within the Gulf water.

Salinity of the surface waters increases from approximately 36.6‰ near the entrance to 40.6‰ near the northwest end of the basin (Kuwaiti shores). Due to the combined effects of water cooling and dense surface waters sink to the bottom, raising salinity and lowering temperatures of these deep waters. Moreover, water flowing out of the Gulf follows the deeps near the Masandam Peninsula (Purser and Seibold, 1973).

Future Potential of the Gulf Water Use in Irrigation

Irrigation water is a factor actively interacts with soil, climate and crops in agricultural processes. Therefore, evaluation criteria of water quality are not possible independent of the other components. In the present study, there are several constraints that should be taken into consideration in evaluating available options for using Gulf water in irrigation. These are poor soil properties, harsh climate, particularly high summer temperature, and limited resources of good quality water (low salinity and SAR).

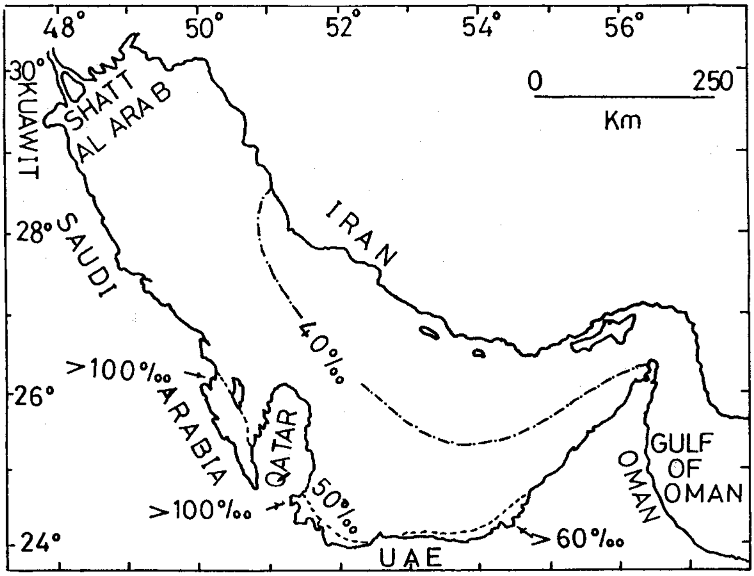

Fig. 1 : Map showing salinity trends within the Arabian Gulf (After Purser and Seibold, 1973).

As a case study, the winter crop barley *Hordeum vulgare* was selected to carry out the following assessment of the posibility of being partially or totally irrigated with the Gulf water. Barley was selected because of its tolerance to solution salinity as high as 12 ds m^{-1} (Hassan *et al.,* 1970). According to Maas and Hoffman (1977), linear reduction in yield per each unit increment (ds m^{-1}) in solution salinity beyond the above threshold salinity is 5% of the maximum yield. Therefore, increasing solution salinity to 14 ds m^{-1} would allow a 90% yield of barley.

Plant response to salinity stress could also be evaluated in terms of time–weighted salinity (EC_w) (Pearson *et al.,* 1966). The EC_w is calculated as in the following:

$$EC_w = \Sigma t_i(EC_i) / \Sigma t_i$$

Where t is the period (days) during which the crop was subjected to irrigation with water of a given salinity (EC_i).

Based upon the above approach, barley could be irrigated by either one of the following techniques:

1a – Applying mixed Gulf water with good quality water. If one assumes an average salinity of Gulf water to be 65 ds m^{-1}, then a mixture of 1:6 (Gulf water to good quality water) could be applied directly to the field. Problem of high sodicity of the new blend is not generally anticipated since high electrolyte concentration is expected to offset sodicity hazard. If soils selected for carrying such a practice are coarse–textured with good drainage, then sodicity problem will be negligible.

The results of chemical composition of sea water (Table 1) show that B concentration is 4 $\mu g\ mL^{-1}$. Dilution of the Gulf water 7 times would bring down B concentration to 0.57 $\mu g\ mL^{-1}$. According to Keren and Bingham (1985) barely is a semitolerant crop to B toxicity, and can tolerate B concentration in soil solution up to 2.1–4.0 $\mu g\ mL^{-1}$. Accordingly, it is unlikely to encounter a serious B toxicity problem, even when irrigating with undiluted Gulf water. However, blending technique would save only 1/6 the amount of applied good quality water.

1b – Applying Gulf water by means of a sprinkler irrigation system to be immediately followed by a minimum application of good quality water. The amount of good quality water should be sufficient to dilute the highly saline Gulf water left on plant leaves or stored in the upper horizon of soil profile. The premise of this technique depends on the assumption that plant can efficiently utilize good quality water stored in some layers of the soil profile on the expense of saline water stored in other layers (Bingham and Garber, 1970).

Moreover, applying good quality water after saturating the soil profile with saline water will substantially reduce the downward movement of good quality water and thus increase the water use efficiency of barley. The major requirement for using such a method is to have good soil drainability; preferably, discharging excess drainage water back to the Gulf body.

2 – Applying good quality water at the early stage of barley growth (germination and seedling emergence) to be followed by alternative applications of Gulf and good quality waters. The major criterion of such a method is to obtain a time–weighted salinity, all over the growth period, not to exceed the threshold concentration of barley (EC^{w} = 12 ds m^{-1}).

3 – Shore – cropping of barley strains known to be exceeding salt tolerant. This technique has recently been adopted in California where barley cultivars were cultivated in sand dunes irrigated with undiluted water from the Pacific Ocean (Epstein, 1977; Wood, 1977). Yield of barley was as high as 1710 kg ha^{-1}, and quality of grain (protein content, fat, carbohydrates and fiber) was not changed.

In conclusion, utilization of the Gulf water in irrigation would be a future possibility, especially with the increasing demand for food. To deal with such a sensitive, though essential, reseach activity, a careful plan should be designed to meet the following questions: (i) where, how, and how much irrigation water should be applied? (ii) what are the most suitable crops to be cultivated? (iii) what would be the long term environmental consequences when such a nonconventional agriculture is introduced?

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عن استعمال مياه الخليج العربي في الري : امكانية مستقبلية

طالب أبو شرار

تحتوي مياه البحار على نسبة من الكلوريد تصل إلى ٣٥٪ وتغلب أيونات الكلوريد والصوديوم من حيث المحتوى الوزني لمجموع الكاتيونات والأنيونات فتصل نسبتيها إلى ٨٩,٩٨ ، ٧٧,٣٩٪ بالترتيب . كما أن قيمة معامل أو امصاص الصوديوم (SAR) مرتفعة (٥٩,٨٩) . ويغلب أيون الماغنسيوم ضمن الكاتيونات ثنائية الشحنة حيث يزيد تركيزه ٥,٢ مرة عن تركيز أيون الكالسيوم .

ولذلك فإنه لابد من مراعاه تدبير مياه التربة الملائمة حين استخدام مياه البحر في الري وحيث أن تبادل المياه بين الخليج العربي والمحيط الهندي ينحصر من خلال مضيق هرمز ، فإن الجانب الغربي الضحل للخليج العربي تزيد فيه تركيز الكلوريد حيث تتفاوت بين ٦٠٪ ، ٧٠٪ .

ولذلك فإن المحاصيل التي يمكنها تحمل الملوحة المرتفعة هي التي يمكن ريها بمياه الخليج العربي . وحيث أن الشعير يمكنه تحمل ملوحه في حدود ١٢ درجة بدون أن تتأثر انتاجيته وأن أي إضافة بسيطة من الملوحة فوق ١٢ تؤدي إلى انخفاض في الانتاجية بما يعادل ٥٪ لكل إضافة ، لذلك فإن مياه الخليج العربي يمكن استخدمها في ري الشعير بعد معالجتها بأسلوب التحلية الوزنية مع استخدام الري التبادلي بين المياه العذبه المحلاه والمياه وذلك يوفر على الأقل ١٦٪ من المياه المستخدمة في الري التقليدي ولقد نوقشت من خلال البحث استراتيجيات عدة بشأن استخدام المزج بين مياه ذات نوعيات جيدة مع مياه الخليج العربي لأغراض الري .