Organic material in soil

Decaying organisms

Dead organisms decay by the action of microbes in soil. This happens at the end of all food chains. The product is a complex organic mixture of many high relative molecular mass organic compounds.

Dead organic material contains a variety of nitrogen-containing compounds such as proteins. These are hydrolysed by various enzymes in a series of reactions that lead finally to the formation of ammonia, NH_3. This is called ammonification.

Nitrification

Ammonia is converted to nitrate ions in soil in a three step process called nitrification.

Step 1

In aqueous solution, ammonia molecules and ammonium ions exist in dynamic equilibrium,

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

The position of equilibrium depends on the pH of the solution. Decreasing pH will shift the position of equilibrium to the right.

Step 2

Ammonium ions are oxidised to nitrite ions, $NO_2^-(aq)$, by oxygen. The reaction is catalysed by *Nitrosomonas* bacteria.

$$2NH_4^+(aq) + 3O_2(g) \rightarrow 2NO_2^-(aq) + H_2O(l) + 2H^+(aq)$$

Step 3

Nitrite ions are oxidised further to nitrate ions, $NO_3^-(aq)$, by oxygen. The reaction is catalysed by *Nitrobacter* bacteria.

$$2NO_2^-(aq) + O_2(g) \rightarrow 2NO_3^-(aq)$$

The complete process (ammonification followed by nitrification) is called nitrogen mineralisation.

Nitrogen fertilisers

Nitrogen fertilisers are also a source of water-soluble nitrogen compounds in soil water. Most nitrogen-fertilisers contain ammonium ions and/or nitrate ions. However, their use has raised environmental concerns because heavy application can lead to wash-off from the soil getting into streams and rivers.

Urea is also used as a nitrogen fertiliser. Urea is inactive, but hydrolyses in soil water to release ammonia:

$$CO(NH_2)_2 + H_2O \rightarrow CO_2 + 2NH_3$$

This hydrolysis reaction is catalysed in soil by the enzyme urease, which is found in a number of bacteria. This slow reaction means that nitrogen is made available to plants in a controlled way.

Organic acids

Organic material resulting from decay is sometimes referred to as humic material and the organic compounds fall into two categories: humic acids (insoluble) and fulvic acids (soluble).

The presence of these organic compounds increases the acidity of soil water.

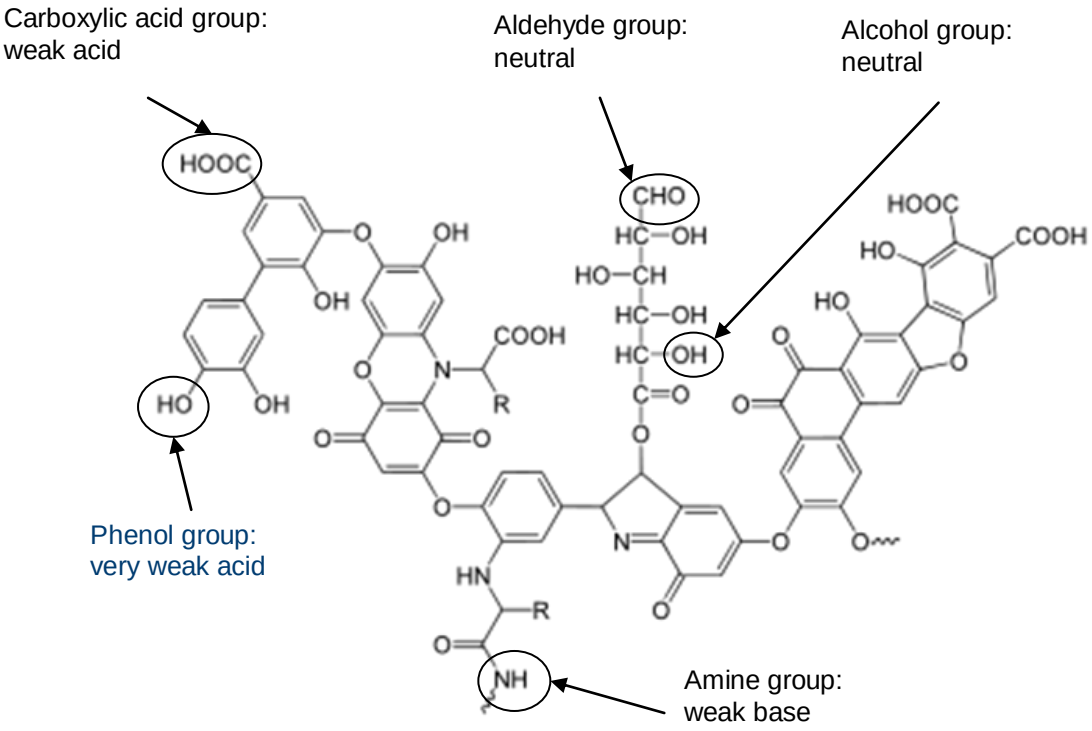

Figure Functional groups that affect pH.

An important function of organic material is to complex with metal ions, holding them in the soil and reducing their bioavailability. This can happen by salt formation or more effectively by formation of metal complexes.

Cations form ionic bonds to the surface of particles of organic material, especially if it contains carboxylic acid groups.

$$\text{Organic}{-}\text{COOH(s)} + H_2O(l) \rightleftharpoons \text{Organic}{-}\text{COO}^-(s) + H_3O^+(aq)$$

$$\text{Organic}{-}\text{COO}^-(s) + K^+(aq) \rightleftharpoons \text{Organic}{-}\text{COO}^-K^+(s)$$

This is the equivalent of simple insoluble salt formation.

Organic compounds, including carboxylic acids, can form complexes with metal ions. This happens when the metal ion is able to form coordinate (dative covalent) bonds.

Various organic groups in organic compounds found in soil can act as ligands, donating one or more lone pairs of electrons to form coordinate bonds.

Again an equilibrium reaction is established. For example:

$$\text{Organic}{-}(COO^-)_2 + Cu^{2+}(aq) \rightleftharpoons \text{Organic}{-}(COO)_2Cu$$

The strength of the coordinate bond determines the position of equilibrium. It is the equivalent of a stability constant for a metal complex. See also *Availability of nutrients*.

Finding out

What are the changes of the oxidation state of nitrogen during nitrification?