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Bioremediation of Soil Pollution by Polychlorinated Biphenyls in Solid Waste Dismantling

Nan Yan*

Dalian Jiaotong University, Dalian, China

**corresponding author*

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Abstract: With the increase in electronic products, the resulting e-waste has also increased, and people have begun to make a profit by processing this e-waste and recycling the metals in it. In my country, the early electronic dismantling industry was dominated by small workshops, with small restrictions, simple processes, no environmental protection measures, and lack of supervision by government agencies, resulting in heavy pollution of waste generated during the dismantling process, especially the soil environment. The main purpose of this paper is to study the soil pollution caused by PCBs in solid waste dismantling and related bioremediation. In this paper, the treatment methods of PCB pollution were analyzed, and the mechanism of microbial degradation of PCBs was studied. Finally, a virtual polluted soil was conducted to compare the neural network and Kriging analysis methods. The experiment found that by further comparing the spatial distribution of different estimation results, compared with the original global pollution distribution in Figure A, the estimation result of GFBP is closer to the original distribution than the estimation result and Kriging estimation result, indicating that the estimation result of GFBP is better.

1. Introduction

It is the current research hotspot to explore the degradation laws of PCBs in complex environmental soil systems, enhance the efficiency of soil bioremediation technology and try to apply them. At present, phytoremediation studies on PCBs-contaminated soil have been reported, but few phytoremediation studies have been conducted on long-term aged soils and low bioavailability PCBs. Most of the existing phytoremediation studies are limited to laboratory studies on simulated polluted soils., it is urgent to carry out more phytoremediation research on actual contaminated soil, pilot scale or above, to discover the problems of phytoremediation technology in the field, and to promote the practical application of phytoremediation [1-2].

In a related study, McCarthy et al. used a combination of statistical, signal processing, and graph-based informatics techniques to assess variability in polychlorinated biphenyl (PCB) data [3], providing graph-based visualizations that linked quantitative contamination Two complementary approaches to research. In addition, a peak-fitting technique based on L2 error minimization is used to autonomously calculate the amount present per PCB. Aziza et al. performed Soxhlet extraction of soil samples with a dichloromethane (DCM)/n-hexane solvent mixture and cleanup on a column packed with Florisil and silica [4]. The PCBs in the samples were quantified by gas chromatography-mass spectrometry. The results obtained were used to assess ecological and human health risks, suggesting potential risks to organisms and humans from exposure to PCBs in these soil profiles.

This paper first briefly introduces the soil pollution caused by PCBs, and then analyzes the pollution caused by the dismantling of electronic solid waste. Then, it analyzes the formulation of soil remediation target values and models, and mentions soil risk control values and soil remediation. The relationship and difference between the target value and related concepts, and then refer to the relevant soil remediation target value calculation models: RBCA model and CLEA model; in terms of calculation, the quantitative methods in the preparation process are introduced; the treatment methods for PCB pollution are mentioned, including physical remediation method, chemical remediation method and bioremediation method; analyze the mechanism of microbial degradation of PCBs, and introduce the preparation of artificial simulated polluted soil in detail; finally, virtual polluted soil and compare neural network and Kriging analysis methods.

2. Design Research

2.1. Pollution of Soil by PCBs

Soil is the largest gathering place for PCBs [5-6]. The PCBs-containing wastewater and solid waste generated in industrial production are discharged and treated arbitrarily, the direct incineration of garbage, and the sedimentation of PCBs particles in the gas environment will eventually accumulate in the soil, making the content of PCBs in the soil the highest, especially PCBs. Soil in and around the site of dismantling and storage of equipment such as chemical production plants and capacitors.

2.2. Analysis of Pollution Production

Table 1. Analysis table of pollution production links

Type of contaminant	Pollution production link	Potential soil contaminants
Waste water	Site washing wastewater; raw materials, waste scraps, wastes, etc. Piled up in the open air are leached by rainwater, and the initial rainwater	Copper, lead, zinc, cadmium, nickel, arsenic, mercury, chromium
Solid waste	Random stacking of waste and slag	PCBs, volatile organic pollutants
Exhaust gas	Incineration process of dismantled waste circuit boards	PCBs, metal-containing particulate matter, volatile organic compounds

Manual dismantling: Use manual dismantling tools such as vise and scissors to dismantle wires, cables and waste circuit boards, separate the plastic sheath and wire core, and obtain metals such as copper, aluminum and waste plastics; Metals such as copper, iron, aluminum, tin, and electronic components with recycling value such as integrated blocks, capacitors, and tubes, and a small part of precious metals such as gold, silver, and platinum. Components such as integrated blocks, capacitors, and pole tubes are classified and sold to the second-hand electrical appliance market, and the dismantled metals and waste plastics are sold to the acquired manufacturers.

Extract solder and general components: put the circuit board that has been disassembled and separated from valuable components on the iron plate and heat it to melt the tin on the circuit board. After most of the tin is melted, put it on a flat place for beating, This can loosen the components on the circuit board, and then use tweezers and other tools to pull them out from the surface of the circuit board, and the falling solder will drop on the iron plate to form solid tin, which can be sold after accumulation and accumulation.

Waste treatment: circuit boards that are separated from valuable components and tin, some contain a small amount of copper, are transported to an external factory for crushing and copper extraction, and some worthless circuit boards and other waste are incinerated on site.

2.3. Soil Remediation Target Value Formulation and Model

(1) Soil risk control value

On the basis of the calculation results of risk characterization of the construction land soil pollution risk assessment procedure, the acceptable soil concentration value of the plot is calculated by using the specified value of the acceptable risk level [7-8].

(2) Soil remediation target value

After carrying out risk assessment according to the technical guidelines for soil pollution risk assessment for construction land, the risk control value is obtained, and then comparing with the risk screening value, risk control value, soil background value, etc., it is concluded that the level of soil pollutant concentration can be reduced to an acceptable risk level., and has a feasible, economical and reasonable soil concentration value after restoration [9-10].

(3) The connection and difference between concepts

There are different standard grades for different soil types, which are mainly used to guide activities such as agricultural and forestry production. Work. The soil background value reflects the concentration level of a certain pollutant in the soil of a specific area, which is of great significance for carrying out soil survey and sampling, guiding agricultural and forestry production and plot risk assessment [11-12].

The difference between the soil pollution risk screening value and the soil pollution risk control value: the screening value is generally lower than the control value. When the survey and sampling find that the pollutant concentration in the plot is greater than the screening value, a risk assessment should be carried out to determine whether the risk level is acceptable. When the pollutant concentration is greater than the control value, the risk level is considered unacceptable, and soil management and remediation should be carried out.

The relationship between the soil risk control value and the restoration target value: the soil risk control value is based on the calculation result of risk characterization in the construction land risk assessment program, and the acceptable concentration value of soil pollutants in the survey plot is calculated by using the model. It must be equal to the restoration target value. The determination of the restoration target value can only be obtained after comparing the risk control value with the soil pollution screening value, the control value, and the soil background value [13-14].

The connection between the concepts is shown in Figure 1.

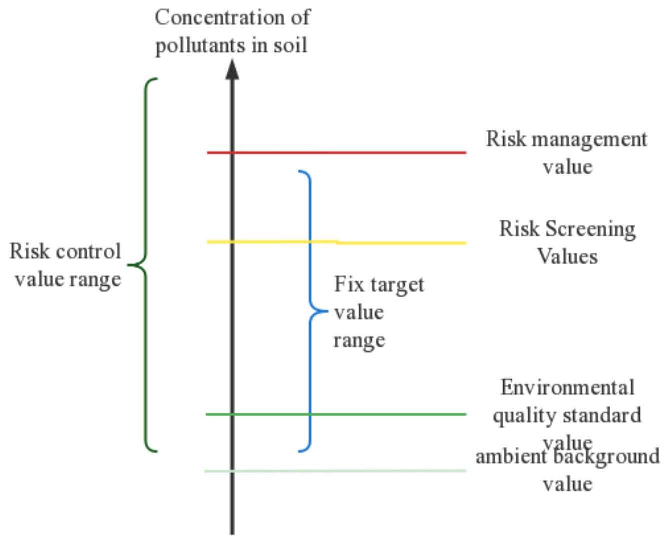

Figure 1. Linkage of concepts related to soil remediation

(4) Calculation model of relevant soil remediation target value

1) RBCA model

The RBCA model specifies two types of land use: residential land and industrial land. The model divides the health risks of contaminated sites into three levels, and studies the migration of site pollutants between soil, air and groundwater. The RBCA model evaluates the carcinogenic toxicity of pollutants in the soil. The pollutants in the soil enter the human body through oral intake, skin contact, inhalation, etc., and then cause harm [15-16].

2) CLEA model

The CLEA model defines three types of land use: residential land with gardens, leased agricultural land, and commercial/industrial land. The mode is divided into basic mode and advanced mode. The parameters of the basic mode are all default values, and the parameters of the advanced mode can be modified. There are three routes for soil contaminants to enter the recipient: oral ingestion of contaminated soil, inhalation through the nose and mouth, and absorption of contaminants through physical contact. The CLEA model identifies three sources of uncertainty in the risk assessment process, namely parameter uncertainty, model uncertainty and scenario uncertainty [17-18].

2.4. Quantitative Methods

The internal standard method was used for quantitative analysis. First, the standard solution was prepared, PCb209 internal standard was added, and the relative peak area was compared with the concentration, and the relative response factor RRF was finally calculated.

$$RRF = \frac{Ms}{As} \times \frac{Mi}{Ai} \tag{1}$$

In the formula, Ms refers to the mass of the standard substance, As refers to its peak area; Mi refers to the peak mass of the internal standard substance, and Ai refers to its peak area.

$$Mq = Aq \times PPF \times \frac{Mj}{Aj} \quad (2)$$

In the formula, Aq—the peak area of the desired substance; Mq—the mass of the desired substance; Aj—the peak area of the internal standard in the sample; Mj—the mass of the desired substance sample.

3. Experimental Study

3.1. Treatment Methods for PCB Pollution

PCBs have caused serious harm to the human environment, and have attracted the attention of all countries in the world. Countries have passed relevant laws and regulations to prohibit the production and use of PCBs to reduce residues. Scholars at home and abroad continue to propose new repair methods for PCBs pollution. For PCBs residues with different concentrations and different forms, the repair plan should be selected according to the actual situation, which is usually divided into the following three types.

(1) Physical repair method

Physical repair is generally through deep burial, transfer, thermal desorption, solvent leaching, etc., but traditional physical methods are only suitable for areas with less PCBs pollution, and traditional physical repair cannot fundamentally solve the harm of PCBs to the environment., can only temporarily alleviate the pollution of PCBs to the environment. With the advancement of science and technology, new physical repair methods such as photodegradation and ultrasonic degradation have also been gradually applied to the degradation of PCBs, and have achieved remarkable results.

(2) Chemical repair method

Chemical remediation methods are divided into incineration and non-incineration. The incineration method can be further divided into high temperature incineration, plasma incineration and cement kiln according to the incineration conditions; the non-incineration technology mainly reacts PCBs with chemical reagents, and generates low chlorine through sulfidation reduction, redox, hydrogenation, oxidative chlorination, etc. Substitute compounds or less toxic substances. The United States, Japan and other countries have carried out deep research on chemical remediation methods. The advantages of chemical remediation methods are thorough treatment and easy operation. However, this method also has obvious defects, such as high cost and easy secondary pollution. Therefore, chemical technology is required. Further improve.

Among the chemical treatment methods, the most promising is the catalytic hydrogenation technology, which uses heavy metals as catalysts to destroy the benzene ring structure by hydrogenating the benzene ring on the PCBs. The research results show that for the contaminated soil with a concentration of PCBs of 4000 mg/kg, the concentration of PCBs can be reduced to less than 0.027 mg/kg after treatment by this method. The high-efficiency degradation rate and mass degradation make this method very popular. Welcome, but the large-scale application is limited due to heavy metal poisoning due to the involvement of heavy metals.

(3) Bioremediation

Bioremediation refers to the method of reducing the toxicity of pollutants by degrading pollutants into simple compounds under the intervention of organisms. Compared with physical and chemical methods, biological methods have the advantages of economical and environmental protection, no secondary pollution, and fast reaction speed. However, biodegradation is also affected by the growth and metabolism of organisms and environmental factors. There are two different metabolic forms for the degradation of PCBs by microorganisms. One is that microorganisms can use PCBs as the only carbon source and energy source without additional carbon source and energy source, and degrade PCBs through their own metabolic process; the other is The co-metabolism process is to degrade PCBs under the conditions of the growth of microorganisms in the presence of external carbon sources and energy sources.

3.2. Mechanism of Microbial Degradation of PCBs

So far, two pathways for microbial degradation of PCBs have been unanimously recognized by researchers. One is the dechlorination reduction process under anaerobic conditions, and the other is the oxidation process under aerobic conditions. The number of chlorine atoms in chlorine is different, and the degradation pathways of microorganisms also show different forms. In general, the chemical properties of high chlorine atoms with more than 6 substituted chlorine atoms are relatively stable. In the anaerobic process, anaerobic microorganisms pass through reduction reactions. The chlorine atoms are removed to generate biphenyl compounds with low degree of chlorination. For PCBs with less than 5 chlorine atoms, the oxidation process is mainly carried out. Through the metabolism of aerobic microorganisms, the low-chlorinated PCBs are finally added oxygen to open the ring to generate chlorine. Substituting benzoic acid, studies have shown that for low-chlorinated PCBs generally through aerobic oxidation process, PCBs can be degraded without going through anaerobic reductive dechlorination pathway; while for high-chlorinated PCBs, they are first generated through anaerobic pathway Low-chlorine PCBs, and then undergo oxidative ring opening, eventually generate less toxic chlorobenzoic acid, and then the chlorobenzoic acid-degrading bacteria can finally completely mineralize it.

3.3. Preparation of Artificial Simulated Contaminated Soil

The artificially simulated contaminated soil was used as the experimental soil. The soil collected from the farmland near the dismantling point of electronic and electrical waste in the aforementioned Chapter 2 requires that the concentration of PCBs and PAHs in the soil is lower than img/kg, the concentration of Qi is lower than 100 mg/kg, the concentration of Pb is lower than 100 mg/kg, and the concentration of Cd is lower than 100 mg/kg. The concentration is less than 1 mg/kg. Because there are many homologs of PCBs and PAHs, typical homologs PCb28, 52, 118, 153, 180 are selected for PCBs, and phenanthrene and pyrene are selected for addition of polycyclic aromatic hydrocarbons.

Before preparing the contaminated soil, first pick out the soil with large particles such as stones and vegetation roots, crush the large pieces of soil with a wooden stick or hammer, and pass through a 10-mesh sieve for use.

(1) Dissolve 90.75g Cu(N03)2.3H20, 38.3768gPb(N03)2, 1.98gCd(N03)2-4H2O in 21 deionized water, sprinkle this solution on 60kg of soil, and continue to add water until All soils are mud-packed. (in a 200L plastic bucket)

(2) Mix the soil with Mengzi in a plastic bucket.

(3) Put the mixed soil in the bucket. In order to speed up the air-drying, when the soil is slightly agglomerated, spread it on the kraft paper.

(4) After the soil is air-dried, take part of the soil to air-dry and sieve, add 600m1 of PCBs (PCb28 52 118 153 180) and PAHs (phenanthrene and pyrene) mother liquor to 600g of air-dried soil (water content 0), Stir well and wait until the acetone is completely volatilized to prepare 600g

of 1000mg/kg PCBs and 1000mg/kg PAHs contaminated soil;

(5) In addition, take 5400g of clean soil, thin it by 2mm, and lay it flat on 1 square meter of kraft paper, paying attention to the thickness. Then 600g of 1000mg/kg of polluted soil was evenly sprinkled on the 5400g of clean soil, and then mixed sentences by the method of quartering. Preparation of 100mg/kg PCBs and 100mg/kg PAHs contaminated soil 6kg.

(6) Take 54kg of clean soil, pass it through a 2mm sieve, and spread it on 5 square meters of kraft paper with an even thickness. Then 6kg of 100mg/kg of contaminated soil was sprinkled on the 54kg of clean soil, and then repeated 20 times through the quartering method. Preparation of Wmg/kg PCBs and 10mg/kg PAHs polluted soil 60kg.

(7) Aging for 30 days.

(8) After 30 days, the aged soil was divided into 8 groups on average, and the mixed test of organic pollutants and heavy metals was carried out respectively, until the concentration difference between the groups did not exceed 10%, the soil could be considered as usable.

(9) The concentrations of Cu, Pb, and Cd in the final soil were 400 mg/kg, 400 mg/kg, and 12 mg/kg, respectively, the concentration of PCBs was 10 mg/kg, and the concentration of PAHs was 10 mg/kg.

4. Experiment Analysis

4.1. Virtual Contaminated Soil

In order to verify the accuracy of neural network-like technology in the spatial estimation of polluted soil, this section uses a virtual polluted soil as the research object for analysis and comparison. Through language programming and optimization, two sets of simulated pollution data are obtained, and the two sets of data meet the following conditions:

(1) Experimental group, 20×20 three-dimensional correlation data, one layer (20×20) of data was randomly selected in this study, a total of 400 points were used as the PCBs pollution concentration in the virtual polluted soil, and the data showed a normal distribution;

(2) Control group, one-dimensional randomly generated data (20×20).

After the data was obtained, the data were filled into a 20×20 grid from left to right and bottom to top, respectively, for subsequent analysis. The virtual soil PCBs concentration and basic statistical analysis are shown in the table.

From the figure, the concentration of PCBs is between 50-25μg/kg. In order to facilitate subsequent analysis, PCBs are divided into three grades. Below 120μg/kg belongs to the first grade (low concentration grade), and the concentration is between 120 and 180μg. Those between /kg belong to the second level (medium concentration level), and those higher than 180 μg/kg belong to the third level (high concentration level). It was found that the concentration distribution of the control group was relatively scattered, and there was no obvious agglomeration between high and low concentrations, while the data of the experimental group had a normal distribution, and the spatial distribution had obvious agglomeration, indicating that the data had good spatial correlation. Neural-like network and Kriging analysis were performed on the experimental group data.

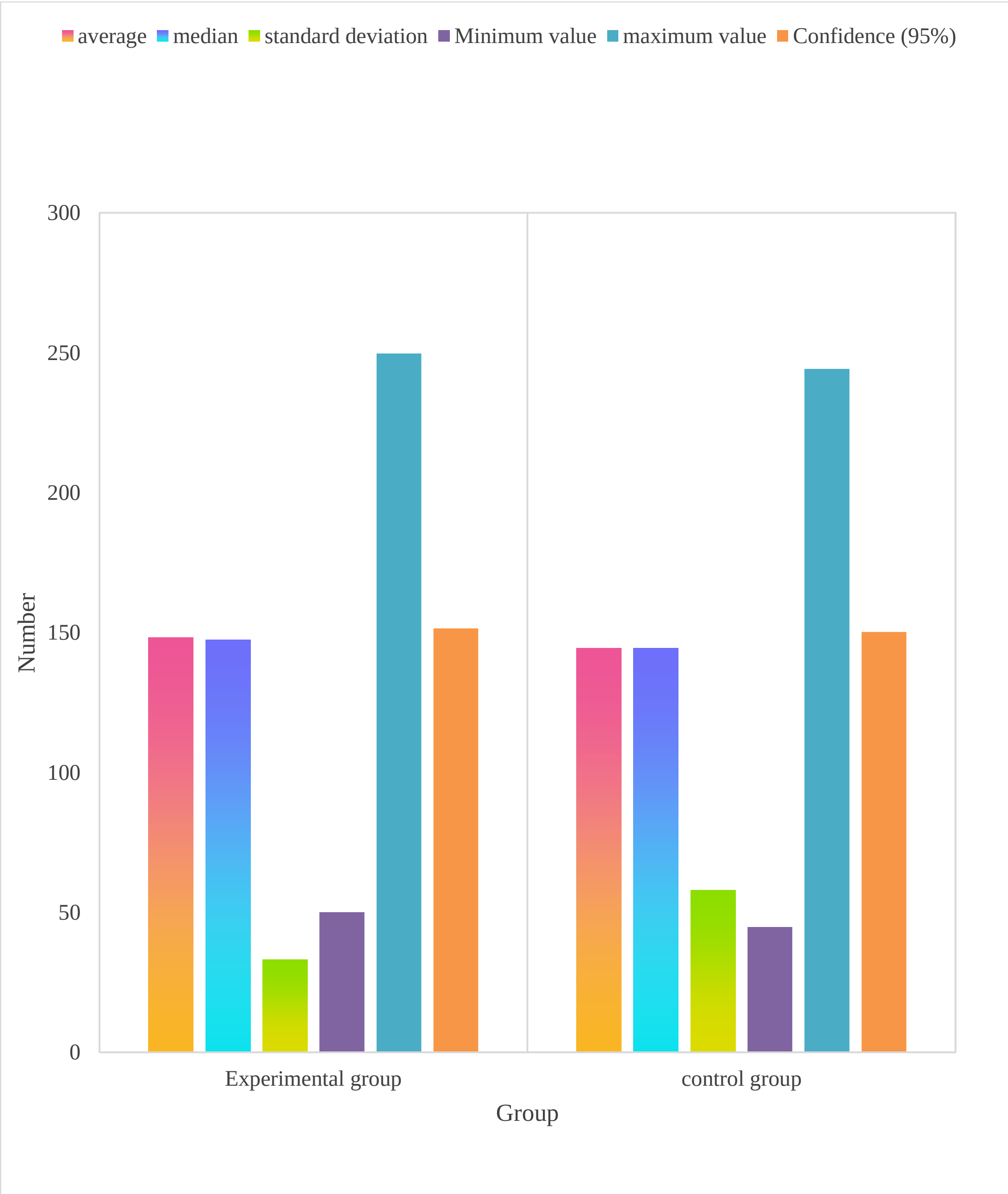

Figure 2. Virtual soil PCBs concentration and basic statistical analysis diagram

4.2 Comparison of Class Neural Network and Kriging Analysis Method

Taking the virtual soil as the research object, using the established neural network model to conduct spatial analysis, and then using GIS as the analysis software to carry out Kriging analysis on the same sampling data to estimate the spatial distribution of pollution, and the estimation results and the neural network estimation results Compare.

Taking 40 points randomly sampled as the research object, the results of different estimation models are shown in the table and figure.

Table 2. Comparison of spatial estimation results with random sampling of 40 points

	Low concentration <120μg/kg		Medium concentration <120-180μg/kg		High concentration>180μg/kg	
	points	Proportion	points	Proportion	points	Proportion
Raw data	71	18.1%	275	68.9%	52	13.1%
Random sample	5	12.5%	26	67.4%	8	20.0%
CFBP	54	13.9%	276	69.4%	69	17.2%
FFBP	61	14.7%	263	66.1%	77	19.2%
Kriging	10	2.5%	304	75.9%	89	22.4%

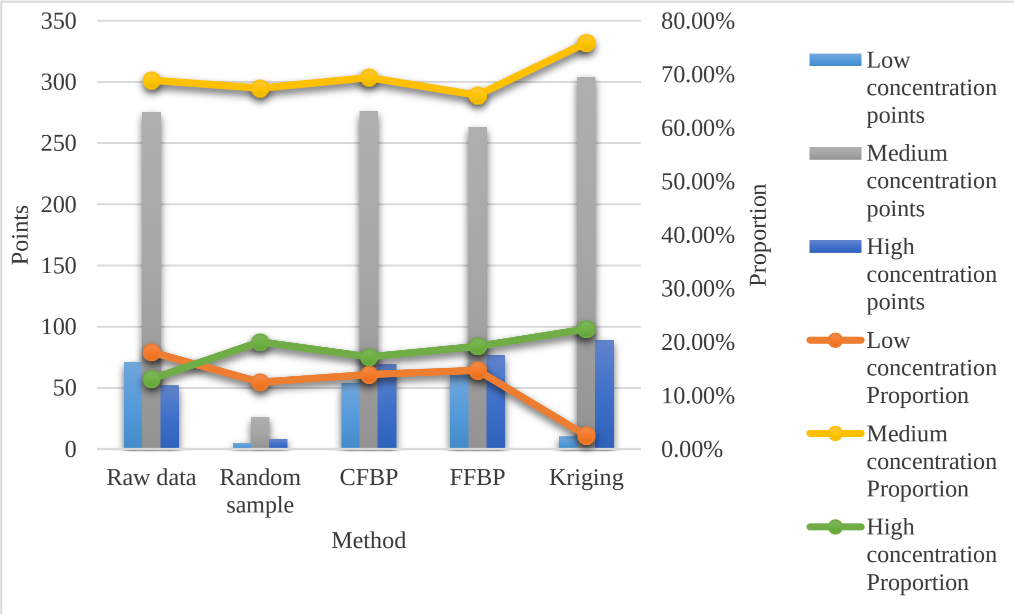

Figure 3. Comparison and analysis of spatial estimation results by randomly sampling 40 points

From the graph analysis, the estimation results using GFBP and FFBP neural networks are better than the Kriging estimation results. Taking the low concentration level as an example, compared with the original proportion (18%), the estimated results of GFBP and FFBP are both around 14%, while the estimated result of Kriging is only 2.5%; for the medium concentration level, the original proportion is 69%, GFBP, FFBP, and Kriging estimates were 69.3%, 66%, and 75.8%, respectively. For high concentration levels, the original ratio was 13%, and GFBP, FFBP, and Kriging estimates were 17%, 19.3%, and 21.8%, respectively. Further comparing the spatial distribution of different estimation results, compared with the original global pollution distribution in Figure A, the estimation result of GFBP is closer to the original distribution than the estimation result and Kriging estimation result, indicating that the estimation result of GFBP is better.

5. Conclusion

The combination of electricity and electronic solid waste has resulted in severe contamination of soils and other areas in parts of our country with heavy metals and persistent organic compounds. The use of bioremediation technology to treat organic contaminated soil is a hot research topic at present, but the final research on bioremediation technology at home and abroad is still lacking. To this end, this paper first briefly introduces the soil pollution caused by PCBs, analyzes the pollution generated by the dismantling of electronic solid waste; formulates soil remediation target values and models, and analyzes soil risk control values, soil remediation target values, and The relationship and difference between related concepts; the mechanism of microbial degradation of PCBs was analyzed, and the preparation of artificial simulated contaminated soil was introduced in detail; the virtual contaminated soil found that the concentration distribution of the control group was relatively scattered, and there was no obvious agglomeration between high and low concentrations. However, the data of the experimental group were normally distributed, and the spatial distribution had obvious agglomeration phenomenon, indicating that the data had good spatial correlation.

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