Soil Buffering and Management of Acid Soils

1. Acids increase the H⁺ ion concentration in solution
2. Bases are the opposite of acids
4. When acids and bases are in equal amounts in a solution, the pH is 7. Neutral pH.
5. When the number of acids exceeds the number of bases the pH is lowered. (acid conditions)
6. When the number of bases exceeds the number of acids, the pH is raised. (basic/alkaline conditions)

\[
\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}
\]

Acid (≈10) Base (≈6)

Acidic basic

0 7 14
Two types of acidity in soils:

Active Acidity
Exchangeable Acidity
Active Acidity

Acidity associated with the soil solution

Typically a 1:1 or 2:1 extract
10 g soil and 10 mL water
10 g soil and 20 mL water

Exchangeable Acidity

Acidity associated with cation exchange sites on mineral or organic colloids.

Types of Acidity

<table>
<thead>
<tr>
<th>Active Acidity</th>
<th>Exchangeable</th>
</tr>
</thead>
<tbody>
<tr>
<td>H⁺ H⁺ H⁺ H⁺ H⁺</td>
<td>Al³⁺ Na⁺ H⁺ Na⁺ H⁺</td>
</tr>
<tr>
<td>H⁺ H⁺ H⁺ H⁺ H⁺</td>
<td>H⁺ Ca²⁺ H⁺ Al³⁺</td>
</tr>
<tr>
<td>H⁺ H⁺ H⁺ H⁺ H⁺</td>
<td>Ca²⁺ H⁺ Al³⁺ Ca²⁺</td>
</tr>
</tbody>
</table>

Soil Solution

Clay minerals/Organic matter
Percent Base Saturation

(base charge)
Exchangeable bases (cmol/kg)
Cation exchange capacity (cmol/kg)
Base charge = 12
Exch. Cap. = 27
% B.S. = 44.4%

Base Cations: Na, K, Mg, Ca

Soil Buffering

The ability of soils to resist changes in pH

Due to ultimate equilibrium between solution and colloids.

pH = 6
Soil Buffering

Add acid: HCl => H⁺ + Cl⁻

Soil Buffering

Final equilibrium

Base

A substance which decreases the Hydrogen ion concentration in solution

OH⁻
CO₃²⁻
SO₄²⁻
A substance which decreases the Hydrogen ion concentration in solution

\[
\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}
\]

\[
\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{HCO}_3^-
\]

(Neutralization)

NaOH
CaCO₃

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**Soil Buffering**

Equilibrium between solution and colloids.

\[
\begin{align*}
\text{Na}^+ & \quad \text{H}^+ & \quad \text{Ca}^{2+} \\
\text{K}^+ & \quad \text{H}^+ & \quad \text{H}^+ \\
\text{Na}^+ & \quad \text{H}^+ & \quad \text{H}^+ \\
\text{Ca}^{2+} & \quad \text{H}^+ & \quad \text{K}^+ \\
\text{pH} = 6
\end{align*}
\]

Clay minerals/Organic matter

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**Soil Buffering**

Add Base: \(\text{NaOH} + \text{H}^+ = \text{Na}^+ + \text{H}_2\text{O}\)

\[
\begin{align*}
\text{Na}^+ & \quad \text{Na}^+ & \quad \text{H}^+ & \quad \text{Na}^+ & \quad \text{Ca}^{2+} \\
\text{K}^+ & \quad \text{H}^+ & \quad \text{OH}^- \\
\text{Na}^+ & \quad \text{Na}^+ & \quad \text{OH}^- \\
\text{Ca}^{2+} & \quad \text{H}^+ & \quad \text{K}^+ \\
\text{pH} = 7
\end{align*}
\]

Clay minerals/Organic matter
Soil Buffering

NaOH

\[ \text{Na}^+ + \text{H}^+ + \text{H}_2\text{O} \rightarrow \text{NaOH} \]

\[ \text{Clay minerals/Organic matter} \]

\[ \text{pH} = 6.3 \]

Active Acidity

<table>
<thead>
<tr>
<th>Plant</th>
<th>pH Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>6.0 – 8.0</td>
</tr>
<tr>
<td>Sweet Clover</td>
<td>6.0 – 8.0</td>
</tr>
<tr>
<td>Beets</td>
<td>5.5 – 8.0</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>5.5 – 8.0</td>
</tr>
<tr>
<td>Spinach</td>
<td>5.3 – 7.5</td>
</tr>
<tr>
<td>Peas</td>
<td>5.3 – 7.5</td>
</tr>
<tr>
<td>Carrots</td>
<td>5.3 – 7.5</td>
</tr>
<tr>
<td>Cotton</td>
<td>5.0 – 7.2</td>
</tr>
<tr>
<td>Wheat</td>
<td>5.0 – 7.2</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>4.5 – 5.5</td>
</tr>
<tr>
<td>Potatoes</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Blueberries</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Azaleas</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

Sometimes soil pH must be adjusted to accommodate plants.

Liming: raising soil pH

\[ \text{MgCO}_3 + \text{CaCO}_3 \rightarrow \text{Ca}^{2+} + \text{CO}_3^{2-} \]

\[ \text{Displaces cations} \]
\[ \text{From exchange sites} \]

\[ \text{Combines with} \]
\[ \text{Hydrogen ions} \]
\[ \text{neutralization} \]

\[ \text{CO}_3^{2-} + \text{H}^+ = \text{HCO}_3^- \]
Soil Buffering

Add Base: $\text{CaCO}_3 \rightarrow \text{Ca}^{2+} + \text{CO}_3^{2-}$

$\text{Na}^+ \quad \text{Na}^+ \quad \text{H}^+ \quad \text{K}^+ \quad \text{Ca}^{2+}$
$\text{CO}_3^{2-} \quad \text{K}^+ \quad \text{H}^+ \quad \text{Ca}^{2+}$
$\text{Clay minerals/Organic matter}$

$\text{CO}_3^{2-} + \text{H}^+ = \text{HCO}_3^-$

Buffering Capacity

1. CEC
   - Kaolinite
   - Smectite
   * Organic Matter

2. % base saturation
pH and Nutrient Availability

Florida Soils Tend to be Acidic

Aluminum Toxicity

Aluminum most available at low pH
**Macro-Nutrients**

Generalizations: N\textsubscript{H}_4\textsuperscript{+} users below pH 5.5

\[
\text{NH}_4^+ \rightarrow \text{NO}_3^-
\]

Ammonium may accumulate
Organism dependent.

Phosphorus: H\textsubscript{2}PO\textsubscript{4}\textsuperscript{-} and HPO\textsubscript{4}\textsuperscript{2-}

Greatest availability at pH 6-7

Potassium: K\textsuperscript{+}
Liming tends to increase availability
(Increased CEC)

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**Micro-Nutrients**

Boron, manganese, iron, cobalt copper, zinc

- Oxides of these metals tend to be broken down at low pH
- Availability generally increases
  With increasing soil acidity
  (low pH)
- Acidity can be local: roots - acids