RELATION BETWEEN HEAT OF WETTING, MOISTURE EQUIVALENT AND UNFREE WATER

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INTRODUCTION

Water is one of the best indices of the physical characteristics of soil. Texture, structure, colloidal and organic contents, activation of surface, etc., tend to be revealed by the behavior of the soil toward water. Heat of wetting, moisture retentiveness, unfree water, etc., are mainly the resultant and expression of these characteristics.

The question of the relationship of these various soil-water manifestations to each other is obviously of much interest. If the relationship is of positive nature, then it is also of considerable practical importance, because in that case the simplest, most convenient and rapid method could be selected to obtain the other relationships and to make a comparative study of soils.

With these objects in view a comparative study was made of the relationship that exists between a number of soil-water manifestations, but principally those of heat of wetting, moisture-equivalent and unfree water.

METHODS AND PROCEDURE

The heat of wetting was determined according to the method described in a former publication (2).

It consisted of placing about 50 gm. of air-dry soil in a wide glass tube and allowing it to dry in an electrically heated oven at a temperature of 105°C. for about 24 hours. The tube was then taken out, closed with a rubber stopper and allowed to attain the room temperature. After the exact weight and temperature were ascertained, the soil was quickly and carefully poured into a calorimeter containing 100 gm. of water and the heat of wetting was ascertained. Extreme care was taken before mixing to have both the soil and water at exactly the same temperature and very nearly that of the room temperature. In order to be able to convert, if necessary, the rise of temperature into heat calories, the water-equivalent of the calorimeter was determined. This was found to be 25 gm. of water. The specific heat of soils was about .200 for the mineral soils and about .300 for the organic soils.

The unfree water was measured by means of the dilatometer method already described (1) with the modification of washing the soils free of soluble salts before their unfree water was measured. This was done in order to eliminate any effect of soluble salts on the unfree water. Two different moisture contents were employed for each soil, one was at about the optimum stage and the other at the proportion of 20 gm. of soil to 15 cc. of water. Before the final measurement was made, the soils were subjected to freezing and thawing once or twice. The soils were then placed at a temperature of $-1.5^{\circ}\text{C}.$ and allowed to come to equilibrium and the volume on the dilatometer stem recorded. They were then immersed at a temperature of about $-12^{\circ}\text{C}.$ for about fifteen minutes, and then returned to the original temperature.

After equilibrium was attained, the volume on the dilatometer stem was again read and from the two readings the unfree water could be calculated. The term unfree water is used in this paper to designate the soil water remaining unfrozen at the temperature of slightly below zero. All the water which freezes very readily at or very near zero is designated as free water. The free water is beyond the direct influences of the soil and freezes like water in mass, while the unfree water is under the direct influences of the soil and consequently is not at liberty to freeze as the free water.

For the moisture-equivalent the Briggs-McLane apparatus was used. The machine was regulated to run at a speed of about 2450 revolutions per minute and was allowed to run for 40 minutes. Thirty grams of the finer textured types of soil were used, 30 gm. of sand, and 10 to 15 gm. of the peats and muck.

RESULTS

The experimental results obtained on the heat of wetting, unfree water and moisture equivalent on a number of different types of soils, and the relationship that exists between these different soil-water manifestations, are shown in the adjoining table.

There is a rather close relationship in the various soils between the unfree water and the heat of wetting. The ratio ranges only from 0.0408 in soil 20 to 0.0675 in soil 1 with an average ratio of 0.05305 for all of the soils.

It would appear that there is a tendency for soils with much organic matter to give a smaller ratio than soils with very little or no organic matter. But the organic matter content, cannot be entirely responsible for this difference because peat and muck which represent the extreme organic soils have a ratio as large as the mineral soils with no or very little organic matter. A more satisfactory explanation for the difference seems to be found in the hypothesis that among soils causing about the same amount of water to become unfree, some possess a more activated surface, which results in more heat of wetting. Experimental results along this line will be presented in greater detail in a subsequent paper.

Considering next the ratio of moisture-equivalent and heat of wetting it is seen that there is not a very close relationship between these two factors in the various soils. The ratio ranges from 0.0953 in soil 20 to 0.3233 in soil 5 with an average ratio of 0.1685 for all of the soils. The ratio is quite close in many of the soils, but in others it varies considerably.

It is not surprising that there is no closer relationship between the heat of wetting and moisture-equivalent, because besides the naturally different specific properties of the various soils which would affect these two factors differently, the moisture-equivalent method does not give a true and an exact equivalent of moisture for all soils. In very fine textured and colloidal soils which allow the water to get out only with much difficulty and especially when compacted by centrifuging, the moisture-equivalent is considerably greater than it should be in comparison with that in coarse textured and porous soils. In some of the clay soils, for instance, the moisture-equivalent is as much as 25 per cent above what it should be. Results obtained by the

freezing point method indicate that with some soils the moisture-equivalent obtained is true but with others it is too high. When the moisture-equivalent, therefore, is not absolutely true in all of the different soils, its relationship with the heat of wetting would tend to vary accordingly. But even if the moisture-equivalent, were absolutely true in all the soils, probably its rela-

TABLE 1
Relationship between heat of wetting, unfree water and moisture-equivalent

SOIL NUMBER	SOIL TYPE	HEAT OF WET- TING	UN- FREE WATER	MOIST- URE EQUIV- ALENT	U.W.* H.W.	M.E.† H.W.	M.E.‡ U.W.
		°C.	per cent	per cent			
1	Sand.....	0.2	1.35	3.8	0.0675	0.1900	2.815
2	California Handford sandy loam.....	0.8	5.2	15.0	0.0650	0.1875	2.885
3	Ohio silt loam.....	0.7	4.6	21.8	0.0657	0.3114	4.740
4	Ohio silt loam.....	0.7	3.6	21.3	0.0437	0.3043	5.917
5	Cornell silt loam.....	0.9	5.25	29.1	0.0583	0.3233	5.541
6	Pennsylvania silt loam.....	0.9	5.0	28.9	0.0555	0.3211	5.780
7	Pennsylvania silt loam.....	1.1	7.0	29.2	0.0636	0.2655	5.600
8	Rhode Island sandy loam.....	1.1	6.0	21.7	0.0545	0.1972	3.617
9	Michigan silt loam.....	1.65	10.20	25.5	0.0618	0.1546	2.500
10	Wisconsin Superior clay.....	1.95	10.75	28.2	0.0548	0.1446	2.635
11	California Capay clay.....	2.0	11.1	33.5	0.0555	0.1675	3.020
12	Michigan clay loam.....	2.2	13.6	30.2	0.0618	0.1373	2.221
13	California Willows clay.....	2.2	12.9	32.2	0.0586	0.1464	2.496
14	Minnesota Clyde silt loam.....	2.55	11.0	29.8	0.0431	0.1170	2.710
15	Minnesota black surf.....	2.85	14.0	36.5	0.0491	0.1281	2.607
16	Illinois clay loam.....	2.9	15.2	36.3	0.0524	0.1252	2.338
17	Minnesota Fargo clay.....	3.0	16.0	39.0	0.0533	0.1300	2.438
18	Iowa Carrington clay loam.....	3.4	16.0	36.5	0.0472	0.1074	2.282
19	Illinois clay loam.....	3.5	14.3	35.8	0.0408	0.1023	2.504
20	Illinois black clay loam.....	3.5	14.7	34.0	0.0420	0.0971	2.313
21	California Merced clay.....	4.0	17.8	40.2	0.0445	0.1005	2.258
22	California Stockton clay adobe.....	4.1	18.7	49.5	0.0456	0.1207	2.647
23	Wisconsin black clay loam.....	4.9	20.9	46.7	0.0426	0.0953	2.235
24	Muck.....	8.0	37.0	95.5	0.0462	0.1194	2.581
25	Muck.....	12.6	67.0	147.0	0.0532	0.1167	2.194

* Percentage of unfree water divided by rise of temperature of 50 gm. of soil in 100 gm. of water.

† Moisture-equivalent divided by rise of temperature of 50 gm. of soil in 100 gm. of water.

‡ Moisture-equivalent divided by percentage of unfree water.

tionship with the heat of wetting would not be exceedingly close in the various soils, because the two factors are affected differently by soil properties and conditions.

It was originally thought that there might be a rather close relationship between the heat of wetting and moisture-equivalent since both factors were considered to be controlled principally by three properties, namely, texture, colloidal and organic matter content. It is evident from the experimental

results obtained, however, that there is at least one more property coming into play which affects the results appreciably, namely the activation or nature of the surface.

The ratio between the unfree water and the moisture-equivalent shows that there is not a very close and consistent relationship between the two factors. The ratio ranges from 2.194 in soil 25 to 5.917 in soil 4 with an average ratio of 3.1456.

Comparison of the three ratios with one another shows, also, that there is no very close and consistent parallelism or relation between any two ratios.

SUMMARY

In this paper are presented the results of an investigation conducted to ascertain the relationships that exist between heat of wetting, unfree water, and moisture-equivalent of soils. The experimental results show that there is a close and consistent relationship between the heat of wetting and the unfree water, but there appears to be no close and regular relationship between the heat of wetting and moisture-equivalent or between unfree water and moisture-equivalent.

Evidences obtained go to indicate that the moisture-equivalent method does not give a true and absolutely equivalent moisture in all of the various soils. Some of the fine textured and colloidal soils contain considerably more moisture than their true moisture-equivalent.

REFERENCES

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