Distribution of Heavy Metal Cr Content in Soils on Both Sides of Traffic Roads and Its Ecological Health Risk Assessment

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Abstract. Taking the surface soil of traffic road in Yiyang Industrial Park as the research object, the content of heavy metal Cr in 27 soil samples was collected and measured, the content features of heavy metal Cr in soil samples are analyzed. Using the single factor pollution index and potential ecological hazard index, environmental risk index and the method of health risk assessment model for soil heavy metal pollution and health risks to study the spatial distribution characteristics. The results show that the content of heavy metal Cr in surface soil is the highest at the intersection. In traffic sections 1 and 2, the Cr content of surface soil generally followed the distribution of unary quadratic function. As the distance from the intersection increased, the Cr content of soil heavy metal first decreased and then increased. On the whole, there was no Cr pollution on the traffic section, slight Cr ecological hazard and slight total potential ecological hazard, and no environmental risk; heavy metals Cr in surface soil has health risks, and the contribution rates of carcinogenic risks of the three exposure routes are respectively: inhalation of soil particles >skin contact> oral intake, and non-carcinogenic risk contribution rates of the three exposure routes are respectively: inhalation of soil particles >skin contact> oral intake.

1. Introduction
The original meaning of heavy metals refers to metals with a density greater than 4.5 g/cm³, but from the perspective of environmental pollution, heavy metals mainly refer to metals with significant biotoxicity such as cadmium, mercury and arsenic (metals)[1]. When the content of heavy metal elements in the soil exceeds the background value caused by natural geological processes and excessive deposition, soil heavy metal pollution occurs. The main causes of heavy metal pollution in the soil include: secondary enrichment of soilformation, high background of soil texture and human production and living activities. Among them, a series of human activities such as automobile exhaust, “three wastes” emissions and construction are the main reasons for exacerbating soil heavy metal pollution[2]. Road traffic is one of the main sources of heavy metal pollution in cities. The wear of the vehicle engines, tires, lubricants and gold-plated parts releases heavy metals. Therefore, heavy metals content in road dust and soil on both sides is relatively higher [3]. Heavy metals accumulate and migrate in the soil for a long time, and there are many realistic and potential risks to the ecological environment and human health. The evaluation method is also very important in the research of soil heavy metal pollution. Since the 1960s and 1970s, the evaluation of heavy metal pollution in soil has become one of the global
Therefore, strengthening the monitoring and evaluation of heavy metal pollution in soil is of great significance for detecting the health risks of heavy metal ecology.

Yiyang geographical coordinates for longitude 110°43'02"~112°55'48", north latitude 27°58'38"~29°31'42", is a subtropical humid continental monsoon climate, terrain and low in west. Located in the northern part of Hunan Province, it is one of the core cities of the Dongting Lake eco-economic circle and one of the 3+5 urban agglomerations of Changsha-Zhuzhou-Xiangtan. The total land area of Yiyang City is 12,144 square kilometers, accounting for 5.83% of the total area of Hunan Province. The land quality is good, and the soil is mostly weathered by shale, which is acidic and contains high nutrients. By the end of 2017, the resident population reached 439.20 million. However, there is currently no ecological and human health risk assessment for heavy metals in the surface soil of traffic roads in Yiyang Industrial Park. Therefore, it is extremely urgent to study the heavy metal pollution status of Yiyang City, especially the traffic roads in the densely populated industrial parks and evaluate the human health risk. This paper takes the topsoil of the industrial park area with concentrated population of Yiyang as the research object. Through the determination of Cr content in surface soil, the pollution degree of heavy metal Cr is evaluated by single factor pollution index method, potential ecological hazard index method and environmental risk index method. Based on the soil health risk assessment model in China's "Technical Guidelines for Risk Assessment of Contaminated Sites" (HJ2503-2014), the carcinogenicity risk and non-carcinogenicity risk of human health caused by heavy metal pollution in the surface soil of industrial parks under three exposure routes was studied.

2. Methods

2.1. Surface soil sample collection

The surface soil sample on both sides of the traffic road (the whole journey is about 1.4km) of Yiyang Industrial Park was collected on cloudy days in March 2017. The sampling area is mainly divided into three parts, with the intersection as the center, the left side of the intersection is the traffic section 1, and the right side of the intersection For the traffic section 2, sampling according to a certain distance, and setting 4 sampling points at the intersection to collect 20 soil samples. The distribution of sampling points is shown in Figure 1. The soil on the surface of the soil (0-10 cm) was collected with a shovel, sealed in a polyethylene plastic bag, and the sampling point number was correctly marked. The samples were collected according to the principle of random, uniform and equal volume. The sampling points were arranged according to the “plum blossom shape”. The number of sub-samples was more than 5, and after mixing, 1 Kg samples were obtained by the quarter method. Bring the collected soil samples back to the laboratory, remove the gravel, roots and biological debris, and then dry them in a cool place. About 10 g of samples were ground in an agate mortar, and then through a 100 mesh nylon sieve, bagged and sealed for later use.

2.2. Reagents and instruments

Most of the reagents used in the experiment were from Hengxing reagent, acetone was from Fuyu reagent, nitric acid and sulfuric acid were Guaranteed reagent, and the rest were analytically pure; all water was distilled water, and the standard solution of Cr was made in the laboratory. Determination of heavy metal Cr element using ultraviolet spectrophotometer (Shimadzu UV-2000, Hitachi, Japan).

2.3. Sample processing and determination

The soil was pretreated by HNO₃-H₂SO₄ digestion. Weigh 0.1-0.2g soil sample, add 10mL (2:1) HNO₃-H₂SO₄ mixture, place at room temperature for 24h, heat digestion, digest to colorless or milky viscous liquid about 2mL, cool, filter Volume. The supernatant after constant volume was measured by the ultraviolet spectrophotometer for the content of heavy metal Cr, and each soil sample was made in three parallels.
2.4. Surface soil pollution degree evaluation method

At present, the commonly used evaluation methods at home and abroad are index method, mathematical model method and other methods. The index method mainly includes the single factor pollution index method, the Nemero index method, the enrichment factor method, the pollution load index method, the ground accumulation index method, the potential ecological hazard index method and the environmental risk index method [5]; Including fuzzy mathematics evaluation method, grey clustering method, analytic hierarchy process, matter-element analysis method, set pair analysis and triangular fuzzy number coupling evaluation method [4,6,7]; other methods mainly include geostatistical model based on GIS technology Evaluation methods, artificial neural network model (ANN) evaluation methods based on GIS technology, human health-based risk assessment methods, morphological-based risk assessment coding (RAC) methods, and biological evaluation methods [8]. At present, there are many methods for evaluating heavy metals in soils at home and abroad, such as Nemero index method, environmental risk index method, and gray clustering method. In addition, domestic and foreign scholars have proposed evaluation methods and models for secondary soil ratio evaluation, TCLP method, nonlinear topological method, T-value classification method and projection pursuit classification model (PPC) for soil pollution evaluation [9]. These methods have more or less limitations and deficiencies in practical applications. In the evaluation process, multiple methods are often needed in combination to achieve the expected results.

The single factor pollution index method. The single factor pollution index \( P_i \) is a relatively dimensionless index used to evaluate soil, crop pollution level or soil environmental quality grade, and can comprehensively reflect the pollution degree of each element. Most basic evaluations use this method. [10]. The calculation formula is as follows:

\[
P_i = \frac{C_i}{S_i}
\]

- \( P_i \) — the environmental pollution index of the ith element in the soil (\( P_i < 1 \), no pollution; \( 1 < P_i \leq 2 \), mild pollution; \( 2 < P_i \leq 3 \), moderately polluted; \( P_i > 3 \), severe pollution)
- \( C_i \) — the measured content of the ith element in the soil (mg / Kg)
- \( S_i \) — the soil background value of the ith element pollutants (mg / Kg)

The single factor pollution index method can reflect the pollution degree of each evaluation factor, and facilitate the comparative analysis between the pollution factors, so as to quickly judge the main pollution factors of the soil environment. This method has clear objectives and simple operation, but it does not consider the toxicity of soil heavy metals, and the actual soil environment is often the result of multiple factors, so it is mainly used for the evaluation of specific regions of single factor pollution [11].

The potential ecological hazard pollution index method. The potential ecological hazard pollution index method was proposed by the Swedish scientist Hakanson [12] in 1980. The method focuses on toxicology, considers the toxicity of heavy metals and possible environmental and ecological hazards, and introduces the toxicity response coefficient of heavy metals, reflecting the comprehensive impacts of pollutants, and measuring the potential hazards of heavy metal pollutants to the soil environment. Widely used in the analysis of soil ecological hazards in China. The calculation formula is as follows:

\[
E_i = T_i \times C_i
\]

\[
RI = \sum_{i=1}^{n} E_i = T_i \times C_i = T_i \times C_i / C_i^v
\]

- \( E_i \) — the potential ecological hazard index of the ith element
- \( C_i \) — the enrichment factor of the ith element in soil
- \( C_i \) — the measured value of the ith element in soil
- \( C_i^v \) — the reference value calculated
- \( T_i \) — the toxicity coefficient of the ith element (\( Zn = 1 < Cr = 2 < Cu = Ni = Pb = 5 < As = 10 < Cd = 30 < Hg = 40 \)), mainly used to reflect the toxicity level of heavy metals and the sensitivity of organisms to heavy metal pollution
RI—potential ecological hazards of many heavy metals.
Liu Cheng et al [13], Ma Deyi et al [14], Yuan Hongming [15] after research and discussion showed that if the measured sediments are less than the eight species proposed by Hakanson (PCB, Hg, Cd, As, Pb, For Cu, Cr and Zn), the corresponding Eri value and RI value range should be adjusted according to the type and quantity of pollutants measured. The adjustment calculation process can be found in reference [16]. The Eri and RI standards for this study are shown in Table 1.

### Table 1. The Eri and RI standards for this study

| $E_i$ | The degree of ecological hazard of the ith element | $RI$ | Total potential ecological hazard |
|-------|--------------------------------------------------|------|----------------------------------|
| <2    | Minor ecological hazard                          | <2.26| Minor ecological hazard          |
| 2~4   | Medium ecological hazard                         | 2.26~4.52 | Medium ecological hazard       |
| 4~8   | Strong ecological hazard                         | 4.52~9.04 | Strong ecological hazard       |
| 8~16  | Very strong ecological hazard                    | ≥9.04| Extremely strong ecological hazard |
| ≥16   | Extremely strong ecological hazard               |      |                                  |

The potential ecological hazard index method comprehensively considers the heavy metal content, pollution concentration, environmental sensitivity to heavy metal pollution, biotoxicity levels and differences of various elements and their synergistic effects, which can comprehensively reflect the potential impact of various heavy metals on the ecological environment. It can reflect the difference of contribution rate of each heavy metal, and eliminate the influence of regional difference and heterogeneous pollution. However, the determination of the weight and heavy metal toxicity response coefficient in the calculation process is subjective [17-20].

The environmental risk assessment method. The environmental risk assessment method was proposed by Rapant et al. [21] in 2003, which can quantitatively measure the environmental risk of heavy metal contaminated soil or sediment. The critical values and grading standards of heavy metals in this method are shown in Tables 2 and 3. The calculation formula is as follows:

$$I_{ERi} = \frac{C_{Ai}}{C_{RI}} - 1$$

$$I_{ER} = \sum_{i=1}^{n} I_{ERi}$$

IERi — the environmental risk index of the ith element exceeding limit
CAi—analytical concentration of the ith element
CRi—limit-risk concentration of the ith element
IER—overall index of environmental risk of evaluated sample (Note: if CAi < CRi, it is 0)

### Table 2. Evaluated parameters and their limit-risk values

| parameter | As | Cd | Co | Cr | Cu | Hg | Ni | Pb | Zn |
|-----------|----|----|----|----|----|----|----|----|----|
| limit (mg·Kg⁻¹) |    |    |    |    |    |    |    |    |    |
| 29        | 0.8| 20 | 130| 36 | 0.3| 35 | 85 | 140|    |

### Table 3. The scale of environmental risk assessment level

| $I_{ER}$ | Environmental risk assessment level |
|----------|--------------------------------------|
| 0        | no risk                              |
| 0~1      | low risk                             |
| 1~3      | medium risk                          |
| 3~5      | high risk                            |
| >5       | very high risk                       |
The Environmental Risk Index method can use numbers to express the environmental hazards of heavy metal pollutants, and clarify the contribution of heavy metals to environmental pollution, but it does not reflect the characteristics of heavy metal pollution in time and space.

2.5. Soil heavy metal health risk assessment method

The health risk assessment (HRA) was first proposed by the National Institute of Engineering and the National Academy of Sciences (NAS) in 1972. Health risk assessment was conducted in four aspects: hazard identification, exposure assessment, toxicity assessment and risk characterization [22]. Currently, this method has been adopted by many countries and international organizations.

In the 1980s, the United States Environmental Protection Agency (USEPA) completed the development of the technical guidelines for risk assessment guidelines and related laws in the 1980s, and initiated health risk assessment and governance for typical contaminated sites. In 2014, China formulated and published reference [23-24]. The content of heavy metals in the soil of contaminated sites and their harm to human health are closely related to the distance of pollution sources, types and fluidity of environmental media and seasons [25]. Health risks are classified into non-carcinogenic and carcinogenic risks, with reference to the International Cancer Research Agency and the US Environmental Protection Agency's criteria for the classification of carcinogens [26].

Cr is a highly toxic teratogenic, mutagenic, and carcinogenic substance. It is one of the 129 key pollutants recognized by the USEPA. Cr acts as a persistent potential toxic pollution. Domestic and foreign scholars have studied the health risks of different exposure routes [27-28]. HJ Zhang et al [29] research on the pollution status of chromium slag contaminated sites in a chemical plant in Qinghai, indicating that Cr in the soil mainly poses risks to human health through drinking ground and skin contact. Y Huang [30] found that in the soil of a chromium slag contaminated site in Qingdao, Cr in the soil has a carcinogenic risk to human health. Some models have been developed at home and abroad, such as the CalTOX and RBCA models in the United States, the CLEA model in the United Kingdom, and the Csoil model in the Netherlands [22, 31]. The domestic HERA model is conducive to simplifying the evaluation of site health risks. In China, WJ Zhang et al [32] conducted a comparative study on the RBCA- and CLEA models in the health risk assessment of a contaminated site. PR Guo et al [33] applied the RAGS model to evaluate the health risks of heavy metals in the electroplating plant soil. McKnight Ursula S et al [34], Li J et al [35] and Kokangül Ali et al [36] scholars have improved on the above-mentioned pollution site health risk assessment model.

Heavy metal exposure pathways and models. Exposure assessment is a process of measuring, estimating or predicting the intensity, frequency, and duration of target pollutants exposed to environmental media by the population, and is a quantitative basis for health risk assessment. The exposure assessment is mainly to identify potential sensitive populations and exposure routes, to investigate and estimate the exposure parameters of the exposed population, the frequency of exposure, exposure time, average body weight, etc., and calculate the daily average exposure. The reference[23]divide the site exposure scenarios into sensitive land and non-sensitive land based on different land use patterns and human activity patterns.

The traffic roads in this study belong to non-sensitive land. According to the non-sensitive land exposure route recommended in reference[23], Cr is a non-volatile pollutant. Three ways of oral intake, skin contact and inhalation of soil particles were selected as the main route of exposure. For the carcinogenic and non-carcinogenic risks, the results of the exposure calculation formula, exposure parameters and daily average exposure of heavy metals in adults under the above three exposure routes are shown in Tables 4 and 5, respectively.
### Table 4. Formula for calculating soil exposure under three exposure routes

| Exposure Route   | Formula Description | Expose Formula Expression |
|------------------|---------------------|----------------------------|
| **Oral Intake**  | Carcinogenic Risk   | \[ OISER_{ca} = \frac{OSIR \times ED \times EF \times ABS}{BW \times AT} \times 10^{n} \] |
|                  | Non-carcinogenic Risk | \[ OISER_{nc} = \frac{OSIR \times ED \times EF \times ABS}{BW \times AT} \times 10^{n} \] |
| **Skin Contact** | Carcinogenic Risk   | \[ DCSER_{ca} = \frac{SAE \times SSAR \times ED \times EF \times ED_{\text{in}} \times ABS}{BW \times AT} \times 10^{n} \] |
|                  | Non-carcinogenic Risk | \[ DCSER_{nc} = \frac{SAE \times SSAR \times EF \times ED_{\text{in}} \times ABS}{BW \times AT} \times 10^{n} \] |
| **Inhaled Soil Particles** | Carcinogenic Risk | \[ PISER_{ca} = \frac{PM \times DAIL \times ED \times PIAF \times \left(fspo \times EFO + fspl \times EFI\right)}{BW \times AT} \times 10^{n} \] |
|                  | Non-carcinogenic Risk | \[ PISER_{nc} = \frac{PM \times DAIL \times ED \times PIAF \times \left(fspo \times EFO + fspl \times EFI\right)}{BW \times AT} \times 10^{n} \] |

### Table 5. Meaning, value and calculation result of each parameter in the formula of exposure calculation model

| Parameter  | Numerical Value | Unit   | Parameter  | Numerical Value | Unit   |
|------------|-----------------|--------|------------|-----------------|--------|
| OSIR       | 100             | Mg/d   | E_v        | 1               | Times/d |
| ED_r       | 25              | a      | PIAF       | 0.75            | /      |
| EF_r       | 250             | D/a    | fspo       | 0.5             | /      |
| BW         | 56.8            | Kg     | fspl       | 0.8             | /      |
| ABS_r      | 1               | /      | EFO_r      | 62.5            | d/a    |
| AT_r       | 26280           | d      | EFI_r      | 187.5           | d/a    |
| SAE        | 2854.63         | cm²    | OISER_r    | 4.19×10^{-7}    | mg/(Kg.d) |
| SSAR        | 0.2             | mg/cm² | OISER_r    | 1.21×10^{-6}    | mg/(Kg.d) |
| ABS_d      | 0.01(CrVI)      | /      | DCSER_r    | 2.39×10^{-8}    | mg/(Kg.d) |
| PM_{10}    | 0.15            | m³/d   | PISER_r    | 4.95×10^{-9}    | mg/(Kg.d) |
| DAIL        | 14.5            | m³/d   | PISER_r    | 1.43×10^{-8}    | mg/(Kg.d) |

Toxicity assessment. The main content of toxicity assessment is to analyze the harmful effects of pollutants on human health, including carcinogenic and non-carcinogenic effects, as well as the toxicity mechanism and dose-effect relationship of pollutants to human health through different exposure routes. In this study, toxicity-related parameters were selected according to reference [23]. See Table 6 for details.

### Table 6. Daily reference dose and carcinogenic slope factor for each exposure route of heavy metal Cr

| Exposure Route   | Oral Intake | Skin Contact | Inhaled Soil Particles |
|------------------|-------------|--------------|------------------------|
| SF               | 0.5         | 20           | 329.05                 |
| RfD              | 3.00×10^{-3} | 7.5×10^{-5}  | 2.55×10^{-5}           |

Risk characterization. Risk characterization is the final step of health risk assessment. The estimation process of population health risk probability of exposure to target pollutants is a comprehensive assessment of the three processes of hazard identification, exposure assessment and toxicity assessment. The main content of risk characterization is to calculate the carcinogenic risk and hazard quotient of a
single pollutant in soil through a single route and to conduct uncertainty analysis. The risk-causing risk and nucleus of the pollutants obtained by the risk characterization can be used as an important basis for determining the extent of pollution. If the sampling point of a single pollutant with a carcinogenic risk value exceeding 10^-6 or a hazard quotient exceeding 1 is calculated, the area represented should be classified as an unacceptable contaminated area. The formula for calculating the carcinogenic risk and hazard quotient based on the exposure route is shown in Table 7.

Table 7. Computational models of carcinogenic risk and hazard quotient for three exposure routes

| Exposure route       | Formula description   | Formula expression | Uncertain analytical model                                                                 |
|----------------------|-----------------------|--------------------|-------------------------------------------------------------------------------------------|
| oral intake          | Carcinogenic risk     | \( CR_{oi} = OISER_{oi} \times C_{oi} \times SF_a \)          | Carcinogenic risk contribution rate analysis \( PCR = \frac{CR}{CR_{oi}} \times 100\% \)   |
|                      | Hazard quotient       | \( HQ_{oi} = \frac{OISER_{oi} \times C_{oi}}{RfD} \)           | Non-carcinogenic risk contribution rate analysis \( PHQ = \frac{HI}{HQ_{oi}} \times 100\% \) |
| skin contact         | Carcinogenic risk     | \( CR_{dc} = DCSER_{dc} \times C_{dc} \times SF_d \)          |                                            |
|                      | Hazard quotient       | \( HQ_{dc} = \frac{DCSER_{dc} \times C_{dc}}{RfD} \)           |                                            |
| inhaled soil particles| Carcinogenic risk     | \( CR_{ip} = PISER_{ip} \times C_{ip} \times SF_i \)          |                                            |
|                      | Hazard quotient       | \( HQ_{ip} = \frac{PISER_{ip} \times C_{ip}}{RfD} \)           |                                            |

3. Results

3.1. Distribution of heavy metal content in surface soils on both sides of traffic roads with distance

The distribution of heavy metal Cr concentration and its variation with distance at each sampling point on the traffic road of an industrial park in Yiyang is shown in Figure 2 (the left side represents the Cr concentration and distribution of the traffic section 1 and the right represents the Cr content and distribution of the traffic section 2). In the case, the blue dotted line is the background value of the Cr element in the surface soil, and the red line is the tendency of the Cr content to vary with the distance). According to reference[37], the background value of heavy metal Cr in Hunan surface soil is 64.9mg/Kg. In the study area, the average mass concentration of heavy metal Cr at the intersection, traffic section 1, traffic section 2 and total traffic section are 84.97, 63.33, 40.56, 51.34mg/Kg, respectively. The average Cr content at the intersection was higher than the background value of Cr in Hunan soil, and it was the highest value of the whole traffic section, which was 1.31 times of the background value of Hunan soil. The average content of the remaining traffic sections did not exceed the background value. Among the 20 soil samples, 40% of the samples exceeded the soil background value. In the soil samples of traffic section 1, 50% of the samples exceeding the background value, and the soil samples of the traffic section 2 except the intersection, none of the other samples. Exceeded the background value.
According to the research results, the heavy metal Cr content in the surface soil on both sides of the traffic road changes with the horizontal distance from the intersection, and generally obeys the quadratic function distribution, and the distance from the intersection increases first and then increases; The degree of change of the traffic section 2 is more obvious than that of the traffic section 1, which may be related to the traffic environment. The other ends of the traffic sections 1 and 2 are Y-type intersections, and the traffic volume of the traffic section 1 is more frequent than that of the traffic section 2.

3.2. Evaluation of Heavy Metal Cr Pollution in Surface Soil of Traffic Roads

See Table 8 for the results of various pollution assessment calculations, pollution levels and pollution levels of the surface soil total metal Cr on both sides of the traffic road in an industrial park in Yiyang. At the crossroads, the single factor pollution index is 1.309, the index is greater than 1, and there is slight Cr pollution. The ecological hazard degree and total potential ecological hazard of heavy metal Cr are medium and no environmental risk. In traffic section 1, 50% of the sampling points have a single factor index greater than 1, and the ecological hazard of heavy metal Cr is medium, the single factor index is less than 1 at 250-420 m, and the ecological hazard of heavy metal Cr is slight. Traffic section 1 has no overall Cr pollution; at 0-150m, the total potential ecological hazard is moderate, and the rest are mild ecological hazards. Traffic section 1 has a slight total potential ecological hazard and no environmental risks. In the traffic section 2, except for the sampling points at the intersection, the single factor index is less than 1, and there is no Cr pollution. The ecological hazard degree and total potential ecological hazard of heavy metal Cr are slight and there is no environmental risk. There is no Cr pollution in the study area, the degree of ecological damage is slight, and there is no environmental risk.

**Fig.1.** Distribution of heavy metal content in surface soils on both sides of traffic roads in horizontal distance
### Table 8. Heavy metal Cr content and pollution at each soil sampling point

| Distance from the intersection (Mg/Kg) | $C_r$ | Single factor pollution index | Potential ecological hazard index | Environmental risk index method |
|----------------------------------------|-------|-------------------------------|----------------------------------|--------------------------------|
|                                        | $C_r$ | $P_{C_r}$ | $E_r$ | $RI$ | $RI_{ec}$ | $I_{ecr}$ |
| Traffic section 1 600 68.033 1.048 mild 2.096 Medium 2.096 Minor 0 no risk | 450 65.45 1.008 mild 2.016 Medium 2.016 Minor 0 no risk | 420 42.75 0.659 no 1.318 Minor 1.318 Minor 0 no risk | 370 48.165 0.742 no 1.484 Minor 1.484 Minor 0 no risk | 350 50.275 0.775 no 1.55 Minor 1.55 Minor 0 no risk | 300 57.494 0.886 no 1.772 Minor 1.772 Minor 0 no risk | 150 74.595 1.149 mild 2.298 Medium 2.298 Medium 0 no risk | 15 80.323 1.238 mild 2.476 Medium 2.476 Medium 0 no risk | 0 84.97 1.309 mild 2.618 Medium 2.618 Medium 0 no risk |
| Traffic section 2 0 84.97 1.309 mild 2.618 Medium 2.618 Medium 0 no risk | 300 39.095 0.602 no 1.204 Minor 1.204 Minor 0 no risk | 400 39.5 0.609 no 1.218 Minor 1.218 Minor 0 no risk | 450 26.715 0.412 no 0.824 Minor 0.824 Minor 0 no risk | 500 26.437 0.407 no 0.814 Minor 0.814 Minor 0 no risk | 610 25.455 0.392 no 0.784 Minor 0.784 Minor 0 no risk | 620 26.63 0.410 no 0.82 Minor 0.82 Minor 0 no risk | 720 55.72 0.859 no 1.718 Minor 1.718 Minor 0 no risk | 40.56 0.625 no 1.250 Minor 1.250 Minor 0 no risk |
| total average | 51.34 0.791 no 1.582 Minor 1.582 Minor 0 no risk |

#### 3.3. Health Risk Assessment of Surface Soil on Both Sides of Traffic Roads

The calculation results of the carcinogenic risk, hazard quotient, carcinogenic and non-carcinogenic risk contribution rate of heavy metal Cr in the surface soil on both sides of the traffic road in Yiyang Industrial Park are shown in Table 9. The results showed that the carcinogenic risk values of heavy metal Cr under the three exposure routes were all greater than $10^{-6}$, so there is a health risk of Cr pollution in this area. Under the traffic section, the carcinogenic risk value and the hazard quotient of the inhaled soil particle exposure route are far higher. The carcinogenic risk values of both exposure routes and oral exposure were above 70%, and the carcinogenic risk contribution rates of the three exposure routes were as follows: inhaled soil particles > skin contact > Oral intake; the contribution rate of non-carcinogenic risk of the three-exposure route is: skin contact > inhaled soil particles > oral intake.
### Table 9. Carcinogenic Risk, Hazard, Carcinogenic and Non-Carcinogenic Risk Contribution Rate of Heavy Metal Cr under Three Exposure Routes (n is the number of samples)

| exposure route | oral intake | skin contact | inhaled soil particles |
|---------------|-------------|--------------|-----------------------|
| Traffic section 1 (n=10) | Carcinogenic risk | $1.33 \times 10^{-5}$ | $3.03 \times 10^{-5}$ | $1.03 \times 10^{-4}$ |
| | Hazard quotient | 0.128 | 0.290 | 0.178 |
| | Carcinogenic risk contribution rate | 9.07 | 20.67 | 70.26 |
| | Non-carcinogenic risk contribution rate | 21.48 | 48.66 | 29.86 |
| intersection (n=4) | Carcinogenic risk | $1.78 \times 10^{-5}$ | $4.06 \times 10^{-5}$ | $1.38 \times 10^{-4}$ |
| | Hazard quotient | 0.171 | 0.390 | 0.238 |
| | Carcinogenic risk contribution rate | 9.06 | 20.67 | 70.27 |
| | Non-carcinogenic risk contribution rate | 21.40 | 48.81 | 29.79 |
| Traffic section 2 (n=8) | Carcinogenic risk | $8.50 \times 10^{-6}$ | $1.94 \times 10^{-5}$ | $6.61 \times 10^{-5}$ |
| | Hazard quotient | 0.082 | 0.186 | 0.114 |
| | Carcinogenic risk contribution rate | 9.04 | 20.64 | 70.32 |
| | Non-carcinogenic risk contribution rate | 21.47 | 48.69 | 29.84 |
| The whole (n=20) | Carcinogenic risk | $1.08 \times 10^{-5}$ | $2.45 \times 10^{-5}$ | $8.36 \times 10^{-5}$ |
| | Hazard quotient | 0.104 | 0.235 | 0.144 |
| | Carcinogenic risk contribution rate | 9.08 | 20.61 | 70.31 |
| | Non-carcinogenic risk contribution rate | 21.53 | 48.65 | 29.82 |

### 4. Conclusion

The content of heavy metal Cr in the surface soil on both sides of the traffic road in Yiyang Industrial Park is the highest at the intersection. In the traffic sections 1, 2, the content is subject to the quadratic function distribution, and the distance from the intersection increases. Large, soil heavy metal Cr content first decreased and then increased.

The heavy metal Cr in the surface soil on both sides of the traffic road in Yiyang Industrial Park has slight Cr pollution, medium Cr ecological hazard and medium total potential ecological hazard at the intersection, and no environmental risk; there is no Cr pollution on the whole traffic section, slight Cr ecological hazard and slight Total potential ecological hazard, no environmental risks.

There is a health risk of heavy metal Cr in the surface soil on both sides of the traffic road in Yiyang Industrial Park. The contribution rate of the three types of exposure routes is: inhaled soil particles > skin contact > oral intake, non-carcinogenic risk contribution of three exposure routes The rate is in order: skin contact > inhaled soil particles > oral intake.

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