7.3 Soil pH Ranges

Definitions

Sodic soil: A soil containing sufficient sodium to interfere with the growth of most crop plants having an exchangeable-sodium percentage of 15 or more.

Calcareous soil: A soil containing sufficient calcium carbonate, often with magnesium carbonate, to effervesce visibly when treated with cold 0.1 N hydrochloric acid.

Arable soil: A soil which is suitable for the production of cultivated crops in an economical and practical manner.

Forest soil: A soil developed under forest vegetation.

Acid sulfate soil: A soil which is potentially extremely acidic (pH<3.5), because large amounts of reduced forms of sulfur are oxidized to sulfuric acid when it is drained or excavated.

Concepts

The optimum pH for arable crops in the humid temperate regions is between 5 to 7 (Table 7.1). Calcareous soils are found in arid regions and are dominated by Ca^{++}, Mg^{++}, K^+, and Na^+. The pH range for these soils is 7.0 to 8.5. Calcium carbonate precipitates at pH 8.5, therefore these soils do not exceed this pH. Sodic soils have a high concentration of exchangeable sodium. The pH range of these soils ranges from 8.5 to 10.5. Soils under forest vegetation have a greater amount of leaching. Therefore, the basic cations are leached and the dominant cations are Al^{3+}, $Al(OH)_x$, and H^+. The dominant cation and anion in acid sulfate soils are H^+ and SO_4^{2-}, respectively.

Table 7.1. Dominant cations and pH ranges of different types of soil

Type of soil	pH range	Most influential cations
Sodic soils	~8.5 to 10.5	Na^+
Calcareous soils	7.0 to 8.5	Ca^{++}, Mg^{++}, K^+, Na^+
Arable soils (Humid regions):	5 to 7	Ca^{++}, Mg^{++}, K^+, $Al(OH)_x$, H^+
Forest soils	3.5 to 5.8	Al^{3+}, $Al(OH)_x$, H^+
Acid sulfate soils	2 to 4	H_2SO_4

The pH in pedons also varies with the degree of soil development, as determined by the soil forming factors, under natural conditions. Pedons contain differentiated horizons which have different pH values. Therefore, there is a marked difference in the pH of different soil horizons (Table 7.2). Management practices such as liming, use of ammonium-based fertilizers and elemental sulfur can also influence soil pH in specific horizons or in the whole pedon.

Table 7.2. Reaction (pH) of soil horizons in pedons belonging to different soil orders (data extracted from Soils of Canada, Volume 1; Clayton et al., 1977)

Orthic Black Chernozem		Black Solod		Dark Gray Luvisol		Orthic Ferro-Humic Podzol	
Horizon	**pH**	**Horizon**	**pH**	**Horizon**	**pH**	**Horizon**	**pH**
Ah	7.2	Ap	5.9	L-F	6.3	L-H	3.0
AB	7.6	AB	5.2	Ah	6.1	Ae	4.0
Bm	7.7	Bnt1	4.9	Ae	5.5	Bhf	4.4
Bms	7.9	Bnt2	5.6	AB	5.4	Bf	4.4
Bmk	8.1	BC	7.5	Bt	5.8	Bm	4.4
Cca	8.2	Cks	7.7	BC	6.8	BCx	4.7
II Cca	8.4			Ck	7.2	C	4.7

Soil colloids have a net negative charge that is satisfied by cations. The composition of the cation exchange complex varies according to the soil pH. The distribution of cations in diagnostic horizons of pedons belonging to different soil orders is presented in Table 7.3.

Table 7.3. Distribution of exchangeable cations in soil samples obtained from diagnostic horizons of different soil orders (data extracted from Clayton et al., 1977).

<table>
<tr><th>Soil Horizon</th><th>pH</th><th>Ca^{2+}</th><th>Mg^{2+}</th><th>K^{+}</th><th>Na^{+}
%</th><th>H^{+}</th><th>Al^{3+}</th><th>CEC
($cmol_c$/kg)</th></tr>
<tr><td>Chernozemic Ah</td><td>6.6</td><td>79</td><td>11</td><td>2</td><td>1</td><td>7</td><td>0</td><td>72</td></tr>
<tr><td>Solonetzic Bnt</td><td>5.6</td><td>34</td><td>54</td><td>1</td><td>9</td><td>2</td><td>0</td><td>66</td></tr>
<tr><td>Luvisolic Bt</td><td>5.8</td><td>72</td><td>19</td><td>3</td><td>1</td><td colspan="2">5</td><td>50</td></tr>
<tr><td>Podzolic Bhf</td><td>4.4</td><td>14</td><td>6</td><td>3</td><td>0</td><td colspan="2">77</td><td>11</td></tr>
<tr><td>Podzolic Bfh</td><td>4.4</td><td>0</td><td>0</td><td>2</td><td>0</td><td colspan="2">98</td><td>7</td></tr>
</table>

Applications

The percent base saturation can be calculated as follows:

$$\text{Base saturation (\%)} = \frac{\Sigma \text{ Ca, Mg, K, Na}}{\text{Cation Exchange Capacity}} \times 100$$

If the data are already in percentages, then the cation exchange capacity is equal to 100%. From the data provided in Table 7.3, the percent base saturation and the ratio of Ca^{2+}: Na^{+} can be calculated. Hydrogen ion concentration increases as the pH decreases. Under acidic conditions, H and Al ions dominate the cation exchange, therefore, as the pH decreases, the percent base saturation also decreases (Table 7.4).

Solonetzic soils have a Bn or Bnt horizon. Solonetzic B diagnostic horizons must have an exchangeable Ca: exchangeable sodium ratios which are less than 10. In the example presented in Table 7.4, the ratio is 4:1. Although this soil still has a significant concentration of Ca ions, the proportional increase in Na ions disperses clay particles and markedly affects the properties of soil as described in Section 5.4.2.

Table 7.4. Selected chemical properties of diagnostic soil horizons as a function of soil pH

Soil Horizon	pH	CEC ($cmol_c$/kg)	Percent Base Saturation	Ca^{2+}: Na^+ ratio
Chernozemic Ah	6.6	72	93%	72:1
Solonetzic Bnt	5.6	66	98%	4:1
Luvisolic Bt	5.8	50	95%	72:1
Podzolic Bhf	4.4	11	23%	Undefined
Podzolic Bfh	4.4	7	2%	Undefined

7.4 Exchange Complex Dynamics

Definitions

Exchangeable cation: A positively charged ion held on or near the surface of a solid particle by a negative surface charge. This positively charged ion may be replaced by other positively charged ions in the soil solution. Usually expressed in centimoles or millimoles of charge per kilogram. For example, Ca^{2+}, Mg^{2+}, K^+ and Na^+ are base-forming exchangeable cations and Al^{3+} and H^+ are acidic exchangeable cations.

Base-forming cations: Those cations that form strong (strongly dissociated) bases by reaction with hydroxyl, e.g., K^+ forms potassium hydroxide ($K^+ + OH^-$). In most soils, Ca^{2+}, Mg^{2+}, K^+ and Na^+ predominate. Historically, these are called bases because they are cations of strong bases.

Bound H and Al: These forms of hydrogen and aluminum ions are held tightly by pH-dependent sites on organic and mineral colloids.

Adsorption: The process by which atoms, molecules, or ions are taken up from the soil solution or soil atmosphere and retained on the surfaces of solids by chemical or physical binding.

Adsorption complex: A collection of various organic and inorganic substances in soil that is capable of adsorbing ions and molecules.