Assessment of Heavy Metal Pollution in Soil Surrounding a Company in Jiaxing, China

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Abstract: The content of eight elements of Sb, Cu, Co, Pb, As, Ni, Cd and Cr in soil samples in the northwest direction at different horizontal distance and depth under the prevailing wind and southeast of China was determined by taking the surrounding soil of an auto parts company in Jiaxing, a key monitoring enterprise in Jiaxing, as the target. The soil ground accumulation index and potential ecological hazard index are used to assess the risk of heavy metal pollution. The results show that: there are four kinds of heavy metals in the surface soil which are higher than the national soil background value, in which Sb and Cd heavy metal elements generally exceed the standard value, but there is no obvious law of the concentration distribution in the plane, and human activities have a strong disturbance to the heavy metal in the region, but the wind direction has little influence. The soil Cd around the auto parts company have reached a very polluted level, Sb reaches medium-strong pollution, Ni, As, Pb, Co, Cu, Cr Five kinds of heavy metals are mild-medium, and the pollution degree of each metal does not decrease with the increase of soil depth, and there is no regularity in longitudinal distribution. As, although the carcinogenic risk of two kinds of heavy metals in Ni is acceptable, there are potential carcinogenic risks, which should be controlled and given high attention and prevention.

1. Introduction
As one of the natural circle layers, soil provides an important place for the migration, retention and deposition of substances in the atmosphere, water bodies and organisms. Heavy metal pollution in soil is usually long-term, concealed, difficult-to-disappear and irreversible pollution. The heavy metals are hardly movable in the soil and have a long residence time. In addition, heavy metals are difficult to be degraded by microorganisms. Once they are absorbed by animals and plants through water, plants and other media, they are easy to enter the human food chain and affect human health. It is referred to by the environmental science community as a “chemical time bomb”. Heavy metals are listed as hazardous pollutants due to their toxicity and persistence in the environment.

The content of eight elements of Sb, Cu, Co, Pb, As, Ni, Cd and Cr in soil samples in the northwest direction at different horizontal distance and depth under the prevailing wind and southeast of China is determined by taking the surrounding soil of an auto parts company in Jiaxing, a key monitoring enterprise in Jiaxing, as the target. The soil ground accumulation index and potential ecological hazard index are used to assess the risk of heavy metal pollution condition. Such meticulous research will help to understand the current pollution situation and predict the development trend of pollution in a more detailed way, in order to provide a basis for the early warning of soil environmental quality in Jiaxing City.
2. Material and Methods

2.1. Research area description

The automobile parts company of Jiaxing in this study is located in an industrial zone of Jiaxing City, with advantageous geographical location and abundant water resources. It mainly produces and sells key automotive parts, brake assemblies, drive assemblies, automotive lamps, automotive rearview mirrors, rear tails, sealing materials (excluding hazardous chemicals), metal plastic crafts for automotive decoration (excluding gold jewelry). Although the auto parts company has begun to take shape and has advanced production technology, it will inevitably damage the surrounding environment to some extent while driving local economic growth. In this study, eight common heavy metal elements, Sb, Cu, Co, Pb, As, Ni, Cd and Cr, are selected for pollution assessment and risk assessment based on the general characteristics of waste disposal of auto parts companies and the specific conditions around auto parts companies.

2.2. Sample collection and testing

2.2.1. Sampling. In order to reveal the ecological risk of heavy metal pollution (Sb, Cu, Co, Pb, As, Ni, Cd and Cr) around an auto parts company in Jiaxing, 10 sample points (1-10) of soil samples are collected along the periphery of the factory. See Figure 1 for the location of each sample point.

Figure 1. Surrounding Sampling Map of an Automobile Parts Company in Jiaxing

Considering the difference between the surface layer and the deep soil, the surface soil sampling adopts the grid distribution method to collect 0-10cm samples, and 10 points are collected according to the site area. Soil profile samples are collected in 3 layers of 0-10cm, 10-20cm, 20-30cm, with 10 sections of profile samples, 30 samples in total, and a total of 30 samples. After collecting the soil samples from the site and numbering them on the collection bag, they should be taken back to the laboratory, and the soil samples of each layer should be sampled by quartering method and labeled with bags. The soil sample is naturally air-dried, and the impurities such as plant leaves, roots and stones are removed. After fully grinding, the soil samples are passed through a 100 mesh nylon sieve and mixed well. After fully mixing, the soil samples are separately packed into a special kraft paper bag for analysis and testing.

2.2.2. Analysis and testing. The contents of Sb, Cu, Co, Pb, As, Ni, Cd and Cr in soil are determined by inductively coupled plasma spectrometry. Cr(VI) is sampled by diphenylcarbazide spectrophotometry. The reagents used in the experiment are all in the pure grade. The experimental articles used are all soaked in 10% dilute nitric acid for 24 hours, and then washed again with ultrapure water. In order to
ensure the accuracy of the analysis, the blank and parallel samples are made throughout the experiment, and the national standard soil reference material (GSS-1) is added for quality control during the test. The recovery rates of various metals are within the allowable range of the national standard reference materials.

2.3. Ecological risk assessment method

2.3.1. Ground accumulation index method. The degree of contamination of heavy metals in sediments is quantitatively evaluated using the ground accumulation index proposed by Muller [1].

The calculation formula is:

\[ I_{\text{geo}} = \log_2 \frac{C_n}{1.5B_n} \]  

Where: \( I_{\text{geo}} \) is the ground accumulation index; \( C_n \) is the measured mass fraction of the element, mg/kg; \( B_n \) is the background mass fraction of the element, mg/kg; and the constant 1.5 is the conversion coefficient (to eliminate the background value change caused by the rock difference).

2.3.2. Potential ecological Hazard index method. Heavy metal pollution risk assessment uses Hakanson's potential ecological hazard index method [2]. Potential ecological hazard indices include single pollution coefficient, heavy metal toxicity coefficient and single potential ecological hazard coefficient. The calculation formula is:

\[ C_i^f = \frac{C_i}{C_i^r} \]  

\[ C_a = \sum_{i=1}^{m} C_i^f \]  

\[ E_i^r = T_i^f \times C_i^f \]  

\[ RI = \sum_{i=1}^{m} E_i^r \]  

Where: \( C_i^f, C_i, C_i^r \) are the single pollution coefficient, measured value and reference value of heavy metal; \( T_i^f, E_i^r \) are the toxicity response coefficient and potential ecological risk coefficient of heavy metal; \( C_a \) is comprehensive pollution coefficient; \( RI \) is a potential ecological hazard index. The \( T_i^f \) of heavy metals Cd, Sb, Ni, Pb, Co, Cu, Cr, As are 30, 40, 5, 5, 5, 5, 2, 10 [3], respectively.

3. Results

3.1. Test results of heavy metal content in soil

Analyze and test the soil samples of 30 sampling points in the survey area, and calculate the maximum, median, minimum, arithmetic mean, geometric mean, standard deviation, coefficient of variation, coefficient of skewness and coefficient of kurtosis of the test results of all samples according to the mathematical statistics method. In this study, the geometric mean of soil in China is selected as the background value [4]. See Table 1 for detailed results.

| Monitoring index | Number measuring points | Sequential statistics | Arithmetic | Geometry | Coefficient of variation | Skewness coefficient | Kurtosis coefficient |
|------------------|-------------------------|-----------------------|------------|----------|-------------------------|---------------------|---------------------|
| Ni               | 30                      | minimum value: 1.16   | maximum value: 31.63 | mean value: 17.53 | standard deviation: 7.98 | skewness: 0.02 | kurtosis: -0.62 |
| As               | 30                      | minimum value: 0.22   | maximum value: 4.48  | mean value: 1.63  | standard deviation: 1.07 | skewness: 0.76 | kurtosis: 0.47 |
In addition to natural factors, soil heavy metal pollution is also related to the production of modern industrial and mining and agriculture and the impact of human activities, which is the main cause of heavy metal pollution in soil. It can be seen from Table 3 that the 30 samples collected, the heavy metal elements such as lead, cobalt and other pollutants have a coefficient of variation greater than 70%, which is moderately or strongly mutated, indicating that the main pollutants in the soil are affected by man-made sources to a certain extent or stronger. According to the data in the above table, the greater the coefficient of variation, the deeper the influence of human activities on the content of heavy metals. Once the coefficient of variation exceeds 30%, it can indicate that such metals have been seriously affected by humans. The coefficient of variation of the eight heavy metals in the auto parts company from the smallest to the largest is Cd<Cr<Sb<Cu<Ni<As<Pb<Co. Among them, Co's coefficient of variation reached 94.74% as strong variation, which indicates that the content of Co is seriously affected by human activities; it may be because auto parts companies are close to roads, where vehicle exhaust emissions, tire wear and corporate emissions are commonly excessive. Except for Cd, the coefficient of variation of the other seven elements exceeds 30%, which indicates that such metals have been seriously affected by human. The contents of nickel, arsenic, copper, antimony, chromium and cadmium are relatively small, and the influence of human activities is small. This is similar to the results of Dai Bin [5] et al. on soil heavy metals in typical industrial cities in Shandong Province, Zn>Cr>Pb>Ni>Cu>As>Cd>Hg, in which Hg, Zn and Cd are highly skewed. The three elements are subject to large positive deviations from human activities.

### 3.2 Assessment results of ground accumulation index method

According to the calculation results, it can be seen from Table 2 that Cd has reached a very serious pollution level in the heavy metals around Jiaxing Minhui Auto Parts Co., Ltd., and Sb has reached medium-strong pollution, and Ni, As, Pb, Co, Cu, Cr five heavy metals are mild- moderate. According to the average value of the ground accumulation index, the pollution is ranked from strong to weak as Cd>Sb>Co>Cr>Ni>Cu>Pb>As. Relatively speaking, the accumulation of Cd and Sb heavy metals is more serious in the soil. Similar to the results of Han Ping [6] and others on the ecological risk assessment of soil heavy metal pollution in Shunyi District, Beijing, the maximum Cd and Sb exceeds 1, and the $I_{geo}$ standard deviation of Cd and Sb is the largest, indicating the degree of dispersion of the $I_{geo}$ value of these two elements in the soil sample is large, that is, the degree of variation is large.

| Element | Statistical number | Average value | Minimum value | Maximum value | Standard deviation | Classification | Pollution level |
|---------|--------------------|---------------|---------------|--------------|-------------------|---------------|----------------|
| Ni      | 30                 | 0.1308        | 0.0086        | 0.2360       | 0.0595            | 1             | Mild to moderate |
| As      | 30                 | 0.0217        | 0.0009        | 0.0622       | 0.0160            | 1             | Mild to moderate |
| Pb      | 30                 | 0.0879        | 0.0348        | 0.4849       | 0.0777            | 1             | Mild to moderate |
| Co      | 30                 | 0.2373        | 0.0012        | 0.8261       | 0.2248            | 1             | Mild to moderate |
| Cu      | 30                 | 0.1031        | 0.0444        | 0.3977       | 0.0668            | 1             | Mild to moderate |
| Sb      | 30                 | 2.0537        | 0.9180        | 3.5621       | 0.7234            | 3             | Medium strong   |
| Cr      | 30                 | 0.1480        | 0.1036        | 0.3448       | 0.0448            | 1             | Mild to moderate |
| Cd      | 30                 | 13.9926       | 7.2015        | 21.7397      | 3.6698            | 6             | Extreme pollution |
According to the calculation results of the ground accumulation index classified frequency of 8 elements (Table 3), the pollution frequency of Cd, Sb, Ni, Pb, Co, Cu, Cr and As is the largest, all reaching 100% (calculated according to the background value of soil environment in China, which refers to the percentage of the level above level 1.)

From the point of view of pollution frequency distribution, Cd is in a very serious pollution degree, and Sb has different degrees of pollution, but the pollution is lighter, below strong pollution level. Ni, Pb, Co, Cu, Cr and As are lightly polluted at the mild-moderate pollution level. It can be seen that the ground accumulation index method has the advantage of further refining the heavy metal pollution level of the soil, and provides a basis for the study of soil heavy metal pollution in the main factories of Jiaxing City.

### Table 3. Ground Accumulation Index Classified Frequency Table (%)

| Heavy metal | Pollution-free | Mild to moderate pollution | Moderate pollution | Medium-strong pollution | Strong pollution | Strong-extremely serious pollution | Extremely serious pollution |
|------------|----------------|---------------------------|-------------------|------------------------|----------------|------------------------------------|---------------------------|
| Ni         | 0              | 100                       | 0                 | 0                      | 0              | 0                                  | 0                         |
| As         | 0              | 100                       | 0                 | 0                      | 0              | 0                                  | 0                         |
| Pb         | 0              | 100                       | 0                 | 0                      | 0              | 0                                  | 0                         |
| Co         | 0              | 100                       | 0                 | 0                      | 0              | 0                                  | 0                         |
| Cu         | 0              | 100                       | 0                 | 0                      | 0              | 0                                  | 0                         |
| Sb         | 0              | 6.66                      | 46.67             | 36.67                  | 10             | 0                                  | 0                         |
| Cr         | 0              | 0                         | 0                 | 0                      | 0              | 0                                  | 0                         |
| Cd         | 0              | 0                         | 0                 | 0                      | 0              | 0                                  | 100                       |

### 3.3. Assessment results of potential ecological Hazard index method

#### 3.3.1. Assessment of pollution levels

Calculate the $C_i^d$ and $C_i^m$ of each heavy metal by using formulas (2) and (3), and obtain the spatial variation trend of soil heavy metal pollution coefficient around Jiaxing Minhui Auto Parts Co., Ltd. From Figure 2 and Figure 4, it can be seen from Figure 2 that Cd and Sb vary greatly with the point position; the change trend of Co is relatively flat, indicating that the content of heavy metal Co is relatively uniform in the region; Ni, Pb, Cu, Cr, and As are almost on the same straight line, with minimal volatility. According to the average value of $C_i^d$, the order of soil heavy metal pollution degree around Jiaxing Minhui Auto Parts Co., Ltd. is obtained: Cd (69.72) > Sb (10.23) > Co (1.18) > Cr (0.74) > Ni (0.65) > Cu (0.46) > Pb (0.44) > As (0.15). According to the classification standard of Table 3, it can be determined that Cd and Sb belong to a strong-extremely serious pollution, Co belongs to a moderate pollution level, and Cr, Ni, Cu, Pb, and As belong to a mild pollution level.

It can be seen from Figure 3 that the $C_i^d$ spatial difference of 30 sampling points is significant, among which the sampling points 1b, 6c, 7a, 8c, 10a and 10b are relatively high; the sampling points 9a and 9c are relatively low. According to the average value of $C_i^d$, the maximum 6 levels of heavy metal pollution at each point are obtained as follows: 10b (131.34) > 8c (124.13) > 10a (122.10) > 1b (117.40) > 7a (113.98) > 6c (110.16) (1a represents the first sampling point 0-10cm, 1b represents the first sampling point 10~20cm, 1c represents the first sampling point 20~30cm). According to the classification standard of Table 3, each sampling point is in a extremely serious pollution level, indicating that heavy metal pollution in the soil around Jiaxing Minhui Auto Parts Co., Ltd. is very serious, and should be highly valued by relevant departments.

#### 3.3.2. Ecological risk assessment

It can be seen from Figure 4 that the $E_i^r$ values of Cd and Sb are significantly higher than the other six heavy metal elements, respectively 1076.53 > 3249.80 and 182.96 > 709.98; $E_i^r$ values of Ni, Pb, Co, Cu, Cr, As of all sampling points are all below 30. According to
the average value of $E_i^{II}$, the corresponding risk rankings of 8 heavy metals are obtained: Cd (2091.71) > Sb (409.34) > Co (5.91) > Ni (3.26) > Cu (2.30) > Pb (2.19) > Cr (1.47) > As (1.47). It can be judged from the classification standard of Table 3 that Cd and Sb are at extremely high risk levels, and Ni, Pb, Co, Cu, Cr, and As are at a light risk level. Cd and Sb have extremely high $E_i^{II}$ values, in addition to the relatively high $C_j$ of the two, and also related to $T_i^{II}$. The potential ecological risk contribution rates of 8 heavy metals to soil heavy metal pollution around Jiaxing Minhui Auto Parts Co., Ltd. are: Cd (83.08%) > Sb (16.26%) > Co (0.23%) > Ni (0.13%) > Cu (0.092%) > Pb (0.087%) > Cr (0.059%) > As (0.058%). It can be seen from the contribution rate that the potential ecological risk of heavy metals in the study area is mainly controlled by Cd and Sb, which requires special attention from relevant departments. This is similar to the results of Yang Peifeng [7] and others on the risk assessment of soil heavy metal pollution in the shoreline of the Klulun River. The potential ecological risk contribution rates of the seven heavy metals to the heavy metal pollution in the coastal zone of the Klulun River are: Cd (86.19%) > As (12.68%) > Zn (0.6%) > Pb (0.29%) > Ni (0.11%) > Cu (0.11%) > Cr (0.01%); the potential ecological risk of soil heavy metals is mainly affected by Cd and As.

As can be seen from Figure 5, the sampling point 10b has the highest risk level, and its RI value is as high as 3976.34; the sampling points 8c and 10a have relatively close RI values of 3737.80 and 3691.12, respectively. According to the criteria of Table 3, all 30 sampling points are at extremely high risk levels.
4. Discussion

(1) Analysis of soil heavy metals by three evaluation methods reveals that there is serious pollution in the soil environment around Jiaxing Minhui Auto Parts Co., Ltd.

(2) The ground accumulation index is ranked from large to small, and the pollution level is ranked from strong to weak as: Cd > Sb > Co > Cr > Ni > Cu > Pb > As; Cd reaches the extremely serious pollution, and Sb reaches medium-strong pollution; the five heavy metals Ni, As, Pb, Co, Cu and Cr are mild-moderate pollution.

(3) $E_i^r$ value of heavy metal pollution degree ranking: Cd (69.72) > Sb (10.23) > Co (1.18) > Cr (0.74) > Ni (0.65) > Cu (0.46) > Pb (0.44) > As (0.15); Cd Sb is at a very high risk level, and Ni, Pb, Co, Cu, Cr, and As are at a light risk level. The RI results showed that the heavy metal content of the 30 sampling points is at a high-risk level.

(4) The analysis of the contribution rate of potential ecological risk of heavy metals in soil shows that Cd and Sb should be the priority control objects of soil management and ecological restoration around Jiaxing Minhui Auto Parts Co., Ltd.

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