# RECOVERY OF SORBED FERTILIZER PHOSPHORUS BY THREE WATER EXTRACTION METHODS

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## ABSTRACT

The replenishment of P in the soil solution is of considerable importance from the standpoint of plant nutrition, for the reason that the quantity of inorganic P in the solution phase at any time, is usually insufficient to meet crop requirements over the whole of the growing season.

Through this study we are concerned in the phosphorus recovery from the soil solid phase that have received different levels of P-additions and of acidification applying three different water extraction methods.

A calcareous loamy soil of $pH_{H_2O} = 7.9$ was incubated with 0, 80 and 320 $mgP.kg^{-1}$ soil for one month. Different four levels of acidification (pH 7.9; 7.3; 6.0 and 4.5) were adjusted by adding calculated volumes of HCl and incubating the soil samples for further one month, then equilibrated with different rates of phosphorus as 0; 80; 160 and 240 $\mu gP.10cm^{-3}$. The desorbed quantity of phosphorus was determined applying EUF, HWP and multistep desorption methods.

Some part of the added phosphorus can be recovered by all methods, depending on the dose and time of P addition (previous or recent), on acidity of the soil and on the method used. The desorbable phosphorus amounts are in average 19% of the sum of P-loading at 0 $mgP.kg^{-1}$ level, and 31 and 64% at 80 and 320 $mgP.kg^{-1}$ levels, respectively.

## INTRODUCTION

Adsorption of phosphate consists of a fast and slow reaction (Barrow, 1978) and the desorption process behaves similarly. Fast desorption, which occurs by ligand exchange such as hydroxyl, citrate, oxalate, acetate and tartarate, appears to be complete in a few hours. Desorption of phosphate in the vicinity of plant roots however, may be more influenced by local pH changes than by the microbial production of organic anions (Tinker, 1980).

The effect of change of pH on phosphate desorption depends on the soil properties. There are reports that phosphate concentration is increased by raising the pH (Barrow, 1984 and Grinsted, 1982) which would be expected because of the effect of $OH^-$ ions as a displacing ligand, but there are also reports that it is decreased, possibly because raising the pH to about 6 increases the hydrolysis and polymerization of aluminium onto which phosphate ions are adsorbed (Haynes, 1982).

An annual crop usually takes up about 5 to 25 percent of the phosphate supplied by a single application of water-soluble phosphate fertilizer (Cooke 1966). The recovery has usually been calculated as the difference in uptake between crops grown on un-fertilized and fertilized plots. Recoveries of fertilizer phosphate depend on the conditions of the experiment where a wide range of recoveries can be expected.

Here we are intended to study the phosphorus recovery from the soil applying three different methods of water extraction: multiple desorption, EUF and HWP techniques.

Suntheim and Matzel (1985) used a continuous water extraction method (KWE) involving a simpler technique, hereby water is filtered at constant speed through a soil-sand mixture, and the amount of phosphorus is determined from the extract. Németh (1976) developed an electro-ultra-filtration (EUF) method and an instrument suitable for serial analysis. The EUF method is a water extraction method regulated by an electric field and accelerated through the use of vacuum. The EUF method is also suitable for determining the kinetics of the release of nutrients into solution (Füleky 1987). Körschens et al., (1984), used hot water to measure the available C and N contents of soils in a Soxhlet extraction process technically similar to the measurement of lipids. The majority of elements can be extracted in detectable amounts by the method of Hot Water Percolation provided that, they are present in the soil in an available, readily soluble form (Füleky and Czinkota 1993).

## MATERIAL AND METHODS

The phosphorus experiment was carried out on a calcareous loamy soil from Keszthely, Hungary. The soil samples were incubated for one month at room temperature at field water capacity moisture level with different rates of phosphorus (0, 80 and 320 $mgP.kg^{-1}$). Four acidity levels (pH 7.9, 7.3, 6.0 and 4.5) were adjusted by adding HCl. The soil samples were incubated for a further month.

The multistep phosphorus desorption study was applied to the soils with different previous P-additions under two levels of acidity (pH 7.9 and 4.5). For this purpose, phosphorus adsorption was determined with different P-levels: 0, 80, 160 and 240 $\mu gP.10cm^{-3}$ (recently additions) as 1 g soil and 10 $cm^3$ of aqueous phosphate solution for 24 hours, and after that phosphorus desorption was measured by extraction with distilled water through 12 steps.

The EUF procedure was applied to the incubated soil samples under two levels of acidification pH (7.9 and 4.5) after adsorption experiments with phosphorus solutions (0. 80, 160 and 240 $\mu gP.10cm^{-3}$ (recently additions)) as described in multistep water extraction technique. The residual solid phase was transferred quantitatively into the container of the EUF apparatus. The desorption has been conducted under a constant field strength of 400 V $5cm^{-3}$ and temperature of 20 $^o$C. Ten- minute fractions were collected for 400 minutes (Németh, 1976).

Hot Water Percolation (HWP) was carried out on the soils that have only received previous P-additions (0, 80 and 320 $mgP.kg^{-1}$ soil) with a wide range of pH (7.9, 7.3, 6 and 4.5) in an instrument resembling a coffee percolator. The replaceable sample holder was filled with 40 g sample as mixture of 30 g soil with 10 g washed sand. Water was preheated to 102-

105 °C in the container and passed through the sample at a pressure of 120-150 kPa and collected in 100 $cm^3$ aliquots. The experiments and determinations were carried out on 5 percolations per soil (Füleky and Czinkota 1993). The first 100 $cm^3$ aliquot was obtained on average time after ≈1.2 minutes, while the average time required for the 500 $cm^3$ extract was ≈ 4.0 minutes.

## RESULTS AND DISCUSSION

The multistep extractable phosphorus amounts applying the model solved from the two simultaneous equations (stepwise and Freundlich one third exponent) detected by Tolner et al., (1995) showed that, where the lower doses of P-fertilization is presented, the lower desorption of phosphorus is observed, so with the increasing of phosphorus fertilization (both previous and recent) increase the desorbable amount of phosphorus. The same conclusion was drown with the increasing of acidity, where the desorbable-P amount also increased. The same conclusions were proved by the consequences of the EUF and HWP methods (Figure 1, 2 and 3) respectively.
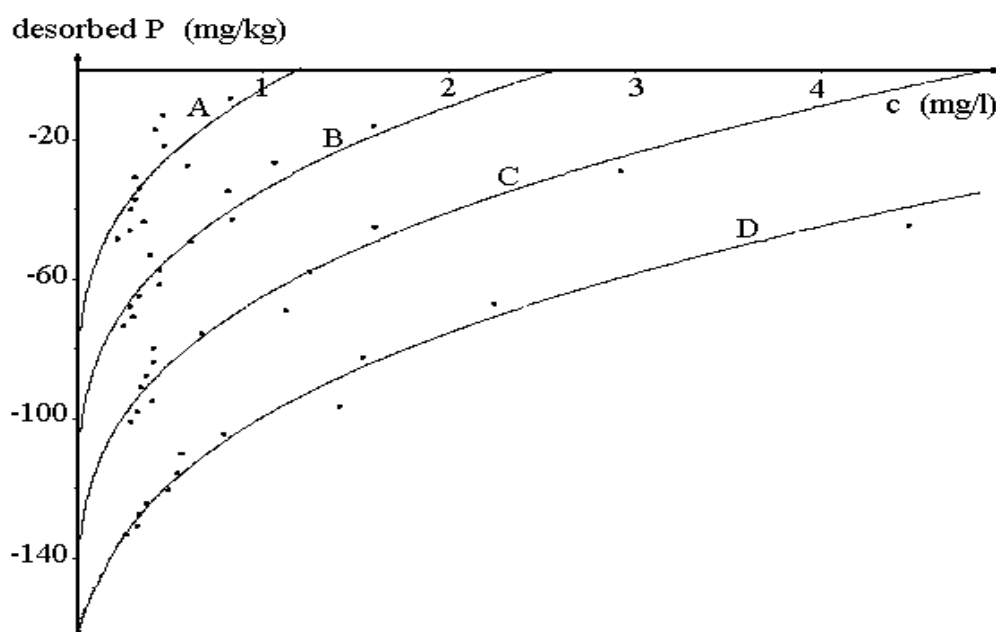


Figure 1. Desorbed phosphorus amounts from soil at P80 and pH 7.9,
as a function of recent P additions,
using multistep water extraction technique.
*A, B, C, D are nominal P-doses 0, 80, 160 and 240 $\mu g.g^{-1}$ soil respectively.*

The recovery of phosphorus has been calculated using the amounts of desorbed phosphorus at different levels of P loading  and of acidification and taking into consideration that the reference point for our calculation is the desorbed-P from the control treatment (P0 and pH 7.9) resulting from each technique.

 The obtained results lead to that, that the added phosphorus can be recovered by all methods, depending on the time of P addition (previous or recent) and on the acidity of the soil. At the same time, the values calculated through EUF technique confirmed the mentioned behaviour predicted from multistep desorption method, that the phosphorus recovery percentage increase
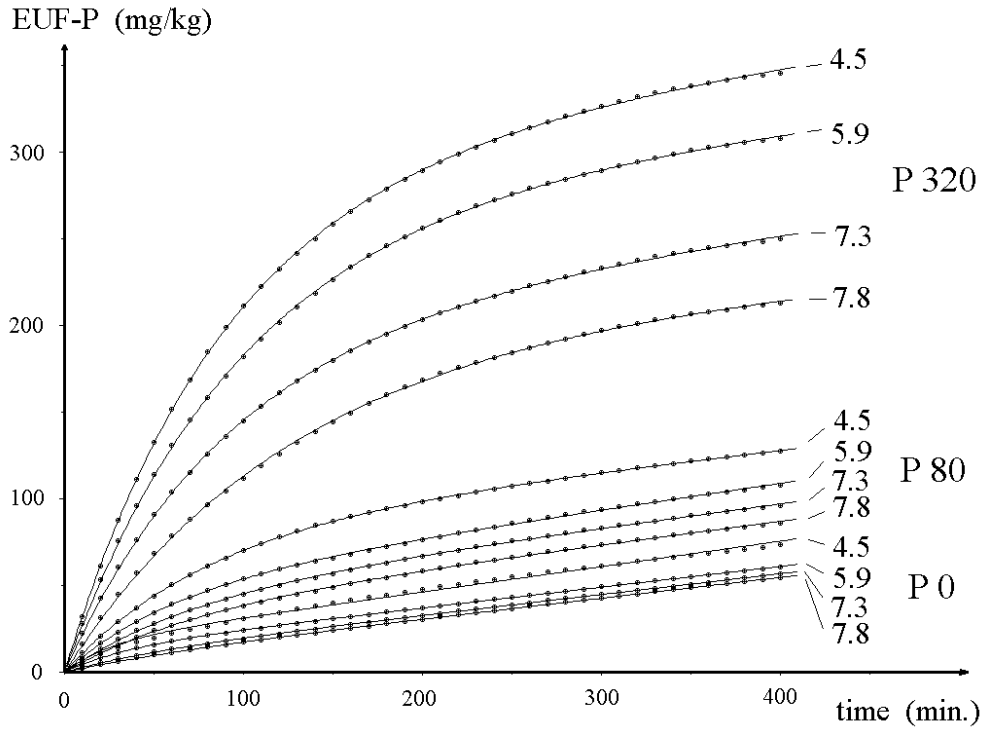


Figure 2. Desorbed phosphorus quantities from soils as a function
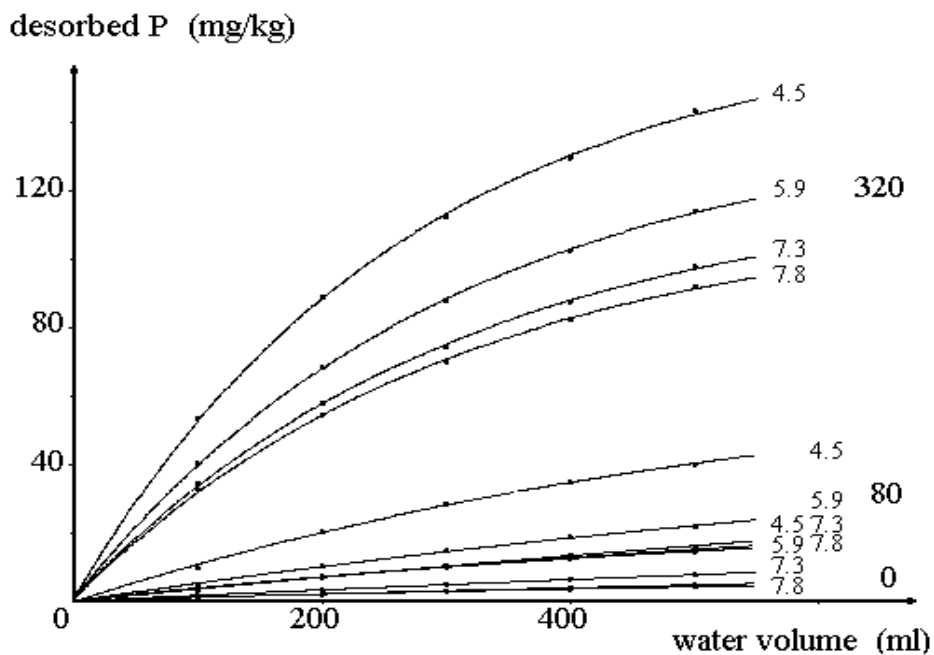of previously added-P and acidification, using EUF technique.

Figure 3. Desorbed phosphorus quantities from soils as a function
of previously added-P and acidification, using HWP technique.

with the increasing of phosphorus additions of both previous and recent additions. The same conclusion was also demonstrated in the case of acidified soils (Tables 1 and 2). The results that phosphorus recovery percentage increases with the increasing of phosphorus loading are in agreement with Obigbesan and Mengel (1981) and Judel et al., (1985). Steffens (1994) used the EUF technique to investigate the kinetics of P release from soils fertilized with different P fertilizers. His findings were that, the total amount of extracted-P (EUF method) was higher from the fertilized treatments than from comparable no-P treatments.

The comparative prediction was fulfilled by calculating the average values extracted from multistep and EUF techniques in both cases, non-acidified and acidified soils, and shows that, the desorbable phosphorus amounts are approximately 19% of the sum of P-loading at 0 $mgP.kg^{-1}$ level, and rise to about 31 and 64% at 80 and 320 $mgP.kg^{-1}$ levels respectively. In the case of acidification, the corresponding values are 22, 37 and 61% of the sum of added phosphorus, respectively. So, the recovery percentages are somewhat higher than those of non-acidified soils depending on the P-loading. With general conclusion, in acidified cases, the phosphorus recovery are higher than in non-acidified soils especially at lower phosphorus doses (recent 0 level) while with the increasing of P-loading the opposite is true. The results that the recovery increases with the increasing of acidification are in agreement with earlier findings of Haynes, 1982. Grinsted (1982) found increased desorption as the soil pH was lowered from 6.2 to 4.5.

The observations concluded from HWP technique (Table 3) showed that, the phosphorus recovery increases also with the P-loading and acidification, and the values are lower than those calculated from the earlier two methods, indicating that the phosphorus released by this technique is less compared to the multi-step and EUF methods.

**CONCLUSION**

The added phosphorus can be recovered by all studied methods, depending on the time of P addition (previous or recent) and of the acidity of soil. The phosphorus recovery percentage increases with the increase of phosphorus additions in both cases, previous and recent additions.

The desorbable phosphorus amount percentages are approximately 19% of the sum of P-loading at 0 $mgP.kg^{-1}$ level, and rise to about 31 and 64% at 80 and 320 $mgP.kg^{-1}$ levels, respectively. With general conclusion, in acidified cases, the phosphorus recovery are higher than those of non-acidified soils, while with the increasing of P-loading the opposite is true.

Table 1. Phosphorus recovery percentages as a function of (previous+recent)
P-additions and of acidification, using multi-step water extraction technique.

| Previously | Non-acidified soil, pH 7.86 | | | | Acidified soil pH, 4.51 | | | |
|---|---|---|---|---|---|---|---|---|
| added-P | Recently added phosphorus (mgP.kg$^{-1}$) | | | | | | | |
| (mgP.kg$^{-1}$) | 0 | 80 | 160 | 240 | 0 | 80 | 160 | 240 |
| 0 | - | 11 | 23 | | 16 | 27 | 36 | |
| 80 | 15 | 23 | 31 | 41 | 24 | 34 | 40 | 48 |
| 320 | 50 | 60 | 65 | | 54 | 55 | 62 | |

Table 2. Phosphorus recovery percentages as a function of (previous+recent)
P-additions and of acidification, using EUF technique.

| Previously | Non-acidified soil, pH 7.86 | | | | Acidified soil pH, 4.51 | | | |
|---|---|---|---|---|---|---|---|---|
| added-P | Recently added phosphorus (mgP.kg$^{-1}$) | | | | | | | |
| (mgP.kg$^{-1}$) | 0 | 80 | 160 | 240 | 0 | 80 | 160 | 240 |
| 0 | - | 14 | 28 | | 8 | 17 | 22 | |
| 80 | 13 | 28 | 42 | 67 | 27 | 22 | 37 | 46 |
| 320 | 67 | 77 | 82 | | 47 | 59 | 65 | |

Table 3. Phosphorus recovery percentage as a function of previously
added-P and of acidification, using HWP method.

| Previously added-P (mg.kg$^{-1}$) | Acidification pH | | | |
|---|---|---|---|---|
| | 7.86 | 7.25 | 5.99 | 4.51 |
| 0 | - | 0 | 2 | 6 |
| 80 | 4 | 4 | 7 | 14 |
| 320 | 21 | 23 | 27 | 34 |

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