Replaceable aluminum and total acidity

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The soil particles are electrically charged and can therefore bind different ions that are dissolved in the soil liquid at their surface. The electrostatically bonded ions are interchangeable and can replace places with other charged ions.

Jordproverna i tygpåsar för transport till laboratoriet i Uppsala. Foto: Ola Borin.

If the composition of the soil fluid is changed, this directly affects the composition of the exchangeable ions. An example of this is acid deposition with precipitation that leads to lowered pH (= increased hydrogen ion concentration) in the groundwater and increased release of aluminum ions (Al^{3+}) in the groundwater. Some of the hydrogen and aluminum ions in the ground water change places with some of the base cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}), which was electrostatically bound to the soil particles. Thus, the content of exchangeable hydrogen and aluminum ions also increases as the pH in the soil decreases. The sum of the exchangeable hydrogen and aluminum ions is referred to as total acidity or titratable acidity. The proportion of replaceable aluminum of the total acidity generally increases sharply at pH values below 4.5.

Swedish soils have a negative net charge

In Sweden, most soils have a negative net charge. One consequence of this is that cations bind better in the soil than anions. Examples of replaceable cations are calcium (2+), magnesium (2+), potassium (1+), ammonium (1+), hydrogen (1+) and aluminum (3+). The numbers in brackets indicate the charge of the ions. Both hydrogen ion (H^{+}) and aluminum ion (Al^{3+}) exhibit acidic properties and are often referred to as acidic cations. Al^{3+} can be called an acidic cation because it can release hydrogen ions when Al^{3+} is dissolved and hydrolyzed in water according to the following reactions:

$$Al^{3+} + H_2O \leftrightarrow Al(OH)^{2+} + H^{+}$$

$$Al^{3+} + 2H_2O \leftrightarrow Al(OH)_2^{+} + 2H^{+}$$

High concentrations of Al^{3+} in the soil fluid can have a toxic effect on the roots of the plants. However, the plants are differently sensitive to Al^{3+} . Our common tree species are quite durable and can withstand fairly high concentrations of Al^{3+} , while most arable crops are adapted for higher pH values and thus sensitive to low pH values followed by high concentrations of Al^{3+} in the soil fluid.

Maps of exchangeable aluminum in various humus forms and horizons during the period 1993-2002

Maps of total acidity in Swedish woodland 1993-2002

Facts:

Determination of interchangeable aluminum and total acidity

Replaceable aluminum

Approximately 10 g of air-dried humus or mineral soil sample is weighed into a polyethylene shake bottle (250 ml). Then 100 ml of 1 M KCl solution is added and the sample is then shaken in a shaker for two hours. The solution is filtered through a paper filter (ashless filter paper, Munktell 00K, diameter: 18 cm). Then 10 ml of the extract is taken out and 40 ml of 0.125 M HCl solution is added. The aluminum concentration in this sample is analyzed on ICP-AES (inductively coupled plasma emission spectrophotometer with quantification by emission spectroscopy). On the remaining 90 ml of the extract, pH (pH-KCl) is measured.

Total acidity (titratable acidity)

To determine the total acidity (TA), 50 ml of the same extraction solution (1N NH_4OAc solution, buffered to pH 7.0) is used, as in the determination of exchangeable base cations (see above). The solution is titrated until it reaches pH 7.00 with either 0.1 M NaOH (if initial pH was less than 7.00) or 0.1 M HNO_3 (if initial pH was higher than 7.00). The titration is performed with the same automatic titration system as in the pH measurement.

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