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Forecasting solute breakthrough curves through the unsaturated zone using artificial neural network

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Abstract

In this study, solute breakthrough curves through the unsaturated zone were predicted using artificial neural network (ANN) by numerical tests and laboratory experiments. In the numerical tests, applicability of ANN model to prediction of breakthrough curves was evaluated using synthetic data generated by HYDRUS-2D. An appropriate strategy of ANN application and input data form were recommended. The ANN model was validated by laboratory experiments comparing with HYDRUS-2D simulations. The results show that the ANN model can be an effective method for forecasting solute breakthrough curves through the unsaturated zone when hydraulic data are available.

key words: unsaturated zone, solute breakthrough curve, artificial neural network

1. Introduction

Recently, applications of ANN to forecasting water resource variables are increased (Zealand et al., 1999; Jain et al., 2004). For the solute transport problems, ANN applications to predict the transport parameters and solute distribution in groundwater have been studied (Morshed and Kaluarachchi, 1998; Almasri and Kaluarachchi, 2004). It is essential, however, to predict the solute transport with respect to elapsed time for accurate predictions of the amount of solutes reaching to the groundwater table and coupled simulation with transport model of the saturated zone. In this study, applicability of ANN to prediction of solute breakthrough curves through unsaturated zone for various input events was investigated by numerical tests and laboratory experiments.

2.Numerical tests

For numerical tests, 300 cm high vertical hypothetical sand profile was given as a domain. The top boundary of the domain was set as a constant flux boundary and the bottom was set as a seepage boundary. For solute breakthrough data, solute transport was simulated using HYDRUS-2D, which is a finite element model for simulating the groundwater flow and transport in variably saturated media. For ANN applications, input variables included water flux, solute injection time, injected solute concentration and elapsed time. The normalized solute mass at the bottom boundary was used as an output variable. In Test 1, ANN applicability was investigated using a simple network (Figure 1 (a)). The result of the ANN prediction showed that there occurred large errors at the beginning part of breakthrough curves (Figure 2 (a)). Therefore, in Test 2, a new design of ANN was suggested (Figure 2 (b)). The suggested ANN model resolved the problem in Test 1 and yield better prediction results (Figure 2 (b)). Table 1 shows the comparison of prediction efficiencies between Test 1 and Test 2.

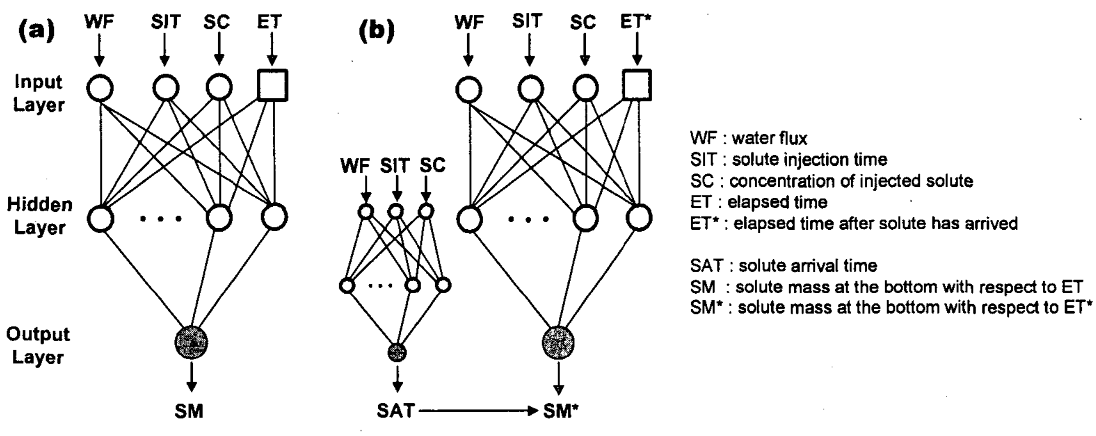

Figure1. Schematic diagrams of ANNs for numerical tests: (a) Tets 1 and (b) Test 2

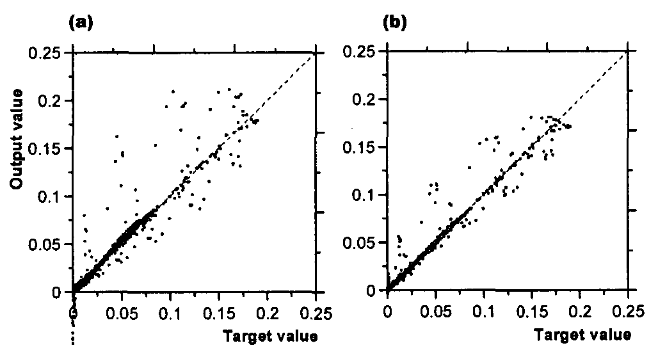

Figure2. The comparison of prediction results between Test 1 and Test 2

Table1. The comparison of prediction efficiencies between Test 1 and Test 2

Prediction efficiency	Test 1	Test 2
Root mean square error	1.41×10^{-2}	7.07×10^{-3}
Mean error	-7.51×10^{-4}	-5.30×10^{-1}
Correlation coefficient	0.946	0.983

3.Laboratory experiments

The suggested ANN model was validated by laboratory data. For laboratory experiments tracer infiltration tests were conducted in a sand column of which the height was 25 cm and the diameter was 5.4 cm (Figure 3). As a tracer, bromide ion was used. Input variables included water flux and bromide injection time. The bromide concentration collected at the bottom was used as a output variable.

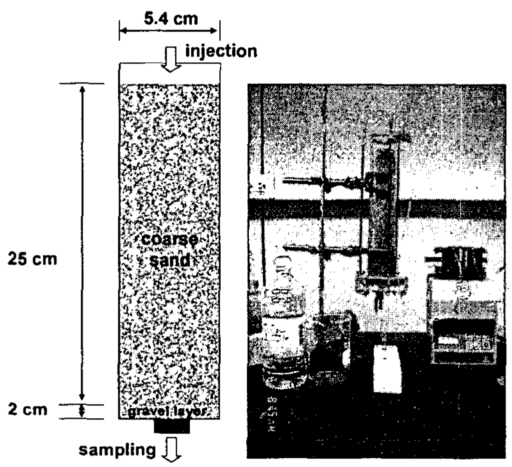

Figure3. Schematic diagram and picture of the laboratory experimental setting

The results of the ANN model prediction, compared with HYDRUS-2D simulations, showed that the ANN model can predict the solute breakthrough curves effectively when hydraulic data are available (Figure 4).

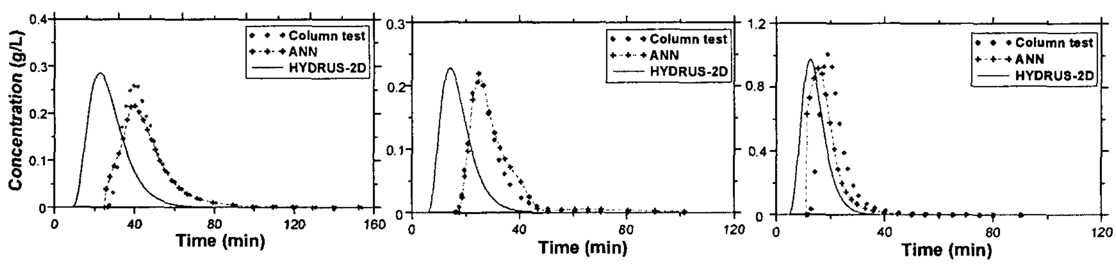

Figure4. The results of ANN application to laboratory data

4.Conclusions

In this study, we evaluated the applicability of ANN to prediction of solute breakthrough curves through the unsaturated zone by numerical tests and laboratory experiments. In numerical tests, we suggested an ANN model which was appropriate to this problem. The results of laboratory experiments represented that the ANN model can be a useful method to characterizing the solute transport through the unsaturated zone when hydraulic data are available.

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