SOLUTE TRANSPORT IN A LAYERED FIELD 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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1992

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ABSTRACT

Although concern about the effects of movement of chemicals through soil has brought about a need for greater understanding of solute transport, the question as to where best to focus the research effort remains open.

Initially a philosophical framework was presented that described in a general sense how research into solute transport has been conducted. It was argued that we must combine modelling with experimentation for effective progress in understanding, and that the efforts in field versus lab experimentation and process- versus non-mechanistic modelling should be balanced. Currently there is a need for more field experimentation, but the preferred direction of the modelling effort is less clear. Both process-based and non-mechanistic models are considered in order to deduce the effect of soil layering on solute transport.

Field experiments were carried out on a soil consisting of three layers of distinct texture. This soil was instrumented with porous cup samplers at four depths at twenty sites. There was also a 2 m^2 lysimeter within the plot.

In the first experiment irrigation was used to supplement rainfall in order to leach a surface application of solid KCl through the soil. Porous cup samples of the soil solution were collected on numerous occasions and soil cores less often. The experiment of the following year was similar in design except that no irrigation was used. Finally, in the third year, the lysimeter was instrumented with porous cup samplers and the same experimental design repeated on a smaller scale.

A convection-dispersion (CDE) model was applied to the lysimeter data. This was successful, provided that the surface soil and assumed Dirac delta solute input were not included in the calibration. Layering within the profile appeared to have little effect on solute transport. The transport porosity was revealed to be two-thirds of the water-filled porosity, thus a substantial part of the water-filled porosity did not transport solute. The CDE modelling of the field data was not particularly successful, probably due to the spatially variable nature of solute transport and water application.

The Aggregated Mixing Zone (AMZ) model was also used. This model subdivided the transport porosity into convective and dispersive components, and also allowed for non-interacting flow paths. Although the AMZ model was conceptually appealing, parameterisation of the model was found to lack discrimination. Little further understanding of solute transport was gained from this model.

Textural differences in the soil seem to be overwhelmed by both small-scale heterogeneity of water application and solute movement in the soil, especially near to the surface. It was apparent that processes occurring in the surface soil require much more attention than they have been afforded in the past.

Both process-based modelling and field experimentation will increase our understanding of solute transport. It also seems that an increased effort in improving measurement techniques will be advantageous.

ACKNOWLEDGEMENTS

Funding for the work done in this thesis was provided by two organisations that, as a result of recent restructuring, no longer exist. They were the Ministry of Works and Development and the Department of Scientific and Industrial Research.

Thanks are due to Professor Bob White, now at School of Agriculture and Forestry at the University of Melbourne, who was chief supervisor for much of the time. He initiated the work and sought the initial funding.

Dr Dave Scotter, of the Department of Soil Science, provided background guidance and thoughtful discussion throughout the thesis, and later became chief supervisor. Thanks for this as well as the discussions of choice tramping spots in the Ruahines.

Dr Brent Clothier (Environmental Physics Group, HortResearch) found himself co-opted informally, and then formally onto the supervision team. During this study he gave freely of his time and provided much zestful argument, as well as friendship. Brent also was closely involved in the final writing of the thesis. Without his inspiration, encouragement and guidance the thesis probably would not have been completed within the deadline. He deserves, and has, my great appreciation.

The last appointment to the supervisorial team was Dr Paul Austin, then of the Department of Production Technology at Massey University, but now at Cambridge Control, Cambridge, United Kingdom. Paul encouraged a line of research that probably would otherwise have been ignored and, as well as his modelling skills, brought a different perspective to many discussions. I hope he appreciated the ensuing debate.

At various times the following people assisted in the field work.

Katy Grainger and Hugh Forlong helped instrument the field. Hugh also carried on with the experimental work while I was ill in 1988.

Most of the students in the Department of Soil Science in 1989 helped spread fertiliser on the plot.

Malcolm Boag, Dave Scotter, and Alister Pickens tried to help me get the irrigation system started in 1989, fought over who would get to wear the Gortex raincoat, and provided solace when it wasn't needed.

Ross Wallace and especially Ian Furkert helped with those jobs that just couldn't be done by one person, such as mowing the 0.35 ha plot with standard lawnmowers.

John Julian deserves special mention. He helped organise equipment, coaxed the irrigation pump, did all sorts of jobs that made the field work possible, and terrified me with his cross-country driving.

Thanks to all these people and to those whose, although not included formally here, efforts are nevertheless appreciated.

Thanks to Dave Barker for the final proof reading of the thesis. This was much appreciated.

Jacque Rowarth, Prue Williams, Peter Kemp, and Robyn Simcock all proved to be wonderful friends during this study. Thanks also to the members of the Manawatu Tramping and Skiing Club with whom I spent too many sanity-preserving days, both enjoyable and miserable, in New Zealand's wonderful forests, rivers, and mountains.

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a_i	parameter in A	-
b_i	parameter in B	-
c	soil solution concentration	M L^{-3}
c^f	flux concentration	M L^{-3}
c^r	resident soil solution concentration	M L^{-3}
c^{Φ}	field-scale soil solution concentration	M L^{-3}
c_i	input solute concentration	M L^{-3}
c_o	output solute concentration	M L^{-3}
c_p	concentration in rainfall	M L^{-3}
c_r	concentration in irrigation	M L^{-3}
e	error, deviation of model from data	-
f	solute travel-time probability density function	T^{-1}
f	defined by equation (A.8)	-
g	solute life-time probability density function	T^{-1}
g	defined by equation (A.9)	-
i	dummy variable	-
j	number of intervals of cumulative drainage	-
j	dummy variable	-
k_i	AMZ model parameter, defined by (5.14)	-
l	dummy variable	-
n	dummy variable (Appendix B)	-
n_a	number of a_i parameters in A	-
n_b	number of b_i parameters in B	-
n_c	number of c_i parameters in C	-
n_d	number of d_i parameters in D	-
n_f	number of f_i parameters in F	-
n_i^z	number of tanks in i^{th} series at depth z	-
n_k	number of delays on the ARMA input	-
q^{-1}	delay operator	-
s	slope of the saturated water vapour curve	M L^{-1} T^{-2}
s	Laplace variable (Ch. 5)	-

t	time	T
v	pore-water velocity	$L\ T^{-1}$
x	number of pathways	-
x_i	proportion of water passing through i^{th} path	-
z	depth or calibration depth	L

A	cross-sectional area	L^2
A	ARMA equation polynomial	-
B	ARMA equation polynomial	-
C	ARMA equation polynomial	-
C	Laplace transform of c	-
C_i	Laplace transform of c_i	-
C_o	Laplace transform of c_o	-
C_r	count ratio	-
D	dispersion coefficient	$L^2\ T^{-1}$
D	ARMA equation polynomial (Ch. 5)	-
E	evapotranspiration rate	$L^3\ L^{-2}\ T^{-1}$
F	ARMA equation polynomial	-
F	defined by equation (A.2)	-
H	total solute uptake by herbage	$M\ L^{-2}$
I	cumulative drainage density	$L^3\ L^{-2}$
$\bar{I}$	average drainage density	L
I^{Φ}	field-average drainage	$L^3\ L^{-2}$
J^{Φ}	field-average solute flux	$M\ L^{-2}\ T^{-1}$
J_w	water flux	$L\ T^{-1}$
L	calibration depth	L
M	amount of applied solute	$M\ L^{-2}$
N	number of samples	-
P	rainfall	$L^3\ L^{-2}$
Q	water flow rate	$L^3\ T^{-1}$
Q	cumulative drainage	L^3
Q_{in}	solute mass entering soil volume	M
Q_{out}	solute mass leaving soil volume	M
R	irrigation	$L^3\ L^{-2}$

R_n	net radiation per unit area and time	M T^{-3}
V_c	convective volume	L^3
V_m	mixed volume	L^3
V_t	total volume	L^3
Z	prediction depth	L

α_i	AMZ model parameter, defined by (5.12)	-
β_i	AMZ model parameter, defined by (5.13)	-
γ	psychometric constant	M L^{-1} T^{-2}
θ	volumetric water content	L^3 L^{-3}
$\hat{\theta}$	estimated volumetric water content	L^3 L^{-3}
θ_{st}	transport porosity	L^3 L^{-3}
θ_{im}	porosity inactive in solute transport	L^3 L^{-3}
θ_{TDR}	θ measured with a TDR	L^3 L^{-3}
λ	dispersivity	L
λ	latent heat of vaporisation of water (Ch. 2)	L^{-2} T^{-2}
μ	mean of the lognormal distribution	-
μ_{field}	field average mean of lognormal distribution	-
ρ_b	bulk density	M L^{-3}
ρ_s	Spearman correlation coefficient	-
ρ_w	density of water	M L^{-3}
σ	standard deviation of the lognormal distribution	-
σ_{field}	field average of the lognormal distribution	-
τ	input time	T

$\mathscr{L}$	Laplace operator
E	expectation
E_f	expectation at field scale
E_l	expectation at local scale
E_{field}	expectation of field-average BTC
Var	variance
Var_f	variance at field scale
Var_l	variance at local scale
Var_{field}	variance of field-average BTC
Cov	covariance