PPGM — L 76 — 74

STUDY ON THE ADSORPTION AND DESORPTION OF FERTILIZER PHOSPHATES BY THE SOIL SUSPENSIONS

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A B S T R A C T

The adsorption and desorption of fertilizer phosphate by soil suspensions were studied with the purpose to improve the efféciency of the use of phosphate fertilizer in rice growing countries.

Experiments have shown that the applied phosphate fertilizer was quickly adsorbed by the soil and that the bulk of the fertilizer phosphate got bound to the soil complex. These bound fertilizer phosphates could readily be desorbed by flooding of the soil up to a certain amount.

TABLE OF CONTENTS

I. INTRODUCTION

A study of the distribution of the fertilizer phosphate adsorbed by the soil and in the aqueous solution of soil suspensions will lead to a more efficient use of the fertilizer in a rice growing country.

In determining the adsorption of the fertilizer phosphate by the soil a labelled fertilizer was used in these experiments. Radioisotope P^{32} is preferable to other tracers because it can be detected in very small concentrations. The use of the phosphate tracer was based on the assumption that it would behave similarly to the labelled medium.

Since it is not possible to discriminate between the phosphate of the soil and that of the fertilizer by means of classical chemical methods, phosphate fertilizer labelled with appropriate radioactive P^{32} is the only direct means of following the fate of the fertilizer phosphate in the soil and in the aqueous solution of the soil suspension. Retardation or even retention of the tracer, owing to the adsorption and ion-exchange capacity of the soil will be observed by the experiments. It is this residence of the fertilizer phosphates in the soil and in the solution of the soil suspensions in relation to time and at different quantities of the phosphate fertilizer applied which will be studied.

Also the influence of flooding on the desorption of the fertilizer phosphates bound by the soil will be investigated.

I.1. MATERIALS AND EQUIPMENT

Soil. Clayey soil containing 0,17 micro mole soluble phosphate per gram soil was used as soil suspension.

P - fertilizer. Technical grade superphosphate containing 20,3% P_2O_5 soluble in water and technical grade double-superphosphate containing 43,9% soluble P_2O_5 were used without any pretreatment in these experiments.

Labelled compound. $KH_2P^{32}O_4$ supplied by The Radiochemical Centre Amersham with an activity of 1 mCi/ml on the date of the experiments was used to label the P-fertilizer solutions.

Counters. The activities of the samples were measured with a liquid scintillator and with an end-window G.M. counter.

Spectrophotometer. The determination of the non-active phosphate concentration was carried out with a Zeiss spectral-photometer PMQ II.

I.2. EXPERIMENTS

To study the capacity of the soil to adsorb the applied fertilizer phosphate in relation to time, solutions of labelled P - fertilizer with a same phosphate concentration were applied to soil suspensions, each containing a same amount of soil and an equal volume of water. The phosphate concentration of the applied labelled superphosphate solution was equal to that of the phosphate concentration of the applied labelled double-superphosphate solution. As blank solutions were used a lablled superphosphate solution and a labelled double-superphosphate solution which phosphate concentrations were known.

After some intervals of time the aqueous solution of the soil suspensions was taken, centrifuged and its activity measured. This activity was compared with the activity of the blank solution, to calculate the amount of the fertilizer phosphates adsorbed by the soil

Fig. I shows the fertilizer phosphates adsorbed by the soil in relation to time at a fixed amount of P - fertilizer applied to the soil suspensions. It was shown by this experiment that the bulk of the applied fertilizer phosphate got bound by the soil at a relatively small period of time and that equilibrium was reached after about 24 hours.

To investigate the capacity of the soil to adsorb varying amounts of P - fertilizer applied to it, different quantities of labelled superphosphate or labelled double-superphosphate solutions were added to soil suspensions so that each of the final prepared sample contained the same amount of soil, the same volume of water, but different quantities of the applied phosphate fertilizer.

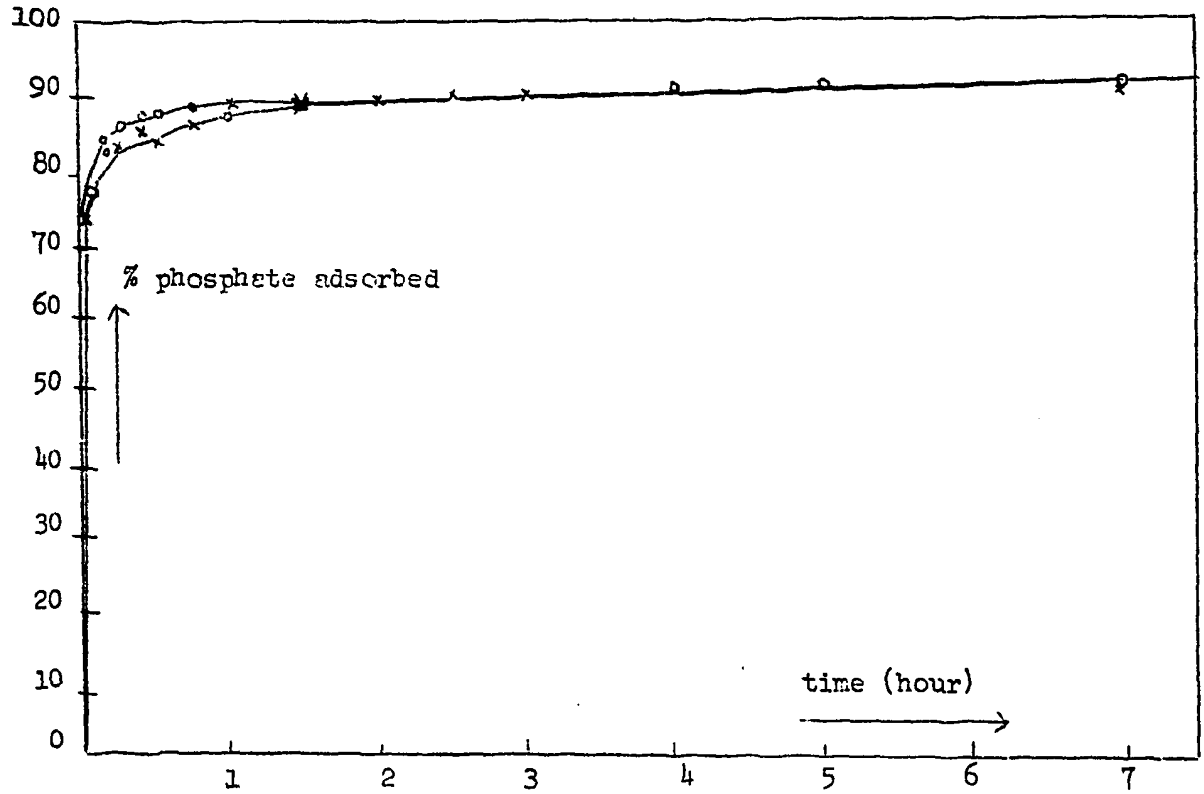
After 24 hours when equilibrium was reached the activities of the supernatants of the centrifuged soil suspensions were measured. These activities were compared with the activities of the blank solutions. The blank solutions were solutions of P-fertilizers which phosphate concentrations were known.

If the insoluble soil phosphate was neglected, the Freundlich's equation

$$a = k c^n$$

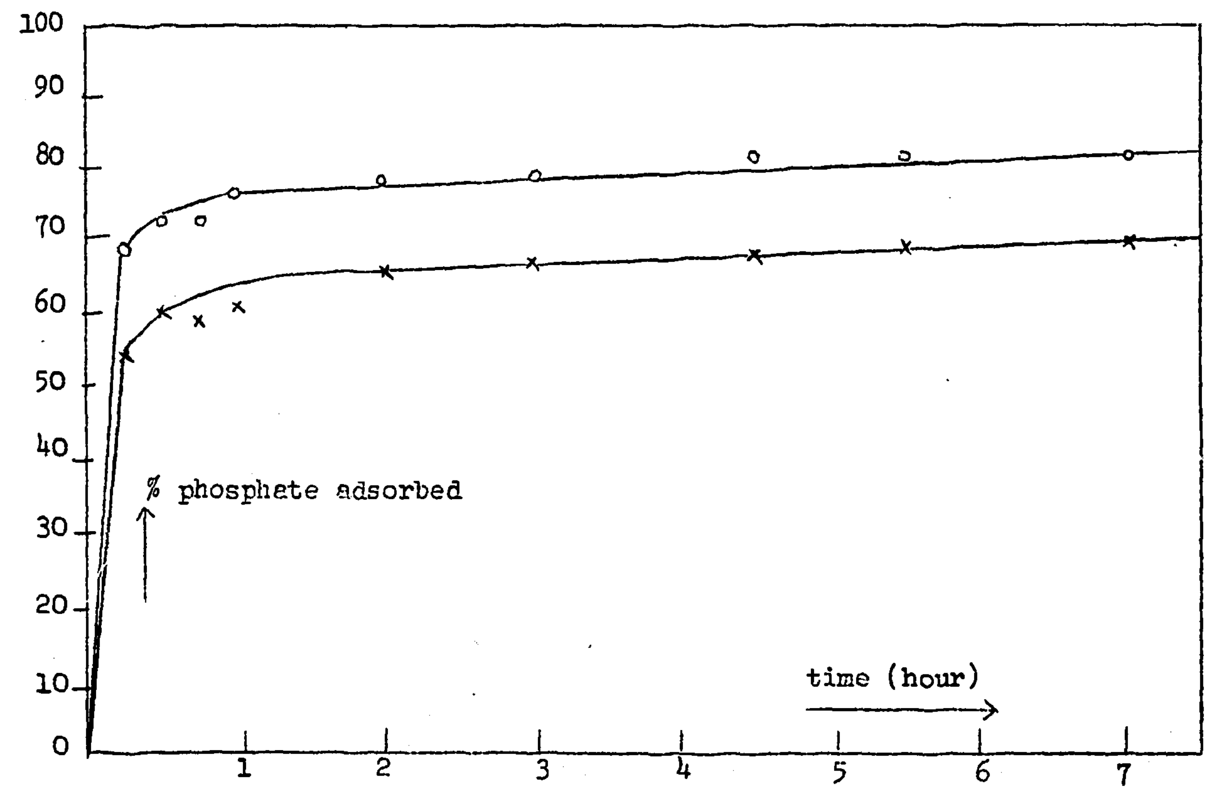
could be used to discribe the capacity of the soil to adsorb the fertilizer phosphate. In this equation a=micro mole fertilizer phosphates

FIG. I. Adsorption of fertilizer phosphate in relation to time by soil suspensions containing 5 gram soil and 25 ml water.



O———O 9,72 micro mole phosphate of the superphosphate applied.

X———X 9,72 micro mole of the double-superphosphate applied.



O———O 29,8 micro mole phosphate of the superphosphate applied.

X———X 29,8 micro mole phosphate of the double-superphosphate applied.

adsorbed by 1 gram of soil and c = the concentration of the fertilizer phosphate in the solution = micro mole phosphate per ml, both obtained by the experiment, while k and n are constants. The constants k and n' could be estimated from the Freundlich's equation written in another form.

$$\log a = n \log c + k$$

Using for a and c the data obtained by the experiment gave for k = 10 and n = 0,5. Fig II shows the curves of the Freundlich's equation. This experiment gave an information about the quantity of the fertilizer phosphate adsorbed by the soil in relation to the amount of the P-fertilizer applied.

The following experiments were carried out to study the influence of flooding on the desorption of the fertilizer phosphate which was bound by the soil. In this experiment, to a set of soil suspensions each containing a same amount of soil, different quantities of labelled superphosphate solutions or different quantities of labelled double-superphosphate solutions were applied and after that each sample was diluted to a same volume of water. A solution of P-fertilizer with a known phosphate concentration was used as a blank solution. After 24 hours all the water on the surface of the soil of each sample was drained and its activity measured. Comparing this activity with that of the blank solution the concentration of the fertilizer phosphate in the aqueous solution and the amount adsorbed by the soil could be calculated.

Then to the remaining soil suspension of each sample a volume of water equal to that which was formerly drained was added. After

24 hours the samples were centrifuged and the surface water was drained again and its activity measured and compared with the activity of the blank solution.

This treatment was repeated four times subsequently,each time with an interval of time of 24 hours. By doing this the amount of the fertilizer phosphate in the aqueous solution and that which was bound by the by the soil after each time of flooding could be calculated. Fig III shows the desorption of the fertilizer phosphate applied to the soil after five times subsequent flooding. It was shown by this experiment that most of the fertilizer phosphate got bound to the soil and that the bound fertilizer phosphate could be readily desorbed by flooding up to a certain amount.

1.3. DISCUSSION

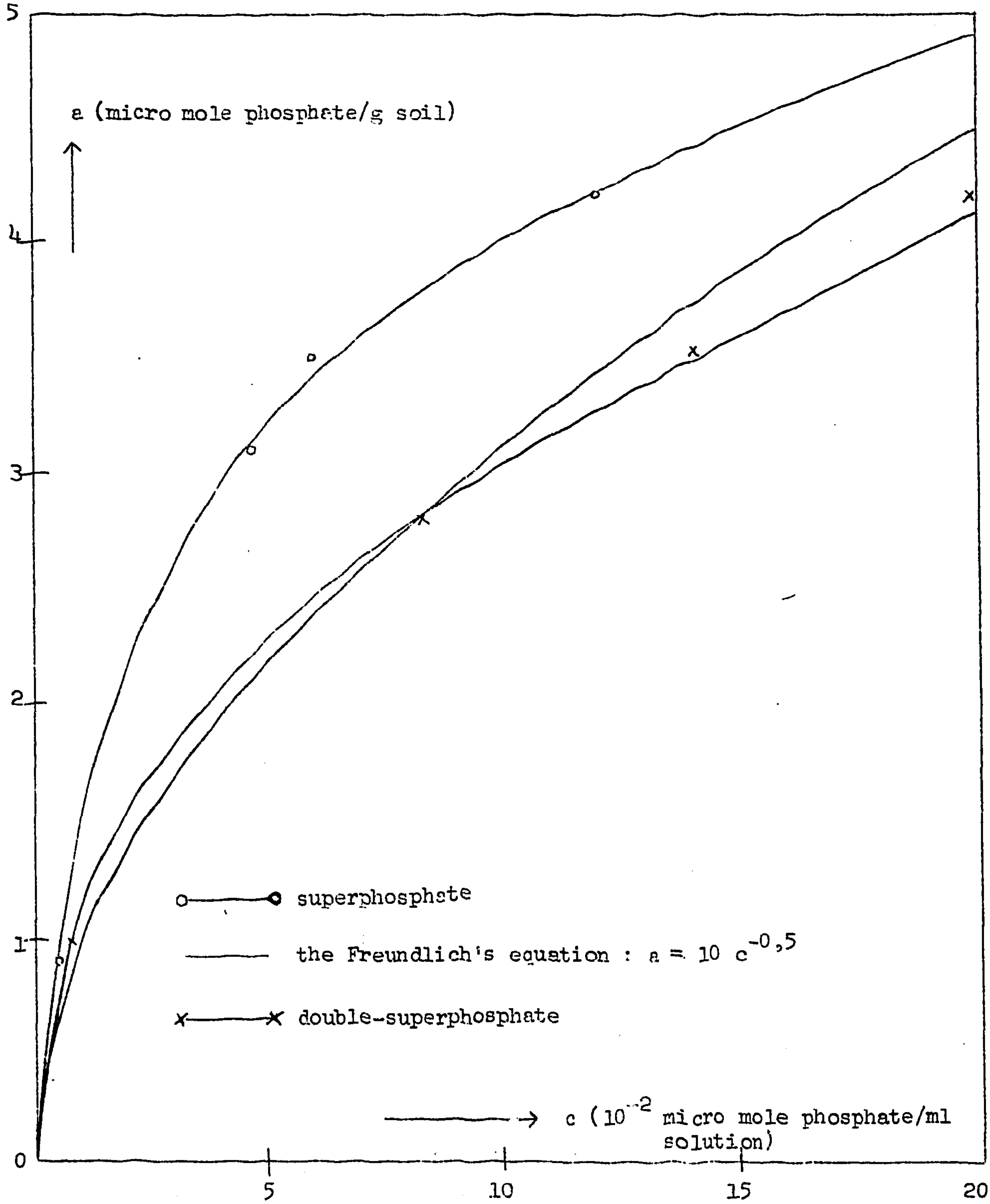
All calculation in these experiments were based on the assumption that the fertilizer phosphate applied were adsorbed by the soil without exchanging it with the insoluble soil phosphate and that the concentration of the soluble soil phosphate was neglected.

By doing this calculations were simplified and the Freundlich's equation could be obtained.

Data obtained by using superphosphate with 20,3% P_2O_5 and double-superphosphate with 43,9% P_2O_5 are not exactly the same,although the quantities of the fertilizer phosphate applied were nearly equal. This means that the nature of the fertilizer has also its influence on the adsorption and desorption of the fertilizer phosphate in a soil-water system.

FIG. II

The Freundlich's isotherm of the adsorption and desorption of the fertilizer phosphate by soil suspensions



II. CONCLUSIONS

Experiments have shown that the bulk of the fertilizer phosphate from the P-fertilizer applied to the soil gets bound to the solid soil complex.

The amount of the fertilizer phosphate adsorbed by the soil depends upon the nature of the P-fertilizer, the quantity of the applied P-fertilizer, and probably the nature of the soil.

The fertilizer phosphates bound by the soil can readily be desorbed by flooding of the soil up to a certain amount.

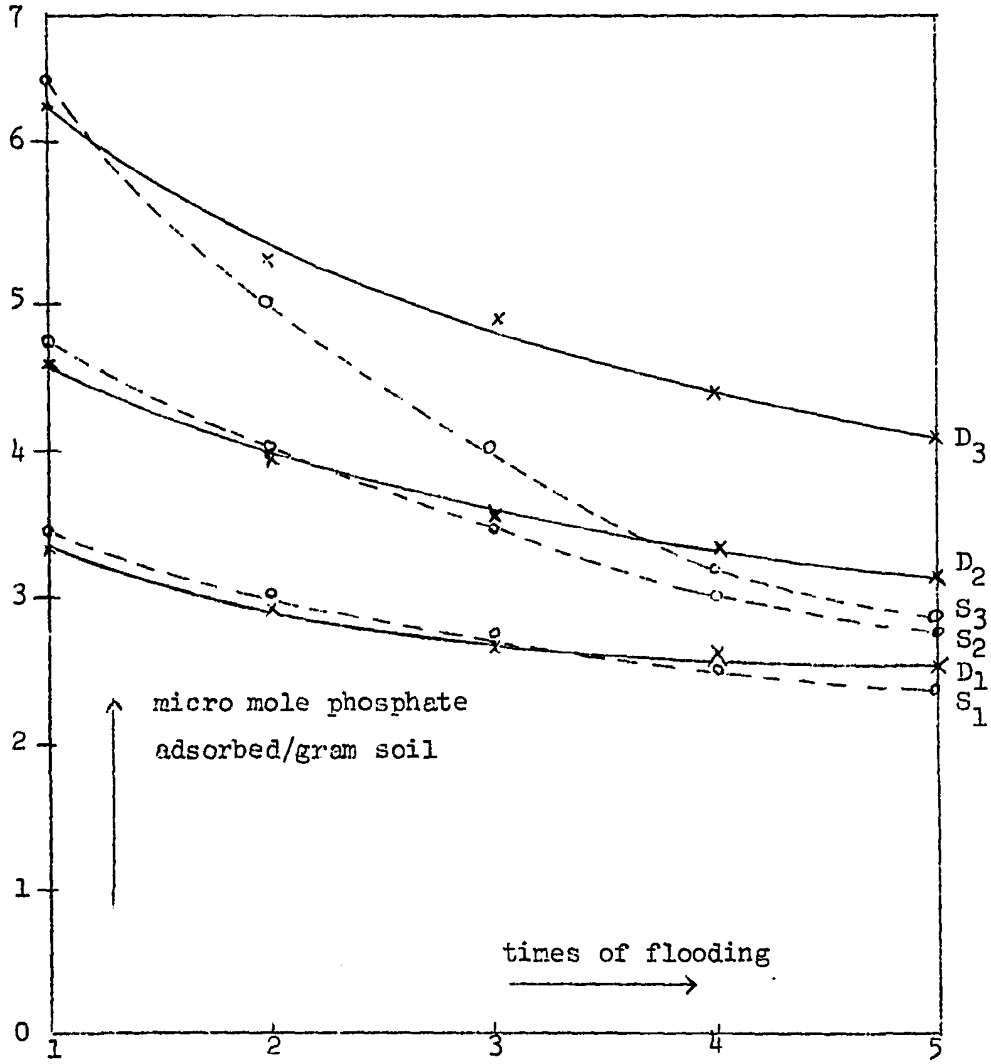
By studying the adsorption and desorption of the fertilizer phosphate in a soil-water system data , the efficiency of the use of the P-fertilizer can be improved, because it is the fertilizer phosphate in the aqueous solution which will be taken up by the plant.

II.1. ACKNOWLEDGEMENT

I wish to thank the INTERUNIVERSITY REACTOR INSTITUTE in Delft for the endowment which made it possible to carry out this research.

FIG. III

The effect of subsequently flooding on the desorption of the fertilizer phosphate bound to the soil suspension



superphosphate

o- - - -o S_1 = 3,9 micro mole phosphate applied to 1 g soil
S_2 = 5,8 micro mole phosphate applied to 1 g soil
S_3 = 9,7 micro mole phosphate applied to 1 g soil

x———x double-superphosphate
D_1 = 3,9 micro mole phosphate applied to 1 g soil
D_2 = 5,8 micro mole phosphate applied to 1 g soil
D_3 = 9,7 micro mole phosphate applied to 1 g soil

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