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ANION MOVEMENT IN A STRUCTURED SOIL

A thesis presented in partial fulfilment
of the requirements for the Degree of
Doctor of Philosophy
in Soil Science at
Massey University

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1980

[illegible]

ABSTRACT

Anion movement in soil was studied both in the laboratory and in the field, using structured "undisturbed" soil and sieved aggregates. The movement of chloride, bromide and phosphorus was investigated. Chloride and bromide being non-reactive in soil, were used to indicate whether the flow was more uniform or preferential, while phosphorus was used to indicate the behaviour of strongly adsorbed anions.

Experiments involving the movement of chloride and phosphorus through columns of 0.5-1 mm soil aggregates provided data on phosphate adsorption during miscible displacement. Chloride breakthrough curves were described well by conventional convective-dispersive theory. For phosphorus, linear adsorption isotherms were determined independently, using solution concentrations and equilibrium times similar to those pertaining in the aggregate columns. Conventional theory using these data predicted reasonably well the early part of the breakthrough curves, but did not predict the observed "tailing" of phosphorus breakthrough curves.

The movement of anions through artificial soil channels and planar cracks was studied. The breakthrough curves showed the movement of both chloride and phosphorus was highly preferential through 0.5 mm diameter channels and 0.17 mm wide planar cracks. The results agreed quite well with model predictions.

The movement of anions through 2.4 litre "undisturbed" soil cores was also studied. Under saturated conditions, both chloride and phosphorus moved preferentially. Dye studies indicated the major pathways were worm channels, root channels, and soil cracks. Under unsaturated conditions when the pressure potential was maintained at -0.02 bar (at which channels larger than 0.15 mm diameter and cracks wider than 0.07 mm would be drained), the breakthrough curves for bromide were much less preferential than under saturated conditions. The experimental set-up for this experiment was designed so that the blockage of natural flow paths was minimized and the effects of porous plates at either end of the cores were avoided.

Two field experiments were conducted at a mole-tile drained site on Tokomaru silt loam (a Fragiaqualf). One experiment investigated the movement of chloride and phosphorus solution ponded on the soil surface. The breakthrough curves for both chloride and phosphorus percolating from the surface to the mole-drains indicated the movement was very preferential, both anions reaching the mole-drains located at 400 mm depth within a minute of their application to the soil surface. Dye staining indicated the movement occurred mostly through worm channels and plant root channels associated with planar cracks.

The other field experiment investigated the leaching of bromide under both ponded water and natural rainfall conditions. When the same amount of water was considered, leaching by rainfall was more effective than by ponding. However, under both water treatments, relatively large amounts of applied bromide remained unleached near the soil surface, while some bromide moved deep into the soil profile. Interception and stem flow appeared to be important factors causing non-uniform leaching under pasture by natural rainfall. Very considerable variation in bromide concentration between replicate soil samples was found, with a log-normal rather than normal distribution. Quite different leaching patterns were found in soil under pasture and in a soil which had been cultivated and cropped.

ACKNOWLEDGEMENT

I wish to express my sincere thanks to Dr D.R. Scotter, for his guidance, criticism, discussion, and encouragement throughout this study. Also for his friendship, interest, and help offered to me at all times.

Thanks are also extended to Mr R.W. Tillman, and Dr J.K. Syers, Soil Science Department, Massey University, for their help and valuable discussion.

The achievement of this study would not be possible without a Columbo Plan Scholarship offered by the New Zealand Government, and study leave given by Khon Kean University, Thailand, which I very much appreciate.

To Robin Tillman and John Sykes, thanks for their assistance with soil sampling, and to Tipvanna and Pisanu, for their assistance with the preparation of this manuscript.

To my family and Suvit, thanks for their continual support and encouragement at all times.

Finally to Miss Vivienne Mair, for excellent typing and preparation of this manuscript.

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LIST OF SYMBOLS

		DIMENSIONS
a	radius of a sphere	L
B	Brenner number ($B = vd/E$)	none
C	solution concentration	$M\ L^{-3}$
C_e	effluent concentration	$M\ L^{-3}$
C_i	influent concentration	$M\ L^{-3}$
C_{im}	concentration of solute in immobile region	$M\ L^{-3}$
C_m	concentration of solute in mobile region	$M\ L^{-3}$
C_o	initial solute concentration in the layer near the soil surface to depth z_o	$M\ L^{-3}$
D	molecular diffusion of solute in water	$L^2\ T^{-1}$
D_s	molecular diffusion of solute in soil	$L^2\ T^{-1}$
d	soil column length	L
E	dispersion coefficient	$L^2\ T^{-1}$
E_{Cl}	dispersion coefficient of chloride	$L^2\ T^{-1}$
ET	evapostranspiration	L
g	acceleration due to gravity	$L\ T^{-2}$
I	infiltration rate	$L\ T^{-1}$
i	depth of water input or interger	L or none
K	hydraulic conductivity	$L\ T^{-1}$
k	Freundlich solution distribution coefficient	L^3M^{-1}
k_I	Freundlich solution distribution coefficient for adsorption site I	L^3M^{-1}
k_1	adsorption rate coefficient	T^{-1}
k_2	desorption rate coefficient	T^{-1}
k_3	adsorption rate coefficient for site II	T^{-1}
k_4	desorption rate coefficient for site II	T^{-1}
N	a constant in the Freundlich equation	none
n	number of samples	none
Q	flow rate	L^3T^{-1}
q	Darcy flux density	$L\ T^{-1}$
R	retardation factor ($R = \frac{\rho_b}{\theta} k$)	
r	correlation coefficient, or radial distance in equation (B.1)	none or L
S	solute adsorbed per unit mass of soil solids	$M\ M^{-1}$

S_I	amount of solute adsorbed per unit mass of soil for site I	$M\ M^{-1}$
S_{II}	amount of solute adsorbed per unit mass of soil for site II	$M\ M^{-1}$
s	standard deviation of x	
s_L	standard deviation of ln x	
t	time	T
V	cumulative volume of effluent	L^3
V_o	liquid-filled pore volume	L^3
V_e	volume of effluent when $C_e/C_i = 0.5$	L^3
v	average pore water velocity ($v = q/\theta$)	$L\ T^{-1}$
x	variable (usually C or lnC)	
$\bar{x}$	mean of x	
$\bar{x}_L$	mean of ln x	
Z	z-vt	L
z	distance in direction of v	L
z_o	initial depth of solute near the soil surface	L
α	diffusional transfer coefficient	T^{-1}
η	viscosity of fluid	$M\ L^{-1}\ T^{-1}$
ψ	pressure potential	L or $M\ L^{-1}\ T^{-2}$
θ	volumetric water content in soil	$L^3\ L^{-3}$
ρ_b	bulk density	$M\ L^{-3}$
ρ_f	fluid density	$M\ L^{-3}$