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Numerical Simulation Study of Salt Discharge by Subsurface Pipes

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Abstract

The subsurface pipe salt drainage technology is used to improve saline land by controlling the groundwater level and efficiently using precipitation or irrigation water to change the soil water-salt transport pattern, thus affecting the soil salt distribution pattern and soil properties. In this paper, we summarize the problems of soil water and salt transport model simulation under the buried conditions of subsurface pipe, and present the current problems and development prospects of the subsurface pipe salt drainage technology.

Keywords

Salt Discharge; Subsurface Pipe; Numerical Simulation.

1. Introduction

The management and exploitation of saline soils is a global issue that is being researched by scientists around the world. Excess water and salt are discharged by establishing surface and underground drainage systems. Ground drenching is an engineering measure, which is a traditional saline improvement and development method and has been applied successfully worldwide, especially in some places with sufficient water resources [1]. However, if the drainage setup is not perfect, the ground drenching method can only temporarily make the shallow soil in a desalinated state, and there are serious consequences of raising the water table and secondary soil salt routing? Open trench drainage and subsurface pipe drainage are the two most common drainage methods in production practice. Subsurface pipe is a porous pipe laid under the ground, and compared with open trench drainage, it has the characteristics of small excavation works, occupying less arable land, low maintenance cost and long service life, so the subsurface pipe as an important drainage and salt removal technology has been applied and developed in different degrees at home and abroad [2]. Usually, subsurface pipes are widely used in cotton fields, rice fields, etc., mainly to drain excess water from the fields and effectively control the groundwater level, and the parameters of pipe material, pipe diameter, burial depth, and spacing are the most considered factors in the design of the layout, of which the two most important factors are the burial depth and spacing, and the design needs to consider different soil types, topography, and local hydrological conditions.

In order to take full advantage of the benefits and ensure the normal growth of crops, the dark pipe can have both drainage and irrigation functions: when the farmland has too much water (rainy season), the dark pipe can be used to drain and lower the groundwater level; when the farmland has not enough water (dry season), the subsurface pipe can also be used for underground irrigation to supply water to crops from the lower part of the rhizosphere. In addition, during the application of dark pipe drainage, the lower the water table is not the better, and different geographical conditions and crop growth needs should be fully considered to control the dark pipe junk water capacity [3]. Research on soil water - salt movement has accumulated extremely abundant results, among which numerical simulation methods are one of the most important means to understand, predict and analyze soil water and salt dynamics [4]. Different study areas, different conditions such as groundwater depth, soil type, climate, topography, and cropping pattern, require different indicators such as subsurface pipe laying method, spacing, depth, and drenching pressure salt scheme. Compared with field experiments and physical models, it is more convenient and effective to use numerical simulations to obtain and verify the information on the burial parameters of the culverts and the desalination effect of the soil [5]. Numerical simulation techniques can not only simulate soil water and salt transport according to different soil types and meteorological conditions, etc., and study the continuous change pattern of water and salt within the soil layer, but also predict the destination and dynamics of water and salt within the soil layer in the future. Therefore, this paper intends to summarize the problems in the simulation of soil water and salt transport models under the conditions of buried subsurface pipes, and propose the current problems and development directions of the subsurface pipe salt drainage technology.

2. Application of Numerical Simulation in Subsurface Pipe Salt Discharge

When simulating the drainage (irrigation) of a subsurface pipe, the movement of soil water and groundwater between the pipes is usually generalized to a profile 2D flow and the subsurface pipe is approximated as a point sink (source). Like the simulation of soil moisture dynamics, the transport pattern of soil salts under subsurface pipe drainage conditions can also be generalized to a profile 2D flow problem and described by the convection-dispersion equation (CDE) [6]. The equations describing soil moisture and salt movement are generally complex, and in order to solve their computational problems, the combined application of numerical simulation and computers has led to the rapid development of numerical models for soil moisture and salt movement research since the 1980s, and a number of related applications have appeared, such as HYDRUS, DRAINMOD, SWAMP, VS2DT, CHAIN2D, LINKFLOW and SMIILE.

2.1. HYDRUS Models

HYDRUS is a model set based on Richards' equation and CDE equation, which is mainly used to simulate water, energy and solute transport in saturated-unsaturated porous media in a multidimensional spatial range [3]. Li et al. designed shallow salt drainage trenches of different depths based on drip irrigated cotton fields and validated them with the measured results using the HYDRUS-2D model, which showed that the deeper the shallow trench, the better the salt drainage effect, and a salt desalination area could be formed at the drip head when the depth of the trench was 30 cm [7]. Based on a cotton field experiment in the Jidong coastal plain, Sun established a soil water-salt transport model for the root zone of cotton fields, elucidated the response mechanism of cotton growth process and soil water-salt transport, and simulated and summarized the water-salt transport law of cotton fields in the region [8]. Zhao et al. simulated the water-salt transport of farmland in the Mulberry Drop project area under brackish water irrigation conditions, and the results showed that the HYDRUS numerical model could better simulate the soil water-salt transport pattern [9]. Pan et al. analyzed the local soil water-salt transport pattern based on a 5-year field experiment and the HYDRUS numerical model, and the results showed that the soil water transport pattern was basically the same under different irrigation amounts during the reproductive period of maize, and the irrigation amount of 500 m^3/hm^2 could effectively alleviate the accumulation of soil salinity [10]. Li et al. monitored soil salinity changes in the field through controlled irrigation based on a drainage experiment in a saline ditch in Xinjiang, and established a HYDRUS numerical model to simulate and analyze the changes of salinity in saline cotton during one reproductive cycle under open ditch drainage conditions, and the results showed that the average desalination rate of 0-80 cm soil layer reached 50.09%, and the total amount of salinity in 80-200 cm soil layer remained basically the same. The total amount of salinity in the 80-200 cm soil layer remained basically unchanged, and the overall decrease of salinity in the 0-200 cm layer was about 25% [11].

2.2. DRAINMOD Models

DRAINMOD is one of the most widely used hydrological models in the world, which can be used directly or modified for simulation of surface runoff, infiltration, evaporation and drainage in underground (concealed pipe) drainage systems. Singh et al. calibrated and validated the DRAINMOD model with conventional data such as soil and soil transferability functions. The calibrated results showed that the minimum drainage and nitrate-nitrogen losses and maximum crop yield could be achieved with a subsurface pipe burial depth of 1.05 m and a spacing of 25 m [12]. Zhang et al. used the DRAINMOD model to simulate different drainage culvert placement scenarios, and the simulation results showed that the measured and simulated values were in good agreement and could better predict the salinity distribution in the groundwater burial depth and soil profile of saline fields [13]. Youssef et al. used the DRAINMOD model to simulate the drainage performance of agricultural fields over a long period of time [14], and the simulation results showed that Skaggs et al concluded that computer simulation models can be an important tool for analyzing and managing site-specific irrigation, soil salinity, or crop production problems, gave an overview of macroscopic modeling approaches that are based on the Richards equation with a sink term specifying water uptake and an overview of the various parameters of the sink term as a function of water and salt stress is given [15]. Liu et al. simulated the groundwater depth under subsurface pipe drainage and salt discharge conditions in the coastal area based on the DRAINMOD model, and predicted the changes of groundwater depth under different drainage schemes [16]. Guo et al. established a prediction model for the effect of water-salt transport on yield of soil water-salt transport in sub-membrane drip irrigation under brackish water irrigation based on zucchini growth trials and the water-salt transport characteristics of sub-membrane drip irrigation under brackish water irrigation, and the model showed that the model simulation results were in good agreement with the measured results, and could better simulate the soil water-salt pattern and zucchini yield in sub-membrane drip irrigation under brackish water for zucchini [17].

The above numerical model and simulation cases are mainly for the case when the subsurface pipe is in the saturated area, because the simulation depth usually reaches below the water table or even to the water barrier, the lower boundary is impermeable boundary, and the subsurface pipe is permeable boundary or constant flux boundary. When the groundwater is buried deeper and the concealed pipe is in the unsaturated area, especially when the concealed pipe is used as a water supply channel, the lower boundary of the simulation area will no longer be impermeable boundary, and the treatment of the concealed pipe boundary is also different from it, and the model needs to be reconstructed to describe it. Relatively speaking, HYDRUS software is easier to obtain the required parameters, and the interface is reasonably designed, simple to operate, and can be set flexibly according to different boundary conditions and conditions, and has a strong advantage in accurately describing the dynamic changes of water and solute at specific locations in the two-dimensional profile.

3. Conclusion and Prospect

The use of model simulations for subsurface pipe drainage and salt discharge tends to simplify the specific operations and greatly facilitates the determination of the technical parameters. However, the salt discharge from the subsurface pipe is a complex process with many influencing factors. If the dark pipe is in the unsaturated zone and far from the groundwater, whether and how to ensure the good salt discharge effect, how to accurately generalize the dark pipe and the lower boundary conditions, effectively establish the simulation model, explore the effective salt discharge mode, methods and measures for the dark pipe in the unsaturated zone, and reasonably evaluate the salt discharge efficiency of different modes, etc., all these need to be further studied. Therefore, the model simulation of the salt discharge from the subsurface pipe needs to be further studied.

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