**International Journal of Environmental Monitoring and Analysis**
2021; 9(6): 193-200
http://www.sciencepublishinggroup.com/j/ijema
doi: 10.11648/j.ijema.20210906.15
ISSN: 2328-7659 (Print); ISSN: 2328-7667 (Online)

# The Heavy Metal Pollution Assessment of Topsoil in the North Bank of the Yellow River in Shandong Based on Granulation

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## To cite this article:

Han Danmei, Zhu Lidong, Ding Min, Peng Shuzhen, Zhao Qiuyue, Zhang Wei. The Heavy Metal Pollution Assessment of Topsoil in the North Bank of the Yellow River in Shandong Based on Granulation. *International Journal of Environmental Monitoring and Analysis*. Vol. 9, No. 6, 2021, pp. 193-200. doi: 10.11648/j.ijema.20210906.15

**Received**: November 30, 2021; **Accepted**: December 23, 2021; **Published**: December 29, 2021

**Abstract:** With the rapid development of the economy, environmental pollution is becoming more and more serious. As one of the important carriers of industry and agriculture, the soil is one of the key concerns of people. The research on soil heavy metal pollution is also progressing day by day, and there are abundant research results. However, there are few studies on soil heavy metal pollution based on a granular level, most of which are whole-rock samples. Therefore, we evaluated the soil heavy metal pollution in the north bank of the Yellow River in Shandong province from the perspective of grain size. We hope to fill that gap. In this study, we systematically sampled topsoil from 15 sites on the north bank of the Yellow River in Shandong province. It was divided into two components, <20μm and 20-63μm, with a total of 32 data. The contents of heavy metals in soil were determined by ICP-MS. Based on experimental data, the single factor method and comprehensive index method were used to evaluate heavy metal pollution. The results showed that heavy metal pollution conditions were related to soil particle thickness. The contents of heavy metals in fine soil <20μm were higher. Among them, the heavy metal Ni content in 15 points exceeded the safety line, and 2 areas were slightly polluted. The composite index of 16 samples exceeded the safety line, and four sites had minor contamination. The heavy metal content of the soil with 20~63μm, thick particles was generally low, and the pollution evaluation result was clean. The results verified the geochemical characteristics of heavy metals enrichment in fine soil. In addition, the potential ecological hazards of heavy metals in soil particles < 20μm and 20-63μm were evaluated. The results showed slight ecological damage, which may be related to the biological toxicity of heavy metals.

**Keywords:** Shandong Province, The North of the Yellow River, Heavy Metals, Pollution Assessment, Granulation

## 1. Introduction

With the development of industry and agriculture, heavy metal pollution in the soil environment has become a major killer restricting the sustainable development of soil and harming the ecological environment and human health [1-3]. Soil heavy metal pollution is characterized by long residual time, strong concealment, high toxicity, small migration, etc., with strong pollution [4]. Soil heavy metal pollution and hazard assessment has always been an important research field in environmental science [5]. In the past decade, the economy of the lower Yellow River region in Shandong province has developed rapidly, and various environmental problems, especially soil pollution, have become more and more serious. It is urgent to study soil heavy metals [6]. In addition, the accumulation, migration, and transformation mechanism of heavy metals, especially their transfer to animals and humans along the food chain, have gradually attracted public attention [2, 7].

At present, abundant achievements have been made in the study of heavy metal content and environmental quality conditions in the soil of the Old Yellow River Channel in Shandong province, Dagu River in Qingdao, Binhai in Shandong Province, surface sediments of the Yellow River, and eastern Shandong Province [8-10]. However, there are few studies on soil heavy metal pollution assessment based on grain size in China, most of which are whole-rock samples [11]. In particular, the assessment of soil heavy metal pollution in the Shandong area of the north of the Yellow River is blank. In addition, most studies analyze and evaluate the soil heavy metal pollution in Shandong province from the micro-level, without studying the pollution situation from a specific point of view. Therefore, this study hopes to study the heavy metal content in the topsoil of the north of the Yellow River by using the method of grain grading and carrying out a quantitative quality evaluation. Here are the key parts of the job [12].

In this paper, the contents of heavy metals in the surface soil of the north bank of Yellow River in Shandong province were determined by particle size samples (<20μm and 20-63μm), and the pollution and potential ecological harm of heavy metals were evaluated. This is not only conducive to an accurate evaluation of land pollution but also conducive to research and analysis of land pollution sources. In the process of wind transport, fine components <20μm can travel long distances in suspension up to 5KM. The crude fractions of 20~63μm were mainly proximal particles. Therefore, it is of great practical significance to conduct experimental detection and quantitative environmental quality assessment of soil heavy metals in this area [13].

# 2. Material and Method

## 2.1. Region and Sampling

The study area is located in the north of the Yellow River in central Shandong province and belongs to the North China Plain. The terrain is inclined from southwest to northeast. The climate is warm temperate semi-humid monsoon climate, with an average annual temperature of 12~15°C and annual precipitation of 600~800mm [14]. The sampling points on the north bank of the Yellow River in the study area include 15 points including Donga, Chiping, Qihe, Jiyang, Huimin, Binzhou, Qingyun, Ningjin, and Dezhou (Figure 1). The sampling time was November 2015, and the sampling method was mixed sampling within 20cm from the surface. A total of 16 mixed samples were collected from each site (except Huimin Qinghe). Specific sampling sites and planting conditions are shown in Figure 1 and Table 1.

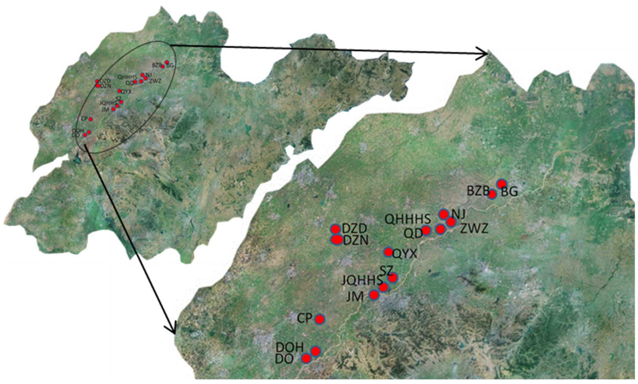


***Figure 1.*** *Illustration of sampling sites of the north of the yellow river in Shandong.*

***Table 1.*** *Sampling list of north china plain and flood plain in Shandong along the Yellow River.*

| Sampling Site | Surface Condition | Soil Status | Sample No. |
|---|---|---|---|
| Right side of G105 of Zhaozhuang Village, Dong'e County (Yangguang Road, Jingshengzhao Village) | Wheatfield | Loess like soil | DO |
| Right side of G105, north of Dong'e Xiwangji Fertilizer Plant | Cotton field | Loess like soil | DOH |
| Next to Guanshi and 309 Qiaoxi, Chiping County | Cotton field | Brownish fragmentary, lacustrine like | CP |
| North of Jiaomiao, Chipping County (turning point from Chipping to Qihe County) | Open space next to the wheat field | Loess like soil | JM |
| Auxiliary bridge of Qihe County | Yellow Riverbank | Yellow River sand | JQHHS |
| South of Sangzi Town, Qihe County (Near Dingzhuang Village, the intersection of Sangxin Road and 309) | Open space | Loess like soil | SZ |
| Next to G220, east of Qudi Toll Station, Jiyang County | Cornfield | Loess mixed | QD |
| Zhaowangzhuang Village, Jiyang | Wheatfield | Loess like soil | ZWZ |
| Yellow River Bridge, Qikou, Qinghe Town, Huimin County | Yellow Riverbank | Low terrace, fine sand | QHHHS1 |
| | | High terrace, sand | QHHHS2 |
| Beiyihezhuang Village, Binzhou City | Open space | Dark soil | BZB |
| Right side of the highway intersection of Binzhou City | Grove | Dark soil | BG |
| Cuijia Village, South External Circle, Southwest Qingyun County | Cornfield | Loess like soil | QYX |
| Next to S314, Dongrenguanzhuang Village, Ninjing County | Cornfield | Loess like soil | NJ |
| Next to S314, Dongweiwangzhuang Town, Dezhou City | Grove | Loess like soil | DZD |
| Dongnan Xiaozandian Village, Dezhou City | Wheatfield | Loess like soil | DZN |

## 2.2. Experiment Method

The granulation experiment is adopted with wet screening-sedimentation, and there are mainly 4 steps: (1) take 25g naturally dried soil samples and remove the organic matter and carbonate with 30% hydrogen peroxide ($H_2O_2$) and 1mol/L acetic acid respectively; add 10ml 0.05mol/L $(NaPO_3)_6$; then put into an ultrasonic cleaner to have an ultrasonic cleaning. (2) Remove the component of >63μm thick particles with 230 meshes (63μm). (3) Gain the component of <20μm: the fine component screened with wet screening is transferred to the sedimentation barrel, and extract its suspension according to the Stokes law. The sedimentation time of 20μm is confirmed according to the room temperature, and it should be repeated 8-10 times till the supernatant of the upper layer is transparent. Stir quickly for 3 minutes each time and make a centrifugal concentration for the extracted suspension of <20μm component to pour the supernatant and transfer the rest to a beaker for drying in a 40°C incubator. (4) Gain the component of 20~63μm: Make the centrifugal concentration for the component of 20~63μm in the sedimentation barrel to pour the supernatant and transfer the rest to a beaker for drying in a 40°C incubator.

The measurement of heavy metal content: The 32 samples of <20μm and 20~63μm gained by centrifugal concentration are ground to be under 200 meshes, and take 2g respectively. The heavy metal factor, Cr, Pb, Cu, Zn, and Ni are tested in the Dyeing Control and Resource Research Laboratory of Nanjing University with an inductively coupled plasma mass spectrometer (ICP-MS).

Based on the experimental data, the study is adopted with the single factor and comprehensive pollution index method in the method of pollution index to have a pollution assessment on the heavy metal content of soil particles of <20μm and 20~63μm; and it is adopted with the potential ecological hazards index method to have an evaluation on the potential ecological hazards of heavy metal.

# 3. The Pollution Assessment of Heavy Metal of Soil Based on Granulation

## 3.1. Assessment Methods and Assessment Standards

The pollution index method of single factor and comprehensive pollution index method is the common methods of the assessment of soil environment quality [14, 15]. For the pollution index method of a single factor, the pollution degree is lighter when the indexes are smaller. The assessment formula of the pollution index method of a single factor is as follow:

$$P_i=C_i/S_i$$

*In the formula, Pi is the single pollution index of the pollutant I; Ci is the measured data of pollutant I; Si is the assessment standard of pollutant. The soil environment is clean and safe when Pi≤0.7; and it could be called clean when 0.7<Pi≤1.0. The soil is slightly polluted when 1.0<Pi≤2.0. The soil is moderately polluted when 2.0<Pi≤3.0. The soil is seriously polluted when Pi≥3.0.*

The comprehensive pollution index is adopted with N. C. Nemerow pollution index method. N. C. Nemerow reflects a comprehensive pollution degree of various pollutants on soil environmental conditions; meanwhile, it also highlights the impact of highly-concentrated pollutants on soil environmental quality. The calculation formula is:

$$P_N=\sqrt{\frac{P^2_i+P^2 i(\max)}{2}}$$

*In the formula, P is the comprehensive pollution index of soil; Pi is the average value of all pollutants in the soil; Pi(max) is the maximal pollution index of a single pollutant in the soil. The grading standard of the method is perfectly the same as the single factor index method.*

Because the soil plantation in the study area is based on the dryland in cultivated land, and fewer groves and river lands are also drylands, so the secondary standard of the National Environmental Quality Standard for Soils (announced in 1995) is selected, which means that the standard for soil environmental quality of cultivated land (dryland) is used as the standard of the heavy metal pollution assessment (Table 2) in this time [16]. The heavy metal of soil is significantly affected by the PH value. The PH measured value in the area is higher than 7.5, so the soil quality standard with the PH >7.5.

## 3.2. The Result of Heavy Metal Content of <20μm Fine Granular Soil and Its Pollution Assessment

The result of heavy metal content, assessment standard, and pollution assessment of <20μm fine granular soil is shown in Table 2 and Figures 2 and 3. The heavy metal content of <20μm fine granular soil is higher. The average content of Cr is 86.9mg/kg; the average content of Pb is 32.3mg/kg, the average content of Cu is 37.4mg/kg; the average content of Zn is 111.8mg/kg and that of Ni is 51.0mg/kg. The coefficient of variation of all elements is smaller, and all of them are smaller than 0.12. The heavy metal content exceeds the background values of soil in Shandong Province. The bioconcentration factor of Ni (Ki) is 2.2, which has been 2.2 times of background values. The assessment standard of each element is based on the secondary standard of the National Environmental Quality Standard for Soils in dryland (GB15618-1995). The assessment result of the single factor pollution index shows that the heavy metal pollution degree of all places, except for South of Sangzi Town, Qihe Town (SZ), and Southwest Qingyun County (QYX) (whose pollution order is Ni>Cr>Zn>Cu>Pb), are Ni>Zn>Cr>Cu>Pb. The pollution of Ni in topsoil is the highest. The pollution index of Ni in the South of Sangzi Town, Qihe Town (SZ), and Southwest Qingyun County (QYX) are 1.08 and 1.23 respectively, which has exceeded the light pollution. While the Ni in other places is in the range of 0.7-0.98, which has exceeded the security cordon, so they should be widely focused. The comprehensive pollution index shows that the Auxiliary Bridge of Qihe County (JQHHS), South of Sangzi Town, Qihe Town (SZ), Southwest Qingyun County (QYX), and Zhaozhuang Village, Dong'e County (DO) have reached light pollution since their pollution indexes are 1.0<Pi≤2.0. Others have exceeded the security cordon to reach 0.78-0.97.

***Table 2.*** *Result of Heavy Metal Content of <20μm Fine Granular Soil and Pollution Assessment Result.*

| Location | Content (mg/Kg) | | | | | Single Factor Pollution Index (Pi) | | | | | Comprehensive Pollution Index ($P_N$) | Assessment Result |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cr | Pb | Cu | Zn | Ni | Cr | Pb | Cu | Zn | Ni | | |
| QH-HHS1 | 77.6 | 30.4 | 31.6 | 102.9 | 43.5 | 0.31 | 0.09 | 0.32 | 0.34 | 0.73 | 0.81 | Basically clean |
| QH-HHS2 | 94.3 | 37.2 | 39.9 | 125.3 | 52.3 | 0.38 | 0.11 | 0.40 | 0.42 | 0.87 | 0.97 | Basically clean |
| JQ-HHS | 100.3 | 38.2 | 43.1 | 143.2 | 55.6 | 0.4 | 0.11 | 0.43 | 0.48 | 0.93 | 1.04 | Light pollution |
| NJ | 91.6 | 32.9 | 38.2 | 118.8 | 51.2 | 0.37 | 0.09 | 0.38 | 0.4 | 0.85 | 0.95 | Basically clean |
| DZD | 78.4 | 29.1 | 34.9 | 104.8 | 44.3 | 0.31 | 0.08 | 0.35 | 0.35 | 0.74 | 0.82 | Basically clean |
| SZ | 110.9 | 34.2 | 40.8 | 108.3 | 64.6 | 0.44 | 0.1 | 0.41 | 0.36 | 1.08 | 1.18 | Light pollution |
| DZN | 76 | 30.2 | 33.4 | 106.6 | 42 | 0.3 | 0.09 | 0.33 | 0.36 | 0.7 | 0.78 | Basically clean |
| JM | 76.9 | 25 | 28.8 | 100.3 | 43.3 | 0.31 | 0.07 | 0.29 | 0.33 | 0.72 | 0.80 | Basically clean |
| QYX | 100.1 | 34.3 | 39.4 | 113.2 | 73.7 | 0.4 | 0.1 | 0.39 | 0.38 | 1.23 | 1.33 | Light pollution |
| ZWZ | 83 | 26.1 | 32.7 | 101.2 | 43.9 | 0.33 | 0.07 | 0.33 | 0.34 | 0.73 | 0.82 | Basically clean |
| DOH | 83.9 | 29.5 | 36 | 105.1 | 48.1 | 0.34 | 0.08 | 0.36 | 0.35 | 0.8 | 0.89 | Basically clean |
| CP | 81.5 | 34.1 | 42.1 | 110.9 | 51 | 0.33 | 0.1 | 0.42 | 0.37 | 0.85 | 0.95 | Basically clean |
| BD | 75.7 | 31.1 | 38.9 | 105.9 | 48.2 | 0.3 | 0.09 | 0.39 | 0.35 | 0.8 | 0.89 | Basically clean |
| QD | 80.5 | 31.9 | 35.9 | 102.1 | 47.2 | 0.32 | 0.09 | 0.36 | 0.34 | 0.79 | 0.87 | Basically clean |
| BZB | 82.9 | 31.3 | 34.7 | 113.2 | 48.8 | 0.33 | 0.09 | 0.35 | 0.38 | 0.81 | 0.90 | Basically clean |
| DO | 96.6 | 41.1 | 48.4 | 126.4 | 58.7 | 0.39 | 0.12 | 0.48 | 0.42 | 0.98 | 1.09 | Light pollution |
| Average Value | 86.88 | 32.30 | 37.41 | 111.77 | 51.02 | | | | | | | |
| Coefficient of Variation | 0.10 | 0.10 | 0.10 | 0.08 | 0.12 | | | | | | | |
| National Standard | 250 | 350 | 100 | 300 | 60 | | | | | | | |
| Background values in Shandong | 65.2 | 24.3 | 21.7 | 61.9 | 23.0 | | | | | | | |
| Ki | 1.33 | 1.33 | 1.72 | 1.81 | 2.22 | | | | | | | |

Note: Ki is bioconcentration factors=Measured average value/background values; National standard is the soil quality standard with PH>7.5.

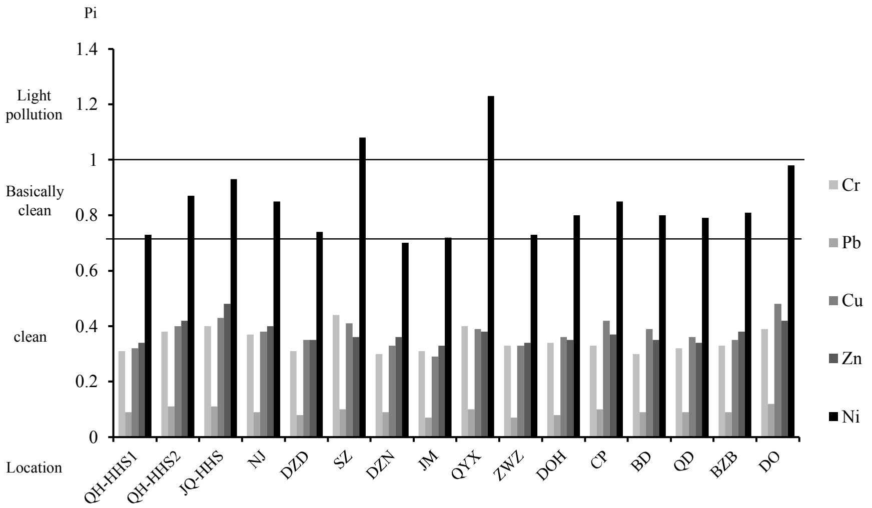


***Figure 2.*** *Single-factor pollution index situation of heavy metal of <20μm fine granular soil and its assessment result.*


***Figure 3.*** *Comprehensive pollution index situation of heavy metal of <20μm fine granular soil and its assessment result.*

### *3.3. The Result of Heavy Metal Content of 20~63μm Fine Granular Soil and Its Pollution Assessment*

The result of heavy metal content and pollution assessment of 20~63μm thick particle soil is shown in Table 3 and Figures 4 and 5. The heavy metal content of the 20~63μm is less than the fine granular soil. The average content of Cr is 53.8mg/kg; the average content of Pb is 16.1mg/kg. The average content of Cu is 13.8mg/kg; the average content of Zn is 42.8mg/kg. The average content of Ni is 21.0mg/kg. All heavy metal contents are lower than the background values of Shandong Province, and the Ki is 0.64-0.91. According to the secondary standard of the National Environmental Quality Standard for Soils (announced in 1995), the indexes of single factor pollution and comprehensive pollution show that the heavy metal of the soil in all collection places of the area is less than 0.42, which is far away from pollution degree. Hence, it could be concluded to be in a clean status. It means that heavy metal of soil has less bioconcentration in thick particle soil. What's more, the order of heavy metal pollution of thick particle soil is different from the fine granular soil, shown to be Cr>Zn>Ni>Cu>Pb, which means that the particle size effect of each pollutant is different.

***Table 3.*** *Result of the heavy metal content of 20~63μm thick particle soil and pollution assessment result.*

| Location | Content (mg/Kg) | | | | | Single Factor Pollution Index (Pi) | | | | | Comprehensive Pollution Index ($P_N$) | Assessment Result |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cr | Pb | Cu | Zn | Ni | Cr | Pb | Cu | Zn | Ni | | |
| QH-HHS1 | 50.6 | 15.79 | 13.1 | 42.29 | 20.34 | 0.20 | 0.05 | 0.13 | 0.14 | 0.10 | 0.24 | Clean |
| QH-HHS2 | 55.18 | 16.5 | 14.57 | 43.48 | 19.87 | 0.22 | 0.05 | 0.15 | 0.14 | 0.10 | 0.26 | Clean |
| JQ-HHS | 77.56 | 17.09 | 15.23 | 42.96 | 19.91 | 0.31 | 0.05 | 0.15 | 0.14 | 0.10 | 0.34 | Clean |
| NJ | 43.86 | 14.78 | 11.21 | 33.8 | 15.42 | 0.18 | 0.04 | 0.11 | 0.11 | 0.08 | 0.20 | Clean |
| DZD | 53.29 | 15.24 | 11.94 | 35.16 | 21.26 | 0.21 | 0.04 | 0.12 | 0.12 | 0.11 | 0.24 | Clean |
| SZ | 52.52 | 15.38 | 13.78 | 39.46 | 19.47 | 0.21 | 0.04 | 0.14 | 0.13 | 0.10 | 0.24 | Clean |
| DZN | 63.84 | 15.48 | 12.6 | 40.98 | 29.71 | 0.26 | 0.04 | 0.13 | 0.14 | 0.15 | 0.29 | Clean |
| JM | 41 | 13.04 | 7.32 | 28.02 | 13.86 | 0.16 | 0.04 | 0.07 | 0.09 | 0.07 | 0.19 | Clean |
| QYX | 51.62 | 17.43 | 14.65 | 42.71 | 20.36 | 0.21 | 0.05 | 0.15 | 0.14 | 0.10 | 0.24 | Clean |
| ZWZ | 59.54 | 14.79 | 12.36 | 40.31 | 20.95 | 0.24 | 0.04 | 0.12 | 0.13 | 0.10 | 0.27 | Clean |
| DOH | 45.05 | 13.62 | 10.05 | 33.34 | 15.98 | 0.18 | 0.04 | 0.10 | 0.11 | 0.08 | 0.21 | Clean |
| CP | 69.54 | 23.88 | 33.65 | 94.12 | 44.47 | 0.28 | 0.07 | 0.34 | 0.31 | 0.22 | 0.42 | Clean |
| BD | 48.14 | 16.33 | 11.7 | 36.6 | 16.48 | 0.19 | 0.05 | 0.12 | 0.12 | 0.08 | 0.22 | Clean |
| QD | 50.54 | 15.47 | 12.35 | 42.39 | 16.8 | 0.20 | 0.04 | 0.12 | 0.14 | 0.08 | 0.23 | Clean |
| BZB | 41.35 | 15.1 | 10.76 | 33.06 | 14.08 | 0.17 | 0.04 | 0.11 | 0.11 | 0.07 | 0.19 | Clean |
| DO | 57.04 | 17.73 | 16.03 | 56.82 | 26.24 | 0.23 | 0.05 | 0.16 | 0.19 | 0.13 | 0.27 | Clean |
| Average Value | 53.79 | 16.10 | 13.83 | 42.84 | 20.95 | | | | | | | |
| Coefficient of Variation | 0.14 | 0.10 | 0.23 | 0.19 | 0.23 | | | | | | | |
| National Standard | 250 | 350 | 100 | 300 | 60 | | | | | | | |
| Background values in Shandong | 65.2 | 24.3 | 21.7 | 61.9 | 23.0 | | | | | | | |
| Ki | 0.83 | 0.66 | 0.64 | 0.69 | 0.91 | | | | | | | |

Note: Ki is bioconcentration factors=Measured average value/background values; National standard is the soil quality standard with PH>7.5.

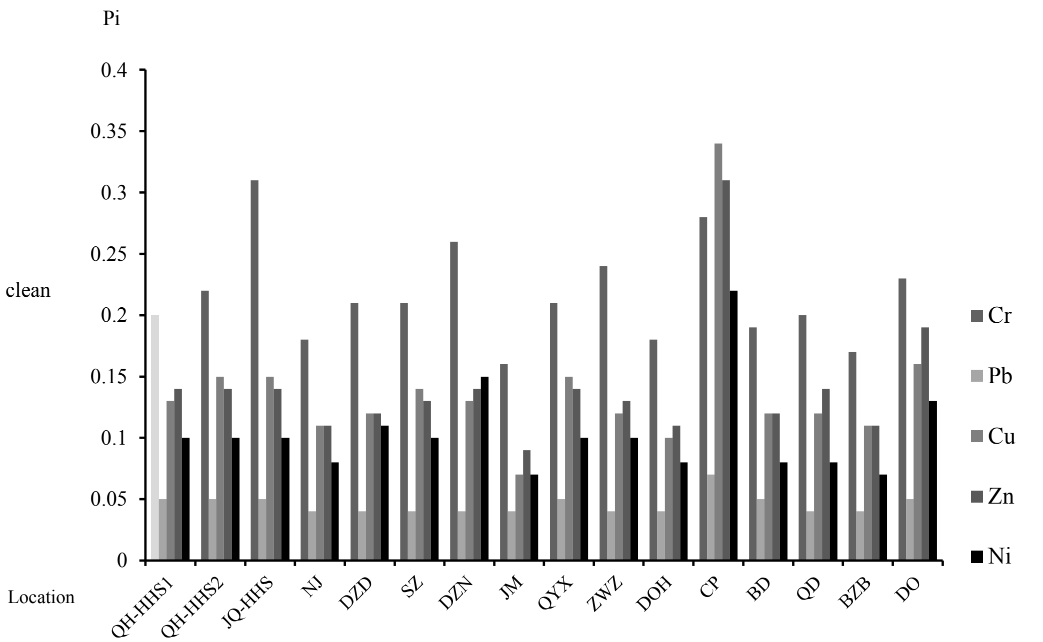


***Figure 4.*** *Single Factor Pollution Index Situation of Heavy Metal of 20~63μm Thick Particle Soil and Its Assessment Result.*

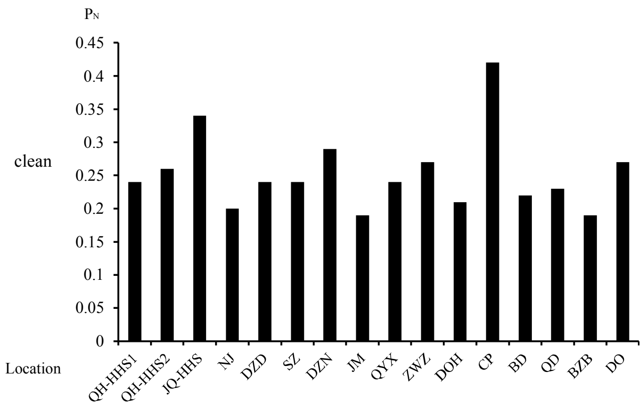


***Figure 5.*** *Comprehensive Pollution Index Situation of Heavy Metal of 20~63μm Thick Particle Soil and Its Assessment Result.*

# 4. Assessment of Potential Ecological Risk

### *4.1. Assessment Method and Assessment Standard*

The paper is adopted with the potential ecological hazards index (Table 4) suggested by Sweden Hakanson [16] to have an ecological hazards assessment. This method would not only think of the ecological effect and environmental effect of heavy metal, but it also considers the environmental toxicological characteristics, which means to assess according to the toxicity levels of various heavy metals and sensitivity of organisms to heavy metal pollution. The toxicity level of heavy metals proposed by this method is Pb=Cu>Cr=Ni> Zn. After the range treatment of toxicity response coefficient, it can be determined as Pb = Cu = 5, Cr = Ni = 2, Zn = 1. The calculation formula of the ecological hazards index is:

$$Cif=Cdi/Cir$$

$$Eir=TirCif$$

$$RI=\Sigma Eir$$

*In the formula, Cif is a pollution index of single metal; Cdi is the measured value of the north bank of the Yellow River; Cir is the heavy metal background reference value of Shandong; Tir is the responding factor of biological toxicity of different metals; Eir is the potential ecological hazards factor of single metal; RI is the potential ecological hazards index of multiple metals.*

To reflect the feature of the area, the heavy metal background values of Shandong are selected as a benchmark (see the following Tables 2 and 3) [17-20].

***Table 4.*** *Division of Pollution Degree of Potential Ecological Hazards Index Suggested by Hakanson.*

| $E^i_r$ | Pollution Degree | RI | Hazards Level |
|---|---|---|---|
| <40 | Slight | <150 | Slight |
| 40~80 | Moderate | 150~300 | Moderate |
| 80~160 | Strong | 300~600 | Strong |
| 160~320 | Very strong | ≥600 | Very strong |
| ≥320 | Extremely strong | | |

***Table 5.*** *Assessment Result of Potential Ecological Hazards of Heavy Metal in Topsoil in the North Bank of the Yellow River in Shandong.*

| Potential Ecological Hazards Coefficient | | | | | | | | | | | | | Assessment Result |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <20μm | | | | | | 20~63μm | | | | | | |
| | $E^i_r$ | | | | | RI | $E^i r$ | | | | | RI | |
| | Cr | Pb | Cu | Zn | Ni | | Cr | Pb | Cu | Zn | Ni | | |
| QHHHS1 | 2.38 | 6.24 | 7.28 | 1.66 | 3.79 | 21.35 | 1.55 | 3.25 | 3.02 | 0.68 | 1.77 | 10.27 | |
| QH-HHS2 | 2.89 | 7.66 | 9.19 | 2.02 | 4.54 | 26.31 | 1.69 | 3.40 | 3.36 | 0.70 | 1.73 | 10.88 | |
| JQ-HHS | 3.08 | 7.86 | 9.93 | 2.31 | 4.84 | 28.02 | 2.38 | 3.52 | 3.51 | 0.69 | 1.73 | 11.83 | |
| NJ | 2.81 | 6.77 | 8.79 | 1.92 | 4.45 | 24.75 | 1.35 | 3.04 | 2.58 | 0.55 | 1.34 | 8.86 | |
| DZD | 2.41 | 5.99 | 8.05 | 1.69 | 3.85 | 21.98 | 1.63 | 3.14 | 2.75 | 0.57 | 1.85 | 9.94 | |
| SZ | 3.40 | 7.04 | 9.41 | 1.75 | 5.62 | 27.22 | 1.61 | 3.16 | 3.18 | 0.64 | 1.69 | 10.28 | |
| DZN | 2.33 | 6.22 | 7.70 | 1.72 | 3.65 | 21.62 | 1.96 | 3.19 | 2.90 | 0.66 | 2.58 | 11.29 | |
| JM | 2.36 | 5.15 | 6.63 | 1.62 | 3.77 | 19.52 | 1.26 | 2.68 | 1.69 | 0.45 | 1.21 | 7.29 | Slight |
| QYX | 3.07 | 7.05 | 9.07 | 1.83 | 6.40 | 27.42 | 1.58 | 3.59 | 3.38 | 0.69 | 1.77 | 11.01 | Ecological |
| ZWZ | 2.55 | 5.38 | 7.53 | 1.63 | 3.82 | 20.91 | 1.83 | 3.04 | 2.85 | 0.65 | 1.82 | 10.19 | Hazards |
| DOH | 2.57 | 6.07 | 8.29 | 1.70 | 4.18 | 22.82 | 1.38 | 2.80 | 2.32 | 0.54 | 1.39 | 8.43 | |
| CP | 2.50 | 7.02 | 9.69 | 1.79 | 4.44 | 25.43 | 2.13 | 4.91 | 7.75 | 1.52 | 3.87 | 20.19 | |
| BD | 2.32 | 6.40 | 8.95 | 1.71 | 4.19 | 23.57 | 1.48 | 3.36 | 2.70 | 0.59 | 1.43 | 9.56 | |
| QD | 2.47 | 6.57 | 8.26 | 1.65 | 4.10 | 23.05 | 1.55 | 3.18 | 2.85 | 0.68 | 1.46 | 9.72 | |
| BZB | 2.54 | 6.45 | 8.00 | 1.83 | 4.24 | 23.07 | 1.27 | 3.11 | 2.48 | 0.53 | 1.22 | 8.61 | |
| DO | 2.96 | 8.46 | 11.16 | 2.04 | 5.11 | 29.73 | 1.75 | 3.65 | 3.69 | 0.92 | 2.28 | 12.29 | |
| Average | 2.67 | 6.65 | 8.62 | 1.80 | 4.44 | 24.17 | 1.65 | 3.31 | 3.19 | 0.69 | 1.82 | 10.67 | |

### *4.2. Assessment Result of Potential Ecological Hazards in Soil*

The assessment of potential environmental hazards in the soil of the area is shown in table 5. For the soil component of <20μm, the potential ecological hazards index of each heavy metal is Cu>Pb>Ni> Zn>Cr; and all of them are less than 8.62. And all of them are far less than 40. The ecological hazards in the soil of 15 places are slight ecological hazards. The average value of the potential ecological hazards index of multiple metals is 24.17, which is far less than 150. It also shows that the environmental hazards in the soil of the area are slight ecological hazards. Given the soil component of 20~63μm, the potential ecological hazards index of each heavy metal and the average value of potential ecological hazards index of multiple metals is smaller, which means the potential ecological hazards are extremely low. In a word, the assessment result of ecological hazards of heavy metal in the soil in the components of <20μm and 20~63μm are in slight ecological hazards, but we also still need to keep alert.

# 5. Conclusion

The heavy metal pollution of topsoil in the north bank of the Yellow River in Shandong is deeply affected by the thickness of soil particles. The heavy metal content of <20μm fine granular soil is higher, and the pollution order of the single factor is Ni>Cr>Zn>Cu>Pb. Ni has exceeded the security cordon, and even 2 places reached the light pollution. Among them, the Ni in the soil would prevent the growth and development of crops and produce some poisons to reduce the yield of crops when it is excessive; besides, it would enter animals and human bodies through the complex food chain and food web and cause harm through bioaccumulation amplification effect [21-23]. The comprehensive indexes of 15 places exceed the security cordon, and 4 of them are in light pollution, which is related to the fact that heavy metals are easily adsorbed by clay minerals and organic colloids. As for the high content of Ni and serious pollution, it should be related to the sewage discharge from surrounding industrial and mining enterprises, and attention should be paid to human activities such as fertilization and irrigation [24]. The more specific reasons would be deeply investigated and tested. The heavy metal contents of 20~63μm thick particle soil are lower than the fine granular soil, and the pollution assessment results are clean. Hence, it proves a geochemical characteristic that heavy metals are apt to be concentrated and accumulated in the fine granular soil, and it could provide a reference for pollution governance and ecology restoration [25]. Because of components of <20μm and 20~63μm, the assessment result of potential ecological hazards of heavy metal is the slight ecological hazards, which is consistent with the pollution assessment result of the single factor method and the comprehensive index method that some places reach the heavy metal pollution. The former mainly think about the heavy metal contents; while the latter would consider the biological toxicity besides contents [26-30].

# 6. Recommendations

In this study, we evaluated the heavy metal pollution in the surface soil of the north bank of the Yellow River in Shandong province. The results also indicate that the problem of heavy metals in soil in this region cannot be ignored. Therefore, we suggest that relevant departments pay attention to this problem and carry out proper treatment and recovery of heavy metal pollution. In addition, in the following study, we hope to conduct large-scale sampling and testing from a wider range, to achieve better research results. In addition, we can also adopt more testing and evaluation methods to study soil heavy metal pollution.

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