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Editorial

Editorial of Special Issue "Advances in Groundwater Flow and Solute Transport: Pushing the Hidden Boundary"

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Abstract: The theme of this special issue is to explore the new territories beyond conventional subsurface flow and transport theories. We have selected 12 articles in this special issue and these articles cover a wide range of problems including (1) Non-Fickian chemical transport in various environments; (2) Non-Darcian flow; (3) Flow and transport in low-permeability media; (4) Vadose zone process; (5) Regional scale groundwater flow and groundwater-surface interaction; (6) Innovative numerical methods. The major contributions of these papers are summarized in this editorial.

1. Non-Fickian Chemical Transport in Various Environments

For this subject, Pannone [1] has adopted a stochastic approach to deal with an evolving-scale heterogeneous formation using power-law semi-variograms. Pannone [1] has analytically shown that dispersion in such a hierarchy system can be ergodic and Fickian or non-ergodic and super-diffusive, based on the scaling exponent value and the magnitude of Peclet number, which was defined in this study as the ratio of the product of the ensemble mean velocity at the initial plume size to the local dispersion. Specifically, a large Peclet number will make the transport process closer to asymptotically ergodic-Fickian conditions. In contrast, a higher scaling exponent will make the transport process closer to a non-ergodic super-diffusive regime. The finding of this article is quite different from what has been reported in previous studies on the same topic.

Also concerning non-Fickian transport, Chen et al. [2] has employed well designed laboratory experiments on flow and transport in synthetic single smooth and rough fractures using a conservative tracer of Brilliant Blue FCF (bis {4-(N-ethyl-N-3-sulfophenylmethyl) aminophenyl}-2-sulfophenyl methylium disodium salt) dye. This study provided visible evidence that the classical advection–dispersion equation failed to capture the long-tailing of breakthrough curves (BTCs), and the continuous time random walk (CTRW) model was better at explaining the long-tailing of BTCs. Furthermore, the coefficient β in the CTRW model was found to be most relevant for characterizing the heterogeneity of the rough single fractures.

Concerning the deep geological repositories for nuclear wastes, Suzuki et al. [3] has pointed out that mass transport of radioactive contaminants displayed anomalous behaviors and often produced power-law tails in BTCs due to the spatial heterogeneities in hosting fractured rocks. This paper proposed a new equation involving an integral term of convolution and fractional derivatives to account for mass exchange between a fracture and porous rock matrix.

2. Non-Darcian Flow

In terms of non-Darcian flow, Wang et al. [4] has conducted a series of experimental flow tests for bimsoils with various slenderness ratios. This study stated that the sample height had a strong influence on the flow characteristics of bimsoils, and the degree of non-Darcy flow decreased with the increase of sample height.

Also focusing on the experimental work of non-Darcian flow, like Wang et al. [4], Chen et al. [2] has conducted flow tests in synthetic single smooth and rough fractures. This study showed that non-Darcian Forchheimer flow was evident in both smooth and rough fractures, and it showed that the non-Darcian coefficient β_c in the Forchheimer equation was most relevant for characterizing the heterogeneity of the rough single fractures.

3. Flow and Transport in Low-Permeability Media

Flow and transport in low-permeability media has become a focal point of research in recent years [5,6]. In this regard, Lu et al. [7] has conducted a field-scale research in Ningchegu site located east of Tianjin of China to investigate flow and transport in continental silty clay, mud-silt clay, and marine silty clay deposits. After analyzing the hydraulic conductivity data collected from 52 boreholes, Lu et al. [7] reported that a Levy stable distribution was a better choice to describe the hydraulic conductivity distribution statistics than the log-normal, normal, Weibull, or gamma distributions.

4. Vadose Zone Process

Vadose zone process (VZP) has been studied more than five decades and still has many controversies. This is partially due to the highly nonlinear flow and transport processes in this zone and partially due to various driving forces coexisting in this zone. Vadose zone serves as an important intermediate buffer zone between the Earth atmosphere and groundwater. Besides hydrological processes, biological and geochemical processes also play active roles in VZP. Three papers of this special issue are focused on VZP. Cheng et al. [8] has reported a field study of influence of irrigation on desert farmland soil moisture dynamics. It included a new type of lysimeter installed below the 150 cm soil profile to continuously measure the so-called deep soil recharge (DSR). This study showed that farmland consisting of an upper 50 cm plough soil and a lower 100 cm filled clay soil can save more water, which is useful in agricultural and water resource management in arid regions.

Also focusing on VZP, Liu and Zhan [9] have proposed a new method of calculating the steady-state evaporation for an arbitrary matrix potential at bare ground surface. This solution expands our present knowledge of evaporation at bare ground surface to more general field conditions, and can be very useful for quick assessment of the amount of evaporation at bare ground.

Concerning the variability of soil depths which are controlled by many natural and environmental factors, Yu et al. [10] has proposed a simple model to describe the relationship between soil depth and infiltration flux taking into account of a non-Gaussian distribution of rock biogeochemical weathering rates. This model demonstrates the importance of fundamental principles of physics to quantify the coupled effects of five major soil-forming factors of Dokuchaev.

5. Regional Scale Groundwater Flow and Groundwater—Surface Interaction

Similar to Suzuki et al. [3] for deep geological repository of high-level radioactive nuclear waste, Cao et al. [11] has focused on the hydrogeological conditions of the Beishan area in China, a repository site of high-level radioactive nuclear waste in China. This study illustrated the special features of regional-scale groundwater flow in the Beishan area, which will be considered in designing the repository facility in this area. In particular, the model is capable of evaluating the influence of the extreme climate and regional faults on the groundwater flow pattern, factors that matter for long-term safe operation of the repository site.

Hydrologic exchange flux (HEF) is a crucial component of hydrological cycle and its strength closely affects the biogeochemical and ecological processes in the hyporheic zone. Focusing on a scale of 1000 m river reach, Zhou et al. [12] has used self-recording thermistors for measuring the vertical thermal profiles and a time series of hydraulic gradients derived from river stage and inland water levels monitoring to estimate HEFs. This method is capable of providing a high-resolution spatial and temporal variation of HEF rates over a large river reach, information that is crucial for understanding the hyporheic zone process.

6. Innovative Numerical Methods

Although numerical methods are routinely used for studying subsurface flow and transport at present, new advancements in this area have never been haltered. Two papers in this special issue represented two examples of continuous endeavor for pushing the boundary of advanced numerical simulation techniques. In one of the two papers, Masciopinto et al. [13] has proposed an innovative approach to model flow and salt transport in fractured coastal aquifers affected by seawater intrusion in Bari, Italy. The model was based on a stochastic method to transfer all real medium heterogeneities into the numerical model. This model provided a reliable estimation of local advancements of the freshwater/saltwater wedge in coastal aquifers, and the numerical model results were corroborated by the non-invasive geophysical measurements including the electrical resistivity tomography (ERT) method at the site.

Focusing on tackling the groundwater flow uncertainties issues, Dong et al. [14] has proposed a new method using the Interval Parameter Perturbation (IPP) principle. The IPP method avoids the dilemma faced by many other statistical and stochastic methods in which the statistical characteristics (such as mean, variance, covariance, etc.) of random variables of concerns must be known a priori, which is usually not feasible in real-world applications. The new IPP method used in Dong et al. [14] did not require the complete statistical characteristics of the random variables. Instead, it only needed the bounded uncertain intervals of variables of concern. The benefit of this method is its capability of analyzing the uncertainties of groundwater flow when it is difficult to obtain the complete statistical characteristics of the hydrogeological systems.

7. Summary

It is our hope that this special issue can stimulate long-lasting interests among the hydrological community to explore the new frontiers of subsurface hydrology in areas that are often either untouched or overlooked before. The advancement of hydrology relies on constant push of knowledge boundary, and this special issue represents one step forward in this direction. We thank all the authors, reviewers, and editorial staff members for producing this special issue.

Conflicts of Interest: The authors declare no conflict of interest

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