Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(7):2370-2374

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Lead pollution in response to transportation: A case study in the rural-urban fringe zone of Suzhou, northern Anhui Province, China

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ABSTRACT

Heavy metal pollution in soil is an important issue in nowadays because it can affect the human health through food chains. In this study, 149 surface soil samples have been collected from the rural-urban fringe zone of Suzhou, northern Anhui Province, China for analyzing the lead concentrations. The results indicate that the lead concentrations range from 7- 42 mg/kg with mean = 13.8 mg/kg. In comparison with the environmental background value of China, only one sample is polluted. However, spatial distribution and cluster analyses suggest that there is a hotspot located near the entrance of the city, and implying that transportation (motor vehicles) is considered to be responsible for the lead pollution in the area. After statistical and spatial outliers removing, the environmental baseline of lead in the surface soil of the area is calculated to be 7.24 – 19.5 mg/kg, and seven samples were identified as polluted.

Key words: Lead pollution, Surface soil, Transportation, Environmental baseline, Outlier identification

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INTRODUCTION

Heavy metals, such as copper, lead, cadmium and arsenic, have long been recognized for their hazards over the health of human beings [1-3]. Although they have only trace levels in the environments (e.g. air, dust, soil and water), the health of human beings can be affected by them through the food chains: from soil or air or water to vegetable, and then animal and human beings [4]. Taking for instance, the releasing of arsenic into the environment during many industrial processes can take bad effects over the human health: e.g. peripheral neuropathy, skin lesions, and lung cancer [5]. And therefore, public concern over heavy metal pollution in the environment is growing every day.

To be a special kind of heavy metals, lead has long been recognized for its bad physiological effects [5]. Moreover, previous studies revealed that it can be released by multiple natural or anthropogenic processes, and motor vehicles are considered to be the major contributor of lead emissions, including on-road motor vehicle gasoline, air emissions of lead from the transportation sector, and particularly the automotive sector.

Soils are critical environments interfaced with air and water, and they are inevitably exposed to direct and indirect effects of human activities. And therefore, contamination by metals in soils has become widespread and serious due to the non-biodegradable nature and long-biological half-lives of these metals [6]. Accumulation of heavy metals in the food chain will have a significant effect on human health in the long term [7].

Suzhou is an agricultural dominated city, more than 80% of the residences in the city are engaged in work related to agriculture, and the area is called as “ocean of fruit and granary” because of its high production of wheat, fruits and vegetables. And therefore, the safety of agriculture, especially its related soil properties, is important for the social and economic evolution of the area.

In this study, a total of 149 surface soil samples in the rural-urban fringe zone in Suzhou, northern Anhui Province, China have been collected and analyzed for lead concentrations, and then analyzed by statistical and spatial analyses, the goals of the paper include: (1) determining the pollution degrees, (2) identifying the sources and (3) establishing the environmental baseline.

EXPERIMENTAL SECTION

SITE DESCRIPTION:

Suzhou is a city located in northern Anhui Province, China. The longitude of the city is between 116°09′and 118°10′, and the latitude is between 33°18′and 34°38′. The total area of the city is 9787 km^2 with its length is 195 km (from east to west) and the width is 151 km (from south to north). The city's land area is 7.8 million acres and the plant area is 15.6 million acres with 200% multiple cropping index, and the main crops in the area include wheat, corn, soybean, cotton, potato, rapeseed, peanuts and fruit etc.

SAMPLING AND ANALYSIS:

A total of 149 surface soil samples (less than 5 cm depth) located in the rural-urban fringe zone of the city have been collected (Fig. 1) in June, 2014. Samples were firstly air-dried in natural conditions (25 – 30 ℃), and the debris of animals and plants had been removed by hands. Then, the samples were powdered to be less than 200 meshes (≤0.075mm) after parching for 24 h at 80 °C in a dryer.

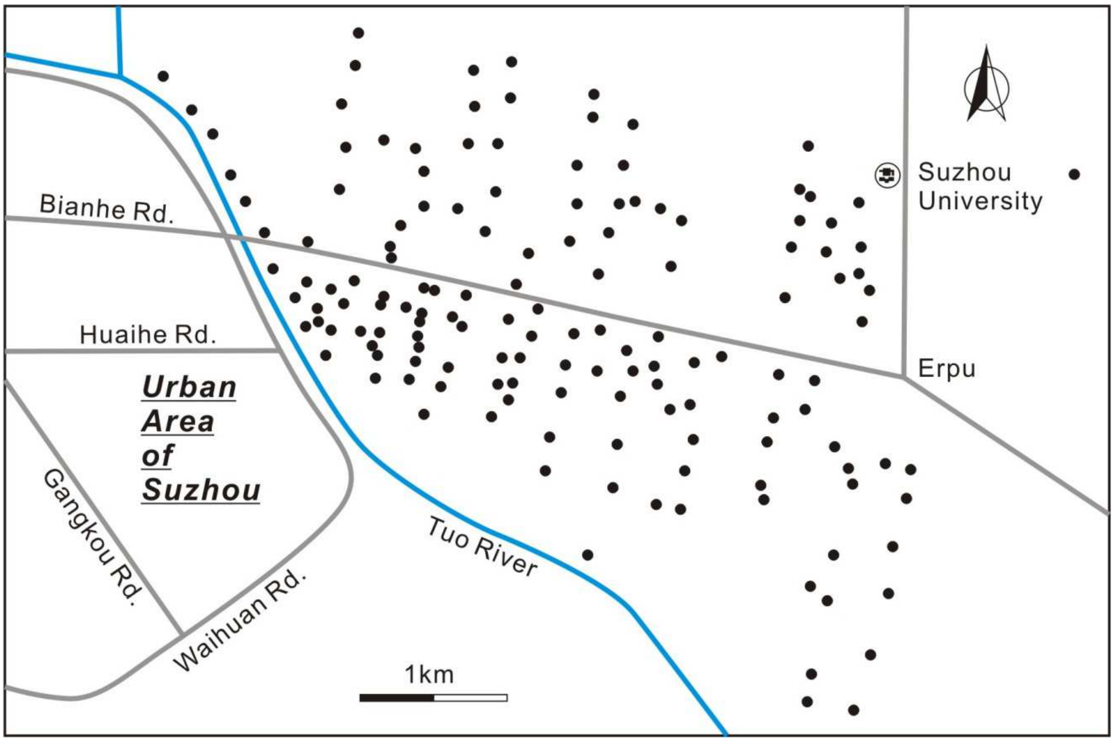

Fig.1: The distribution of sample locations

Then the samples were made into tablets by using a 30t condenser, and then analyzed by XRF (Innov-X Explorer 9000 SDD, USA) for measuring the concentrations of lead in the Engineering and Technological Research Centre of Coal Exploration, Anhui Province, China. National standard sediment sample of China (GBW07307) was analyzed simultaneously for calibration (once per ten samples), and the relative standard derivation is less than 10%.

DATA PROCESSING:

All of the lead concentrations were firstly analyzed by Mystat software (version 12), and the results obtained including minimum, maximum, mean, median, coefficient of variation, skewness, kurtosis and normality test. Then, the lead concentrations were plotted as a contour map along with their locations by the software surfer (version 11). Based on the contour map, the areas with high lead concentrations can be identified. Finally, the software Geoda (version 1.4.6) has been applied for spatial clustering (Univariate Local Moran's I), and then the pollution hotspot can be achieved. And then, the outlier samples (including either statistical or spatial outliers) were removed for establishing environmental baseline.

RESULTS AND DISCUSSION

LEAD CONCENTRATION:

The descriptive statistics of lead concentrations in this study are synthesized in Table 1. As can be seen from the table, the range of lead concentrations is 7 – 42 mg/kg, and their mean lead concentration is 13.8 mg/kg. However, they have lower median value (13 mg/kg) relative to mean value. Previous studies revealed that average enrich factor (average concentration/background) is a good indicator for monitoring the degree of pollution, and three degrees had been subdivided: <1 means light pollution, 1-3 means moderate pollution and >3 means considerable pollution [8]. The soil environmental background value of China (26 mg/kg for lead) [9] is chosen for comparison, and the average enrich factor is calculated to be 0.53, which indicates that the study area has not been dramatically affected by anthropogenic activities.

Moreover, as suggested by previous studies, a low coefficient of variation (< 10%) indicates the low degree of anthropogenic contribution, whereas a high coefficient of variation (> 90%) indicates high degrees of anthropogenic contribution [10]. In this study, the coefficient of variation of lead concentrations is medium (28%), which indicates that the lead concentrations in the surface soil might have been affected by human activities with low degrees. This consideration is further supported by their skewness and kurtosis values, as well as the p-value of Anderson-Darling test, as the p-value is lower than 0.05 (Table 1), which implying that the lead concentrations in this study cannot pass the normality test.

TABLE-1 Descriptive statistics of lead concentrations in the surface soil (mg/kg).

N	Min	Max	Mean	Median	Coefficient of variation	Skewness	Kurtosis	p-value
149	7.00	42.0	13.8	13.0	0.28	2.86	18.1	< 0.01

SPATIAL DISTRIBUTION:

Mapping the spatial distribution of contaminants in soils is essential for pollution evaluation and risk control [11], and a large number of methods (e.g. inverse distance weighting, local polynomial, ordinary kriging and radial basis functions) have been applied for solving this issue. In this study, the lead concentrations, in combination with the values of longitude and latitude, have been processed by the software surfer (version 11), and the gridding method is chosen for natural neighbor.

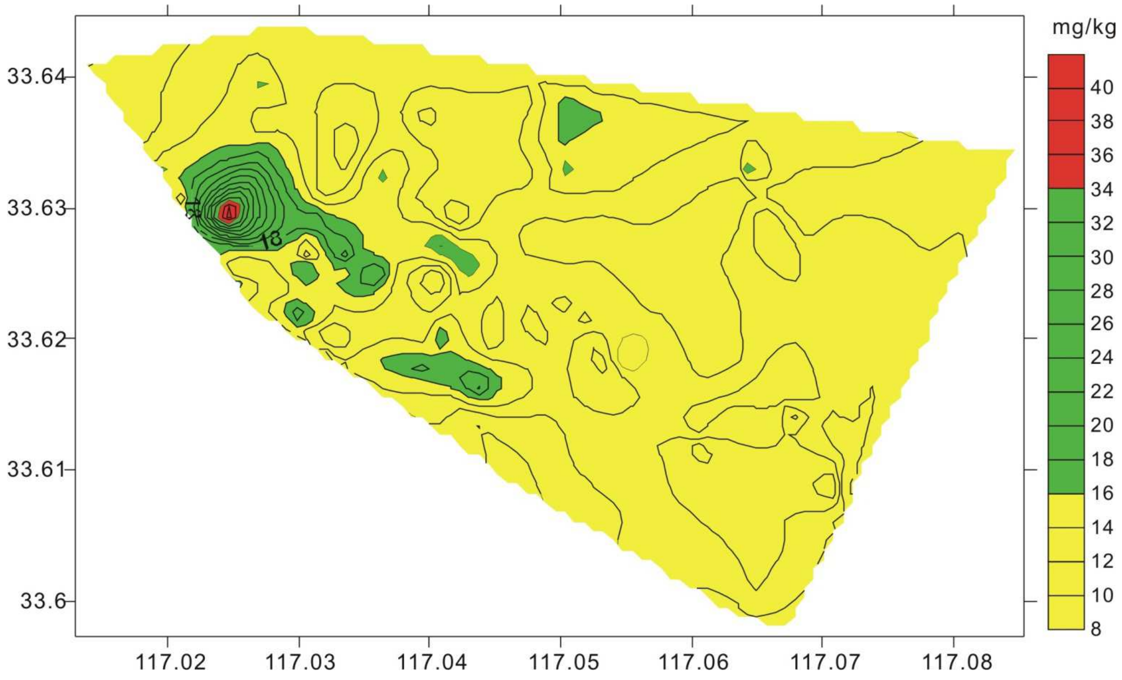

Fig. 2: Contour map of lead concentrations

The spatial distribution of lead concentrations is shown in Fig. 2. For a more clear expression, only three types of colors (yellow, green and red) have been chosen. As can be seen from the figure, the proportions of different colors are following the decreasing order: yellow > green > red. And the areas with high lead concentrations are located in the west of the map. In comparison with the map of sample locations (Fig. 1), the red area with high lead concentration (> 30 mg/kg) is located in the parking lot with high density of transportation, where is the entrance into the city. This result indicates that the motor vehicles are responsible for the high concentrations of lead in the surface soil.

OUTLIER IDENTIFZICATION AND BASELINE EVALUTION:
Outlier identification is important for the establishment of environmental baseline, and a large number of methods have been carried out for solving this issue, including statistical and non-statistical. Among the methods, the most popular used statistical method is boxplot [12], which based on the calculation of upper and lower inner fences (lower: 25% percentile – 1.5×(75% percentile - 25% percentile); upper: 75% percentile + 1.5×(75% percentile - 25% percentile)), and the concentrations outside the inner fences are considered to be outliers. Based on this consideration, the upper and lower inner fences of lead concentrations are then calculated to be 3.5 and 23.5 mg/kg, respectively, and there is only one sample with high lead concentration (42 mg/kg) can be identified as outlier.

Another consideration is spatial outlier, which means that the samples with unusual values relative to their neighborhood are considered to be outliers (spatial outlier) [13] and the Moran's I is a commonly used indicator of spatial autocorrelation: one is the global Moran's I, which is used to study the overall spatial autocorrelation, whereas LISA (local indicators of spatial association) is applied to identify the degree of spatial autocorrelation in each specific location [14]. More importantly, the LISA can also be used for identifying the existence of local spatial clusters by generating cluster maps [15], which can be used for identifying the spatial hotspot and outliers [16].

The results of obtained from the software GeoDa is shown in Fig. 3. All of the samples in this study have been classified into five categories: not significant (129 samples) and significant (20 samples). Moreover, all of the significant samples can be classified into four secondary categories: 10, 4, 3 and 3 for high-high, low-low, low-high and high-low, respectively.

According to previous studies [16], either high-high or low-low samples can be clustered to be spatial clusters, whereas high-low and low-high samples are considered to be spatial outliers. As can be seen from Fig. 3, one hotspot can be identified, which is located in the west of the map, and it is located similar to the area with high lead concentrations (Fig. 2), which further supporting the idea that the motor vehicles are responsible for lead pollution in the surface soil.

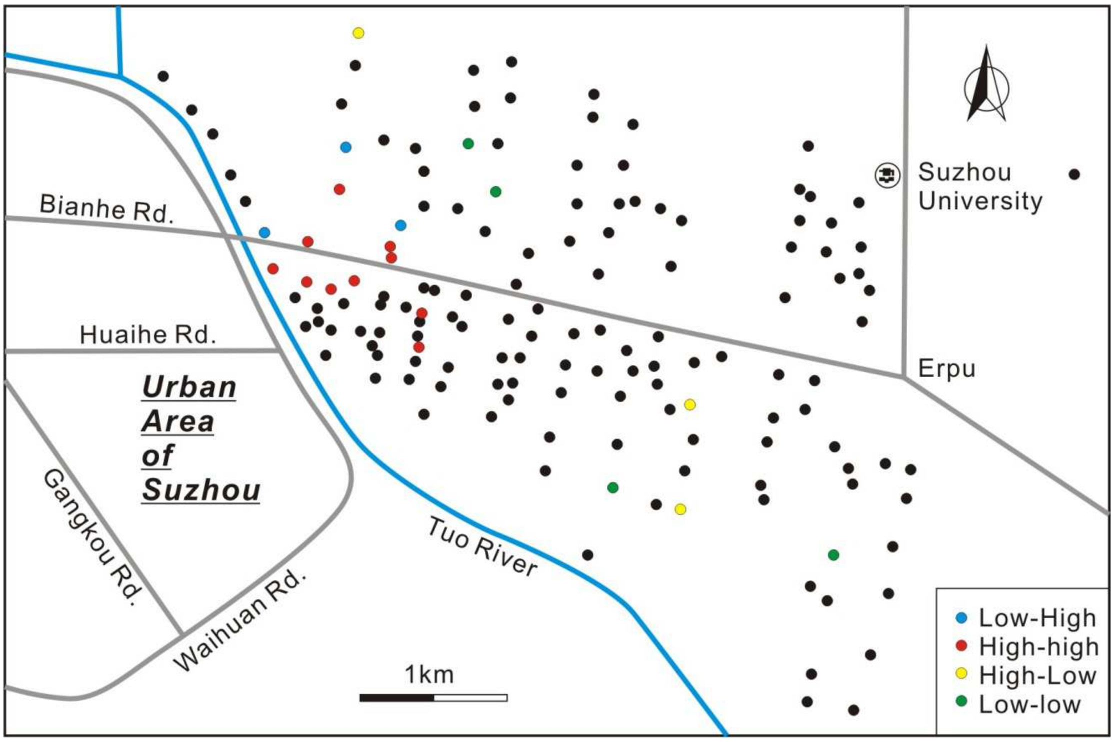

Fig. 3: Result of spatial clustering.

According to the results of spatial clustering (Fig. 3), 16 samples in high-high, high-low and low-high clusters were then considered to be outliers, and the rest of the samples (after removing the statistical outlier) were then used for establishing the environmental baseline (mean ± 2σ) [17], and the result is calculated to be 13.4 ± 6.14 mg/kg (7.24 – 19.5 mg/kg), which is similar to the result obtained by model based objective methods (8.6 – 18.0 and 8.5

– 17.5 mg/kg) [18]. Based on this baseline, seven samples can be identified as polluted.

CONCLUSION

Based on the analyzes of lead concentrations in the surface soils collected from the rural-urban fringe zone of Suzhou, northern Anhui Province, China, the following conclusions have been made:

(1) The samples except for one have low lead concentrations relative to the environmental background value of China;
(2) Coefficient of variation, in combination with spatial distribution of lead concentrations suggest that the lead concentrations in the surface soil of the study area have been slightly affected by human activities, and transportation is considered to be the most important one;
(3) After statistical and spatial outlier removing, the environmental baseline is then set to be 7.24 – 19.5 mg/kg, and according to this criterion, seven samples were identified as polluted.

Acknowledgement
This work was financially supported by National Natural Science Foundation of China (41302274 and 41173106). Thanks are also to Z Xie and C Guo from the Suzhou University for their help in sampling and analyses.

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