Contamination and health risk assessment of heavy metals in soil surrounding an electroplating factory in Jiaxing, China

Ting-ting Liu

1Department of Civil Engineering, Tongji Zhejiang College, Jiaxing, Zhejiang, 314051, China

*Corresponding author’s e-mail: liusha@zju.edu.cn

Abstract: To investigate the heavy metals pollution degree of in the soil around an electroplating factory and evaluate the health risk caused by contaminated soil. Based on soil in the vicinity of an Electroplating factory in JiaXing, soil in different horizontal distance and depth below wind direction direction of research region were sampled, and the heavy metal content were measured. The heavy metal pollution status was analyzed by using index of Geoaccumulation and health risk assessment. The results showed that the average index of Geoaccumulation (Igeo) of the 7 heavy metal (Cr, As, Pb, Ni, Cu, Zn, Cd) in the region was higher than 5, and it was at the extremely serious pollution level. The content of As in the middle part soil (10~20 cm) reaches the maximum of 2109.25mg/kg, As pollution is relatively serious, and the average value exceeds the limit by 119.39 times. Cd is the least contaminant, but still reaches a medium-pollution. EDI non-carcinogenic exposure to As was greatest in children when ingestion of oral food. Conclusion Health risk assessment indicates of As intake by oral food has far exceeded the warning value, and there exist a high Risk of cancer, while Ni has a potential Risk of cancer. Therefore, we should pay great attention to these two heavy metal and prevention and treatment of the polluted soil.

1. Introduction
At present, with the rapid development of industrialization, the overall situation of soil pollution in Jiaxing City is severe, and the drawbacks of environmental pollution, especially the use of electroplating technology and illegal discharge, have aggravated the local environmental pollution problem [1]. The pollution of heavy metal elements in the soil of Jiaxing City will pose a serious threat to the safety of agricultural products and restrict the healthy development of the agricultural product industry [2], and at the same time pose a certain degree of threat to the health and safety of residents [3]. In particular, the methods used in metal surface treatment processes typically involve a wide range of chemicals and some heavy metals [4-5]. These chemicals and heavy metals may subsequently be present in the waste generated by these processes, producing large amounts of toxic, hazardous gases and solid and liquid contaminants that are emitted into the environment and contaminate the environment. For example, a large number of acidic, alkaline aqueous solutions and heavy metal-containing solutions, even toxic chemicals, such as cadmium, cyanide, chromate and other pollutants, have caused soil problems during the circulation of the atmosphere and water. In order to carry out the implementation of Jiaxing City’s soil prevention and control work and promote the construction of ecological civilization, according to the "Zhejiang Municipal People’s Government’s Notice on Printing and Distributing the Clean Soil Action Plan of Zhejiang Province" (Zhe Zhengfa [2011] No. 55, combined with the actual situation of Jiaxing City, The Jiaxing Clean
Soil Action Plan was formulated. At present, although some scholars have conducted research on the heavy metal content in Jiaxing City [3,9-11], the number of survey points is small, the survey period is long, and most of them are limited to a certain element. A comprehensive and systematic survey of soil heavy metal pollution in key areas of Jiaxing City has not been reported. A metal surface treatment company is located in Zhuangshi Village, Fengqiao Town, Nanhu District. It is located in the center of the Yangtze River Delta metropolitan area. It can reach Shanghai, Hangzhou and Suzhou within 25 hours from Jiaxing City. The Jiajiasu Expressway connects the 07,01 provincial road through the town and runs through the Hangzhou Bay Bridge. The traffic is very convenient. The company is mainly engaged in processing, metal processing, die-casting processing, etc. It is a professional production and processing company with a factory area of 2000m², which is specialized in processing nickel, chromium and other metal products for various metal products enterprises. While contributing to the local economy, the plant has also had a huge impact on the surrounding environment. In order to make rational use of land resources and protect human health, this study is based on the health of residents and chooses to conduct pollution assessment and health risk assessment. Based on the evaluation of the eco-environmental effects of heavy metal pollution in soils, the soil accumulation index and potential ecological hazard index of heavy metals in soil were used as pollution assessment indicators to evaluate the heavy metal pollution levels of agricultural soils in the study area. It is helpful to control the heavy metals in farmland soils in Jiaxing City, thus the supervision has guiding significance. The research group discussed the pollution situation of seven typical heavy metals (Cr, As, Pb, Ni, Cu, Zn, Cd) in the surrounding agricultural land of Jiaxing City, and conducted risk assessment to provide a reference for early warning of soil environmental quality in Jiaxing City.

2. Material and Methods

2.1. Main instruments and reagents
KHT-001 Multi-Function Soil Sampler (Jintan Kanghua Co., Ltd.), Agilent 7500A Inductively Coupled Plasma Mass Spectrometer (ICP-MS) (Agilent, USA), 0.1 mg Sensing Analytical Balance (METTLER TOLEDO, USA), PTFE digestion tanks, etc. Nitric acid (GR, Shanghai Shenggong Bioengineering Co., Ltd.), hydrochloric acid (GR, China National Pharmaceutical Group Corporation), perchloric acid, hydrofluoric acid (AR, China Pharmaceutical Group Corporation).

2.2. Sample Collection
From March 21st to June 21st, 2018, set sampling points (Figure 1.) in the downwind direction of Sino-French Surface Technology Processing Company in Jiaxing City, Zhejiang Province. A total of 30 samples were collected. The average temperature during sampling is 20 to 34 °C and the average atmospheric pressure is 100 kPa. The sampling process is strictly in accordance with the technical requirements and test methods of NY/T 395-2000 "Technical Specifications for Farmland Soil Environmental Quality Monitoring". The grid method was used to conduct sampling, and the soil pollution situation of the surface of the block was investigated to find out the distribution of heavy metal concentration in the key blocks. At the same time, through more cross-sectional sampling, the depth of pollution of heavy metals in the soil is further investigated. Specifically, along the perennial wind direction of the factory’s southeast windward area which is 100 m away from the edge of the plant, we collected soil samples from top to bottom according to vertical depths of 0 to 10, 10 to 20, and 20 to 30 cm, for a total of 30 samples. For the sampling diagram, see Figure 1 for sampling. Collect 1 to 2 kg of the sample into the sampling bag and mark the sample’s information and number. Bring it back to the laboratory and place it in a ventilated place. It is naturally dried. After grinding, it is passed through a 100-mesh nylon sieve to dissolve.
2.3. Sample determination and analysis

The total amount of metal in the soil is measured by flat-plate digestion. Accurately weigh 0.2000 g of the sieved soil in Teflon, wet the soil with a few drops of deionized water, add 10 mL of HCl, and place it on a hot plate. After heating to near dryness, add 5 mL of HNO₃, 5 mL of HF and 3 mL of HClO₄. After heating at a high temperature, if there is residue remaining, repeat the addition of the three kind of acid until the solution in the crucible is clear and transparent, then transfer to a 50mL volumetric flask for constant volume filtration. The intrinsic analysis of soil constituent elements was carried out by inductively coupled plasma spectroscopy (ICP-MS) [12]. The reagents used in the experiment were all excellent grades. All the experimental articles were soaked in 10% dilute nitric acid overnight and then washed with ultrapure water. Blank and parallel samples were used as controls throughout the process. The recovery rate of each metal is within the allowable range of national standard reference materials.

2.4. Heavy metal pollution risk assessment

2.4.1. Ground Accumulation Index Method. The method was proposed by German scientist Muller to quantitatively evaluate the extent of heavy metal pollution in sediments [13,14]. In addition to considering the human pollution factors and environmental geochemical background values in the evaluation process, factors such as the variation of background values caused by natural diagenesis are also considered [15].

\[
I_{geo} = \log_2 \left[ \frac{C_i}{K \times C_{ni}} \right]
\]

In the cumulative index formula: \( C_i \) is the content of element i in the sediment; \( C_{ni} \) is the geochemical background value of the element in the sediment [16];K is a factor taken to account for variations in background values that may cause changes in background values (typically 1.5)The calculation results are classified according to the ground accumulation index evaluation criteria (Table 1) [17].

| Project | Classification | The degree of pollution |
|---------|----------------|------------------------|
| Igeo    | 0              | None pollution         |
| 0<Igeo ≤1 | 1              | Light to moderate pollution |
| 1<Igeo ≤2 | 2              | Moderate pollution     |
| 2<Igeo ≤3 | 3              | Moderate to severe pollution |
3<\text{Igeo} \leq 4 & 4 & \text{Severe pollution} \\
4<\text{Igeo} \leq 5 & 5 & \text{Severe pollution} \\
5<\text{Igeo} \leq 10 & 6 & \text{Extremely Severe pollution}

2.4.2. Human Health Risk Assessment Method. Heavy metals in the soil mainly cause harm to the human body through three ways: direct inhalation of soil dust in the air through mouth and nose breathing; transmission in the food chain of fruits, vegetables and food which is cultivated in contaminated soil; direct contact with heavy metals contaminated soil [18]. In the industrial process of metal surface treatment, a large amount of soot is generated and close to the farmland. The above three ways may become the main ways to endanger human health. Therefore, this study included three methods for the non-carcinogenic risk assessment and carcinogenic risk assessment of heavy metals for human health [19].

2.4.2.1. Exposure assessment calculation. The amount of pollution ingested by inhaling soil dust through breathing:

$$EDI_{\text{breathing}} = \frac{CS \times IR_{a,i} \times EF \times ED}{PEF \times BW \times AT} \times 10^6$$

Amount of contamination ingested through direct skin contact with soil:

$$EDI_{\text{skin}} = \frac{CS \times SA \times AF \times ABS \times EF \times ED}{BW \times AT} \times 10^6$$

Direct intake of soil pollution by mouth:

$$EDI_{\text{mouth}} = \frac{CS \times IR_{\text{soil}} \times EF \times ED}{BW \times AT} \times 10^6$$

Total exposure:

$$EDI_{\text{total}} = EDI_{\text{breathing}} + EDI_{\text{skin}} + EDI_{\text{mouth}}$$

In the formula: EDI breathing, EDI skin, EDI mouth are respiratory inhalation, skin contact, direct oral intake respectively and total intake of pollutants in the above three ways, mg/kg, daily; CS is soil heavy metal content, Mg/kg; IR soil is soil intake, m³/d; IR air is air intake, m³/d; PEF is soil dust production factor m³/kg; SA is skin contact surface area, cm²/d; AF is skin adsorption coefficient, mg/cm²; ABS is the skin absorption rate, %; EF is the exposure frequency, d/a; ED is the exposure period / a; BW is the body mass, kg; AT is the average duration of action, d.

The environmental risk assessment criteria for adults and children vary greatly when conducting exposure assessments. According to China’s site environmental assessment guidelines, USEPA health risk assessment method and the world’s actual research conclusions in recent years [20-25], the values of each exposure assessment parameter in this evaluation are shown in Table 2.
Table 2. Values of exposure assessment parameters

| Parameter       | Evaluation       |                |
|-----------------|------------------|----------------|
|                 | Children         | Adult          |
| IR_{soil} / (m^3/d) | 200              | 100            |
| IR_{air} / (m^3/d)  | 7.5              | 15             |
| EF / (d/a)       | 350              | 350            |
| ED/a            | 6                | 30             |
| SA / (cm^2/d)   | 1600             | 5000           |
| AF / (mg/cm^2)  | 0.07             | 0.2            |
| ABS             | 0.001            | 0.001          |
| PEF / (m^3/kg)  | 1.36×10^9        | 1.36×10^9      |
| BW/kg           | 15.9             | 55.9           |
| AT/d            | carcinogenic     | None carcinogenic |

2.4.2.2. Toxicity assessment and risk characterization. Toxicity assessment is the relationship between the population’s exposure to contaminants and the likelihood of negative effects [26]. Among the six heavy metals studied in this paper, Cu, Pb, Cd, and Ni all have non-carcinogenic health risks, and Pb, Cd, and Ni have carcinogenic risks at the same time [24]. The non-carcinogenic and carcinogenic effects of heavy metals such as Cu, Pb, Cd and Ni are shown in Table 3. The non-carcinogenic effect parameter is the reference dose (RfD) of heavy metals under each exposure pathway, and the carcinogenic effect reference number (SF) is the carcinogenic slope factor of Cd and Ni.

There is a carcinogenic and non-carcinogenic risk for each exposure route. The non-cancer risk level can be calculated by dividing the daily exposure of heavy metals by the chronic reference doses of mouth, skin, and respiratory. The formula is:

\[ HI = \sum HQ_i, \quad HQ_i = \frac{EDI_j}{RfD_j} \]

In this formula: HI is the total risk level of non-carcinogenesis under three exposure pathways of soil heavy metal, such as by mouth, breath and skin contact; HQi is the non-carcinogenic risk level of different intake pathways; EDIj is the average daily intake of pollutants in different pathways, mg/(kg.d); RfDj is the chronic reference dose for each route, mg/(kg.d) (See Table 3). When HQi<1 or HI<1, there is no significant non-carcinogenic health risk; When HQi>1 or HI>1, there is a non-carcinogenic health risk, the greater the value, the higher the non-carcinogenic health risk.

The level of carcinogenic risk is calculated by multiplying the average daily intake over the entire life span by the carcinogenic slope coefficient of mouth, skin contact and breath.

Its calculation formula:

\[ (Risk)_T = \sum Risk_i, \quad Risk_i = EDI_i \times SF_i \]

In this formula: Risk, is the carcinogenic risk index under different ways of soil heavy metals; (Risk)T is the comprehensive cancer risk index for soil heavy metal; EDIi is the average daily intake of different pollutants per day, mg/(kg.d); SF is the carcinogenic risk slope coefficient of various pathways, (kg/d)/mg (Table 3). Risk is the cancer-causing health index, usually expressed as the number of cancer patients in a certain number. The acceptable risk value for carcinogens defined by the
US Environmental Protection Agency is that the risk of cancer in a lifetime exceeds the normal value of $10^{-4}$ to $10^{-6}$. When risk $<1 \times 10^{-6}$, it is considered that there is no carcinogenic risk; when $1 \times 10^{-4} \geq$ Risk $\equiv 1 \times 10^{-4}$, the carcinogenic risk is considered to be in an acceptable range.

Table 3. Values of RfD and SF in different pathways of heavy Metals[27]

| Heavy metals | RfD$_{mouth}$/ [mg/(kg.d)] | RfD$_{breath}$/ [mg/(kg.d)] | RfD$_{skin}$/ [mg/(kg.d)] | SF/ [(kg.d)/mg] |
|--------------|----------------|----------------|----------------|----------------|
| Cd           | $1 \times 10^{-2}$ | $1 \times 10^{-3}$ | $1 \times 10^{-5}$ | $3.8 \times 10^{-1}$ |
| Ni           | $2 \times 10^{-2}$ | $2.06 \times 10^{-2}$ | $5.4 \times 10^{-3}$ | $8.4 \times 10^{-1}$ |
| As           | $3 \times 10^{-4}$ | $3.83 \times 10^{-6}$ | $3 \times 10^{-4}$ | $1.5 \times 10^{0}$ |
| Zn           | $3 \times 10^{-1}$ | 0 | $3 \times 10^{-1}$ |

2.5. Statistical analysis
The experimental data was processed and analyzed by Excel 2016 software.

3. Result

3.1. Analysis of current situation and sources of heavy metal pollution
The survey was conducted on three layers of the downwind soil around a metal surface treatment company in Jiaxing City. A total of 30 sampling data were used for regional analysis. According to the average value of the soil in the Hangjiahu Plain as the background value and the standard value of various elements specified in the soil environmental quality standard GB 15618-1995 secondary standard (pH<6.5), the exceed multiple can be used to display the pollution degree of heavy metals in a simple and straightforward manner. The coefficient of variation reflects the interference of human activities on heavy metal content. In order to investigate the overall pollution situation of the heavy metals around the Jiaxing metal surface treatment company and the influence of the distance between Isocation and the source, the average value of the heavy metals in the downwind direction of the study area and the heavy metal content at three different sampling depths were obtained. The results are shown in Table 4 and Figure 2.

Table 4. Heavy metal content in surface soil (0~10cm) (n=30, $\bar{x} \pm s$)

| Element | Cu   | Zn   | Cr   | Pb   | Cd   | Ni   | As   |
|---------|------|------|------|------|------|------|------|
| Detection range (mg/kg) | 32.78~68.70 | 817.25~1478 | 70.85~170.38 | 70.45~281.13 | 8.63~23.22 | 67.1~104.8 | 2109.25~5517.5 |
| Average (mg/kg) | 50.64±2.35 | 1053.55±158.69 | 121.72±12.85 | 195.62±37.58 | 14.98±2.67 | 69.81±11.25 | 3581.67±561.25 |
| SV/% | 22 | 19 | 25 | 28 | 28 | 24 | 27 |
| Over standard rate/% | 47 | 100 | 0 | 13 | 100 | 100 | 100 |
| Average exceeding the standard multiple (mg/kg) | 1.01 | 4.21 | 0.48 | 0.78 | 49.93 | 1.74 | 119.39 |
| Jiaxing soil background value (mg/kg) | 23.8 | 74.8 | 74.9 | 25.1 | 0.12 | 31.8 | 6.77 |
Figure 2. Average content of heavy metals in different soil layers (mg/kg)

It can be seen from Table 4 that the seven heavy metals tested in the surface soil of the metal generally exceed the standard, the over-standard rate of Zn, Ni, Cd and As is 100%, the over-standard rate of Cu is 47%, the over-standard rate of Cr is the lowest, and the over-standard rate of Pb is also 13%. The coefficient of variation reflects the effect of human activities on the content of heavy metals. The larger the coefficient of variation, the stronger the interference of human activities [30-32]. The coefficient of variation of 7 heavy metals measured by electroplating factory was in the order of large to small: Pb=Cd>As>Cr>Ni>Cu>Zn. Among them, the coefficient of variation of Pb and Cd reached 28%, indicating that the Pb and Cd content around the plant area was more seriously affected by humans. Followed by As, the coefficient of variation reached 27%, probably due to the metal residue caused by the use of arsenic fertilizers. The coefficient of variation of the other four heavy metals, Cr, Ni, Cu and Zn, was less than 25%, indicating that the metal content in the soil around the plant area was less affected by human activities.

3.2. The Geoaccumulation index evaluation

The overall evaluation of six heavy metals in the soil around the metal plant and the evaluation results of the metals at different vertical depths using the Geoaccumulation index method are shown in Table 5 and Figure 3.

It can be seen from Table 5 and Figure 3 that the Geoaccumulation index (Igeo) of heavy metals around the metal surface treatment plant is As>Zn>Pb>Cr>Ni>Cu>Cd in descending order. The geoaccumulation index of As is up to 8.16. All soils were polluted by As at different levels. Most of them are in extremely serious pollution levels, and their soil layers are similar in severity. Followed by Zn pollution, the Geoaccumulation index is 6.52, it is seen that the surface layer and deep soil are subject to extremely serious pollution. The overall pollution of Pb and Cr is between strong pollution and extremely serious pollution, and the soil of the middle layer (10~20 cm) is highly polluted. The overall pollution degree of Cu and Ni is at a strong pollution level. Compared with other heavy metals, Cd has the least pollution level, but still reaches the level of moderate pollution. Contamination decreases as the depth of the soil deepens, probably due to the adsorption and diffusion of soil particles.
Table 5. Classification of accumulation Index of heavy Metal contaminated soil around a electroplating factory in Jiaxing

| Heavy metals | The Geoaccumulation index | Proportion of samples per sample/% (sample capacity n=30) |
|--------------|---------------------------|--------------------------------------------------------|
|              | Igeo                      | 0 level | 1 level | 2 level | 3 level | 4 level | 5 level | 6 level |
| As           | 8.16                      | 0.00    | 0.00    | 0.00    | 26.67   | 53.33   | 6.67    | 6.67    |
| Cu           | 3.28                      | 0.00    | 6.67    | 0.00    | 0.00    | 53.33   | 6.67    | 6.67    |
| Zn           | 6.52                      | 0.00    | 0.00    | 0.00    | 0.00    | 6.67    | 0.00    | 93.33   |
| Cr           | 4.13                      | 0.00    | 6.67    | 0.00    | 0.00    | 33.33   | 53.33   | 6.67    |
| Pb           | 4.63                      | 0.00    | 0.00    | 0.00    | 6.67    | 6.67    | 6.67    | 60.00   | 26.67   |
| Cd           | 2.43                      | 0.00    | 0.00    | 46.67   | 13.33   | 26.67   | 0.00    | 6.67    |
| Ni           | 3.59                      | 0.00    | 6.67    | 0.00    | 6.67    | 53.33   | 26.67   | 6.67    |

Figure 3. Vertical distribution of soil heavy metal accumulation index in the study area

As can be seen from Figure 3, the soil Geoaccumulation index of the middle soil (10–20 cm) is mostly at a high level, which may be the result of subsurface infiltration. The Geoaccumulation index of many deep soils (20–30 cm) exceeds the index of surface soil, indicating that the deep soil is also seriously polluted. Among the 7 heavy metals measured in this study, except for the Geoaccumulation index of 46.67% of the soil samples Cd is less than 1, the other 6 heavy metals are in the middle-level pollution. Considering the possible hazards to surrounding residents, heavy metals such as As, Zn, Cd and Ni were selected as risk factors for human health risk assessment.

3.3. Health Risk Assessment

3.3.1. Exposure assessment analysis. In this study, non-carcinogenic daily exposures of four heavy metals, Cu, P, Cd, and Ni, were evaluated in children and adults. The results are shown in Table 6.

Table 6. Non-carcinogenic daily exposure of heavy metals in soil

| Heavy metals | EDI_mouth | EDI_mouth | EDI_skin | EDI_total |
|--------------|-----------|-----------|----------|-----------|
| As           | Maximum   | 1.50E-03  | 2.54E-03 | 6.96E-06 | 3.19E-06 | 1.89E-06 | 5.71E-03 | 2.56E-03 |
|              | Minimum   | 2.18E-03  | 1.40E-03 | 1.60E-06 | 1.22E-06 | 7.24E-06 | 2.18E-03 | 1.41E-03 |
| Zn           | Maximum   | 1.53E-03  | 2.54E-03 | 1.12E-06 | 8.56E-07 | 5.07E-06 | 1.53E-03 | 2.54E-03 |
|              | Minimum   | 1.45E-04  | 1.40E-03 | 6.21E-07 | 4.73E-07 | 2.80E-06 | 8.46E-04 | 1.41E-03 |
| Cd           | Maximum   | 2.40E-05  | 3.98E-05 | 1.77E-08 | 1.93E-08 | 7.97E-08 | 2.40E-05 | 3.99E-05 |
|              | Minimum   | 1.48E-05  | 1.45E-05 | 6.56E-09 | 1.09E-08 | 7.56E-09 | 8.93E-06 | 1.48E-05 |
| Ni           | Maximum   | 1.55E-05  | 2.57E-05 | 1.14E-08 | 1.89E-08 | 8.67E-09 | 5.14E-08 | 1.55E-05 | 2.58E-05 |

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As can be seen from Table 6, the content of heavy metals ingested by mouth are much higher than the heavy metal content ingested by the skin contact and respiratory inhalation. The daily intake of heavy metals in the three pathways from large to small is EDI mouth > EDI breath > EDI skin. Children’s mouth intake of heavy metal As is higher than that of adults, but the amount of heavy metals intake through skin contact and breathing is lower than that of adults. The exposure dose reached the maximum when the child ingested As element by mouth, which was $5.70 \times 10^{-7}$ mg/(kg/d). The exposure dose reached the minimum when the child ingested As element by breathing, which was $4.99 \times 10^{-9}$ mg/(kg/d). The adult’s intake doses of the other three metals, Zn, Cd, and Ni, were higher than that of children by mouth intake, skin contact, and respiratory inhalation.

### Health Risk Assessment

The non-carcinogenic and carcinogenic risk evaluation indexes of four heavy metals of As, Zn, Cd and Ni for human health risk are shown in Table 7. It can be seen from Table 7 that the non-carcinogenic risk index (HQi) of the various pathways around a heavy metal surface treatment plant in Jiaxing is partly greater than 1. Relatively speaking, the risk of mouth intake is the greatest, and the non-carcinogenic risk of direct skin contact and respiratory inhalation is relatively small. The results are consistent with Yang Xiaozhi’s [23] research on the health risk assessment of heavy metals in the dust of subway stations. The largest HQi appears when children intake As through mouth, and the maximum value is 12.34; The smallest HQi appears when children intake Zn through breathing, and the minimum is $2.03 \times 10^{-4}$. In addition, the doses of Cd and Ni for mouth intake, skin contact and respiratory inhalation in adults were higher than those in children, which was consistent with the conclusions obtained from the exposure assessment, indicating that the non-carcinogenic risk index is related to the exposure way. Regardless of which exposure way, the non-carcinogenic health risk assessment of As is higher than those of the other three heavy metals. Therefore, the risk of non-carcinogenic health of As is the largest, and the total risk of non-carcinogenic health HQ reaches 12, followed by Zn. The prevention and control of these two elements should be strengthened. In addition, the total HQ of other Ni and Cd non-carcinogenic health risks for adults and children is less than 1, indicating that these elements do not present non-carcinogenic health risks to residents around the plant. When Guo Pengran et al. [33] studied the soil pollution around the electroplating plant, the cancer risk of As and Cr in the soil was found to be $>10^{-4}$, which was higher than the maximum acceptable risk level, and the results of this study were similar.

| Risk index  | Classify | As     | Zn     | Cd     | Ni     |
|-------------|----------|--------|--------|--------|--------|
| HQ<sub>mouth</sub> | Childern | 1.23E+01 | 3.63E+00 | 1.55E-03 | 3.61E-03 |
|             | Adult    | 6.02E+00 | 6.02E-03 | 2.57E-03 | 5.99E-03 |
| HQ<sub>breathe</sub> | Childern | 7.11E-01 | NA     | 1.14E-05 | 2.58E-06 |
|             | Adult    | 1.18E+00 | NA     | 1.89E-05 | 4.27E-06 |
| HQ<sub>skin</sub>    | Childern | 6.91E-03 | 2.03E-06 | 8.67E-04 | 7.48E-06 |
|             | Adult    | 4.10E-02 | 1.20E-05 | 5.14E-03 | 4.44E-05 |
| HI total      | Childern | 1.31E+01 | 3.63E+00 | 2.43E-03 | 3.62E-03 |
|             | Adult    | 7.24E+00 | 6.04E-03 | 7.73E-03 | 6.04E-03 |
| Risk<sub>mouth</sub> | Childern | 5.55E-03 | NA     | 5.89E-06 | 6.08E-05 |
|             | Adult    | 2.71E-03 | NA     | 9.77E-06 | 1.01E-04 |
| Risk<sub>breathe</sub> | Childern | 4.08E-06 | NA     | 4.33E-09 | 4.46E-08 |
|             | Adult    | 6.78E-06 | NA     | 7.18E-09 | 7.40E-08 |
| Risk<sub>skin</sub>  | Childern | 3.11E-06 | NA     | 3.30E-09 | 3.40E-08 |
|             | Adult    | 1.84E-05 | NA     | 1.95E-08 | 2.01E-07 |
| Risk<sub>total</sub> | Childern | 5.56E-03 | NA     | 5.89E-06 | 6.07E-05 |
|             | Adult    | 2.74E-03 | NA     | 9.79E-06 | 1.01E-04 |

For children and adults, the maximum carcinogenic health risk index (Risk) of As appears through the mouth intake, the values are $5.5 \times 10^{-3}$ and $2.71 \times 10^{-3}$ respectively and there is a high risk of cancer. The minimum cancer risk index for As is $3.11 \times 10^{-6}$, which occurs through the skin contact of children. The carcinogenic risk of Ni was consistent with Cd, and the maximum value was found in the mouth intake of adults, which were $1.01 \times 10^{-4}$ and $9.77 \times 10^{-6}$, respectively. There is no cancer risk for Zn. In general, As has a higher total cancer risk index in three ways, far exceeding $1.01 \times 10^{-4}$. 

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Children have higher risk than adults, which should be highly concerned and controlled. In the case of Ni and Cd, adults have higher risk than children and this finding is consistent with the results of the non-carcinogenic risk index. For Ni, the adult cancer risk index for mouth intake is $1.01 \times 10^{-4}$, which has exceeded the warning standard. If no prevention is taken, it will pose a threat to the health of the surrounding residents.

4. Discussion
The content of seven heavy metals in the surface soil around a metal surface treatment company in Jiaxing City generally exceeded the standard. Among them, the over-standard rate of Zn, As, Ni and Cd was 100%, the over-standard rate of Cu was 46.67%, and the Pb was 13.3%. The content of Cr did not exceed the standard. Among them, the coefficient of variation of Pb and Cd reached 28%, indicating that the Pb and Cd content around the plant area was more seriously affected by humans. Followed by As, the coefficient of variation reached 27%, which may be related to the application of pesticides in farmland, and may also be related to nearby agricultural companies [34-35].

The accumulation index ($I_{geo}$) of heavy metals around the metal surface treatment plant is as follows: $As > Zn > Pb > Cr > Ni > Cu > Cd$. The ground accumulation index of As is up to 8.16. All soils were polluted by As at different levels. Most of them are in extremely serious pollution levels, and their soil layers are similar in severity. Followed by Zn pollution, the Geoaccumulation index is 6.52, it is seen that the surface layer and deep soil are subject to extremely serious pollution. The daily intake of heavy metals in the three pathways from large to small is EDI mouth > EDI breath > EDI skin. The non-cancer risk index is related to the exposure pathway. In the study area, the total cancer risk index of As through three exposure pathways is higher, while the carcinogenic hazard of Ni is in the acceptable range, but there is already a potential carcinogenic risk, which should be highly concerned and prevented.

Soil heavy metals are not only related to species, but also related to the relative position and distance of pollution sources. In this study, the content of As in all directions and positions exceeded the soil background value of Jiaxing City[16], and the content of As in the soil of 10–20cm reached the maximum. The average value exceeded the standard value by 119.39 times, which may be caused by the illegal discharge of arsenic-containing wastewater and the atmospheric deposition of exhaust gas in the production process of the adjacent automobile beauty enterprises. In addition, the use of organic arsenic pesticides to control rice diseases has also caused a large amount of arsenic residues. Long-term inhalation of arsenic-containing particles can cause chronic poisoning. Arsenic contamination can cause gastrointestinal, liver, kidney toxicity, cardiovascular toxicity, neurotoxicity, dermal toxicity, blood system toxicity, reproductive harm, and cancers that cause skin cancer, lung cancer, lung cancer, etc. Breathing in the arsenic air for 5 to 10 mins can lead to fatal poisoning, so effective measures must be taken to prevent. Except for As, the average value of Cd exceeds the standard value by 49.93 times, showing the same distribution pattern as As, reaching the maximum value in the soil of 10–20cm depth. Cd is a non-essential element for biosome, and Cd can cause chronic poisoning by the accumulation in the human body through the food chain, leading to liver and kidney damage and prevent bone metabolism [31], so it also needs special attention. The over-standard rate of Zn and Ni reached 100%, which was higher than the soil background value of Jiaxing City. This may be because when it is near the road, vehicle exhaust emissions, tire wear and company’s emissions lead to the over-standard rate. Pb and Cu are similar in average excess multiples, which are similar to the soil background value of Jiaxing City. Cr has the lowest over-standard rate and average over-standard multiple of the tested seven heavy metals, which may be related to the drainage channel. In Jiaxing, the dominant wind direction is the southeast wind. In this study, the overall enrichment of heavy metals is 100m in the southwest direction rather than in the downwind direction. Zhao Renxin’s [32] studies in Inner Mongolia concluded that the influence of wind direction on heavy metal distribution is not significant. There are three main reasons for this phenomenon: interference from sewage from other enterprises; interference from pesticides in farmland; atmospheric deposition caused by wind; The disturbance of the airflow caused by the vehicles passing by the west of the plant
has weakened the role of natural wind direction.

5. Conclusion
As pollution is serve, the As content in the middle layer of soil is the highest, and the average value exceeds the standard value by 119.39 times. The Cd pollution level is the lightest, but still reaches the medium pollution dose. The health risk assessment indicates that the health risk index (Risk) of As through mouth intake has far exceeded the warning value, and there is a high risk of cancer. Ni has potential cancer risk, and these two elements should be highly concerned and prevented.

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