

重金屬於灌溉渠道傳輸之路徑與不確定性分析

The Transportation Tracks and Uncertainty Analysis of Heavy Metals in the Irrigation Channel

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摘要

保護農地即為生產環境的永續經營，國內農地污染事件對自然環境及糧食作物造成衝擊及危害，也因此引起重視。其中監察院於 2015 年之「國內農地污染防治之檢討」報告書中指出，灌溉用水水質不佳為造成農地土壤污染之主要因素。而臺灣因長年未周全考慮土地分區管理之整體規劃，形成農工事業空間混雜現象，加上灌排分離系統缺乏妥善規劃，當含有重金屬之工業廢水隨著灌溉水流入農地，將對環境、作物甚至人體健康造成威脅。因此分析灌溉圳路中之污染物傳輸，其累積負荷量之影響評估可協助污染防治措施的管理規劃。

為更有效掌握重金屬於渠道傳輸變化情形，實行完整的水質監測往往受到許多限制，而藉由水質模式的輔助，能將污染物在水體中複雜的物理及化學作用以數理方程式計算並可量化。本研究旨在應用 WASP (Water Quality Analysis Simulation Program) 模式模擬彰化新圳灌溉水體水質，針對 4 項指標污染重金屬，分析總鉻、銅、鋅及鎳於渠道中傳輸路徑，並深入探討：1. 重金屬溶解態和吸附態傳輸佔比，以及吸附態藉沉降與再懸浮作用在水體與底泥間之質量交換。2. 建立預設情境，模擬極端事件下圳路污染負荷傳遞動態。3. 以結合受限制蒙地卡羅模擬於概似不確定性估計(GLUE)，分析模式輸入參數對模擬結果之不確定性。

本研究藉由 WASP 模擬分析灌溉渠道中重金屬傳輸途徑並予以量化，完成重金屬於控制體積之質量平衡圖，得以清楚顯示傳輸過程變化。另外情境模擬結果評估圳路涵容能力及高污染潛勢區域，能進一步掌握農地土壤污染負荷狀況。最後模擬結合不確定性分析獲得重金屬污染濃度範圍機率分布，改善定率型模式受限於單一模擬值的資訊偏差，並應用於水質汙染風險評估，將利於進行污染負荷削減決策之規劃，以維護安全的農產環境。

關鍵詞：受限制蒙地卡羅模擬，概似不確定性估計(GLUE)，重金屬，灌溉渠道，WASP 模式

Abstract

Protecting farmland is the sustainable way for production environment. Domestic farmland pollution incidents have caused impact and harm to the natural environment and food crops, so it aroused public attention. In 2015, Control Yuan pointed out that poor irrigation water quality was the main factor causing farmland soil pollution. In Taiwan, the land zoning management has not been fully considered for many years, resulting in a mixed phenomenon of agricultural and industrial space. And the lack of proper planning of the irrigation and drainage separation system, when the industrial effluents which contain heavy metals flow into the farmland, it will pose a threat to the environment, crops and even human health. Therefore, the analysis of pollutant transport in irrigation channels and the impact assessment can help the management planning of pollution prevention measures.

In order to more effectively grasp the changes of heavy metals in channels transport, the performance of complete water quality monitoring is often subject to many limitations, and with the aid of water quality models, the complex physical and chemical effects of pollutants in water can be calculated and quantified by mathematical equations. The purpose of this study is to apply the Water Quality Analysis Simulation Program (WASP) to simulate the water quality of Xin irrigation channel in Changhua. According to 4 indicators of heavy metal pollution, analyze the transport tracks of total chromium, copper, zinc and nickel in the channel, and to further explore: 1. The proportion of heavy metal dissolved and adsorbed sediment, as well as the mass of adsorption between water and sediment by settling and resuspension. 2. Set up the scenarios to simulate the dynamics of pollution load transfer on Xin channel in extreme events. 3. The uncertainty of the model input parameters on the simulation results is analyzed by combining the constrained Monte Carlo simulation with the Generalized Likelihood Uncertainty Estimation (GLUE).

In this study, WASP model was used to analyze and quantify the transport tracks of heavy metals in the irrigation channel, and achieve the mass balance diagram of heavy metals in the control volume, which could clearly show the concentration variety in the transport process. In addition, the results of the scenario simulation show that the assessment of the assimilative capacity and high pollution potential area of Xin channel, which can further grasp the soil pollution load of farmland. Finally, the probability distribution of heavy metal pollution can be obtained by simulations combined with uncertainty analysis, and improves the information bias of the deterministic model limited by the single simulation value. The application in water pollution risk assessment will be beneficial to plan pollution load reduction decisions, so as to maintain a safe agricultural environment.

Keywords: constrained Monte Carlo simulation, GLUE, heavy metal, irrigation channel, WASP model