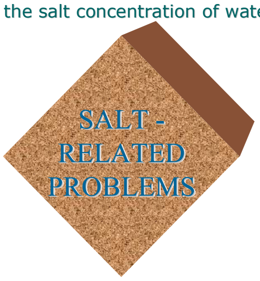
Salinity

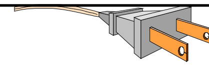
Water Deficits (Salinity-A measure of the salt concentration of water)

Ion Toxicities



Ion Imbalances

Soil Permeability-Sodicity - A measure of the sodium [Na+] concentration in relation to the calcium [Ca+2] and magnesium [Mg+2] concentrations of water



Salinity Measurement

- Measured as the electrical conductivity of water (EC_w)
- Expressed as decisiemens per meter (dS/m); formerly as mmhos/cm.

Table 2. Terms, units and conversions.

Symbol	Meaning	Units
Total Salinity		
TDS	Total dissolved solids	mg/L[a] ppm[b]
EC	Electrical conductivity	dS/m[c] μmho/cm[d] μmho/cm[e]
Conversions		
1 dS/m = 1 mmho/cm = 1000 mmho/cm		
1 mg/L = 1 ppm		

[a]mg/L = milligrams per liter
[b]ppm = parts per million
[c]dS/m = deciSiemens per meter at 25° C
[d]mmho/cm = millimhos per centimeter at 25° C
[e]μmho/cm = micromhos per centimeter at 25°C

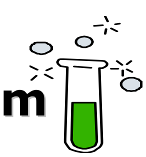
Sodicity Measurement

- Measured as the sodium absorption ratio of water (SAR_w)
- Expressed as the ratio:

$$(SAR = NA/\sqrt{(Ca+Mg)/2}$$

- Where the concentration of each ion is expressed in milliequivalents per liter (meq/L)

Problem



With a water-quality report providing sodium, calcium, and magnesium concentrations as 76, 146, and 39 mg/L, how do we express these in meq/L?

Element	Atomic Weight (g/mole)
Calcium, Ca	**40**
Carbon, C	12
Chlorine, Cl	35.5
Copper, Cu	63.5
Hydrogen, H	1
Iron, Fe	55.9
Magnesium, Mg	**24.3**
Manganese, Mn	55
Nitrogen, N	14
Oxygen, O	16
Phosphorus, P	31
Potassium, K	39
Sodium, Na	**23**
Sulfur, S	32
Zinc, Zn	65.4

Ion	Molecular Wt. (mg/mmole)	Valence (#)	Equivalent Wt. (mg/meq)
Sodium (Na^+)	23	1	23
Calcium (Ca^{2+})	40	2	20
Magnesium (Mg^{2+})	24	2	12

Sodium: 76 mg/L / 23 mg/meq = 3.3 meq/L

Calcium: 146 mg/L / 20 mg/meq = 7.3 meq/L

Magnesium: 39 mg/L / 12 mg/meq = 3.2 meq/L

$SAR_W = 3.3/([7.3+3.2]/2)^{1/2} =$

$3.3/(5.25)^{1/2} = 3.3/2.29 = 1.44$

Ion	Multiply by
Bicorbonate	0.11119
Ca	0.04990
Carbonate	0.33333
Chloride	0.02820
Mg	0.08224
Potassium	0.02558
Nitrate	0.01613
Sodium	0.04350
Sulphate	0.02082

Exchangeable Sodium Ratio (ESR)

Exchangeable Sodium Ratio (ESR) is determined from exchangeable Sodium (Nax) and cation exchange capacity (CEC) (me/100g) by the following relationship:

ESR = Nax/(CEC-Nax)

ESR = Kg x SAR
Where, Kg is Gapon coefficient.
(0.0041 to 0.0875)

- With respect to sodicity, it is the proportion of adsorbed exchangeable sodium relative to the cation exchange capacity (often expressed as the exchangeable sodium percentage, ESP/ ESR), rather than the absolute amount of exchangeable sodium, that is relevant along with the total salt concentration of the infiltrating and percolating water and the soil pH.
- Because ESP/ ESR and the sodium adsorption ratio of the saturation extract ,are so closely related, SAR is commonly used as a substitute for ESP and as an index of the sodium hazard of soils and waters.

Residual Sodium Carbonate

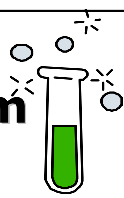
$$RSC = [CO_3^{-2}] + [HCO_3^{-}] - [Ca^{+2}] + [Mg^{+2}]$$

Where [ ] = ion concentrations in milliequivalents per liter (meq/L)

RSC Hazard (Residual Sodium Carbonate

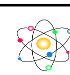
RSC	HAZARD
< 0	none
0-1.25	low
1.25-2.50	medium
>2.50	high

Problem



With a water-quality report providing a bicarbonate concentration of 366 mg/L, how do we express this in meq/L and what is its significance?

Atomic Weights

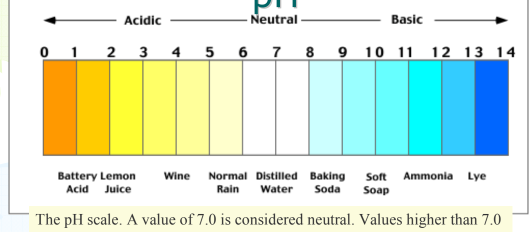


Element	Atomic Weight (g/mole)
Calcium, Ca	40
Carbon, C	**12**
Chlorine, Cl	35.5
Copper, Cu	63.5
Hydrogen, H	**1**
Iron, Fe	55.9
Magnesium, Mg	24.3
Manganese, Mn	55
Nitrogen, N	14
Oxygen, O	**16**
Phosphorus, P	31
Potassium, K	39
Sodium, Na	23
Sulfur, S	32
Zinc, Zn	65.4

Residual Sodium Carbonate

RSC = [0] + [6.0] - [7.3] - [3.2] = -4.5

pH



The pH scale. A value of 7.0 is considered neutral. Values higher than 7.0 are increasingly alkaline or basic. Values lower than 7.0 are increasingly acidic. The illustration above also describes the pH of some common substances.

Soil fertility is directly influenced by pH through the solubility of many nutrients. At a pH lower than 5.5, many nutrients become very soluble and are readily leached from the soil profile. At high pH, nutrients become insoluble and plants cannot readily extract them. Maximum soil fertility occurs in the range 6.0 to 7.2.

LOWERING SOIL PH

If soil pH is above 8.0, some action may be needed to reduce pH

Amend the soil with organic matter. On average, soils with higher organic matter contents have lower pH. Peat or sphagnum peat moss are highly acidic and will lower soil pH more than other organic amendments.

Add elemental sulfur (90 or 99% sulfur material) annually at a rate of 6 to 10 pounds per 1000 square feet of area. Elemental sulfur slowly oxidizes in soil to form sulfuric acid. Test the soil occasionally and stop adding sulfur when pH has reached desirable levels.

Use acidifying fertilizers such as ammonium sulfate and other products with label designations indicating an acidic reaction in the soil. With repeated use these materials may reduce soil pH.

Chemical Applications

- **TREATMENT FOR ACID SOILS (if soil pH is under 5.5) ...**

Recommendations for weak alkaline solutions to raise soil pH :

Option 1: Dry powder alkali

- **Sodium Bicarbonate *OR***
- **Sodium Carbonate (Soda Ash) *OR***
- **Calcium Hydroxide (Lime)**

Apply alkali at 0.5% (half of 1%) per volume of material

***Example* : Say, 60 cu.m of material x 0.5%**

= 0.3 x (1.4 density tonnage)

= 420 kg (17 x 25 kg bags)

Dry powder should be scattered on the surface and blade mixed or mixed in with a rotary hoe. The soil pH should then be checked and if it is within the required limits .

Chemical Applications

Option 2: Alkali in liquid form

Example : Sodium Bicarbonate Solution *OR*

Sodium Carbonate Solution

- The solution be made up at 1:200 (1kg powder to 200 litres of water) and then applied at 4 litres per 30 sq.m (1 litre per 8 sq.m).
- Blade mix the soil after spraying with the weak alkali liquid solution.

Check soil pH and if it is within the required limits proceed with application of

Chemical Applications

- **TREATMENT FOR ALKALINE SOILS (if soil pH is over 8) ...**

Recommendations for weak acid solutions to reduce pH :

Option 1: Dry powder acid

Sodium Bisulfate - *OR*

Citric Acid *OR*

Lactic Acid *OR*

Sulphamic (Sulfamic) Acid - NOT Sulfuric *OR*

Adipic Acid

Apply acid at 0.5% (half of 1%) per volume of material

Example : Say, 60 cu.m of material x 0.5%

= 0.3 x (1.4 density tonnage)

= 420 kg (17 x 25 kg bags)

Dry powder could be scattered on the surface and blade mixed or mixed in with a rotary hoe.

Chemical Applications

Option 2: Acid in liquid form

Example : Acetic *OR*

Phosphoric Acid *OR*

Sulphuric (Sulfuric) Acid

that liquid acid be diluted at 1:200 and then applied at 4 litres per 30 sq.m (1 litre per 8 sq.m).

Blade mix the soil after spraying with the weak acid liquid solution.

Soil Types

SOIL TYPE	ECe	pH	ESP	SAR
Saline	>4 dS/m	< 8.5	<15%	< 12
Sodic	< 4 dS/m	>8.5	>15%	>12
Saline-Sodic	>4 dS/m	>8.5	>15%	>12

pH

H_2O ------> $OH^- + H^+$

Concentration of H ions * Concentration of OH ions= 10-14(a const)

Concentration of un dissociated HOH molecule

Concentration of [H+] =10-14/(Concentration of OH-)= 10-7 (neutral)
= OH- + H+= 10-7
Because concentration H+ or H- ion in per liter of water is 10-7 gms. As this figure is inconvenient for use, logarithm of its reciprocal is used for indicating PH value.

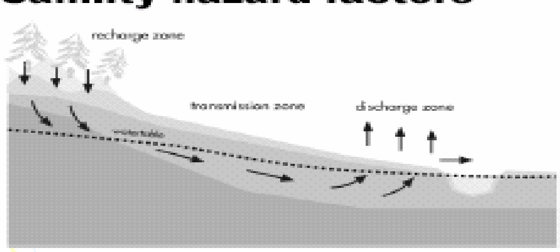
pH = - log $[H^+]$ = 7 for distilled water

pH Scale 0 to 14:

10^0 10^{-7} 10^{-14} M H^+ Conc

0----------------------7-------------------------------14 pH

Salinity hazard factors



In areas with shallow water tables, water containing dissolved salts may move upward into the rooting zone.

This occurs by capillary action (similar to the way a wick works), where evaporation serves as the suction of water up through the soil

Range and Rating for salinity Hazard indicators

Ground water salinity (mg/l)

Rating

- 0-500 1
- 500-1500 3
- 1500-3000 8
- >3000 10

Vegitation

- Forest 10
- Wood land 9
- Low wood land 8
- Tall & shrub land 6
- Low open shrrub 3
- Grass land 1

Aquifer yield (l/s)

- 0-0.5 10
- 0.5-5 5
- >5 1

Laterite

- Present 10
- Absent 1

Rain fall

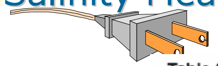
- <400mm 1
- 400-600 4
- 600-800 6
- 800-1200 10
- 1200-1400 6
- 1400-1600 4
- >1600 1

•**Saline soils are the easiest to correct;**

•**sodic soils are more difficult.**

•**Each type of soil has unique properties that require special management.**

Salinity Measurement



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[e]µmho/cm = micromhos per centimeter at 25°C

Amendments Required to Neutralize Residual Carbonates

RSC * 234 lbs gypsum/acre-foot

RSC * 133 lbs sulfuric acid/acre-foot

Steps for treating sodic and saline-sodic soils

Correcting saline-sodic and sodic soils is a slow process that must be carried out in steps:

1. Treat the surface first, then continue to the lower depths.
2. Apply an amendment to the soil surface and disk it in.
3. Add 10 to 12 inches of water. As when correcting saline soils, you must add enough water to dissolve as well as maintain the calcium concentrations in solution and to move the salts and sodium through the soil.

Salinity Control

There are three ways to manage saline soils.

• First, salts can be moved below the root zone by applying more water than the plant needs. This method is called the **leaching requirement** method.

•The second method, where soil moisture conditions dictate, combines the leaching requirement method with **artificial drainage**.

•Third, salts can be moved away from the root zone to locations in the soil, other than below the root zone, where they are not harmful. This third method is called **managed accumulation**.

Table 3. Estimated water application needed to leach salts.

Percent Salt Reduction	Amount of Water Required
50%	6 inches
80%	12 inches
90%	24 inches

Example: If a soil's electrical conductivity is 8 mmhos/cm, and you want to reduce it to 4 mmhos/cm. This represents a 50 percent reduction in salts. Therefore, 6 inches of water would be required.

Saline soils

To reduce the level of salinity in affected soils, electrical conductivity in the irrigation water should be <0.5 dS m-1). Where high-quality surface water is used (EC ~0), the amount of water required to reduce a given ECe to a critical-level ECc can be calculated as follows:

Aiw=Asat[(ECe /ECc)+1]

Where

Aiw represents the amount of irrigation water (in cm) added during irrigation and

Asat is the amount of water (cm) in the soil under saturated conditions.

For example, to lower an initial ECe of 16 dS m-1 to 4 dS m-1 in the top 20 cm of a clay loam soil (Asat = 8cm), about 40 cm of fresh water is required. Subsurface drains are required for leaching salts from clay-textured soils.

Table 2. Typical soil amendments for correcting saline and saline-sodic soils[1]

Amendment	Chemical Formula	Purity, %[2]	Approximate No. Pounds to Supply 1,000 Pounds of Soluble Calcium[3]
Gypsum	$CaSO_4\ 2H_2O$	100	4,300
Calcium chloride	$CaCl_2\ 2H_2O$	100	3,700
Sulfur[4]	S	100	800
Sulfuric acid[4]	H2 SO_4	95	2,600
Iron sulfate[4]	$FeSO_4\ 7H_2O$	100	6,950
Aluminum sulfate[4]	$Al(SO_4)318H_2O$	100	5,550
Lime-sulfur solution[4,5]	Calcium polysulfide	24	3,350

[1] From USDA Agriculture Information Bulletin No. 195. (1)
[2] With purities less than these, additional material will need to be supplied.
[3] Assumes free carbonates present to react with the amendments that contain no calcium.
[4] Sulfur amendments are only used in soils that contain free calcium carbonates.
[5] Expressed as sulfur content.

- **Sodic soils:** Apply gypsum ($CaSO_4$) to reduce Na saturation of the soil
- The amount of Ca^{2+} contained in gypsum required to reduce the ESP to a target level can be estimated as follows:

$$Ca\ (kg/ha) = (ESP_0 - ESP_d) \times CEC \times B \times D \times 20.04$$

where

- ESP_0 is the original and ESP_d is the target ESP value (% of CEC),
- CEC is in cmolc/kg, B is the bulk density (g cm-3),
- D is the soil depth (m) to be reclaimed

Requirement of gypsum or sulphur

Exchangable sodium content of the soil(m.e/100gm)	Gypsum(Tones /Acre.ft)	Sulphur(Tons /Acre.ft
1	1.7	0.32
2	3.4	0.64
3	5.2	0.96
4	6.9	1.28
5	8.6	1.6
6	10.3	1.92
7	12.0	2.24
8	13.7	2.24
9	15.5	2.88
10	17.2	3.2

Chemcial reactions

- 2Na+CaSo4= Ca+(Na2So4) Leached out
- 2S+3O2 = 2SO3
- SO3+H2O = H2So4
- H2So4+Caco3= CaSo4+Co2+H2O
- 2Na+CaSo4= Ca+(Na2So4) Leached out

CaSo4= Gypsum
S= Sulphur

Dos and Don'ts after reclamation

Do's

1. Use limited irrigation water for all crops
2. The drains should be well maintained
3. The water table should be kept at sufficiently low level
4. Irrigation canals / field channels should be lined
5. The soils should be tested periodically.

Don’ts

- Do not use excess irrigation water
- Do not keep the land fallow for a longer period
- Do not allow drains to chock
- Do not take salt sensitive crops
- Do not use saline water for irrigation

Salinity Mapping

1 Salinity Hazard Mapping

Salinity Hazard Mapping identifies those areas with the potential for salinisation from shallow groundwater and the onset of dryland salinity.

Hazard mapping provides one source of information incorporated in Land Use Capability Mapping..

2 Land Use Capability Mapping
In addition to salinity, land use capability mapping examines other physical characteristics such as soil type, slope, geology, water table, etc. to identify suitable landuse

3 Groundwater Vulnerability Mapping
Vulnerability mapping currently categorizes groundwater systems and their potential to be degraded. Highly vulnerable systems need to be protected from the onset of dry land salinity.

4. Water Supply Sources and Availability (particularly water quality)
5 Road Maintenance/Repair

Several questions should be addressed before rehabilitation is attempted:

- Is it economically/socially/politically acceptable?
- Is it possible to provide drainage?
- Is leaching water available?
- Is the soil/water chemistry right?
- Are appropriate vegetation, other biota and land management systems available?
- Should appropriate biota be (re) introduced?
- Will there be unacceptable off-site effects?