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LETTER TO THE EDITOR

Establishment of Diffusion Characteristics Extraction Model of Heavy Metal Pollution in Agricultural Soil

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The patterns of heavy metal pollution in agricultural soils in China are diverse, and the risk of regional pollution is prominent. Heavy metal pollution mainly includes strong spatial heterogeneity of heavy metals in soil, large differences in heavy metal accumulation between soil types and crop varieties, serious soil acidification, imbalance of soil elements, difficulty in reversing the trend of heavy metal accumulation in soil, insignificant linear relationship between soil and crop in heavy metal accumulation, imperfect remediation technology, and lack of long-term risk control mechanism of remediation measures. In order to further clarify the diffusion characteristics of heavy metal pollution in agricultural soils, based on a large number of spatial distance data and heavy metal content data, Kriging interpolation method is used to draw the spatial distribution map of heavy metal elements and establish a spatial distribution model. At the same time, the mathematical model of heavy metal pollution degree in agricultural soil surface is established. The pollution degree of agricultural soil is evaluated by Nemerow comprehensive index method and single pollution index method, and the main cause of heavy metal pollution is found to be industrial activities. Finally, the convection-dispersion-adsorption equation model of heavy metal pollutants in agricultural soils is established by analyzing the main characteristics of heavy metal pollutants in the process of transmission.

Agricultural soils; Heavy metal pollution; Kriging interpolation method; Nemerow composite index method

1 INTRODUCTION

Heavy metal pollution in soil refers to the phenomenon that the content of heavy metals is too high due to excessive deposition of trace metal elements in soil caused by human activities. Heavy metal pollution in agricultural soils is closely related to the quality and safety of agricultural products and the health of farmland ecosystems, which has attracted extensive attention of governments and scientists. The situation of heavy metal pollution in agricultural soils in China is severe (Yin et al. 2018). According to the National Soil Pollution Investigation Bulletin issued by the Ministry of Environmental Protection and the Ministry of Land and Resources in 2018, the over-standard rate of agricultural soils in China is 21.4%, with Cd, Ni and Cu being the most prominent. In order to effectively improve the environmental quality of human living, objectively understand the soil anomaly, carry out correct analysis and evaluation on the anomaly phenomenon, and finally find solutions to the problem, as well as ways to improve the environment pollution problem has become the focus of attention (Mana et al. 2017). This paper establishes an optimization model based on data acquisition to analyze and study heavy metal pollution in agricultural soils.

Ruiping Wu published an article entitled “Removal of Heavy Metal Ions from Industrial Wastewater Based on on

Chemical Precipitation Method" in Ekoloji (Issue 107, 2019). This paper proposed a method of removing heavy metal ions from industrial wastewater based on chemical precipitation. Instruments and reagents are used to prepare heavy metal ion solutions, industrial wastewater and absorption. Adhesives are used to fuse metal ion solutions with industrial wastewater. Calcium hydroxide is placed in industrial wastewater solution to react directly with heavy metal ions. Through a series of processes, such as complexation reaction, sedimentation and heavy metal ion concentration detection, a precipitate which is insoluble in water is finally formed and absorbed by biofilm adsorbent. In this paper, the separation methods of heavy metals are mainly discussed, but the diffusion and transfer of heavy metals are not thoroughly analyzed.

According to Kibria (2016), geological cumulative index method and potential ecological hazard index method were used to evaluate heavy metals in soil, and the sources of metal pollution were analyzed by stratified comparison, dustfall method and distance analysis combined with statistical analysis. The results showed that the variability of Pb in profile mainly came from coal combustion or other human activities. Hg and As elements may came from the release of coal combustion together. Distance from the mining area was not the main factor affecting the difference of heavy metals, but may also be related to topography, slope direction, wind direction and other factors. This paper only proves that the correlation between heavy metal pollution and mining area location is low, and there is no specific in-depth study on other factors. Fatoba (2016) summarized various methods of heavy metal pollution assessment, and expounded the advantages and disadvantages of each method and the appropriate objectives. At the same time, the classification standards of related methods were also described, which could provide a powerful reference for the reasonable and accurate evaluation of heavy metal pollution. However, this paper lacks the support of scientific data theory and is incomplete. According to Duan (2016), 160 surface soil samples were collected from 8 agricultural districts and counties in Chongqing. The contents of 8 heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in soil samples were analyzed according to the Technical Specification for Soil Environmental Monitoring (HJ/T 166-2004) and the Standard for Soil Environmental Quality GB 15618-1995. The pollution status and difference of 8 heavy metals in different districts and counties were compared. In addition, the accumulation characteristics of heavy metals in soil and the potential ecological risk grade in the study area were discussed by using the method of land accumulation index and potential ecological risk index. The results showed that Cd, Cr, Cu, Hg and Zn in agricultural soils accumulated to a certain extent, and showed multiple accumulation of heavy metals. The accumulation of Cr was universal, and Hg was the main element affecting the comprehensive potential ecological risk of agricultural soils. In this paper, only the agricultural soils of the above eight agricultural districts and counties were investigated, which has limitations.

In view of the drawbacks of the above methods, two different modeling methods are proposed to study the diffusion characteristics of heavy metal pollution in agricultural soils. The purpose of this study is achieved by Kriging interpolation method and Nemerow composite index method. The experimental results show that the proposed method has high detection accuracy and overall performance.

2 IDEA DESCRIPTION

2.1 Proposal and Analysis of Question

2.1.1 Data Acquisition

The original data of the research object in this paper are from the subjects of the National University Mathematical Modeling Competition. The sampling points in the original data are from the agricultural soils of different regions. The data table lists the location, elevation and functional areas of the sampling points, the concentration of eight major heavy metal elements at the sampling points, and the background value of eight major heavy metal elements.

2.1.2 Question

Firstly, in order to objectively understand the abnormal phenomena of heavy metals content in agricultural surface soil, it is necessary to analyze the spatial distribution of eight heavy metals on the surface, so as to obtain the pollution degree of heavy metals in different areas through mathematical models. Secondly, in order to effectively control the environment and improve the quality of the environment, it is necessary to find out the main causes of heavy metal pollution and its transmission characteristics through the above analysis. Finally, effective control measures should be taken to improve soil environmental quality after determining the location of pollution sources.

2.1.3 Question Analysis

Firstly, in order to calculate the spatial distribution of heavy metals in agricultural surface soil, the physical location of each sample point is known by collecting data, and Kriging interpolation method is used to plot the contours of the spatial distribution of heavy metals and the content of heavy metals in each physical location. The spatial distribution map of heavy metals can be fitted by drawing software, and the pollution degree of heavy metals in different places can be measured by PN index (Marrugonegrete et al. 2017). Secondly, through the Nemerow index obtained from the above problems, we can find out which region is the most seriously polluted by heavy metals, and find out the main causes of pollution, so as to obtain the most seriously polluted areas, the main causes of heavy metal pollution and the characteristics of transmission. Finally, through analysis, it is known that heavy metal pollutants will be absorbed, transformed and migrated in soil. The main ways of heavy metal adsorption in soil are specific adsorption and electrical adsorption. Through research and analysis, we can see that the main factors affecting heavy metal content include the flow mode of liquid fluid in soil, the diffusion mode of pollutants in soil, and the influence mode of pollutant adsorption by solid skeleton in soil. Therefore, we can use differential equation theory to establish mathematical models to seek solutions to improve the quality of soil environment.

2.1.4 Hypothesis and Symbolic Agreement of Question

In the process of establishing the model, the following assumptions are made: firstly, the environment selected by the sampling points is conducive to the development of soil type characteristics; secondly, the sampling sites are not disturbed by obvious man-made disturbances, nor do they suffer from obvious soil damage. Finally, the sampling sites should cover all land types as much as possible. At the same time, the following symbolic conventions are made: Pi-i represents the individual pollution index of a pollutant; Ci-i represents the actual measured value of a pollutant; Si-i represents the background value of a pollutant; PN represents the comprehensive pollution index of various pollutants; PNc represents the comprehensive pollution index of the improved comprehensive pollution evaluation model of various pollutants.

2.2 Establishment and Solution of Model

2.2.1 Spatial Distribution of Major Heavy Metal Elements in Surface Soil

According to the spatial distribution of contaminated heavy metals, and based on the values of all sampling points in the original data, a three-dimensional spatial graph is established by Kriging interpolation method.

Model 1: Kriging interpolation method

Based on the large amount of data obtained and 319 sample data of system grid distribution points, Sufer 10.3 software (Hu et al. 2017) released by golden software company is used to obtain the whole area's three-dimensional spatial graphics by Kriging interpolation method. Then assuming that elevation has no effect on the spatial distribution of heavy metals, Kriging interpolation method is still used, x and y are independent variables, and the sample data of eight major heavy metals are taken as dependent variables to continue drawing images. For intuitive purposes, contour maps are used to represent the spatial distribution of eight major heavy metals.

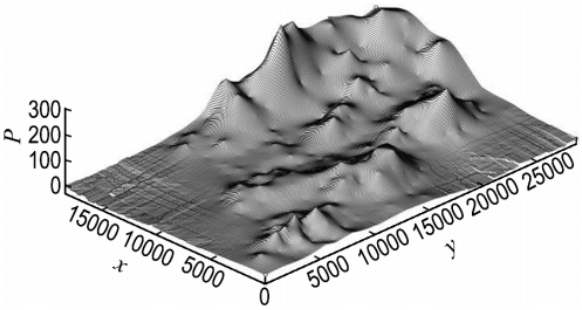

Figure 1 Spatial model of sample data

2.2.2 Analysis of Heavy Metal Pollution in Different Urban Areas

According to the national standards of soil environmental quality, single factor pollution index and Nemerow pollution index are used to evaluate the pollution degree of heavy metals in different regions.

Model 2: Single pollution index method and Nemerow pollution index evaluation model and its improvement model

Firstly, the evaluation criteria of Nemerow pollution index in national standards are found, and then the background values of heavy metals are analyzed. Considering the different contents of heavy metals in different regions, the background values should also be different. The background values are divided into five categories according to the function of agricultural soil types, with the content from low to high (Tiwari et al. 2016). According to Model 2, the PN and PNC corresponding to all sampling points in each region are calculated, and the pollution degree of heavy metals can be determined by calculating the Pi composite index.

2.2.3 Diffusion Characteristics Extraction of Heavy Metal Pollution

Through data analysis, it is found that the content of heavy metal pollutants in agricultural soils near industrial zones is the highest. The main sources of pollution are emissions from production activities, including harmful metal emissions from factories, metal smelting, dye production and so on. For example, mercury (Hg) from mercuride production in industrial zones, copper (Cu) from copper products production, and several other heavy metals from smelting and electroplating are important causes of heavy metal pollution. In addition, lead and other heavy metals in agricultural soils near the main roads are more serious, which is also the main cause of heavy metal pollution.

Based on the analysis of the characteristics of heavy metal elements in soils, it is concluded that the migration of heavy metal elements in soils is affected by the following factors: convective factors, i.e. how liquid fluids flow in soils; diffusion factors, i.e. how pollutants diffuse in soils; and adsorption factors, i.e. how pollutants are affected by the adsorption of solid skeleton in soils.

3 RESULTS

In this paper, two models are established to solve the related problems, which are as follows: (1) Kriging interpolation method is used in Model 1, and Kriging interpolation method requires higher representativeness of sampling points; (2) Nemerow pollution index evaluation method is used in Model 2, which is widely used to evaluate environmental quality. Nemerow pollution index evaluation method reflects the role of various heavy metal pollutants in soil, and the impact of higher concentration of pollutants on environmental quality is the focus of reflection. At the same time, the pollution level of various pollutants and the pollution degree of a specific pollutant are considered, so that it can adapt to the increasing number of pollutants, and deal with the extreme value problem more reasonably, maintaining a certain physical significance, and making the comprehensive evaluation of soil

environmental quality more reasonable.

4 DISCUSSION

Heavy metal pollution in agricultural soils is a serious problem in China. It is urgent to improve environmental pollution by understanding soil characteristics. In order to comprehensively study the diffusion characteristics of heavy metal pollution in agricultural soils, three models are constructed for experimental analysis, namely Kriging interpolation method, Nemerow comprehensive index method and convection-dispersion-adsorption equation model of heavy metal pollutants in agricultural soils. This paper will help people attach importance to the concept of agro-soil ecological service function, aiming at restoring the health of agro-ecosystem, so as to realize the three-step strategic thinking of "investigation-classification-management and control". It will also establish a simple and feasible scheme for controlling heavy metal pollution in agricultural soils, which is suitable for local conditions, cost-effective, and will promote the development of the prevention and control of farm-land pollution in China.

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