

CHAPTER – 2

Sources and Quality of Irrigation Water

Dr. M. R. Kabir

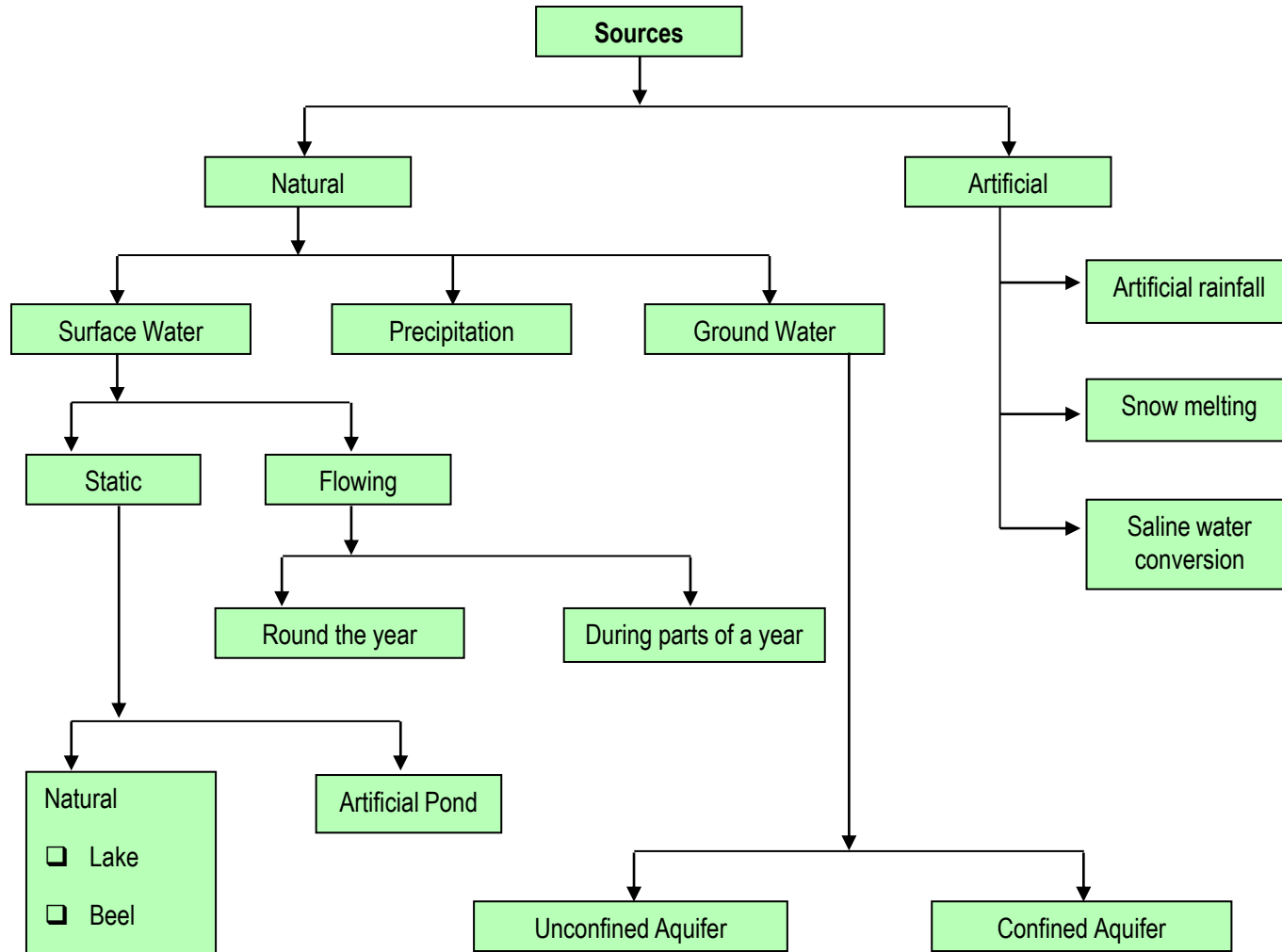
Professor and Head, Department of Civil Engineering

University of Asia Pacific (UAP), Dhaka

LECTURE 5



Sources of Irrigation water



Consideration for surface water as a source

- ❑ Lowest available water
- ❑ Crop water requirement
Water needed (S_1) = $R_1 - x_1$
Where, R_1 = Crop water requirement
 x_1 = Effective rainfall
- ❑ Water quality (salinity & toxicity)
- ❑ Water right – Other users
 - Domestic water supply
 - Navigation
 - Fish culture
 - Industry
 - River morphology
- ❑ Control structure
 - Initial cost
 - Operating & maintenance cost

Consideration for ground water as a source

- Crop water requirement
- Availability of surface water source
- Position of ground water table
- Water quality
- Ground water recharge
- Environmental impact

Conjunctive use of ground water & surface water

- ❑ Use of both Surface Water (SW) & Ground Water (GW)
- ❑ Such a way that Ground Water recharges & draft balances with each other.
- ❑ Factors governing the percentage of sharing SW & GW
 - Natural recharge
 - Artificial recharge
 - Aquifer characteristics
 - Availability of surface water
 - Availability of fuel
 - Operation & maintenance cost for pumps
 - Economic consideration

Storage of surface water or rainfall

- Availability of space
- Series of droughts can be easily overcome by GW storage
- Water table control easier
- Ground water is recharged

Quality of Irrigation water

Good quality water is essential for high production

Physical : Color, odor, silt

Chemical : Salt, alkaline

Biological : Coliform

Water quality related problems

- Salinity
- Water infiltration rate
- Toxicity
- Miscellaneous

Various impurities in irrigation water

Every water may not be suitable for plant life. The quality of suitable irrigation water is very much influenced by the constituents of the soil which is to be irrigated.

The various types of impurities, which make the water unfit for irrigation, are classified as:

- 1) Sediment concentration in water.
- 2) Total concentration of soluble salts in water.
- 3) Concentration of sodium ions to other cations.
- 4) Concentration of potentially toxic elements present in water.
- 5) Bicarbonate concentration as related to concentration of Ca plus Mg.
- 6) Bacterial concentration

(1) Sediment concentration in water

- Organic soils, the fertility is improved.
- Eroded areas sediment; it may reduce the fertility or decrease the soil permeability.
- Sediment water increases the siltation and maintenance costs.

(2) Total concentration of soluble salts

Salinity concentration of the soil solution (C_s)

$$C_s = \frac{CQ}{I - C_u - P_{eff}}$$

Where,

Q = Quantity of water applied

C_u = Consumptive use of water, i.e, the total amount of water used by the plant for its growth.

P_{eff} = Useful rainfall

$C_u - P_{eff}$ = Used up irrigation water

C = Concentration of salt in irrigation water

CQ = Total salt applied to soil with Q amount of irrigation water

Total salt concentration in water is expressed as:

- Parts per million parts of water (ppm)
- Milligram per liter of water (mg/l)
- Electrical Conductivity of water (EC)

(a) Parts per million (ppm)

The result of a chemical analysis of water are usually report in parts per million of the various substances present in the sample. One part per million (ppm) means one part in a million parts. As commonly measured and used, parts per million in numerically equivalent to milligrams per liter.

Amount in excess of 700 ppm	Harmful to some plants
More than 2000 ppm	Injuries to all crops



(b) Milligram per liter (mg/l)

(c) Electrical Conductivity (EC)

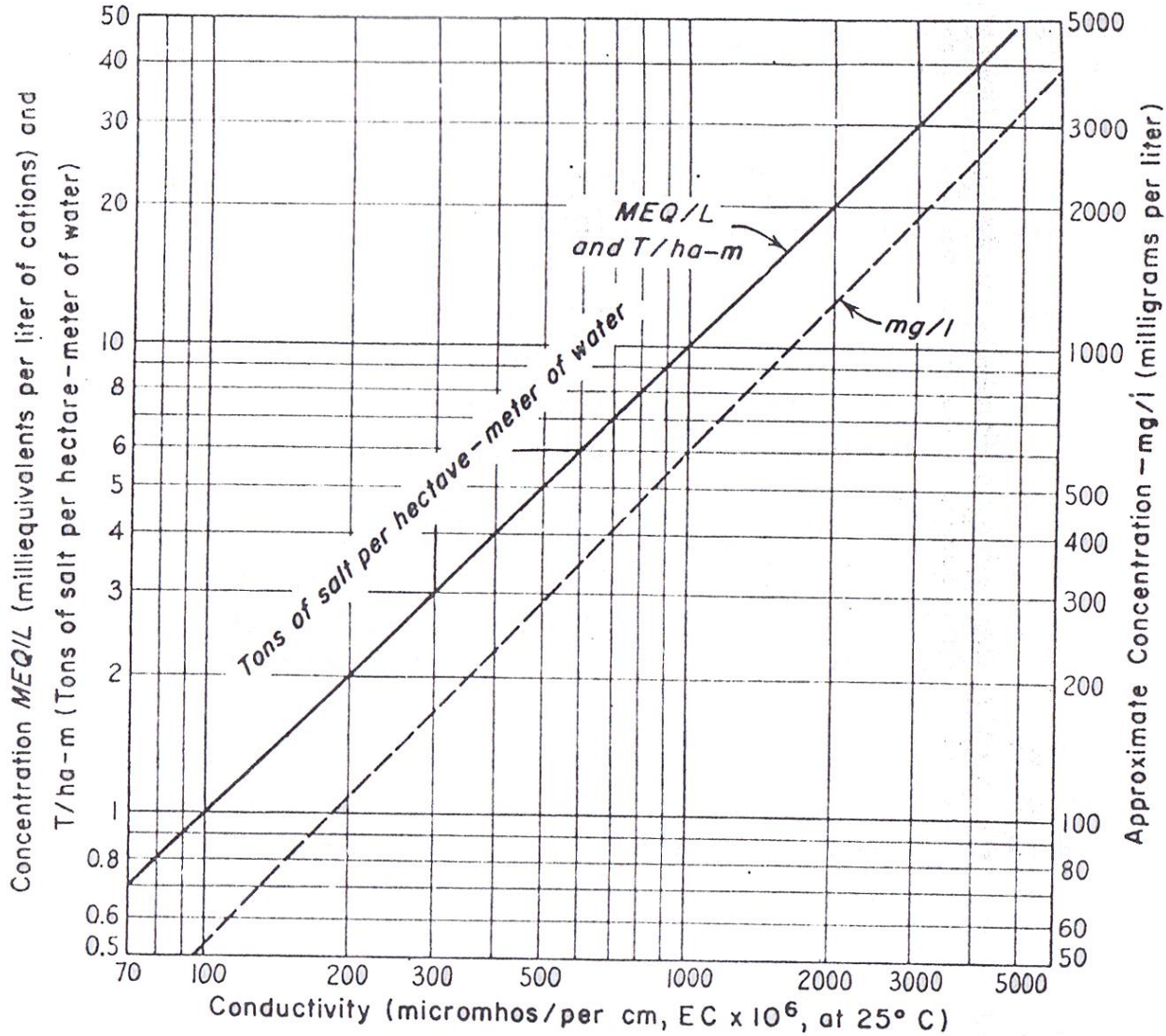
It is the reciprocal of the Electrical resistivity. Quantitatively the electrical resistivity is the resistance, in ohms, of a conductor, metallic or electrolytic, which is 1 cm long and has a cross-sectional area of 1 cm² at 25°C.

Units:

EC = Reciprocal ohms/cm or mhos/cm.
 millimhos/cm (10^{-3} mhos/cm)
 micromhos/cm (10^{-6} mhos/cm)

SL	Electrical Conductivity (micro mhos/cm at 25° C)	Type of water
1	Up to 250	Low Conductivity Water (C1)
2	250 to 750	Medium Conductivity Water (C2)
3	750 to 2250	High Conductivity Water (C3)
4	Above 2250	Very High Conductivity Water (C4)

Cont.....Electrical Conductivity (EC)



(3) Relative proportions of sodium ions

Most of the soils contain Ca^{++} and Mg^{++} ions and small quantities of Na^+ . The percentage of the Na^+ is generally less than 5% of the total exchangeable cations. If this percentage increases to about 10% to more, the aggregation of soil grains breaks down. The soil becomes less permeable and of poorer tilth. It starts crusting when dry and its pH increases towards that of an alkaline soil. High sodium soils are, therefore, plastic, sticky when wet, and are prone to form clods, and they crust on drying.

The methods for determining relative proportion of sodium ions to other cations are:

- a) Sodium absorption ratio (SAR)
- b) Exchangeable sodium percentage (ESP)
- c) Sodium percentage (SP)

(a) Sodium Adsorption Ration (SAR)

A ratio for soil extracts and irrigation water used to express the relative activity of sodium ions in exchange reaction with soil in which the ionic concentration are expressed in milli-equivalents per liter..

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

SL	SAR	Type of water
1	0 to 10	Low Sodium Water (S1)
2	10 to 18	Medium Sodium Water (S2)
3	18 to 26	High Sodium Water (S3)
4	More than 26	Very High Sodium Water (S4)

(a) Sodium Absorption Ration (SAR)

A ratio for soil extracts and irrigation water used to express the relative activity of sodium ions in exchange reaction with soil in which the ionic concentration are expressed in milli-equivalents per liter.

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

SL	SAR	Type of water
1	0 to 10	Low Sodium Water (S1)
2	10 to 18	Medium Sodium Water (S2)
3	18 to 26	High Sodium Water (S3)
4	More than 26	Very High Sodium Water (S4)

(b) Exchangeable Sodium Percentage (ESP)

It is the degree of saturation of the soil exchange complex with sodium and may be calculated by the following formula:

$$\text{ESP} = \frac{\text{Exchangeable Sodium (milli-equivalent/100 gm soil)}}{\text{Cation exchange capacity (milli-equivalent/100 gm soil)}}$$

Where, ionic exchange is in milliequivalent per 100 gm soil

Cation Exchange:

Interchange of a cation in solution with another cation on a surface active material.

Cation Exchange Capacity (CEC):

The total quantity of cations which a soil can absorb by cation exchange usually expressed as milli-equivalence per 100 grams. Measured value of the cation exchange capacity depends somewhat on the method used for its determination.

Exchangeable Cation:

A cation that is adsorbed on the exchange complex and which is capable of being exchange with other cations.

Equivalent Weight:

It is the combining capacity of an element or radical with hydrogen. It is the weight in grams of an ion or compound that combine with or replace 1 gm of hydrogen.

Equivalent weight = Atomic weight/valency

For example: Equivalent weight of Na^+ = $23/1 = 23$

Equivalent weight of Cu^{++} = $40/2 = 20$

Equivalent weight of Cl^- = $35.5/1 = 35.5$

Note:

Milliequivalent weight = Equivalent weight/1000

Milli-equivalent (meq): One thousand of an equivalent.

Milli-equivalent per liter (meq/litre): A milli-equivalent of an ion or a compound in 1 liter of solution.

(c) Sodium Percentage (SP)

The moisture percentage of a saturated soil paste expressed on dry wt. basis.

$$\text{SP} = \frac{\text{Na}^+}{\text{Na}^+ + \text{Ca}^{++} + \text{Mg}^{++} + \text{K}^+} \times 100$$

Where, ionic concentration is in (me/l)

LECTURE 6



(4) Concentration of potentially toxic elements

- A large number of elements such as B, Se etc. may be toxic to plants.
- B is essential to plant growth
- Even for the most tolerant crops, the $[B] \geq 4$ ppm.
- B is generally present in various soaps.
- Se even in low concentration, toxic, and must be avoided.

Table: Relative tolerance of some crop to Boron

SL	High	Medium	Low
1	Sugar beat	Cotton	Black walnut
2	Gladiolus	Radish	Nary beam
3	Onion	Field peas	Pear
4	Carrot	Barley	Apple

(5) HCO_3^- concentration as related to concentration of Ca plus Mg

Residual Sodium Carbonate (RSC)

Indicate the residual carbonates in excess of the lime elements.

$$\text{RSC} = (\text{CO}_3^- + \text{HCO}_3^-) - (\text{Ca}^{++} + \text{Mg}^{++})$$

Where, ionic concentrations are in (me/l)

Table: Quality Rating of Ground Water

Water quality		EC (dS/m)	SAR (mmole/l) ^{1/2}	RSC (me/l)
Good		< 2	< 10	< 2.5
Saline				
(i)	Marginally Saline	2 ~ 4	< 10	< 2.5
(ii)	Saline	4	< 10	< 2.5
(iii)	High SAR saline	4	> 10	< 2.5
Alkaline Water				
(i)	Marginally Alkali	< 4	< 10	2.5 – 4.0
(ii)	Alkali	< 4	< 10	4.0
(iii)	Highly Alkali	Variable	10	4.0

(6) Bacterial contamination

Bacterial contamination of irrigation water is not a serious problem, unless the crops irrigated with highly contaminated water directly eaten, without being cooked. Cash crops like cotton, nursery stock, etc. which are processed after harvesting, can, therefore, use contaminated waste waters, without any trouble.

- Good Water, $EC < 2$, and $SAR < 10$
- Saline Water, $EC = 2$, and $SAR < 10$
- High SAR saline water, $EC = 4$, and $SAR > 10$
- Alkali water, EC variable, SAR variable, $RSC > 2.5$

Precautions in saline water use

Use of saline water in irrigation creates many problems. When situation demands its use, the following points should be borne in mind:

- Water should be applied in excess amount than required to meet the water deficit in the crop root zone to leach down the surplus salts.
- Excess salt should be leached down by abundant irrigation particularly before sowing.
- Soil should be lighter in texture, porous and permeable so that the leaching operation is easy. Clay soils do not allow easy leaching and are likely to become saline at a faster rate.
- Irrigation should be frequently applied to avoid shortage of available water to plants and a sudden variation in salt concentration of the salt solution.

- ❑ Water table should be lowered to a depth from which there is no reaching of water and salts in the root zone. Low water table encourage a good drainage of the soil.
- ❑ Land should be properly graded and leveled as greater salt accumulation occurs in higher part of an uneven field.
- ❑ Drainage of the field must be properly maintained to prevent water logging.
- ❑ Soil should be maintained in good physical condition with addition of organic matter and by proper tillage.
- ❑ Liming of soil may be undertaken if sodium content of irrigation water is likely to cause injury to soil or crops.
- ❑ All corrective measures should be undertaken to keep sodium ion concentration in soil as low as possible. Sodium ion concentration should not exceed 12 percent of the total cation exchange capacity or the soil exchange complex.

The foregoing measures would make the use of saline water much safer for irrigation and ensure better crop growth and yield.

Guidelines for using poor quality water

Special consideration:

- Use of gypsum when saline water (having SAR > 20 and/or Mg/Ca ratio > 3 and rich in silica) induce water stagnation during rainy season and crops grown are sensitive to it.
- Leaving the field fallow during the rainy season is helpful when SAR > 20 and water of higher salinity and used in lower rainfall areas.
- Additional phosphorus fertilization is beneficial especially when Cl/SO₄ ratio in water is greater than 20.
- Canal water preferably be used growth stage including pre-sowing irrigation for conjunctive use with saline water.
- If saline water is to be used for seedling of crops 20% extra seed rate and quick post-sowing irrigation (within 2 – 3 days) will ensure better germination

- ❑ When $EC_{iw} < EC_e$ (0 – 45 cm soil at harvest of rab crops) saline water irrigation just before the onset of monsoon will lower soil salinity and will raise the antecedent soil moisture for greater salt removal by rains.
- ❑ Use organic materials in saline environment enhance yields.
- ❑ Accumulation of B, NO_3 , Fe, Si, F, Se and heavy metals beyond critical limits proves toxic. Expert advice prior to the use of such water may be obtained.
- ❑ For soils having (i) shallow water table (within 1.5 m in kharif season) and (ii) hard sub-soil layers, the next lower EC_{iw} /alternative mode of irrigation (canal/saline) is applicable.

Leaching Requirement

Leaching is the process of dissolving the soluble salts and removing the same from the desired soil layers by the downward movement of water.

- A quantity more than the normal requirements of the crops to avoid accumulation of salts.
- It is done by ponding water on the soil surface by bunds or borders and allowing a downward movement of water through the soil column
- The efficiency of leaching depends on **the amount of water applied**, the **uniformity of water distribution** and the **adequacy of drainage** in the field.
- Fertilizers should be applied only after leaching is completed.

Leaching Requirement may expressed as:

$$LR = D_d/D_{iw} = EC_{iw}/EC_d \text{ ----- (1)}$$

Where,

LR = Leaching requirement, expressed as a ratio or as percent

EC_{iw} = Electrical conductivity of irrigation water, mSiemens/cm

EC_d = Electrical conductivity of drainage water, mSiemens/cm

D_d = Depth of drainage water, cm

D_{iw} = Depth of irrigation water, cm

The leaching requirement is the additional water required to the normal consumptive use of water by crops. Therefore,

$$D_{iw} = D_c + D_d \text{ ----- (2)}$$

Where,

D_c = Consumptive use of water

Using equation (3) to estimate D_d from equation (4)

$$D_{iw} = D_c / (1 - LR) \text{ ----- (3)}$$

Again, expressing the leaching requirement in equation (2) as EC ratio of irrigation and drainage waters, equation (3) stands as:

$$D_{iw} = [EC_d / (EC_d - EC_{iw})] \times D_e \text{ ----- (4)}$$

Another equation for determining leaching requirements in soil

$$LR = \frac{EC_w}{5EC_e - EC_w}$$

Relation between Leaching Requirement (LR), Available Water (AW) and Evapotranspiration (ET) is

$$AW = \frac{ET}{1 - LR}$$

Leaching Requirement of saline soil

$$D_{iw}/D_s = d_s/d_w \times SP/100 \times \Delta EC_e/EC_{iw} \text{-----} (5)$$

Where,

D_{iw} = Depth of irrigation water, cm

D_s = Depth of soil, cm

d_s = Density of soil (bulk density), gm/cm³

d_w = density of irrigation water, gm/cm³

ΔEC_e = Change in electrical conductivity of saturation extract of the soil

EC_{iw} = Electrical conductivity of irrigation water, $\mu\text{S}/\text{cm}$

Under high water table conditions, evaporation brings up the soluble salts and deposits the salts in upper layers of soil increasing the salinity. The change in salinity of the soil may be determined by the following equation:

$$\Delta EC_e = D_g/D_s \times EC_g/SP \times d_w/d_s \times 100 \text{-----} (6)$$

Where,

D_g = Depth of ground water evaporated, cm

EC_g = Electrical conductivity of ground water, mS/cm

Leaching Method

- Leaching of soil is done by ponding water on the soil surface by bunds or borders and allowing a downward movement of water through the soil column.
- Rectangular checks and level borders are employed when the soil is level.
- Contour checks can be used when the land slope is more.
- Sprinkler irrigation is usefully employed to leach out salts especially when the soils are cracked and very permeable.
- Intermittent ponding of water is superior to continuous ponding of water for effective leaching.
- The efficiency of leaching depends on the amount of water applied, the uniformity of water distribution and the adequacy of drainage in the field.

- ❑ The sensitive crops or the crops with low salt tolerance have higher leaching requirement and require frequent leaching during a growing season. Leaching of salts once or twice in a growing season is enough for salt tolerant crops. It is usually needed to apply little more water than actually required by crops in areas where salinity is a problem. Occasional analysis of soil is required where irrigation water contains salts.

In areas where leaching is practiced for growing crops, fertilizers should be applied only after leaching is completed and in little higher amounts to make up the loss of nutrients during leaching of salts.

The nitrogenous fertilizers are highly soluble and are prone to leaching.

In areas where salinity is a problem and leaching of salt is essential for crop growing, the drainage of land should be good. Usually, a high water table and the soil salinity occur simultaneously.

Planning of irrigation development should also consider the development of drainage in particular region. If the ground water is of good quality, the water the high water table can be pumped out and used for irrigation in the area or in the nearby areas.

Some important equations

- ❑ Salt concentration, mg/l or ppm = $640 \times \text{EC}$, mmhos/cm
- ❑ Total cation concentration, me/l = $10 \times \text{EC}$, mmhos/cm
When EC is measured up to the range of 5 mmhos/cm at 25° C
- ❑ Osmotic pressure, atmospheres = $0.36 \times \text{EC}$ mmhos/cm
- ❑ Parts per million (ppm)/equivalent weight = me/l
- ❑ Equivalent weight = Atomic weight/valency

Problem – 1

- a) What is the classification of irrigation water having the following characteristics: Concentration of Na, Ca and Mg are 22, 3 and 1.5 milli-equivalents per liter respectively, and the electrical conductivity is 200 $\mu\text{mhos/cm}$ at 25° C?
- b) What problems might arise in using this water on fine textured soils?
- c) What remedies do you suggest to overcome this trouble?

Solution:

$$(a) \quad \text{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} = \frac{22}{\sqrt{\frac{3+1.5}{2}}} = 14.67$$

- ❑ If SAR value is between 10 to 18, then it is classified as Medium Sodium Water and is represented by S2 (**See table**)
- ❑ If the value of Electrical Conductivity is between 100 to $\mu\text{S}/\text{cm}$ at 25°C , the water is called of Low Conductivity (C1) (**See table**)

\therefore Given water is classified as **C1-S2 water (ans)**

(b) In fine-textured soils, the medium sodium (S2) water may create the following problems:

- Soil becomes less permeable.
- It starts crusting when dry.
- It becomes plastic and sticky when wet.
- Its pH increases towards that of alkaline soil.

(c) Gypsum (CaSO_4) addition, either to soil or to water is suggested to overcome sodium hazards posed by the given water.

Problem – 2

Express 8300 ppm of sodium salt concentration in mmhos/cm, μ mhos/cm and mhos/cm

Solution:

We know, Salt concentration in ppm or mg/l of water = $640 \times \text{EC}$ in mmhos/cm

$$\begin{aligned}\therefore \text{EC} &= \text{ppm salt concentration}/640 \\ &= 8300/640 \\ &= 12.97 \text{ mmhos/cm} \\ &= 12.97 \times 1000 = 12970 \mu\text{mhos/cm} \\ &= 12.97/1000 = 0.012 \text{ mhos/cm}\end{aligned}$$

End of Chapter – 2

