**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** > 4dsm-1  **SAR** < 13(mmoleL-1 )1/2  **ESP** < 15  **PH** < 8.5 | **EC** < 4dsm-1  **SAR**> 13(mmoleL-1 )1/2  **ESP** > 15  **PH** > 8.5 | **EC** > 4dsm-1  **SAR** > 13(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-, SO4-, S- involve information of saline soil. While those present in small quantity Cations like K+, NH4+ and Anions like Carbonates,Bicarbonates and nitrates.

When salt concentration is veryhigh a part of Ca+, Mg+ react with CO3 to formCalcium carbonate, Calcium sulphateMg Sulphate etc. The precipitate on these salts increases the proportion of sodium in solution as well as the exchange complex. Their dominance reducesso Na Show dominance insoil 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.

**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

1. **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 |

1. **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 |

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

* Solanchak: EC > 4 dsm-1 🡪 25cm
* Solonetz pH, ESP > 15 🡪 40cm

1. **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 dsm-1 | <4 dsm-1 |
| pH | <8.2 | >8.2 |
| ESP | <15 | >15 |
|  | Cl-1, SO₄-, HCO3- Present  CO3 is absent | HCO3-, CO3 of Na+ is present |

1. **Pakistani System:**

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

1. **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.

1. **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** | **ECe** |
| S0 | Salt free | <4 dsm-1 |
| S1 | Slightly saline | 4-8 dsm-1 |
| S2 | Moderator saline | 8-12 dsm-1 |
| S3 | Strongly Saline | 12-16 dsm-1 |
| S4 | Very Strongly saline | >16 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.

1. **Thur Punjsala:**

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

1. **Thur Nau:**

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

1. **Thur Juzvi:**

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

1. **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:**

**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
2. Chemical Methods
3. Biological Methods
4. Hydro-Technical Methods
5. Electro-Technical Methods
6. Synergistic Approach
7. **Physical Methods:**
8. Deep ploughing
9. Sub soiling
10. Sanding
11. Hauling
12. Horizon mixing
13. **Deep ploughing:**

It consists of the depth from about **40cnm** 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 **gypepheorous** means the soil containing large quantity of gypsum.

1. **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.

1. **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.

1. **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.

1. **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.

1. **Chemical methods:**

Effectiveness of chemical depends on:

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

**Classification:**

1. Inorganic amendments
2. Organic amendment
3. **Inorganic amendments:**

|  |  |  |
| --- | --- | --- |
| **Soluble calcium salts** | **Slowly soluble calcium salts** | **Acidifying material** |
| * CaCl2 * Gypsum * Phosphogypsum   These are by product during manufacturing phospho-fertilizer. | * CaCO3 * CaSO4 | * Ca mobilizer in soil * Convert in easily soluble form. * H2SO4, HCl, HNO3 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:

2Na + CaSO4 ⇌  Ca + Na2SO4

1. **Sulphur Apply:**

2S + 3O2 ⇌ 2SO3

SO3 + H2O ⇌ H2 SO4

H2 SO4 + CaCO3 ⇌ CaSO4 + CO2

2Na + CaSO4 ⇌  Ca + Na2SO4

1. **Iron Sulphur:**

FeSO4 + H2O ⇌ H2 SO4 + FeO

H2 SO4 + CaCO3 ⇌ CaSO4 + CO2 + H2O

2Na + CaSO4 ⇌  Ca + Na2SO4

1. **HCL**

HCl + CaCO3 ⇌ CaCl2 + CO2 + H2O

2Na + CaSO4 ⇌  Ca + Na2SO4

1. **HNO3**

HNO3 + CaCO3 ⇌ Ca(NO3)2 + CO2 + H2O

2Na + CaSO4 ⇌  Ca + Na2SO4

**For non Calcareous:**

1. **Gypsum:**

2Na + CaSO4 ⇌  Ca + Na2SO4

1. **Sulphur Apply:**

2S + 3O2 ⇌ 2SO3

SO3 + H2O ⇌ H2 SO4

H2 SO4 + CaCO3 ⇌ CaSO4 + CO2

2Na + H2 SO4 ⇌  2H+ + NaSO4

1. **Iron Sulphur:**

FeSO4 + H2O ⇌ H2 SO4 + FeO

2Na + H2 SO4 ⇌  2H+ + NaSO4

1. **H2 SO4**

2Na + H2 SO4 ⇌  2H+ + NaSO4

1. **HCL**

HCl + CaCO3 ⇌ CaCl2 + CO2 + H2O

2Na + HCl ⇌  H+ + NaSO4

1. **HNO3**

HNO3 + CaCO3 ⇌ Ca(NO3)2 + CO2 + H2O

2Na + CaSO4 ⇌  Ca + Na2SO4

1. **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 course 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 course particles.
5. In Pakistan gypsum powder is less then 30 mesh size is marketed.
6. **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.

CO2 + H2O→ H2CO3→ Carbonic acid

1. Reaction of this H2CO3 with native slowly soluble CaCO3 to form more soluble Ca(HCO3)2.
2. Release of calcium ions from Ca(HCO3)2.
3. 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 redamation of sodic or saline soil is vital.
* The ability of some plant specie to grow in a wide range of stress condition. Expended 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 that 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 ration of divalent to total cations (with concentrations expressed in mmolcL-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:

1. Management of reclaimed SAS:

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

1. 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.

1. Measures for reducing the replacement of ground water and enters of salt into irrigation areas.
2. 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.

1. 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.

1. Control of surplus irrigation:

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

1. 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.

1. 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.

1. 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.

1. Field leveling:

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

1. 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.

1. Measures to reduce the ground water evaporation:

Following measures help to reduce ground water evaporation:

1. 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.

1. 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.

1. Tree plantation along the roads and channel:
2. It is used to reduce wind velocity and evaporation losses.
3. 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.

1. 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 stablish 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.

P-Na2CO3 →Na3 PO4

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.

1. **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.

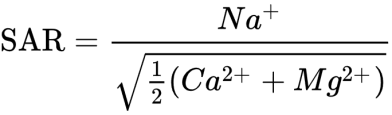
* Salinity hazards
* Sodicity hazards
* Toxicity hazards
* **Salinity hazards:**

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:



1. 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:

* 1. The irrigation system including main canals, branches and distributaries
  2. Link canals
  3. Water courses and irrigated fields
  4. Rainfall
  5. Rivers
  6. 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 affective 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.

### ****Effects of Salinity on Plant Growth and soil properties****

Salinity becomes a problem when enough salts accumulate in the root zone to negatively affect plant growth. Excess salts in the root zone hinder plant roots from withdrawing water from surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone. For example, when plant growth is compared in two identical soils with the same moisture levels, one soil receiving salty water and the other receiving salt-free water, plants are able to use more water from the soil receiving salt-free water. Although the water is not held tighter to the soil in saline environments, the presence of salt in the water causes plants to exert more energy extracting water from the soil. **The main point is that excess salinity in soil water can decrease plant available water and cause plant stress.**

Soil water salinity is dependent on soil type, climate, water use and irrigation routines. For example, immediately after the soil is irrigated, plant available water is at its highest and soil water salinity is at its lowest. However, as plants use soil water, the remaining water is held tighter to the soil and becomes progressively more difficult for plants to obtain. As the water is taken up by plants through transpiration or lost to the atmosphere by evaporation, soil water salinity increases because salts become more concentrated in the remaining soil water. Thus, evapotranspiration (ET) between irrigation periods can further increase salinity

### ****Effects of Salinity on Soil Physical Properties****

Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative and potentially lethal effects on plants. As a result, **salinity cannot be increased to maintain soil structure without considering potential impacts on plant health.**

**Effects of Sodium and Sodicity on Soil Physical Properties**

Sodium has the opposite effect of salinity on soils. The primary physical processes associated with high sodium concentrations are soil dispersion and clay platelet and aggregate swelling. The forces that bind clay particles together are disrupted when too many large sodium ions come between them. When this separation occurs, the clay particles expand, causing swelling and soil dispersion.

Soil dispersion causes clay particles to plug soil pores, resulting in reduced soil permeability. When soil is repeatedly wetted and dried and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. **The three main problems caused by sodium-induced dispersion are reduced infiltration, reduced hydraulic conductivity, and surface crusting.**

Salts that contribute to salinity, such as calcium and magnesium, do not have this effect because they are smaller and tend to cluster closer to clay particles (Figure 1). Calcium and magnesium will generally keep soil flocculated because they compete for the same spaces as sodium to bind to clay particles. **Increased amounts of calcium and magnesium can reduce the amount of sodium-induced dispersion.**

### ****Relationship Between Salinity and Sodicity and Soil Physical Properties (EC/SAR)****

The relationship between soil salinity and its flocculating effects and sodicity and its dispersive effects influence whether or not soil will stay aggregated or become dispersed under various salinity and sodicity combinations. As irrigation water with low salinity is applied to the soil by irrigation or rainfall, this water flows into the spaces between clay particles (micropores). If salinity of the applied water is low relative to soil salinity, swelling and dispersion of clay particles results. In contrast, irrigation water with higher salinity than the soil tends to cause particles to stay together, maintaining soil structure.

**Impacts of salinity and water logging on environment**

Salinity affects: farms – salinity can decrease plant growth and water quality resulting in lower crop yields and degraded stock water supplies. Excess salt affects overall soil health, reducing productivity. It kills plants, leaving bare soil that is prone to erosion. if the level of salts in the soil water is too high, water may flow from the plant roots back into the soil. This results in dehydration of the plant, causing yield decline or even death of the plant. Crop yield losses may occur even though the effects of salinity may not be obvious. Crops need air to a greater or lesser depth in the soil. Waterlogging of the soil stops air getting in. In irrigated agricultural land, waterlogging is often accompanied by soil salinity as waterlogged soils prevent leaching of the salts imported by the irrigation water.

Waterlogging is the saturation of soil with water. Soil may be regarded as waterlogged when it is nearly saturated with water much of the time such that its air phase is restricted and anaerobic conditions prevail. ... In agriculture, various crops need air (specifically, oxygen) to a greater or lesser depth in the soil. n agriculture, various [crops](https://en.wikipedia.org/wiki/Crop) need [air](https://en.wikipedia.org/wiki/Earth%27s_atmosphere) (specifically, [oxygen](https://en.wikipedia.org/wiki/Oxygen)) to a greater or lesser depth in the soil. Waterlogging of the soil stops air getting in. How near the water table must be to the surface for the ground to be classed as waterlogged, varies with the purpose in view. A crop's demand for freedom from waterlogging may vary between seasons of the year, as with the growing of [rice](https://en.wikipedia.org/wiki/Rice) (*Oryza sativa*).

In [irrigated](https://en.wikipedia.org/wiki/Irrigation) agricultural land, waterlogging is often accompanied by [soil salinity](https://en.wikipedia.org/wiki/Soil_salinity) as waterlogged soils prevent [leaching](https://en.wikipedia.org/wiki/Soil_salinity_control) of the [salts](https://en.wikipedia.org/wiki/Sodium_chloride) imported by the irrigation water whereby the soil blocks off all water and is so hard it stops air getting in and it stops oxygen from getting in.