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Nitrate Transport Characteristics in the Soil and Groundwater

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Abstract

Nitrate as heat transfer and storage media can be widely used in solar thermal power, nuclear power, and other industrial engineering. If the leaked nitrate cannot be timely recovered, it will probably dissolve in the water, and then transport to the soil and groundwater. In this paper, a numerical model was built to simulate large-scale migration of nitrate in the soil and groundwater, and then the unsteady diffusion performance of nitrate in the groundwater was studied to prevent and reduce the environment pollution of leaked nitrate. The soil system was constructed by the loam and sand, and different groundwater levels and crossing flow rates were also considered. The results showed that the vertical nitrate diffusion range was mainly impacted by the groundwater depth and annual precipitation. As the groundwater depth was deeper or the local annual precipitation was larger, the nitrate pollution can permeate deeper. As the crossing velocity increased, the horizontal pollution range remarkably increased and the vertical pollution range decreased, and the saturated soil layer was more obviously influenced by the crossing flow.

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Keywords: nitrate; soil and groundwater; permeation; crossing flow; numerical model

1. Introduction

As heat transfer fluid and storage medium, molten salt can be applied in many thermal energy storage systems [1]. In China, the present energy situation makes that the majority of application is in the solar power technology [2]. According to chemical composition, molten salt has many types as nitrate molten salt, carbonate molten salt and

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fluoride molten salt, etc. Because of favorable stability at high temperature and low vapor pressure, the nitrate is widely used in realistic utilization [3]. Ternary nitrate (40%$NaNO_2$-53%KNO_3-7%$NaNO_3$) was adopted in the concentrated solar system of Themis plant, and its operating temperature range is 150oC-550oC [4]. By using nitrate (60%$NaNO_3$-40%KNO_3) as the solar receiver and storage fluid, the MSEE generated 4700 kg/h steam at 504 ºC in the salt-to-water stream generator [5]. Many other concentrated solar plants also used the multiple nitrates as working medium to transfer and store energy [3, 6]. The fluid using popularity of multiple salts [7] is in order to decrease the fluid melting point temperature for more steady running conditions.

Although the nitrate is widely used in many thermal transmission and storage device, in case of exceeding the service life of the equipment, aging fluid tank and tubes or other accidental situations, the salt would leaked from heat transfer system. Thus if there is no unexpectedness, the leaked nitrate would timely recovered, but if the uncontrollable emergencies was encountered, such as earthquake, mountain torrents and rainstorm, etc., leaking nitrate couldn't be handled immediately. The contamination would flow to the ground and then migrate in the groundwater. Furthermore, the solute transport research about inorganic salt corroborated that nitrification was not supposed to happen on the fully saturated soil samples [8]. Hence, diffusion range and concentration of the pollution at specific location should be confirmed. Then reasonable and effective environment protection range will be provided by this investigation about nitrate diffusion in the groundwater.

As Simulation model, HYDRUS-1D model have been used to study the leaching in the soil [9-11]. Wang et al. [12] detected the leaching of accumulated N under heavy rainfall, high irrigation rate in growing season and with different amounts of initial accumulated N. Ramos et al. [13] successfully simulated water and solute transport in two multicultural experiments, in which water with different salinity and nitrogen concentrations was used. The model of transient water flow and nitrogen transport were established by Kurtzman et al. [14] to calibrate the data of two vadose zone profiles in the sandy-loam soils.

In this paper, the large-scale migration of nitrate in the soil and groundwater was simulated by HYDRUS-1D model, and then the unsteady nitrate diffusion in the groundwater and the scope of nitrate contaminant were evaluated and investigated.

Nomenclature

θ	volumetric water content (m^3/m^3)
K	unsaturated hydraulic conductivity function (m/s)
S	sink term (1/s)
C	solute concentration in the liquid (kg/m^3)
s	solute concentration in the solid(kg/m^3)
u	pore-water velocity (m/s)
D	dispersion coefficient tensor (m^2/s)
W	liquid volume of somewhat introduced source sink term (m^3/t)
ρ	soil bulk density (kg/m3)
Γ_D, Γ_N	Dirchilet, and Neuman type boundary segments, respectively
Γ_g	gradient type boundary segment
q	outward fluid flux (kg/m^2s)
C_0	outward fluid flux (kg/m^3)
h_0	initial pressure head (m)

2. Modelling and analysis

2.1. System description

In this paper, a 2D system (10×10 m） was built to simulate large-scale migration of nitrate in the soil and groundwater (Figure 1). The upper and lower layers of the soil system were constructed by the loam and sand respectively, and the material characteristics were shown in Table 1. The groundwater depth is the vertical distance between the highest position of groundwater and the ground surface. The local precipitation flows from the top to