Study on heavy metal pollution in soil by electronic information processing

Yang Haoran 1

1. Graduate School of Geosciences, Shandong University of Science and Technology, Qingdao 266590, China

*Corresponding author’s e-mail: skddkxy@sdust.edu.cn

Abstract: In order to deeply analyze the influencing factors and main sources of soil heavy metal pollution in Huangdao District of Qingdao, 35 soil samples collected from the electronic information area of Haier Industrial Park and Ao kema Industrial Park in Huangdao District were selected as the research objects, and the significant biological toxicity of Cd, Cr, Cu, Hg, Ni, Pb, Zn, As in the soil samples were analyzed and the result shows that the variation coefficients of Cr and Ni were examined high, which indicated that the pollutants mainly came from the production and processing activities in the electronic information area. Besides, in accordance with the soil risk assessment level, the analysis of heavy metal pollution status and human health risks of the site in the electronic information area were accomplished and also alarmingly conveyed an obvious risk carcinogenic grade of Cr and As with the “hand-mouth exposure” as the transmission routine of the highest carcinogenic risk level, which urges us to be vigilant.

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1. Introduction

With the rapid development of economy in the 21st century, China has gradually become a big manufacturing country and its electronic information processing industry has sprung up. Even these electronic manufacturing enterprises have good economic benefits, they also have many some disadvantages, such as the underdeveloped industrial equipment and extensive management, lack of environmental protection facilities, which cause serious environmental pollution problems. Among them, heavy metal pollution in soil might affect the yield and quality of crops, and then endanger human life and health through the food chain. In recent years, the reports of heavy metal pollution in soil lead to people’s blood lead exceeding the standard and suffering from cancer are on the rise1-4, indicating that soil heavy metal pollution has posed a great threat to human life and health, and has received more and more attention from the society. In order to prevent and control the harm of soil heavy metal pollution, the State Council approved the “Twelfth Five Year Plan for comprehensive prevention and control of heavy metal pollution” in 2011, which raised the prevention and control of soil heavy metal pollution to the level of national planning. Among many pollution sources, the pollution of electronic information processing zone is one of the most important pollution ways of shallow soil heavy metal pollution. The proportion of heavy metal pollution in soil pollutants is more prominent, and its most significant feature is that it is difficult to be degraded by soil microorganisms. Therefore, it accumulates in shallow soil for a long time and causes chronic toxicity to animals and plants, which is harmful to human health. In soil inorganic pollutants, heavy metals are more
prominent. It is mainly because that heavy metal can not be decomposed by soil microorganisms, but are easy to accumulate and transform into more toxic methyl compounds, and some even accumulate in the human body with harmful concentrations through the food chain, seriously endangering human health. The industrial and mining enterprises that discharge heavy metals into the environment through “three wastes”, such as electronic information processing plants, household appliances manufacturing and other electronic information processing industries, etc, which have caused extremely serious pollution and damage to the surrounding soil, is one of the main sources of heavy metal pollution\cite{5}. Besides, hexavalent chromium, cadmium and other toxic and harmful substances are widely distributed in electronic products. After simple treatment through pickling, incineration and other processing methods, they are input into the environment through atmospheric dust, waste water and waste gas, thus causing serious pollution to the environment. Cadmium compounds are possible to cause serious damage to human body, especially kidney. And lead might affect children’s intellectual development and cause chronic toxicity to animals, plants and microorganisms. And hexavalent chromium can be absorbed through the cell membrane and accumulated in the body \cite{6}. Therefore, electronic products manufacturing activities in the electronic information processing zone have great harm to the surrounding environment, human beings, animals and plants. Since the 1970s, with the rapid development of electronic information processing industry, the soil heavy metal pollution has also shown a growing trend. With the rapid development of science and technology, many new materials are used in electronic products as soon as they are invented, which makes the composition of electronic products constantly change. Research shows that the electronic products processed in electronic information zone often maintain arsenic, cobalt, silver, aluminum, palladium, cadmium, chromium, bismuth, copper, iron, manganese, zinc, antimony, nickel and other heavy metal elements.

In general, the two main causes of soil heavy metal pollution include external natural factors and internal human factors. Among them, the production and manufacturing activities of electronic products in the electronic information area are the main sources of heavy metal. Through spatial analysis of element content \cite{7-10}, multivariate statistics and other methods, the pollution sources of heavy metals with significant toxicity in shallow soil are analyzed, and relevant prevention and control measures are formulated, so as to curb the emission of toxic heavy metal pollutants at the source and improve the soil ecosystem to a certain extent.

This study intends to carry out soil sample collection and analysis in Haier and Aucma electronic information industrial processing zone, Huangdao District, Qingdao city. Based on the results of sample analysis and comprehensive investigation in the contaminated area, the study analyzed the risk of soil heavy metal ions produced by electronic information processing on human health and made the health risk assessment in accordance by the model and parameters recommended by Technical guidelines for risk assessment of contaminated sites. The evaluation results can provide a reference for the effective restoration and reasonable development and utilization of the industrial land in the electronic information area. Therefore, it is of great practical significance to widely investigate the sources and pollution modes of heavy metal pollutants in soil, the spatial distribution characteristics and migration rules of heavy metal elements, and the risk assessment of human ecological environmental health.

2. Materials and methods

2.1. Overview of the research area
Qingdao Huangdao District Haier and Aucma electronic information industry processing zone is located on the West Bank of Jiaozhou Bay, 36°00'-36°01'N and 120°14'-120°15'E. There are No.2 harbour expressway, No.1 harbour expressway and other expressways around it. The electronic information area is located in the north temperate monsoon region, with humid air, abundant rainfall, moderate temperature, four distinct seasons, obvious marine climate characteristics. It is cold in spring, cool in summer, mild in autumn and warm in winter. And the annual average temperature is 12.5 °C, the average temperature in summer is 23 °C, the average rainfall is 696.6 mm, and the average annual
frost free period is 200 days\textsuperscript{[11]}. The main soil in the study area is loam and clay loam, sandy loam, sandy clay loam.

2.2. Sample collection
In order to analyze the pollution of heavy metal ions in the soil caused by electronic information processing in Qingdao City, the research in accordance with \textit{Determination of Regional Ecogeochemistry Assessment} collected the soil samples of Haier and Aucma electronic information zones in Huangdao District of Qingdao city in May and July of 2019. Utilizing the grid sampling method, the surface soil and profile soil on both sides of the road between the factories in the electronic information area of Aucma Industrial Park and Aucma Industrial Park were selected as the samples with the sampling points determined and recorded by Ovi map. After sorting out the longitude and latitude coordinate data of these sampling points, the plane position distribution map can be generated by using the user projection transformation function of Map Gis 6.7.

The net weight of each sample is not less than 1Kg. After mixing evenly, a soil sample is formed. There were 35 samples in total, 15 soil surface (0-20cm) soil samples and 20 soil profile samples in two soil profiles which means 10 soil samples were collected from per profile in the scope between the ground and 200 cm below ground(0 ~ 200cm). After the collection, these samples were hung in the air to remove the moisture in the soil and then dry naturally. And a clean 20-mesh nylon sieve\textsuperscript{[12]} were used to sieve them, removing the branches and pebbles that were accidentally mixed into these samples. Finally, these samples were prepared well for the future analysis with the particle sizes of less than 100 meshes.

2.3. Sample analysis method
Eight toxic heavy metal elements Cd, Cr, Cu, Hg, Ni, Pb, Zn, As were detected by atomic fluorescence spectrometry (AFS8520). The detection limits of as and Hg were 0.01 mg · kg\textsuperscript{-1} and 0.02 mg · kg\textsuperscript{-1}, respectively. Cr, Zn, Pb, Cd, Cu and Ni were detected by inductively coupled plasma mass spectrometry (ICAP RQ). The detection limits were 0.4 mg · kg\textsuperscript{-1}, 1.5 mg · kg\textsuperscript{-1}, 1.9 mg · kg\textsuperscript{-1}, 0.02 mg · kg\textsuperscript{-1}, 0.6 mg · kg\textsuperscript{-1} and 0.3 mg · kg\textsuperscript{-1}, respectively. All the collected soil samples were sent to the fifth exploration team of Shandong Coalfield Geology Bureau for detection and analysis. According to the technical rules of soil geochemical survey, all the soil samples are strictly evaluated according to the technical rules of soil geochemical survey. The analysis and discussion of the experimental data are carried out in Excel.

3. Results and discussion

3.1. Distribution characteristics of heavy metal elements in soil profile
The distribution map of heavy metal Cd, Cr, Cu, Hg, Ni, Pb, Zn and as in P-1 and P-2 profiles around Haier and Aucma electronic information area in Huangdao District of Qingdao city is shown in Figure 2. It can be seen from Figure 2 that the enrichment characteristics of various heavy metal elements in each profile have different distribution rules.

The P-1 profile in Figure 2 shows the distribution of Cd, Cr, Cu, Hg, Ni, Pb, Zn and As in the natural state with less external human disturbance. It can be seen from the P-1 profile in Figure 2 that among all heavy metal elements, except the maximum content of Cd element appears in the shallow soil at the depth of 0-20cm, the maximum values of other heavy metal elements appear in the deep soil below the depth of 20cm. The element contents of Hg, Pb and as in soil profile decreased rapidly in the depth of 40-60 cm, while the element contents of Cr, Cu, Ni and Zn increased significantly in the depth of 40-60 cm. From the analysis of the content change characteristics of the whole profile, although the content of heavy metals in the shallow soil changed significantly within the depth of 60 cm, the content of Cd, Cr, Cu, Hg, Ni, Zn, As and other elements in the depth range of 60-160 cm showed a downward trend. In the soil layer below 160 cm, the content of each element was relatively stable, and the change trend was relatively small. The content of Pb increased slightly from 0 to 60cm,
fluctuated from 60cm to 160cm, and increased from 160 to 200cm. However, from the overall change of each element profile, the surface content of most heavy metal elements is relatively high, and each element is generally distributed near the background value[13].

The P-2 profile in Figure 2 shows the soil profile near the road outside the factory building of Haier Industrial Park without human disturbance. From the absolute value of element content, except for Hg, Pb and As, the change trend of other heavy metal elements is basically the same as that of P-1 profile, which reflects the similarity of surface soil parent material in electronic information area. There are some differences in distribution patterns. In the land on both sides of the road outside the industrial information area, except for Zn, the content of heavy metal elements in the profile is similar The maximum content of elements is located in the surface soil at the depth of 0-20cm, while the maximum content of other elements in the profile is not enriched in the surface soil, which is obviously due to the migration of elements to the deep soil under the natural state. Under the depth of this layer, the content of elements in the profile shows a trend of gradual decrease, and the depth where the content changes tend to be stable is relatively close in recent years, the content of most elements reached the maximum at the depth of 60cm, and the content of most elements decreased rapidly at the depth below 60cm, and reached the minimum at the depth of 160cm. The content showed an upward trend from 160cm to 200cm, reflecting the characteristics of soil parent material, and the heavy metals in the soil migrated downward at the new interface.

By analyzing the distribution of heavy metal content in the above two profiles, the following rules are found. The content of Cd is the highest in the top layer of the profile, and gradually decreases in the lower layer of the soil. There are several possible explanations, one is that the surface pollution gradually increases with the accumulation of time, the other is that the heavy metal elements migrate to the deep soil under the action of solute transport, such as rainfall, and the distance of pollutant migration to the deep soil It will show an increasing trend with the passage of time. In the case of no external human disturbance, the element content distribution pattern of upper high and lower low will usually be maintained. However, according to the data analysis of the test results, the accumulation rate of heavy metal elements in the shallow soil is greater than its migration rate to the deep soil. Therefore, throughout the whole element soil profile, the shallow soil is more stable The spatial distribution of heavy metal elements in deep layer is still very obvious. In P-1 profile, the content distribution of Cr, Cu, Ni and Zn presents a spatial distribution pattern of low content in shallow and deep layers and high content in middle layer. The surface layer of soil presents a more obvious distribution pattern of heavy metal content deficit. It can be inferred that the content of Cr, Cu, Ni, Zn and other heavy metal elements imported into soil layer by industrial activities such as human activities Heavy metal elements such as Cr, Cu, Ni and Zn were leached by water and accumulated in the middle layer of soil profile.

According to a large number of studies at home and abroad, this paper analyzes the spatial distribution characteristics of heavy metal pollution in the horizontal and vertical directions in different industrial areas from various dimensions. It is generally believed that due to the continuous processing of electronic products, the resulting heavy metal elements are continuously accumulated in the soil, and due to the influence of organic matter and colloid in the soil on heavy metal elements Therefore, a large number of toxic heavy metal elements produced by human activities migrate to the deep soil, resulting in the slow down of the downward migration process of heavy metals in the soil. However, in this study, the distribution of Cr, Cu, Ni and Zn in P-1 profile shows that under the condition of light human disturbance and low content of heavy metals, there is still an obvious migration and distribution law of heavy metals in the soil, and the spatial distribution characteristics of heavy metals in the soil can be more comprehensively reflected by the grid chessboard sampling method.

3.2. Study on migration law of heavy metals in soil

The migration of heavy metal elements in soil not only depends on the chemical properties of various products produced and processed in the electronic information area, but also depends on the
environmental factors and physical and chemical characteristics of soil[14]. According to the method of Tessler[15], a large number of scholars at home and abroad divide the forms of heavy metal elements in soil into carbonate state, exchangeable state, iron manganese oxide bound state and organic sulfide state And residual state. The distribution characteristics of heavy metals are the result of the extremely complex physical and chemical long-term interaction. In the profile spatial distribution characteristics, the migration of heavy metals in soil can be summarized as horizontal and vertical migration. The heavy metal pollutants produced in the process of electronic products processing are affected by soil colloid adsorption, substitution, chelation and biochemistry Most of the heavy metal elements are fixed in the shallow soil, and gradually accumulate with the passage of time. Therefore, through the soil profile in the electronic information area, it can be seen that a large number of heavy metal elements are fixed in the surface of the soil. Therefore, in most cases, it is more difficult for the toxic heavy metal elements in the soil to accumulate in the deep soil. Therefore, in general, it is difficult for the heavy metal elements in the soil to accumulate in the deep soil. The difficulty of heavy metal migration to the deep layer will increase, and the content of toxic heavy metal elements in the profile distribution shows a certain decrease trend. However, some profile content distribution maps in this study reveal that the content of some heavy metal elements in the deep layer is higher than that in the shallow layer, and the content of heavy metal elements in the vertical soil shows a gradual decline trend, which indicates that the content of heavy metal elements in the vertical layer is higher than that in the shallow layer. The upward migration is affected by the attributes of heavy metal elements, the way and degree of soil development and utilization, the accumulation time of pollutants, and various soil parameters, which shows a complex regularity and needs further research.

3.3. Basic properties of urban soil

The pH value of soil in China is generally ph4-9. The pH value of soil is not only affected by climatic conditions, but also related to the nature of soil parent material and human activities. In Qingdao City, Shandong Province, located in East China, the pH value of soil in most areas ranges from 6.50 to 7.50, belonging to neutral soil[16]. The pH value of the soil near Haier and Aucma electronic information area in Huangdao District of Qingdao city is shown in Table 1. From table 1, it can be seen that the maximum pH value of all soil samples is 8.7, the minimum pH value is 6.3, and the average value is 7.31. The pH value of most soil samples is higher than that of other areas of Qingdao City, which belongs to weak alkaline soil. Therefore, it can be concluded that the pH value content in the electronic information area is on the high side It may be closely related to the production and manufacturing activities of electronic products in the electronic information zone, and the alkaline substances in the soil may come from the processing and transportation of raw materials of electronic products and the electronic information zone, the input of alkaline substances generated in the assembly and processing activities of electronic products such as refrigerators, washing machines and air conditioners, the hydrolysis of heavy metal ion salts, and air pollution Due to various external factors such as the deposition of particles, the high salt content in weak alkaline soil makes it difficult for plant roots to absorb water and nutrients in the soil, causing "physiological drought" and nutrient deficiency. Even if there are abundant nutrients in the soil, its absorbability will be very low, and the availability and solubility of calcium, magnesium, boron, manganese, copper and other trace elements in alkaline soil will be high. The activity of soil microorganism will be seriously inhibited in the hyperalkaline soil, which will inhibit the transformation and supply of nitrogen and other nutrients. Alkaline soil may cause irreversible impact on the surrounding ecosystem and vegetation, which should be paid great attention to.

| Table 1  pH value content of soil around electronic information area |
|-------------------|-------------------|-------------------|-------------------|-------------------------------|
| **medium parameter** | **average value** | **minimum value** | **Maximum value** | **Coefficient of variation** |
| Soil (n = 35) | PH value | 7.31 | 6.3 | 8.7 | 11 |

(1) n represents the number of samples
3.4. Content and distribution characteristics of heavy metal ions in soil

According to the analysis results of soil samples from Haier and Aucma electronic information area in Huangdao District of Qingdao City, the statistical table of 8 toxic heavy metal elements was obtained (Table 2).

According to the data in Table 2, it can be found that the total amount of heavy metal elements Cd, Cr, Cu, Hg, Ni, Pb, Zn and As in Haier and Aucma electronic information industry processing zone in Huangdao District of Qingdao are 0.070-0.295, 29.4-505.2, 10.3-31.5, 0.012-0.054, 15.2-170, 21.6-48.9, 35.8-179 and 0.945-11.4 mg·kg⁻¹, respectively. The coefficient of variation is Cr > Ni > Cd > As > Zn > Hg > Cu > Pb. Among them, Cr, Ni and other heavy metal elements have prominent coefficient of variation, which indicates that the spatial dispersion of these two elements is large, and the spatial distribution variation characteristics are significant. The pollutants mainly come from the production and processing activities in Haier and Aucma electronic information zone, while the coefficient of variation of Hg, Cu, Pb and other elements is small, which is less affected by the external man-made environment, and the natural environment is the main source. The main pollution source is the sediment pollutants in the environment. The pollution degree of Cr element is obvious, and the content of heavy metals in some samples is higher than the national control standard, which should be paid great attention to.

### Table 2  Statistics of toxic heavy metal elements

| Name of study area | characteristic value | Cd   | Cr    | Cu    | Hg    | Ni    | Pb    | Zn     | As    |
|-------------------|----------------------|------|-------|-------|-------|-------|-------|--------|-------|
| Haier Industrial Park, Huangdao District, Qingdao | minimum value/mg·Kg⁻¹ | 0.028 | 29.4  | 10.3  | 0.012 | 15.2  | 21.6  | 35.8   | 0.945 |
|                   | Maximum/mg·Kg⁻¹      | 0.295 | 505.2 | 31.5  | 0.054 | 170   | 48.9  | 179    | 11.4  |
|                   | average value        | 0.096 | 68.3  | 18.5  | 0.024 | 29.7  | 29.2  | 70.3   | 4.75  |
|                   | standard deviation   | 0.05  | 78.01 | 5.03  | 0.01  | 26.27 | 6.18  | 31.74  | 2.22  |
|                   | Coefficient of variation | 52    | 114   | 27    | 42    | 88    | 21    | 45     | 47    |
|                   | <Screening criteria/% | 100   | 0     | 100   | 100   | 100   | 100   | 100    | 100   |
|                   | Screen-Control standard/% | 10    | 91    | 0     | 0     | 0     | 0     | 0      | 0     |
|                   | >Control standard/%  | 0     | 9     | 0     | 0     | 0     | 0     | 0      | 0     |

The selection of spatial interpolation model is the key factor to study and analyze the spatial distribution characteristics of heavy metals in soil and evaluate soil pollution [17-18]. 6.7 trace plane isoline method to draw the spatial distribution of soil heavy metal content (Fig. 3). As shown in Fig. 3, there are certain differences in the spatial distribution of heavy metal elements. The spatial distribution characteristics of heavy metal content in Haier and Aucma electronic information area are not uniform, showing a trend of local high content and gradually decreasing to the surrounding areas. The spatial distribution characteristics of Cr, Pb, Zn and other elements are particularly obvious, while other elements generally present a scattered extreme value distribution pattern. Among them, the distribution areas of high value points of different elements are slightly different. The high value areas of Zn generally appear in the eastern and central and western parts of the electronic information area. In this area, air conditioners and ice are mainly produced. The main reasons for the high content of elements in this area are box and special steel plate, while the high content areas of Cr are generally distributed in the northeast of Aucma Industrial Park and the southwest of Haier Industrial Park, while the rest areas belong to low value areas, which may be closely related to the energy-saving refrigerators and quick-frozen storage equipment produced in the electronic information area. Different from the high value area of element content of Cr, it shows that there are significant differences in pollutant sources and pollutant types of these two elements, while the high value area of element content of Pb and Zn.
has a certain similarity. The extreme value of element content presents a strip northeast southwest distribution, which is generally distributed in Shanghai Road area in the north of Haier Industrial Park in the Development Zone, mainly producing and processing air conditioners. Using electronic products, it shows that the pollution sources of these two heavy metals have a certain degree of similarity; the high value areas of Cd and Ni are generally located in the northeast and southwest of the electronic information area, showing a sporadic block distribution, which may have a very close relationship with the production and processing of wine cabinets and ultra-low temperature quick freezing equipment, showing a relatively uniform spatial distribution. The high value areas of As, Hg and other heavy metal elements are generally located in the Middle East and southeast of the electronic information area, mainly showing the characteristics of massive distribution. In this area, the production and processing of special steel plate is the main source of pollutants leading to the high content of heavy metals in the soil, and the high value of Cu is the main source of pollutants. The area is generally distributed in the middle, South and a small part of the northern part of the electronic information area, showing a banded northeast southwest distribution characteristics, mainly producing refrigerators, freezers, electric water heaters and other household appliances, which is the main reason for the high content of heavy metals in this area.

In order to measure the severity of heavy metal pollution in the soil of Aohai District in Qingdao, we collated the data in Table 3. Table 3 lists Shandalu electronic information industry base and Shandong electronic industry base in Fenghuang district. Through comparison, we can draw the following conclusions: among the heavy metal elements in Haier and Aucma electronic information area of Huangdao District, the average content of Cd, Cu, Hg and As is lower than Shandalu electronic information industry base, Shandong electronic industry base in Fenghuang District, and the average content of elements in Shandong Province Background value and national soil layer average, the average content of Cr and Ni in Haier and Aucma electronic information area is lower than Shandalu electronic information industry base, higher than Shandong electronic industry base in Fenghuang area, the average value of soil layer in Shandong Province and the whole country, the average value of soil layer of Pb is higher than Shandalu electronic industry base, Shandong electronic industry base in Fenghuang area, Shandong Province and the whole country, but lower than that of the whole country. According to the statistical data analysis of Excel table, the pollution of Pb is the most serious in Haier and Aucma electronic information processing zone in Huangdao District, which may be closely related to the processing and manufacturing of special steel plates, household appliances, batteries, refrigerators, etc. in Haier and Aucma electronic information processing zone. The application of lead in industry has a long history, But its toxicity was recognized hundreds of years ago. Studies have shown that lead can cause a series of physiological and biochemical changes, affect the central and peripheral nervous system, cardiovascular system, long-term exposure to lead can lead to elevated blood pressure, toxic myocarditis and myocardial damage. Lead can increase oxygen free radicals in the body, produce lipid peroxidation damage, including myocardial cell membrane and myocardial microsomal membrane, and can affect the cation transport enzyme of myocardial microsomal membrane, overload Ca\(^{2+}\) ions in aorta and other vascular cells, accumulate Ca\(^{2+}\) in myocardial cells, cause membrane ion transport disorder, and lead to myocardial cell dysfunction. Even studies have shown that when children's blood lead level is more than 10\(\mu\)g / D, it can cause irreversible damage to their intelligence development, and there are often no enough clinical manifestations to attract attention at this time\(^{19}\). Although the toxicity of lead to human body has aroused certain attention, the toxic and harmful pollutants produced in the production process of electronic products, and the lead content produced by the boiler combustion in the electronic information processing area, are mainly Harmful gases, including the use of lead containing household appliances, such as air conditioners, are still serious. Therefore, we should be highly alert to the risk of children's pollution caused by the production and processing of lead containing mechanical products in the production workshop, enhance the awareness of environmental protection and strengthen pollution control measures.
Table 3  Background values of soil elements in Shanda road electronic information industry base, Fenghuang area Shandong electronic industry base, Shandong Province and the whole country

|       | Shanda road electronic information industry base | Shandong electronic industry base in Fenghuang District | Mean value of soil layer |
|-------|-----------------------------------------------|--------------------------------------------------------|--------------------------|
|       | Mean value of soil layer                       | Shandong Province                                      | whole country             |
| Cd    | 0.150                                         | 0.146                                                  | 0.132                    | 0.097                    |
| Cr    | 68.5                                          | 63.0                                                   | 62.0                     | 61                       |
| Cu    | 25.10                                         | 21.30                                                  | 22.6                     | 22.6                     |
| Hg    | 0.036                                         | 0.037                                                  | 0.031                    | 0.065                    |
| Ni    | 30.1                                          | 26.5                                                   | 27.1                     | 26.9                     |
| Pb    | 24.1                                          | 21.6                                                   | 23.6                     | 26                       |
| Zn    | 68.4                                          | 63.3                                                   | 63.3                     | 74.2                     |
| As    | 10.4                                          | 10.6                                                   | 8.6                      | 11.2                     |

3.5. Health risk of heavy metal ions in soil on human, animals and plants.

In the surface soil of Haier and Aucma electronic information industry processing zone in Huangdao District of Qingdao, due to the continuous production of electronic components and other production activities of electronic information processing plants such as Haier Industrial Park and Aucma Industrial Park, the pollution degree of surface soil is deepening, and the accumulation of heavy metal elements is more and more serious, which has a negative impact on the surrounding ecological environment, human and animals. The threat to the life and health of animals is also increasing. Therefore, there is a great possibility to enter the human body through three ways: direct hand mouth intake, skin contact and respiration. In this study, USEPA's health risk assessment model was used, which was proved to be effective by a large number of studies and widely used in the world. Studies show that [20-21], heavy metals mainly enter the human body through the following three ways: direct hand mouth exposure The formula for inhalation, skin contact and inhalation through respiratory system are as follows:

\[
ADD_{\text{ing}} = \frac{CS \times CF \times EF}{AT} \times \left(\frac{IngR_{\text{child}} \times ED_{\text{child}}}{BW_{\text{child}}} + \frac{IngR_{\text{adult}} \times ED_{\text{adult}}}{BW_{\text{adult}}}\right) \quad (1)
\]

\[
ADD_{\text{inh}} = \frac{CS \times EF}{PEF \times AT} \times \left(\frac{InhR_{\text{child}} \times ED_{\text{child}}}{BW_{\text{child}}} + \frac{InhR_{\text{adult}}}{BW_{\text{adult}}}\right) \quad (2)
\]

\[
ADD_{\text{derm}} = \frac{CS \times CF \times SL \times ABS \times EF}{AT} \times \left(\frac{SA_{\text{child}} \times ED_{\text{child}}}{BW_{\text{child}}} + \frac{SA_{\text{adult}} \times ED_{\text{adult}}}{BW_{\text{adult}}}\right) \quad (3)
\]

The values of model variables refer to the EPA soil health risk assessment method in the United States, the guidelines for site environmental assessment in China and the relevant research at home and abroad. In the evaluation process, the content and value of each parameter of the formula are shown in Table 4 and table 5.
Table 4  Risk parameters of heavy metal exposure in soil

| parameter | Parameter meaning                              | Parameter value | children | adult        |
|-----------|-----------------------------------------------|-----------------|----------|--------------|
| CS        | Heavy metal concentration/ (mg/kg)            | Actual measurement | 200      | 100          |
| IngR      | Oral intake rate/ (mg/kg)                     |                 | 200      | 100          |
| CF        | Conversion factor                             | $10^{-6}$       | 10^{-6}  | 10^{-6}      |
| EF        | Exposure frequency                            | 365             | 365      |              |
| ED        | Duration of exposure                          | 18              | 53       |              |
| BW        | Weight                                        | 32              | 59       |              |
| AT        | Average contact time                          | $71 \times 365$ | 71×365   |              |
| „AF       | Adsorption coefficient of soil to skin        | 2000            | 2000     |              |
| SA        | Skin contact area                             | 0.713           | 2.344    |              |
| ABS       | Skin adsorption coefficient                   | 0.001           | 0.001    |              |
| InhR      | Air intake rate                               | 8.61            | 13.77    |              |
| PEF       | Radiation factors of soil particles           | $1.36 \times 10^9$ | 1.36×10^9 |              |

Among them, the calculation formulas of non carcinogenic risk are as follows:

$$HQ = \frac{ADD}{RfD}$$ (4)

$$HI = \sum HQ_i$$ (5)

$$HI_{i,j} = \sum HI_i$$ (6)

In the above formula, HQ is the health risk of a heavy metal element to human body through one way, add is the long-term daily intake, RfD is the reference dose of long-term daily intake of non carcinogenic pollutants, which means that the heavy metal element intake per kilogram of human body per day will not cause the largest number of pollutants with adverse reactions, hi is the overall non carcinogenic risk index, when HQ and hi are less than 1.0, anthropogenic soil heavy metals may cause harm to human health. The following table lists the reference dose RFD of soil heavy metal elements Cd, Cr, Cu, Hg, Ni, Pb, Zn, As and other heavy metal elements on human health risk under different exposure routes. The formula is used to calculate the health risk HQ and overall health risk hi of soil heavy metal elements of Haier and Aucma electronic and information industry processing zone in Huangdao District of Qingdao city.
Table 5  Average daily doses for each heavy metal and exposure pathway/μg•(kg•d)$^{-1}$

| heavy metal | RfD(μg/kg·d) | Intake | skin | breathing |
|-------------|--------------|--------|------|-----------|
| Cd          | 1.00         | 1      | 0.01 |           |
| Cr          | 3            | 0.0286 | 0.06 |           |
| Cu          | 40.0         | 40     | 1.2  |           |
| Hg          | 0.3          | 0.015  | 0.086|           |
| Ni          | 20           | 20.6   | 5.40 |           |
| Pb          | 3.5          | 3.52   | 0.525|           |
| Zn          | 300          | 300    | 60   |           |
| As          | 0.3          | 0.00383| 0.3  |           |

According to table 6, it can be seen that the non carcinogenic size of heavy metals through the three exposure routes of ingestion, skin contact and respiration are as follows: the average values of Cd, Cr, Cu, Hg, Ni, Pb, Zn and As in the soils of Haier and Aucma electronic information zone in Huangdao District of Qingdao city are not significantly different from each other, and they are less than 1 in terms of content distribution. The overall pollution degree and the harm to human health of electronic information area in Huangdao District are small, but the risk value generated by hand mouth pathway is generally high, especially the pollution of Cr and As is the most serious. If the high concentration is maintained, it is likely to cause harm to human body by hand mouth pathway in electronic information area.

According to table 7, it can be seen that the average cumulative health risks of Cd, Cr, Cu, Hg, Ni, Pb, Zn and As in soils from different exposure routes are close to each other, and the differences are not obvious. The contents of Cd, Cr, Cu, Hg, Ni, Pb, Zn and As in soils from Haier and Aucma electronic information areas in Huangdao District of Qingdao city are obviously less than 1, indicating that the overall health hazards of Cd, Cr, Cu, Hg, Ni, Pb, Zn and As in soils are relatively low. However, the maximum values of Cr and As are greater than 0.1. The heavy metal elements with higher non carcinogenic risk are Cr, As, Pb, Ni and so on. Among them, the non carcinogenic health risk value of As is the largest, and it is the main source of harm to human life and health. The pollution degree of each heavy metal element in hand mouth exposure pathway is greater than that in respiratory exposure pathway. The cumulative health risk of each heavy metal element to human body is at a low level, and the maximum value is generally less than 1. Cr, Ni, Pb From the maximum content, the highest content of Cr, As and other elements is between 0.5 and 1, there is a certain risk of cancer, which should be paid great attention to. At the same time, it also shows that there are significant differences in the impact of different kinds of heavy metal elements on human health. The accumulation of the same element through different exposure ways will continue to increase the impact on human health. The order of harmfulness is As > Cr > Pb > Ni.

Table 6  HQ value of non carcinogenic exposure risk of heavy metals under different exposure routes

| project | result | Feeding | skin | breathing |
|---------|--------|---------|------|-----------|
| Cd      | minimum value | 0.00 | 0.00 | 0.00 |
|         | Maximum   | 0.00 | 0.00 | 0.00 |
|         | average value | 0.00 | 0.00 | 0.00 |
|         | minimum value | 0.03 | 0.00 | 0.00 |
| Cr      | Maximum   | 0.48 | 0.00 | 0.00 |
|         | average value | 0.07 | 0.00 | 0.00 |
|         | minimum value | 0.00 | 0.00 | 0.00 |
| Cu      | Maximum   | 0.00 | 0.00 | 0.00 |
|         | average value | 0.00 | 0.00 | 0.00 |
|         | minimum value | 0.00 | 0.00 | 0.00 |
| Hg      | Maximum   | 0.00 | 0.00 | 0.00 |
In conclusion, in the process of health risk assessment of electronic information area, we should pay attention to the possible carcinogenic risks of different human exposure routes, especially the carcinogenic risks of "hand mouth direct intake" and "respiratory system" exposure routes, especially the pollutant sources of Cr and As and the possible carcinogenic areas. Therefore, we should pay close attention to the health status of children living in the area around the electronic information area, and do a good job in health risk prevention guidance.

4. Conclusion

(1) The average content of Cr, Ni, Pb, Zn in the soil of Haier and Aucma electronic information area in Huangdao District of Qingdao city is higher than the background value of soil elements in Shandong Province, which belongs to serious pollution and has potential ecological security risk. In terms of element content, Cr is the most important ecological risk factor, which should be highly vigilant and concerned Cr > Ni > Cd > As > Zn > Hg > Cu > Pb, in which the coefficient of variation of Cr, Ni and Cd is larger, indicating that the spatial variation of Cr, Ni and Cd is significant, and the pollutants mainly come from the internal production and processing activities of Haier and Aucma electronic information zone.

(2) According to the USEPA health risk assessment model, the site risk degree of Haier and Aucma electronic information area was evaluated. The results showed that: in general, the soil heavy metal elements in Haier and Aucma electronic information area of Qingdao had less harm to human health, but Cr and As showed obvious carcinogenic risk. The carcinogenic risk of "hand mouth exposure route" is significantly higher than that of "respiratory exposure route" and "skin contact exposure route". Different exposure routes will continue to increase the risk of human health, and the carcinogenic risk of children is significantly higher than that of adults.

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