

Salt affected soils

The general term that is used for the soils which are adhesively affected or modified for the growth of most of the crop plants because of the presence of the soluble salts and exchangeable sodium or both.

Classification of the salt affected soils

There are three categories of salt affected soil

1. Saline soils (white alkali soil)
2. Sodic soils (black soil)
3. Saline Sodic soils (mixed white black soils)

Saline soils:

The soil which have sufficient amount of soluble salts and not containing excess amount of exchangeable sodium and adhesively affected the growth of the most of crop plants is called saline soils most of the soluble salts of saline soils are composed of cations of sodium, magnesium, and calcium and anion of chloride, sulphate and bicarbonates and small quantity of cations like potassium, and ammonium and anions of nitrate and carbonates may occur in these soils

Sodic Soils:

The soil, which has enough exchangeable sodium and not contain excess amount of soluble salt and adhesively affect the growth of the most of crop plants is called sodic soils. Soil selection, soil aeration, soil hydraulic activity is disturbed due to presence of this sodium.

Saline sodic soils:

The soil which have both, exchangeable sodium and soluble salts that adhesively affect the growth of most of crop plants.

Criteria for these soils:

Saline soil	Sodic soil	Saline-sodic soil
$EC > 4\text{dsm}^{-1}$ $SAR < 13(\text{mmoleL}^{-1})^{1/2}$ $ESP < 15$ $PH < 8.5$	$EC < 4\text{dsm}^{-1}$ $SAR > 13(\text{mmoleL}^{-1})^{1/2}$ $ESP > 15$ $PH > 8.5$	$EC > 4\text{dsm}^{-1}$ $SAR > 13(\text{mmoleL}^{-1})^{1/2}$ $ESP > 15$ $PH > 8.5$

Extent of salt affected soils

In world:

In world there are 800 million-hectare soils are salt affected from which 397 million-hectare soil is saline and 434 million-hectare is sodic soil and in world there are more than 100 countries have salt affected soils arid to semi-arid region

In Pakistan :

Total 6.7-million-hectare soil is salt affected according to survey of **1988**

Survey in **1983** (thousand per hectare)

Province	Saline	Sodic	Saline sodic
Punjab	504		2081
Sindh	1342	28	950
KPK	501		14
Balochistan	175		129

In Pakistan:

→ 56% of total soil is saline sodic and 44% of total soil is saline.

In Punjab:

→ 80% of saline sodic and 20% of saline.

Brackish water:

Water which have more EC, SAR, and RSE is called Brackish water.

Erosion:

It is a combination of three words detach, transport, and deposition

Sources of salts in the soil

- **Parent material**
- **Irrigation water**

If we irrigate a crop in single irrigation of 10cm its means that we are adding 120-180 kg hectare⁻¹ salts in the soils.

- **Underground water (brackish water)**

If we irrigate a crop in single irrigation of 10cm its means that we are adding 1.5 mega gram hectare⁻¹ salts in soil.

- **Sea water intrusion**

It is the movement of sea water into the fresh ground water causing contamination of ground water by the salts. It is a natural process that can be made more worst by the human activity as well. Sea water intrusion is caused by the decreased in ground water level

- **Flood water**

- **Wind**

- **Fertilizer/insecticides**

- **Rainfall**

Acid rain is the initial rainfall after a very long period cause more problematic salts in the soils

- **Gas from vehicle and industries**

- **Industrial wastewater and sewerage water major problem in poor countries.**

Genesis of salt affected soil:

Origin: through different process and practices for the development of soil from parent material.

- Reducing in size of P.M.
- Rearranging the material particles
- Addition of different material and salt.
- Development of different horizons.

Factors contribute:

1. Salty parent materials
2. Uneven distribution of rain fall
3. Aridity
4. Physiographic unevenness
5. Irrigation water

Salty parent material

The major original source of salt in Pakistani soils are primary minerals in parent material which serve as a primary source of soil formation. As Pakistan is situated in arid to semi-arid region of the world where temperature is very high, and rainfall is low which results in adequate leaching of salts in root zone so accumulation of soluble salts and exchangeable sodium. Have been continues for 1000 years during the process of soil formation is called primary or old salt affected soil.

These soils existed in Pakistan before the induction of artificial irrigation system which increases the intensity of this problematic soil very drastically (badly).

Unevenness Distribution of rainfall:

In Pakistan most of the rainfall occur during the monsoon season from (July-Aug) well during major part of year salts present in soil try to move upward with water through capillarity action so on surface when water evaporate it will left the salts on the surface of soil which ultimately result in salt affected soil.

Aridity:

Most of the Pakistani soils are present in arid to semi-arid zone. Where rainfall is received during the year is not enough to leach away the salt present in the soil from root zone area.

Physiographic unevenness:

The micro unevenness of the soil surface is generally not observable this situation can't be seen from different depth after rainfall. The water flow from one part to an other part on the soil and accumulate in the area where there is a low effective leaching so accumulation of salt take place in uneven soil which result in formation of salt affected soil in patches after the evaporation of water accumulated in uneven places.

Secondary salt effect irrigation water:

Secondary or man-made salt effected soils have formed after the introduction of artificial canal. The extent of secondary salt effected soil is very small as compared to primary salt affected soil.

Following are the main contributor or factors which are involve in formation of secondary salt effected soil in Pakistan.

- In enough or uneven application of irrigation water.
- Imperfect soil drainage.
- Water logging.
- Poor quality of ground water or application of brackish water.
- Lack of proper soil and water management.
- Seepage (horizontal movement of water).

Sodication:

It is the process where exchangeable Na^+ contents are high most of the salt present in salt affected soil occurs as cations like Ca^+ , Mg^+ , Na^+ and Anions like Cl^- , SO_4^- , S^- involve information of saline soil. While those present in small quantity Cations like K^+ , NH_4^+ and Anions like Carbonates, Bicarbonates and nitrates.

When salt concentration is very high a part of Ca^+ , Mg^+ react with CO_3 to form Calcium carbonate, Calcium sulphate Mg Sulphate etc. The precipitate on these salts increases the proportion of sodium in solution as well as the exchange complex. Their dominance reduces so Na Show dominance in soil solution and exchange site.

Why saline soil provides the way sodic soil?

Because the Cation or anion present in Saline Soil, interact with each other and form precipitate. This formation of precipitation provides the way for Na^+ to show dominancy.

Disadvantage of Sodic soil:

- Soil is dispersed
- Poor drainage
- Soil will be darker in color

Why the sodic soil is black in Color?

A Soil have Organic matter which is darker in color, Soil have pores which are specified for air and water movement, when the soil is irrigated, water enters the pore spaces and blocks the pores. It creates the anaerobic conditions, organic mattes is also present in standing water. Organic matter is not decomposed due to the anaerobic conditions. Due to the evaporation, water evaporates from the soil and the organic matter is left behind. This organic matter gives black color to the soil.

Why Saline Soils are White?

Due to the presence of excess Soluble Salts like Ca, Mg that are white in color.

Root Zone Salinity

Surrounding of roots from which root extract water and nutrient from soil for the growth is called root zone. The plant extracts water from the soil by applying the force greater than that force which holds the water to the soil. If the plant cannot make sufficient internal adjustment and exert enough force it is not able to get the sufficient water and will suffer with water stress this happen when soil become very dry. Similarly salt in soil solutions, increases force of plant must exert to extract water and this additional force is called **osmotic effect** or **osmotic potential**.

If there are two similar soils at the same water content, but one is salt free and other is salty. Plant can get and use more water from normal soil as compare to the salt affected soil. Soil also have affinity for water so if water contain salts, more energy per unit water must be expended by the plant, to absorb salt free water from the relatively salty soil solution.

How to measure root zone salinity?

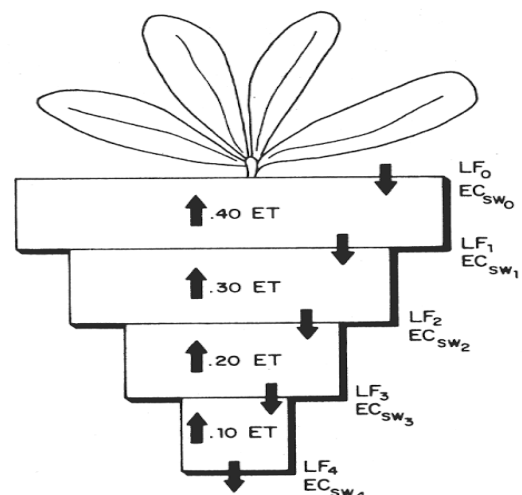
Average of 5 points:

Is needed to measure the salinity:

- Soil water salinity at the soil surface i.e.: EC_{sw0} .
- Soil water salinity at the bottom of upper quarter of root zone i.e.: EC_{sw1} .
- Soil water salinity at the bottom of 2nd quarter of root zone i.e.: EC_{sw2} .
- Soil water salinity at the bottom of 3rd quarter of root zone i.e.: EC_{sw3} .
- Soil water salinity at the bottom of 4th quarter of root zone i.e.: EC_{sw4} .

Which is equal to salinity of drain water.

$$EC_{sw4} = EC_{dw}$$



Assumption:

Different assumption was used to calculate EC at different root zone depth.

1. Soil water salinity of applied irrigation water = 1dsm^{-1}
2. Crop water demand (ET) = 1000mm/season
3. Crop water use pattern = 40,30,20,10
4. Desired leaching fraction (L.F) = 0.15

This mean that 15% of applied irrigation water leaches down that is enter root zone and percolates below the root zone while 85% is used by the crop to meet its ET and water loss through the surface by evaporation.

Leaching fraction:

The fraction of water that passes through the entire rooting medium and percolates below that is called as leaching fraction. It is denoted by L.F.

$$\text{L.F.} = \frac{\text{water leached}}{\text{Water applied}} \quad \text{_____ (a)}$$

If water salinity (ET_w) and L.F. is known than both the salinity of drained water that leaching to percolate below the root zone. So, the salinity of drained water can be measured.

$$\text{EC}_{\text{dw}} = \frac{\text{EC}_w}{\text{L.F.}} \quad \text{_____ (1)}$$

EC_{dw} percolate below the root zone which is equal to EC_{sw} than EC_w is applied water and L.F.

$$\text{EC}_{\text{dw}} = \text{EC}_{\text{sw}} = \frac{\text{EC}_w}{\text{L.F.}}$$

1. With L.F. 0.15 the applied water (AW) need to meet both crop demand ET and L.F. which is determined by the follow equation.

$$\text{AW} = \frac{\text{ET}}{1 - \text{L.F.}} = \frac{1000}{1 - 0.15} = \frac{1000}{0.85}$$

$$\text{AW} = 1177\text{mm of water.}$$

2. Salinity of soil water at surface EC_{sw0} must be very close to salinity of applied water and assuming LF_0 is equal to 1.

$$EC_{dw0} = EC_{sw0} = \frac{EC_w}{L.F_0} = \frac{1}{1} = 1 \text{ dsm}^{-1}$$

3. Salinity of soil water drainage from the bottom of root zone region is found by determine the LF of that water using eq(a) than salinity of soil water using eq (1).

For the bottom of 1st quarter:

$$\begin{aligned} LF_1 &= \frac{1176 - 0.04(1000)}{1176} \\ &= 0.66 \\ EC_{sw1} &= \frac{EC_w}{LF_1} = \frac{1}{0.66} = 1.5 \text{ dsm}^{-1} \end{aligned}$$

For the bottom of 2nd quarter:

$$\begin{aligned} LF_2 &= \frac{1176 - 0.04(1000) - 0.03(1000)}{1176} \\ &= 0.40 \\ EC_{sw2} &= \frac{EC_w}{LF_2} = \frac{1}{0.40} = 2.5 \text{ dsm}^{-1} \end{aligned}$$

For the bottom of 3rd quarter:

$$\begin{aligned} LF_3 &= \frac{1176 - 0.04(1000) - 0.03(1000) - 0.02(1000)}{1176} \\ &= 0.23 \\ EC_{sw3} &= \frac{EC_w}{LF_3} = \frac{1}{0.23} = 4.3 \text{ dsm}^{-1} \end{aligned}$$

For the bottom of 3rd quarter:

$$LF_4 = \frac{1176 - 0.04(1000) - 0.03(1000) - 0.02(1000) - 0.01(1000)}{1176}$$

$$= 0.15$$

$$EC_{sw4} = \frac{EC_w}{LF_4} = \frac{1}{0.15} = 6.7 \text{ dsm}^{-1}$$

$$EC_{sw} = EC_{sw} + EC_{sw1} + EC_{sw2} + EC_{sw3} + EC_{sw4}$$

$$EC_{sw} = 1 + 1.5 + 2.5 + 4.3 + 6.7$$

$$EC_{sw} = 3.2 \text{ dsm}^{-1}$$

Average root zone of that specific crop = 3.2 dsm^{-1} .

Classification of Salt Affected Soils:

1. USDA System:

1st USDA system in 1954. **USDA** stands for United States Department of Agriculture.

Divide based on:

EC, SAR, ESP, pH

They classify the soil into three groups:

- Saline
- Sodic
- Saline sodic

2. USSR system:

Union Soviet Socialist Republic.

They divided the salt affected soil into two groups.

- Solanchak
- Solonetz

In this system, they do not included EC, they included the percent (%) of salt present as percent of dry weight.

Solanchak:

These are those soils which contain more than 2% soluble salt on dry weight bases in upper 30cm depth of soil. Furthermore, depending on concentration of soluble salt and type of salt they further divided into more categories.

{Non saline, slightly saline} -----have no salt

{Moderately saline, strongly saline}

{Solanchak}

Solonetz:

This group is classified based on ESP and are divided into two groups.

1. Chernozem

2. Chestnut or brown soil

Chernozem:

Which are very black in color, rich with humus must present in cooled and temperate regions. e.g. grassland of European Russia.

Chestnut or brown soil:

They have low organic matter, brown color Solonetz are further divided based on ESP.

Categories	Chernozem	chestnut
Weakly Solonetz	<10	<5
Moderately Solonetz	11-15	5-10
Strongly Solonetz	16-30	11-16
Solonetz	>30	>16

3. Australian system:

They classified the soil based on % of salt, ESP and pH.

On the basis they categorize into three types:

Type of soil	Category 1	Category 2	Category 3
Saline (% of salt)	Non-saline <0.1% NaCl	saline >0.1 %NaCl	Highly saline >0.3%NaCl
Sodic (ESP)	Sodic <6	Moderately sodic 6-14	Highly sodic >14
Alkaline (pH)	Non alkaline <8	Alkaline 8-9.5	Strongly alkaline >9.5

4. FAO-UNESCO System: (Food and Agriculture Organization United Nation Educational Scientific and Cultural Organization) They categories the soil into two groups:

- Solanchak: $EC > 4 \text{ dsm}^{-1} \rightarrow 25\text{cm}$
- Solonetz $pH, ESP > 15 \rightarrow 40\text{cm}$

5. The Indian System:

- Nature of soluble salts should be added as index.
- Instead of 8.5pH, they considered 8.2 pH because at this, sodication is start and precipitate forms.

	Saline	Sodic
EC	$>4 \text{ dsm}^{-1}$	$<4 \text{ dsm}^{-1}$
pH	<8.2	>8.2
ESP	<15	>15
	$\text{Cl}^{-1}, \text{SO}_4^{-}, \text{HCO}_3^{-}$ Present CO_3 is absent	$\text{HCO}_3^{-}, \text{CO}_3$ of Na^{+} is present

6. Pakistani System:

- SSP (soil survey of Pakistan)
- WAPDA (Water and power development authority)
- DLR (Directorate of land reclamation)

i. SSP (Soil survey of Pakistan):

Also study physical and morphological features of soil. They follow the US salinity in addition to this they also included physical features of soil porosity, soil structure, soil texture, soil drainage and horizon development to give more clear and better differentiation of the salt affected soils.

ii. WAPDA (Water and power development authority):

They divided the salt affected soil on the basis of EC without any consideration of SAR, ESP and pH.

Symbol	Class Name	EC_e
S_0	Salt free	$<4 \text{ dsm}^{-1}$
S_1	Slightly saline	$4-8 \text{ dsm}^{-1}$
S_2	Moderator saline	$8-12 \text{ dsm}^{-1}$
S_3	Strongly Saline	$12-16 \text{ dsm}^{-1}$
S_4	Very Strongly saline	$>16 \text{ dsm}^{-1}$

DLR (Directorate of land reclamation):

Office is in Lahore. They divided Salt affected soil into 5 groups described below.

1. Thur Kohina:

This is never been cultivated due to salinity.

2. Thur Punjsala:

Which has gone out of cultivation **more than 5** (five) years.

3. Thur Nau:

Which has gone out of cultivation **during 5** (five) years.

4. Thur Juzvi:

Land under the cultivation but have visible patches of the salt to the extended 20% of acre.

5. Thur Tirk:

It is the land where the salt in the root zone hampers the opening of cotton bolls.

Reclamation of SAS:**Suitability of Method/Factors.**

1. Physical, chemical, and biological character of soil.
2. Internal soil drainage.
3. Pressure of herbal plain.
4. Climate conditions.
5. Contents and types of salts.
6. Quality and quantity of leaching ability of water.
7. Quality and depth of underground water.
8. Desired weight of removal of sodium from sodic soil.
9. Presence of gypsum and lime in soil.
10. Availability and cost of amendment.
11. Availability of equipment for soil silage if needed.
12. Crops grown in region.
13. Time available for the reclamation.

Method of SAS Reclamation:

1. Physical Methods
2. Chemical Methods
3. Biological Methods
4. Hydro-Technical Methods
5. Electro-Technical Methods
6. Synergistic Approach

Reclamation of soil:

Remove the problem 100% from soil.

Management of soil: Don't

remove 100% the problem just manages for some time.

1. Physical Methods:

- a) Deep ploughing
- b) Sub soiling
- c) Sanding
- d) Hauling
- e) Horizon mixing

a) Deep ploughing:

It consists of the depth from about **40cm** to **150 cm**. It was found that single deep ploughing having **40-75cm** depth economically improve the calcareous soil both physically and chemically. So under condition where subsoil is more sodic than the surface, deep ploughing should be avoided. However, this method is very helpful to speed up the soil reclamation if the **gypheorous** means the soil containing large quantity of gypsum.

b) Sub Soiling:

Its beneficial effects may continuous for several years. If the lime layers are broken otherwise the beneficial effects may persist only for one season. Sub Soiling was found more effected tool for reclamation of calcareous saline-sodic soils with rice-wheat rotation for the period of 3 years.

c) Sanding:

It is also effective for making a fine texture but not highly clay surface soil more permeable by mixing sand in it. Sand ease root penetration and better air and water permeability which facilitates the leaching of salts. The depth of applying sand should be at least 10cm for mixing with the surface soil for better results.

d) Hauling:

This tech is used to removal of salt affected surface soil and replacing it with good soil up to the desired depth. It is the beneficial, but it might not be applicable everywhere due to its high cost.

e) Horizon Mixing:

This method is used when surface is good but upper sub soil has undesirable characters. This situation is occur in saline sodic or sodic soil having favorable surface but slowly permeable sodium effected B horizon which is underlain by more permeable horizons sometime containing gypsum. The object of soil profile mixing is to retain the surface soil. This is done by removing surface soil and then deep ploughing of subsurface soil and then again placing the surface soil.

2. Chemical methods:

Effectiveness of chemical depends on:

- Soil properties
- Plant growth stages
- Cost of chemicals
- Handling of chemical
- Availability of chemicals
- Application difficulties

Classification:

- Inorganic amendments
- Organic amendment

i. Inorganic amendments:

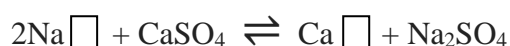
Soluble calcium salts	Slowly soluble calcium salts	Acidifying material
<ul style="list-style-type: none"> • CaCl_2 • Gypsum • Phosphogypsum <p>These are by product during manufacturing phospho-fertilizer.</p>	<ul style="list-style-type: none"> • CaCO_3 • CaSO_4 	<ul style="list-style-type: none"> • Ca mobilizer in soil • Convert in easily soluble form. • H_2SO_4, HCl, HNO_3 etc.

Chemical reaction:

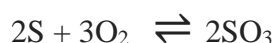
for Calcareous saline-sodic soil:

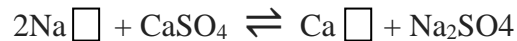
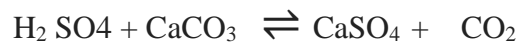
1. Gypsum:

When we apply gypsum in saline sodic or sodic soil. This type of reaction takes place:

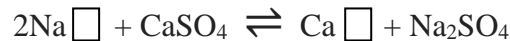
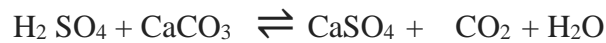
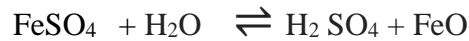


2. Sulphur Apply:

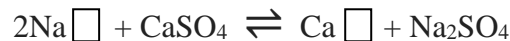




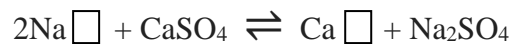
3. Iron Sulphur:



4. HCL

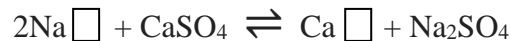


5. HNO₃

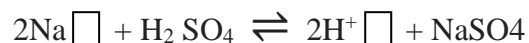
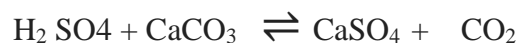
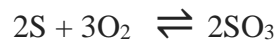


For non Calcareous:

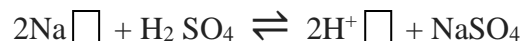
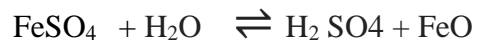
1. Gypsum:



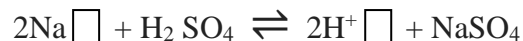
2. Sulphur Apply:



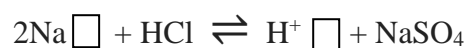
3. Iron Sulphur:

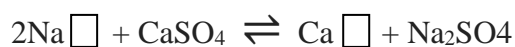


4. H₂ SO₄



5. HCL



6. HNO₃**ii. Organic Amendments:** (Organic matter application)

- That is crucial for improving Physical, Chemical, Biological and fertility.
- Properties for both normal for SAS.
- That is also used to reclaim the soil

➤ It includes:

- Farm yard manure
- Waste material
- Green Manuring etc.

A). Waste material:

1. Extensive use is not possible.
2. Its effect is very slow.

Example: sugar industries, molasses, presumed etc.

→Plays an important role.

→Through growing green crop, slaten house material.

B). Methods of Soil Reclamation / Amendment Application:

1. Methods of Amendment Application to sodic soil if classic's in determine the reclamation efficiency.
2. The Amendments like Sulphur acid. When added to the water passing through mater irrigation system may cause damage to the pipes or channels
3. In cause of gypsum uniform spreading and depth of mixing is very important surface application of gypsum and mixing up to the 10 cm depth is called more effective for soil having surface crusting and inflation.

C). Partial Size:

1. Maintenance of adequate level of solved calcium size amendment is also very important
2. The effect of partial size and source in cause of gypsum are crucial for the rapidly dissolution of amendment to supply the soluble calcium
3. Generally, the fine grade gypsum improves the sodic and SS early than the pores grade of gypsum because of the greater dissolution

4. The coarse grade gypsum gives slow ions which are maintain or increase the lime, so it has been maintain mixture the particular to have the initial replied desolation are of sum fine gypsum followed by longer and sustain released by calcium from the coarse particles.
5. In Pakistan gypsum powder is less then 30 mesh size is marketed.

3. **Biological method:**

Growing of plants on the salt affected soil to reclaim it.

Major part of plants above ground ----- shoots

Below the ground ----- Roots

Shoots:

- Provide shade.
- Lower the soil temperature
- Mulching
- Decrease evaporation rate
- Check upward salt movement through capillary reaction.

Root:

- Change the pH of soil
- Lower the oxygen of concentration
- Release organic compound
- Channels for soil solution
- Increase the micro organism activities
- Physical and chemical properties are also influence.

5 point mechanism:

- 1) Released of CO₂ through respiration.
- 2) Formation of H₂CO₃ by dissolution of CO₂ in water.

$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{Carbonic acid}$$
- 3) Reaction of this H₂CO₃ with native slowly soluble CaCO₃ to form more soluble Ca(HCO₃)₂.
- 4) Release of calcium ions from Ca(HCO₃)₂.

5) Replacement of sodium with calcium on exchange sites.

Choice of plants:

- ✓ Plants are growing in saline and sodic environment may face certain limitation particularly in the form of biomass production.
- ✓ Soil salinity may reduce crop yield by disturbing the H₂O and nutritional balance of plant growth by deteriorating soil physical condition or by disturbing the plant nutrition due to excess sodium in the root medium.
- ✓ The selection of plant specie capable of producing satisfactory biomass during reclamation of sodic or saline soil is vital.
- ✓ The ability of some plant specie to grow in a wide range of stress condition. Expanded their adoptability and utility as compare to other crops.
- ✓ Crop the inclusion of kallar grass. Sesbania or sordan as the first crop to start and speed up reclamation of sodic/saline-sodic soils.
- ✓ The salt tolerant plant species generally perform more efficiently in calcareous saline-sodic/sodic soil than the non-calcareous soils.
- ✓ In calcareous soils, their roots act as Ca⁺² mobilizers via dissolution of the native CaCO₃.

Electro reclamation method:

- ✓ It refers to the reclamation of saline sodic and sodic soils through electro dialysis.
- ✓ The treatment with electric current may speed up reclamation of the salt affected soil.
- ✓ This method of soil reclamation has shown some encouraging results which indicate increase solubility of CaCO₃ to supply Ca⁺² to replace the exchangeable Na⁺ moreover, this method created an environment which was effective for leaching of soluble salts and exchangeable Na⁺.
- ✓ It is too early to recommend this method for practical use in agriculture of Pakistan and elsewhere in the world.

Synergistic approach:

Under certain conditions, reclamation can be speedup by combining the various reclamation methods, e.g. a saline-sodic soil having an impermeable layer of **15cm** width at a soil depth. In case, a combination of physical and chemical method may be better than use of either chemical or physical method alone. In most of the cases, this approach for the reclamation of saline-sodic/sodic soils at farmers level.

Hydro-technical method:

- ✓ This method initially makes use of the effect of the high electrolyte concentration of saline water on soil permeability and subsequently, in successive dilution of the valence dilution effect.

- ✓ The **valence dilution effect** was demonstrated by Eaton Sokoloff (1935) for reclaiming sodic soil.
- ✓ In a soil water where monovalent and divalent cations in solution are in equilibrium with the adsorbed cation. The addition of water to the system alters the equilibrium condition. This dilution of the soil solution favors the adsorption of divalent cations like Ca at the cost of monovalent cations like Na^+ .
- ✓ The reverse is true when the soil solution is concentrated due to evaporation.
- ✓ The ratio of divalent to total cations (with concentrations expressed in $\text{mmol}_\text{c}\text{L}^{-1}$) of the water should be at least 0.3.
- ✓ Some nature waters meet this ratio, but in many cases some additional Ca^+ can be introduced by:
 - 1) Apply gypsum to soil and followed by leaching with high salt water.
 - 2) By placing gypsum stones in the water channels to add Ca^+ in the salty water through gypsum stone dissolution.

Problem:

The major problem with this method is:

- ✓ Facilities required to collect, convey and the saline water.

Management of SAS:

A) Management of reclaimed SAS:

Following measures are included to manage the reclaimed Salt Affected Soil.

i. Measures for maintaining the downward balance of salt and water movement on the salts:

Where ever the natural drainage is available or artificial drainage has been provided prevention of salinization can be done. If the balance of movement of water is maintain downward in the soil profile.

E.g.:

- More water is applied then the water moving upward in the soil profile under the evapotranspiration forces. This can be achieved by the use of irrigation depth greater then consecutive use of crop.

ii. Measures for reducing the replacement of ground water and enters of salt into irrigation areas.

a. Planted water utilization:

It can be practiced in accordance with the nature of soil, depth of ground water, type of agriculture crop and type of economy in each irrigation system. This effort reduces the entry of water and soluble salts by **20-30%** of head water intake.

b. Water uses according to weather conditions:

The study of autumn, winter, spring and summer weather forecast shall be done so that water should be applied properly in dry season and watering should be avoided in winter/wet season.

c. Control of surplus irrigation:

Surplus irrigation water must never be spread in any part of irrigation area and flood water has been controlled.

d. Seepage:

It must be kept to a minimum losses in the area where channel and water channel are not lined may be as high **45%** good result may be obtain by lining of channel through clay material.

e. Remodeling of old irrigation systems:

Irrigation system have not been rebuild from long ago so measures these old irrigation system according to requirement of modern agriculture.

f. Provision of water for domestic purpose:

The use of irrigation channel for delivery of water for domestic purpose during the time without irrigation must be avoided to control the water seepage for this purpose special channel, special ponds have been constructed.

g. Field leveling:

Field must be leveled under the conditions where surface irrigation method used. This will improve the water efficiency.

h. Correct planning for rice growing:

Rice required huge amount of water so rice growing area must be selected. They must present at the same distance from the main area of irrigation land and have good artificial drainage.

iii. Measures to reduce the ground water evaporation:

Following measures help to reduce ground water evaporation:

a) Plant cover over the field:

It is necessary to keep cover plants over the field to reduce evaporation. Plants cover provides the shade to field and acts as a mulch and thus reduce the evaporation.

b) Improve the soil structure:

Soil structure can be improve by addition of organic matter, green manuring, deep ploughing, cultivation in relation to irrigation schedule, helps to retain more water by improving the soil structure which leads to reduce the evaporation rate.

c) Tree plantation along the roads and channel:

d) It is used to reduce wind velocity and evaporation losses.

e) Use of ground water:

If the ground water quality is appropriate or under permeable limit then pumping out of this water for irrigation purpose results reduction of water loss through evaporations but under the conditions where quality of under ground water is very poor e.g. have high salts concentration. This practice should be avoid.

B) Management of salt affected soil:

- **Selection of salt tolerance crops:**

Plant capacity to survive the effects of excess soluble salts presence in the growth medium.

1. Plants have ability to survive salt in affected soil acceptable yield of crop on the salt affected soil is mostly **50%** reduce yield. Relative yield of salts on salt affected soil as compare to with is yield under the similar growing condition.

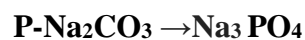
- Soil fertility
- Physical condition of soil
- Salts distribution in soil
- Moisture
- Irrigation practices
- Plant growth stages
- Plant species
- Variety
- Availability of water

Different plant crops have different ability against the salinity, sodicity:

Crop	Salinity	Sodicity
Barley	Tolerant	Non Tolerant
Bean	Sensitive	Sensitive
Corn	Moderately sensitive	Sensitive
Cotton	Tolerant	Moderately Tolerant
Kallar grass	Tolerant	Tolerant
Rice	Sensitive	Tolerant
Sesbania	Moderately Tolerant	Tolerant
Wheat	Moderately Tolerant	Moderately Tolerant

1. **Fertilization:**

Salinity and sodicity or their combination produce unfavorable nutrients ratio in host soil. Excess of Na and deficiency of macro and micro nutrients are common in sodic and saline soil. The prominent factors responsible for low nutrients availability in sodic soil are the high pH and poor soil physical condition. For this reason special fertilizer management is important for optimum production of crop. Salt affected soils general have low organic matter and nitrogen. Green manuring of Sesbania species have an important stablsh practice to improve the nitrogen level and reduce the salinity sodicity hazards in the soil. In sodic soil **25%** extra nitrogen should be applied over the rate recommended for non sodic soil of particular region. Sodic and non sodic soils generally have high availability soil because of high concentration sodic carbonate of soluble sodium phosphate results in the formation of soluble sodium phosphate.



On the basis of studies, it has been concluded that sodic soil after reclamation they did not require additional fertilizer for **4-5 years**. Similarly it has been suggested that **50%** reduction in the recommended dose of P-fertilizer may be done for rice-wheat rotation grown up to the 3 year after reclamation without yield loss. Increasing salinity sodicity result in deficiency of Ca and Zn etc. so application of calcium containing fertilizer (calcium nitrate, single super phosphate) and zinc contating fertilizer (zinc sulphate) should be added be for the optimum production. So generally it is reclaimed that application of fertilizer except P contating fertilizer to the SAS should be done at higher rate (15 -20%) then the normal soil from sustainable problem.

2. Planting Technique:

In selecting the crops for SAS specific attention should be given to the salt tolerate of the crops during the germination stage because poor germination results to poor stand of the crop. The problem is become more complicated when different crops plants like cotton which is more tolerant in later stages of growth and more sensitive during the germination stage.

Under the field conditions it is possible by the modification of planting practices minimize the tendency of salts of accumulate around the seed those are sensitive of salts during germination stage seed of crops sprouts only when they are placed so as to avoid excessive salts build up around them. The pattern of salt build up around them changes with the shape of bed on which seeds are grown.

➤ **Irrigation water:**

Life of plant and animals depends upon air, water and food these influenced by:

- Plant growth
- Organic matter
- Weathering process
- Solution
- Air and soil temperature

➤ **Source of water:**

- Rainfall
- Atmosphere water
- Flood water
- Ground water

➤ **Irrigation quality:**

Hazards due to application of poor quality water.

- Salinity hazards
- Sodicity hazards
- Toxicity hazards

➤ **Salinity hazards:**

This problem is directly related to quantity to salt dissolved water contain salts and mostly all the dissolved salts are left in soil after the applied water is loss by evaporation from surface soil or through transpiration. Same salts are leach down from root one but sooner or later accumulation which are harmful to the most crop plants salinity hazards are expressed in term of EC or TSS present in the water.

➤ **Sodicity hazards:**

This problem develop when irrigation water contains relatively more Na as compare to application of this type of water results in accumulation of Na ions on exchange complete. This accumulation hydraulic conductivity.

1. Na adsorption ratio SAR it express in:

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

2. Carbonates and bicarbonates problem. This problem occurs when irrigation water contain high concentration of carbonate and bicarbonate ion. Then that of Ca and Mg ions. Prolong use of this water will expedite /will results in Sodication by in activating. The Ca and Mg ion of the water. Through precipitation of these ion in form Ca-Carbonate and Mg-Carbonate. This process indirectly results in increase of Na ions and decrease of Ca and Mg ions on the exchange site.

➤ **Toxicity hazards:**

It occurs when various ions in irrigation water taken up by the plants and accumulated in high amount results in crop damage. The degree of damage depend upon 2 factors.

1. Uptake of particular ions
 2. Sensitivity to that ions of specific crop.
- Damage of crops results when toxic ions are absorbed in significant amount with water taken up by the plants roots. The absorbed ions move to the leave where they accumulate during the transpiration usually result in burning of leaf tips and leaf edges. Most important ions are Na, Cl, B.
- These ions have a very toxic effect to the various plants if present in excess amount.

Water Logged Soils:

Waterlogged means saturated with water. Both soils temporarily saturated with water and soils having ground water tables permanently near the soil surface are called waterlogged. Therefore, all forms of excess water in the root zone of soil or on the soil surface cause waterlogging. Only a few crops can survive under such conditions.

Sources of Waterlogging:

A large part of the water diverted from rivers does not reach the field crops. It is estimated that 45-50% of the water is lost from the main canals, branches, distributaries, main water courses and farmer branches. Part of this water leaks into the ground. During the past 60 to 100 years, this leakage has gradually raised the ground water table and has caused waterlogging over large areas. In some cases, the water table has risen to the crop root zone or even to the soil surface. The ground water tables for two periods are shown in Table:

Area with different ground water depths (1000 hectares)

			Depth in meters			
	Survey year	Total area surveyed	0-0.9	0.9-1.8	1.8-3.0	0-3.0
Punjab	1953-65	4832.5	109.2	580.8	1214.7	1904.7
	1977-78	4933.8	326.5	578.3	934.1	1838.3
KPK	1971-75	175.9	9.7	13.2	6.8	29.7
	1977-78	212.2	3.1	5.3	3.7	14.1
Sindh and Baluchistan	1977-78	3392.1	151.7	768.4	1047.5	1967.7
Pakistan	1953-75	5008.4	118.9	594.0	1221.4	1934.4
	1977-78	8538.0	481.3	1352.1	1985.3	3818.7

Source WAPDA (1979)

Areas having a ground water table within 1.5 meters of the land surface are classified as disaster areas and those where the water table is within 3 meters are classified as waterlogged, according to WAPDA. The main sources of waterlogging are recharge from:

- The irrigation system including main canals, branches and distributaries
- Link canals
- Water courses and irrigated fields
- Rainfall

- e. Rivers
- f. Subsurface flow from higher to lower areas

Constructions of irrigation networks, roads, rail links, factories and housing colonies in the path of natural drains has interrupted surface runoff at many places, resulting in the accumulation of water during the monsoon season, a part of which contributes to waterlogging through seepage.

Effects on plant growth:

Excess water in the root zone restricts root growth and therefore adversely affects plant growth. The above ground parts of the plant may be affected directly by water on the soil surface. Under arid conditions like those of Pakistan, excess water is usually accompanied by salinity. Under such conditions, the harmful effects of salinity and waterlogging on plants are not easy to separate. In fact, the adverse effects of salinity and waterlogging are more than additive.

The first effect of excess water in soil is to replace air in the soil pores. Leading to oxygen deficit and reduced plant growth. A minimum concentration of oxygen in the root zone is essential for normal growth otherwise a high soil moisture level in itself is not necessarily detrimental to plant growth. Transport of gases in the soil is also seriously decreased, as gas diffusion mainly takes place in air-filled pores; the rate of diffusion of oxygen through water is 1000 times slower than that through air. Limited exchange of gases will thus not only decrease the oxygen concentration in the soil, but also increase carbon dioxide concentration to levels that are harmful to plants. Low O₂ and high CO₂ concentrations have a direct effect on a number of physiological processes like transpiration and ion and water absorption. After the disappearance molecular oxygen, the concentrations of CO₂ and toxic products of anaerobic microbial activity like methane and organic acid increase. In addition, in submerged soils, ammonia, which is toxic to many crop plants, is the major form of N. Under waterlogged conditions, concentrations of phosphorus iron, manganese and silicon increase and that of zinc decreases. The increase in the concentration of ferrous iron in waterlogged soils may also be toxic to crop plants.

Control measures:

Since the appearance of water logging in 1925, various control measures have been suggested by workers in the Punjab. The important ones are discussed below:

Seepage interceptors drain. Drains constructed to intercept seepage water from the source (canals) are called seepage interceptor drains. They are constructed parallel to the source of seepage water, their dimensions and length depending on the size and length of the seepage source. Such drains were constructed along both sides of the upper Chenab canal. They proved infective in controlling the ground water.

Tree plantation along the spoil banks: This method was also not very effective.

Surface drains: Surface drains proved relatively effective in carrying away canal seepage water and rainfall runoff. Between 1933 and 1944 a large number of surface drains totaling about 5340 km in length were constructed in the Punjab. Between 1967 and 1970 quite a few surface drains were also constructed in Sindh.

Lining of canals: In 1938-39, the Haveli Canal was the first to be lined at the time of its construction. Later on the main Thal Canal, Balloki-sule-manki Link and portions of BRB Link were lined. The lining of canals reduced seepage by about 75%.

Pumping of ground water: Pumping out ground water has always been effective in lowering a shallow ground water table. Pumping not only lowers the ground water but also provides additional water for irrigation where its quality is suitable. The constructions of drains and pumping by tube well have proved to be quite effective against waterlogging.

After the success of these measures and following the recommendations of the Revelle report (Revelle 1964), many salinity control and reclamation projects were established in the Punjab, Sindh and KPK. These projects were intended to lower the ground water table and supply additional water for irrigation and the reclamation of saline soils.

PRACTICAL

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stone dissolution. The major problem with this method are facility to collect and treat the saline H_2O .

Practicle

Soil Sampling

Q: Why we soil Sample? (SAS)


Can we recommend the

⇒ Glycophytes plants ? — Cannot

⇒ Halophytes plants ? — Can tolerate salinity

⇒ water depth

⇒ availability & quality of irr. water.

- (1) Judgement Sampling: appearance, experience
- (2) Simple Random Sampling. Homogenous field condition.
- (3) Stratified Sampling.  Heterogenous field not uniform size (eg. soil)
- (4) Systematic Sampling.

Judgement Sampling: Sampling locations are selected based on the judgement of researching or extension worker. These sites may be selected ^{acco} regarding to vision appearance of soil condition or growing

Date: / / plants and ^{diff} crops, water courses, canals etc.

Simple Random Sampling: It is Based on assumptions that each sample has an equal chance of being Selected. The table of random no. is needed to select sampling location. It is better to establish a grid through out the field and then using the table of random no. Select coordinates for the locations of observations. Simple random sampling is more appropriate for a homogenous field.

Stratified

This technique is more appropriate for a heterogenous area to consist of subdividing the area of interest into relatively uniform sub-plot. Each sub-plot is relatively sampled. Sub-plot need not to be a equal size but they must not overlapped. Selection of some plant might be based on differences in crop appearance, soil texture, salt accumulation on the surface soil.

Systematic Sam

This technique consist of randomly selecting the starting point and then sampling the total area at equal interval along the grid ^{or} transect.

The advantage of this technique is that the area of interest is completely covered whereas the some part of field may not be sampled in simple random Sampling.

Precautions:

- (1) Draw the composites of soil sample representing the smallest possible area has the salt affect soil or extremely variable
 - (2) Acc. to FAO 15, 20 and 25 Sub-samples should be drawn for a composite sample representing less than 1, ~~1-2~~ 3 and 3-5 hectare respectively
 - (2) There must not be dislodgement of an upper layer while collecting the deeper layers. while using the auger.
 - (3) Soil Sample if possible should be taken when soil is reasonable dry.
 - (4) In areas to be sampled it is important to make a map showing initial sampling points.
- subsequent sample should be take

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at sample but definite distance away from the previous sampling points.

- (1) Each sample should be put in a plastic bag along with a identification table.
- (2) Care must be exercised to avoid contaminations of soil sample once drawn from the field.

theory

B \Rightarrow Management of Salt affected Soil:
A \Rightarrow Management of Reclaimed SAS

Management of Reclaimed SAS

Following measures are included to manage the Reclaimed SAS

\rightarrow measures for maintining downward balance of salt and water movemend of the soil:

Wherever the natural drainage is available or artificial drainage has been provided, balance of impropae of water downward in the soil profile is maintained. If H₂O is applying then the

THE ANALYSIS OF IRRIGATION WATER

Objectives

1. To quantify the quality of irrigation water to gauge its effects on soil quality
2. To estimate the suitability of water for crops
3. To know the nature, type and amount of salts present to avoid the soil from becoming salty
4. For recommending suitable measures to use the available water.

Methods of sampling

1. Sample should be true representative of the water to be analysed
2. If new tube well is being installed, water sample should be collected from every 50 feet intervals.
3. In case of existing tube well, it should be run for 15-20 minutes and sample should be collected from the discharge pipe and not from the water channel
4. Samples from the rivers, streams should be taken from running water. The properties of samples may vary during analysis due to the following factors.
 - With depth of sampling
 - rate of flow of water
 - Distance from the bank of canal
 - Time of the year
5. It is best to take an integrated sample from top to bottom and in the middle of stream.

Sample size

Analysis of water for irrigation purposes requires at least one liter of water.

Storing

1. Clean plastic / glass bottles should be rinsed two to three times with water to be collected.
2. Filled the bottle up to the top and tightly capped.
3. The bottles should not be washed with any detergent.
4. Sample should be refrigerated and analysed as quickly as possible, so that chemical changes during storage can be minimized.
5. Sample should be analysed within seven days of collection.

Labeling

Samples should be labeled with

- Canal / stream/ tubewell/tap water
- Date of collection
- Depth
- Name of the collector

MEASUREMENT OF THE ELECTRICAL CONDUCTIVITY (EC) OF IRRIGATION WATER

Principles

Electrical conductivity meter measure the electrical conductance of any solution containing inorganic soluble salts. In general more the salts present in water more will be the intensity of current passing through it.

Apparatus

Electrical conductivity apparatus consist of

- Solu bridge
- Micro pipette Conductivity cell

EC meter is designed by US Soil Salinity Laboratory. Conductivity cell consist of micro pipette with a rubber bulb and two 1cm^2 platinum electrodes 1 cm apart housed in a glass bulb. Second glass bulb is empty which is filling limit. Solu Bridge incorporates an automatic temperature correction device and scale is calibrated to read directly in d Sm^{-1} at 25°C .

Procedure

- (i) Standardization
- (ii) Actual Measurement
- (i) **Standardization**

The instrument must be standardized with 0.01N KCl (0.7456 g KCl /L) solution. The EC of this standard solution will be $1.4118 \text{ m moh cm}^{-1}$ or d Sm^{-1} at 25°C . Fill the conductivity cell with 0.01 N KCl solutions. Before filling it is rinsed with the standard solution 2 or 3 times. Fill with care that no air bubbles are present in between the electrodes and they are fully dipped in standard solution. Note the temperature of the standard solution with a thermometer and adjust it on the instrument by rotating the temperature knob. Note the EC reading on meter by pressing the key with other hand to connect the circuit until you get the maximum opening of V-shape shadow in magic eye. Calculate the cell constant by formula

$$K = 1.4118 \text{ d Sm}^{-1} / \text{Observed EC (d Sm}^{-1}) \text{ of solution}$$

$$\text{Corrected EC of water} = K \times \text{EC of water}$$

- (ii) **Actual Measurement**

Measure the temperature of the water sample and set the temperature compensation dial of the Solu Bridge accordingly. Rinse the pipette cell with water sample and then fill it up to the empty glass bulb avoiding air bubble. Close the contact switch and balance the instrument. The point of balance is indicated by the maximum opening of the “magic eye” i.e., a V-shaped shadow. Read conductivity and record it in d Sm^{-1} at 25°C . If no shadow appears it means the sample is too saline, it should be appropriately diluted and obtained reading multiplied by dilution factor.

Units of EC

Higher the salt contents lesser the resistance to the flow of current. The resistance (R) is defined by the Ohm's law as the ratio of electrical potential (E) in volts and strength of the current (I) in amperes:

$$E / I = R \text{ ohm's}$$

Conductivity (C) is the reciprocal of resistance i.e.,

$$C = I/R \text{ mhos}$$

Ohm when written in reverse order becomes mhos; which is the unit of conductance.

Since both the platinum plates in the cell are 1 cm apart thus the unit (old) is written as mhos/cm at standard temperature (25 C°).

Old units

EC = mhos/cm at 25°C

EC X 10³ = mmhos / cm at 25 °C

EC X 10⁶ = u mhos / cm at 25 °C

New units

mhos /cm = S m⁻¹ at 25 °C

mmhos / cm = d S m⁻¹ at 25 °C

Calculation of total soluble salts (TSS) or Total Dissolved solids (TDS) in irrigation water

BY EC METER

Principle

The main source of soluble salts which are present to some extent in all soils and irrigation water is the primary mineral. Accumulation of these salts in excess amounts takes place by drainage and seepage from other areas and this condition is said to be saline. Electrical conductivity is used for the determination of total concentration of soluble salts or ionized constituents in water. It is related to the sum of cations or anions as determined chemically and it is also correlated with the total dissolved solids.

Conversion Factor

The determined electrical conductivity (EC) is multiplied with an appropriate factor i.e., 10 to estimate the total dissolved solids or total soluble salts.

For example

Observed EC of irrigation water = K d S m⁻¹

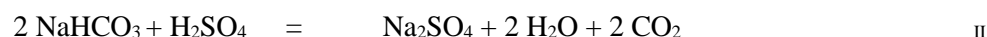
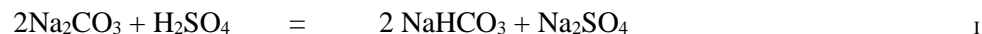
TSS or TDS in irrigation water = K X 10 me L⁻¹

Note: The factor is appropriate for irrigation waters having EC in the range 0.1 to 5.0 d S m⁻¹. For higher values, consult the graph given in the USDA, hand Book No. 60. p. 10-15.

Measurement of Total soluble anions (CO₃²⁻, HCO₃⁻, Cl⁻, and SO₄²⁻) and cations (Na⁺, Ca + Mg) in given irrigation water

ANIONS**CARBONATES (CO₃)****Principle**

Carbonates can be determined by titrating against (N/10) sulfuric acid (H₂SO₄) using phenolphthalein as an indicator.

Chemical Reaction**Procedure**

Take 50 ml irrigation water in a flask with the help of pipette. Add 2-3 drops of phenolphthalein, if no colour appears, carbonates are absent but if pink colour develops, carbonates are present. Titrate it against N/10 sulfuric acid to a colourless end point. Take three readings. Save the flask along with its contents for bicarbonates and chloride determination.

Calculations

Volume of irrigation water taken = 50 mL

Volume of N/10 H₂SO₄ used = R₁ mL (Final reading – initial reading)

Actual volume of H₂SO₄ used = 2 × R₁ = 2 *R₁

50 mL of irrigation water contains CO₃ = 2R₁ × N/10 me

1000 mL ___ do ___ = 2R₁ × N/10 × 1000/50

= 4 R₁ me L⁻¹

BICARBONATES (HCO₃⁻)**Principle**

Bicarbonates can be determined by titrating against standard H₂SO₄ using methyl orange as an indicator.

Chemical reaction**Procedure**

To the same conical flask (i.e. after the end point for carbonates) add 2-3 drops of methyl orange and titrate against N/10 H₂SO₄ to a pinkish yellow end point. Save the flask as such for chloride analysis.

Calculations

Volume of irrigation water taken	= 50 mL
Volume of N/10 H ₂ SO ₄ used	= R ₂ mL
Actual volume of H ₂ SO ₄ used	= **R ₂ - R ₁
50 mL of irrigation water contains HCO ₃	= (R ₂ - R ₁) N/10 me
1000 mL ___ do_____	= (R ₂ - R ₁) N/10 × 1000/50 me
	= 2(R ₂ - R ₁) me L ⁻¹

* R₁ is the amount of acid used to convert carbonates to bicarbonates equation, while for the completion of reaction, same amount of acid used would be still needed to further convert HCO₃ to CO₂ and H₂O as shown in equation II. Thus R₁ is the amount of acid used for half reaction and 2R₁ is the amount of acid used for whole reaction. Hence R₁ is multiplied by a factor of 2.

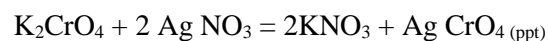
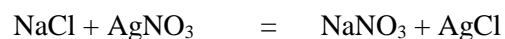
**R₂ is the total amount of acid used to neutralize the bicarbonates present in the sample after the titration for HCO₃ which means that the sample contains bicarbonates. Therefore the actual amount of acid used for neutralizing the originally present HCO₃ would be R₂-R₁

CHLORIDES (Cl⁻)

Principle

Chlorides can be determined by titrating against standard silver nitrate (AgNO₃) solution using potassium chromate (K₂CrO₄) as an indicator.

Chemical reaction



Procedure

To the same conical flask (i.e, after the end point for carbonate and bicarbonate) add 3 drop of potassium chromate and titrate against N/20 AgNO₃ to a brick red precipitate/colour.

CALCULATIONS

$$\begin{aligned}
 \text{Volume of irrigation water taken} &= 50 \text{ mL} \\
 \text{Volume of N/20 AgNO}_3 \text{ used} &= R_3 \\
 50 \text{ mL of irrigation water contains HCO}_3 &= R_3 \times N/20 \text{ me} \\
 1000 \text{ mL} \quad \text{--- do ---} &= (R_3 N/20 \times 1000/50 \text{ me L}^{-1}) \\
 &= R_3 \text{ me L}^{-1}
 \end{aligned}$$

SULPHATE (SO₄⁻)**PRINCIPLE**

Sulphate can be determined by difference method

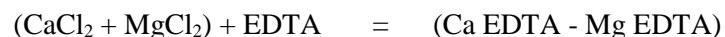
PROCEDURE

Total anions are obtained by multiplying the electrical conductivity by factor of 10. Sulphates are estimated by subtracting the sum of anions (except SO₄⁻) from the total dissolved anions.

$$\text{SO}_4^- \text{ meL}^{-1} = \text{TSS} - (\text{CO}_3 + \text{HCO}_3 + \text{Cl}^-)$$

CATIONS**CALCIUM + MAGNESIUM (Ca + Mg)****Principle**

Ca + Mg in irrigation water is determined by titrating against N/100 or 0.01N versinate (*EDTA) solution using **EBT indicator in presence of a buffer solution.

Chemical reaction**Procedure**

Where $\text{Na}^+ = \text{TSS} - (\text{Ca}^{++} + \text{Mg}^{++})$ ----- All units in me L^{-1}

CRITERIA FOR THE FITNESS OF WATER

	Fit	Marginal	Unfit
US soil salinity lab., staff , 1954			
EC (dSm^{-1})	< 0.8	0.8-1.0	>1.0
SAR (mmoles L^{-1}) ^{1/2}	< 8.0	8-10	>10
RSC (meL^{-1})	<1.25	1.25-2.50	>2.50
Department of Agriculture, Govt., of Punjab, (Bhatti, 1986)			
TDS (ppm)	<800	800-1000	>1000
SAR (mmol L^{-1}) ^{1/2}	<8	8-10	>10
RSC (me L^{-1})	<1.25	1.25-2.50	>2.50
WAPDA			
TSS (ppm)	<1000	1000-2000	>2000
SAR (mmol L^{-1}) ^{1/2}	<10	10-18	>18
RSC (me L^{-1})	<2.5	2.5-5.0	>5.0

We use

TSS less than 15 meL^{-1}

RSC less than 2.25 meL^{-1}

SAR less than $10 (\text{mmolL}^{-1})^{1/2}$

Report

A water sample is said to be fit for irrigation if all the three above limits are less otherwise water shall be considered unfit even if one out of all these is over the specified limit.

Determination of Na^+ in saturation extract of soil by flame photometer

Principle:

Sodium is determined by flame photometer. Analysis through flame photometer is based on the measurement of the intensity of characteristics line emission given by the element to be determined. When a solution of salt is sprayed into a flame, the salt gets separated into its component atoms because of the high temperature. The energy provided by flame excites the atoms to higher energy levels (the electrons of atom go to high energy level). When the electrons return back to the ground or unexcited state, they emit radiation of characteristic wave length (line emission spectrum). The intensity of these radiations is proportional to the concentration of particular element in solution which is measured through a photo cell in the flame photometer.

Equipment and Reagents

1. Flame photometer with Na filter
2. Volumetric flask (100 mL)
3. Sodium chloride standard solution :Dissolve 5.845 g of A.R. grade NaCl in distilled water and make volume to one Litre. It will give 100 mL^{-1} of sodium. This solution is treated as stock solution.
4. From this solution take 0, 1, 2.5, 5.0, 7.5 and 10 mL in volumetric flasks of 100 mL capacity and make the volume by further adding distilled water. This will give a series of standard solutions having 1, 2.5, 5.0, 7.5 and 10.0 mL^{-1} Na.

Method

1. Read the operation manual of flame photometer. Set the Na filter. Start the compressor and light the burner of flame photometer. Keep air pressure at 5 lbs and adjust the gas feeder so as to have a blue sharp flame cones.

2. Adjust the zero reading of the meter by feeding distilled water. Now feed standard sodium solution of the highest value in the standard series ($10 \text{ mL}^{-1} \text{ Na}$) and adjust the flame photometer to read full value of emission in the scale i.e. 100 reading.
3. Feed different standard sodium solutions one by one and record the emission value (reading) for each.
4. If concentration of Na is high in extract than dilute it by taking 10 mL extract (aliquot) of sample in a 100 mL volumetric flask and make volume 100 mL by distilled water.
5. Feed the diluted extract in flame photometer and note the reading.

Note: If flame photometer does not show reading of unknown, it indicates that the concentration of Na in unknown (diluted extract or aliquot) solution is higher and is out of the range of flame photometer scale. In such situation, further dilute the extract (unknown solution) and take the reading.

Observations

Reading of known solutions (Standard solutions)

S.No.	Concentration of Na in known solution (mL^{-1})	Reading on flame photometer
1	1.0	
2	2.5	
3	5.0	
4	7.5	
5	10.0	

Reading of unknown solution = x

Plot a standard curve between concentration and readings of standard sodium solutions. Obtain concentration of Na in unknown solution from the standard curve.

Calculations

Na (meL^{-1}) in soil extract = Na (meL^{-1}) as obtained from curve x Dilution factor, if any

(Here, volume of extract = 100; Aliquot taken = 10, hence, dilution factor is $\frac{100}{10} = 10$)

Na (ppm) = meL^{-1} x equivalent weight of Na (23) =

Result : The concentration of Na⁺ in saturation extract is -----
 meL^{-1} or ----- ppm.

Determination of K^+ in saturation extract of soil by flame photometer

Principle

Potassium emits an yellow colour (404 millimicrons) flame when excited in the flame. The intensity of emission is proportional to the concentration of potassium in the sample.

Materials required

- (i) Flame photometer (ii) Volumetric flasks 50, 100 and 1000 ml
- (iii) 100 ml beaker and (iv) A.R. grade potassium chloride salt

Reagents

- A. Ammonium acetate, approximately 1 N, To 700 or 800 ml. of water add 57 ml of concentrated acetic acid and then 68 ml of concentrated ammonium hydroxide. Dilute to a volume of 1 litre and adjust to pH 7.0 by the addition of more ammonium hydroxide or acetic acid.
- B. Potassium chloride, 0.02 N. Dissolve 1.491 gm of dry potassium chloride in water and dilute to a volume of exactly 1 litre.
- C. Potassium chloride 0.02 N in 1 N ammonium acetate. Dissolve 1.491 gm of dry potassium chloride in reagent A. Dilute to a volume of exactly 1 liter with additional A.
- D. Lithium chloride (0.05 N. Dissolve 2.12 gm of dry lithium chloride in water and dilute to 1 liter.

Procedure

Using reagents B and D, prepare a series of standard KCl solutions, each containing the same concentration of lithium chloride. Prepare a similar series of standard potassium solutions using reagents C and D, and use A for dilution. The concentrations of potassium chloride are 0, 0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 1.5 and 2.0 meq L^{-1} . Calibrate the flame photometer for operation over the concentration range 0 to 0.5 meq L^{-1} of potassium. Pipette an aliquot of the solution to be

analyse containing less than 0.1 meq L^{-1} of potassium into a 50 ml volumetric flask. Add an amount of reagent D which when diluted to a volume of 50 ml, will give a concentration of lithium chloride exactly equal to that in the standard potassium chloride solutions. Dilute to volume with water or with A, if ammonium acetate extracts are being analysed, mix and determine the potassium concentration by use of the flame photometer and the appropriate calibration curve.

Calculations

$$\text{in soil extract (me L}^{-1}\text{)} = \frac{(\text{me L}^{-1} \text{ of K from calibration curve} \times 50) \text{ K}}{\text{ml. in aliquot}}$$

Results:

$$\text{K in soil extract (me L}^{-1}\text{)} = \text{-----}$$

Determination of gypsum requirement of sodic soil (Schoonover 1952)

The reclamation of alkali soil (pH in water suspension exceeding 8.5) requires gypsum treatment for replacement of sodium ions from the exchange complex. The sodium so released has to be leached out by flooding. The gypsum requirement can be determined by adding a known excess of saturated solution of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to soil and estimating its unreacted amount by EDTA (versenate) titration.

Reagents

- (i) Saturated calcium sulphate solution : About 5g of pure $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ taken in one litre of distilled water, shake mechanically for 10 minutes and filtered it through ordinary filter paper.
- (ii) Ammonium chloride-ammonium hydroxide buffer of pH 10 : 67.5 g pure ammonium chloride dissolved in 570 mL of concentrated ammonia solution (sp. Gr. 0.88) and diluted to one litre with distilled water and adjusted to pH 10 (Caution : Liquid ammonia should be refrigerated before opening the bottle).
- (iii) Eriochrome black T indicator : 0.5 g of eriochrome black T and 4.5 g of hydroxylamine hydrochloride (AR) dissolved in 100 mL of 95% ethyl alcohol.
- (iv) 0.01 N calcium chloride solution : 0.500 g of AR grade calcium carbonate taken in little excess of AR HCl (about 10 mL of dil. acid) and the solution made upto one litre with distilled water.
- (v) Standard versenate (EDTA) solution 0.01 N : 2.0 g of ethylene- diamine- tetra acetic acid disodium salt and 0.05 g of MgCl_2 (AR) dissolved in water and diluted to 1 litre; the solution to be standardized against 0.01 N calcium chloride.

Procedure

5g of soil is taken in a 250 mL conical flask to which 100 mL of the saturated CaSO_4 solution is poured in, shaken for 5 minutes and filtered through Whatman No. 1. After rejecting first few mL, 5mL of the extract is pipetted into a 100 mL flask or porcelein dish and diluted to about 25 mL with distilled water. One mL of $\text{NH}_4\text{Cl} - \text{NH}_4\text{OH}$ buffer and 3 to 4 drops of eriochrome black T indicator are added and titrated with the standard EDTA solution untill the colour changes from wine red to blue. Similarly, 5 mL of the saturated CaSO_4 solution is titrated separately to determine the Ca concentration as described in exercise 3.

Observations

(i) Ca + Mg in soil extract

S.No.	Vol. of aliquot taken (mL)	Burette reading		Vol. of EDTA used (mL)
		Initial	Final	
1				
2				
3				

(ii) Ca in saturated gypsum solution

S.No.	Vol. of saturated gypsum solution taken (mL)	Burette reading		Vol. of EDTA used (mL)
		Initial	Final	
1				
2				
3				

Calculation

$$\begin{aligned} \text{Ca (meL}^{-1}\text{)} &= \frac{\text{normality of the EDTA} \times \text{mL of the EDTA} \times 1000}{\text{mL of saturated CaSO}_4 \text{ Solution taken}} \\ &= \frac{\text{-----}}{\text{-----}} \\ &= \text{-----} \\ \text{Ca +Mg (meL}^{-1}\text{)} &= \frac{\text{normality of the EDTA} \times \text{mL of the EDTA} \times 1000}{\text{mL of soil extract (filtrate) taken}} \\ &= \frac{\text{-----}}{\text{-----}} \\ &= \text{-----} \end{aligned}$$

Gypsum requirement in meL⁻¹ 100 g = [(Ca concentration in saturated gypsum solution (meL⁻¹) minus Ca – Mg concentration in filtrate (meL⁻¹)] x 2

$$= \frac{\text{-----}}{\text{-----}}$$

Gypsum requirement : in metric tons (tonnes) per hectare (15 cm soil depth)

$$= 1.72 \times \text{G.R. (meL}^{-1} \text{ 100 g of soil)}$$

$$= \text{-----}$$

Result : Gypsum requirement of soil is -----t ha⁻¹.

