Bioecology
Module: Soil Science

Lecture 5.
Soil water. Retention and potentials

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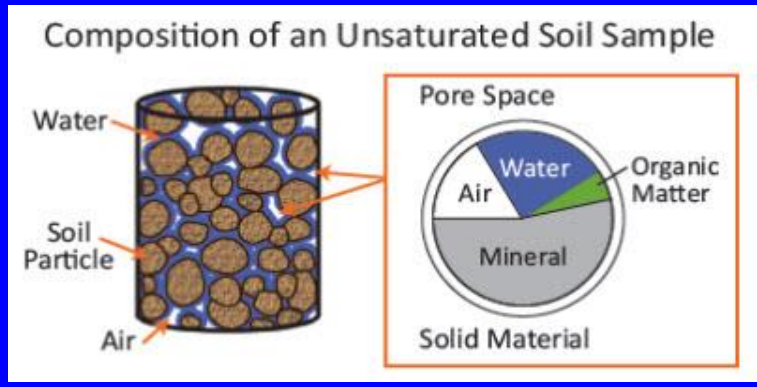
Importance of Soil Water

- Soil water serves as a solvent and carrier of food nutrients for plant growth
- Yield of crop is more often determined by the amount of water available rather than the deficiency of other food nutrients
- Soil water acts as a nutrient itself
- Soil water regulates soil temperature
- Soil forming processes and weathering depend on water
- Microorganisms require water for their metabolic activities
- Soil water helps in chemical and biological activities of soil
- It is a principal constituent of the growing plant
- Water is essential for photosynthesis

For optimum water used, it is vital to know how water moves into and through the soil, how the soil stores water, how the plant absorbs it, how nutrients are lost from the soil by percolation, and how to measure soil water content and losses.

Soil also serves as a regulated reservoir for water because it receives precipitation and irrigation water. A representative cultivated loam soil contains approximately 50% solid particles (sand, silt, clay and organic matter), 25% air and the rest 25% water, only half of this water is available to plants because of the mechanics of water storage in the soil.



Factors Affecting Soil Water

1. Texture: Finer the texture, more is the pore space and also surface area, greater is the retention of water.

2. Structure: Well-aggregated porous structure favors better porosity, which in turn enhance water retention.

3. Organic matter: Higher the organic matter more is the water retention in the soil.

4. Density of soil: Higher the density of soil, lower is the moisture content.

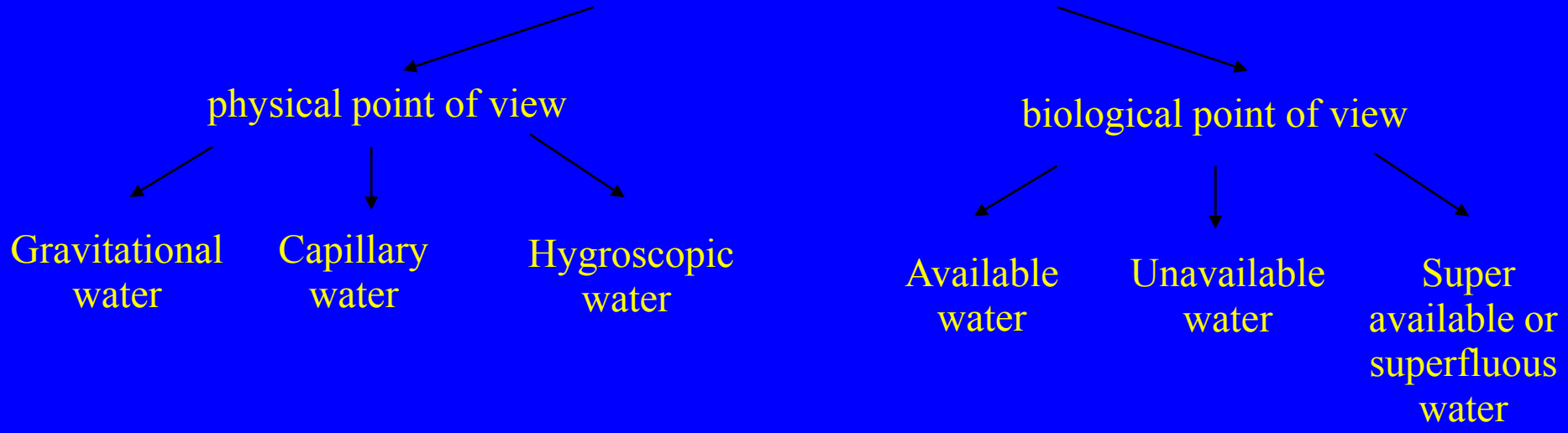
5. Temperature: Cooler the temperature, higher is the moisture retention.

6. Salt content: More the salt content in the soil less is the water available to the plant.

7. Depth of soil: More the depth of soil more is the water available to the plant.

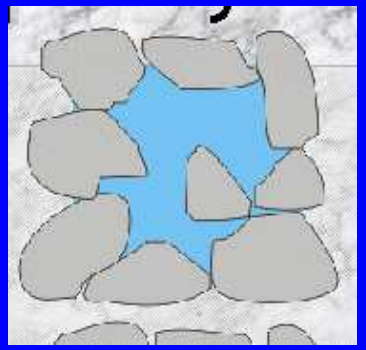
8. Type of clay: The 2:1 type of clay increases the water retention in the soil.

Classification of soil water



Gravitational water

Gravitational water occupies the larger soil pores (macropores) and moves down readily under the force of gravity. Gravitational water is of no use to plants because it occupies the larger pores. It reduces aeration in the soil. Thus, its removal from soil is a requisite for optimum plant growth. Soil moisture tension at gravitational state is zero or less than 1/3 atmosphere.



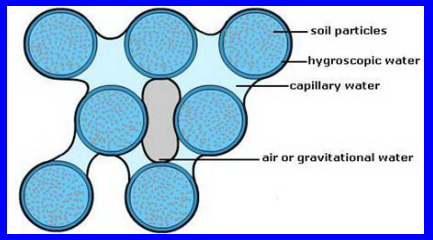
Factors affecting gravitational water:

1) Texture: Plays a great role in controlling the rate of movement of gravitational water. The flow of water is proportional to the size of particles. The bigger the particle, the more rapid is the flow or movement. Because of the larger size of pore, water percolates more easily and rapidly in sandy soils than in clay soils.

2) Structure: In platy structure movement of gravitational water is slow and water stagnates in the soil. Granular and crumby structure helps to improve gravitational water movement. In clay soils having single grain structure, the gravitational water, percolates more slowly. If clay soils form aggregates (granular structure), the movement of gravitational water improves.

Capillary water

Capillary water is held in the capillary pores (micro pores). Capillary water is retained on the soil particles by surface forces. The molecules of capillary water are free and mobile and are present in a liquid state. Capillary water is known as available water. The capillary water is held between 1/3 and 31 atmosphere pressure.



Factors affecting capillary water:

1) Surface tension: An increase in surface tension increases the amount of capillary water.
2) Soil texture: The finer the texture of a soil, greater is the amount of capillary water holds. This is mainly due to the greater surface area and a greater number of micro pores.
3) Soil structure: Platy structure contains more water than granular structure.
4) Organic matter: The presence of organic matter helps to increase the capillary capacity of a soil. Organic matter itself has a great capillary capacity. Undecomposed organic matter is generally porous having a large surface area, which helps to hold more capillary water. The humus that is formed on decomposition has a great capacity for absorbing and holding water. Hence the presence of organic matter in soil increases the amount of capillary water in soil.

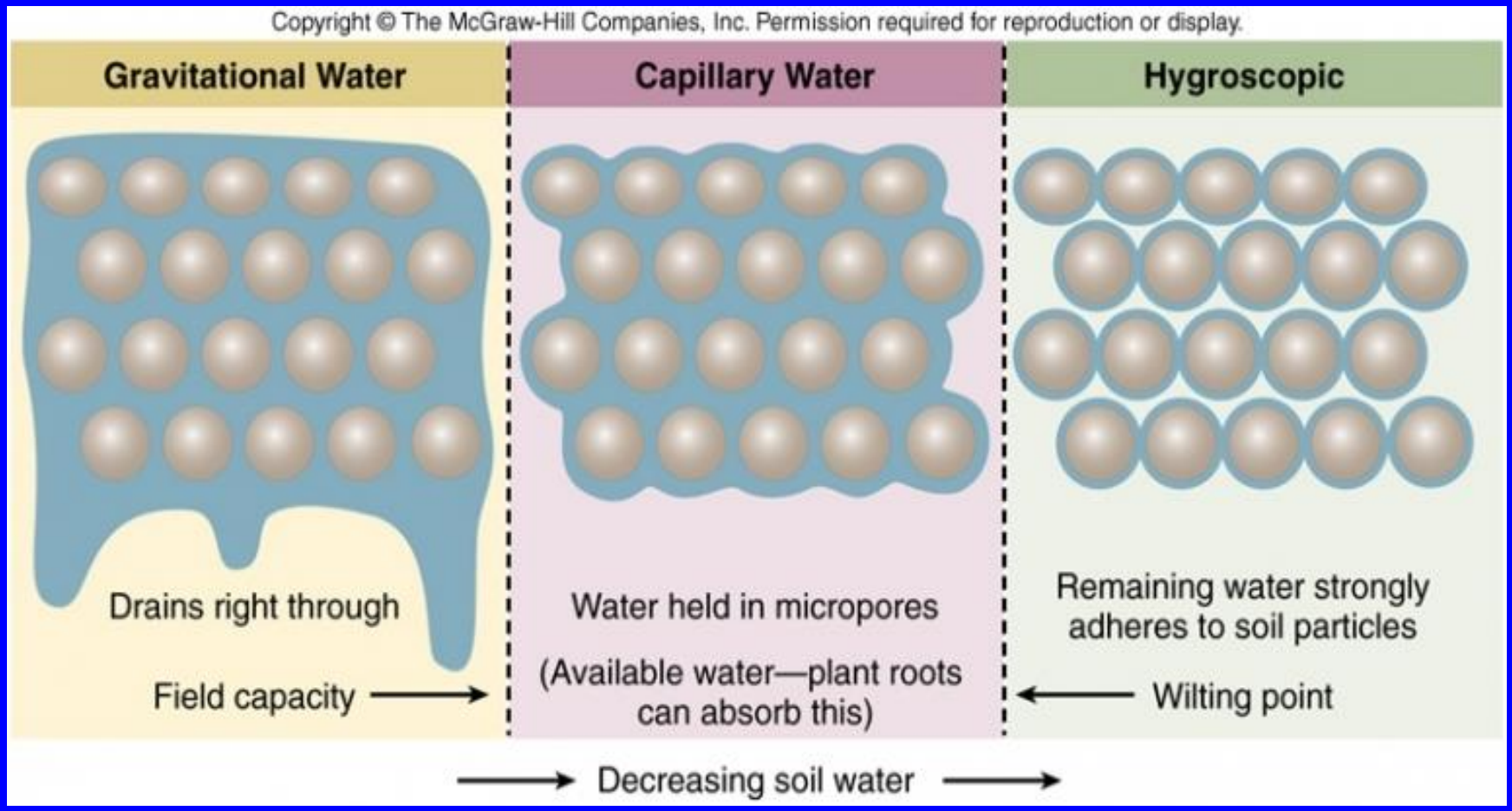
Hygroscopic water

Hygroscopic water is the water that held tightly on the surface of soil colloidal particle. It is essentially non-liquid and moves primarily in the vapour form.
Hygroscopic water held so tenaciously (31 to 10000 atmosphere) by soil particles that plants cannot absorb it. Some microorganism may utilize hygroscopic water. Hygroscopic water cannot be separated from the soil unless it is heated.

Factors affecting hygroscopic water:

1) Size of soil particles. The smaller the particle, the greater is the amount of hygroscopic water it adsorbs.

2) Soil Texture. Fine textured soils like clay contain more hygroscopic water than coarse - textured soils. The amount of clay and also its nature influences the amount of hygroscopic water.



Biological Classification of Soil Water

There is a definite relationship between moisture retention and its utilization by plants. This classification based on the availability of water to the plant.

1) **Available water**: The water which lies between wilting coefficient and field capacity. It is obtained by subtracting wilting coefficient from moisture equivalent.

2) **Unavailable water**: This includes the whole of the hygroscopic water plus a part of the capillary water below the wilting point.

3) **Super available or superfluous water**: The water beyond the field capacity stage is said to be super available. It includes gravitational water plus a part of the capillary water removed from larger interstices. This water is unavailable for the use of plants. The presence of super-available water in a soil for any extended period is harmful to plant growth because of the lack of air.

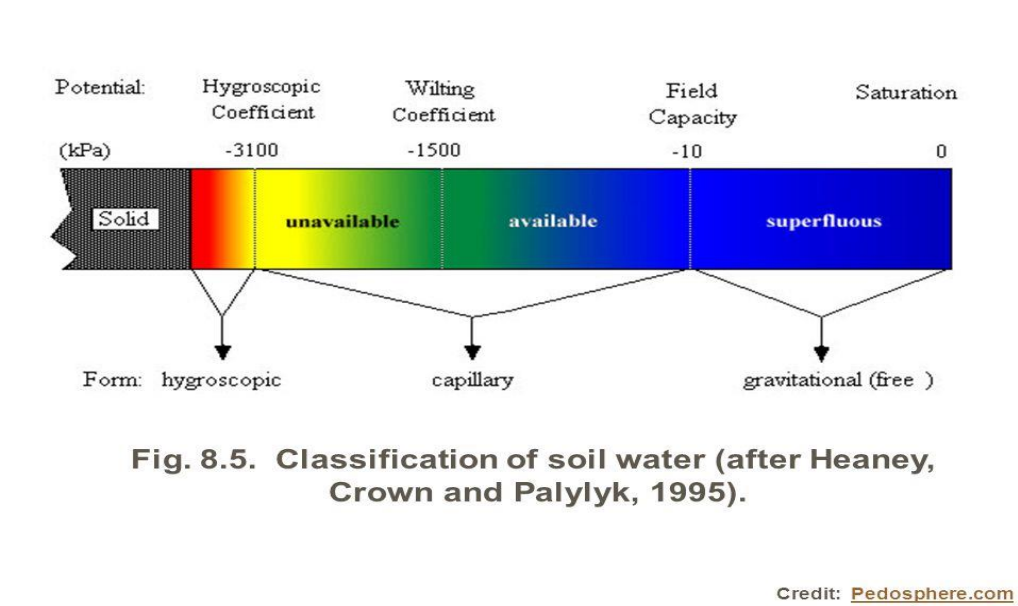


Fig. 8.5. Classification of soil water (after Heaney, Crown and Palylyk, 1995).

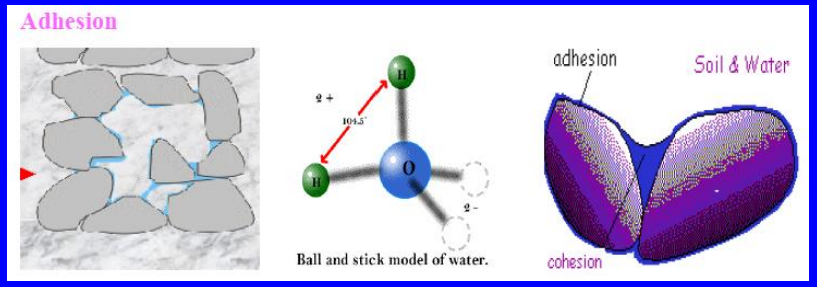
Credit: Pedosphere.com

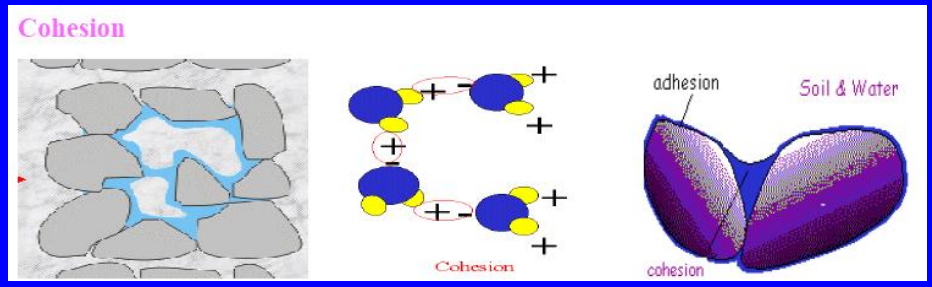
Retention of Water by Soil

The soils hold water (moisture) due to their colloidal properties and aggregation qualities. The water is held on the surface of the colloids and other particles and in the pores. The ***surface moisture tension*** is the forces responsible for retention of water in the soil after the drainage has stopped are due to surface tension and surface attraction. The ***suction*** is the force with which water is held.

The water retained in the soil by following ways:

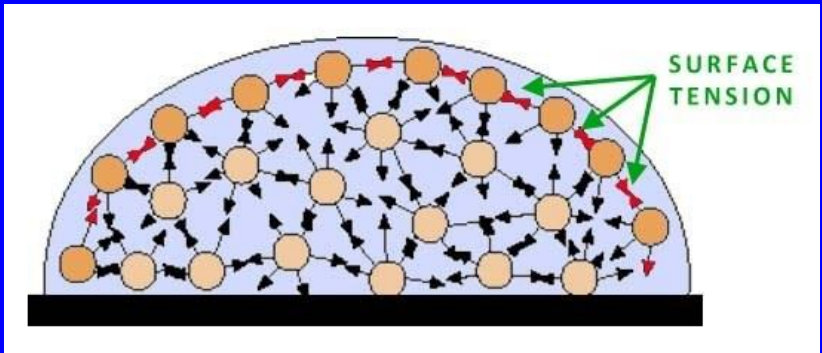
1. **Cohesion and adhesion forces**: These two basic forces are responsible for water retention in the soil. The cohesion is the attraction of molecules for each other. The adhesion is the attraction of water molecules for the solid surface of soil. By adhesion, solids (soil) hold water molecules rigidly at their soil - water interfaces. These water molecules in turn hold by cohesion. Together, these forces make it possible for the soil solids to retain water.

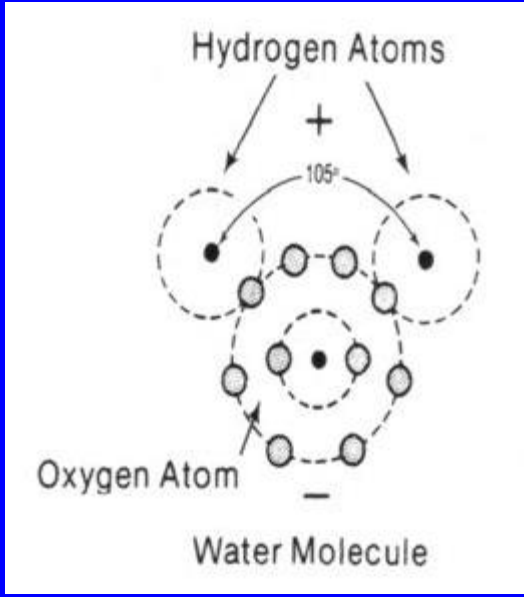




2. **Surface tension**: This phenomenon is commonly evidenced at water-air interfaces. Water behaves as if its surface is covered with a stretched elastic membrane. At the surface, the attraction of the air for the water molecules is much less than that of water molecules for each other. Consequently, there is a net downward force on the surface molecules, resulting in sort of a compressed film (membrane) at the surface. This phenomenon is called surface tension.

3. **Polarity or dipole character**: The retention of water molecules on the surface of clay micelle is based on the dipole character of the molecule of water. The water molecules are held by electrostatic force that exists on the surface of colloidal particles. By virtue of their dipole character and under the influence of electrostatic forces, the molecules of water get oriented (arranged) on the surface of the clay particles in a particular manner.





The water molecules attached to the clay surface present a layer of negative charges to which another layer of oriented water molecules is attached. The number of successive molecular layers goes on increasing as long as the water molecules oriented. As the molecular layer gets thicker, orientation becomes weaker, and at a certain distance from the particle surface the water molecules cease to orientate and capillary water (liquid water) begins to appear. Due to the forces of adsorption (attraction) exerted by the surface of soil particles, water gets attached on the soil surface. The force of gravity also acts simultaneously, which tries to pull it downwards. The surface force is far greater than the force of gravity so water may remain attached to the soil particle. The water remains attached to the soil particle or move downward into the lower layers, depending on the magnitude of the resultant force.

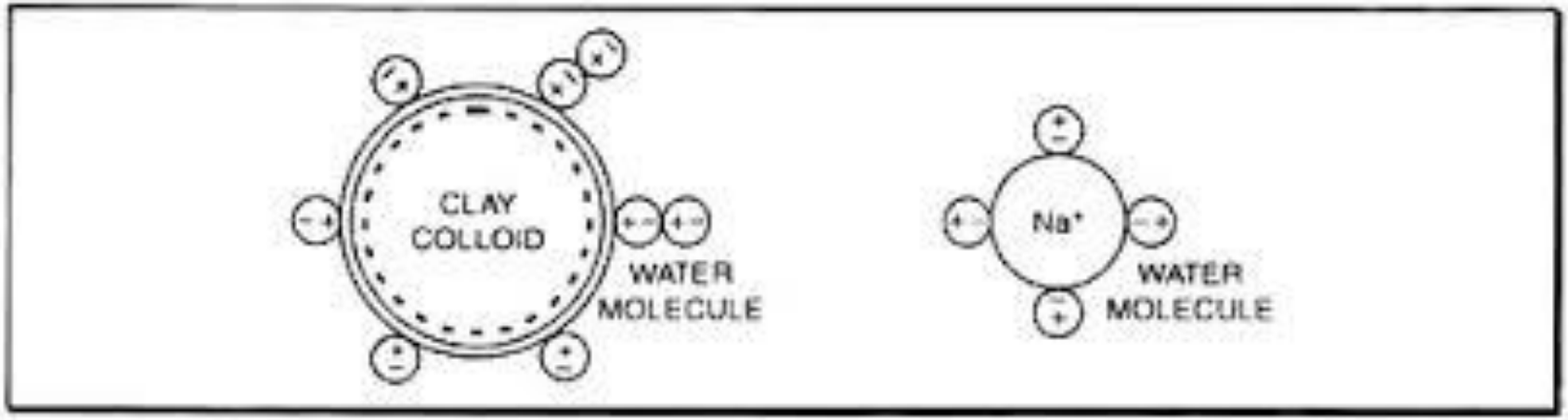


Fig. 4.1. Orientation of water molecules on the surface of clay micelle and cation.

Thank you for attention!