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SALINE GROUND WATER AND ITS USE FOR IRRIGATION

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The paper describes analytical data on the quality of ground waters used for irrigation in the states of Rajasthan, Haryana, Punjab, Uttar Pradesh and Gujarat. Many of these waters considered unfit according to the U.S.D.A. standards have been utilized for irrigation over a long period without much adverse effect on the soil and crop growth. The work on the use of water of varying quality on sandy soils at Jobner (Rajasthan) and Hissar (Haryana) has been reported. At Jobner, higher yield of wheat grain was obtained and the salt concentration in soil was kept at much lower level using 15% leaching than without leaching. At Hissar, the sub-surface drip method of irrigation produced higher yield of radish even with poor quality water as compared to the ordinary surface method. Thus, with adoption of suitable management practices and irrigation methods highly saline waters within certain limits can be used to grow good crops without much harmful effects.

Despite rapid development of several river valley irrigation projects in India in recent years, ground water still constitutes the major source of irrigation in the arid and semiarid regions. More than 50% of the irrigated area in Rajasthan and in parts of Punjab, Haryana and Uttar Pradesh is covered by well waters, though irrigation by well waters is being used in some other states as well. In certain areas, however, underground waters are not being used because of their questionable quality. Several standards for judging the quality of irrigation waters have been proposed from time to time, but the one suggested by U.S. Salinity Laboratory (1954) is most widely used. Some of the criteria used for classifying the irrigation waters include: (i) electrical conductivity, (ii) soluble sodium percentage, (iii) sodium adsorption ratio, (iv) residual sodium carbonate, (v) Kelley's index, (vi) Puri's salt index, and (vii) boron content.

Quality of Ground Waters in Certain Parts of India

A number of systematic studies on the quality of well waters have been made in Rajasthan, Punjab, Haryana, Uttar Pradesh and Gujarat. The work has been reviewed in detail by Bhumbla (1969). Consolidated data on the quality of waters from different districts of Rajasthan have been reported by Paliwal (1970), while the distribution of ground waters according to E.C. and S.A.R. values has been reported by Mondal (1964) and according to E.C. and percentage of divalent cations by Bhandari *et al.* (1970). According to Shankarnarayan *et al.* (1965) the ground waters of Jodhpur and Pali districts have E C. in the range of 900-5500 micromhos/cm.

These data indicate that most of the waters are medium to highly saline. In general, the quality of well waters of western Rajasthan is more poor, but it improves in the eastern and southern regions having comparatively higher rainfall. Highly saline waters are dominated by sodium and chloride ions, while low and moderately saline waters contain relatively greater proportion of divalent cations and sulphate and bicarbonate anions. Many waters show predominance of Mg over Ca particularly in western Rajasthan. Boron is present in higher amounts in certain cases and may be injurious particularly in heavy textured soils. The boron content of well waters from Rajasthan varies from traces to 5 ppm. Paliwal *et al.* (1969) have reported very high fluorine content in well waters of Bhilwara district and have suggested that fluorine should be considered while judging the quality of irrigation waters. The presence of nitrates in sufficient amount in ground waters is considered to counteract the adverse effects of high sodium. The nitrate content in the range of 0.12 to 11.27 ppm was reported in the ground waters of Jodhpur and Paliwal districts by Paliwal and Maliwal (1966) and in the ground waters of Nagaur district by Paliwal and Gandhi (1969).

The chemical composition of ground waters from different districts of Punjab as reported by Bhumbla (1969) shows an increase in the content of carbonates and bicarbonates in certain areas, resulting in high RSC values. The use of some of these waters needs addition of gypsum to reduce the harmful effects.

The average quality of ground waters of Haryana reported by Bhumbla (1969) shows that sodium is the most predominant cation followed by magnesium, while calcium forms hardly 10% of the total cations. Chloride is more predominant among the anions.

Kanwar and Manchanda (1964) concluded that the higher amounts of nitrate and potassium in the well waters of Gurgaon and Mohindergarh districts help the crop to tolerate the injurious effects of sodium. A high amount of fluorine in some of the waters has been reported by Kanwar and Mehta (1968).

Mehrotra (1969) reported the analysis of a large number of well waters from U.P. The results show that the well waters from Mathura district are highly saline and contain bicarbonates as the predominant anions with considerable amount of carbonates. Recently, Gupta (1971a) has reported lithium content in the ground waters of Mathura district and has remarked that the waters with conductivity of 6000 micromhos/cm or more contain lithium in toxic amounts (>0.05 ppm).

Information on the quality of ground waters from different areas of Gujarat has been given by Talati (1969), who has stated that more than 50% of the waters contain residual sodium carbonate.

Observations on the Use of Brackish Water in Certain Parts of India

Most of the ground waters in arid and semiarid areas of India are highly saline with preponderance of Na followed by Mg among cations and Cl followed by SO_4 among anions, though carbonates and bicarbonates are present in high concentration in the waters of low EC value and in relatively better rainfall areas. Boron occurs in medium to high amounts. Quite a majority of these ground waters will be considered unfit for irrigation in accordance with the U.S.D.A. standards. Nevertheless, they have been used for irrigation over a long period without much adverse effect on the soil and crop growth. According to Paliwal (1969) crops like wheat and barley have been grown in Rajasthan successfully with irrigation waters having EC more than 9000 micromhos/cm. Almost similar observations have been made with highly saline waters in sandy soils of good permeability from Gurgaon, Mohindergarh and Hissar districts of Haryana by Kanwar (1961) and Singh and Bhumbla (1968), from Gujarat by Talati (1969), from Jobner by Singh *et al.* (1967) and many others. In Pali and Jodhpur districts waters of very high salinity are in use for decades where local wheat variety '*Kharchia*' is grown successfully without any deteriorating effect. Satyanarayana *et al.* (1967) concluded that many waters apparently of questionable quality may be used with success on well drained light soils and may not show harmful effects unless the water table is high. Use of saline water for irrigation in Mathura and Agra districts of U.P. has been injurious due to high water table. The use of even relatively less saline water brought about salinity in the poorly drained soils of Amritsar (Kanwar, 1961).

In areas where some salt accumulation takes place in the root zone, cultivation is done on alternative years, so that the salt concentration is reduced considerably by leaching during rainy season. Gupta and Abichandani (1970) stated that irrigation waters predominant in divalent cations create only salinity problem, which can be controlled by leaching caused by rainfall and subsequently by liberal irrigation in the winter season. The harmful effect of sodium increases with an increase in the carbonate and bicarbonate content of water, but RSC due to carbonate is more injurious than due to bicarbonate (Kanwar & Kanwar, 1968). According to Saxena *et al.* (1966) waters up to RSC value of 6.82 m.e/I are utilized for irrigation in Jalore district. Mathur *et al.* (1964) reported that wheat and barley crops grow well with waters containing high amounts of boron (2.8 to 4.1 ppm) in Jodhpur and Pali districts. However, greater concentration of boron may become hazardous in the heavy textured soils. Use of gypsum has been reported to reduce boron hazard of saline waters containing 1 to 5 ppm boron (Gupta, 1971b). The higher amounts of potassium and nitrate in the irrigation waters have been found to minimise the deleterious effect of sodium (Kanwar & Manchanda, 1964).

Kanwar (1961) considered soil texture as an important factor and included soil texture and crop tolerance in triangular diagram proposed for evaluating the quality of irrigation water. Based on analysis of 73 samples of well waters and the irrigated soils from Hissar district, Singh and Bhumbla (1968) concluded that in general, EC of the saturation extract was about half of the EC of the irrigation water in soils with a clay less than 10%, $\frac{3}{4}$th in soils with 10 to 20% clay and $1\frac{1}{2}$ times in soils having 20 to 30% clay. They found a significant correlation between the texture of the soil and the effect of irrigation water on soil salinity. These workers proposed the EC limits of irrigation water for different soil textural classes. The work of Talati (1969) indicated that good crops could be grown up to 3000 ppm of total soluble salts in sandy soils, but the use of saline water containing even 2000 ppm salt caused accumulation of salts in silty to clayey soils within a period of 3 to 5 years. Although the well waters of Chambal command area of Kota and Bundi districts are of medium quality, continuous accumulation of salinity is taking place due to the clayey nature and impeded drainage of the soils (Mehta & Talati, 1959 and Nathani *et al.* 1966). Thus, in heavy textured soils of poor permeability salt accumulation takes place even with relatively less use of saline waters.

Experiments on the use of Saline Water on Sandy Soils

In order to evaluate the methods for using saline waters on sandy soils for growing crops without any adverse effect, experiments were undertaken at Jobner (Rajasthan) and at Hissar (Haryana) under the I.C.A.R. Coordinated Scheme for Research on Water Management and Salinity.

(*i*) *Experiments on leaching requirement at Jobner*

The experiment was conducted in metallic drums (55 cm dia. × 90 cm depth) to determine the leaching requirement of a non-saline sandy soil for different qualities of irrigation waters for maintaining a proper salt balance. The drums filled with local sandy soil were buried in the ground within a cropped area with an arrangement for collection of leachates from the bottom.

Treatments

(a) Qualities of irrigation water — EC 2, 4, 8 and 12 mmhos/cm

(b) Leaching requirement — 0%, 15%, and 30%

Irrigation was applied at 30% available moisture and each treatment was replicated thrice. The irrigation water was prepared artificially and consisted of Ca: Mg: Na in the ratio of 1: 2: 27 and Cl: HCO_3 : SO_4 in the ratio of 3: 2: 1. Wheat S-227 was sown and the crop was thinned to 16 plants in each drum.

Results : The analysis of the leachates collected from different treatments is given in Table I, which shows that there was no significant variation in the *p*H of the leachates due to different treatments, but the EC increased with an increase in the salt content of irrigation water, though this increase was not proportionate to the quantity of salts in the irrigation water. There was very little difference between the two levels of leaching. Further, the EC of the leachates was generally higher than the

TABLE I

E.C. and pH *of the leachates under different qualities and quantities of irrigation waters*

Treatments (Quality of irrigation waters)	E.C. of leachates under different leachings						*p*H
	1970-71			1971-72			
	0%	15%	30%	0%	15%	30%	
2 mmhos/cm	8.0	9.1	6.5	5.2	8.4	6.3	7.2
4 mmhos/cm	20.5	10.8	9.0	7.7	13.3	12.8	7.1
8 mmhos/cm	19.5	15.0	14.9	9.1	17.6	19.1	7.0
12 mmhos/cm	22.5	19.2	19.4	10.3	21.0	21.5	7.0
Mean	17.6	13.5	12.5	8.1	15.1	14.9	

EC of the irrigation water, indicating thereby leaching of salts with irrigation water. This shows that with provision of proper leaching saline waters can be used for irrigation on sandy soils without causing serious hazards of salinization, though much speculation at this stage is not justified as this was the first crop. Addition of excess water over 15% leaching could not bring about any significant beneficial effects.

The data on grain and straw yields of wheat per drum under different treatments are given in Table II, from which it will be seen that the yield of wheat grain was higher with irrigation waters of EC 2 and 4 mmhos/cm as compared to those having EC of 8 and 12 mmhos/cm. There was no consistent trend of difference between the yield levels at EC 2 and 4 mmhos/cm. In general, higher yields were obtained with leaching than without leaching.

TABLE II

Grain and straw yield (g/drum) of wheat under different qualities and quantities of irrigation water

		Qualities of irrigation water (mmhos/cm)				Leaching		
		2	4	8	12	0%	15%	30%
Grain	1970-71	31	35	23	26	23	38	26
	1971-72	158	145	128	104	126	133	143
Straw	1970-71	190	206	181	195	191	183	204
	1971-72	400	380	268	232	300	323	339

After the harvest of wheat crop soil samples were collected from 0-15, 15-30, 30-45, 45-60 and 60-75 cm depths and were analysed for EC values in the saturation extract. For the sake of brevity, the data have been presented in Table III for the whole depth of 0-75 cm and not layer-wise.

TABLE III

E.C. of saturation extract of soil under different qualities and quantities of irrigation water after harvest of wheat

Treatments (Quality of irrigation water)	Leaching		
	0%	15%	30%
C_1 — 2 mmhos/cm	5.5	2.9	3,1
C_2 — 4 mmhos/cm	4.4	5.0	4.9
C_3 — 8 mmhos/cm	12.4	8.7	6.3
C_4 — 12 mmhos/cm	13.8	12.5	13.0

The data of Table III reveal maximum accumulation of salts with irrigation waters of higher salinity and where no leaching was done. Leaching to the extent of 15% and 30% kept the salt concentration of the soil at a lower level in the case of irrigation waters having EC up to 8 mmhos/cm. In general the EC of the saturation extract of the soil has increased with the increase in the EC of irrigation waters. There was no significant difference between the effects of 15% and 30% leaching.

(ii) *Experiment on the method of irrigation at Hissar* :

The experiment was conducted on a non-saline sandy loam soil in the field in micro plots (3×2.5m) to examine if the drip (trickle) method of irrigation can be employed with advantage in using saline well water for irrigation.

Treatments

(a) *Methods of irrigation*

T_1 — Sub surface drip method through perforated plastic tubes — the amount of water was applied daily equal to 50% of the cumulative pan evaporation value.

T_2 — Surface drip — The amount of water was applied daily equal to 50% of the cumulative pan evaporation value.

T_3 — Ordinary surface method — 35 mm water was applied at 75% of the cumulative pan evaporation value.

T_4 — Ordinary surface method — 64 mm water was applied at 75% of the cumulative pan evaporation value.

(b) *Quality of irrigation water*:

(i) Good quality canal water (EC about 180 micromhos/cm)

(ii) Poor quality tubewell water (EC 6500 micromhos/cm)

Results

A late variety of radish was grown and the data on radish yield and water use efficiency are given in Table IV, a perusal of which shows that the maximum yield and water use efficiency were obtained with sub-surface drip method of irrigation with both

TABLE IV

Yield and water use efficiency in case of radish

Treatments	Good quality water			Poor quality water	
	Average yield q/ha	Yield per unit of water	% increase over poor quality water	Average yield q/ha	Yield per unit of water
Subsurface drip	268.1	29.8	13.6	236.0	26.2
Surface drip	174.9	19.4	11.1	157.5	17.5
Surface 35 mm	163.5	13.7	65.2	98.9	8.7
Surface 65 mm	138.7	11.6	105.5	67.5	5.6
C.D. at 5%	62.2			47.1	

good and poor quality waters. Although the yield and water use efficiency were higher in all the treatments with good quality water as compared to poor quality water, the yield in case of poor quality water has been increased tremendously by the drip method of irrigation as compared to the ordinary surface method. This indicates that sub-surface drip method gives higher yields of radish even with poor quality water. Thus, a proper cho:ce of the irrigation method can also be beneficial in using saline waters for irrigation for obtaining good yields of certain crops like radish.

Conclusion

From the above it is evident that the saline ground waters, which are considered unfit according to the present standards, can be used successfully for irrigation on permeable sandy soils with proper leaching without any injurious effects on the soil or the crop. The trickle method of irrigation is also helpful in this respect. When the effects of saline ground waters on crop performance and on the irrigated soils are compared, it is observed that the various standards proposed so far for judging the quality of irrigation waters do not hold good under Indian conditions and there is a urgent need for suitably modifying them for practical application under different agro-climatic conditions. Besides, the chemical composition of irrigation waters, due attention has to be given to the physical and chemical properties of soil including depth, clay content and type of clay mineral, drainage characteristics, water table, topography, climatic conditions, crop varieties and management practices etc. The distribution pattern and intensities of rainfall in different areas have to be considered for developing these criteria. With adoption of suitable management practices and irrigation methods highly saline waters within certain limits can be used to grow good crops successfully without much harmful effects.

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