HYSTERESIS IN SORPTION

XVI. Sorption of Water on Some Indian Soils and Soil Fractions

BY MISS SHARDA GULVADY,* K. SUBBA RAO‡ AND B. SANJIVA RAO,§ F.A.SC.
(Department of Chemistry, Central College, Bangalore, S. India)

Received January 6, 1947

INTRODUCTION

THE problem of retention of moisture by soils has been extensively studied by numerous workers. Recent investigations on the phenomenon of Hysteresis in sorption[3] have thrown much light on the porous structure of rigid and elastic adsorbents. With a view to investigate the porous structure of soils, a study of hysteresis was undertaken with reference to the sorption of water on a red laterite soil and black cotton soil and on the clay, silt and fine sand fractions of the soils. The decrease in sorptive capacity of the soils on the removal of organic matter has been studied.

EXPERIMENTAL

Mechanical analysis of soils.—According to the International Society of Soil Science, soil passing through a 2 mm. sieve called "Fine earth" is divided into the following four fractions—coarse sard (2–0·2 mm.), fine sand (0·2–0·02 mm.), silt (0·02–0·002 mm.) and clay (less than 0·002 mm.). The international method A was employed for resolving the soil into these fractions.[9] In place of ammonia, sodium hydroxide was used as the dispersing agent.

Estimation of organic matter in the soil.—For the estimation of organic matter in the soil, the new modified volumetric method using chromic acid[6,7,8] was adopted. The results of the mechanical analysis of the two soils are given in Table I. The accuracy of the method is 2%.

Activation of the soil and soil fractions.—Soil particles passing through 20-mesh sieve but retained by 30-mesh sieve were used. In the case of soil fractions, the dry powder passing through 100-mesh sieve was used. The samples were activated by heating to 80° C. for 6 hours in vacuum obtained by the Cenco hyvac pump.

* Research Scholar, Indian Institute of Science, Bangalore.
‡ Senior Research Fellow of the National Institute of Sciences of India.
§ Principal and Professor of Chemistry, Central College.

TABLE I

Mechanical fractions	Fractions of red soil per 100 gm. soil	Fractions of black cotton soil per 100 gm. soil
	gm.	gm.
Coarse sand ..	40·6	5·2
Fine sand ..	22·6	45·5
Silt ..	2·9	15·5
Clay ..	30·7	33·9
Organic matter ..	0·25	0·63

Sorption and desorption of water vapour.—The quartz fibre spring technique[3] was employed in the study of sorptions and desorptions of water vapour on the soils and soil fractions. A suitable amount of the activated adsorbent was placed in the bucket. The adsorbent was degassed by evacuation for 6 hours at 10^{-2} mm. A series of sorptions and desorptions of water vapour at 30° C. was conducted. The results are indicated in Figs. 1 and 2.

The sorptive capacities (for water vapour at saturation pressure) of red laterite soil and black cotton soil before and after treatment with

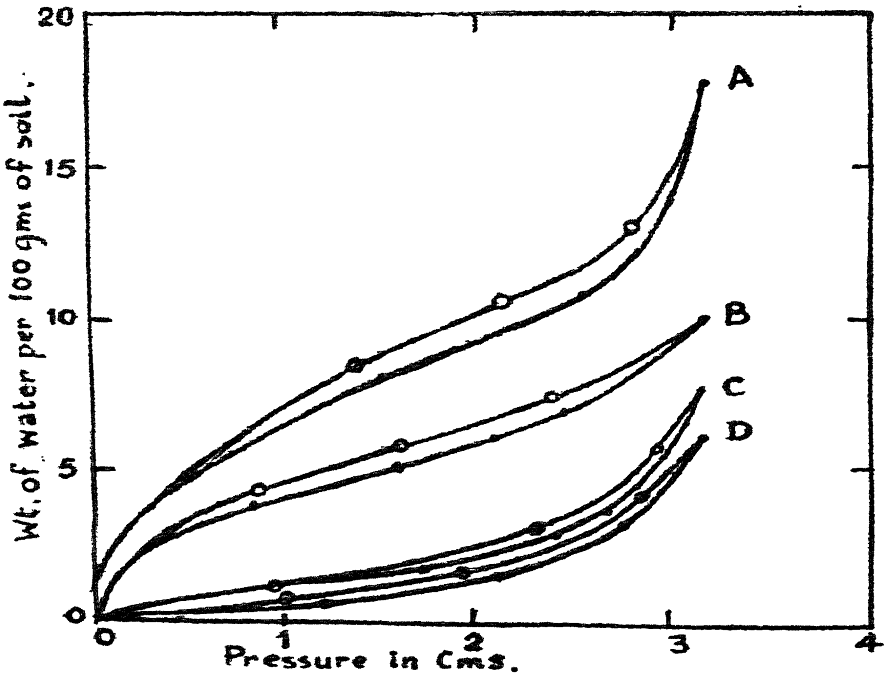

FIG. 1

Sorption and desorption of water vapour on

A. Black cotton soil with organic matter (3rd cycle).
B. ,, ,, without organic matter (2nd cycle).
C. Red soil with organic matter (3rd cycle).
D. ,, without organic matter (2nd cycle).

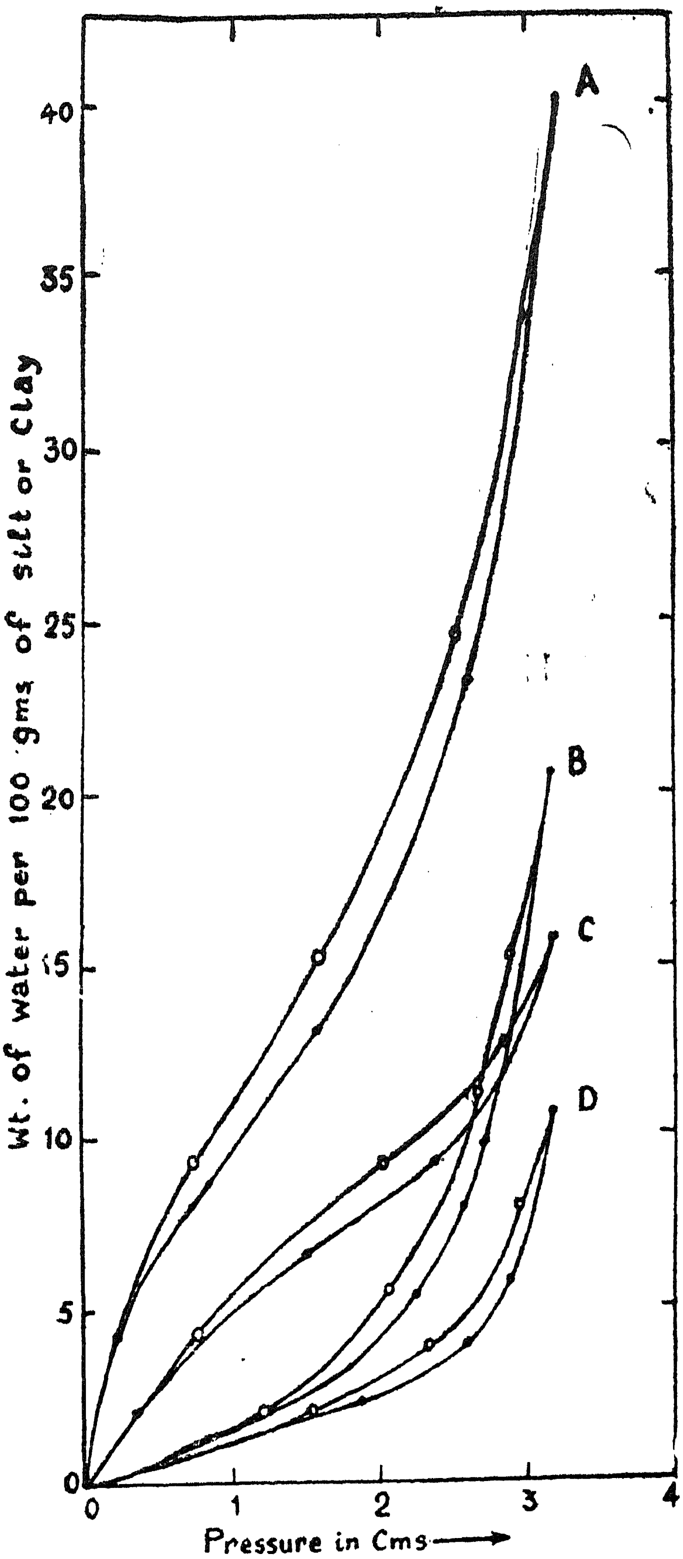

FIG. 2

Sorption and desorption of water vapour on

A. Clay from black cotton soil (2nd cycle).
B. Clay from red soil (2nd cycle).
C. Silt from black cotton soil (2nd cycle).
D. Silt from red soil (2nd cycle).

hydrogen peroxide and of their fractions—clay, silt and fine sand—are given in Table II.

TABLE II

Soil and soil fractions	Red soil. Sorption of water per 100 gm.	Black cotton soil. Sorption of water per 100 gm.
	gm.	gm.
Soil with organic matter ..	8·0	18·0
Soil without organic matter ..	6·2	9·9
Fine sand ..	0·4	0·5
Silt ..	11·2	15·8
Clay ..	21·5	40·6

From the percentage of the various fractions of the soil and their sorptive capacities for water at saturation pressure, total sorption contributed by the various fractions in 100 gm. of soil has been calculated. This in relation to the sorption of the original and hydrogen peroxide treated soils has been indicated in Table III.

TABLE III

Red soil and its fractions	Sorption of water	Black cotton soil and its fractions	Sorption of water
Red soil original ..	8·0 %	Black cotton soil original	18·0 %
Red soil treated with hydrogen peroxide ..	6·2 %	Black cotton soil treated with hydrogen peroxide	9·9 %
Fine sand (22·6 gm. at 0·4%) .. 0·09 Silt (2·9 gm. at 11·2%) .. 0·33 Clay (30·7 gm. at 21·5%) 6·6	7·02%	Fine sand (45·5 gm. at 0·5%) .. 0·23 Silt (15·5 gm. at 15·8%) 2·45 Clay (33·9 gm. at 40·6%) 13·76	16·44%

DISCUSSION

The sorptive capacities of red laterite soil and black cotton soil at the saturation pressure of water are 8 gm. and 18 gm. respectively per 100 gm. of activated soil. The difference in sorptive capacities is obviously due to several factors such as difference in chemical composition, soil fractions, organic matter and soil structure.

As is to be expected, removal of organic matter of the soil by treatment with hydrogen peroxide reduces the sorptive capacity of the soil for water. The red soil had 0·25% organic matter while the black cotton soil had 0·63%. On removal of organic matter, red soil suffered a decrease in sorptive capacity from 8·0% to 6·2% and black cotton soil from 18·0% to 9·9%. The effect of a given amount of organic matter on pore space seems to depend on the nature of the constituents of the soil. The exact picture of the spatial distribution of the organic matter in soils is obscure.

The sorptive capacity of fine sand is negligibly small, while that of silt is much higher. Clay has markedly higher sorptive capacity than silt. The increase in sorptive capacity from fine sand to silt and from silt to clay is more marked in the black cotton soil than in the red soil. It is noteworthy that clay from black cotton soil takes up nearly twice the amount of water sorbed by clay from the red soil. Similarly, silt from the black cotton soil takes up more water than that from red soil, Table II and Fig. 2.

Knowing the percentage of the three soil fractions—fine sand, silt and clay and their sorptive capacities it is possible to calculate the total sorption of water as contributed by the three fractions, Table III. In red soil, total sorption of water due to these fractions in 100 gm. of soil is 7·02 gm. whereas those of the original and hydrogen peroxide treated soils are 8·0% and 6·2% respectively. The total value contributed by the component fractions is intermediate between those of the original and hydrogen peroxide treated soils. In the case of the black cotton soil, the total sorption contributed by the fractions is 16·44 gm. This value is also intermediate between sorption by the original soil (18·0%) and hydrogen peroxide treated soil (9·9%).

In all the systems investigated, permanent and reproducible hysteresis loops have been obtained. This indicates that unlike elastic adsorbents like rice,[1] gum arabic,[2] and proteins,[5] the soils and their fractions are rigid porous systems, having cavities with constricted ends which are responsible for the hysteresis effect. The soils thus retain more of water during desorption than during sorption.

Soil in nature is periodically exposed to extremes of weather—very dry and highly humid. By virtue of the rigidity of its structure, a soil subjected to extremes of weather, when changed from highly humid condition to one of normal humidity retains greater amount of water than what it would hold when changed from very dry weather. This excess of water amounting to about 1% may be negligible when soil is saturated with water in highly humid weather but is appreciable in weather of normal humidity in which water holding capacity of the soil is less than half. For example at 50% humidity, red soil holds only 2% water. Compared with this, the excess 0·5% water-entrapped in the cavities is quite considerable. It is probable that the hysteresis effect exhibited by soils is of practical importance in the conservation of moisture by soils in nature.

Summary

Studies in sorption and desorption of water vapour at 30° C. on red laterite soil and black cotton soil and their fractions—fine sand, silt and

clay have been carried out. Sorptive capacity of fine sand is found to be very small. That of silt is higher. Clay fractions have the highest sorptive capacity. Removal of organic matter lessens the sorptive capacity of the soil.

The soils and their fractions have all yielded permanent and reproducible hysteresis loops. There is thus evidence that in soils we are dealing with rigid systems having cavities with constricted ends. The practical importance of the hysteresis effect in soils in nature is indicated.

References

1. Rao, K. S. .. *Current Science*, 1939, **8**, 256.
2. ———— .. *Ibid.*, 1940, **9**, 19.
3. ———— .. *J. Phys. Chem.*, 1941, **45**, 500.
4. ——— and Rao, B. S. .. *Proc. Ind. Science Congress*, 1942, 3, 67.
5. Rao, G. N. S., Rao, K. S., and Rao, B. S. "Hysteresis in Sorption, XV," *Proc. Ind. Acad. Sci.*, 1947, **25**, 221.
6. Tiurin, I. V. .. *Pedology*, 1931, **26**, 36–37.
7. ———— .. "Genesis Cartogr Soils Dokuchaieve Soil Inst," *Acad. Sci., U.S.S.R.*, 1935, 139–58.
8. Waksman .. *Humus*, Bailliere, Tindall and Cox, London, 1936, 404–05.
9. Wright, C. H. .. *Soil Analysis, Physical and Chemical Methods*, Thomas Murby & Co., London, 1934, 33.