灌溉渠道重金屬傳輸及污染風險評估

Modeling Heavy Metal Transportation and Risk Assessment of Water Pollution in Irrigating Channels

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摘要

農田污染公害事件時有所見，而農田污染多歸因於灌溉水質不良。台灣因為缺乏良好的國土使用分配，使得工廠、畜牧場林立於農地之間，又灌排系統欠缺完整規劃，當工業廢水、家庭污水以及降雨造成道路逕流等點源及非點源污染進入灌溉系統，並藉由渠道作為污染物傳輸媒介進入農田，造成農田污染。因此能掌握灌溉渠道污染源及其傳輸路徑，進一步評估灌溉水水質超標之風險，做為執行總量管制之依據，能有效降低灌溉水水質污染事件的發生。

本研究旨在應用 WASP (Water Quality Simulation Program)模式分析彰化新圳灌溉渠道中總鉻、銅、鋅和鎳 4 種標的重金屬的污染傳輸情形，並結合水理資訊，探討污染物於水體及底泥間的交互作用，掌握重金屬污染物於溶解態與吸附態間之轉換。研究中主要討論沉降速率、再懸浮速率、延散係數及分配係數等較敏感輸入參數的不確定性對模擬結果的影響。藉由執行蒙地卡羅模擬(Monte Carlo Simulation，MCS)再以拉丁高階方塊取樣法（Latin Hypercube Sampling，LHS）和參數矩形區塊取樣（Orthogonal Sampling）均勻配對，再應用於概似不確定性分析(Generalized Likelihood Uncertainty Estimation，GLUE)，評估模擬結果之不確定性。

研究進一步透過此類序率模擬結果，得出重金屬濃度的機率分布，提供後續圳路水質污染的風險評估。結果顯示，研究期間重金屬總鉻、銅、鋅和鎳濃度超過各類水質標準機率皆為 0，因此再以更嚴格之灌溉水水質原標準的 10%來檢視，也僅有鎳超過之風險為 5%。最後將 GLUE 得出之濃度範圍納入農地安全使用年限計算，用以評估灌溉水重金屬污染對農地土壤之影響，結果顯示農地安全使用年限最短的為鎳，範圍落在 308 年至 697 年之間。

綜整研究結果，整體而言，環保署針對新圳於 2018 年執行總量管制後，其水質有明顯改善，因此目前尚無需進行污染負荷削減。本研究結果量化灌溉渠道水質及農田重金屬污染超標之風險，提供後續管理者執行污染管制措施的參考資訊。

關鍵詞：重金屬，灌溉渠道，WASP 水質模式，概似不確定性估計(GLUE)，風險評估

Abstract

Pollution incidents of farmland are the most common, and farmland pollution is mostly attributed to poor irrigation water quality. Factories and livestock farms are scattered among farmlands in Taiwan due to the lack of appropriate planning for land use allocation. Moreover, the irrigation and drainage systems are improperly separated from wastewater discharge, which leads to water pollution, especially heavy metal, generated from industrial wastewater and domestic sewage, and road runoff pollution caused by rainfall enter the irrigation system, eventually enter the farmland. Consequently, many public nuisance events of heavy metal pollution resulted from those misplaced pathways. Therefore, effectively lessening the pollution sources of the irrigation channel and comprehensively tracing pollutant transport, and to further evaluate the risk of irrigation water quality exceeding the standard as the basis for the implementation of total control can reduce the occurrence of irrigation water pollution incidents.

This study aims to apply the WASP (Water Quality Simulation Program) model to analyzing the transport tracks of four heavy metals including total chromium, copper, zinc, and nickel, in the channel of Changhua Xin irrigation system. In addition, the interaction of pollutants in the water body and the sediment is discussed, and the conversion of heavy metal pollutants between dissolved and adsorbed states is mastered. In the study, four sensitive input parameters of settling velocity, resuspension velocity, partition coefficient, and dispersion coefficient were employed in uncertainty analysis. The analysis was approached through the constrained Monte Carlo Simulation (MCS), which integrates Latin Hypercube Sampling (LHS) and Orthogonal Sampling. It not only achieves the same computation efficiency as traditional MCS does, but also tremendously reduces the number of calculations. Next, the Generalized Likelihood Uncertainty Estimation (GLUE) in combination with the constrained MCS was executed to acquire uncertainty results.

The study further uses the stochastic model simulation results to obtain the probability distribution of heavy metal concentrations, which provides a risk assessment of water pollutant concentrations in Changhua Xin irrigation system. The risk assessments conclude that the probabilities of all four heavy metal concentrations greater than various water quality standards are zero. If the more stringent 10% of original irrigation water quality standard has been applied for closer inspection, only 5% of the nickel concentrations exceed the upper limit. Finally, various scenario simulations were performed to assist the assessment of requiring years to meet the regulatory standards for farmlands contaminated from irrigation water. The outcomes show that the least span of safe farming is metal nickel with range from 308 to 697 years.

Overall, the water quality of Changhua Xin irrigation system has improved significantly after pollution control managements in 2018, so there is no need to implement pollution loading reduction for the time being. This study quantify the risk of excessive heavy metal pollution in irrigation channels, and provides more thorough information for decision-makers to effectively

control the heavy metal pollution in irrigation system via appropriate managements.

Keywords: Heavy metal, Irrigation channel, WASP model, Generalized Likelihood Uncertainty Estimation(GLUE) , Risk assessment