Effect of Reclaimed Water on Desert Soil

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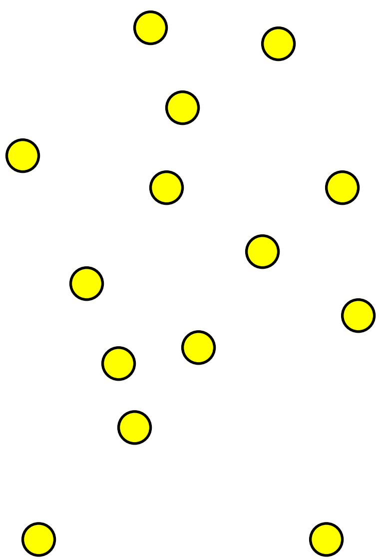
Reclaimed Water

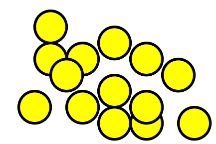
- Let's separate impacts of reclaimed water on soil from effects on people or on growing plants
  - Pathogens may impact people
  - Plants can be directly affected by salts, nutrients, specific ion toxicities, and indirectly by soil physical properties
  - Soil physical properties can be affected by salt and sodium
- In this presentation, we're only going to consider impacts on soil physical properties, not on plant growth or people

Soil clay particles can be unattached to one another (*dispersed*) or clumped together (*flocculated*).

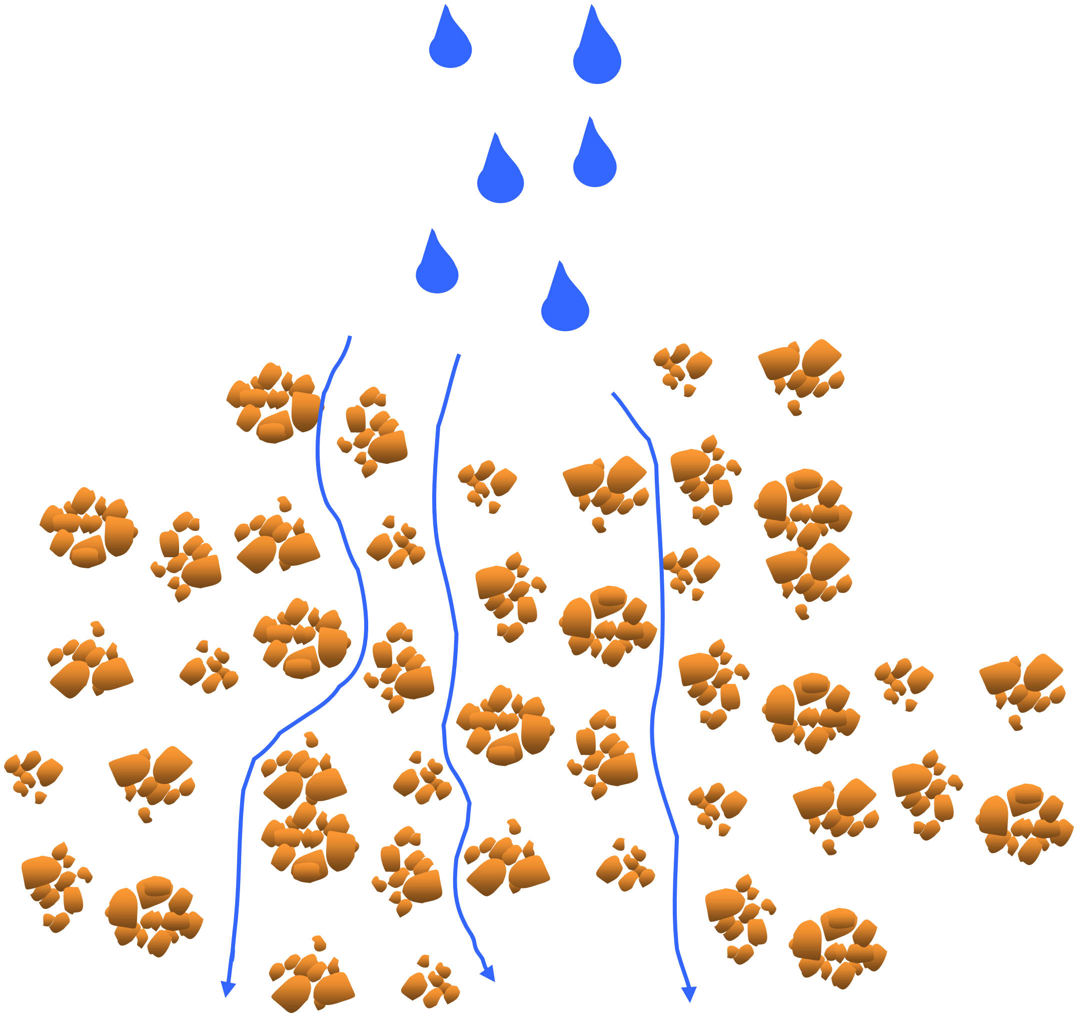
Dispersed Particles



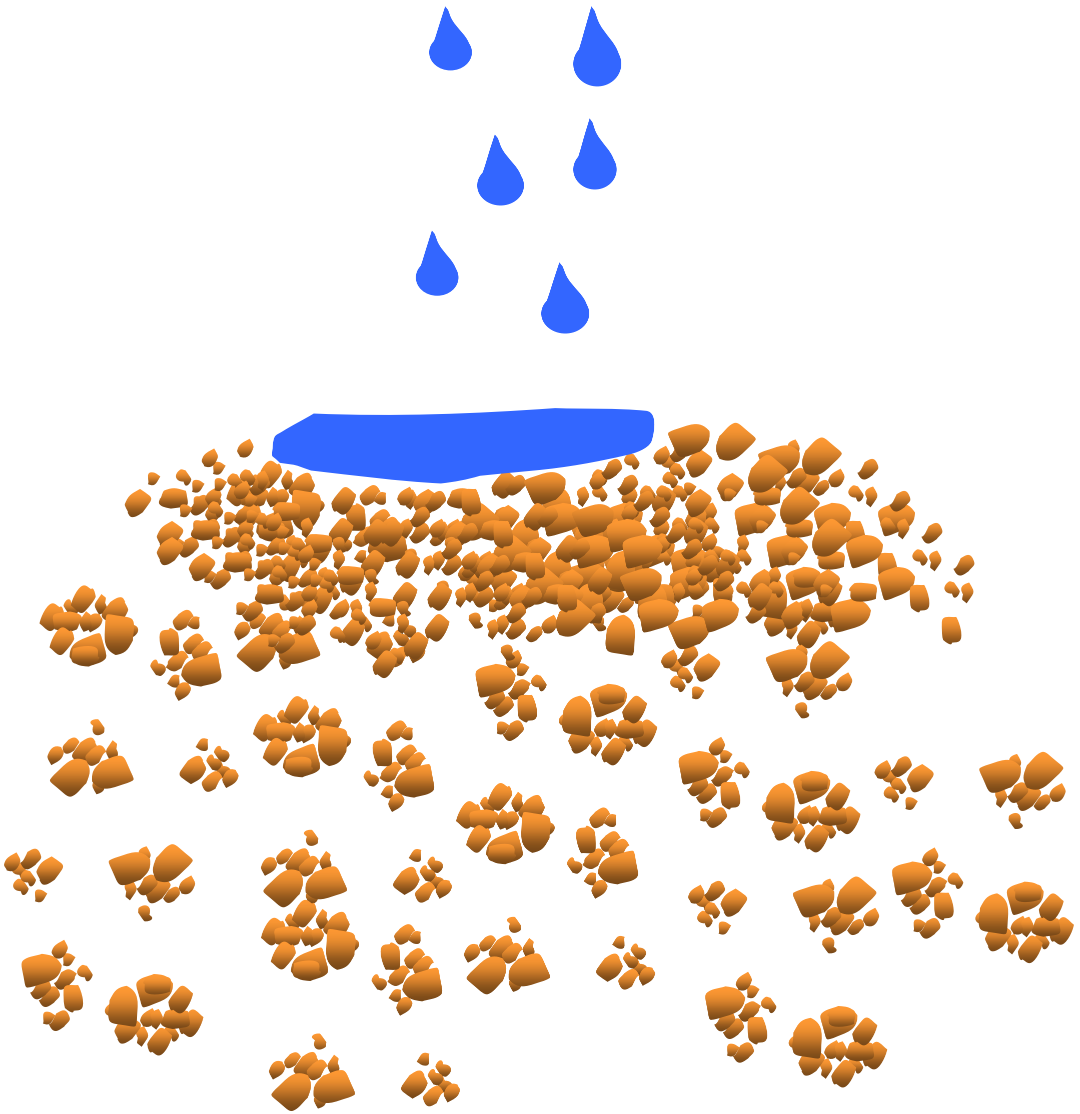
Flocculated Particles



Flocculation is important because water moves mostly in large pores between aggregates. Also, plant roots grow mainly between aggregates. When empty, these large pores supply oxygen to roots and soil microbes.



In all but the sandiest soils, dispersed clays plug soil pores and impede water infiltration and soil drainage.

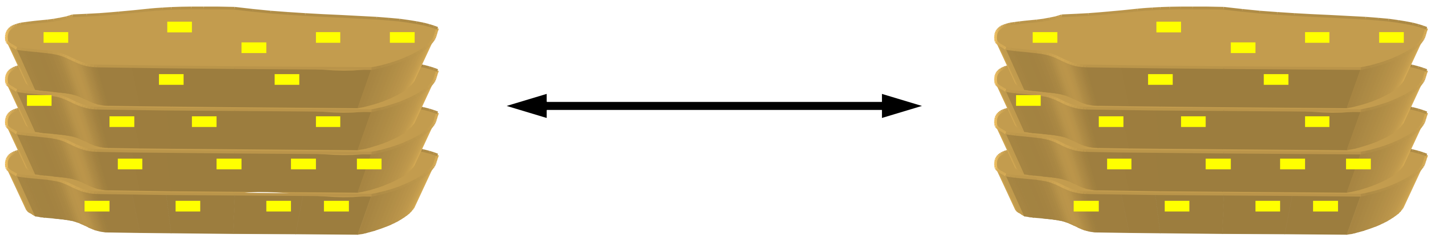


Why do soils flocculate?

Why do soils disperse?

To answer these questions, we need to understand something about the nature of soil clay particles.

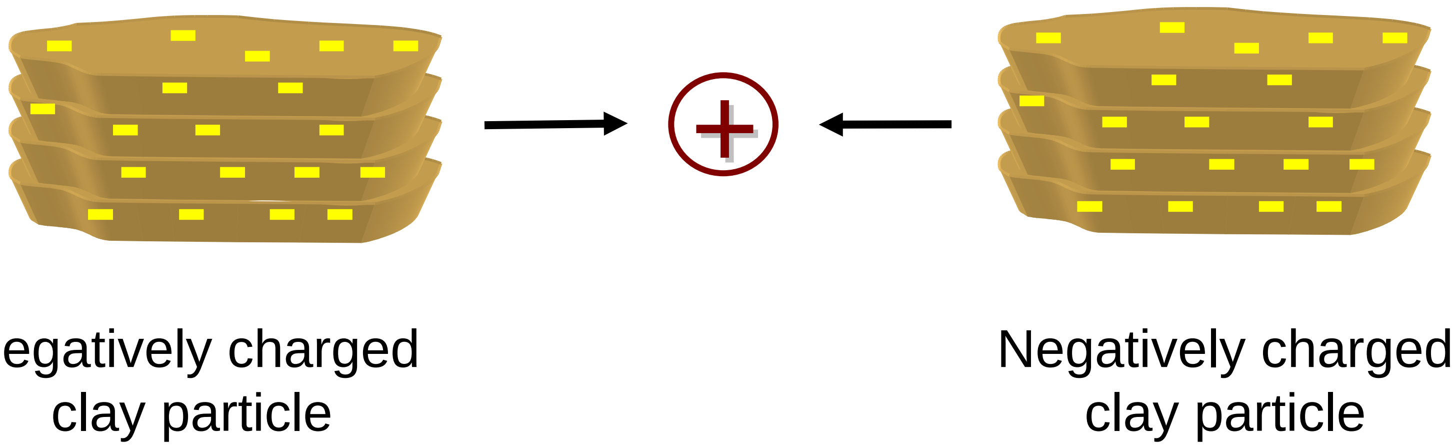
Most clay particles have a negative electrical charge. Like charges repel, so clay particles repel one another.



Negatively charged clay particle

Negatively charged clay particle

Cations (positively charged molecules) can make clay particles stick together (flocculate). Some cations are very good flocculators, others are not so effective.



Flocculating Cations

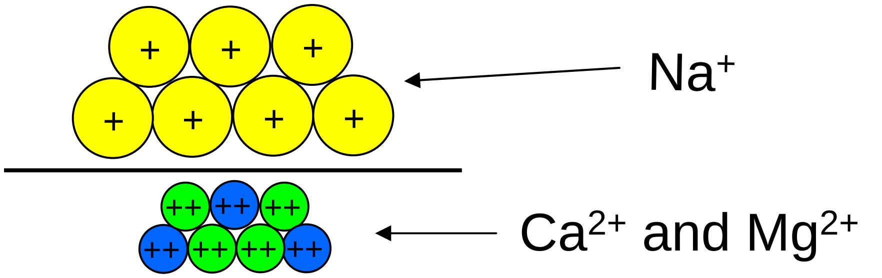
- We can divide cations into two categories
  - Poor flocculators
    - Sodium
  - Good flocculators
    - Calcium
    - Magnesium

Ion		Relative Flocculating Power
Sodium	Na^{+}	1.0
Potassium	K^{+}	1.7
Magnesium	Mg^{2+}	27.0
Calcium	Ca^{2+}	43.0

Sumner and Naidu, 1998

Sodium Adsorption Ratio

The ratio of ‘bad’ to ‘good’ flocculators gives an indication of the relative status of these cations:



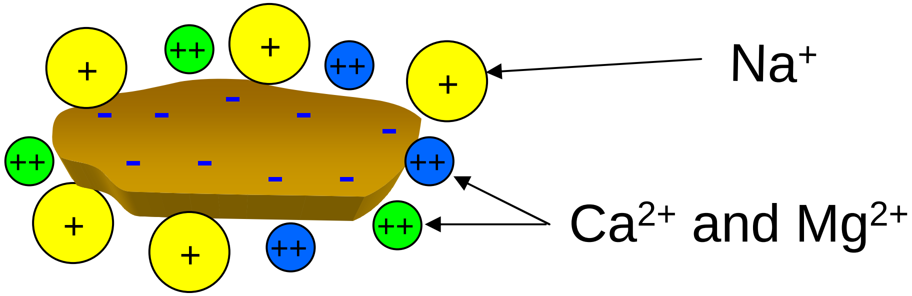
Mathematically, this is expressed as the ‘sodium adsorption ratio’ or SAR:

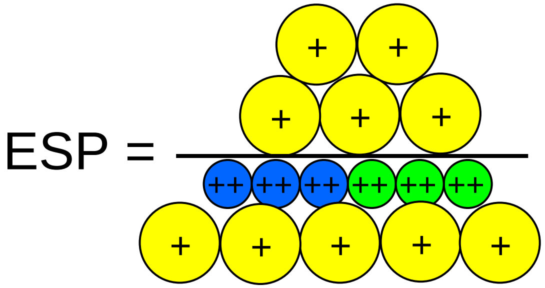
$$SAR = \frac{[Na^+]}{\sqrt{[Ca^{2+}] + [Mg^{2+}]}}$$

where concentrations are expressed in mmoles/L

Exchangeable Sodium Percentage

An alternative to SAR is ESP, Exchangeable Sodium Percentage





Mathematically, this is expressed as the percentage of the CEC (cation exchange capacity) that is filled with sodium in units of charge per mass (cmol(+)/kg)

$$ESP = \frac{Na^+}{\text{Cation Exchange Capacity}}$$

SAR and ESP are approximately equal numerically

Electrical Conductivity

Ions in solution conduct electricity, so the total amount of soluble soil ions (salts) can be estimated by measuring the electrical conductivity (EC) of a soil water extract.

EC is measured in units of conductance over a known distance:

deci-Siemens per meter or dS/m

Soil with a high EC is salty; soil with a low EC is not.

Irrigation water is also characterized by measuring

- EC
  - to determine salinity level
- SAR
  - to express the amount of sodium relative to the amount of calcium and magnesium

Soluble Salts

Salts are combinations of cations (positively charged molecules) and anions (negatively charged molecules).

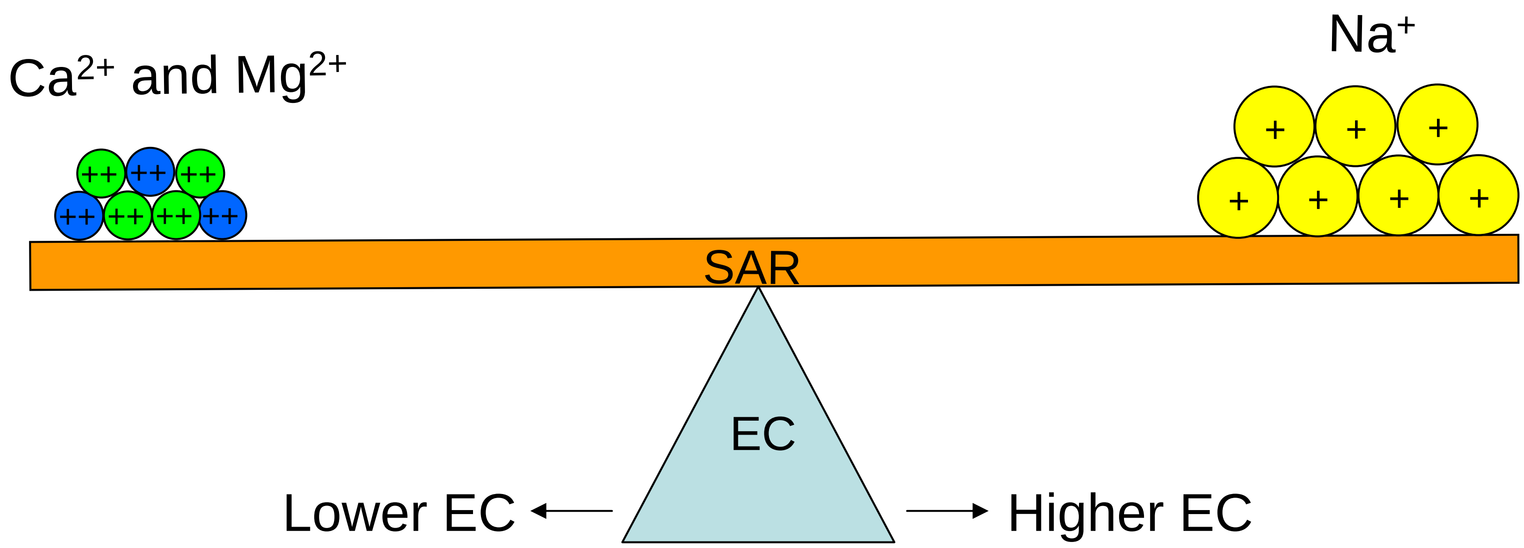
- Common soluble cations found in saline soils:

Calcium	Ca^{2+}
Magnesium	Mg^{2+}
Sodium	Na^{+}
Potassium	K^{+}

- Common soluble anions found in saline soils:

Chloride	Cl^{-}
Sulfate	SO_4^{2-}
Carbonate	CO_3^{2-}
Bicarbonate	HCO_3^{-}
Nitrate	NO_3^{-}

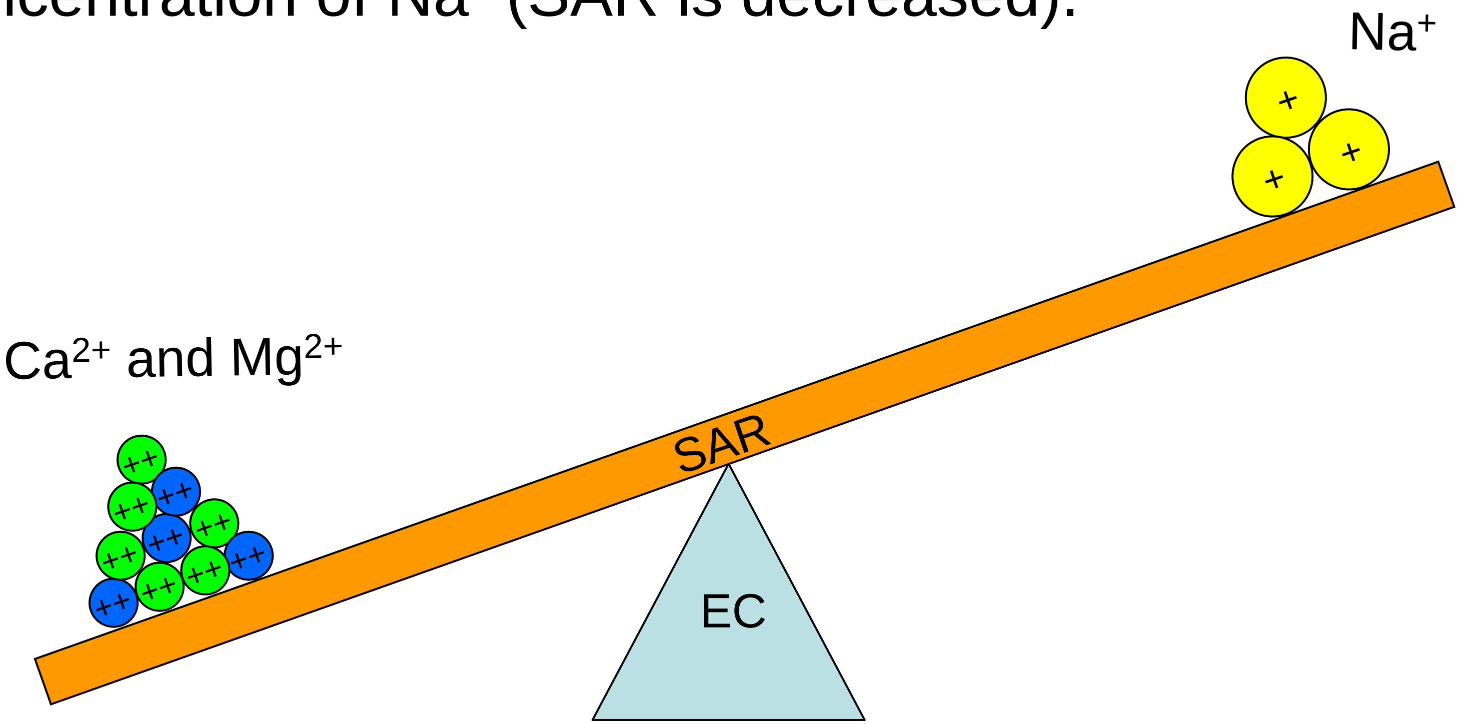
Aggregate stability (dispersion and flocculation) depends on the balance (SAR) between (Ca^{2+} and Mg^{2+}) and Na^{+} as well as the amount of soluble salts (EC) in the soil.



Flocculated soil

Dispersed soil

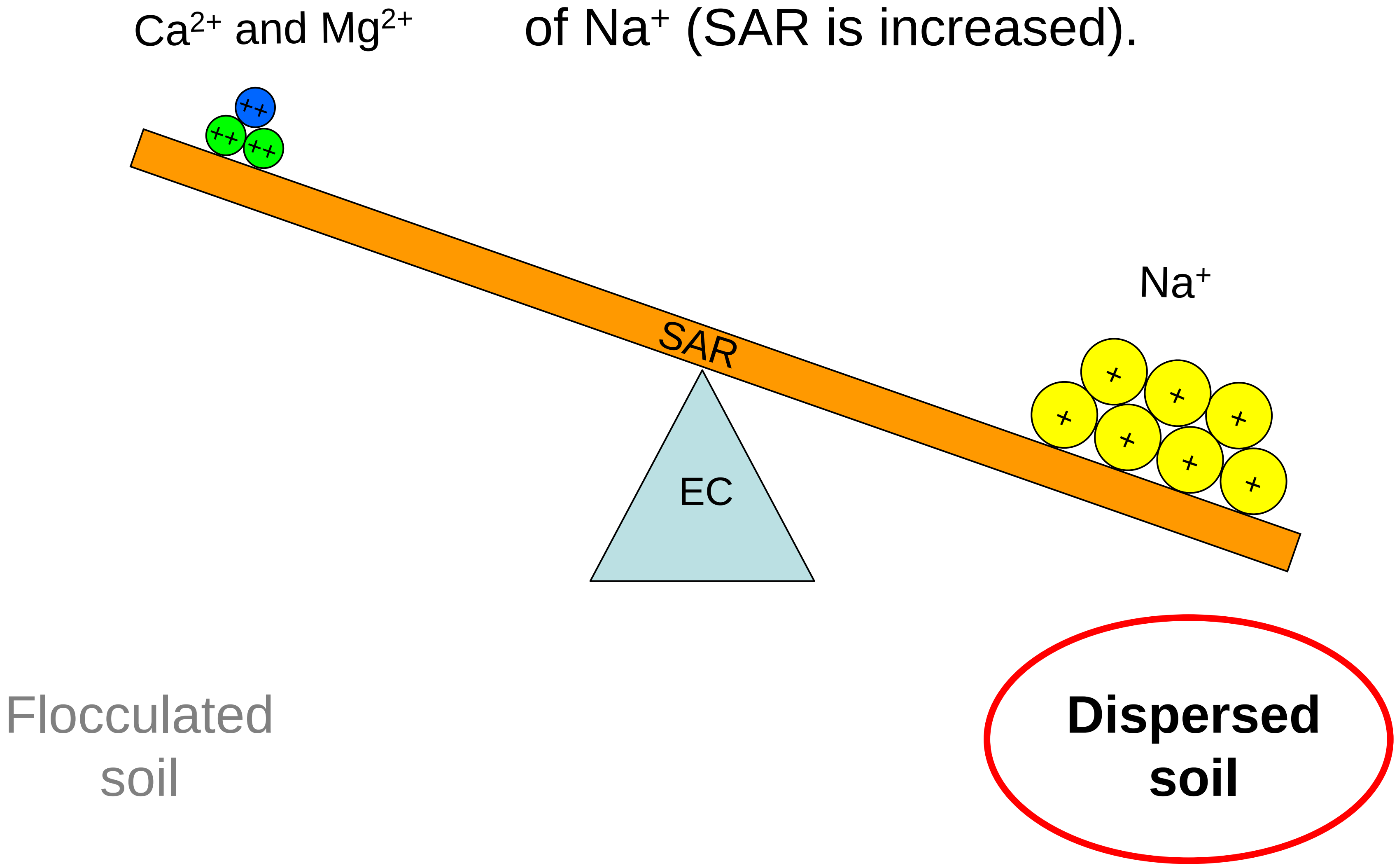
Soil particles will flocculate if concentrations of (Ca^{2+} + Mg^{2+}) are increased relative to the concentration of Na^{+} (SAR is decreased).



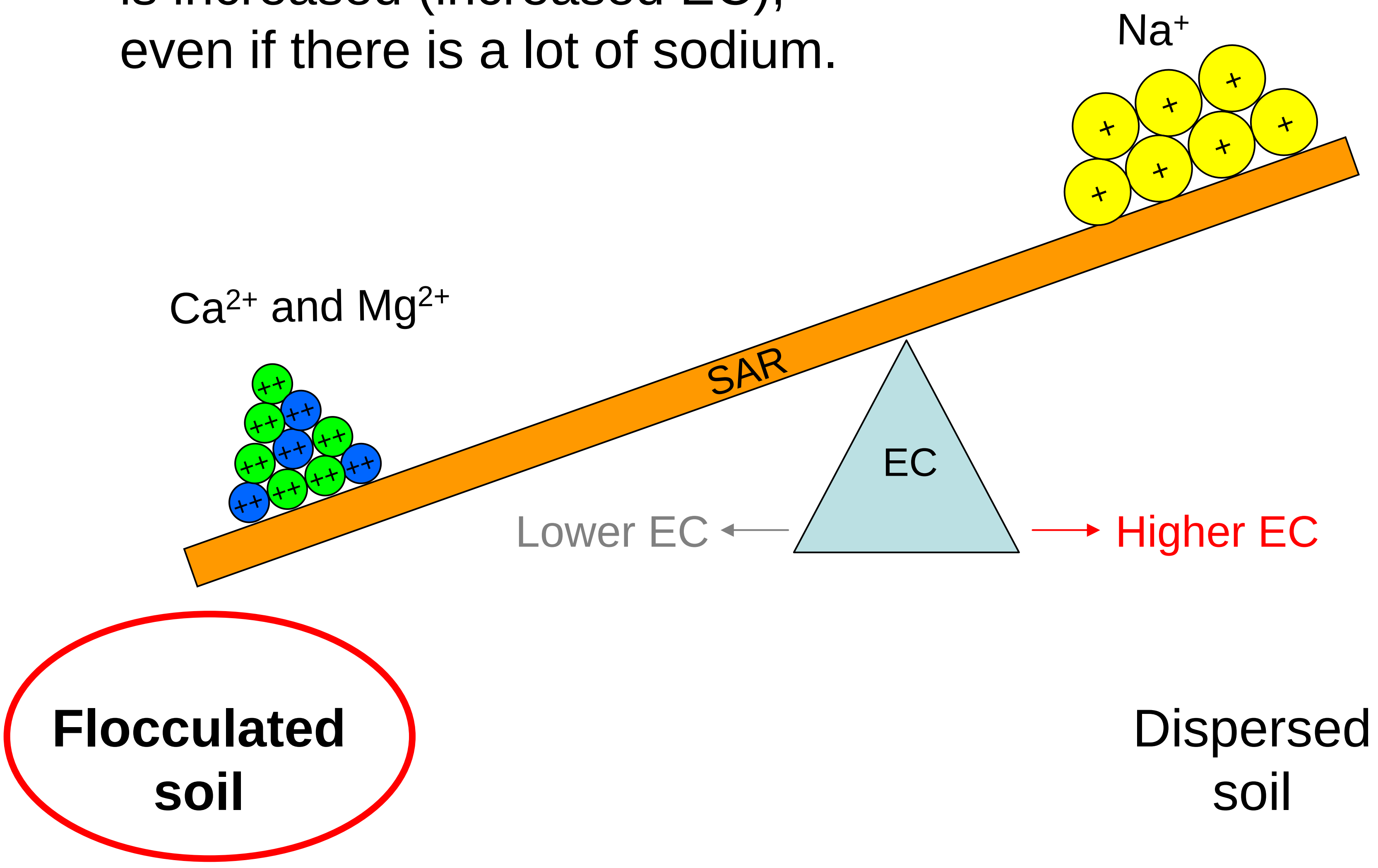
Flocculated soil

Dispersed soil

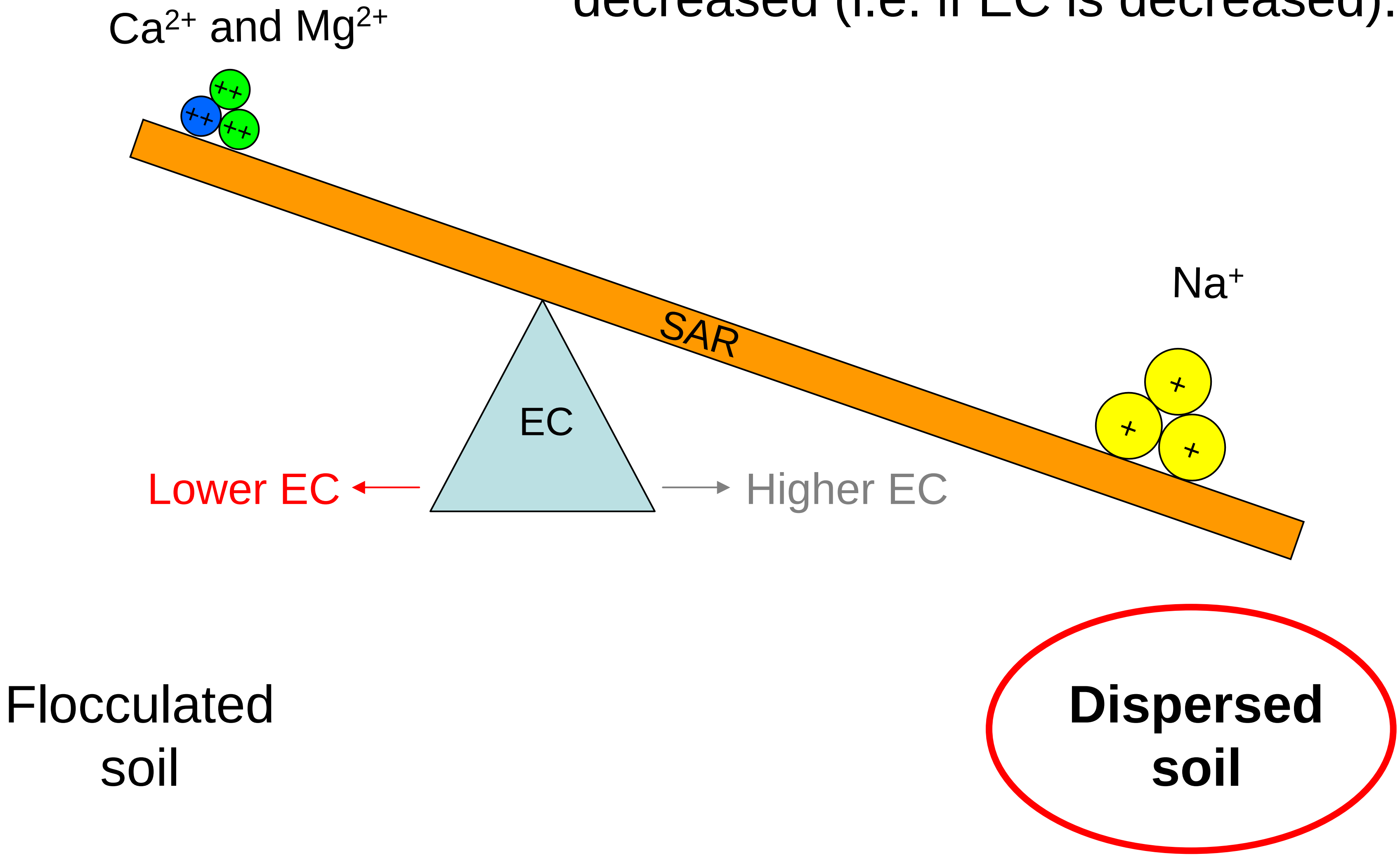
Soil particles will disperse if concentrations of (Ca^{2+} + Mg^{2+}) are decreased relative to the concentration of Na^+ (SAR is increased).



Soil particles will flocculate if the amount of soluble salts in the soil is increased (increased EC), even if there is a lot of sodium.



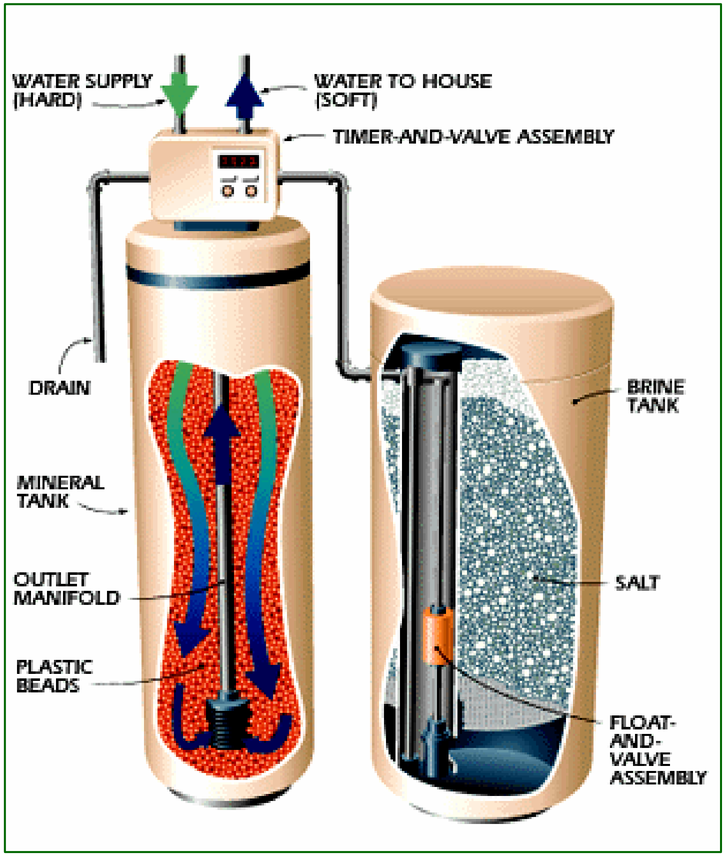
Soil particles may disperse if the amount of soluble salts in the soil is decreased (i.e. if EC is decreased).

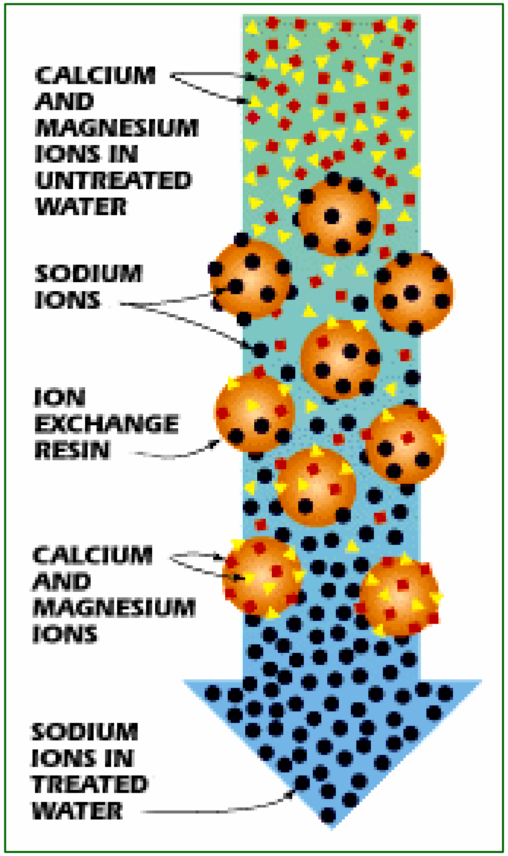


What does this have to do with reclaimed water?

- As we have already seen, reclaimed water may differ from potable water
  - Increased salt due to evaporative losses (occurs when water is used for cooling)
  - Increased sodium (where water is ‘softened’

“Softened” Water





Softened water has a higher SAR, but equivalent EC, relative to un-softened water

Illustrations from Popular Mechanics, August 1998

Recognizing sodium-affected soils.

I. Sodium-affected soils tend to form polygonal cracks when they dry.


Recognizing sodium-affected soils.

II. Sodium-affected soils disperse when mixed with water.

Recognizing sodium-affected soils.

III. Water infiltrates very slowly into sodium-affected soils

Recognizing sodium-affected soils.

IV. Soil chemical analysis

SAR or EC greater than ~ 10

depends on salinity and soil texture/mineralogy

SAR or EC increasing over time

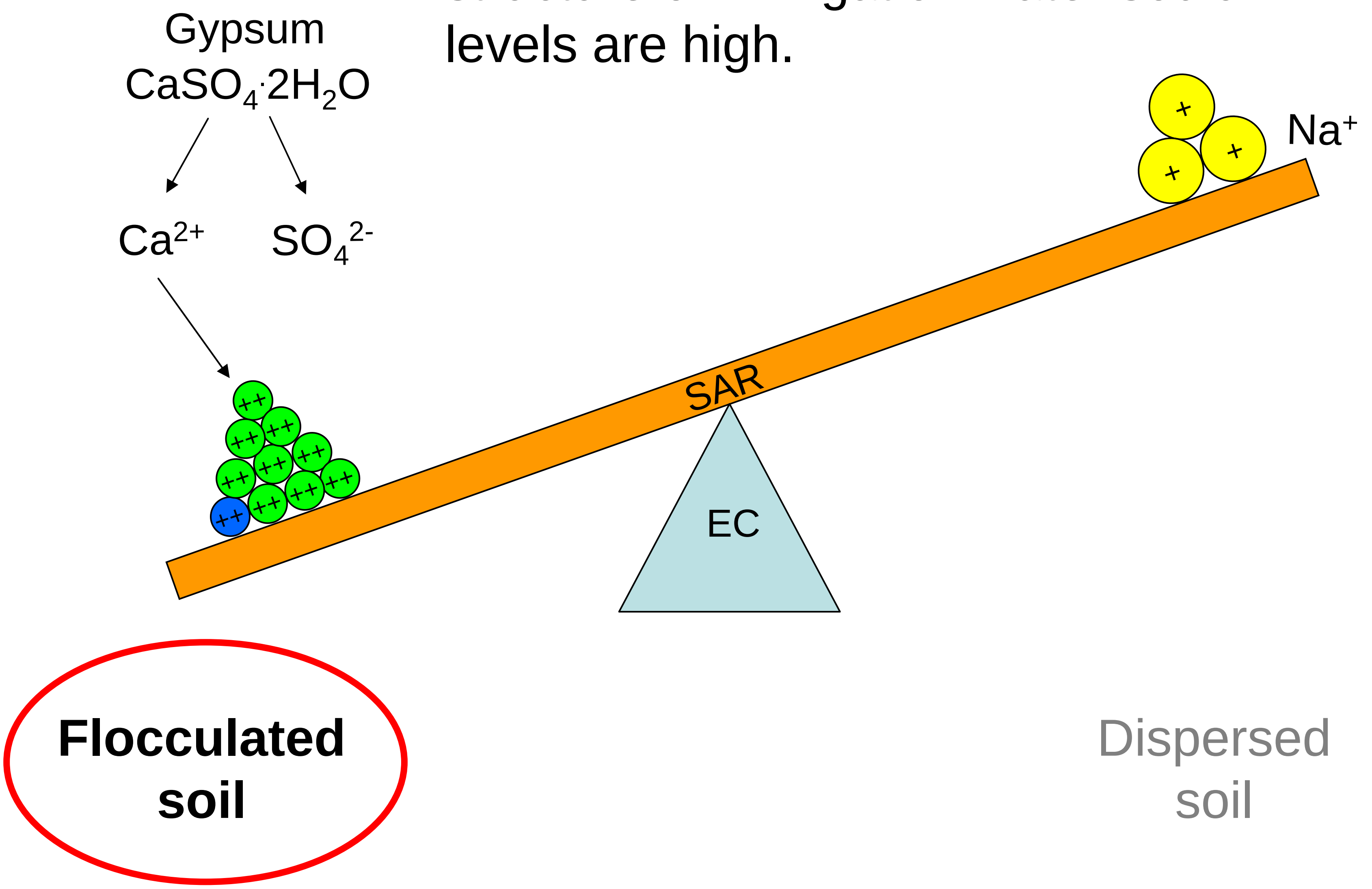
Water SAR should not be greater than ~ 6 to 10

also depends on salinity level

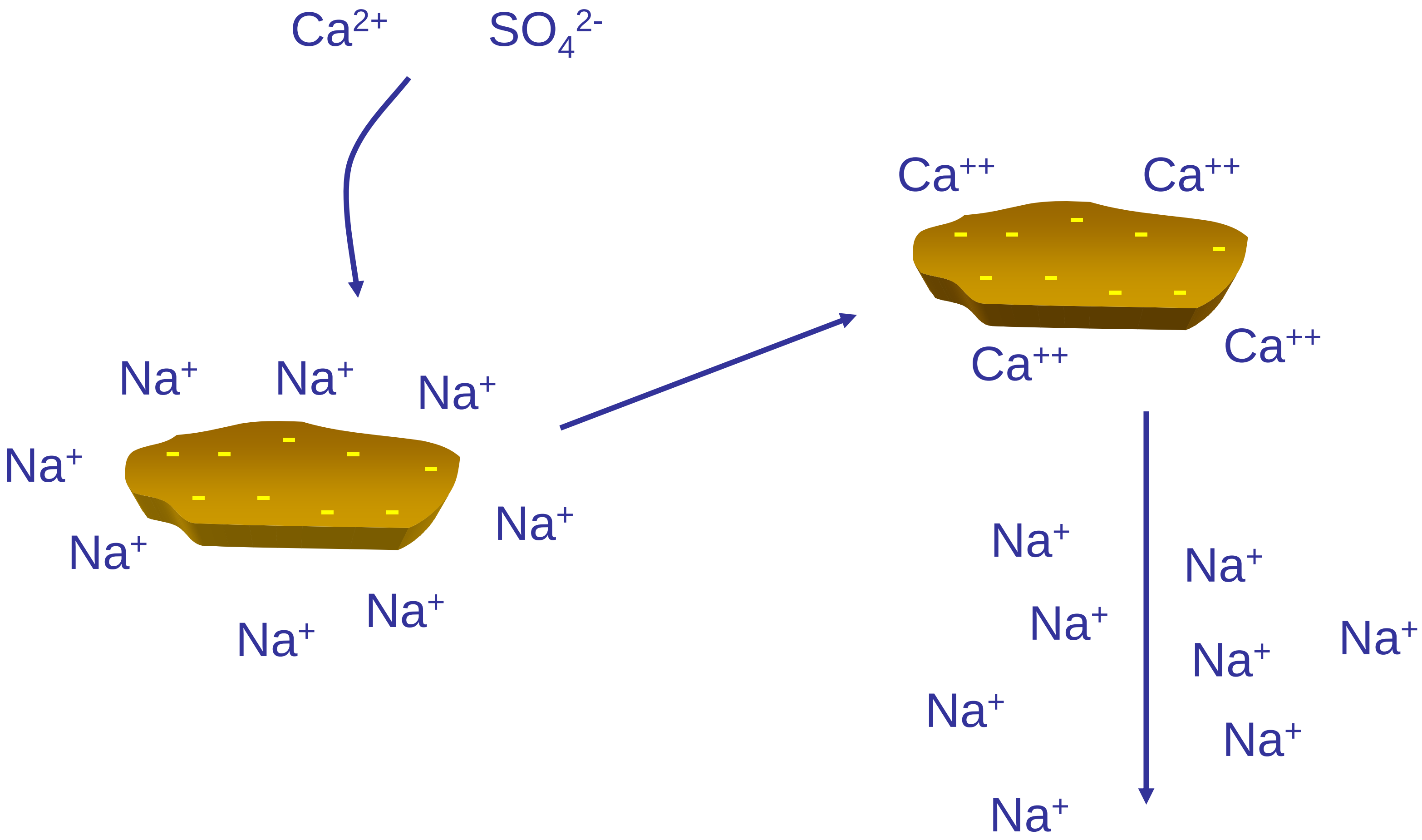
Reclaimed Water

- Salinity
  - Increased salinity in reclaimed water may actually be good for soil, because higher salt levels improve soil structure
  - This may not be good for growing plants
- Sodium
  - This is bad for soil structure, and may require adjustments to management practices

Increasing *soluble* calcium improves aggregate stability in soils with poor structure or if irrigation water sodium levels are high.



Apply gypsum *before* leaching salts out of soils susceptible to dispersion. Replacing sodium with calcium before leaching will stabilize soil structure.



Sulfuric acid can be used instead of gypsum on calcareous ($CaCO_3$ containing) soil only.

- Sulfuric acid dissolves calcium carbonate in the soil

$$H_2SO_4 + CaCO_3 \rightarrow CO_2 + H_2O + CaSO_4$$

and makes gypsum!

Managing soil structure

- Be aware of the quality of irrigation water. Water with high levels of sodium (high SAR) will tend to destabilize (disperse) soil.
  - Have irrigation water analyzed or ask your water provider for analyses.
  - If you have high sodium irrigation water, the water and/or the soil may need amendments such as gypsum or sulfuric acid.
- Observe your soil.
  - If water infiltrates very slowly, or if rain water infiltrates more slowly than irrigation water, the soil may have a sodium problem.
  - Sodium impacted soils may noticeably crack when dry.
- Analyze your soil.
  - Laboratory analysis can tell you the soil EC and SAR.