



FACULTY OF MEDICAL SCIENCES

SOIL COLLOIDS

Thomas Graham (1861) coined the term 'colloid' (Greek Kolla= glue eidos= like) In a true solution as sugar or salt in water the solute particles are dispersed in the solvent as single molecules or ions. In this case the diameter of dispersed particles ranges from 1A^0 to 10A^0 (0.00001 to 0.001μ).

In a suspension as sand stirred in water, the solute particles are aggregates of millions of molecules. The diameter of these particles is of the order of 2000A^0 or more.

When the diameter of the particle of a substance dispersed in a solvent ranges from about 10A^0 to 2000A^0 the system is termed a colloidal solution, colloidal dispersion or simply a colloid (0.001 to 0.2μ) Some of the soil particles are of colloidal size and exhibit colloidal properties in soil system. Soil colloids are broadly classified as inorganic and organic colloids. Inorganic colloids based on the shape are divided into crystalline and amorphous colloids.

General Properties of Colloids

- 1 Shape
- 2 Size
- 3 Surface area
- 4 Electrical charge
- 5 Adsorption
- 6 Plasticity
- 7 Cohesion
- 8 Swelling & Shrinkage
- 9 Flocculation & Deflocculation
- 10 Brownian movement
- 11 Tyndal effect

Shape : The mineral colloids are laminated, made up of layers of plates or flakes or even rods. The different units or flakes of clay minerals are held together with varying degrees of force depending upon the nature of the clay mineral.

The edges of clay minerals are of clean cut or frayed or fluffy. In all cases clay minerals are developed more in the horizontal axis than of vertical axis.

- 1 Kaolinite ----Hexagonal crystals
- 2 Montmorillonite -- Flakes
- 3 Humus----- Variable
- 4 Halloysite---- Rod shaped

Size and Surface Area : Colloids are extremely small in size. The upper limit in diameter for the colloidal state is generally considered to be about one micron. Some with upper limit of 2μ exhibit colloidal properties but they are not technically colloids.

The colloids expose a large surface area per unit mass. The external surface area of one gram of clay colloid is at least 1000times that of one gram of sand. Certain silicate clays with expanding plate like makeup offer internal surfaces besides external surface area. The total surface area of soil colloids ranges from $10\text{m}^2/\text{g}$ for clays with only external surfaces to more than $800\text{m}^2/\text{g}$ for clays with extensive internal surfaces. The colloidal surface area in the upper 15 cm of a hectare of a clay soil could be as high as 7,00,000 sq. kms.

Electrical Charge: The colloidal surfaces, both external and internal characteristically carry negative and / or positive charges. For most colloids electronegative charges predominate, although some mineral colloids in very acid soils have a net positive charge.

Adsorption : Adsorption of cations / anions and water is the important consequence of the charges on colloids. The negatively charged colloids are of practical significance, as they attract hundreds of thousands of positively charged ions (cations). This gives rise to an ionic double layer.

The adsorption of ions is governed by the type and nature of ion, ion concentration and the type of colloidal particle.

- Higher is valency, higher the adsorption (excepting H^+)
- With same valency, the ion with more atomic weight is preferred.
- Concentration of the ion in the solution also determines the adsorption rate.

Plasticity: Soil containing more than about 15% clay exhibits plasticity that is pliability and the capability of being molded. This property is due to the plate like nature of the clay particles and the combined lubricating and binding influence of the adsorbed water. Thus the particles of plastic soils easily slide over each other, much like panes of glass with films of water between them.

Plasticity is of practical importance because of its influence on tillage operations. The clayey soils with smectite type clay minerals present a significant problem, by not allowing to obtain a stable granular structure.

Montmorillonite > Illite > Kaolinite

Swelling and shrinkage: Some clays swell when wet and shrink when dry. After prolonged dry period, soils rich in smectite minerals often are criss-crossed by wide deep cracks that, at first, allow rain water to penetrate rapidly. Later, because of swelling, such a soil is likely to close up and become much impervious than one dominated by kaolinite or illite.

Inter crystal expansion; adsorbed ions for water and air entrapped are primarily responsible for swelling. **Cohesion:** It indicates the tendency of clay particles to stick together. This tendency is due primarily to the attraction of the clay particles for the water molecules held between them. Hydrogen bonding between the clay surfaces and water and also among water molecules is the attractive force responsible for cohesion. It results in the formation of some resistant hard clods. Smectites and fine grained micas exhibit a noticeable degree of cohesion. In contrast, humus reduces the attraction of individual clay particles for each other.

Brownian Movement: The continuous rapid zigzag movement executed by a colloidal

particle in the dispersion medium is called Brownian movement or Motion (Robert Brown, 1927).

In a colloid suspension, the colloidal particles are under constant rapid motion. They move in a short straight line path in the medium and change their path abruptly due to collision with other colloidal particles or molecules of dispersion medium.

The smaller the particle, the more rapid is its movement and more often does it collide. The Brownian movement is mainly responsible for the coagulation or flocculation of colloidal particles.

Tyndal Effect : Dust particles float in air form a colloidal suspension. If a strong beam of light is passed through such suspension the particles appear bigger than original size. This is due to the diffusion of light by the colloidal sized particles, which is called “Tyndal Effect”.

Flocculation : Aggregation or clumping together of individual, tiny soil particles is called flocculation.

Clay particles by virtue of carrying negative charge on its surface repel each other and disperse in the medium. When the negative charge is satisfied by cations, which are tightly held on clay surface, the repulsive forces would be very minimum. It leads to coagulation or flocculation of soil particles.

From the stand point of agriculture, flocculation is generally beneficial because it is the first step in the formation of stable aggregates or granules. The ability of common cations to flocculate soil colloids is in the general order of $Al^{3+} > H^+ > Ca^{2+}, Mg^{2+} > K^+ > Na^+$. Incidentally the colloidal complexes of humid and sub-humid region soils are dominated by aluminum, hydrogen, calcium and magnesium and those of semi-arid regions are high in Calcium and magnesium ions.

Deflocculation : It is the dispersion of colloidal particles, due to the repulsion of negatively charged particles. Under deflocculated condition particles move away from each other, and act independently.

Dispersion is encouraged by the large number of water molecules associated with each micelle and with the adsorbed cations. Highly hydrated monovalent cations like

Na^+ do not effectively reduce the electro negativity of the micelle and are loosely held. It makes the individual micelles to repel each other continuously and stay in dispersion.

Dispersion can be reduced by (i) decreasing the pH of the medium (ii) replacing the sodium with H^+ , Ca^{2+} , Mg^{2+} and Al^{3+} like cations and (iii) increasing the salt concentration in the soil solution.