Flocculation and Dispersion

Flocculation is the process, where the individual particles of clay are coagulated to form floccular aggregates.

The degree and permanence of flocculation depend upon the nature of the ions present.

For example, calcium and hydrogen tend to increase flocculation.
Dispersion is defined as a process in which the individual particles are kept separate from one another. This is accomplished by potassium and sodium.

Thus, depending upon the cations present in a soil, it may be either in a flocculated (aggregated) or in a dispersed (massive) state.
Sodium saturated clays have a thick electric double layer surrounding the ion, that means the clays remain in suspension.

Calcium suppresses the double layer and cause flocculation, while tri- and tetravalent ions are more efficient in causing flocculation.
Soil clay particles can be unattached to one another (dispersed) or clumped together (flocculated) in aggregates. Soil aggregates are cemented clusters of sand, silt, and clay particles.
Flocculation is important because water moves mostly in large pores between aggregates.
Dispersed clays plug soil pores and impede (block) water infiltration and soil drainage.
Most clay particles have a **negative electrical charge**.

Like charges repel, so clay particles **repel** one another.
Common soil cations include sodium (Na⁺), potassium (K⁺), magnesium (Mg²⁺), and calcium (Ca²⁺).

Cations can make clay particles **stick together** (flocculate).
Flocculating Cations

We can divide cations into two categories

– Poor flocculators
  • Sodium
– Good flocculators
  • Calcium
  • Magnesium

<table>
<thead>
<tr>
<th>Ion</th>
<th>Relative Flocculating Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>Na⁺</td>
</tr>
<tr>
<td>Potassium</td>
<td>K⁺</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg²⁺</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca²⁺</td>
</tr>
</tbody>
</table>
Flocculating Power of Cations

Cations in water attract water molecules because of their charge, and become hydrated.

<table>
<thead>
<tr>
<th>Cation</th>
<th>Charges per molecule</th>
<th>Hydrated radius (nm)</th>
<th>Relative flocculating power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>1</td>
<td>0.79 or (0.36)</td>
<td>1.0</td>
</tr>
<tr>
<td>Potassium</td>
<td>1</td>
<td>0.53 or (0.33)</td>
<td>1.7</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2</td>
<td>1.08 or (0.43)</td>
<td>27.0</td>
</tr>
<tr>
<td>Calcium</td>
<td>2</td>
<td>0.96 or (0.41)</td>
<td>43.0</td>
</tr>
</tbody>
</table>

Water molecule is polar: (+) on one end, (-) on the other end.

Cations with a single charge and large hydrated radii are the poorest flocculators.
Sodium Adsorption Ratio, SAR

The SAR provide a good **indication of the stability** of clay soil structure to breakdown and particle dispersion, at least for nonmarine clays.

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

\[
\text{SAR} = \frac{[\text{Na}^+]}{\sqrt{\left(\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2}\right)}}
\]

SAR (meq/liter)\(^{1/2}\)

It can be determined by chemical analysis of pore water.

SAR > 1-2 Soil is dispersive
Electrical Conductivity

Ions in solution conduct electricity, so the total amount of soluble soil ions 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.
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

Ca\(^{2+}\) and Mg\(^{2+}\)

Na\(^+\)
Soil particles will flocculate if concentrations of \((\text{Ca}^{2+} + \text{Mg}^{2+})\) are increased relative to the concentration of \(\text{Na}^+\) (SAR is decreased).
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).
Soils can be classified by the amount of soluble salts (EC) and sodium status (SAR). This classification can tell us something about soil structure.

Soils with high levels of exchangeable sodium (Na) and low levels of total salts are called sodic soils.

<table>
<thead>
<tr>
<th>Soil Classification</th>
<th>EC</th>
<th>SAR</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;4</td>
<td>&lt;13</td>
<td>Flocculated</td>
</tr>
<tr>
<td>Saline</td>
<td>&gt;4</td>
<td>&lt;13</td>
<td>Flocculated</td>
</tr>
<tr>
<td>Sodic</td>
<td>&lt;4</td>
<td>&gt;13</td>
<td>Dispersed</td>
</tr>
<tr>
<td>Saline-Sodic</td>
<td>&gt;4</td>
<td>&gt;13</td>
<td>Flocculated</td>
</tr>
</tbody>
</table>
Observe your soil - sodic soils often crack when dry
Increasing *soluble calcium* improves aggregate stability in soils with poor structure.