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基于随机模糊理论的土壤重金属潜在生态风险评价及溯源分析

Potential ecological risk assessment based on stochastic-fuzzy simulation for soils and pollution source identification

关键词：重金属 土壤 生态风险评价 随机模糊理论 溯源分析

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作 者 单位

李 飞 1. 湖南大学环境科学与工程学院, 长沙 410082;2. 环境生物与控制教育部重点实验室(湖南大学), 长沙 410082

黄瑾辉 1. 湖南大学环境科学与工程学院, 长沙 410082;2. 环境生物与控制教育部重点实验室(湖南大学), 长沙 410082

李 雪 1. 湖南大学环境科学与工程学院, 长沙 410082;2. 长沙学院生物工程与环境科学系, 长沙 410022

刘文楚 1. 湖南大学环境科学与工程学院, 长沙 410082;2. 环境生物与控制教育部重点实验室(湖南大学), 长沙 410082

曾光明 1. 湖南大学环境科学与工程学院, 长沙 410082;2. 环境生物与控制教育部重点实验室(湖南大学), 长沙 410082

摘要：鉴于常用确定性土壤环境污染评价法难以真实、全面地表征实地污染信息,借助随机-模糊耦合理论及多元统计分析技术,建立了基于随机模糊的土壤潜在生态风险评价及溯源分析的决策支持体系.实例研究表明:实例地区土壤中Cd和Ni隶属于极强生态污染和强生态污染的概率分别为100%和26%,应作为优先控制污染因子;40000次模拟下随机模糊评价法得出的实例区域各重金属潜在生态危害系数值的绝对误差基本均小于对应单纯蒙特卡罗模拟方法评价结果的绝对误差,故随机模糊评价法更适用于常见的样本少、样本精度低等情况,可集成更多土壤环境信息;随机模糊评价法可直接通过实数间计算得到结果隶属于各生态风险等级的可信度,在计算效率(1.5 h)上超过单纯的模糊评价方法(3.5 h);基于对模型不确定性的考虑,提出了基于Monte Carlo抽样下的随机模糊模拟(MC-TFN)和Latin Hypercube抽样下的随机模糊模拟(LH-TFN)的联合模拟法,使评价过程更加稳健可靠.多元尺度分析技术下的溯源结论更有助于在评价结果基础上有的放矢地进行相关环境治理与修复决策.

Abstract：To avoid the shortcomings of the deterministic pollution assessment for soils, a potential ecological risk assessment system based on stochastic-fuzzy simulation was developed in combination with pollution source analysis. Soil in a region contaminated by heavy metals was used to test and verify the system. The results showed that Cd and Ni had the probability of 100% and 26%, respectively, in extreme and strong ecological pollution degrees, therefore should be controlled with high priority. By comparing the data from different assessment methods at 40000 simulations, we concluded that the potential ecological risk assessment method based on stochastic-fuzzy simulation was more suitable to samples with small size or low accuracy which can integrate more information associated with the case soils. In addition, the developed method had high computational efficiency, and showed the grades of potential ecological risk for each heavy metal with corresponding confidence levels. Afterwards, with consideration of model uncertainty, the combined simulations with Monte Carlo-triangular fuzzy numbers and Latin Hypercube-triangular fuzzy numbers were suggested, and this combined simulations made the assessment more robust. Multi-dimensional Scaling was utilized to identify sources of heavy metals. It was concluded that the developed system provided the decision-makers with further integrated and scientific references for targeted pollution treatment.

Key words：heavy metals soils potential ecological risk assessment stochastic-fuzzy simulation source identification

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