LECTURE 27

ASSESSMENT OF IRRIGATION WATER QUALITY

Water quality parameters, management

Irrigation water quality criteria

Water quality is determined according to the purpose for which it will be used. For irrigation water, the usual criteria include salinity, sodicity, and ion toxicities.

Various criteria are considered in evaluating the quality of irrigation water namely:

1. Salinity hazard
2. Sodium hazard
3. Salt index
4. Alkalinity hazard
5. Permeability hazard
6. Specific ion toxicity hazards

SALINITY HAZARD

The concentration of soluble salts in irrigation water can be classified in terms of Electrical Conductivity (EC) and expressed as dS m^{-1}. There are four classes of salinity *viz*., C_1, C_2, C_3 and C_4.

The classes C_1 and C_2 of water are considered suitable for irrigation purposes (no problem). C_3 and C_4 classes of water are not suitable for irrigation purpose (severe problems).

Water class	***EC (dS m^{-1})***	***Remarks***
C_1 - Low salinity	0-0.25	Can be used safely
C_2 - Medium salinity	0.25-0.75	Can be used with moderate leaching
C_3 - High salinity	0.75-2.25	Can be used for irrigation purposes with some management practices
C_4 - Very high	2.25-5.00	Can not be used for irrigation purposes

SODICITY HAZARD

High concentrations of sodium are undesirable in water because sodium adsorbs on to the soil cation exchange sites, causing soil aggregates to break down (deflocculation), sealing the pores of the soil and making it impermeable to water flow. The sodicity hazard of irrigation water is usually evaluated by:

- Sodium Adsorption Ratio (S 11 (1/8)
- Adjusted SAR
- Sodium to calcium activity ratio (SCAR)
- Sodium ratio
- Figure of merit

Sodium adsorption ratio (SAR)

United States Salinity Laboratory (USSL) staff introduced the concept of sodium adsorption ratio (SAR) to predict the sodium hazard. It is calculated as

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Where all the ions expressed as me L^{-1}

The sodium hazard of irrigation water expressed through SAR does not take into account the effect of anionic composition. Sodicity hazard also classified as S_1, S_2, S_3 and S_4.

Water class		***SAR***	***Remarks***
S_1	low sodium hazard	0-10	Little or no hazard
S_2	medium sodium hazard	10-18	Appreciable hazard but can be used with appropriate management
S_3	High sodium hazard	18-26	Unsatisfactory for most of the crops
S_4	Very high sodium hazard	> 26	Unsatisfactory for most of the crops

<u>Adjusted SAR</u> : To predict sodicity hazard more correctly for those water which contain appreciable amounts of HCO_3 but no RSC. Ayers and Wescot pointed out that sodicity hazard of these irrigation waters should be determined by Adjusted SAR to be calculated as follows.

$$Adj.\ SAR = SAR\ (1 + (8.4 - pHc)$$

Where SAR = Sodium Adsorption Ratio

pH_C = $(pK_2 - pKc) + pCa + p\ (Alk)$

$pK_2 - pKc$ = conc. of Ca + Mg + Na in me L^{-1}

pCa = Ca in me l^{-1}

pAlk =from conc. of CO_3+ HCO_3 in me L^{-1}.

The adjusted SAR should be evaluated for such water which have EC higher than 1.5 and less than 3.0 dS m^{-1} because only this group of water are more likely to have twin problem of RSC and SAR.

Sodium to Calcium Activity Ratio (SCAR)

The application of SAR to the group of water, which have EC > 5 dS m^{-1} and Mg/Ca ratio > 1 is obviously questionable. For the ground water having EC > 5 dS m^{-1} and dominance of magnesium over calcium, the SAR value should be calculated as $Na^+ / \sqrt{Ca^{2+}}$.

The classification of SAR/ SCAR ratio was given by Gupta (1986) by following 6 classes of sodicity.

1. Non-sodic water (< 5)
2. Normal water (5-10)
3. Low sodicity water (10-20)
4. Medium sodicity water (20-30)
5. High sodicity water (30-40)
6. Very high sodicity water (>40)

Sodium ratio

Sodium ratio = $\frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$

For good water, this ratio should not exceed one.

Figure of merit

This term was proposed by Cassidy to express the relative proportion of divalent to monovalent cation and calculated by

Figure of merit = $\frac{(Ca^{2+} + Mg^{2+})}{Na^{+} + K^{+}}$

Salt index

It is also used for predicting sodium hazard. It is the relation between Na^{+}, $Ca^{2+,}$ and $CaCO_3$ present in irrigation water.

Salt index = (Total Na) - (total Ca-Ca in $CaCO_3$) x 4.85

Where all ions are to be expressed in ppm. Salt index is negative for all good water and positive for those unsuitable for irrigation.

Alkalinity hazard *is evaluated by*

Residual Sodium Carbonate (RSC)

Residual Sodium Bicarbc 11 (4/8)

Bicarbonates (HCO_3^-) occur in low salinity water and its concentration usually decreases with an increase in EC. The proportion of bicarbonate ion is higher than calcium ions are considered undesirable, because after evaporation of irrigation water bicarbonate ions tend to precipitate calcium ions. Hence, the effect of bicarbonate together with carbonates evaluated through RSC.

RSC = $(CO_3^{--} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$, all ions expressed as me L^{-1}.

RSC (me l^{-1})	***Water quality***
< 1.25	Water can be used safely
1.25 - 2.5	Water can be used with certain management
> 2.5	Unsuitable for irrigation purposes

Since carbonate ions do not occur very frequently in appreciable concentrations, and as bicarbonate ions do not precipitate magnesium ions, Gupta suggested that alkalinity hazard should be determined through the index called Residual Sodium Bicarbonate (RSBC) to be calculated as below.

RSBC = $HCO_3^- - Ca^{2+}$, all ions expressed as me L^{-1}.

Based on RSC/ RSBC ratio there are 6 alkalinity classes proposed

Non-alkaline water (-ve)
Normal water (0 me l^{-1})
Low alkalinity water (2.5 me l^{-1})
Medium alkalinity water (2.5-5.0 me l^{-1})
High alkalinity water (5.0-10.0 me l^{-1})
Very high alkalinity water (> 10.0 me l^{-1})

Permeability hazard

High sodium in the irrigation water can cause severe soil permeability problem. Permeability is affected not only by high sodium but also by CO_3^{2-} and HCO_3- content in water. A part of CO_3—and HCO_3- is precipitated as $CaCO_3$ (or) $MgCO_3$ removing Ca and Mg from irrigation water and leads to increased proportion of solution. The effect on permeability has been evaluated by the term permeability index, which is calculated as

$$\textbf{Permeability index} = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100$$

Where ions are expressed as me L^{-1} . If permeability index value exceed 65, water is considered suitable for irrigation.

SPECIFIC ION TOXICITY HAZARD

Sodium: Among the soluble constituents of irrigation water, sodium is considered most hazardous. Excess of sodium ions characterizes the water as saline or alkaline depending upon its occurrence in association with chloride/ sulphate or carbonate/ bicarbonate ions. For some time in the past, the quality of irrigation water used to be evaluated with respect to sodium based on soluble sodium percentage (SSP) calculated as below.

$$\textbf{SSP} = \frac{\text{Soluble sodium concentration}}{\text{Total cation concentration}} \times 100$$

It has been useful in characterizing water, since a high value indicates **soft water** and low value **hard water**. When water with excess of sodium (SSP=66) is used for irrigation, pa 11 (6/8) orbed by the soil. Both, soils and plants are adversely affected by high sodium irrigation water. Sodium soils are relatively impermeable to air and water. They are hard when dry, difficult to till and plastic and sticky when wet. These adverse physical conditions prevent germination and are generally unfavourable for plant growth. Even though, sodium is not as essential as other nutrients, it is taken up freely by many plants and it may be specifically toxic to plants.

Magnesium: It is believed that one of the important qualitative criteria in judging the irrigation water is its Mg content in relation to total divalent cations, since high Mg content in relation to total divalent cations, since high Mg adsorption by soils affects their physical properties. A harmful effect on soils appears when Ca: Mg ratio decline below 50.

$$\text{Mg Adsorption Ratio} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}$$

Chlorides: The occurrence of chloride ions in irrigation water increases with increase in EC and sodium ions. Therefore, these ions are most dominant in very high salinity water. Unlike sodium ions, the chloride ions neither affect on the physical properties of the soil, nor are adsorbed by the soil. Therefore, it has generally not been included in modern classification system. However, it is used as a factor in some regional water classification.

$$\text{Chloride Concentration (me L}^{-1}\text{)} = \frac{Cl^{-} + NO_3^{-}}{CO_3^{--} + HCO_3^{-} + SO_4^{--} + Cl^{-} + NO_3^{-}}$$

Chloride concentration (me l^{1}***)***	***Water quality***
4	Excellent water
4-7	[illegible] 11 (7/8) od water
7-12	Slightly usable
12-20	Not suitable
> 20	Not suitable

Sulphate: Sulphate salts are less harmful when compared to chlorides. This is because when both the ions occur in this concentration, only half of the sulphate ions contribute to salinity due to the fact that approximately half of the sulphates gets precipitated as $CaSO_4$ while the other half remains in soluble form as Na-$MgSO_4$ in the soil. That is the reason, the potential salinity of irrigation is calculated as $Cl^- + \frac{1}{2} SO_4^{--}$.

Eaton proposed three classes for sulphate

< 4 me l^{-1} - Excellent water
4-12 me l^{-1} - Good to injurious
> 12 me l^{-1} - Injurious to unsatisfactory

Potential salinity

It can be worked out by using the formula Cl + 1/2 SO_4^{2-} where ions are expressed in me l^{-1}.

Potential salinity (me L^{-1})	*Remarks*
3-15	Can be recommended for medium permeability soils
3-7	Recommended for soils of low permeability

Boron: It is evident that boron is essential for the normal growth of the plant, but the amount required is very small. The occurrence of boron in toxic concentration in certain irrigation water makes it necessary to consider this element in assessing the water quality. The permissible limits of boron in irrigation water are:

Boron class	**Crops**			**Remarks**
	Sensitive	**Semi-tolerant**	**Tolerant**	
Very low	< 0.33	< 0.67	< 1.00	For safely use
Low	0.33-0.67	0.67-1.33	1-2.0	Can be managed
Medium	0.67-1.00	1.33-2.00	2.0-3.0	Unsuitable

High	1.0-1.25	2.00-2.50	3.0-3.75	Unsuitable
Very high	> 1.25	> 2.50	> 3.75	Unsuitable

Fluorine: fluorides are only sparingly soluble and are in only small amounts. The concentration of fluoride ranges from traces to more than 10 mg L^{-1} in natural water, and surface water do not exceed 0.3 mg L^{-1} unless they are polluted. Irrigation with fluoride saline water (upto 25 mg L^{-1}) has not been found to affect yield of wheat. Therefore, it is doubtful if fluoride requires any monitoring in India. At present, the average concentration of fluoride has not been observed to be very high (10 mg l^{-1}).

Nitrate: Very frequently ground water contain high amount of nitrate. When such type of irrigation water is applied on soils continuously, various properties of soils are affected.

	< 5	No problem
NO_3 me l^{-1}	5-30	Intensity of problem is moderate
	> 30	Intensity of problem is severe

Lithium : Lithium is a trace element may be found in most of saline ground water and irrigated soils. It has been found that 0.05-0.1 ppm of lithium in water produce toxic effects on growth of citrus. It has also been reported that saline soils of varying degrees found in India contain lithium upto 2.5 ppm. Fortunately, the germination of majority of crops is not affected with this level of lithium content.