

Study on the Transport Mechanism of Soil Water Ions in Unsaturated Zone

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Abstract: In order to understand the law of solute transport in the unsaturated zone, this paper selects a beach of the Yellow River in jiaozuo area as the study area, and uses Hydrus software to simulate some typical hydrochemical ions in the unsaturated zone. The Hydrus software is a numerical model developed by the National Saline soil Improvement Center in 1991 for simulating water, energy and solute transport in variably saturated porous media. Hydrus-1d is a one-dimensional version of the Hydrus software, which is commonly used to simulate water and solutes. The results show that Hydrus-1D can simulate the study area well with a high degree of fitting. Due to agricultural activities around the simulated area, the actual value of Cl⁻ is higher than the simulated value.

Keywords: Solute transport, Hydrus, Agricultural activity, Cl⁻.

1. Introduction

The Yellow River is the mother river of the Chinese nation. A thorough understanding of the law of solute transport in the unsaturated zone of the Yellow River beach is conducive to in-depth analysis of the changes in the water quality of the Yellow River. Therefore, based on Hydrus software, this paper uses numerical simulation method to simulate the conventional water ion in the unsaturated zone of the Yellow River beach. Pan, WY et al. fully simulated nitrate migration in riparian filtration process with Hydrus, established an empirical formula for riparian filtration describing this relationship, and verified it [1]. Wang, XF et al calibrated and verified the soil hydraulic parameters of Hydrus based on the experimental data in 2016 and 2017, and used the Agricultural Production System simulator (APSIM) to generate the growth period and irrigation system of summer maize[2]. By measuring soil water content, soil water evaporation and root water absorption (RWU) and comparing them with Hydrus simulation results, Wang, XF et al clarified the possible mechanism of summer maize growth in water-resistant soil[3]. Urbina, CAF et al improved the analytical estimation of $w(f)$ and $D(Ag)$ of macropore number in previous studies, and established a general functional meta-model to describe the vertical heterogeneity of macropore number by using inverse estimation of Hydrus model[4]. Yang, YL et al. used Hydrus to simulate the water movement of layered soil with a surface repelled thickness of 10 cm, and the results showed that Hydrus could effectively simulate the water movement in clay loam with different repelled degrees and depths[5]. Er-raki, S et al. used Hydrus numerical model to estimate the soil water (Theta), actual crop evapotranspiration (ETa) and its components (crop transpiration, Ta and soil evaporation) at different depths. The results showed that under different water management conditions, both the deep and deep percolation amount of irrigated winter wheat increased significantly[6]. Xu Jun-zeng, a parameter inversion based on Hydrus build and verify the negative pressure micro irrigation soil moisture movement inversion model, and combining the inversion model of negative pressure micro embellish to fill a variety of combination situation of soil moisture simulation

results and typical facilities crop root system distribution characteristics and law of water requirement, to find a suitable for different facilities crop of negative pressure irrigation technical parameters combination[7]. Ding Yuntao et al. used Hydrus model to simulate soil moisture content at depths of 0 ~ 120 cm, water flux at the lower root boundary (at depths of 100 cm) and water absorption rate of crop roots, and the simulation results were highly reliable[8]. Zhang Wei et al established a biological retention facility model based on Hydrus, calibrated model parameters through facility test data, and verified the reliability of the model. The results showed that the simulation results were reliable[9]. Zhang Fanchen et al. obtained soil moisture and rainfall data by using field monitoring method. Combined with laboratory experiments and Hydrus model, they analyzed the influence of irrigation and rainfall conditions on soil moisture content[10]. Wang Guoshuai et al. made use of Hydrus model to carry out dynamic simulation of water and salt in different periods on sand dunes, sandland-wasteland boundary and wasteland, revealed the characteristics of water and salt migration in desert oases, and evaluated the agro-ecological status of desert oases[11]. Li Qi et al., based on long-term soil moisture observation data of winter wheat planting sites in the test station and laboratory soil column tests, applied the Hydrus model to clarify the variation and distribution characteristics of soil moisture and salt, explore the driving factors affecting water and salt transport, and evaluate the applicability of the Hydrus model to simulate water and salt transport in the study area[12]. The above results show that the numerical simulation of unsaturated zone by Hydrus is feasible.

2. Overview of the Study Area

Jiaozuo is located in a transitional zone between the Taihang Mountains and the north Henan Plain, with a gradual slope from northwest to southeast and a decrease from north to south. It extends from the mountains in the north to the plains in the south, and the whole area presents a step change and distinct hierarchy. The average slope is 2‰. The highest point is 1,955 meters above sea level, and the lowest point is 90 meters above sea level.

The Yellow River flows through Mengzhou, Wen County,

Wu zhi County, in Wu Zhi County exit in Jiaozuo area. The total length of rivers within the territory of 149.6 kilometers, there are fengshi River, Dayu River, Yanwa River, Xiankou River, Bai Dao River, Python River, Qin River and other tributaries into. The average annual flow is 1440 m³ / s, the average annual runoff is 46.8 billion m³, and the maximum flow is 22,000 m³ / s (1958). The annual discharge from June to September accounts for about 80% of the annual discharge, which brings some difficulties to the development and utilization of the Yellow River resources. Due to the large amount of sediment carried in the upper and middle reaches of the loess plateau, the riverbed within the territory is on average 2-3 meters above the surface of the embankment, and there have been 66 breaches in history. After 1950s, a series of irrigation projects were built, such as the People's Shengli Canal, Wujia Irrigation Area, Baimaquan Irrigation Area and Baipo Irrigation Area in Mengxian County, which turned the Yellow River from harm to benefit.

3. Sample Collection

Through field observation and investigation, the sampling point of this experiment was set in the Yellow River under jiaozheng Yellow River Bridge, and the migration and transformation law of water chemical ions in the unsaturated zone of the Yellow River beach along the Yellow River and the influencing factors were analyzed.

According to the standard of 《Technical Guidelines for Environmental Impact Assessment groundwater Environment》, in principle, the stratified sampling of unsaturated zone should include at least 0-0.2m and 0.2-0.8m, and should reach the water surface when necessary. Sampling points were set at the Yellow River beach on the north and south banks of the Yellow River. In order to make the data clearer, the soil profiles of the sampling points were stratified. Each soil profile was set at 20cm and marked according to the sampling depth of each sampling point.

In this experiment, a total of 3 sampling points were selected, namely, 3 sections were selected for simulation. In the process of field sampling, one soil sample was collected from the stratum for each layer of the samples, and the impurities such as residual plants left in the soil are removed. The samples were layered and labeled in sequence according to the sampling order, and then putted into the polyethylene sampling bag. The sampling bags should be tightly sealed, sequentially numbered and labeled, and taken to the laboratory for ion concentration measurement.

4. Sample Treatment

After the soil samples in the unsaturated zone were collected and returned, the impurities such as plant roots and stone grains in the granular soil were removed, and the impurities were placed on the containers and placed in a cool and ventilated place under room temperature. When the sample was semi-dry, the larger clods were crushed and then left to dry. After the experimental samples were completely air-dried, the soil samples were ground and screened with a 1mm sieve, and then putted into sample bags for later use.

Preparation of soil extract: Mainly according to 《the preparation method in Soil Agrochemical Analysis》, the air-dried soil sample was sifted through a 1mm sieve, then 50g was weighed with an accuracy of 0.01, and put into a dried 500mL wide-mouthed bottle, according to 1: The proportion

of 5 in the bottle to add 250mL to remove CO₂ of distilled water (distilled water boiling 15min immediately after use), with a rubber plug will be wide mouth bottle plug tight, after the use of shock machine shock 15min (the experiment with artificial full shock 30min). Then, the water phase filtration membrane of 0.45μm was immediately used for filtration, and the initial 10mL of the purified liquid was discarded. The filtrate was collected and transferred to a 500mL polyethylene bottle, sealed and stored in the refrigerator at 4°C for future use.

5. Research Method

Hydrus-1D is a simulation software used to calculate the law of water and solute transport in unsaturated zones. It can be used to establish mathematical models with different boundary conditions. If the coordinate axis is established with the ground as the starting point, and the z-axis is the positive coordinate under orientation, then the one-dimensional basic water transport equation in saturated-unsaturated zone is:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left[k \left(\frac{\partial h}{\partial z} + 1 \right) \right] - s \quad (1)$$

In formula (1), θ is volumetric water content, h is negative pressure water head; z and t are vertical coordinates and time variables respectively; s is water absorption by root system, and s is 0 in no plant area.

The model is a saturated-unsaturated Darcy flow, and the Richards equation is used as the governing equation of the flow, ignoring the influence of air in the water movement. The convection-dispersion equation explains the solute transport; Galerkin linear finite element solution to the model equation. Software can set different flow boundaries (constant head, variable head boundary, constant flux boundary, free drainage boundary, atmospheric boundary and seepage boundary, etc). When calculating the vertical one-dimensional water movement, the lateral and horizontal water movement is ignored, and the Richards equation is used to solve the soil water movement numerically:

$$c(h) \frac{\partial h}{\partial t} = \frac{\partial}{\partial z} \left[k(h) \left(\frac{\partial h}{\partial z} - 1 \right) \right] - s(z, t) \sqrt{b^2 - 4ac} \quad (2)$$

In formula (2), $c(h)$ is specific water capacity; θ is volume water content; $k(h)$ is hydraulic conductivity; z is soil depth and t is time; H is the total head; $s(z, t)$ is the water absorption rate of soil roots per unit volume per unit time; a , b and c are empirical coefficients.

6. Simulation Results

In the simulation, every 20cm is taken as a kind of soil type and the initial soil profile is assumed to be in the static equilibrium state. Combined with the actual situation, the shallow groundwater level of the four profiles is 1.6m underground, and the top and bottom pressure water heads are set, and the program is used for automatic interpolation to form the initial conditions. The soil profile is discretized into multiple nodes, with every 1cm as the spacing, and multiple observation points are set on the discrete profile, and the observation points are taken as the data output points to obtain

the simulation data. An observation point is arranged every 20cm from top to bottom of the vadose zone to indicate the distribution of solute in the vertical direction. The simulation time is 5d. At the same time, typical water chemical ions are

taken as an example to illustrate the simulation process. According to the actual sampling results, various parameters are input into the model, and the simulation results are as follows:

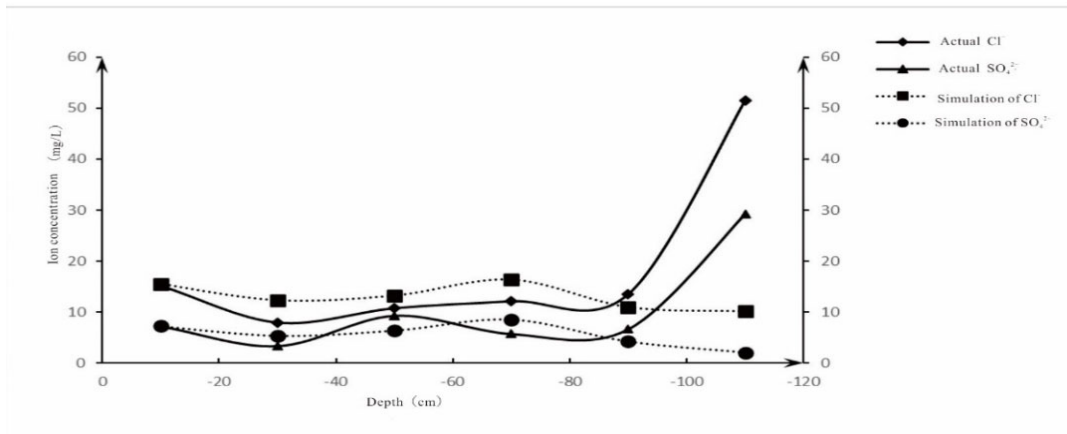


Figure 1. Profile 1 Comparison of simulated and measured typical hydrochemical anions

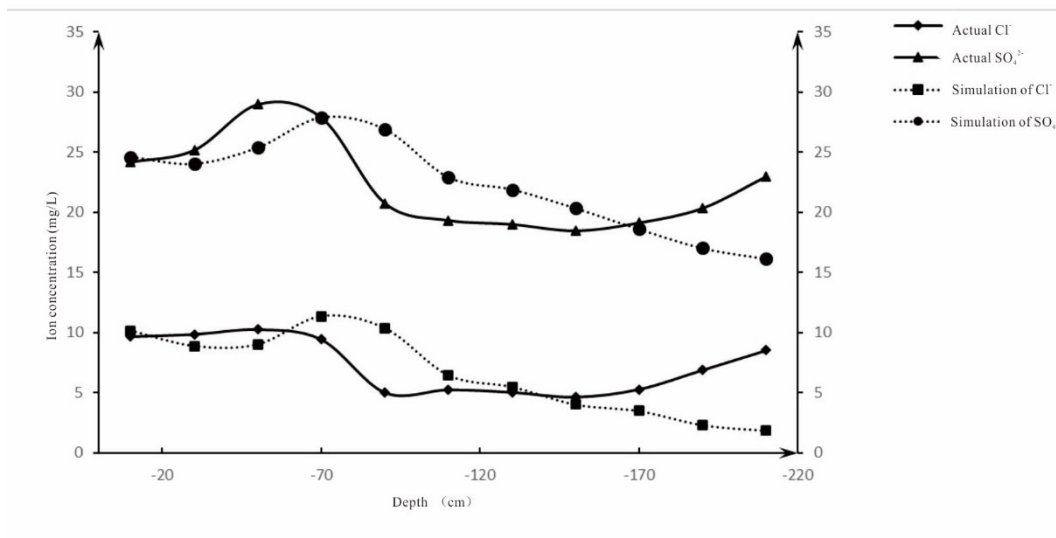


Figure 2. Profile 2 Comparison of simulated and measured typical hydrochemical anions

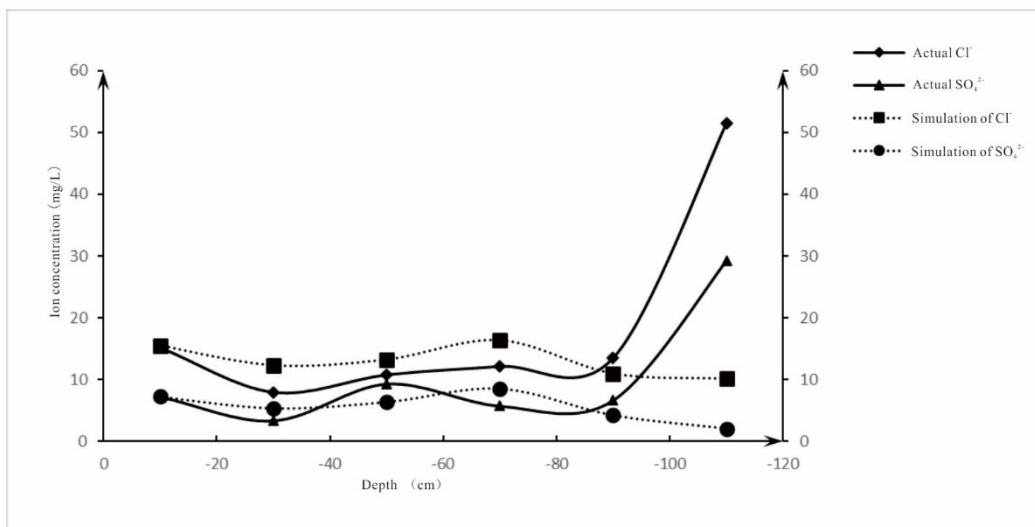


Figure 3. Profile 3 Comparison of simulated and measured typical hydrochemical anions

7. Conclusion

(1). Through the Hydrus-1D simulation of ion content of the simulation results have consistency, are first increases,

then decreases with the measured values change by simulated without considering the original ion content in the soil, and considering the adsorption and exist in the process of migration in the same medium attenuation phenomenon, so

over the continue infiltration in the simulation of hydrochemistry ion concentration is low.

(2). Hydrus-1D software simulation shows that the water chemical ion migration is affected by water migration in the Yellow River beach area. In the shallow soil, it is mainly affected by rainfall infiltration. When approaching shallow groundwater, water chemical ions mainly come from groundwater recharge. In the process of infiltration recharge, it is disturbed by the water recharge of the Yellow River, but its influence is very small.

(3). Due to the influence of human activities, the solute transport will be affected to some extent, which is not completely consistent with the simulation results.

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