**Application of Computational Fluid Dynamics in Groundwater Pollution Remediation**

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**Abstract.** Computational fluid dynamics is widely used in scientific research in various fields. This paper introduces the basic principles of computational fluid dynamics numerical simulation calculation, and summarizes the simulation analysis of pollutant migration and diffusion in the surface underground-groundwater recharge process, the streamline fluid numerical model characteristics and the application of groundwater pollution control and restoration. It provides a reference for the selection of numerical models in groundwater pollution survey simulation and control restoration research.

1. Introduction

Computational fluid dynamics (CFD) is an important branch of fluid mechanics. It has been widely used in aerospace, machinery manufacturing, hydraulic engineering, chemical engineering, sanitary engineering and environmental pollution prevention (groundwater pollution repair) [1, 2]. Especially with the development of computer technology, CFD as an important calculation means such as environmental quality assessment prediction, pollution prevention and remediation engineering, is of great significance to the distribution of water flow field and the migration and diffusion simulation of pollutants. Chinese water resources are unevenly distributed in time and space, while groundwater as an important water resource has already extracted 18% of the country's total groundwater. In the north, 33% of agricultural irrigation water, 50% of industrial water and 65% of domestic water come from groundwater. At present, more than 90% of urban groundwater is polluted to varying degrees, and the sources of pollution are complex, the types of pollutants are large, and the span of pollution time and space is large. The quality of groundwater resources directly affects the quality of surrounding wells, which affects people's health. At the same time, groundwater has the ability to regulate and indirectly affect the stability of the water environment associated with it. The key to groundwater pollution is the temporal and spatial distribution of pollutant concentration. The degree of pollution is determined by the initial concentration, duration and environmental properties of the pollutants. The main goal of computational fluid dynamics is to explore the diffusion and migration of pollutants after they are placed in water bodies. The relationship between the concentration of pollutants and the time and space. For the study of complex groundwater flow field and pollutant migration and diffusion law, it is...
necessary to use effective mathematical model for simulation analysis. Compared with field measurement and physical model research, mathematical model simulation analysis is more time-saving and cost-saving, while obtaining a large amount of valuable value. The research results are more practical for the study of large investment and long period of time.

2. The fundamental of computational fluid mechanics

Computational fluid mechanics (CFD) uses the principles of mass conservation, momentum conservation and energy conservation, adopts appropriate laminar flow (turbulence) model, appropriate boundary conditions and initial conditions, and uses numerical calculation method to solve the fluid flow main control equation to simulate fluid flow and variation law. CFD not only masters the theoretical knowledge of fluid mechanics, but also needs to understand multidisciplinary knowledge such as computational geometry, numerical analysis, fluid physicochemical properties and mechanism of change. The key to the computational fluid dynamics numerical solution lies in the discreteness of the computational region, the dispersion of numerical equations and the solution amplification. According to the discrete principle, CFD is divided into finite difference method (FDM), finite volume method (FVM) and finite element method (FEM).

The earliest and most classical finite difference method (FDM) is used to divide the study area into differential meshes. The finite mesh nodes replace the continuous solution domain and the difference quotient instead of partial differential to solve the kangaroo equations. FDM is mainly used in hyperbolic equations and parabolic equations. The disadvantage is that the adaptability to complex regions is poor and the conservation of numerical solutions is difficult to guarantee. The finite element method is a numerical solution developed in the 1980s. It absorbs the kernel of discrete processing in the finite difference method, and adopts a reasonable method of selecting the approximation function to integrate the region in the variational calculation. The biggest advantage is that it has good adaptability to irregular areas, but it has a large workload and a slow speed, and has high requirements on computer hardware configuration.

The finite volume method (FVM) divides the calculation area into control volume units, and divides the differential equation into a set of discrete equations for each control volume, where the unknown is the dependent variable at the grid point. False set the variation law of the variable at the grid point, and the differential equation solves the integral of each control volume unit. The biggest advantage of FVM is that it is applicable to various grid types (triangles, quadrilaterals), adapts to irregular complex shape research areas, has good conservation, and the physical meaning of discrete equation coefficients is clear, which is the current flow and heat transfer mass transfer problem. One of the most widely used methods in numerical calculations.

3. Application of computational fluid dynamics in groundwater pollution remediation

As an important natural resource, groundwater has become more and more prominent due to a large number of agricultural non-point source pollution, industrial enterprise site pollution, point source drainage and over-exploitation. Therefore, groundwater pollution control and repair technology has also become a hot research topic to be solved. Groundwater pollution control includes pollution source control and pollution plume control. Pollution restoration is mainly divided into in situ repair, ectopic repair and monitoring of natural attenuation repair, such as underground aeration (micro-nano bubble technology) and other repair techniques.

3.1. Groundwater seepage pollution groundwater simulation

Surface water bodies such as rivers, reservoirs and lakes are recharged to groundwater through seepage. Because of the water level difference between surface water and groundwater, organic/inorganic pollutants in surface water bodies enter groundwater aquifers under specific hydrogeological conditions, causing deterioration of groundwater quality. Even the loss of development and utilization value, groundwater and soil environment in polluted areas, affecting environmental quality and endangering human health. Studies have shown that the groundwater
pollution and prevention of groundwater requires the establishment of a river-unsaturated-saturated flow model to explore the migration path of pollutants from surface water to groundwater, diffusion capacity, and extent of influence, attenuation law, and analysis of surface water pollution. The contribution, duration and surface water quality, geological conditions, hydrodynamic conditions, distance from surface water bodies and other key factors polluting groundwater, and various interaction mechanisms in the process.

The interaction between the surface water body and the groundwater body is divided into two types: the water and solute recharge of groundwater receiving groundwater and the water and solute recharge of groundwater. As more and more pollutants are detected in groundwater, the establishment of a river-groundwater system coupling simulation has become an urgent need. The new regulations of the European Union (EU) Water Framework Directive (WFD) call for enhanced management of the sustainable development of water resources and associated ecosystems in surface water-groundwater systems. K. Kayabali studied the effects of polluted rivers on the chemical environment of groundwater, and obtained the concentration of total phosphorus, total nitrogen, organic matter and bacteria without a simple correlation with the distance from the polluted river. Ryan T. Bailey et al. used UZF-RT3D to establish a numerical model to simulate the migration and transformation of NO\textsubscript{3}-N [3]. The results showed that the measures to reduce fertilization and repair channel lining were better, and pointed out that the world-wide irrigation and fertilization-based rivers. The alluvial plain is basically similar to the study area, and the results of the study have universal application value. Haizhu Hu et al. used FEFLOW to establish a two-dimensional finite element steady flow numerical model to simulate the migration and transformation of four solute NO\textsubscript{3}, NH\textsubscript{4}, DOC and DO in river-groundwater systems under submerged recharge conditions.

3.2. Groundwater pollution control and repair simulation

Groundwater pollution control and restoration research, first regional natural geographical features, hydrogeological background, groundwater types, burial conditions, flow field distribution, aquifer distribution and water relations with surface water, establish a water temperature geological conceptual model. Further, the sources, emission methods and duration of groundwater pollution are clarified, and a numerical simulation model of the study area is established. Model boundary conditions, initial conditions and model parameters, including permeability coefficient, rainfall infiltration coefficient, water supply, dispersion, effective porosity, diffusion coefficient, etc., are model-verified.

Computational fluid dynamics numerical models are widely used in various types of ground-water pollution control and restoration research. For example, using VISUAL MODELFLOW simulation to study the distribution and migration and transformation of heavy metal pollution in the groundwater of Xiangtan manganese ore mine in South China, and to predict the potential pollution plume and pollution degree of pollutants [4]. Wu Guangwei simulated the influence of the North China Cogeneration Project on groundwater flow field and water quality through MODELLFLOW software, and analyzed the potential pollution risks and scope of petroleum pollution under accident conditions. Li Yuepeng established the distribution of shallow groundwater flow field in Weihe River Basin, and studied the effects of groundwater depth, river seepage prevention and river pollution degree on the migration and transformation of river-groundwater system pollutants, and proposed the groundwater protection and restoration of polluted rivers. Mode [5]. Luo Chengjie used MODFLOW and MT3D modules to simulate the migration of ammonia nitrogen in groundwater under the simple coverage of landfills and the closure schemes of different pumping wells, and quantitatively studied the migration of pollutants in groundwater in landfill areas under various working conditions. Diffusion characteristics, landfill anti-seepage requirements and groundwater pollution prevention measures are proposed.
4. Computational fluid dynamics numerical model

French hydrologist Darcy obtained Darcy's law through experiments, which revealed the combination of water seepage velocity and hydraulic gradient in saturated soil in 1865, as the beginning of quantitative analysis of groundwater seepage movement. Then the study of Dupuit formula and Tess formula opened a new chapter in numerical simulation research. With the rapid development of computer technology, in order to meet the needs of different types of groundwater pollution control and remediation, numerical simulation as an ideal tool for researching and predicting the migration and transformation of pollutants in different environmental media has been rapidly developed and applied well. The establishment of the required hydrogeological parameters and access is also constantly improving. At present, the numerical models of computational fluid dynamics for groundwater resource development, pollution control and restoration are: FEFLOW, MODFLOW, VISUAL MODEFLOW and GMS.

Germany developed FEFLOW to simulate the two-dimensional nonlinear flow and solute migration of saturated porous media. Later, with the promotion and improvement of the application, it gradually evolved into a multi-functional and widely applicable software. MODFLOW was created in the early 1980s in the United States to study the numerical simulation of groundwater flow in porous media. Due to its universality in all aspects, it has been gradually extended to various fields, and thus it has become the most widely used groundwater in the world. Motion numerical simulation software. In China, most of the VISUAL MODFLOW software research involves the application of groundwater resources, the water inflow of deposits, the site selection of construction projects, and the prediction and evolution prediction of groundwater. VISUAL MODELFLOW has powerful advantages and is simple and convenient to simulate the process of groundwater migration. The entire software package includes MODFLOW, MODFLOW-SURFACT, MODPATH, Zone Budget, MT3Dxx/RT3D, MGO and Win PEST.

5. Conclusion

Computational fluid dynamics has been successfully applied to the simulation of site saturated-unsaturated pollutant transport law, surface water-groundwater recharge and pollution simulation prediction, and regional groundwater pollution control and restoration. The numerical simulations of FEFLOW, VISUAL MODEFLOW, GMS, etc. The software has also been widely used and vigorously developed, prompting the rapid development of the groundwater pollution repair industry.

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