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PHOSPHATE RETENTION IN THE ORGANIC HORIZON OF
A STAGNOPODZOL SOIL

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PREFACE

The exercise outlined in the following note was carried out as part of a project studying the effects of clearfelling on nutrient cycling in a forested catchment near Beddgelert, North Wales (ITE. Project T09005a1).

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Introduction

In a recent study of the impact of clearfelling on element cycling in sitka spruce plantations* a large flux of phosphate from the felling brash into the soil was observed following felling. The phosphate was, however, efficiently retained in the O and E horizons of the ferric stagnopodzol soil (Avery 1980)¹³, with very little reaching the Bs horizon. The retention of the phosphate in the upper soil could have been due to incorporation into the microbial biomass or to physico-chemical adsorption onto soil surfaces, or to a combination of both mechanisms. This paper reports the results of a preliminary study designed to assess the relative importance of the two mechanisms in the retention of phosphate in the O horizon.

Materials and Methods

Undisturbed samples of the O horizon, contained in experimental columns, were subjected to a number of treatments which are described below. The columns consisted of PVC pipes 5.9cm in diameter and 8cm deep, with a nylon mesh of 100 microns aperture at the base coupled to a 6.3cm diameter downpipe connector for support. The columns were supported on wooden racks and beakers were placed underneath to collect the leachates under zero tension (figure 1). The soil was sampled intact in the field by manually inserting the pipes into the O horizon of the forest floor. The

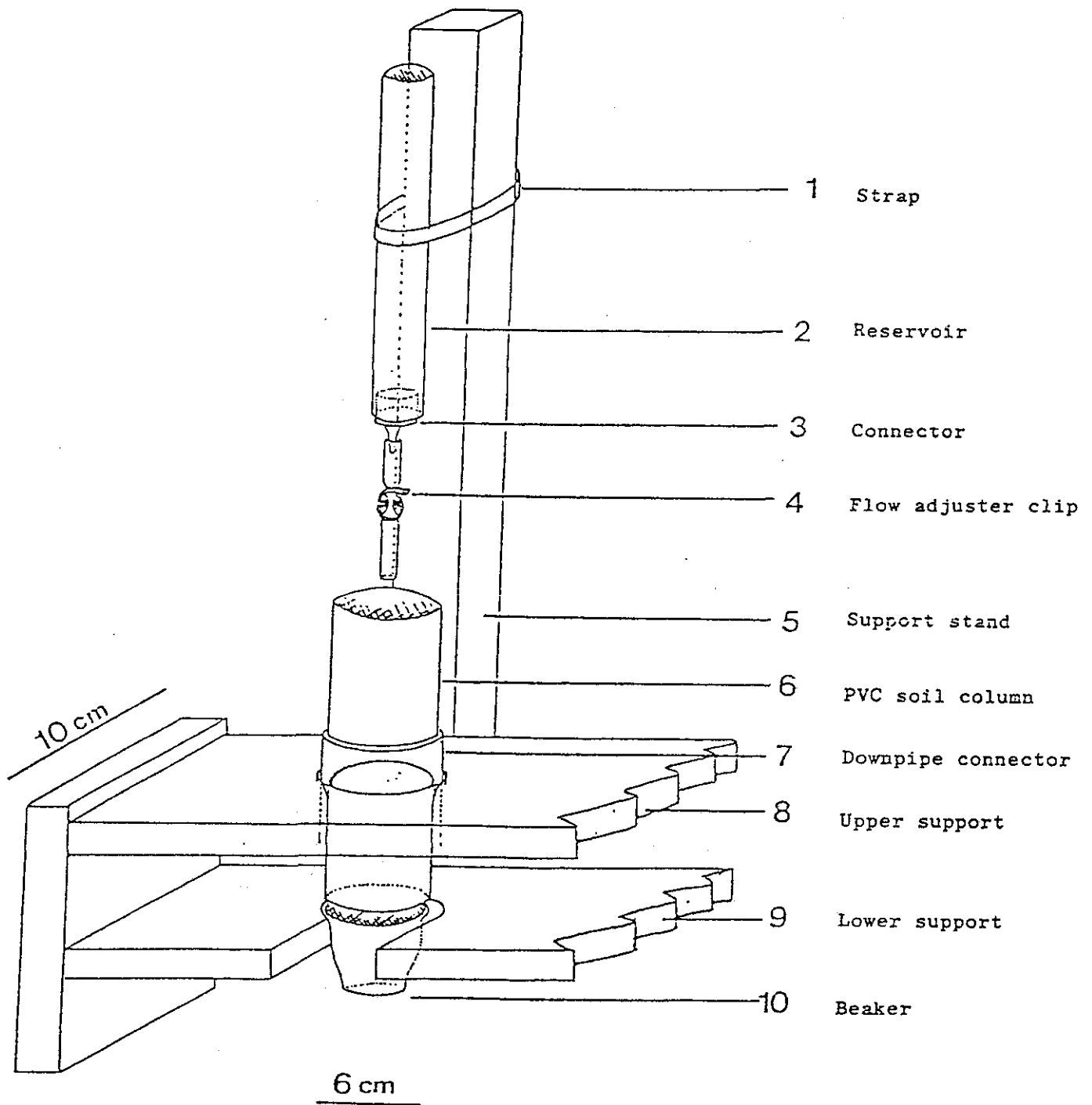


Fig 1. Experimental Soil Column

organic horizon of the soil had a depth of 6-8cms (including the litter layer), a pH of 3.9 (post-felling) and a loss on ignition value of 64% (at 648K). The study took place in the laboratory at 293K for the duration of the experiment; humidity was not controlled.

A total of 4 treatments were applied during the experiment with 3 replicates per treatment. The first treatment used a 10mg/l PO₄-P solution (approx); as the potassium salt. This was to determine the response of the soil to applied phosphate. The second treatment comprised a mixed solution of 0.2% Panacide (a general purpose bacterio-fungicide) and 10mg/l PO₄-P (approx). This solution was used to determine the response of the soil to applied phosphate, in the absence of an active microbial population. In the third treatment, the O horizon material was leached with distilled water. This was to estimate the amount of phosphate released from the soil, in the absence of an additional phosphate input. The final treatment comprised 0.2% Panacide solution. This solution was applied to observe the effects of Panacide on the release of phosphate from the organic horizon.

Each column received treatment with one of the above solutions for a period of 7 weeks. 30mls of the respective solution was applied per day for 5 days a week. At the end of each week, the volumes of the leachates in the beakers were measured and sub-samples taken for analysis. Phosphate was determined colorimetrically using a UV/Visible spectro photometer. Ammonium molybdate-ascorbic acid reagents were used for the colorimetric determination of phosphate. A problem was encountered during the determination of phosphate in leachates and applied solutions containing Panacide. The non-polar nature of Panacide (5,5'-dichloro-2,2'-dihydroxydiphenylmethane) ensured a comparatively low solubility in the solvent

(water) at 293K (solubility 0.003g/100ml solvent at 298.15K). During phosphate determination, sample acidification with dilute sulphuric acid increased the ionic strength of the solvent with the result that Panacide precipitated out of solution. This caused interference with the phosphate assay. This was overcome by centrifuging the samples at 1000rpm for 5 minutes, and thereafter removing the aqueous fraction for phosphate determination. This procedure did not appear to significantly affect the results of the phosphate analysis.

Results and Discussion

Table 1 summarizes the results obtained from treatment with 10mg/l PO₄-P solution and shows that the O horizon material retained a proportion of the applied phosphate, and that the percentage of the total phosphate added which was retained in each week, gradually declined during the course of the experiment (although this is biased to an extent as a result of small differences in the flux of phosphate input in each week). The data obtained from treatment with the solution containing 0.2% Panacide + 10mg/l PO₄-P are summarized in table 2, and show that the soil also retained some of the applied phosphate when treated with this mixed solution. The mean total retention of phosphate however, was lower than that obtained for the treatment with 10mg/l PO₄-P. The percentage of the total phosphate added which was retained in each week, also declined during the course of the experiment. However, there was a more rapid decline in the percentage retained in each week, compared with treatment 1. The data obtained from the treatments with distilled water and 0.2% Panacide solutions are summarized in tables 3 and 4 respectively, and show that the O horizon material released phosphate when either of these

Table 1: Results obtained from treatment 1 (10mg/l PO₄-P solution)
(values for fluxes of PO₄-P in milligrams)

Week No.	Mean In	flux Out	Mean difference in flux(in-out)	S.E +/-	Cumulative mean difference in flux	% input retained
1	1.41	0.768	+0.642	0.073	+0.642	45.5
2	1.47	0.808	+0.662	0.126	+1.300	45.0
3	1.65	1.047	+0.603	0.080	+1.903	36.5
4	1.65	0.995	+0.655	0.060	+2.558	39.7
5	1.65	0.995	+0.655	0.060	+3.213	39.7
6	1.65	1.143	+0.507	0.050	+3.720	30.7
7	1.77	1.230	+0.540	0.100	+4.260	30.5

Table 2: Results obtained from treatment 2 (0.2% Panacide + 10mg/l PO₄-P)
(values for fluxes of PO₄-P milligrams)

Week No.	Mean In	flux Out	Mean difference in flux(in-out)	S.E +/-	Cumulative mean difference in flux	% input retained
1	1.41	0.895	+0.515	0.102	+0.515	36.5
2	1.56	1.245	+0.315	0.013	+0.830	20.1
3	1.56	1.167	+0.393	0.080	+1.220	25.2
4	1.56	1.274	+0.286	0.124	+1.509	18.3
5	1.56	1.364	+0.196	0.174	+1.705	12.6
6	1.73	1.487	+0.238	0.060	+1.943	13.8
7	1.68	1.480	+0.200	0.060	+2.140	11.9

Table 3: Results obtained from treatment 3 (Distilled water)
(values for fluxes of PO₄-P in milligrams)

Week No.	Mean In	flux Out	Mean difference in flux(in-out)	S.E +/-	Cumulative mean difference in flux	% input retained
1	0.00	0.005	-0.005	0.004	-0.005	-----
2	0.00	0.021	-0.021	0.001	-0.026	-----
3	0.00	0.036	-0.036	0.010	-0.062	-----
4	0.00	0.014	-0.014	0.002	-0.076	-----
5	0.00	0.067	-0.067	0.005	-0.143	-----
6	0.00	0.038	-0.038	0.005	-0.181	-----
7	0.00	0.038	-0.038	0.010	-0.219	-----

Table 4: Results obtained from treatment 4 (0.2% Panacide solution)
(values for fluxes of PO₄-P in milligrams)

Week No.	Mean In	flux Out	Mean difference in flux(in-out)	S.E +/-	Cumulative mean difference in flux	% input retained
1	0.00	0.050	-0.050	0.040	-0.050	-----
2	0.00	0.089	-0.089	0.030	-0.139	-----
3	0.00	0.137	-0.137	0.030	-0.276	-----
4	0.00	0.136	-0.136	0.006	-0.412	-----
5	0.00	0.106	-0.106	0.010	-0.518	-----
6	0.00	0.124	-0.124	0.020	-0.640	-----
7	0.00	0.096	-0.096	0.010	-0.740	-----

two solutions were applied. The total amount of phosphate leached was greatest with Panacide treatment; the amount released being over 3 times that obtained with distilled water.

Phosphate retention by the O horizon material which received treatment with the 10mg/1 PO₄-P solution, may be attributed to a combination of physico-chemical adsorption onto the soil surfaces, and uptake by microorganisms. The differences between the fluxes of phosphate input and output, obtained from the soil which received treatment with the mixed solution of 0.2% Panacide and 10mg/1 PO₄-P, probably derives from the effective combination of two mutually opposing processes. These processes are namely, physico-chemical adsorption of applied phosphate onto soil surfaces, and release of phosphate derived from microbial cell lysis. The fact that these columns exhibited overall retention of phosphate, indicates that the former is greater than the latter. Phosphate released from the soil treated with Panacide, is the result of leaching of phosphate derived from microbial cell lysis, and also possibly by the Panacide chemically removing/displacing immobilised P. The phosphate released from the O horizon material which received treatment with distilled water, derives from normal leaching and mineralization processes.

Using the above information, it is possible to assess the relative roles of physico-chemical adsorption and microbial uptake, in the overall retention of phosphate by the soil, from the following expressions:

Adsorption of applied phosphate onto soil surfaces = difference in the flux of PO₄ input and output for treatment 2 - difference in the flux of PO₄ input and output for treatment 4.

The estimated uptake and utilisation of applied phosphate by micro-organisms can then be calculated from the expression:

Uptake of applied phosphate by micro-organisms = (difference in the flux input and output for treatment 1 - difference in the flux input and output for treatment 3) - estimated adsorption of applied phosphate onto soil surfaces.

The data obtained from use of the above expressions are presented in figure 2. The figure shows plots of the estimated cumulative adsorption of PO_4 onto soil surfaces and uptake by micro-organisms against time, and shows that physico-chemical adsorption onto the soil surfaces accounts for more than 60% of the total phosphate retention by the soil at the end of the experiment.

There are a number of criticisms which can be made against this type of study and which need to be taken into consideration before any firm conclusions can be reached. Firstly, as in all such experiments, it was assumed that the microbe population inhabiting the soil under laboratory conditions was comparable to that in field conditions. This, quite possibly could be an incorrect assumption; particularly as the study was carried out at 293K. Secondly, the estimate of the total amount of phosphate adsorbed onto the soil surfaces was calculated using the assumption that Phosphate and Panacide act independently of each other; ie. Panacide was assumed not to affect the process of adsorption of phosphate onto soil surfaces. This is a major assumption which has not been substantiated. Finally, it should be noted that the study was carried out using applied solutions which had pH values of 5.6, as compared with a mean pH value of 4.5 for leachate solutions collected beneath felling brash in field conditions.

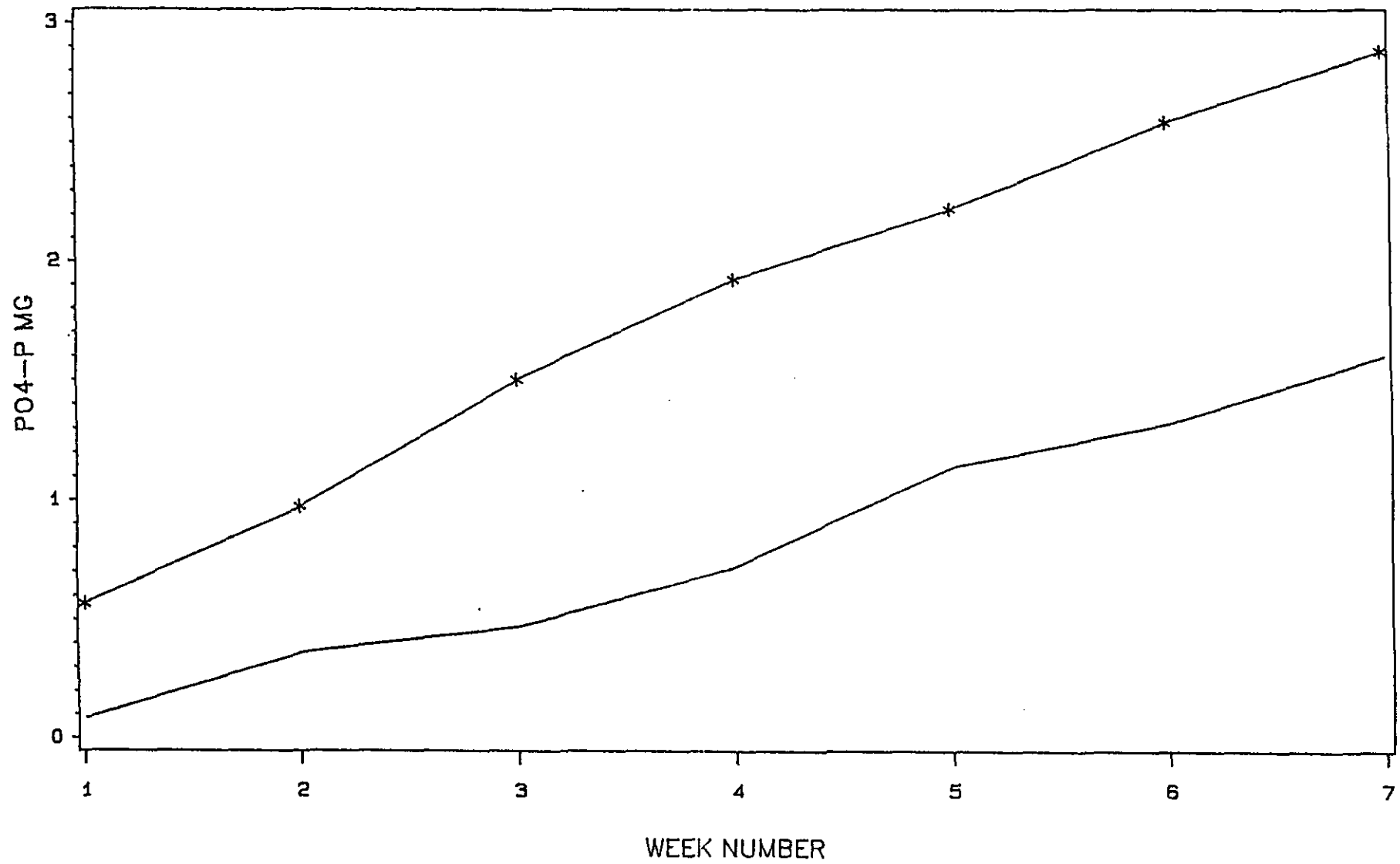


FIG 2. ESTIMATED CUMULATIVE PHYSICO-CHEMICAL ADSORPTION of Phosphate onto soil surfaces (-*-*) and incorporation into microbial biomass (____) against time.

However, after taking the above reservations into consideration, some conclusions can be reached concerning the fate of the applied phosphate, and its retention by the O horizon. Clearly physico-chemical adsorption onto soil surfaces is the major process involved in the retention of phosphate by the organic horizon; this is further exemplified by the appropriate phosphate sorption isotherm which is shown in appendix 1. This shows that the O horizon has a relatively high sorption index, and indicates that physico-chemical adsorption of the applied phosphate would be quite marked (the isotherms for the E and Bs horizons indicate that physico-chemical adsorption is the predominant process involved in phosphate retention in the lower soil horizons). Secondly, it appears likely that uptake and utilisation by the microbial population is also important, even though its actual contribution to the overall level of phosphate retention is difficult to estimate. Furthermore, the results obtained from treatment with 0.2% Panacide solution, ie. Treatment 4, give some indication of the relative levels of PO_4 incorporated in the microbial biomass prior to any additional phosphate input (although this should not be taken as indicative of the 'actual' amount of phosphate held in the microbial biomass ie. some of the phosphate released by microbial cell lysis would subsequently be adsorbed onto the soil surfaces).

Suggestions for further work:

- 1 Use of isotopically labelled P as the input would enable one to determine with greater accuracy, the fate of the applied phosphate.
- 2 Use of in-situ soil columns in the field would further complement the above study. It is suggested that chloroform fumigation and/or HCO_3 extractions of P from such columns over time, would provide estimates of the amounts of P immobilised in the microbial biomass, and the total amounts of HCO_3 extractable PO_4 to be followed with time.

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* Study site: Beddgelert forest, N.Wales.

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Appendix 1

Phosphate sorption isotherms and sorption indices³ for the O, E and Bs horizons of the ferric stagnopodzol soil.

Temperature = 293K.

Table 5: Phosphate sorption indices for the O, E and Bs horizons

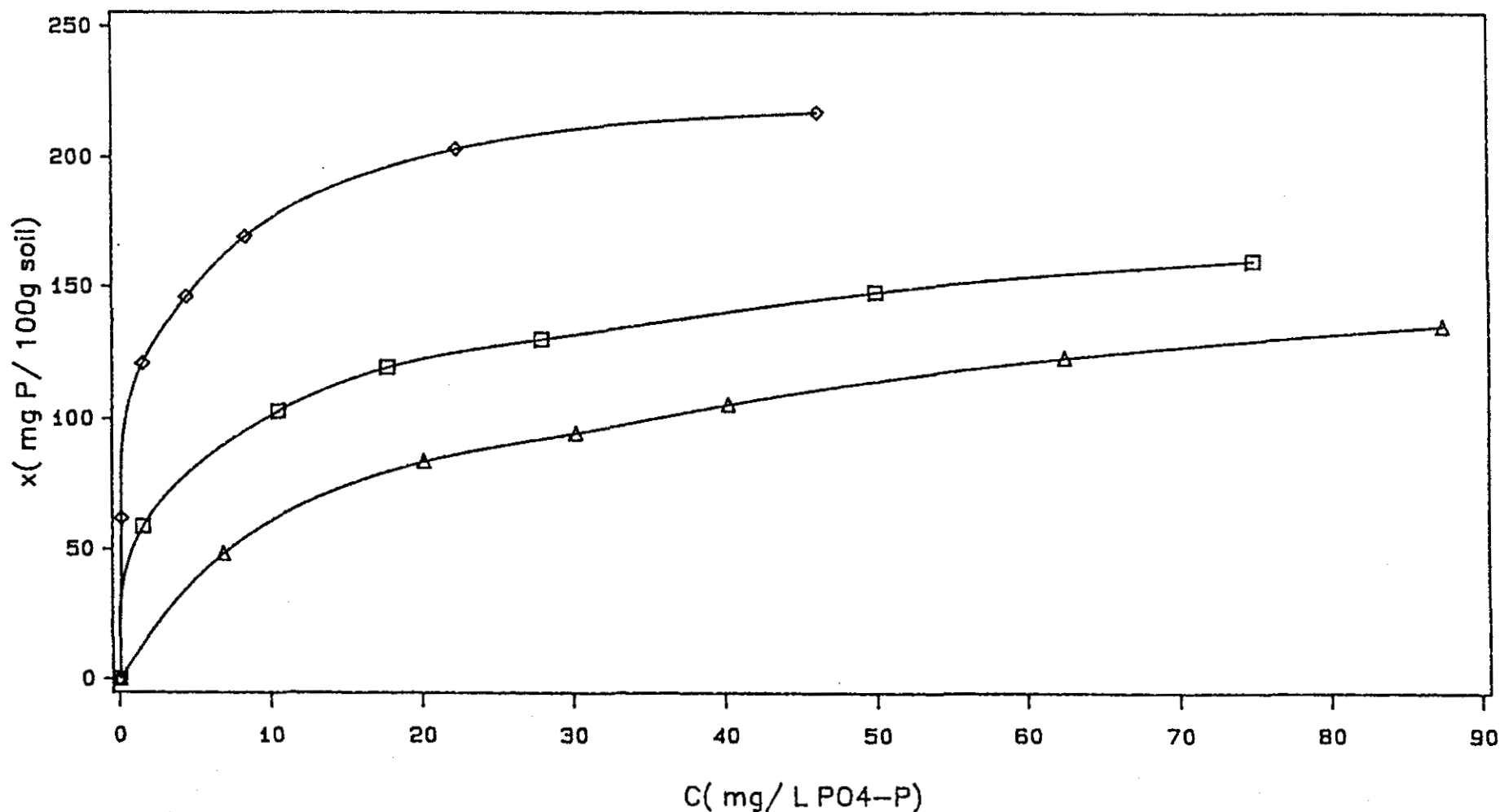
Horizon	Phosphate sorption index
O	63.86
E	100.30
Bs	224.50

Sorption index = $x/\log C$ (for addition of 150mg P/100g soil)

Unit for sorption, x: mg/100g soil

Unit for concentration, C: mg/l

Phosphate sorption isotherms for the O, E and Bs horizons of a ferric stagnopodzol soil
Site: Beddgelert forest, N.Wales



Plot of sorption x against equilibrium concentration C
Key: O=Triangle E=Square Bs=Diamond