Application of an Interpolation Method in Pollution Survey by Matlab

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Abstract. In order to make a pollution survey assessing the levels of Cd and Hg, this study drew the pollution spatial distribution map by using inverse distance weighting interpolation to analyze 33 sampling points in a phosphorus chemical plant. The results indicated that the content of Cd in 89.5% areas and Hg in 73.2% areas were above the standard. According to the pollution spatial distribution maps, the points of high Cd value are concentrated in brimstone pools and the points of high Hg value concentrated in brimstone pools, phosphoric acid workshop and storage.

1. Introduction

Phosphorus chemical industries make a large contribute for development of industry, its main products are white phosphorus (P₄), phosphoric acid (H₃PO₄), sodium tripolyphosphate (Na₅P₃O₁₀), phosphate fertilizer and so on [1]. The products service to all areas of the society, such as agriculture, industry, national defense. Currently, a large proportion of phosphorus production comes from China, which has the mature Phosphorus chemical industry system recent decades [2]. With the development of phosphorus chemical industries and the increasing demands of society, its environmental problems are becoming the focus of the government and the owners of chemical plants. Striving to reduce contaminated soils and to prevent further pollution, Chinese government agencies had set environmental quality standard for soils in 1995, which showed that the owners of chemical plants should use effective measures, such as environmental protection and site remediation, to guarantee compliance with the standard [3].

Aimed to soil pollution, site remediation used biological, physical, and chemical technologies in conjunction with one another to reduce the contamination within a safe and acceptable level [4]. However, the cost was a problem in practical engineering [5]. Generally, traditional survey methods evaluated the pollution of the sites by accounting the scale of polluted sampling points. Reaching a certain scale of polluted sampling points means that the whole sites would be remedied, always leading to exorbitantly expensive cost which cannot be afford by the factory owner.

In order to provide methods for reducing the cost, drawing the pollution spatial distribution map was given rise to serious restorers concern. The pollution spatial distribution map would help those owners who can only restore exceeded areas in the site. By simulating test of computer, it was convenient to draw the pollution spatial distribution map.
2. Materials and methods

2.1. Study area

A phosphorus chemical plant used electric furnace method (pyrophosphoric acid process) to produce the outcome of yellow phosphorus, industrial phosphoric acid and sodium phosphate founded in 2000, in Leshan, Sichuan, and was closed by local government for environmental problems in 2015. The plant site was at 103°14′45.00″E, 29°14′38.00″N, covered 41528 m². The plant included stockyards, brimstone pools, an electric furnace workshop, a synthesis workshop, a phosphoric acid workshop, a packaging workshop, a storage for production, office buildings and a mess hall. The main process of the phosphorus chemical plant was shown in figure 2.

![Figure 1](image1.png)

**Figure 1.** Layout chart of phosphorus chemical production factory field in Leshan

![Figure 2](image2.png)

**Figure 2.** The process flowsheet of the phosphorus chemical plant

2.2. Sample Collection and pre-processing

33 sampling points were collected from different functional areas, as shown in figure 1. In general, soil samples were collected to the depth of 0-20 cm and 20-40 and then mixed thoroughly to give the sample of 150g soil [6]. In the laboratory, soil samples were air-dried and grinded until passing a 0.25mm sieve, then stored in the dryer.

2.3. Sample Processing

The pH was measured by glass electrode method (soild-water ratio was 1:2.5) with a digital pH meter (PHSJ-4F, China). Heavy metals were measured by ICP-AES (Iris intrepid II), after 0.5g of sampling soil were dissolved in the mixture of HF (40%, 5ml), HNO₃ (68%, 7.5ml) and HCLO₄ (70%, 7.5ml).
2.4. Analyses methods and software
Matlab R2016a (Mathworks Inc) as the based system was used in graphing, statistics and analyses. In order to study the spatial distribution of heavy metals, interpolation was one of the methods which used points with known values to assign values at others [7]. The precision of interpolation based on different methods [8]. Inverse distance weighting, a widely used interpolation method, was evaluated in this study [9].

2.4.1. Inverse distance weighting (IDW). Inverse distance weighting is based on Tobler's First Law of Geography, all attribute values on geographic surface are related to each other, but closer values were more strongly related than the further ones[10]. In this study, the formula of interpolating function is:

\[
  z(x) = \frac{\sum_{i=1}^{n} w_i z_i}{\sum_{i=1}^{n} z_i}
\]

Where \( z(x) \) is the predicted value, \( z_i \) represents the value of a known point, \( n \) is the number of sampling points, in this study, \( n=33 \). \( w_i \) is the assigned weight of point \( i \), \( d_i^{-u} \) is the distance between point \( i \) and the prediction point. The closer the two points are, the weight value is greater [11].

3. Results and discussion

3.1. The pollution spatial distribution map of pH
According to figure 3, the points of low value pH are concentrated in brimstone pools (4#, 5#, 6# and 7#) and phosphoric acid workshop (8# and 9#), the areas of low pH are northwest of the site. According to the process flowsheet (figure 2), phosphate ore was washed and crushed in brimstone pools, smelted in electric furnace and classified to P4 and slag. A part of P4 will be fed into the phosphoric acid workshop to produce phosphoric acid with concentrated nitric acid (HNO3) [12].

![Figure 3](image)

Figure 3. The pH of sampling points and the distribution map. The horizontal axis shows 29°14′40.00″N to 29°14′43.00″N with 0 to 5, the vertical axis shows 103°14′54.00″E to 103°14′37.00″E with 0 to 5. The pH of sampling points is in (a), and the pollution spatial distribution map of pH is in (b).

3.2. The pollution spatial distribution map of cadmium (Cd)
The points of high Cd value are concentrated in brimstone pools (4#, 6# and 7#), the areas of high Cd value are northwest of the site. According to the environmental quality standard for soils, the standard of Cd is under the level of 0.60 mg per kilogram soils, therefore, 23 sampling points of 33 points exceed the standard [13]. According to most studies, Cd\(^{2+}\) is normally concentrated in the areas with
low value of pH [14, 15]. Oppositely, in high pH areas the concentration of Cd is low, because Cd$^{2+}$ is precipitated in high pH condition, easily washed and swept instead of permeating through soils [16]. On the basis of the distribution map, the areas of 37168 m$^2$ are count up which exceed the standard.

![Figure 4](image)

**Figure 4.** The Cd of sampling points and the distribution map. The cadmium value of sampling points is in (a), and the pollution spatial distribution map of Cd is in (b).

### 3.3. The pollution spatial distribution map of mercury (Hg)

The points of high Hg value are concentrated in brimstone pools (4#, 6#, 7# and 10#), phosphoric acid workshop (8# and 9#) and storage (15#), the areas of high Hg value are northwest of the site. The 8 sampling points of 33 points exceed the standard of 1 mg per kilogram soils, according to the environmental quality standard. On the basis of the distribution map, the areas of 30398 m$^2$ are count up which exceed the standard.

![Figure 5](image)

**Figure 5.** The Hg of sampling points and the distribution map. The mercury value of sampling points is in (a), and the pollution spatial distribution map of Hg is in (b).

### 4. Conclusion

This study provided a method in pollution survey, which assessed the levels of heavy metals or other pollution sources by the certain amount of known sampling points. By the distribution maps, it was available to observe and count up the areas which concentrated in Cd, Hg or other pollution.

This method would contribute to reducing the cost of site remediation, for it confirmed the areas which were above the standard. The owners of polluted sites could only restore areas of above the standard instead of the whole sites according to the distribution maps. In this study, it counted up that the content of Cd in 89.5% areas and the content of Hg in 73.2% areas were above the standard.
Further, it quantized and visualized the spatial distribution features of the pollution, therefore, it showed that the pollution of Cd concentrated in brimstone pools, the pollution of Hg concentrated in brimstone pools and phosphoric acid workshop. Those areas may be the sources of pollution, so it prepared for further investigation to verify.

Although this method was completed by a model and showed the pollution spatial distribution maps, its prediction accuracy of the content for soil heavy metals was subject to some uncertain factors. As followed: (a) The value of unknown point more than or less than sampling points would lead to miscalculate the surrounding points of this unknown point; (b) The value between two sampling points had significant difference would lead to increase the content of areas surrounding the point with less value.

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