PRELIMINARY STUDIES ON THE LABORATORY SIMULATION OF NUTRIENT
TRANSFERS WITHIN A PODZOL SOIL

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PREFACE

The exercise outlined in the following note was carried
out as part of a project studying geochemical cycling in an
upland grassland catchment near Plynlimon, mid Wales
(ITE Project 594). A general introduction to this project
is available as Bangor Research Station Occasional Paper
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Introduction

Laboratory soil columns have been used in a variety of ways in leaching studies involving pollutants (e.g. Barbarick et al (1980), Tyler (1978), Boreham et al 1976), and for simulating the release and movement of nutrients in solution through a soil profile (e.g. Adams & Boyle (1979), Cronan (1980), Enright (1978), Levesque and Hanna (1966)). Although a number of shortcomings have been recognised, for example disturbance of the soil and column edge effects altering solution pathways (Cronan (1978), Jackson and Hall (1978)), soil columns can be of immense value for modelling soil systems.

The work described here is part of a longer investigation into the release and cycling of plant nutrients from soil materials (Hornung 1981). The object of this experiment was to determine the suitability of laboratory soil columns as a means for exploring the movement of ions in solution, through the various soil profiles encountered in the cycling study. It is hoped from this to conduct further experiments to verify and explain trends established from field sampling of the soil solution using porous cup samplers and tray type lysimeters.

Materials and Methods
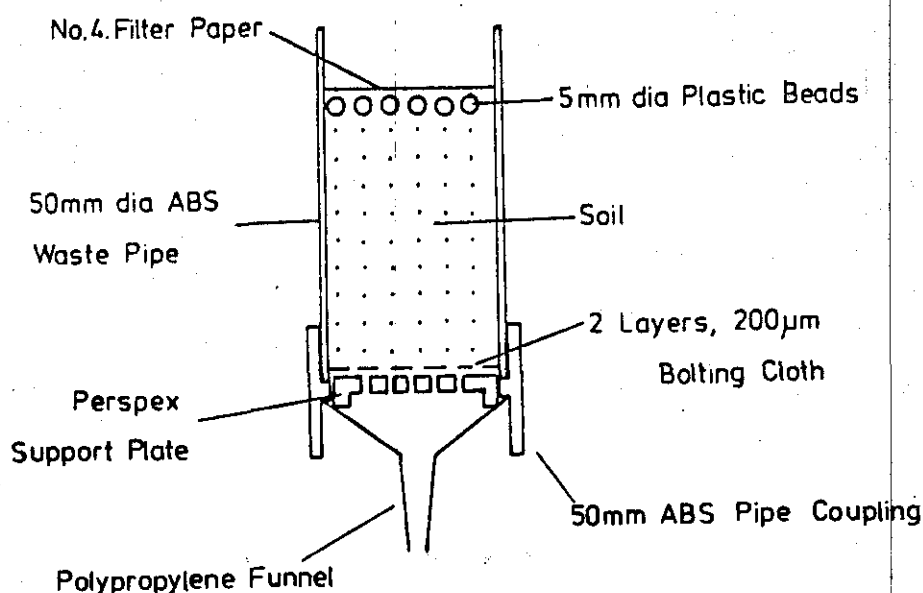
Leaching Columns

The leaching columns were constructed from commercially available

white ABS plastic waste pipe (50 mm I.D.). The column base
was made using a 50 mm ABS pipe coupling with a polypropylene
funnel cemented into one end. The soil was supported on a
performated perspex plate (50 mm diameter), shaped to rest
on top of the funnel. (See Figure 1). This plate was
removable to allow the column to be washed out effectively
for re-use. A suitable length of waste pipe was then
cemented into the base assembly. ABS solvent adhesive and
methylene chloride solvent were found to be satisfactory in
assembling the columns.

Two discs of 200 μm nylon bolting cloth were placed on the
base plate to prevent loss of fine material. The top of the
soil was protected with a single layer of 5 mm diameter plastic
beads covered with a disc of Whatman No 4 filter paper. This
combination diffuses the leaching solution across the top of

Figure 1

Soil Leaching Column

Not to scale

the soil surface and prevents surface pitting by water droplets.
The leaching solutions were input to the columns from plastic
dropping funnels and collected from the base of the columns
in 250 ml polypropylene bottles. The apparatus was carefully
cleaned using DECON and tap water followed by leaching with
dilute nitric acid and rinsing with copious quantities of
distilled water.

Soils and Sampling

The soil used in this work is an Iron-pan Stagnopodzol from
the Hiraethog Series, with a parent material of Silurian
mudstone coluvium (Hatton (1982) pers. comm.). Samples were
taken from the catchment of the Afon Cyff on the lower slopes
of Plynlimon, Mid-Wales.

Samples were taken from the entire depth of each horizon,
except the C. The soil was air dried at room temperature
and sieved through a 2 mm sieve. The sieved samples within
each horizon were then bulked and homogenised.

Leaching procedure

Two sets of columns were carefully packed with soil according
to the scheme given in Table 1. A degree of uniformity to the
packing was achieved by adding small quantities of soil at
a time and moistening each addition with a fine spray of
distilled water. Packed columns were mounted vertically using
pipe clips bolted to a plywood board and supported by a
Dexion frame. A third set of columns was assembled later in
the experiment specifically for Si analyses.
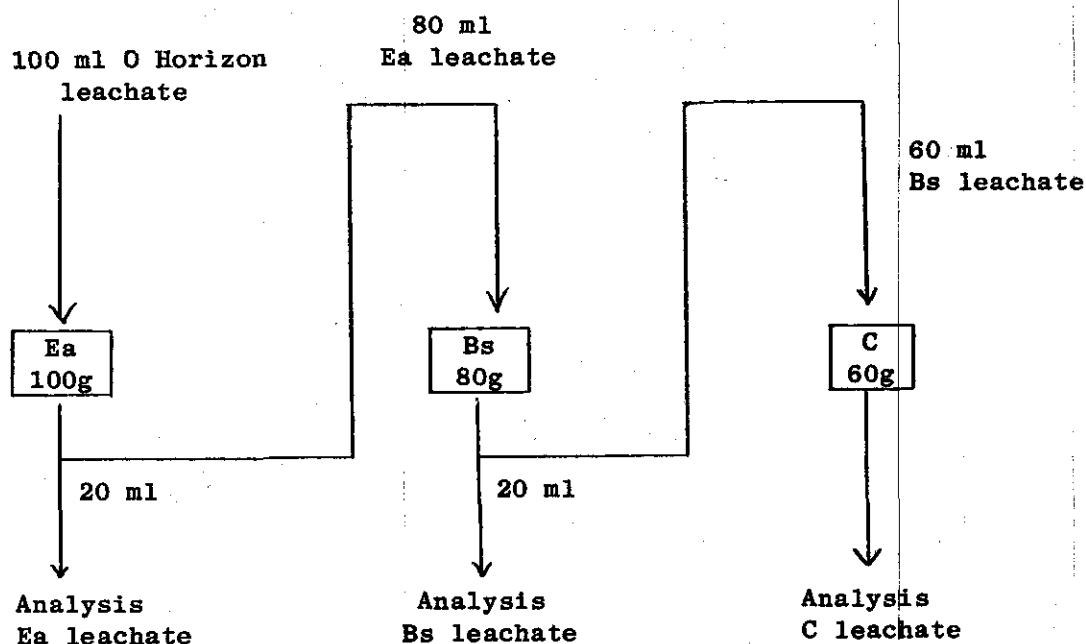
Table 1

Arrangement of Soils

Duplicate A

Column Number	Horizon	Wt. of Soil (g)	Volume (ml)	Solution Origin
A1	Ea	100	100	O
A2	Bs	80	80	Ea
A3	C	60	60	Bs

Volume = weekly volume of leaching solution
Wt. of Soil = weight of soil in columns

Figure 2

Cascade Leaching Scheme

CASCADE LEACHING SCHEME

The leaching solution was collected in the field from the O horizon using plastic tray type lysimeters under the horizon and draining into 21 polypropylene bottles. On return to the laboratory, the 'O' leachate was filtered through 0.45 μm membrane filters and stored at 4°C in acid washed polypropylene bottles.

Comments on the Experimental Procedure

The experiment has shown that the overall patterns of nutrient transfer between the horizons of a podzol soil can be reproduced using laboratory columns. Although the columns should be allowed time to settle down, in order to overcome the effects of disturbance on element release and uptake by the soil. Replication between the sets of columns of actual values of the mass transfers is not always very good, although the overall patterns are quite similar. Given the limitations of the experimental design this result is satisfactory. Additionally, the information required from the column experiments in the context of the nutrient cycling project mentioned earlier, does not require a high level of precision.

The use of a 1:1 soil to solution ratio, whilst giving easily measurable concentrations for analysis, is acknowledged as somewhat artificial. Further work is to be done using columns to equal the thickness of the soil found in each horizon. Volumes of leaching solution will be tailored to fit field conditions.

The choice of column diameter was made on the basis of readily obtainable materials and the availability at Bangor of a soil corer using 50 mm diameter ABS plastic sleeves. The coupling system at the base of the column was devised so as to take the sleeved cores directly, thus helping to reduce the amount of sample disturbance. A large variety of column diameters are reported in the literature varying from 25 mm (Adams and Boyle 1979)

to large "undisturbed" cores of 700 - 800 mm diameter
(Belford (1979) and Tadros and McGarity (1978)). The larger the
column diameter the less pronounced are the effects of edge
drainage (and edge disturbance in the case of cores). A column
design minimising edge drainage effects has been described by
Cronan (1978) and encasing soil cores in heat shrinkable plastic
has been suggested by Bondurant et al (1969) and Mielke (1973).
Whilst a large core size may provide an adequate answer to the
edge effect problem, this has to be balanced against the
practical constraints of physically accommodating and using the
columns. Again, with future work, it is hoped to explore the use
of larger diameter cores of 100 to 150 mm in diameter.

Disturbed soil samples were used in this experiment as they are
easier to collect, store and subsample. The results seem to
have justified the choice although the situation is artificial.
Work with intact cores, as mentioned, may be attempted.

A simple "cascade" leaching scheme was followed and this is
represented in Figure 2. The weights of soil and volumes of
leaching solutions were chosen to give approximately a 1:1 soil
wt. to volume of solution ratio (Jackson and Hall (1978)).

Table 1 shows the weekly (five days) additions of the leaching
solutions to the various columns. The solutions were added
dropwise, taking between two and three hours to pass through the
columns. The solutions were added over a five day period
allowing two days "drying" between additions to simulate field

conditions (Bower 1970). The soils at Plynlimon rarely dry out completely, therefore a longer drying period was not considered justified. Effluent volumes from each column were measured for mass transfer calculations. The leaching continued for a ten week period.

Effluents from the columns were filtered through 0.45 µm membrane filters and split to give a solution for analysis (approx 20 ml) and the leaching solution for the next column in the sequence (Figure 2). Effluent solutions for the duplicate set of columns were analysed for Na and K by flame emission spectrometry and Ca, Mg, Fe, Mn and Al by flame atomic absorption spectrometry. The effluents from the third set of columns were bulked over two weeks to give sufficient solution for Si analysis by the molybdenum blue method (Allen et al 1974) as well as for Fe and Al as before.

Results and Discussion

A balance sheet for the ion transfers for one of the duplicate sets of columns is given in Table 2. The transfers are expressed as the weights of the various ions in micrograms (µg), that is, the product of the volume of solution passing through the horizon and the concentration of each ion. The data show that although the overall ion budgets may show a nett gain, for some of these horizons (e.g. Al in the Bs horizon) there is still an output of ions from the horizon. The overall budgets for the three sets of columns are given in Table 3. The trends shown by the ion budgets for the duplicate sets of columns (sets 1 and 2)

Table 2

Mass Transfer Between Soil Horizons

Units = μg	Ea			Bs			C		
	In	Out	Budget	In	Out	Budget	In	Out	Budget
K	500 g	855	−355	776	822	−46	693	511	+182
Fe	50	4124	−4074	3677	492	+3185	412	136	+276
Al	300	1643	−1343	1476	782	+694	657	456	+201
Ca	220	501	−281	456	280	+176	238	352	−114
Mg	220	428	−208	392	213	+179	180	203	−23
Mn	10	58	−48	53	195	+141	165	175	−10
Na	1670	3322	−1652	3024	3366	−342	2847	2903	−56

Table 3

Overall Ion Budgets for the Three Sets of Leaching Columns

	Set 1			Set 2			Set 3		
	Ea	Bs	C	Ea	Bs	C	Ea	Bs	C
K	−355	−46	+182	−435	+42	+107			
Fe	−4074	+3185	+276	−1312	+866	+181	−630	+438	+69
Al	−1343	+694	+201	−915	+354	+204	−754	+328	−788
Ca	−281	+176	−114	−246	+152	−165			
Mg	−208	+179	−21	−201	+169	−33			
Mn	−48	−142	−11	−48	−88	−17			
Na	−1652	−342	−56	−1595	−303	−202			
Si	−649	−523	+110				−649	−523	+110

Units: μg

agree reasonably well, though the actual values for gains or losses for individual horizons can differ considerably. This result is not unexpected given the heterogeneous nature of soil despite attempts at homogenisation. Horizon budgets for Ca, Mg and Mn, however, agree well for the two sets.

The third set of columns show the same overall pattern for Fe and Al except in the C horizon. Here the horizon is giving a net loss for Al compared to a net gain for the duplicate set of columns. Absolute budget values for Fe are about fifty percent less than for the other two sets of columns, although there is better agreement for Al in the Ea and Bs horizons.

There are probably two major causes responsible for these discrepancies. Firstly, the leaching solution used in the third experiment from the O horizon had to be collected at a different time from that used in the first two sets of columns. The cation compositions for the two batches of O horizon water are similar. The variation in the organic anion content, presumed to be an important leaching agent in the solutions, is unknown. Secondly, as already mentioned, it is possible that the soil material was not thoroughly homogenised and that the variations in the data reflects the true variations within the soil.

The general patterns of transfers displayed by the ion budgets accord with those anticipated in podzol soils. Fe and Al are being actively removed from the eluvial Ea horizon and accumulated in the illuvial, podzolic Bs horizon. With one exception, there

is also a net gain of Fe and Al in the C horizon. This suggests
that the fine material in the "C horizon" is active pedologically
and that the "C horizon" is in fact an illuvial horizon and would
be better designated Bs2. Viewed overall, the iron and aluminium
data suggest that, once mobilised, aluminium remains in solution
longer than the iron. Thus a much higher proportion of the
iron mobilised in the Eag horizon is immobilised in the Bs1,
(between 66 and 78% of the Fe as opposed to 39 and 52% of the Al).
The "C horizons" of the first two sets of columns also output
three times as much aluminium as iron; again indicating the greater
mobility of aluminium. These results accord with data from most
podzols, which show extractable Al levels peaking lower down the
profile than extractable iron levels.

If the data from the full period of the experiment are considered,
all the other solutes also show nett outputs from the Eag
horizon. Potassium is also lost from the Bs but accumulates in
the C while Ca and Mg accumulate in the Bs but have a nett
output from the C horizon. All horizons show a net depletion
of Na and Mn, whilst Si is lost from the Ea and Bs but is
accumulated in the C.

Examination of the weekly data, indicates that almost all the
net outputs of Ca, Mg, Na from the Eag horizon takes place in
the first few weeks after setting up the columns, Figure 3.
Following this flush period an equilibrium develops whereby
the inputs and outputs are essentially in balance. A
proportion of these elements clearly occur in sites from
which they can be readily mobilised. Disturbance of the soil

Figure 3.   Weekly Ca fluxes for two soil horizons
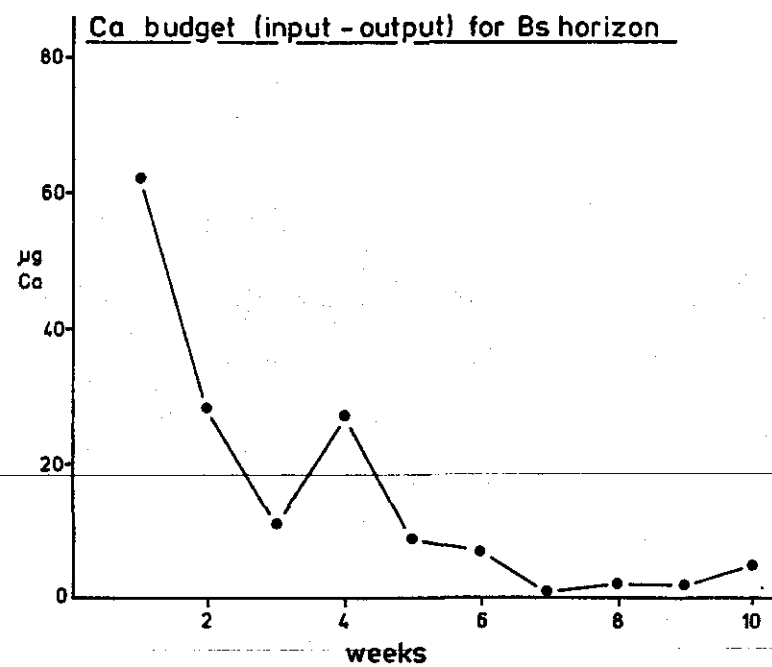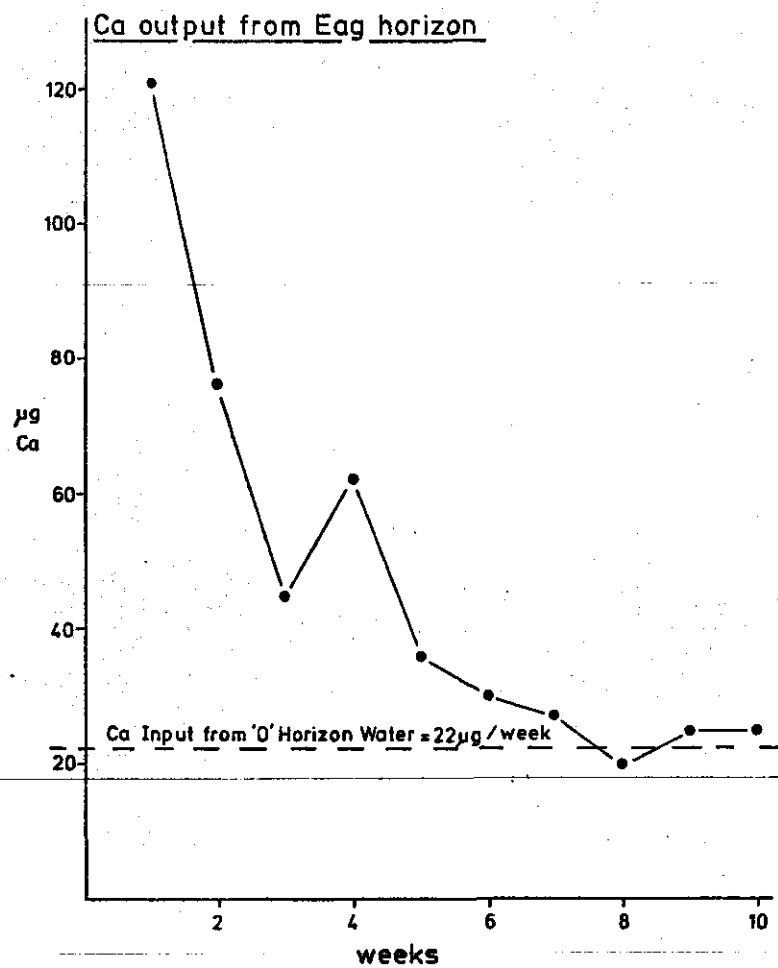
appears to result in the activation and rapid depletion
of these sites. There are no sources of Na in the soil
minerals so the flush of this element was probably from
exchange sites. The accumulation of Ca and Mg in the Bs
was most marked during this flush period (Figure 3) and indicates
the presence of active adsorption surfaces or available
exchange sites. Both elements showed a net output from the C
horizon throughout the experiments indicating a continuing
availability from weathering or exchange sources. Once
equilibrium was established sodium inputs and outputs were
virtually in balance throughout the system.

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