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Transport of bromacil in soils with varying degree of saturation

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Abstract

The effect of water and carbon contents on the bromacil sorption and/or retardation during transport through soils was investigated under steady-state flow conditions. The first set of column experiments was conducted in loamy sand containing 1.5 % organic carbon under three different water contents (23.0, 32.0, and 41.0 %) varying from half to full saturation to measure breakthrough curves (BTCs) of bromide (nonreactive) and bromacil (reactive) tracers injected as a square pulse. In the second set of column experiments, BTCs of bromide and bromacil injected as a step mode were measured in saturated sandy columns with four different powered activated carbon (PAC) contents (0, 0.01, 0.05, and 0.1 %). In addition, equilibrium batch sorption tests were preformed to obtain the distribution coefficient of bromacil for loamy sand and sandy soil added with PAC contents given above. BTCs of bromide and bromacil were analyzed by applying both equilibrium and nonequilibrium (two-site) convection-dispersion equation (CDE) types of transport model to obtain transport and sorption parameters. Model fittings indicated that the nonequilibrium model was more suitable than the equilibrium one to describe bromacil BTCs in soils. Experimental results showed that arrival time of bromacil peak was higher than that of bromide peak in soils, indicating that transport of bromacil was retarded relative to bromide in the observed conditions. Extent of bromacil retardation (R) increased with decreasing water content and increasing PAC content in two soils respectively. Comparison of bromacil retardation between batch and column methods revealed that the column method gave a slightly higher value of R for loamy sand but a much lower value of R for PAC-added sandy soil than the batch method. The magnitude of R difference between the two methods was more pronounced with increasing PAC content in sandy soil.

key word : bromacil, retardation, water content, PAC content, transport model.

Table 1. Experimental conditions of two sandy soils used for column test; different water contents (Exp. 1-3) and powdered activated carbon (PAC) contents (Exp. 4-7)

Exp.	Soil type	Θ (%)	Clay (%)	ρ_b (g cm^{-3})	Organic C or PAC content (%)	Suction pressure (mmbar)	J_w (cm hr^{-1})
1	loamy sand	23.0	5.0	1.58	1.5	330	0.59
2	loamy sand	32.0	5.0	1.58	1.5	120	5.92
3	loamy sand	41.0	5.0	1.58	1.5	0	15.7
4	sandy soil	36.0	0.1	1.49	0.0	-	14.7
5	sandy soil	36.0	0.1	1.49	0.01	-	14.7
6	sandy soil	36.0	0.1	1.49	0.05	-	14.7
7	sandy soil	36.0	0.1	1.49	0.1	-	14.7

Table 2. Fitted parameters of equilibrium and nonequilibrium models.

Exp	Θ	v_w	D	Equilibrium		T_1^a / T_1^b		Nonequilibrium.			
	(%)	(cm hr^{-1})	(cm^2 hr^{-1})	R	r^2	TM	$[T]_{C/C0=0.5}$	R	f	a (hr^{-1})	r^2
1	23	2.6	3.3	1.59	0.91	1.35	-	1.73	0.77	0.004	0.93
2	32	19.4	13.3	1.42	0.88	1.50	-	1.68	0.58	0.028	0.95
3	41	36.9	52.0	1.25	0.95	1.97	-	1.47	0.49	0.352	0.97
4	36	36.6	18.0	1.02	1.00	-	1.1	1.00	1.00	0.000	1.00
5	36	36.0	18.6	1.34	0.91	-	1.3	1.54	0.04	0.067	1.00
6	36	36.4	18.6	3.28	0.94	-	3.3	3.42	0.25	0.055	1.00
7	36	35.7	18.0	5.96	0.97	-	6.2	6.49	0.75	0.019	1.00

Table 3. Comparison of R values between batch, column and travel time methods.

Exp	Θ	J_w	Batch R	J_w/Θ (V_w)	$J_w/R\Theta$ (V_s)	Equilibrium R	Nonequilibrium R
1	0.23	0.592	1.59	2.57	1.62	1.59	1.73
2	0.32	5.920	1.43	18.50	12.94	1.42	1.68
3	0.41	15.696	1.33	38.28	28.78	1.25	1.47
4	0.36	14.680	1.00	40.78	40.78	1.02	1.00
5	0.36	14.680	2.01	40.78	20.29	1.34	1.54
6	0.36	14.680	6.07	40.78	6.72	3.28	3.42
7	0.36	14.680	11.14	40.78	3.66	5.96	6.49

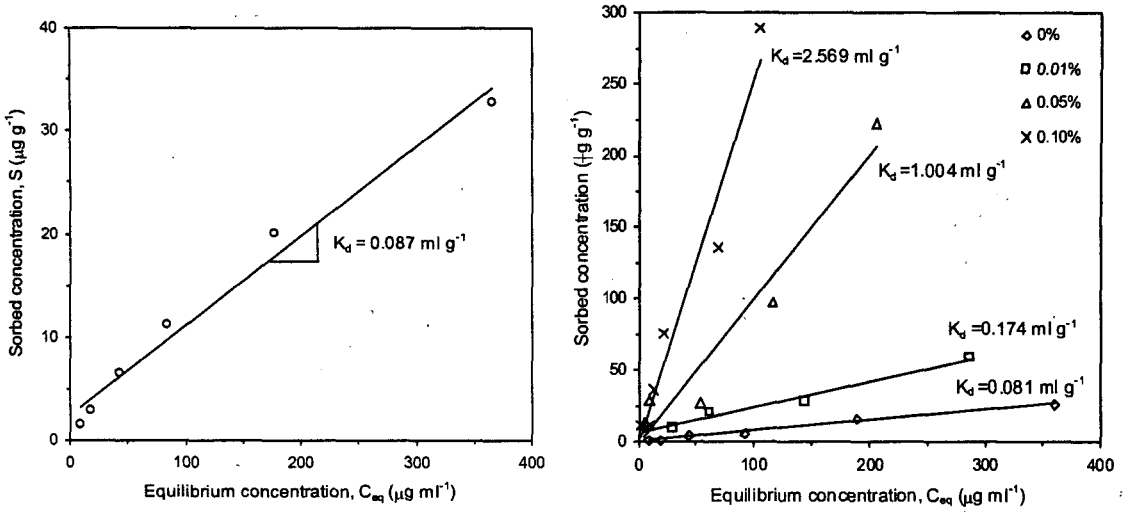

Figure 1. Sorption isotherms for bromacil in (a) loamy sand and (b) PAC-added sandy soil.

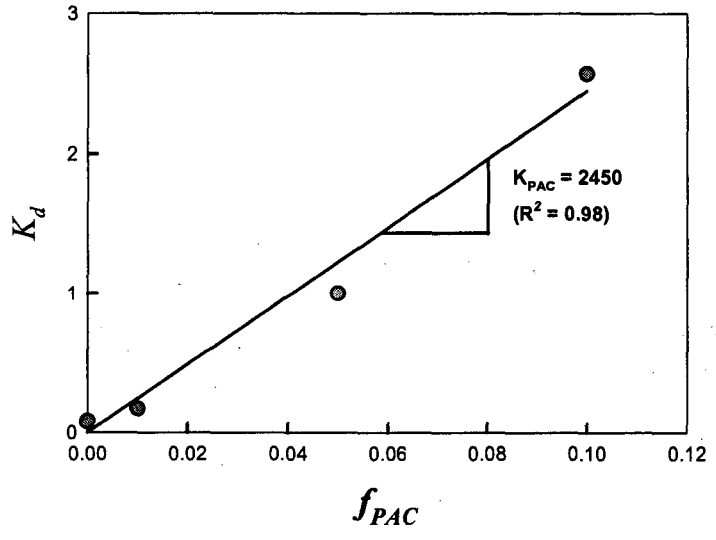

Figure 2. Relationship between K_d and f_{PAC} for PAC-added sandy soil.

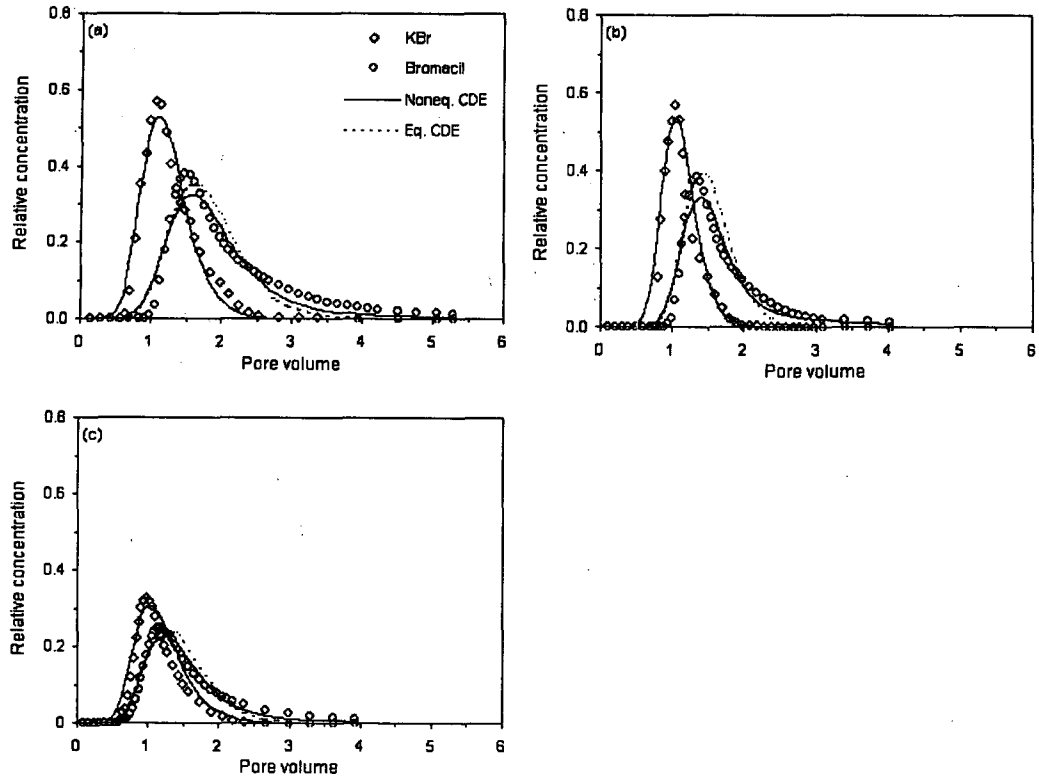

Figure 3. Measured BTCs and model fits for water content of (a) 23.0 %, (b) 32.0 %, and (c) 41.0 % in loamy sand (Exp. 1-3).

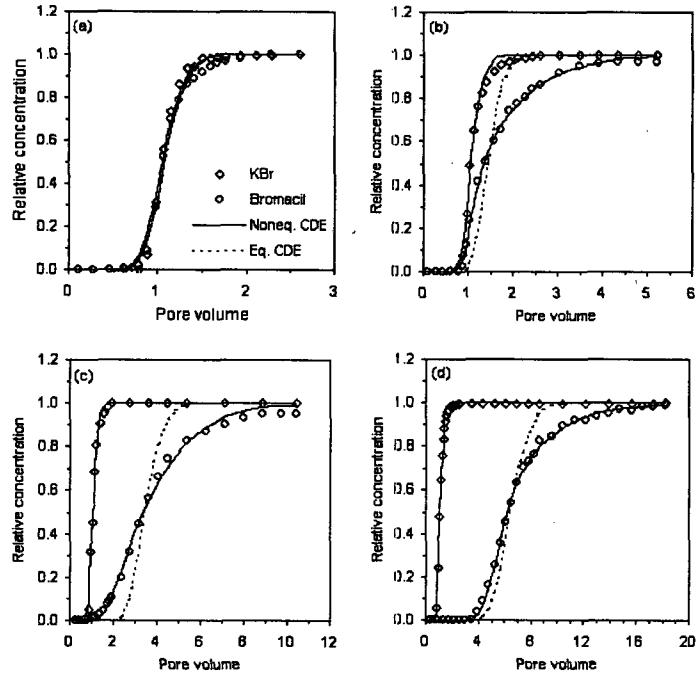

Figure 4. Measured BTCs and model fits for PAC of (a) 0 %, (b) 0.01 %, (c) 0.05 %, and (d) 0.1 % in sandy soil (Exp. 4-7).