以熱示蹤劑試驗與模式評估海岸帶含水層分層流動特性

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摘要

隨著沿海地區經濟日益發展，海岸環境退化的問題逐漸浮現。為改善此現象，了解沿海含水層與海水間動態交換的過程，必是後續管理及規劃沿海含水層不可或缺的一環。本研究的目標是結合創新的現地試驗及三維數值模擬，以此評估臺灣西北部桃園台地沿海含水層的熱和水相互交換過程。為獲取此地分層流動和熱能傳遞特性，我們先於此地進行水力試驗及熱示蹤劑試驗，後運用 MODFLOW 和 MT3DMS 兩種數值模型，以模擬出海淡水交互作用對沿海含水層溫度場的影響。此模型使用於中央大學 TaiCOAST 臨海觀測站中，所獲取的地下水位和溫度觀測資料進行校準。現地試驗結果表明，主動式熱示蹤劑試驗所產生的熱響應與鑽探岩心匹配，並可藉此計算出此地地下水通量，此外，加熱井附近的觀測井，從地下水面到深 12 米間皆有顯著的熱反應，其中，觀測井 BW08 整體反應最為顯著。數值模擬結果與所觀測水位和溫度十分吻合，能以三維的形式提供此地地下水流動特性，且用來計算此地地下水流速及推估熱傳導係數。本研究模擬結果以高空間解析度揭示潮汐變化對沿海含水層的動態影響，為了解沿海含水層系統的地下水排放情況提供了寶貴的見解。

關鍵字：海岸地下水出流、數值模式、熱示蹤劑試驗。

Using thermal tracer tests and numerical models to evaluate the layered flow characteristic in a coastal aquifer system

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Abstract

With the increasing economic development in coastal areas, the problem of coastal degradation has emerged. To facilitate subsequent planning of water resources management, it is essential to determine the coastal aquifer's dynamic exchange with the ocean. In this research, our objective is to integrate innovative experiments and modeling techniques to assess the heat and water exchanges in the coastal aquifer of the Taoyuan Tableland in northwestern Taiwan. Specific hydraulic and heat tracer tests are conducted at this location to obtain the flow and heat transfer characteristics of the layered flow. In subsequent steps, we employed the MODFLOW and MT3DMS numerical models to simulate the influence of interactions between freshwater and seawater on the temperature field of the coastal aquifer. The calibration of the model is based on the groundwater levels and the temperature acquired from monitoring wells which were installed near the coastline at the TAICOAST observation station. The experimental results show that the thermal responses from the active heat tracer test can match the core sample and enable calculation of the groundwater flux toward the sea. Significant thermal responses are observed vertically in the observation well near the heating well, ranging from the water level to a depth of 12 m, with BW08 being the observation well showing the maximum thermal response. The simulation of the numerical model aligns well with the observed water levels and temperature in wells. The simulation provides a 3D depiction of the groundwater flow direction, which was used to calculate the velocity of groundwater flow and estimates thermal conductivity at this site. The results reveal the dynamic impacts of tidal variations on the coastal aquifer at a high spatial resolution, providing valuable insights into understanding the groundwater discharge in this system.

Keyword: Submarine groundwater discharge, Numerical model, Heat tracer test.