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# Copper Spatial Distribution Characteristics in Typical Mining Area Base on Gis Technology

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**Abstract:** The spatial distribution characteristics of copper in soil of Lipu copper mining area was studied using geostatistics approaches combined with GIS. The statistical analyses showed that a concentration of copper was lognormal distribution. The Kriging interpolation maps reflected significant spatial distribution of copper as influenced by both pollution and geological factors. The present study indicated that GIS based geostatistics method could accurately analyze the spatial variation of copper in the mining area. The content of copper in the south was significantly higher than that in the north due to paddy field land uses. In addition, the terrain of four terraces tilted to the center and the broad irrigation accident occurred in the 4th trench in the south of sampling area were also contributed to the higher concentrations of copper.

**Key words:** Copper, spatial characteristics, GIS, geostatistics

## INTRODUCTION

Mining industry has caused serious contamination to arable land in China and the world, this problem is more and more concerned (Shu *et al.*, 1998; Tao, 1997). Mining and smeltering activities not only generated heavy metal pollution but also resulted in determination of soil quality and destruction of the ecological function of the system (Zhang and Ke, 2004). Currently in southern region of China, rapid development in mining industry has produced significant environmental problems including mine soil, water and air pollution (Chen, 1996; He and Zhu, 1987; Gao *et al.*, 1996; Tu *et al.*, 2000) which seriously affected food security and human and animal health. Due to their long-term duration, heavy metal polluted soil is difficult to be remediated (Gao, 1986). Therefore, remediation of heavy metal polluted soils has become a hot issue and understanding of the spatial distribution and variation of heavy metal pollution is an important prerequisite.

The objectives of this study were to investigate the spatial distribution and variation of copper in soils of Hang Pu copper plants, Zhejiang Province of China.

## A STUDY AND RESEARCH PROGRAMS

**Study area:** Zhejiang North-central Pu mine is located in Zhejiang Province, 29° 43'23"N, 119°59'09" E with a total area of the mining area 0.8km$^2$. Hilly terrain within the mining area was a major landscape. Mining land is in the subtropical monsoon climate with annual average temperature of 16.2 and = 10 □ annual accumulated temperature 4924-5233 □. Annual rainfall is 1335.9 mm and annual average evaporation is 1260.7 mm with annual average relative humidity of 75.1%. Soil type is mainly yellow red soil with red sandstone-shale development. Sampling areas are located north of the mining area.

**Soil sampling plan:** Since the mine area had relatively simple topography, the total 48 samples with a space between adjacent points of 10 meter were planned in order to ensure a representative sampling. In the north side of one major irrigation trench, all these sampling were carefully distributed according to the land-use types and topographic characteristics (face, direction and length of ladder status). (Fig. 1)

Mining water overflowing has occurred in the south east side of the 4th irrigation tunnels. Sampling areas was located about 300 meters south side and irrigation canal was along the general direction of flowing through the sampling areas from south to north central region.

**Soil sample collection and analyses:** According to "soil environmental quality monitoring technical specifications (NY/T395-2000)", soils were collected and prepared. Surface soil (0-20 cm) was sampled from each point. Soils were then air-dried and ground through 2 mm sieve for analyses. Soils were analyzed for total lead, arsenic, chromium, copper, zinc, nickel, pH and etc (Institute of Soil Science, 1978).

Copper was determined with British X-ray fluorescence wavelength dispersive spectrometer (Model AFS-820, PANalytical Axios production company).

**Spatial variability analysis method:** In this study, geostatistical spatial analyses were used to generally

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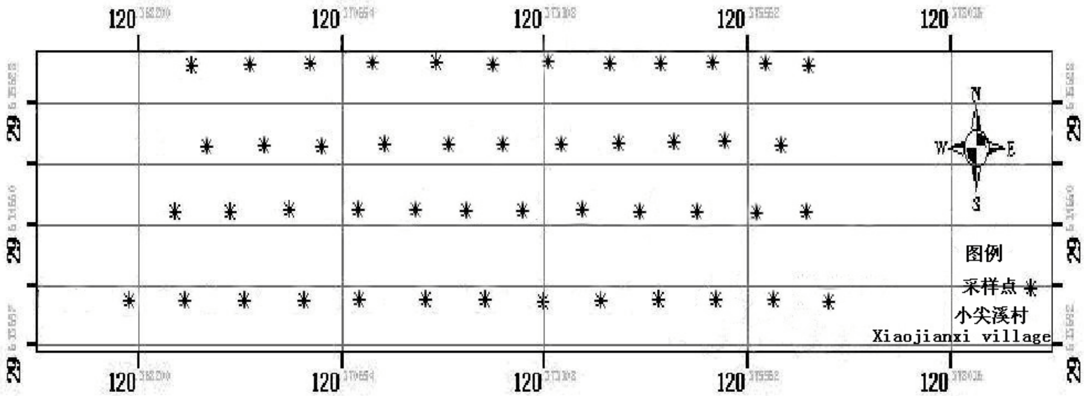


Fig. 1: Distribution of sampling points

semi-variance map and describe spatial variability (Burgess and Webster, 1980). As a best spatial interpolation method it has been widely applied to a regionalized variable characterization in soil science, environmental science and ecology and other fields (Goovaerts, 1999). ArcGIS9.3 was used for this geostatistical analysis, including the semi-variogram (semi-variogram) of the calculation and fitting comparison, Kriging spatial interpolation and simulation error analysis. Semi-variance function is also often referred to as variation function which is studied in geostatistics of soil variability (Guo, 1990). Located in the one-dimensional (two-dimensional or three-dimensional) space in different locations x 1, x 2, ... x n on a certain soil characteristics of the observed value of Z (x 1), Z (x 2), ... Z (x n), Semi-variance [γ (h)] can reflect the spatial dependence of regionalized variables, the calculation can be estimated under:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{n} (Z(X_i) - Z(X_i + h))^2 \quad (1)$$

where, N (h) is used for spacing the number of all pairs of observation points. With h as the abscissa, γ (h) was for the vertical coordinate mapping, that is, semi-variance diagram. Spatial local interpolation (Kriging method) is based on variation of a function and its structural analysis in a limited region of the regionalized variable values for the best linear unbiased estimation method, namely, (is a weighting factor, Z (x) is the sample value, Z is the estimated value):

$$z = \sum_{i=1}^{n} \lambda_i z(x_i)_i \quad (2)$$

## RESULTS AND ANALYSIS

**Statistical analysis of concentration of copper:** Concentration of copper was summarized in Table 1. According to field surveys in 1967, the study area received acid mine waste water outside the Bay. In addition, a heavy application of chemical fertilizers and pesticides may also be important pollution sources for copper.

According to the soil environmental quality standard of China (GB15618-1995), soils in the studied area (pH <6.5) exceeded 100% of copper and zinc, lead standards, 91.67% of arsenic and 79.17% of nickel.

In addition, the skewness and kurtosis analyses indicate that copper negative bias. The frequency distribution histogram (Histogram) showed that copper in soils studied were characterized by normal distribution.

**Heavy metal content of soil under the conditions of the same spatial variation analysis of sexual:** Due to the presence of specific value of the variable which may cause interruption of a continuous surface, experimental semi-variogram will distort or even obscure the inherent spatial structure of the variable characteristics (Zhang *et al*.,1997). In this paper we identified the specific value-domain method (Wang *et al*., 2001), that is, the sample average plus or minus three times the standard deviations, in this interval (±3s) other than the data were as specific values and then the normal maximum and minimum values were used instead of specific values. Subsequent calculations were based on the field data after treatment.

Figure 2 is a study of copper in the isotropic condition. According to the actual variation of the

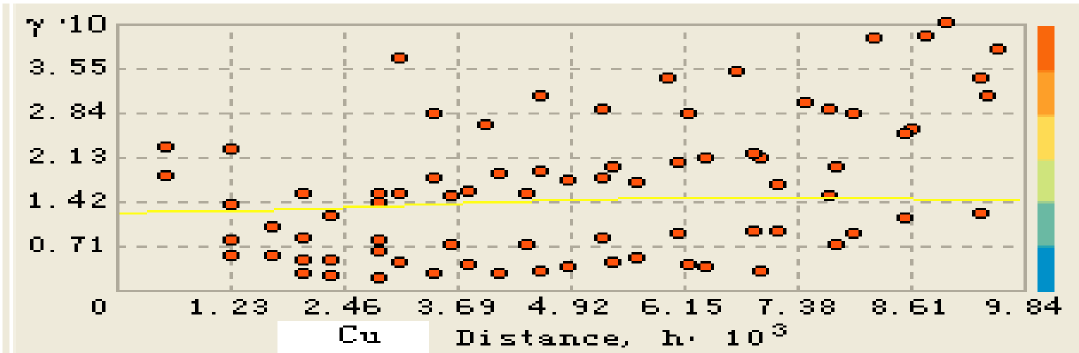


Fig. 2: Corresponding graph of semivariograms of copper

Table 1: Descriptive statistics of copper contents (mg kg$^{-1}$)

| Item | Max | Min | Median | Average | Standard deviation | Skewness | Kurtosis | Distribution type |
|---|---|---|---|---|---|---|---|---|
| Cu | 1095.9320 | 90.9040 | 702.8885 | 664.5950 | 249.3063 | -0.45336 | 2.2543 | Lognormal |

Table 2: Theoretical semivariogram models of copper and its corresponding parameters

| Element | Theoretical model | Variable-range | Sill | Nugget | Nugget/sill |
|---|---|---|---|---|---|
| Cu | Hole effect | 9626.5 | 1.45235 | 1.2587 | 0.866664 |

function, semi-variance for the vertical axis and the sampling distance of abscissa displayed the semi-variance fitting curve drawn map. Copper of the semi-variogram curve has a significant continuous increase in range. When the semi-variance with the increasing of separation distance has reached a certain scale (variable range), the Semi-variance curve becomes flat. The correlation between samples in more than this distance was no longer relevant after and it appeared as when h> a time, γ (h) was at a value of up and down swing, so there is spatial variability of the structure. This change pattern can be used with a threshold value (Sill) models fitted to choose the best theoretical model variogram. Using ArcInfo in the analysis of the statistical analysis module, a variety of model interpolation error may be produced. If the forecast errors are unbiased, then the mean prediction error should be close to zero.

Table 2 shows the best fitting theoretical model and its parameters for copper in the semi-variance selected. The results show that, the Hole Effect model for Cu.

Spacial correlations were controlled by the structural factors and random factors. Structural factors included such as parent material, soil type, climate and soil-forming factors while random factors were farming, management practices, cropping systems, land use patterns, pollution and other human activities.

The optimized model should meet the following criteria: The minimized (close to 0) Standard Mean (Mean Standardized), the minimum root mean square prediction error (Root-Mean-Square), the minimized (close to 0) average standard error (Average Standardized Errors), closest root mean square prediction Error (Root-Mean- Square), closest (to 1) standard root mean square prediction error (Root-Mean-Square-Standardized) (Li *et al*., 2001).

**The simulated values and measured values of the cross-validation:** Cross-validation was conducted in the data of all samples. Each time removing one of the points with the remaining points, the value of the predicted value of the point, was compared to the actual value and the predictive value of the difference between the validations of space-interpolation was used to analyze the degree of accuracy, thus the best Kriging analysis was selected. In theory, the best prediction is equal to the actual measured values and the slope between them should be a linear related. As the spatial interpolation in the process of smoothing (smoothing) effects, the linear slope between the measured values and predicted values is usually less than 1. For example, the predicted values of soil Cu and the measured values of the relevant equation are:

$$Y = 0.71X + 342.779$$

The correlation between measured values and the predictive values of copper at significant level and the correlation coefficient is 0.617 **. ( **At p = 0.01 level)

**Spatial distribution of copper and its pattern:** According to the principles of Kriging interpolation and semi-variogram fitting parameters, Geostatistical Analyst in ArcMap software was applied for analyzing module spatial variability of interpolation. Therefore spatial distribution of trends of copper and the distribution of its

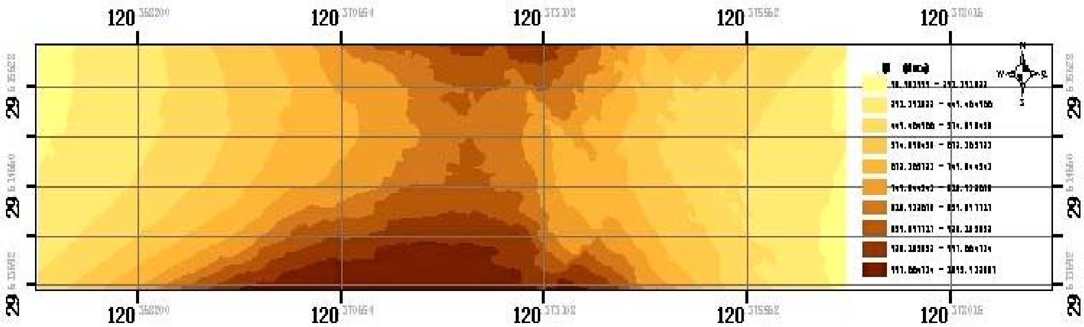

Fig. 3: Interpolation map of Cu

classification map were produced (Fig. 3). Kriging interpolation was affected by variation function model simulation accuracy, the distribution of samples, the selection of the number of adjacent samples and many other factors. Interpolation accuracy may be reflected through the interpolation error. The smaller the variance, i.e., the standard root mean square prediction error close to 1, the more accurate Kriging interpolation (Tang and Yang, 2006).

Figures 3 showed the Kriging interpolation maps for soil copper content (unit: mg / kg). The distribution trends show a north-south direction with higher values in the center. With decreasing from the center of north-south direction the higher values were found in the south than in the north of Grand.

## CONCLUSION

Copper has been significantly accumulated in soils around the 4th trench. The contamination sources may be from both natural, i.e., geochemical sources, or anthropogenic source, i.e., human activities, or combined pollution sources.

In general, Copper distribution showed the high accumulation in the center of the regions with decreasing concentrations form the center towards both south and north direction. In the study area, higher concentrations of Cu were found in the center region in the direction of south-north and concentration of Cu in the south side was higher than that in the north side. This is mainly due to land use patterns and topography of the landscape in the region. Paddy fields were main land use in the south side where irrigation water was through the 4th trench. However, in the north side, vegetable and wasteland were the major land use where runoff flew from the mining tailing area. This may contribute to the high concentrations in the soils of the north side. In addition, the terrain of four terraces tilted to the center and the broad irrigation accident occurred in the 4th trench in the south of sampling area were also contributed to the higher concentration of copper.

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