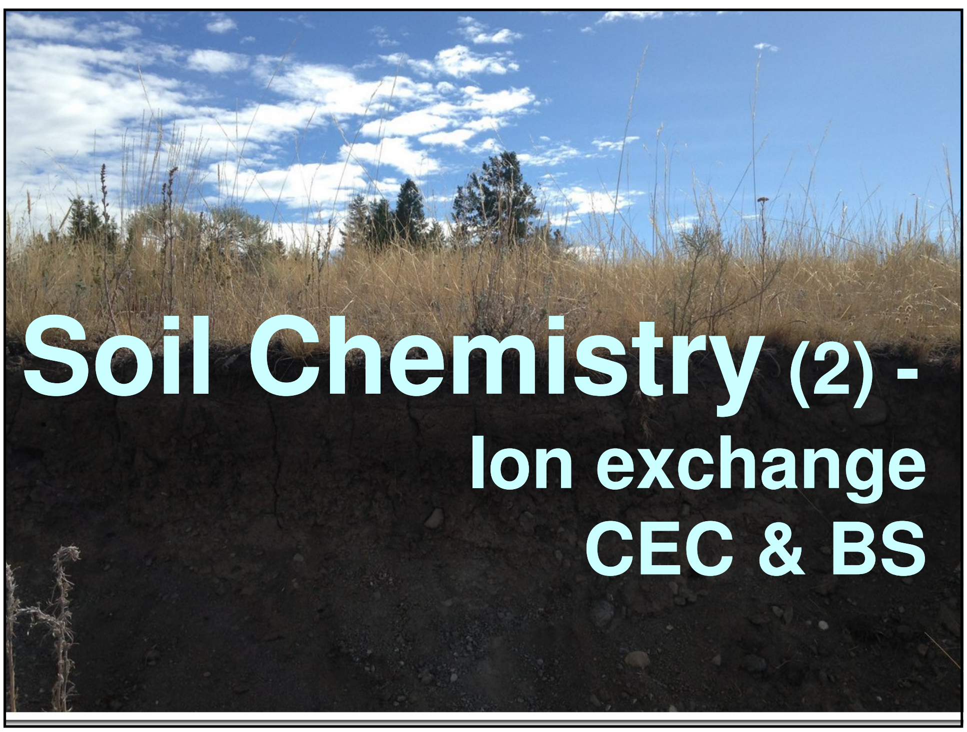

APBI 200
SOIL COMPONENTS


Soil Chemistry (2) -
Ion exchange
CEC & BS

Lecture outline

A. Ion exchange

B. Cation exchange capacity (CEC)

B. Base cations and base saturation

C. Exchangeable Al

D. Anion exchange

Ion exchange reaction:

$$K\text{-}clay + Na^+ \rightleftharpoons Na\text{-}clay + K^+$$

- Ion exchange reactions are:
  - Reversible
  - Rapid
  - Stoichiometric

$$K\text{-}clay + Na^+ \rightleftharpoons Na\text{-}clay + K^+$$

If a high number of Na^+ ions are added, there will be a very high probability of having Na^+ replace all of the adsorbed K^+.

This phenomenon is called **mass ion effect**

Cation exchange capacity

Exchangeable cations are those cations which are readily displaced, by mass ion effect, from negatively charged colloids on which they are adsorbed

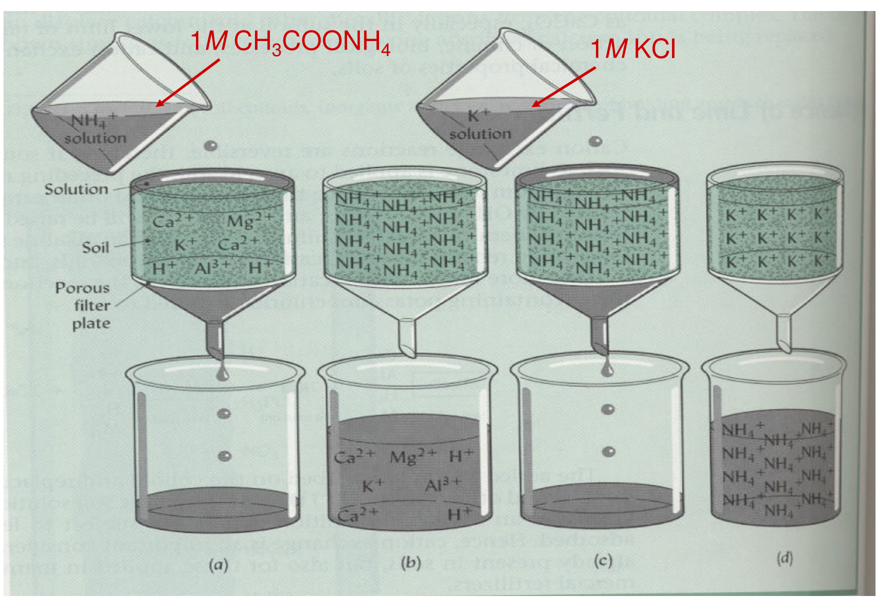
$$K\text{-}clay + Na^+ \rightleftharpoons Na\text{-}clay + K^+$$

Cation exchange capacity (CEC) - number of exchangeable cations which soil solids can adsorb.

Units: $cmol_c$ / kg soil

meq / 100 g soil

Method of CEC determination



Approximate CEC ($cmol_c/kg$)

- Kaolinite: 3-15
- Montmorillonite: ~100
- Fe, Al oxides (sesquioxides): ~3
- Organic matter (humus): 150-250
- Amorphous minerals: 5-350

What is significance of CEC?

- Contributes to soil buffering
- Contributes to nutrient retention in available forms
- Contributes to retention of various contaminants

Such cations as Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} are called **base (or base-forming) cations**

$$Na_2CO_3 + H_2O \rightleftharpoons 2Na^+ + HCO_3^- + OH^-$$

Base saturation (BS) -

fraction of cations on the cation exchange sites occupied by base cations rather by H^+ and Al^{3+}

$$\%BS = \frac{\Sigma(Ca^{2+} + Mg^{2+} + K^+ + Na^+)}{CEC} \times 100$$

Al & soil acidity

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

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

$$Al(OH)_2^+ + H_2O \rightleftharpoons Al(OH)_3 + H^+$$

*Minerals like sesquioxides may acquire a pH-dependant (variable) charge

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Number of exchangeable anions which soil solids can adsorb is **anion exchange capacity (AEC)**

Example of a positive charge formation on Al-oxide:

$$Al(OH)_3 + H^+ \rightleftharpoons Al(OH)_2^+ + H_2O$$

(Mineral gibbsite) (In solution) (Mineral gibbsite with a positive charge)

At high pH this might happen:

Voilá - a negative charge!

$$Al(OH)_3 + OH^- \rightleftharpoons Al(OH)_4^-$$

(Mineral gibbsite) (In solution)