Evaluation of the Capacity of Phosphorus Fixation by the Soil through the Isotopic Exchange, Using $_{15}P^{32}$

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INTRODUCTION

Fixation is a generic word used to designate the transformation of soluble soil phosphate forms into insoluble ones. Any phenomenon that causes a decrease in the orthophosphate ion concentration in a solution in contact with the soil, is responsible for the fixation.

Many anthors (DEAN, 1949; KURTZ, 1953; OLSEN, 1953; HEMWALL, 1952; CATANI & PELLEGRINO, 1957; CATANI & GALLO, 1957; HSU & JACKSON, 1960; WRIGHT & PEECH, 1960) agree that in soils having much iron and aluminum, phosphorus shows a tendency to bind to those elements. In other words, both iron and aluminum compounds (hydrated oxides) present in the soil, are the main reponsible for the phosphorus "fixation".

In some soils of the State of São Paulo (Brazil) where both iron and aluminun hydrated oxides occur in relatively high levels, the phosphate is fixed in appreciable quantity (CATANI & PELLEGRINO, 1960).

All the methods of evaluation of phosphorus fixation capacity by the soil are conventional and furnish variable results, according to the work conditions. JACKSON (1958), describes several methods for determining the phosphate exchange capacity of soils.

The amount of phosphorus fixed by a soil, depends on a series of factors, as: phosphate concentration in the solution, solution pH, reacting time, temperature, relation between the weight of the soil sample and the volume of the solution, and physico-chemical characteristics of the soil itself.

The aim the present work is the evaluation of "fixation" capacity of some soils of the State of São Paulo (Brazil) by means of the isotopic exchange technique, using radioative phosphorus ${}_{15}P^{32}$.

2 — MATERIAL AND METHODS

The material is made up of eight soil sample and the mechanical and physical-chemistry characteristics of which are presented in tables 1 and 2.

TABLE 1

Mechanical characteristic of the soils studied.

Soil number	% sand	% silt	% clay
1 (arenito Bauru)	56,5	36,0	7,5
2 (" ")	47,5	47,5	5,0
3 (Massapé)	17,3	66,9	15,8
4 (")	18,3	60,4	21,3
5 (Terra roxa)	33,3	16,5	50,2
6 (" ")	27,3	27,7	45,0
7 (" ")	35,6	28,0	38,4
8 (" ")	34,6	22,0	43,4

The method used consisted in the saturation of the soil with phosphate through percolation of a 0.1 normal H_3PO_4 solution, washing the excess of phosphoric acid and bringing the soil, saturated of phosphate, in contact with a solution of ${}_{15}P^{31}$ and ${}_{15}P^{32}$, having know specific activity. After a certain time had elapsed, ${}_{15}P^{31}$ and ${}_{15}P^{32}$ were determined and the final phosphorus specific activity of the solution was calculated. At last the ${}_{15}P^{31}$ bound to the solid phase, which represents the fixed phosphorus, was calculated.

The procedure used was the following:

Two grams of soil, air dried and passed through a 2 mm mesh sieve, were transferred to percolating tubes 1.5 cm in diameter and 25 cm high. The tubes were adapted to vacuun filtering flasks and 50 ml of 0.1 normal H_3PO_4 solution was percolated through the soil in the tubes. After the phosphoric acid solution had run through, the soil was leached five times with 10 ml volumes of 80% ethyl alcohol solution an then, the soil was transferred to 250 ml Erlenmeyer flasks. Fifty ml of 0.005 normal H_3PO_4 solution, containing radioactive phosphorus, which had about 2000 cpm/ml were added to the Erlenmeyer, and the flask was shaked for 30 minutes at 30-40 rpm.

The solution of phosphoric acid was allowed to stay in contact with the soil from 30 minutes to 40 hours. Five drops of chlroroform were added to each Erlenmeyer to hinder the action of the soil microorganisms whick could cause the loss of phosphate. When the soil was kept in contact

TABLE 2

Physico-chemical characteristics of the soils studied.

N.º	pH	C %	N %	PO_4^{-3}* m e.%	K m e.%	Ca^{+2} m e.%	Mg^{+2} m e.%	H^+ m e.%	Fe_2O_3 %	Al_2O_3 %
1	6.60	0.62	0.13	0.29	0.20	3.75	0.70	1.61	2.50	3.20
2	5.85	0.45	0.08	0.13	0.23	0.49	0.23	3.13	2.70	3.90
3	5.20	1.23	0.20	0.06	0.23	1.98	0.68	2.60	4.90	12.40
4	4.90	1.37	0.21	0.07	0.11	1.88	0.43	3.84	5.60	13.80
5	5.40	1.08	0.16	0.06	0.23	1.98	0.68	2.60	26.20	20.20
6	6.30	1.01	0.17	0.11	0.20	7.17	1.51	1.77	30.40	23.30
7	6.75	1.10	0.18	0.22	0.18	9.99	2.05	3.39	27.20	21.30
8	6.50	1.32	0.21	0.17	0.30	10.28	1.82	1.04	28.20	20.40

(*) Phosphate soluble in 0.05 normal H_2SO_4 solution.

with the solution for 16 and 40 hours, it was shaked again for 30 minutes at 30-40 rpm before filtering.

After shaking, for every case, it was filtered and in the filtrate the determination of both the radioactive and common phosphorus was performed.

Determination of the Number of Countings per Minute in the Solution

Two ml of solution from each soil treatment, were transferred to appropriate capsules and after drying its content, the number of desintegration per minute was determined (five determination and the background counting was taken care of). At the same time, a counting was performed in 2 ml (after drying) of 0.005 normal H_3PO_4 solution containing ${}_{15}P^{32}$, which was used to put in contact with the soil.

Photocolorimetric Determination of Phosphorus

Five ml of the filtrate were transferred to 50 ml volumetric flask and the phosphorus determination was performed by the phosphovanadomolibdic acid method, as it was described in a previous work (CATANI & PELLEGRINO, 1960).

Calculation of the amount of phosphorus fixed

The calculation of the amount of phosphorus fixed was performed based on the expression:

$$X = \frac{a_1 c}{a_2} - c$$

a_1 = specific activity of phosphorus in the solution berofe entering in contact with the soil.

a_2 = specific activity of phosphorus in the solution after entering in contact with the soil.

c = number of milligrams equivalent of PO_4^{-3} in the solution before entering in contact with the soil and calculated per 100 g of soil.

X = number of milligrams equivalent of phosphate (PO_4^{-3}) fixed by 100 g of soil.

3 — RESULTS AND DISCUSSION

The results obtained for the amounts of phosphorus fixed, performed by isotopic exchange, varying the time of contact of the solution containing radioactive phosphorus with the soil, are shown in table 3.

TABLE 3

Fixation of the anion phosphate expressed in milligrams equivalent of PO_4^{-3} per 100 g of soil, determined by isotopic exchange.

Soil number	Time of contact of the solution with the soil for the isotopic exchange.		
	1/2 hour m e.PO_4^{-3} per 100 g of soil	16 hours m e.PO_4^{-3} per 100 g of soil	40 hours m e.PO_4^{-3} per 100 g of soil
1 (Podzolic sandy soil)	1.25	1.69	1.72
2 (Podzolic sandy soil)	1.22	1.41	0.99
3 (Podzolic clayey soil)	1.94	3.32	3.19
4 (Podzolic clayey soil)	2.85	4.11	4.84
5 (Latosolic clayey soil)	4.76	8.75	7.69
6 (Latosolic clayey soil)	7.44	14.88	13.57
7 (Latosolic clayey soil)	6.51	8.54	8.63
8 (Latosolic clayey soil)	6.25	7.28	8.06

The data from table 3 show that under the conditions of the present work, after 16 hours of contact of solution, which contains radioactive phosphorus, with the soil, the phenomenon of isotopic exchange has actually already reached equilibrium. Thus, while the halfhour period of soil-solution contact was insufficient for the isotopic exchange phenomenon, the 40 hours period offered data similar to the ones obtained in the 16 hours period of contact.

The samples *1* and *2* are sandy soils and relatively poor in hydrated oxides of iron and aluminum. As can be seen by data from table 3, the soils under consideration, have low phosphorus fixation capacity.

The samples 5, 6, 7 and 8 are clayey and relatively rich in iron and aluminum hydrated oxides. The data show that these soils fixed a relatively high amount of phosphorus.

At last, the samples 3 and 4 are clayey and have a medium level of iron and aluminum hydrated oxides. Phosphorus fixation shows intermediate values among sandy soils and clayey soils both rich in iron and aluminum hydrated oxides.

One can see therefore, that the isotopic exchange between the radioactive phosphorus contained in a solution and the phosphorus in the soil, previously saturated with phosphate, allows to stablish a simple and direct method for the determination of the phosphorus fixation capacity by the soil. Besides, it is a method based on a principle equivalent to the one BLUME & SMITH (1954) used for the determination of cation exchange capacity, through the saturation of soil with calcium and posterior isotopic exchange with radioactive calcium.

4 — SUMMARY AND CONCLUSIONS

The present work reports a method of determining the soil capacity of fixing phosphate, based on isotopic exchange which take place when a soil, previously saturated with phosphate, is brought in contact with a solution containing radioactive phosphorus.

Thus, 2 grams of soil, put in percolating tubes, are treated with 50 ml of 0.1 normal H_3PO_4 solution in order to saturate the soil with phosphate. After removing the H_3PO_4 excess, by leaching with hidro-alcoholic solution, the soil was transferred to a 250 ml Erlenmeyer flask which contained 0.005 normal H_3PO_4 solution plus radioactive phosphorus. After shaking and allowing to be in contact (the soil and solution) for 1/2 hour, 16 hours and 40 hours, samples of the liquid were withdrawn for the determination of both ordinary and radioactive phosphorus.

The amount of phosphorus fixed was calculated using the expression:

$X = \dfrac{a_1 c}{a_2} - c$, where a_1 is the specific activity of phosphorus in the solution before entering in contact with the soil; a_2 is the specific activity of phosphorus in the solution after contacting the soil; c is the number of milligrams equivalent of PO_4^{-3} in the solution before entering in contact with the soil; and X the number of milligrams equivalent of PO_4^{-3} fixed by 100 g of soil.

The data obtained allow the following conclusions:

a) The 16 hours period of contact of the solution, wich contains both ordinary and radioactive phosphorus, with the soil saturated with phosphate, was sufficient for the phenomenon of isotopic exchange to have reached equilibrium.

b) The sandy soils which were poor in both iron and aluminum hydrated oxides fixed less phosphorus than the clayey ones which had a medium level of the mentioned oxides. The clayey soils which were rich in both iron and aluminum hydrated oxides fixed more phosphate than the former ones.

c) The evaluation of phosphorus fixation capacity by the soil, using the method of saturating the soil with phosphate and later isotopic exchange, as is presented in this work, is very simple.

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