Jal Vigyan Sameeksha—a publication of
High Level Technical Committee on Hydrology
Vol. III, No. 1, June 1988

Water Quality for Irrigation in the Arid and Semi Arid Region - A Review

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ABSTRACT : *Ground Water is an important source of Irrigation especially in the arid and semi-arid regions. Groundwater quality problems though often complex. generally occur in the four general categories; Salinity, permeability, toxicity and miscellaneous. In this paper an attempt has been made to review the quality of ground water in the arid and semi arid regions for irrigation purposes and its effect on soil properties that reduces the crop growth & productivity.*

1. Introduction

In the Vedas and other ancient scriptures it is said, "It is this water, which comes to us as the milk and honey of the soil, through the vegetations grown upon it, and which activates us as well as nourishes all the animates as well as lengthens the span of their lives."

The global distribution of fresh water indicates that less than 3 per cent of total quantity is of fresh water. However 1/5th of this amount is available in the liquid form. This limited amount is fortunately replenished and, therefore, call for an effective planning and utilisation of water resources from harnessing to management and in some cases re-utilisation. More than 98 per cent of this scarce commodity is in the form of ground water, 1 per cent is in the lakes and ponds while 0.1 per cent each in the rivers and atmosphere. The soil profile carry 0.2 per cent and the rest, a negligible amount is held by various biological forms. India receives annually 420 mham of water supply which includes 20 mham from rivers flowing from other countries. This amount is, accountable as follows :—

(i) Immediate evaporation 70 mham (16.67%)

(ii) Soil Body holds 165 mham (39.2%)

(iii) Surface water in rivers, ponds, lakes etc. 135 mham (32.14%)

(iv) Ground water 50 mham (11.9%)

Exploitation of ground water is an important source of irrigation especially in the arid and semi-arid region. But this water contains measurable quantities of dissolved substances and other toxic elements and adversely affects the soil properties and plant growth, as this water is the only main source of irrigation in this region.

In this paper an attempt has been made to review the quality of ground water in the arid and semi-arid region for irrigation purposes and its effect on soil properties, that reduces the crop growth.

2. Ground Water Quality

Various studies have been made on the quality of ground water in different parts of India. (Bhumla 1972; Paliwal 1972; Kanwar and Manchanda 1964; Mehrotra 1969; Talati 1972; Yadav 1979) and it is understood that most of the ground waters are medium to highly saline. Highly saline waters are dominated by sodium and chloride ions. Water of low to medium salinity contains greater proportion of Ca and Mg and carbonate ions. Boron in present in appreciable quantities in certain waters and may be injurious to plant growth. The presence of nitrate and potassium in some water has been found to counteract the adverse effect of high sodium. Some water have been reported to contain toxic amount of lithium and fluorine.

The mean chemical composition of well waters in some district of Punjab, Haryana and Rajasthan, observed by Yadav 1982; is presented in Table 1.

From Table 1, it reveals that the well waters for the districts of Haryana and Rajasthan are more saline than the districts of Punjab as it is evident from the values of EC and the composition of cations and anions. In general, the quality of well waters are poor and injurious to plant growth. The quality of ground water can be improved through precipitation as it is evident from Table-2, stating the percent distribution of ground waters in different EC classes for the region of Rajasthan. The data indicated in Table 2, show that the water quality is better in the region of Rajasthan where the rainfall distribution is comparatively high.

Table 1 : Mean chemical composition of ground water

State	Number of Samples	Ec×10^3 m mhos/cm	Composition (me/L) Na	Ca^{++} & Mg^{++}	CL^-	Co_3^{2-}	Hco_3^-	SO_4^{2-}	SAR	RSC (me/L)
PUNJAB										
Ferozepur	1702	2.1	14.8	5.8	5.8	0.5	8.5	5.8	8.7	3.4
Bhatinda	1151	2.7	18.5	8.2	10.7	0.8	10.1	5.0	9.1	2.7
Sangrur	400	1.5	11.7	3.5	13.7	0.8	11.2	10.6	9.1	8.0
Amritsar	553	1.0	6.4	3.8	1.7	0.4	8.5	0.5	4.6	5.1
HARYANA										
Gurgaon	5161	4.0	25.5	13.7	20.5	0 4	7.5	—	9.3	1.5
Hissar	3667	5.5	33.5	21.9	29.7	0.1	6.5	—	9.7	0.8
Jind	692	5.6	30.6	24.8	33.0	0.03	7.4	—	9.1	0.7
Rohtak	1963	7.1	42.0	26.2	37.8	0.3	8.8	—	11.5	1.2
RAJASTHAN										
Ajmer	19	5.5	37.7	10.4	18.2	0.8	9.7	24.8	16.0	0.1
Bikaner	249	6.3	45.5	17.3	46.2	—	6.9	12.2	15.0	—
Jodhpur	943	5.5	38.7	12.5	36.7	—	9.7	8.7	15.0	—
Pali	573	5.1	39.2	12.1	22.7	1.1	8.2	10.8	16.0	—

Table 2 : Percent distribution of ground waters of Rajasthan in different EC classes.

EC $\times 10^3$ m mhos/cm	Arid district	Semi-arid district	Humid district
0.75	10	23	41
0.75—2.25	29	48	49
2.25—5.00	27	19	8
5—10	21	8	2
10—15	9	2	—
15	5	—	—

Source : Review of Soil Research in India, Part II, 12th International Congress of Soil Science, N. Delhi, 1982.

3. Water Quality Classification

The classification of water quality depends on factors like, topography. climate, soil drainability, crop tolerance and management practices. From time to time various water quality classification have been proposed by Asghar et. al. 1934; Kanwar 1961; Ramamoorthy 1964; Manchanda 1976. According to USDA standard (Richards 1954), majority of the ground water in India is rated under unfit for irrigation. But experience shows that there is no adverse effect on the soil or on crop grown though they have been used over a long period. On the basis of field experience a tentative classification was proposed by Bhumla and Abrol, 1972 for extension purposes (Table 3). In the proposed limits of water quality rating given in the above table, it is presumed that the ground water-table at no time of the year is within 1.5 m from the surface. If the water table comes up within the root zone, the limits need to be reduced to half. Similarly. if the soil has impeded internal drainage because of the presence of hard-pan, unusually high amounts of clay or some other morphological features, the limit of water quality should again be reduced to half.

Table 3 : Water quality rating in India

Nature of soil	Permissible limit of EC of water for space use (micromhos/cm)	
	Semi-tolerant crops	Tolerant Crops
Deep black soils and alluvial soils; clay 30%, fairly to moderately well drained.	1500	2000
Heavy — textured soils, clay 20—30%, well drained and good surface drainage.	2000	4000
Medium — textured soils; clay 10—20% very well drained internally and good surface drainage,	4000	6000
Light — textured soils; clay < 10% excellent internal and surface drainage.	6000	8000

4. Effect of Saline Water Irrigation on Soil Properties

Changes in soil properties due to saline water irrigation depend upon the depth, texture and structure of the soil, type and swelling characteristics of the clay, lime and gypsum content of the soil, soil permeability and fertility, irrigation methods, management practices and climatic conditions. The details on the effect of saline water irrigation to the soil properties are discussed below.

4.1 Soil Texture : Accumulation of salts in soil profile has got a direct relation with the content of clay. It is eported by Singh & Sharma (1970) that EC of the saturation extract of the soils was about half that of irrigation water when the clay content was less than 10 percent, three fourths if the clay content was between 10 and 20 per cent and 1.5 times if the clay content was between 20 and 30 per cent.

Yadav (1978) reported that saline ground water could be used beneficially in the light-textured soil where easy leaching of the salts would be helpful in/L maintaining a favourable salt balance.

4.2 Sodium adsorption ratio : With increase in the SAR of irrigation water, the SAR of the soil solution also increases and leads to greater adsorption of sodium on the exchange complex. Of course use of saline waters in calcareous soils decreased the sodium hazard because of the release of calcium caused by the dissolution of $Ca\ Co_3$.

4.3 Mg : Ca ratio : In the saline ground water the proportion of magnesium is generally higher than that of calcium, and the Mg : Ca ratio is 4 : 1 or more. Opinions differ on the role of high Mg : Ca ratios of the irrigation waters. However, the effect is more pronounced at higher SAR and in heavy black soils dominated by montmorillonite clay than alluvial soils dominated by illite clays. The adverse effect of higher Mg : Ca ratio is more in non-calcareous than in calcareous soil.

5. Guidelines for Interpretation of Water Quality for Irrigation

To evaluate the suitablity of water for irrigation the basic assumption of the guidelines, evaluated by FAO (1976) areas follows :

5.1 Use of water : The soil texture is sandy loam to clay, with good internal drainage. The climate is semi-arid to arid where effective annual rainfall is low. These guides may, therefore, need adjustment for a monsoon climate or for areas where high precipitation occurs part of the year. Drainage is assumed to be good and no uncontrolled shallow water table is present. Full production capability of all crops is assumed when the guidelines indicate water quality is not a problem. The existence of a potential problem indicates the use of certain tolerant crops may be necessary to maintain full production capability and does not indicate the water is unsuitable for use on any crop.

5.2 Methods and timing of irrigations : Surface and sprinkler method of irrigation are assumed, including flood, basin, strip-check, furrow, corrugation and sprinklers, or any other which applies water on an "as needed" basis. This assumes that crops utilise a considerable portion of the stored soil water before the next irrigation. With these irrigation methods about 15% of the applied water is assumed to percolate below the rooting depth. The guidelines are believed to be too restrictive for drip (trickle) irrigation and high frequency (near daily) sprinkler irrigation. They may need to be modified for subsurface irrigation.

5.3 Uptake of water by crops : Uptake of water by the crop takes place from wherever water is most readily available in the rooting depth. This is normally about 40% from the upper one-quarter of the root zone, 30% from the second quarter, 20% from the third quarter, and 10% from the lowest quarter. Each irrigation will leach the upper soil area and maintain it at a relatively low salinity. Salinity will usually increase with depth and be greatest at the lower part of rooting area. The average salt concentration of the soil solution of the rooting depth is assumed to be three times the concentration of the salts in the applied water and it believed to be representative of the salinity to which the crop responds. This corresponds to a leaching fraction of 16% on the basis of the 40-30-20-10% uptake of water by the crop and average roof zone salinity.

The leached salts will be removed from the upper root zone and many accumulate to some extent in the lower root zone. Thus the salinity of the lower root zone is considered to be of less importance as long as the crop is relatively well supplied with moisture in the upper, "more active", root zone. The leaching requirement will control salts in this lower root zone.

5.4 Degree of Problem : The division of "No Problem", "Increasing Problem" and "Severe Problem" stated in Table-4 is somewhat arbitrary since changes occurs gradually and their is no clear-cut breaking point. Changes

Table 4 : Guidelines for Interpretation of Water Quality for Irrigation

Irrigation Problem	Degree of Problem: No Problem	Increasing Problem	Severe Problem
SALINITY (Affects crop water availability) Cw (mm hos/cm)	< 0.75	0.75—3.0	> 3.0
PERMEABILITY (affects infilration rate into soil)	> 0.5	0.5—0.2	< 0.2
E Cw (mm hos/cm)			
adj SAR			
Montmorillorite (2 : 1 crystal laltice)	< 6	6—9	> 9
illite-Vermiculite (2 : 1 Crystal laltice)	< 8	8—16	> 16
Kaolinite - Sesquioxide (1 : 1 Crystal laltice)	< 16	16—24	> 24
SPECIFICTION TOXICITY (Affects sensitive crops)			
Sodium (Adj SAR)	< 3	3—9	> 9
Chloride (meg/L)	< 4	4—10	> 10
Boron (mg/L)	< 0.75	0.75—2.0	> 2.0
MISCELLANEOUS EFFECTS (affects susceptive crops)			
NO_3—N (or) NH_4—N (mg/L)	< 5	5—30	> 30
HCO_3 (meq/L) (Overhead sprinkling)	< 1.5	1.5—8.5	>8.5
pH		(Normal range 6.5 — 8.4)	

of 10 to 20% above or below the guidelines values may have little significance if considered in proper prospective with other factors effecting yield. Many fields studies and observations as well as carefully controlled research experiments were used as a basis for this division. The divisions have proven to be practical under production agriculture conditions.

This paper evaluates the most common problem encountered and the steps necessary to maintain an acceptable level of agricultural production with the available water supply. Water quality problems though often complex, generally occur in the four general categories viz. Salinity, permeability, toxicity and miscellaneous. Each may effect the crop singly or in a combination of two or more. Such a combination may be more difficult to solve and may affect crop production more severely than a single problem acting by itself. If the problem do occur in combination, the solution is more easily evaluated and understood if considered on a one-problem-at-a-time basis. To evaluate the problems, a number of factors are to be considered and they are:

(i) the level of salts in the water that can be expected to cause a certain type of problem;

(ii) the mechanism of soil-water-plant interactions that cause the loss in production;

(iii) the severity of the problem that can be expected following long term use of water.

(iv) the management alternatives that are available to prevent, correct or delay the onset of the problem.

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