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USA CODEN: JASRHB

Journal of Applied Science And Research, 2021, 9 (5):8-19

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The Pollution Status and Evaluation of Heavy Metals in chemical mixed soil in middle Jiangsu

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ABSTRACT

With the development of economy and industry, chemical plants are playing an increasingly important role. With this, these companies produce a large amount of waste and waste water in the production process. The illegal stacking of these chemical wastes has caused soil damage. Extremely serious pollution has a huge impact on the environment. In this study, a chemical company buried chemical miscellaneous fills near a village. Through data collection and a large number of on-site sampling, the current distribution of eight heavy metal elements in chemical miscellaneous fills was analyzed, and the single-factor pollution index method was adopted respectively. The Nemeiro Pollution Index Method and the Potential Ecological Risk Index Method evaluate the current status of soil pollution in the region, and clarify the impact of chemical miscellaneous fills on the surrounding environment. As, Hg, Cu, Zn, and Cd in chemical miscellaneous fill areas are all polluted. According to the single factor index and Nemeiro index, the main pollutants are Zn and Cd, and in the samples contaminated by Cd, more than 50% The rating results of the points are severe pollution. The main pollution points are 0.5~2.5m depth of A4 and A5 and 0.5m depth of A6. The remaining points are basically severe pollution; according to the potential ecological hazard index method, only Hg and The two elements of Cd reach the level of medium ecological hazard and above, and the points above the medium ecological hazard in the study area are mainly concentrated in two points A4 and A5.

Keywords : Soil , Heavy , Metal Pollution Environmental Quality Assessment

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INTRODUCTION

Since the 21st century, China's economy has developed rapidly, especially the industrial level, which has greatly improved. However, more and more high-polluting enterprises, such as chemical plants, electroplating plants, and mines, have produced a large amount of heavy metal pollution. The discharged pollutants will inevitably leak into the surrounding environment, causing soil and groundwater to be damaged and affected. With the development of urbanization, many cities have carried out structural adjustments, and some high-polluting enterprises have been rectified and shut down. After these companies shut down or moved away, they also left a lot of pollution, especially heavy metal pollution in the soil, which caused great troubles in the later land reuse and became a common environmental pollution problem in the world[1-4] After the soil is contaminated by heavy metals, it will be transmitted through various media such as wind and rain, and will gradually accumulate, which will seriously affect the growth and reproduction of plants, crops and animals, and bring many risks to humans[5-6]. Due to the Love Canal incident[7], the West began to pay attention to the problem of site pollution. The United Kingdom and the United States were the first countries in the world to regard the control of contaminated sites as government work. Soil heavy metal pollution can damage the function of the soil, change the physical and chemical properties of the soil, and disrupt the normal growth and development of crops[8]. About 290,000 sites in the United States are polluted[9]. "The incident triggered concerns about soil pollution, and Congress passed the "Soil Protection Act." The de-industrialization of the United Kingdom in the 1980s revealed that many lands in the United Kingdom were contaminated. After there was not enough land, it became urgent to repair the contaminated land. The "Land Registration Bill" stated that there were more than 100,000 contaminated sites in the United Kingdom. Repair these lands to seek urban development[10]. Han W et al. conducted sampling and analysis on the largest e-waste recycling park in North China and its nearby soil, and found that copper, antimony, cadmium, zinc, cobalt and other elements in the park soil were heavily enriched, and the e-waste recycling park was the main source of pollution. Heavy metal lead is a developmental neurotoxin. Research by Reuben A et al. [11] found that lead pollution in childhood has a greater impact on growth and development. Every 5 g/dL increase in blood lead will reduce socioeconomic status by 1.79 units. .GulsonBL[12]et al. used European women aged 18 to 35 as a research object and found that lead was transferred to the fetus during pregnancy, causing lead poisoning of the fetus to affect its neurobehavior. There are many ways for heavy metals to enter the human body. Lead and cadmium can cause arthralgia, osteomalacia and excessive cadmium in the urine. Excessive chromium can cause liver damage. The accumulation of heavy metals in the body can cause carcinogenesis, teratogenesis, and mutagenesis, and harm the human body. Health [13-15]. Soil pollution prevention and control has become the focus of research urgently. The rapid economic development in the Yangtze River Delta region, the sharp contradictions between the social economy and the environment, improper disposal of urban domestic waste, low resource utilization, and abuse of pesticides and fertilizers have exacerbated the problem of heavy metal pollution in the soil. Therefore, it is very important to explore the heavy metal pollution in this chemical miscellaneous fill area and its impact on the surrounding environment. It is very important to analyze the distribution characteristics of heavy metals in this area, evaluate the pollution degree of heavy metals, and study the migration and diffusion of pollutants in order to study the Comprehensive management and improvement of regional environmental soil provide certain data and theoretical support.

MATERIALS AND METHODS

1.1 An overview of the research area

The chemical miscellaneous fill area is beside the DanjinLicao River in a certain village of Danyang. The plot is about 768m long and 20m wide. It is a chemical plant miscellaneous fill. The landfill depth is about 0.5~3m, and the landfill thickness is 3m. It took about 3 years and was polluted by a variety of heavy metals. The miscellaneous fill site is now used by nearby villagers as crops. The main plants are greens, peanuts, and rape. The site is located in the alternate zone of the Ningzhen hills and the Taihu plain. The terrain is flat, the surrounding area is open and there are few shelters, and the soil is sandy clay. The four seasons are distinct, the precipitation is sufficient, the average temperature is 15 degrees Celsius, the annual average wind speed is 2.9m/s, the dominant wind direction in summer is ESW, and the dominant wind direction in winter is NENW. The main plants in the site are weeds, etc., without forest trees. Birds are mainly sparrows and magpies. No other large wild animals.

Figure1 Site map of chemical mixed fill soil

1.2 Collection and measurement of samples

The chemical miscellaneous fill area is beside the DanjinLicao River in a certain village in Zhenjiang. The plot is about 768m long and 20m wide. It is the original chemical miscellaneous fill of a certain group. The landfill depth is about 0.5~3m, and the landfill thickness is 3m. A variety of heavy metals are polluted, and the miscellaneous fill soil is now used by nearby villagers as crops. The main plants are greens, peanuts, and rape.

Miscellaneous fill areas are arranged in accordance with the soil layout requirements in the "Technical Guidelines for Site Environmental Monitoring (HJ25.2-2014)". According to the collected relevant data, the main landfill area of the plot shall be in accordance with the requirements of the detailed investigation of the site environment: a single monitoring site The area of the block does not exceed 1600m2, and the sampling points are arranged. In other areas, a random arrangement is adopted. When sampling for each monitoring plot, the sampling depth deducts the thickness of the non-soil hardened layer on the surface. The sampling interval for deep soil within 3m is 0.5m, and the sampling interval for 3m-6m is 1m. In accordance with the above-mentioned sampling point layout principle, combined with the actual situation of the site, this site environmental survey has set up a total of 13 soil sampling points with a sampling depth of 3m, and the sampling interval for deep soil within 3m is 0.5m. A total of 78 soil samples need to be collected.The sampling points are shown in Figure 2.

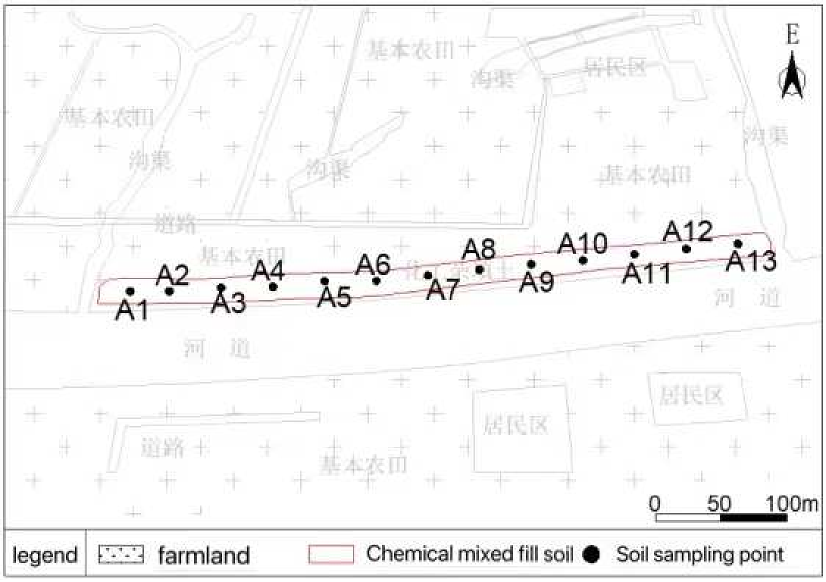

Figure 2 sampling points of chemical mixed fill soil

After mixing the collected soil sample, it is divided into about 100g by quarter method. After the reduced soil sample is naturally air-dried, foreign matter such as stones, animal and plant residues in the soil sample is removed, and the soil sample is ground and pressed, passed through a 2mm nylon sieve, and mixed. Use an agate mortar to grind the soil sample that has passed through a 2mm nylon sieve until it passes through a 100-mesh nylon sieve. After mixing, place it in a polyethylene bag and mark it for later use.

The method for detecting heavy metals in soil is soil pH: "Determination of pH value in soil" (NY/T 1377-2007); Copper and zinc: "Soil quality determination of copper and zinc by flame atomic absorption spectrophotometry" (GB/T 17138- 1997); Chromium: "Determination of Total Chromium in Soil by Flame Atomic Absorption Spectrophotometry" (HJ 491-2009); Mercury: "Determination of Total Mercury in Soil Mass, Total Arsenic and Total Lead by Atomic Fluorescence Method Part 1: Determination of Total Mercury in Soil Determination (GB/T 22105.1-2008); Lead and Cadmium: "Soil Quality Determination of Lead and Cadmium Graphite Furnace Flame Atomic Absorption Spectrophotometry" (GB/T 17141-1997); Nickel: "Soil Quality Determination of Nickel Flame Atomic Absorption Spectrophotometry (GB/T 17139-1997); Arsenic: Determination of Soil Mass Total Mercury, Total Arsenic and Total Lead Atomic Fluorescence Method Part 2: Determination of Total Arsenic in Soil (GB/T 22105.2-2008).

1.3 Data processing evaluation method

1.3.1 Single factor index method

The single factor index method is currently a common method for evaluating heavy metal pollution in China, and it is often used to evaluate heavy metal pollution in soil, air and water.

Calculated as follows:

$$Pi = Ci / Si \qquad (1)$$

Pi is the pollutant single factor index;Ciis the measured concentration of the pollutant, mg/kg; Si is the soil environmental quality standard limit of the pollutant, mg/kg; Pi>1 indicates the degree of soil pollution or the accumulation of pollutants is heavy; Pi<1 indicates that the soil is not polluted or the degree of pollution is lighter; the larger the value of Pi, the more serious the pollution.

The single factor index method is convenient to use and is the basis for other environmental quality indexes, environmental quality classifications and comprehensive evaluations. Appropriate evaluation standards are selected, generally the background value of the study area, which can reflect the degree of artificial pollution of the soil and can also be judged Out of the environmental pollution caused by other ways in the environment. However, the single-factor index method is only applicable to the evaluation of single-factor pollution in a specific area, and the soil environmental system is extremely complex, and environmental pollution is often formed by the combined pollution of multiple pollution factors, so it is not applicable when it is necessary to comprehensively reflect the status of soil pollution. . The shortcomings of the single-factor index method are also very obvious. The evaluation parameters are not related to each other and can only reflect the pollution status of the analyzed soil samples, but cannot fully reflect the comprehensive situation of soil environmental element pollution. The pollution degree evaluation grade is shown in Table1.1.

Table1.1 Evaluation and classification standard of single factor pollution index

grade	Pollution index	Pollution degree
1	$Pi \leq 1$	no pollution
2	$1 < Pi \leq 2$	slight pollution
3	$2 < Pi \leq 3$	light pollution
4	$3 < Pi \leq 5$	Moderate pollution
5	$Pi > 5$	Severe pollution

1.3.2 Nemeiro Index Method (Comprehensive Pollution Index Method)

Nemeiro Pollution Index Method is a commonly used evaluation method for analyzing site pollution. This method integrates the single factor index method to calculate the comprehensive pollution status of multiple heavy metal elements in the site, and can more comprehensively understand the pollution situation of the site. In addition, this method incorporates the weight values of different heavy metal elements into the calculation, takes into account the practical problem of the different impacts of different heavy metal elements on the soil environment, and overcomes the shortcomings of the average value method in sharing various pollutants.

Calculated as follows:

$$P_i = \frac{C_i}{S_i}$$

$$P = \sqrt{\frac{P_{iAVG}^2 + P_{iMAX}^2}{2}} \quad (2)$$

$$P_{iAVG} = \frac{1}{n}\sum P_i \quad (3)$$

P_i is the pollution index of element i; C_i is the measured value of element i; S_i is the evaluation standard of element i selected according to the needs; P_{iMAX} is the largest single pollution index among all elements, and P_{iAVG} is the average value of all element pollution indexes.The evaluation grade of heavy metals in soil by Nemero index method is shown in Table 1.2.

Table1.2 Evaluation and classification standard of nemerow soil pollution index

grade	nemerow soil pollution index	Evaluation grade
1	P≤0.7	Clean (safe)
2	0.7<P≤1.0	Still clean (cordline)
3	1.0<P≤2.0	Light pollution
4	2.0<P≤3.0	Moderately polluted

5	P>3.0	Heavy pollution

1.3.3 Soil pollution evaluation standard value

The research area of this survey is an agricultural area beside a river in a certain village in Zhenjiang. Therefore, the agricultural land soil pollution risk screening value specified in the "Soil Environmental Quality Standard" GB15618-2018 was selected as the soil pollution evaluation standard value in the study area, and the agricultural land soil pollution risk screening value specified in the "Soil Environmental Quality Standard" GB15618-2018 As shown in Table 1.3:

Table1.3 Comparison of screening values of agricultural soil pollutants

		Item	PH＞7.5（ mg/kg）
1	Cd	vegetable field	≤0.60
2	Hg	vegetable field	≤3.4
3	As	vegetable field	≤25
4	Pb	vegetable field	≤170
5	Cr	dry land, vegetable field	≤250
6	Cu	Paddy field, dry land, vegetable field	≤100
7	Zn	-	≤300
8	Ni	-	≤190

RESULT AND DISCUSSION

Single factor index method

The single factor index method is used to evaluate the pollution degree of chemical miscellaneous fill soil, and the pollution index results of different elements at each sampling point can be obtained. The results are shown in Table2.1.

From the point of view of various heavy metals, there are pollutions of As, Hg, Cu, Zn, and Cd in the soil. The pollution range is Zn>Cd>Cu>Hg>As, and the pollution of heavy metals Zn and Cd has the widest distribution range; among them, Cd pollution The degree of pollution is severe. The points with Zn pollution account for 46% of the total survey points, the deepest part of the pollution reaches 3.0m, and the highest pollution index is 4.78; the points with Cd pollution account for 46% of the total survey points, and the pollution is the deepest. The highest pollution index is 11.28; Cu pollution sites account for 31% of the total survey sites, the deepest pollution sites reach 3.0m, and the highest pollution index is 3.55; Hg pollution sites account for the total survey sites The deepest part of pollution is 2.5m, and the pollution index is 2.4; the site is least affected by heavy metal As. Only the three points A4, A5, and A6 are polluted by As, and there is no serious pollution.

From the point of view of the polluted points: heavy metal pollution exists in the 6 points in the table, accounting for 46% of the total survey points. Among them, A4 and A5 are polluted by 5 heavy metals such as As, Hg, Cu, Zn and Cd, with the most types of pollutants. , The pollution is the heaviest; points A3 and A6 are polluted by four heavy metals, As, Cu, Zn and Cd, and A2 is polluted by three heavy metals, Hg, Zn and Cd; and A10 is polluted only by two heavy metals, Zn and Cd. From the point of view, the pollution of miscellaneous fill is relatively concentrated, mainly at points A2, A3, A4 and A5, in the middle of the chemical miscellaneous fill area.

Judging from the depth of soil sampling, the pollution at A4 and A5 is the most serious. Among them, Zn and Cd are polluted by heavy metals at 0.5-2.5m. The maximum pollution of Cu, Zn and Cd is at a depth of 2m at A5. The maximum pollution of heavy metal As is at a depth of 2.5m at point A4, and the maximum pollution of heavy metal Hg is at a depth of 2.5m at point A5. These five heavy metal pollutions exist at 0.5-2.5m, and except for the depth of 3m, each There are heavy pollution points in the depth. This shows that the surface and middle soils are more polluted, and the deep soils are also polluted. Compared with the surface and middle soils, the deep soils are less polluted.

Table2.1 Single factor pollution index calculation results at different depths at each point

point number	Sampling depth(m)	As	Hg	Cu	Zn	Cd	Rating result
A2-1	0.5	-	1.57	-	1.14	1.13	Hg、Zn、Cdslight pollution
A2-3	1.5	-	-	-	1.81	-	Znslight pollution
A3-1	0.5	-	2.15	-	1.28	-	Znslight pollution；Hg light pollution
A3-2	1	-	1.91	-	-	-	Hg slight pollution
A3-4	2	-	1.56	-	-	-	Hg slight pollution
A3-6	3	-	-	1.4	-	1.18	Cu、Cd slight pollution
A4-1	0.5	2.48	-	1.45	3.07	6.85	Cu slight pollution；As light pollution ZnModerately polluted；Cd heavy pollution
A4-2	1	-	1.21	1.39	2.64	6.48	Hg、Cu slight pollution Zn light pollution；Cd heavy pollution
A4-3	1.5	2.96	-	1.54	2.49	6.02	Cu slight pollution；As、Zn light pollution Cd heavy pollution
A4-4	2	-	-	-	1.19	2.53	Zn slight pollution；Cd light pollution
A4-5	2.5	3.51	-	1.67	2.54	5.98	Cu slight pollution；Zn light pollution AsModerately polluted；Cd heavy pollution
A5-1	0.5	2.81	1.27	3.32	4	9.8	Hg slight pollution；As light pollution Cu、ZnModerately polluted；Cd heavy

							pollution
A5-2	1	2.96	-	3.22	3.84	8.82	As light pollution；Cu、ZnModerately polluted Cd heavy pollution
A5-3	1.5	2.64	1.17	3.47	4.13	9.32	Hg slight pollution；As light pollution；Cu、ZnModerately polluted；Cd heavy pollution
A5-4	2	2.84	1.86	3.55	4.78	11.28	Hg slight pollution；As light pollution；Cu、ZnModerately polluted；Cd heavy pollution
A5-5	2.5	2.16	2.4	2.97	4.17	8.75	As、Hg、Cu light pollution；ZnModerately polluted；Cd heavy pollution
A6-1	0.5	1.77	-	1.51	3.27	4.5	As、Cu slight pollution；Zn、CdModerately polluted
A6-4	2	-	-	-	1.49	2.2	Zn slight pollution；Cd light pollution
A10-1	0.5	-	-	-	1.01	-	Zn slight pollution
A10-3	1.5	-	-	-	1.04	-	Zn slight pollution
A10-4	2	-	-	-	-	1.33	Cd slight pollution
A10-5	2.5	-	-	-	2.02	-	Zn light pollution
A10-6	3	-	-	-	1.96	-	Zn slight pollution

Note: "-" means that the pollution index is less than or equal to 1, that is, the index does not exceed the standard.

Nemeiro Index Method

The Nemerow index method is used to evaluate the pollution degree of chemical miscellaneous fills, and the comprehensive pollution index results at different depths of each sampling point can be obtained. The results are shown in Table 2.2.

Table2.2 Nemerow pollution index evaluation of heavy metals in each depth of soil

point number	Sampling depth(m)	Nemeiro Index	Evaluation
A1-1	0.5	0.33	Clean (safe)
A1-2	1	0.32	Clean (safe)
A1-3	1.5	0.38	Clean (safe)
A1-4	2	0.39	Clean (safe)

A1-5	2.5	0.2	Clean (safe)
A1-6	3	0.22	Clean (safe)
A2-1	0.5	1.19	Light pollution
A2-2	1	0.66	Clean (safe)
A2-3	1.5	1.33	Light pollution
A2-4	2	0.25	Clean (safe)
A2-5	2.5	0.3	Clean (safe)
A2-6	3	0.33	Clean (safe)
A3-1	0.5	1.58	Light pollution
A3-2	1	1.39	Light pollution
A3-3	1.5	0.26	Clean (safe)
A3-4	2	1.15	Light pollution
A3-5	2.5	0.37	Clean (safe)
A3-6	3	1.05	Light pollution
A4-1	0.5	5.03	Heavy pollution
A4-2	1	4.72	Heavy pollution
A4-3	1.5	4.43	Heavy pollution
A4-4	2	1.87	Light pollution
A4-5	2.5	4.42	Heavy pollution
A4-6	3	0.22	Clean (safe)
A5-1	0.5	7.19	Heavy pollution
A5-2	1	6.49	Heavy pollution
A5-3	1.5	6.85	Heavy pollution
A5-4	2	8.28	Heavy pollution
A5-5	2.5	6.46	Heavy pollution
A5-6	3	0.71	Still clean (cordline)
A6-1	0.5	3.35	Heavy pollution
A6-2	1	0.27	Clean (safe)
A6-3	1.5	0.25	Clean (safe)
A6-4	2	1.63	Light pollution
A6-5	2.5	0.22	Clean (safe)
A6-6	3	0.66	Clean (safe)
A7-1	0.5	0.19	Clean (safe)
A7-2	1	0.14	Clean (safe)
A7-3	1.5	0.16	Clean (safe)
A7-4	2	0.15	Clean (safe)
A7-5	2.5	0.16	Clean (safe)
A7-6	3	0.26	Clean (safe)
A8-1	0.5	0.17	Clean (safe)
A8-2	1	0.17	Clean (safe)
A8-3	1.5	0.15	Clean (safe)
A8-4	2	0.32	Clean (safe)
A8-5	2.5	0.14	Clean (safe)

A8-6	3	0.14	Clean (safe)
A9-1	0.5	0.15	Clean (safe)
A9-2	1	0.14	Clean (safe)
A9-3	1.5	0.15	Clean (safe)
A9-4	2	0.15	Clean (safe)
A9-5	2.5	0.15	Clean (safe)
A9-6	3	0.14	Clean (safe)
A10-1	0.5	0.75	Still clean (cordline)
A10-2	1	0.64	Clean (safe)
A10-3	1.5	0.77	Still clean (cordline)
A10-4	2	0.99	Still clean (cordline)
A10-5	2.5	1.48	Light pollution
A10-6	3	1.44	Light pollution
A11-1	0.5	0.22	Clean (safe)
A11-2	1	0.2	Clean (safe)
A11-3	1.5	0.21	Clean (safe)
A11-4	2	0.2	Clean (safe)
A11-5	2.5	0.18	Clean (safe)
A11-6	3	0.22	Clean (safe)
A12-1	0.5	0.23	Clean (safe)
A12-2	1	0.17	Clean (safe)
A12-3	1.5	0.19	Clean (safe)
A12-4	2	0.22	Clean (safe)
A12-5	2.5	0.17	Clean (safe)
A12-6	3	0.16	Clean (safe)
A13-1	0.5	0.19	Clean (safe)
A13-2	1	0.21	Clean (safe)
A13-3	1.5	0.19	Clean (safe)
A13-4	2	0.19	Clean (safe)
A13-5	2.5	0.14	Clean (safe)
A13-6	3	0.16	Clean (safe)

It can be seen from Table 2.2 that the miscellaneous fill areas are A1-1~A1-6, A2-2, A2-4~A2-6, A3-3, A3-5, A4-6, A6-2, A6-3, A6 -5~A9-6, A10-2, A11-1~A13-6 Nemero index is evaluated as clean and not polluted by heavy metals; miscellaneous fill areas A5-6, A10-1, A10-3 and A10-4 The four points of soil Nemero index are evaluated as being still clean, between clean and lightly polluted; the miscellaneous fill areas are at points A2-1, A2-3, A3-1, A3-2, A3-4, A3-6, A4-4, A6-4, A10-5, A10-6 Nemero index is evaluated as light pollution; miscellaneous fill areas are at points A4-1~A4-3, A4-5, A5-1 ~A5-5, A6-1, A6-4 Nemero index is evaluated as heavy pollution.

CONCLUSION

(1) According to the single factor index method, the heavy metals Pb, Cr and Ni in the soil of the chemical miscellaneous fill stacking area do not exceed the limit, while the As, Hg, Cu, Zn, Cd elements are all polluted, and the pollution range is Zn> Cd>Cu>Hg>As, most of the pollution

points of Hg and As are light pollution and light pollution, the pollution is lighter, heavy metal Cd pollution is the most serious, most of the pollution points are heavy pollution, especially A4 and A5 At the two points, the pollution is the most serious.

(2) From the Nemeiro composite index, all depth indexes at points A1, A7, A8, A9, A11, A12 and A13 are less than 0.7, which is a clean level; A2-1, A2-3, A3-1, A3-2, A3-4, A3-6, A4-4, A6-4, A10-5, A10-6 Nemero index is evaluated as mild pollution; points A4-1~A4-3, A4-5 , A5-1~A5-5, A6-1, A6-4 Nemero index is evaluated as heavy pollution.

REFERENCE

[1] Soltani N, Keshavarzi B, Moore F, et al. Ecological and human health hazards of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in road dust of Isfahan metropolis, Iran[J]. Science of the Total Environment, **2015**, 505(6): 712-723.

[2] Solgi E, Esmaili-Sari A, Riyahi-Bakhtiari A, et al. Soil Contamination of Metals in the Three Industrial Estates, Arak, Iran[J]. Bulletin of Environmental Contamination & Toxicology, **2012**, 88(4):634-638.

[3] Toth G, Hermann T, Szatmari G, et al. Maps of heavy metals in the soils of the European Union and proposed priority areas for detailed assessment[J]. Science of the Total Environment, **2016**, 565: 1054-1062.

[4] Yang Q, Li Z, Lu X, et al. A review of soil heavy metal pollution from industrial and agricultural regions in China: Pollution and risk assessment[J]. Science of the Total Environment, **2018**, 642: 690-700.

[5] Ragu V, Jarsj J, Grolander S, et al. Plant uptake of elements in soil and pore water: Field observations versus model assumptions[J]. Journal of Environmental Management, **2013**, 126(14): 147-156.

[6] Bolan N, Kunhikrishnan A, Thangarajan R, et al. Remediation of heavy metal(loid)s contaminated soils--to mobilize or to immobilize?[J]. Journal of Hazardous Materials, **2014**, 266(4): 141-166.

[7] Batterham R. Chapter 4-The Chemical Engineer and the Community[J]. **2003**: 67-90.

[8] Khan S, Cao Q, Zheng Y M, et al. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China[J]. Environmental Pollution, **2008**, 152(3): 686-692.

[9] Office of Solid Waste and Emergency Response. Cleaning up the Nations Waste Sites: Markets and Technology Trends[R]2004 Edition. Washington DC: US Environmental ProtectionAgency. **2004**.

[10] Catney P, Henneberry J, Meadowcroft J, et al. Dealing with Contaminated Land in the UK through 'Development Managerialism'[J]. Journal of Environmental Policy & Planning, **2006**, 8(4): 331-356.

[11] Han W, Gao G, Geng J, et al. Ecological and health risks assessment and spatialdistribution of residual heavy metals in the soil of an e-waste circular economy parkin Tianjin, China[J]. Chemosphere, **2018**, 197: 325.

[12] Reuben A, Caspi A, Belsky D W, et al. Association of childhood blood lead levels with cognitive function and socioeconomic status at age 38 years and with IQ change and socioeconomic

mobility between childhood and adulthood[J]. Jama, **2017**, 317(12): 1244.

[13] Gulson B L, Jameson C W, Mahaffey K R, et al. Pregnancy increases mobilization of lead from maternal skeleton[J]. Journal of Laboratory & Clinical Medicine, **1997**, 130(1): 51-62.

[14] Zhang X W, Yang L S, Li Y H, et al. Impacts of lead/zinc mining and smelting on the environment and human health in China[J]. Environmental Monitoring and Assessment, **2012**, 184(4): 2261-2273.

[15] Shaheen N, Irfan N M, Khan I N, et al. Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh[J]. Chemosphere, **2016**, 152: 431-438.