

Salt Affected Soils:

This is the general term used for those soils which have been adversely affected or adversely modified for the growth of most of crop plants because of the presence of excess soluble salts, Exchangeable sodium or both.

Classification of Salt Affected Soils:

- ❖ Saline Soils (White Alkali)
- ❖ Saline-Sodic Soils
- ❖ Sodic Soils (Black Alkali)

Soil classification is According to the USDA System. These soils are differentiated on the basis of these features

- ❖ EC
- ❖ SAR
- ❖ ESP
- ❖ pH

Saline Soils:

Those soils which have sufficient amount of soluble salts to adversely affect the growth of most of crop plants but not containing excessive exchangeable sodium. Most of the soluble salts in saline soils are composed of cations like Na^+ , Ca^{+2} , Mg^{+2} and anions like Cl^- , Sulphate and bicarbonate and small amount of cations like K^+ , NH^+ like Nitrogen, carbonate may occur in these soils.

Saline Soil have following Criteria:

- EC > 4 dsm^{-1}
- SAR < 13(mmol/L)
- ESP < 15
- pH < 8.5

Sodic Soils:

Those soils which have sufficient amount of exchangeable sodium to adversely affect the growth of most of crop plants but not containing excessive soluble salts.

Sodic Soil have following Criteria:

EC < 4 dsm⁻¹
SAR > 13(mmol/L)
ESP > 15
pH > 8.5

Saline Sodic Soils:

Soils having both soluble salts as well as exchangeable sodium in a sufficient amount to adversely affect the growth of most of crop plants.

These are the chemical characteristic of Saline Sodic Soils.

EC ≥ 4 dsm⁻¹
SAR ≥ 13(mmol/L)
ESP ≥ 15
pH ≥ 8.5

Extent Salt Affected Soils:

In World:

More than **800 mhac** area is affected by salt effected soils. Currently **30%** irrigated soils are salt effected soil by the application of **poor quality of water**. Middle of **21st Century** (2050) this ratio become **50%** and **70%** more food will be required to feed the population of **9.7 billion population** at the time of **2050**. In 800 mhac more than **397mhac area is saline and 434 mhac area is comes under the sodic** soils.

In Pakistan:

Total Area: 79 mhac

Salt Affected Soils: 6.7 mhac

- 56% area of Pakistan is Saline–Sodic and 44% area of Pakistan is Saline.
- 80% of Punjab Province is Saline-Sodic and 20% area of Punjab is Saline.
- 6.7 mhac area is salt effected in 1998 but in 1980-1990 it was 5.7 mhac.
In 1980-1990 (Two sources of salt effected soil) Unfit ground water

Province wise (All figures in thousand Hectares)

Province	Saline	Saline-Sodic	Sodic	Total
Punjab	504	2081	---	2585
Sindh	1342	950	28	2321
KPK	501	14	---	516
Baluchistan	175	129	---	304
Total	2523	3176	28	5727

Formation/Genesis of Salt Affected Soils:

Development of soil from the salty parent material is the genesis of salt affected soil or it refers to the origin of soil with special reference to the processes and factors of soil formation for the development of soil from unconsolidated parent material.

Genesis actually includes different substances/factors

- 1) Reducing the size of parent material particles.
- 2) Rearranging of mineral particles.
- 3) Adding organic matter and other materials like salts etc.
- 4) Changing the kinds of minerals.
- 5) Creating horizon formation or development of soil horizon. Genesis process all (it is continuing but very slow process).

Genesis of Salt Affected Soils in Pakistan:

Primary Salt Affected Soils:

1) Salty Parent Material:

The origins and major source of salts in soils. The primary mineral in parent material which serves as the Parent material for the soil formation. In Pakistan like more of arid and semi-arid regions in the world rainfall is inadequate for leaching of salts out of the root zone so soluble salts and exchangeable Na⁺ have been accumulated for thousands of the years during the process of soil formation. This is the case of primary/old ancient salt affected soils.

2) Uneven Distribution of Rainfall:

The most of the rainfall occurs in the moon soon while during the major part of the year. The salts parent in the soil tend to move upward with water through capillary action at the soil structure water evaporates and behind the salts on the surface of soil and causes the formation of salt affected soils.

3) Aridity:

Most of the soils of Pakistan are located under the arid-Semiarid regions. The rainfall that is received during the year is not sufficient to leach away the salts from the root zone. E.g. there is no upward movement of salts. Accumulation of K^+ = Luxury consumption of high concentration than no cause toxicity it can be stored in the soil.

4) Physiographic Unevenness:

This the main factor.

5) Irrigation Water:

This is also contributing the salt formation soils in Pakistan.

6) Underground Water:

This is also contributing the salt formation soils in Pakistan.

Secondary Salt Affected Soils:

These are introduced by the introduction of artificial irrigation system (canal water, poor quality underground water, waste water from industrial city waste). There is also extent of secondary salt affected soil but very less compared to primary salt affected soils.

Irrigation System:

- 1) Insufficient and proper management of soil and water.
- 2) Seepage from the canal and water sources or combination of all these factors attributes towards the formation of secondary salt affected soil.

System of Classification of Salt Affected Soils:

Classify on the basis of EC, pH, ESP, SAR.

- 1) USDA System
- 2) USSR System
- 3) European System
- 4) Australian System
- 5) FAO-UNESCO System
- 6) Indian System
- 7) Pakistani System

1)USDA System:

In 1954 United State Department of Agriculture classify salt affected soils into three categories.

- Saline Soils
- Sodic Soils
- Saline-Sodic Soils

Why Select 4 dsm⁻¹ (Unit) for saline soils?

Because of 4 dsm⁻¹ reduction decline more than 50%. Reduction at 3.5 dsm⁻¹ is 40% ESP is selected.

2)USSR System:

Union Soviet Socialist Republics divided salt affected soil in two groups.

- Solanchak
- Solonetz

i)Solanchak:

Instead of using EC as a differentiated parameter, they use %age of salts on dry weight basis.

“Those soils which contain more than 2% soluble salts in upper 30cm soil called as solanchak soil”.

Solanchak soils depending on the type of salts and concentration of salts.

Solanchak soils are further divided into five groups.

- i. Non-Saline
- ii. Slightly Saline (0.1%-0.6%)
- iii. Moderately Saline (0.7%-1%)
- iv. Strongly Saline (1%-2%)
- v. Solanchak Saline Soils (More than 2%)

ii)Solonetz:

According to USSR System solonetz classify on the basis of ESP of soil. It divided into two groups.

- 1) Chernozem (Black Soil)
- 2) Chustnut (Brown Soil)

Classes	Chernozem	Chustnut
Weekly Solonetz	Less than 10 ESP	Less than 5 ESP
Moderately Solonetz	10-15 ESP	5-10 ESP
Slightly Solonetz	16-30 ESP	11-16 ESP
Solonetz	More than 30 ESP	More than 16 ESP

a)Chernozem:

Rich in humus & Organic matter. These soil present in typical cool temperature to semiarid regions. e.g. Grassland of European Russia

b)Chustnut:

In chustnut has low organic matter or limited Organic Matter.

3)European System: (Genetic Parameter, 1968)

In addition to EC, ESP, pH, of USDA system. They introduce the genetic parameter.

Divided into two categories on the basis of European System.

➤ **Saline Soils:**

With or without structure B horizon

➤ **Sodic Soils:**

With or without structure B horizon

4)Australian System:

They divided the soil on the basis of present of salts, ESP and pH.

- pH_e (Extract of pH)
- pH_s (Paste of Soil)

In this soil is divided into three categories.

- Saline Soil (on the basis of Salt)
- Sodic Soil (on the basis of ESP)
- Alkaline Soil (on the basis of pH)

Soil Type	Category 1 Non	Category 2 Name	Category 3 Strongly
Saline Soil	Less than 0.1 % NaCl	Loam less 0.1% , Clay less 0.2% NaCl	More than 3% NaCl
Sodic Soil	Less than 6 ESP	6-14 ESP	More than 14 ESP
Alkaline Soil	Less than 8 pH	8-9.5 pH	More than 9.5 pH

5)FAO-UNESCO System:

Food and Agricultural Organization- National Educational Scientific and Cultural Organization System. This system introduced in 1974. In this soil is divided into two types.

- Solanchak Soils
- Solonetz Soils

i)Solanchak Soils:

They divided on the basis of electrical conductivity while solonetz soil divided on the basis of ESP. if the soil have $EC_e > 4 \text{ dSm}^{-1}$ with in the 25 cm of soils.

ii)Solonetz:

If the soil have $ESP > 15$ in upper 40 cm depth, this is called as solonetz soil.

6)Indian System:

In addition to USDA System nature of the soluble salts as an important parameter classified as two division.

- Saline
- Sodic

In addition to parameter purposed by the USDA system indian scientist considered the nature of soluble salts as an important index for the grouping of salt affected soils. They argue that pH 8.5 is too high as the ISO electrical pH for precipitation of CuCO_3 at which sodication process start at 8.2 and mostly this pH is associated with ESP of 15 or more considerly these points they grouped the soils into two categories.

Parameter	Saline	Sodic
pH	< 8.2	≥ 8.2
ESP	< 15	≥ 15
EC	$\geq 4 \text{ dsm}^{-1}$	$< 4 \text{ dsm}^{-1}$
Nature of Soluble Salts	Mostly Chlorides, Sulphate, Bicarbonate, but carbonate are absent	Predominance of Carbonate and Bicarbonate

7)Pakistani System:

Three organization which deal the salt affected soils.

- SSP (Soil Survey of Pakistan)
- WAPDA (Water and Power Development Authority)
- DLR (Directorate of Land Reclamation)

i)SSP (Soil Survey of Pakistan):

The SSP follow criteria of US salinity laboratory to differentiate the saline, Sodic and saline-sodic soil. In addition to this, SSP includes some physical i.e drainage, porosity, texture, morphological (Like horizon development, presence of Silichinsides, etc.) to classify problematic soil in more comprehensive way.

ii)WAPDA (Water and Power Development Authority):

Which deals with the electricity and water issues/sector. This organization classify the salt affected soil on the basis of EC.

Symbol	Name	EC (dsm ⁻¹)
S ₀	Salt free	< 4
S ₁	Slightly Saline	4-8
S ₂	Moderatly Saline	8-12
S ₃	Strongly Saline	12-16
S ₄	Very Strongly Saline	> 16

iii)DLR (Directorate of Land Reclamation):

This is first ever organization which was established in Indian subcontinent to deal with the SAS. Main office of DLR regarding to Pakistan is in Lahore. In this soil is divided into five groups.

- 1) Thur Kohna
- 2) Thur Punjsala
- 3) Thur Nau
- 4) Thur Juzvi
- 5) Thur Tirk

a)Thur Kohna:

Land is never come under cultivated due to severe problems of salinity.

b)Thur Punjsala:

Land which has gone out of cultivation for more than last five years.

c)Thur Nau:

Land which has gone out of Cultivation during the last 5 years.

d)Thur Juzvi:

Land which is under cultivation but having the visible areas of salts to the extent of 20% of the acre.

Thur Kohna, Thur Punjsala, Thur Nau, Thur Juzvi .These lands Under observations during March-April Because effect of temperature on salts is not more in March and April.

e)Thur Tirk:

Tirk mean incomplete opening of boll. Lands where salts in the root zone hampers the opening of cotton bolls. Thur Tirk land which observe in October.

Exchange Equation:

Mostly use for the assessment of the concentration of exchangeable ion from soluble ions.

- Nutrient point of view
- Soil Characters

The biggest equation is the **Gapon Equation** introduced by Russian Scientist in 1933. The name of the scientist is Gapon.

Ideal and productive land are occupied by 65% Calcium (Ca), 10% by Magnesium (Mg), 5% by Potassium (K) and 20% Hydrogen ions (H⁺)

Exchange Adsorption process from Kandi point of view.



$\text{XM}_1 \rightarrow$ is the Molecule adsorb from particle surface X.

$\text{M}_2 \rightarrow$ another Molecule in Soil Solution.

This process is reversible. At equilibrium the rate of reaction on the right side is equal to rate of reaction on the left side.

This equation is gave Ca-Na Exchange



The Gapon point out that soil exchange complex. The calcium behave like a sodium when expressed on the equivalent basis.



UNIT:

The Conc. of Ca on Exchange Site Mequ/100g of Soil.

The Conc. of Ca on Soil Solution mmol/L.

K.G = Gapon-Coefficient

$$K.G = \frac{[\text{NaX}] [\text{Ca}]^{1/2}}{[\text{CaX}] [\text{Na}]} \quad \textcircled{4}$$

US Salinity Lab (1954):

Two term introduce of this Equation

- 1- ESR (Exchangeable Sodium Ratio)
- 2- SAR (Sodium Adsorption Ratio)

$$\text{ESR} = \frac{[\text{NaX}]}{[\text{CaX}]} \quad \textcircled{5}$$

$$\text{SAR} = \frac{[\text{Na}]}{[\text{Ca}]} \quad \textcircled{6}$$

$$[Ca]^{1/2}$$

$$ESR = \frac{[NaX]}{CaX + MgX} \quad \textcircled{7}$$

$$SAR = \frac{Na}{(CaX + MgX)^{1/2}} \quad \textcircled{8} \text{ mmol/L}$$

$$SAR = \frac{Na}{(CaX + MgX)^{1/2}} \quad \textcircled{9} \text{ (mmol/L)}^{1/2} \text{ Unit Difference}$$

$$K.G = \frac{[NaX] [Ca]^{1/2}}{[CaX] [Na]} \quad \textcircled{4}$$

$$K.G = ESR \times \frac{1}{SAR} \quad \textcircled{10}$$

$K.G$ Ranges b/w 0.010 to 0.015 $(\text{mmol}^{-1})^{1/2}$ this values depends on the organic matter presence in soil

$$K.G \times SAR = ESR \quad \textcircled{11}$$

Calcium-Sodium System:

ESF (Exchangeable Sodium Fraction)

$$ESF = \frac{NaX}{CEC}$$

$$ESF = \frac{NaX}{CaX + NaX} \quad \textcircled{12}$$

Dividing on this equation by CaX on the Right Side

$$ESF = \frac{NaX / CaX}{CaX / CaX + NaX / CaX}$$

$$ESF = \frac{ESR}{1 + ESR} \quad (13)$$

$$K.G \times SAR = ESR \quad (11)$$

Putting the value of ESR from equation 11

$$ESF = \frac{K.G \times SAR}{1 + K.G \times SAR} \quad (14)$$

ESP (Exchangeable Sodium Percentage)

$$ESP = \frac{NaX}{CEC} \times 100$$

$$ESP = 100 \times ESF$$

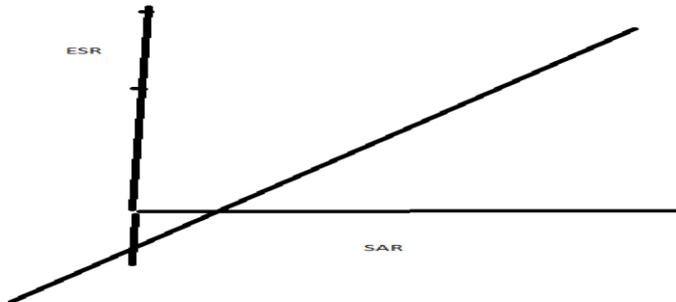
Then multiply equation No. 14 on both side

$$100 \times ESF = 100 \times \frac{K.G \times SAR}{1 + K.G \times SAR}$$

$$100 \times ESF = \frac{100 \times ESR}{1 + ESR}$$

$$ESP = \frac{100 \times ESR}{1 + ESR} \quad (15)$$

ESP measures the sodium percentage on the soil exchange site. A straight line relationship is exist b/w SAR & ESR.



From many arid zone of the world

US laboratory

$$ESR = -0.0126 + 0.01475 SAR \text{ (World Wide)}$$

-0.0126 → **Y-Intercept**

0.01475 → **K.G**

The equation No. 15 can be written as

$$ESP = \frac{100 (-0.0126 + 0.01475 SAR)}{1 + (-0.0126 + 0.01475 SAR)} \quad \text{(Gapon Equation)}$$

Many workers also calculate ESR

For Pakistani Soils:

$$ESR = 0.0063 + 0.0124 SAR$$

$$ESP = \frac{100 (0.0063 + 0.0124 SAR)}{1 + (0.0063 + 0.0124 SAR)}$$

Pakistani values show that positive. It shows that Na is less hazardous.