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POTENTIAL FOR MANAGEMENT

OF THE

PEEL-HARVEY ESTUARY

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PHOSPHORUS MOVEMENT THROUGH SANDY SOILS AND GROUNDWATER IN THE PEEL HARVEY CATCHMENT AREA

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INTRODUCTION

A primary aim of our research is to establish within a defined catchment area actual migration or dispersion of phosphorus applied as phosphated fertiliser through the catchments soil structure and associated groundwater. Phosphorus moves through soil and groundwater with rainfall water as its carrier medium. An understanding of phosphorus movement therefore requires an understanding of how rainfall water moves through the catchment area. This understanding can be derived from a study of the hydrology (including groundwater hydrology) of the catchment. A quantification of the hydrologic cycle over the catchment is necessary to determine the amount of water lost to the atmosphere from evaporation and evapotranspiration, the amount of water flowing as surface run-off and the amount infiltrating through the soil and eventually to the groundwater.

An understanding of the movement of phosphorus through soils and groundwater also requires an understanding of how phosphorus interacts with soil, how it is adsorbed, precipitated and perhaps desorbed from soil and how the adsorption of soil for phosphorus is affected by time.

Finally, we have to combine our understanding of the hydrology and soil chemistry components so that we have a coherent overall picture of the phosphorus movement, especially since phosphorus removal by soil is known to be time dependent. Our work concentrates on providing the link between the groundwater hydrology and soil chemistry components through a modelling technique incorporating both. Though we will rely and make use of results available in the hydrology and soil chemistry areas of the project, we will also conduct laboratory experiments that will provide values for the parameters of our model.

In its initial stages the laboratory work will consist of establishing phosphorus breakthrough curves, a phosphorus adsorption - desorption - dispersion pattern together with initial time dependent adsorption characteristics for each defined soil over its various horizons. We make use as a framework for our experiments and the interpretation of the experimental results a model incorporating the movement of P through soil by convection, hydrodynamic dispersion and time dependent P adsorption by the soil.

From these laboratory determined parameters we will set up a working model which will be able to predict phosphorus movement through a defined catchment of the Peel Harvey Estuarine System. The experimental results presented here are preliminary estimates of these parameters required by the proposed model.

EXPERIMENTAL

In an endeavour to simulate field conditions within the laboratory samples of Jandakot and Gavin soils from the Bassendean soil association were collected within the catchment area (Bettenay, pers. comm. 1984), over three different horizons (A - ground surface to 20 cm, B - 20 cm to 80 cm and C - 80 cm to 150 cm). In situ bulk densities were determined at least at two levels across the profile. Samples were also taken from the hard pan commonly known as coffee rock.

Dispersion coefficient

The dispersion coefficient D was determined from phosphorus breakthrough curves where phosphorus was not adsorbed by the soil. A superimposition technique was used to find D from the experimental data by comparing the breakthrough curves with curves computed from values derived by Brenner (1962) at different B_e values, Figure 1.

Adsorption isotherms

A series of batch tests were conducted on each soil horizon to establish the adsorption isotherms for phosphorus. The tests were done in a shaking water bath at 30°C over a period of 24 hours. Some tests were also performed at 48 and 96 hours. A soil:solution ratio of 1:3 was used, solution samples were 0.01 M with respect to calcium chloride and contained phosphorus in the range 0.5 to 200 mgℓ$^{-1}$ P added in the form of KH_2PO_4. At the end of each time period samples were filtered on a 0.45 μ millipore filter and the filtrate analysed for phosphorus.

Phosphorus Breakthrough Curves

Adsorption - a phosphorus solution containing 40 mgℓ$^{-1}$ P in 0.01 M $CaCℓ_2$ was allowed to flow through each soil horizon at its natural infiltration rate until the inflow and outflow concentrations became equivalent. A fraction collector collected the outflow which was analysed for phosphorus.

Desorption - a solution containing potassium nitrate at 40 mgℓ$^{-1}$ K in 0.01 M $CaCℓ_2$ was allowed to flow through each soil horizon at its natural infiltration rate until the outflow concentration of phosphorus approached zero.

RESULTS

Table 1.

Property / Horizon	Jandakot Soil A	Jandakot Soil B	Jandakot Soil C	Gavin Soil A	Gavin Soil B	Gavin Soil C	Coffee Rock
Bulk Density kgm^{-3} ρ_B	1330	1470	1470	1340	1450	1510	1650
Particle Density kgm^{-3} ρ_P	2390	2620	2640	2450	2600	2620	2480
Porosity	0.44	0.44	0.44	0.45	0.44	0.42	0.33
Hydraulic Conductivity K md^{-1}	9.7	24.4	21.3	7.9	25.7	33.3	
Pore velocity x 10^{-4} V ms^{-1}	2.02	5.55	4.45	1.63	5.55	6.93	
Dispersion Coefficient D m^{2}s^{-1}	8×10^{-6}	-	-	6×10^{-7}	3×10^{-6}	3×10^{-6}	
Brenner Number B_e	2	-	-	20	15	15	
Freundlich Relationship $s = mc^n$ m	4.6	9.3	32	-	-	-	800
n	0.53	0.38	0.33	-	-	-	0.36

DISCUSSION

Bulk density, particle density and hydraulic conductivity

The dispersion coefficient values of between 0.6×10^{-6} to 8×10^{-6} m^2/s at pore velocities of between 2×10^{-4} to 7×10^{-4} m/s are comparable to values reported for sands (Klotz *et al*, 1980). A value of 4×10^{-8} m^2/s was obtained by Mathew *et al* (1982) for Bassendean sand from Canning Vale at a pore velocity of 1.5×10^{-5} m/s.

Adsorption Isotherms

Batch tests conducted over a limited range of phosphorus concentrations and soil:solution ratios have revealed a wide range of characteristics for various soils. The Gavin or deep grey sands have shown no ability to retain phosphorus; however more testing is required varying the soil:solution and time to confirm this initial experimental work. The Jandakot soil horizons together with a coffee rock sample provide the only source of phosphorus adsorption capacity within the catchment area. Jandakot soils show an increasing affinity for phosphorus with depth especially within the C horizons, Figure 2. The adsorption isotherms follow the Freundlich relationship fairly closely. In a similar manner the coffee rock layer shows even a greater affinity for phosphorus and exhibiting a time dependent capacity for phosphorus adsorption. The time dependent adsorption is expected to occur with Jandakot soils as well.

Breakthrough Curves

The phosphorus breakthrough curves illustrate the range of interactions of phosphorus and soils in the transport of phosphorus through soils with differing adsorption properties. These soils have shown:

(i) no adsorption with phosphorus; transport due to convection and dispersion only, Figure 3,

(ii) adsorption with both convection and dispersion, Figure 4, and

(iii) time dependent adsorption, Figure 5.

These differences are of importance when considering the movements of phosphorus from the point of application, through the soil and groundwater to drains and rivers.

FUTURE WORK

Future work should be directed towards field and laboratory investigations. The field programme, which is carried out by CSIRO, should be directed towards estimation of the extent of the coffee rock layer together with an accurate description of the catchment soil profile. Groundwater movement within a defined catchment should also be accurately quantified.

The laboratory programme will concentrate upon further column and batch experiments to obtain the parameters required for the phosphorus-groundwater model of the catchment area.

In terms of management of phosphorus in the Peel Harvey Catchment our work has shown that we ought to be looking for ways of modifying the groundwater hydrology regime to take advantage of the adsorption capacity of coffee rock for phosphorus. It appears that in summer months long contact times between water and the soils (including coffee rock) is large and management of phosphorus by soil adsorption is feasible since adsorption already takes place. In the winter months we need to modify the flow regime to move away from the present regime towards the summer flow regime.

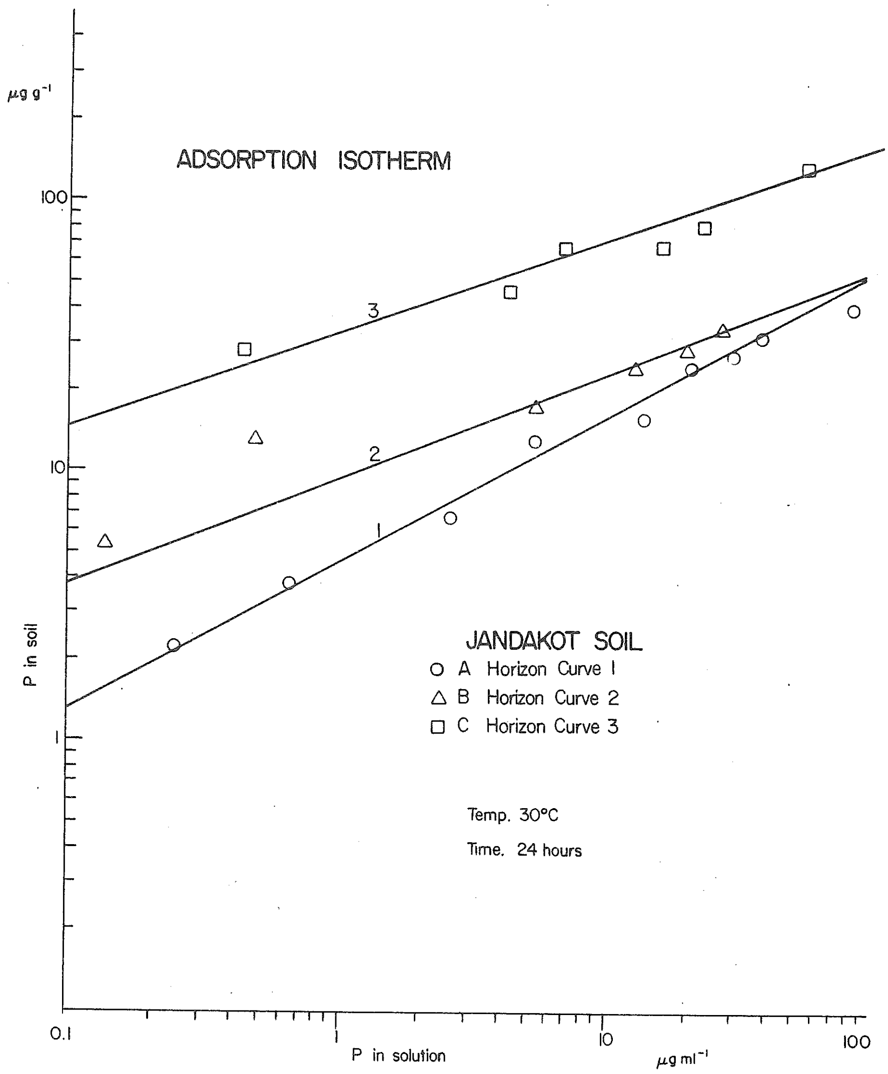

Figure 1.

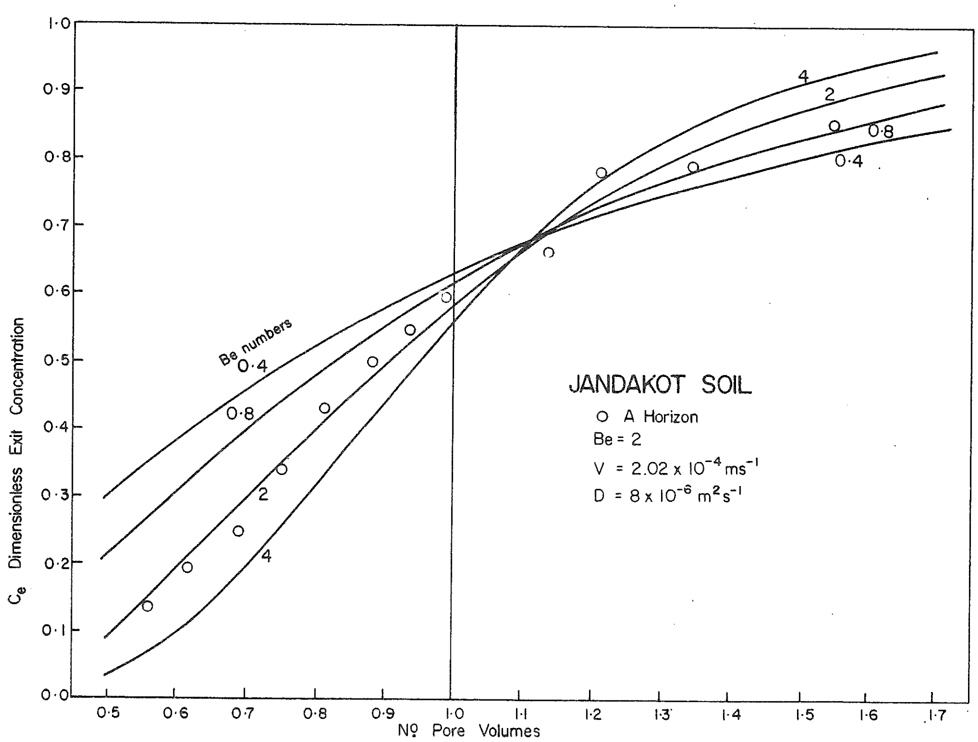

Figure 2.

BREAKTHROUGH CURVES

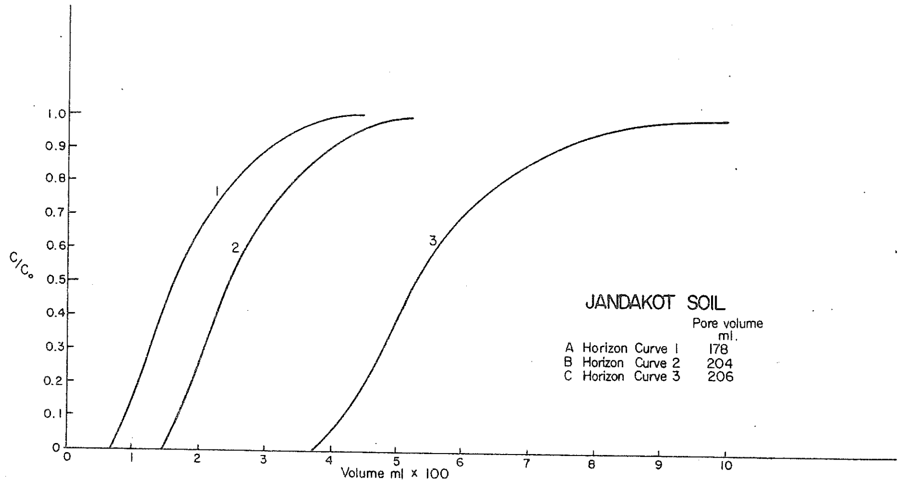

Figure 3.

BREAKTHROUGH CURVES

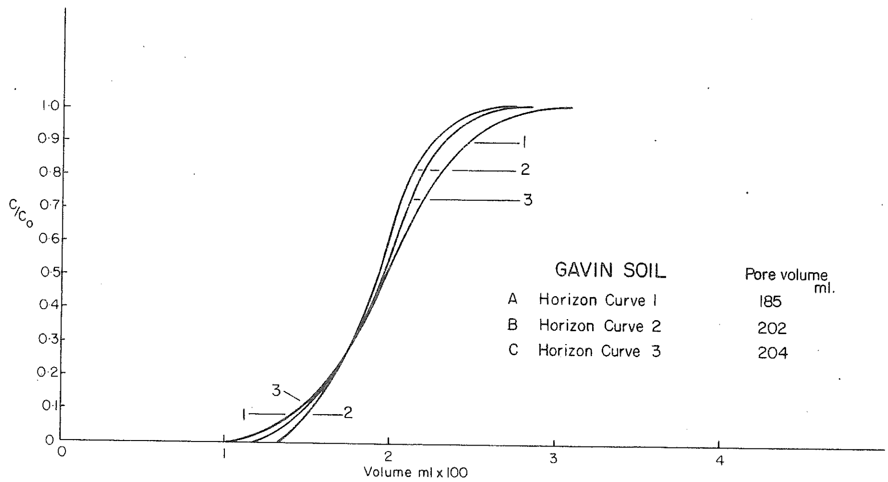

Figure 4.

BREAKTHROUGH CURVE

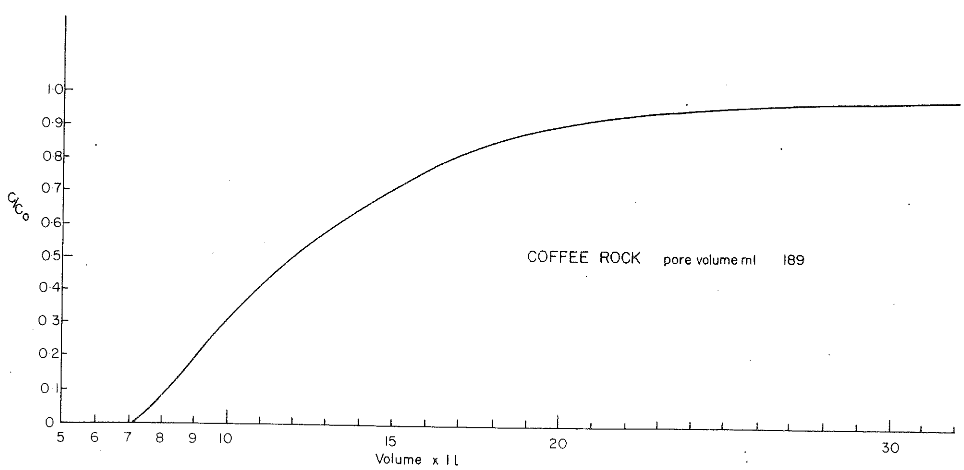

Figure 5.