Water Dislodgment in the Soil

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● THE WATER in the soil, due to the existence of gradients of the principal forces, such as capillary and hydraulic, are in continuous movement, which takes place together with a total or partial dislodgment of the free water present in the soil by the entering water.

The possibility of dislodging the soil solution with the water (or with the solution) is well known in the literature since Schloesing (1). In the course of the last 100 years there have been proposed different variations (2-7). In all these variations the water (or solution, or some other dislodging liquid) fills all the pores of the upper part of the column, and, infiltrating under the hydrostatic pressure, dislodges mechanically the free water present in the soil. Hence, in order to separate the existing water in the soil a high column must be used. In order to reduce the porosity, Kriukov (6) recommends, in addition, to submit previously the soil to a high pressure.

It is evident that in the limit of two solutions a mixture will inevitably be formed due to mutual diffusion. The formation of a mixture will also be favored by the speed of the infiltration and by the structure of the pores.

A disperse system of fine and open pores would be ideal for the complete dislodgment of the free water present in the pores. The failure of many methods proposed formerly for the dislodgment of the soil solution is a consequence of the speed applied.

The dislodgment of the water that is not free (adsorbed) is possible by its substitution with some other miscible liquid, like ethyl alcohol. The dislodgment takes place not by a simple displacement of one liquid by another but by the diffusion of the adsorbed water in the displacing liquid. Liquids which do not mix with water (benzol, etc.) are incapable of dislodging the adsorbed water by the adsorbent and especially by the soil.

Leaving out the dislodgment by infiltration the dislodgment by the capillary movement is considered next. In the course of the capillary saturation the water does not completely fill the pores; therefore, it would be interesting to see to what degree of completeness the dislodgment occurs.

Straprens (8) showed that water in the sand at 3.3 percent moisture begins to move when the limit of capillary elevation is at a distance of 10 cm. This means that the capillary and film water in the sand at that moisture is displaced by the entering water at a distance of 10 cm.

If the sand is well mixed with 2 percent of the solution of a nonadsorbable dye (brom phenol green) and a tube is filled and placed for capillary rise, then the entering water dislodges the solution of the dye and pushes it to the extreme point of the upper part. For a tube 10 cm long, the dye accumulates in the upper part at 0 to 2 cm. This experiment shows that the water entering by capillary rise is capable of dislodging the free water that was present there before. To establish the totality of dislodgment a few experiments were made; these are described later.

Some authors (for instance, 9) think that it is difficult to establish the quantity of the dislodgeable water. Nevertheless, by starting from some evident assumptions the problem can be solved with sufficient approximation. To begin with, it may be supposed that the undislodgeable is also the adsorbed water and at the same time also that which does not dissolve the indicator whose solution is applied as a dislodging agent (for instance, KCl solution). Then, if the soil contains the dislodgeable water the chloride solution will diminish its concentration, and in the contrary case the KCl concentration will increase. Errors may occur if the undislodgeable but dissolving water for the indicator is contained therein. In this case the real volume of undislodgeable water
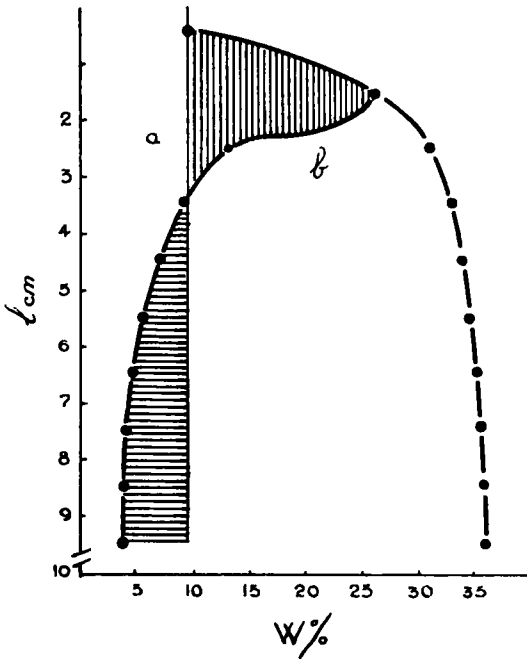
Figure 1. Water dislodgment by the capillary rise of 0.10 N KCl solution in the soil which contained 9.5 percent of water. Ordinate: 1—height of the soil column in cm; abscissa: W—water content in percent: a—water content before the capillary rise; (a + b)—water content after the capillary rise. Entered water—horizontal lines; dislodged water—vertical lines.

should be somewhat greater than calculated. Such an error would be of insignificant importance here, because in a soil of a 29 percent field capacity there would only remain a small percentage of dislodgeable water, as shown later.

Prairie soil with a field capacity of 29 percent and an exchange capacity of 37 me per g was passed through a sieve of 1mm. Different samples of this soil with a variety of moisture contents as well as different KCl contents were prepared. With these samples plastic tubes of ϕ = 2.5 and 10 cm long were filled with a homogeneous densification. Soil columns thus obtained were arranged for capillary rise of water or KCl solution. Thus, the soil water was dislodged by 0.10 N KCl and the KCl solution in its turn by the water.

Thereafter the capillary rise samples were taken at each height (every 1 cm of thickness) and the water and KCl contents made it possible to calculate the dislodgement for each height.

First of all, the possibility of obtaining the water (or the solution) without mixing with the solution (or water, respectively) entering by capillary rise was investigated. The following experiment shows that the major part of the water (or solution) that the soil contained was dislodged by the solution (or water) without forming any mixture.

The soil with a 9.5 percent content of water was put to capillary saturation with 0.1 N KCl. When the rise reached the surface, the water and KCl content of each cm of column was determined. The results of the calculations of dislodgment for each height are given in Figure 1.

These curves show that layer 0.5 - 1.5 cm contains the water that formerly existed in the soil. The following layers contain a mixture. A simple look at the displacement curve will give an idea about the amount of undislodgeable water, which should correspond or be equivalent to the adsorbed water. As is well known, the quantity of adsorbed water is a function of the concentration of the electrolyte in equilibrium. It may be as-
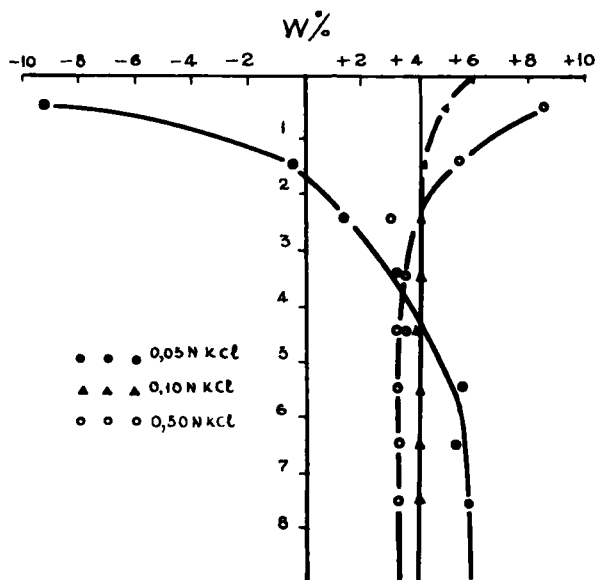
Figure 2. Water dislodgment by the capillary rise of KCl solutions: 0.05 N; 0.10 and 0.50 N in the soil which contained 4 percent of water. Ordinate: 1—height of th soil column in cm; abscissa: W—water content (without KCl solutions) after the capil lary rise. The negative and posite values give the water quantity with and without whic the electrolyte concentration would not change.
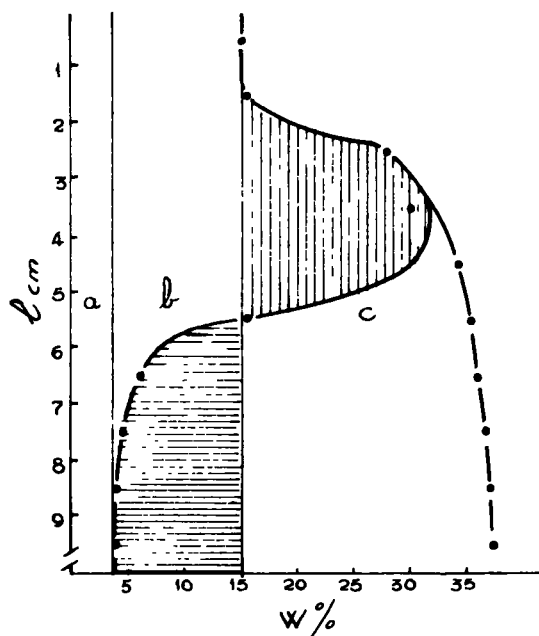

Figure 3. Water dislodgment by the capillary rise of 0.10 N KCl solution in the so which contained 15 percent of water. Ordinate: 1—height of the soil column in c abscissa: W—water content in percent: a—adsorbed water content; (a + b)—water co tent before the capillary rise; (a + b + c)—water content after the capillary ri Entered water—horizontal lines; dislodged water—vertical lines.
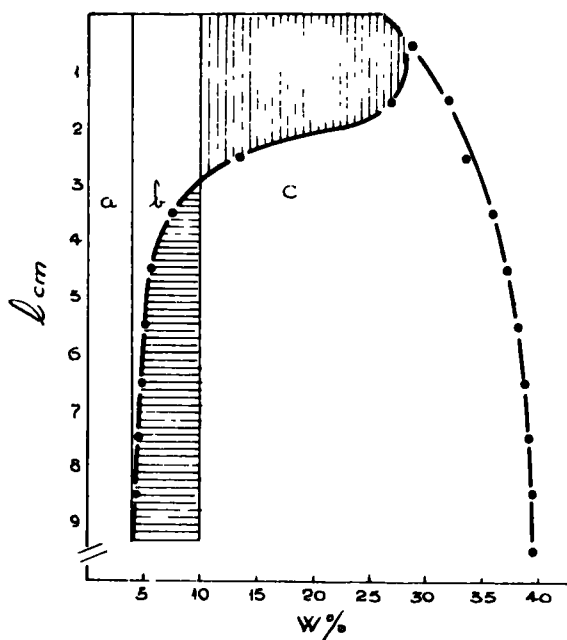
Figure 4. Water dislodgment by the capillary rise of water in the soil which contained 8 percent of water and 6 percent of 0.1 N KCl solution. Ordinate: 1—height of the soil column in cm; abscissa: W—water content in percent: a—adsorbed water content; (a + b)—water content before the capillary rise; (a + b + c)—water content after the capillary rise. Entered water—horizontal lines; dislodged water—vertical lines.

sumed that the amount of undislodgeable water will also be a function of the concentration of the electrolyte.

Experiments have shown effectively that the amount of undislodgeable water is a function of the concentration of the dislodging solution. Thus, when dislodging by the KCl solutions of 0.05 N, 0.10 N, and 0.50 N there were found in this Prairie soil the following quantities of undislodgeable water: 5.8, 3.8, and 3.2 percent.

Figure 2 gives the curves of dislodgment of the soil water (4 percent) by the solutions 0.05 N, 0.10 N, and 0.50 N of KCl. The negative and positive values give the water quantities with and without which the electrolyte concentration would not change. The obtaining of different quantities of the undislodgeable water, when applying the solutions of different osmotic pressures, confirms the idea of the existence of the polymolecular layers on the surface of the particles.

Figures 3 and 4 show the results of dislodgement of the water by KCl and, on the other hand, of the KCl solution by the water. By means of capillary rise all the free water in the soil can be dislodged and even a great part of it without forming a mixture.

Finally, Figure 5 shows the dislodgment by capillary rise in sand. According to Bondagovski (9), by infiltration 3 to 5 percent remains without being dislodged. By using a column of 9 cm of sand with a 5 percent 0.10 N solution of KCl it was possible to dislodge this almost completely by capillary rise of water.

The method of dislodgment can also be used to calculate the change of free energy (Gibbs energy) in function of water content because the osmotic pressure makes such calculations possible.
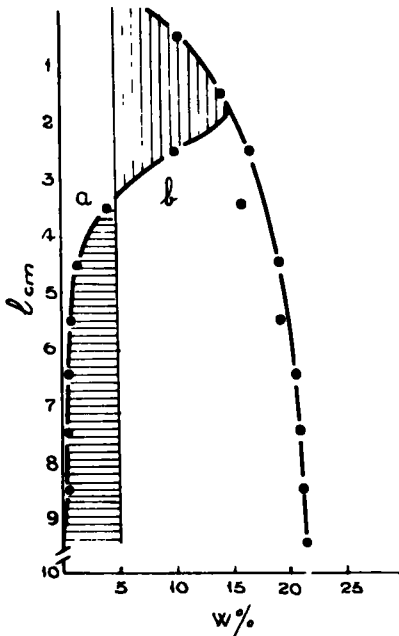
Figure 5. Water dislodgment by the capillary rise of water in the sand, which contained 5 percent of 0.1 N KCl solution. Ordinate: 1—height of the soil column in cm; abscissa: W—water content in percent; a—solution content before the capillary rise; (a + b)—solution and water content after the capillary rise. Entered water—horizontal lines; dislodged water—vertical lines.

SUMMARY

1. The capillary movement of water in the soil is accompanied by complete dislodgement of the free water present in the soil.

2. The dislodged water mixes partially with entering water and one part is left without forming any mixture being detained on the wetting front.

3. The amount of undislodgeable water is a function of the concentration of the electrolyte in equilibrium.

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