Hydraulic and Civil Engineering Technology VI
M. Yang et al. (Eds.)

doi:10.3233/ATDE210194

Health Risk Assessment of Heavy Metals in Soil of Dawu Water Source Area

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Abstract. Taking Zibo Dawu Water Source Area as the research area, with the help of MapGIS and SPSS analysis tools, the health risks Make an evaluation. The results showed that As, Pb, and Ni belonged to the risk-free level, Hg reached a high-risk level, and Cd reached a medium risk level. The source of Cr is similar to Ni, Cd, Pb, As, the source of Ni is similar to Cd, Pb, and the source of Pb is similar to Hg. The comprehensive non-carcinogenic risk indexes of heavy metals for adults and children are 7.94E-03 and 3.38E-03, respectively, and there is no non-carcinogenic risk; the total carcinogenic risk indexes of heavy metals for adults and children are 5.52E-06 and 4.23E-06, respectively , There is a carcinogenic risk that the human body can bear, and the main influencing factors are Ni and Cr. Skin contact is the main way for heavy metals to cause health risks.

Keywords. Dawu water source area, soil heavy metals, health risk assessment

1. Introduction

As an important part of the earth's biosphere, Soil is an important part of terrestrial ecosystem [1]. If the soil environment is polluted and destroyed, its normal function will inevitably be affected [2-3].

Over the last few years, Industrialization and urbanization developed rapidly in China, industrial pollutants, fertilizers, pesticides, and domestic waste have entered the soil through various channels, which causes the increasingly serious problem of soil metal pollution in China [4-6]. The identification methods of typical pollutants include synthetical pollution evaluation method, potential hazard index method, health risk assessment, migration coefficient, positive definite matrix factor analysis, etc [7-9].

Many scholars at home and abroad have carried out research on soil pollution risk assessment, they analyzed farmland, irrigation area, mining area, vegetable base, city

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and other environment types in different regions, and finally made a series of research progress [10]. Francis Douay et al. [11] studied the content of heavy metals in the soil near the smelter and they found that the soil of urban and rural was contaminated by heavy mental elements such as Cd, Zn and Pb, and the health of residents living in the surrounding area was also at risk. Hu BF et al. [12] conducted research in the Yangtze River Delta Coastal Industrial Zone to assess the health risk of heavy metals in soil. The results reported that children had lowest carcinogenic risk, and adults had the highest carcinogenic risk. The results showed that the cumulation of Cd was the heaviest, and it was in the medium risk level. Now the country attaches great importance to environmental protection, so it is very important to study the content and type of heavy metals in soil and make soil environmental quality assessment.

Linzi District, Zibo City, Shandong Province is an important industrial park. Industrial enterprises such as Qilu Petrochemical and Qiwangda Group are located here. These enterprises have made great contributions to national construction and economic development, but they still have an impact on the environment. The Dawu water source is located in Linzi District, which is an an important source of water for drinking and useing in Zibo City. The groundwater in Dawu water source has been polluted [13].

2. Materials and Methods

2.1. Overview of the Research Area

The Dawu water source is situated in Linzi area of Zibo City, which is the largest fractured karst landform in northern China. The source area is about 27 km^2, and the annual average precipitation is 625.8 mm. The atmospheric precipitation is the main recharge source of groundwater. The Dawu water source is a complete hydrogeological unit, with the Aihuaishu fault in the northeast, the Linzi River west of the fault in the southeast, the Jinling fault in the west, and Jinling town and Xinan town in the north [14]. The stratum distributed in the water source area is mainly Ordovician, Carboniferous-Permian and Quaternary stratum. The soil is mainly clay [13].

2.2. Sampling and Sample Determination

According to the urban and topographical distribution characteristics of the study area, the sampling points were arranged in accordance with the requirements of the "Technical Specifications for Soil Environmental Monitoring" (HJ/T 166-2004). thirty-eight sampling points were set up for this sampling (figure 1). Most sampling points only collected surface soils ranging from 0 to 0.2 m, and the depth of collection in key monitoring areas could reach 3 m. When collecting samples, use GPS to record the coordinates and fill in the soil sampling registration form.

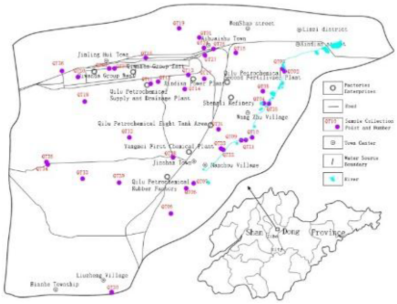

Figure 1. Distribution of soil samples.

The contents of Cr, Ni, CD, Pb, and Hg in the samples were analyzed in the laboratory. The amount of Cd and Pb in soil were determined by graphite furnace atomic absorption spectrometry, Hg and as by atomic fluorescence spectrometry, and Cr and Ni by flame atomic absorption spectrometry.

2.3. Evaluation Method

Health risk assessment method is used to evaluate human non-carcinogenic risk and human carcinogenic risk after chemical exposure [15-16]. In this paper, the mean value of heavy metal content in soil is calculated and evaluated. The calculation formulas as follow (1)-(3) for the average daily intake of adults and children through exposure. According to the guidelines of the U.S. Environmental Protection Agency and the manual of exposure factors, the health risk assessment is carried out, and the non-carcinogenic and carcinogenic risk index of heavy metals to human body calculated as follows (4)-(5).

$$ADD_{ing} = \frac{C \times IngR \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (1)$$

$$ADD_{inh} = \frac{C \times InhR \times EF \times ED}{PEF \times BW \times AT} \times 10^{-6} \quad (2)$$

$$ADD_{derm} = \frac{C \times SA \times SL \times ABS \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (3)$$

$$HI = \sum_{i=1}^{n} HQ_i = \sum_{i=1}^{n} \frac{ADD_i}{RfD_i} \quad (4)$$

$$TCR = \sum_{i=1}^{n} CR_i = \sum_{i=1}^{n} (ADD_i \times SF_i) \quad (5)$$

Where: ADD_{ing} represents the average daily intake of oral; ADD_{inh} represents the average daily intake through respiration; ADD_{derm} represents the average daily intake through skin contact, mg·(kg·d)$^{-1}$; *C* represents the amount of various heavy metals in the soil; *HI* represents the comprehensive non-carcinogenic health risk index of the region, *HQ* represents the non-carcinogenic health risk of a certain heavy metal element; *TCR* and *CR* are comprehensive and single-element carcinogenic health risk indexes, respectively. The parameters and meanings used are shown in table 1 and table 2 [17-19].

According to the "Guidelines for Risk Assessment of Contaminated Sites" promulgated by the Ministry of Environmental Protection of China, if HI<1, the pollutants will not pose a health hazard to the surrounding environment or people, if HI≥1; the pollutants will cause health risk to the surrounding environment. The carcinogenic risk was divided into no risk (TCR<10^{-6}), tolerable risk(10^{-6}≤TCR<10^{-4}) and intolerable risk(TCR≥10^{-4}).

Table 1. Evaluation parameters of exposure model.

Parameter	Meaning	Adult	Child	Unit
IngR	Soil uptake rate	100	200	$mg·d^{-1}$
InhR	Respiratory rate	16	7.6	$m^3·d^{-1}$
EF	Exposure frequency	350	350	$d·a^{-1}$
ED	Exposure years	24	6	a
BW	Average weight	60.5	27.7	kg
AT	Average exposure time (non-carcinogenic)	ED×365	ED×365	d
AT	Average exposure time (carcinogenic)	75.8×365	75.8×365	d
PEF	Particulate matter release factor	$1.36×10^9$	$1.36×10^9$	$m^3·kg^{-1}$
SA	Skin exposure area	5700	2800	cm^2
SL	Skin adhesion coefficient	0.07	0.2	$mg·(cm·d)^{-1}$
ABS	Skin absorption factor	0.001	0.001	—

Table 2. Health risk assessment exposure parameters.

Element	Reference (RfD)			Slope coefficient (SF)		
	Breathing inhalation	Skin contact	Oral intake	Breathing inhalation	Skin contact	Oral intake
Cr	$2.86×10^{-5}$	$6×10^{-5}$	$3×10^{-3}$	$4.2×10^1$	$2×10^1$	$5×10^{-1}$
Ni	$9×10^{-5}$	$5.4×10^{-3}$	$2×10^{-2}$	$8.4×10^{-1}$	$4.25×10^1$	$1.7×10^0$
Cd	$1×10^{-5}$	$1×10^{-5}$	$1×10^{-3}$	$6.3×10^0$	$6.3×10^0$	$6.1×10^0$
Pb	$3.52×10^{-3}$	$5.25×10^{-4}$	$3.5×10^{-3}$	—	—	$8.5×10^{-3}$
As	$3×10^{-4}$	$1.23×10^{-4}$	$3×10^{-4}$	$1.51×10^1$	$3.66×10^0$	$1.5×10^0$
Hg	$8.57×10^{-5}$	$2.1×10^{-5}$	$3×10^{-4}$	—	—	—

3. Results and Analysis

The results calculated using formulas (1)-(5) are shown in table 3 and table 4. The consequences of the non-carcinogenic risk evaluation showed that the total non-carcinogenic risk HI value of various ways was comprehensively compared, and the order of the impact of each heavy metal on adults through the three ways was Cr> As>Pb> Cd> Hg> Ni; the order of impact on children was As>Pb> Cd> Hg> Ni> Cr, the non-carcinogenic risk index values of various metals were all less than 1, indicating that these six kinds of heavy metals would not cause non-carcinogenic risks to adults and children. Among the three different ways of HI of the same heavy metal, skin contact was the main way to cause non-carcinogenesis. The greatest impact on adults was Cr, which could cause lesions in human organs, and the greatest impact on children was As. When considering multiple elements, the total non-carcinogenic risk index of the study area was less than 1, meaning that people in the area were not exposed to non-carcinogenic risk.

Table 3. Non-carcinogenic risk index for adults and children.

	Adult				Children			
	Inhalation	Skin contact	Oral ingestion	HI	Inhalation	Skin contact	Oral ingestion	HI
Cr	4.23E-10	6.84E-03	2.52E-11	6.84E-03	4.39E-10	2.99E-08	1.10E-10	3.05E-08
Ni	6.91E-11	3.91E-05	1.94E-12	3.91E-05	7.17E-11	1.20E-04	8.49E-12	1.20E-04
Cd	3.36E-12	1.14E-04	2.10E-13	1.14E-04	3.48E-12	3.49E-04	9.16E-13	3.49E-04
Pb	1.64E-12	3.72E-04	1.03E-11	3.72E-04	1.70E-12	1.14E-03	4.49E-11	1.14E-03
As	6.51E-12	5.39E-04	4.07E-11	5.39E-04	6.76E-12	1.65E-03	1.78E-10	1.65E-03
Hg	2.83E-13	3.91E-05	5.05E-13	3.91E-05	2.93E-13	1.20E-04	2.21E-12	1.20E-04
Total				7.94E-03				3.38E-03

The carcinogenic risk assessment results showed that when only a single heavy metal was considered, the magnitude of the carcinogenic risk impact on adults and children was Ni> Cr> As> Cd>Pb, and skin contact was the main route of carcinogenic. According to the requirements of “Guidelines for risk assessment of contaminated sites”, Cr and Ni were the main influencing elements and had a certain risk of carcinogenesis. Cr and Ni might cause harm to the human body through skin contact, but within the range of the human body. The study area had no carcinogenic risk that the human body cannot bear.

Table 4. Cancer risk index for adults and children.

	Adult				Children			
	Inhalation	Skin contact	Oral ingestion	TCR	Inhalation	Skin contact	Oral ingestion	TCR
Cr	1.61E-13	2.60E-06	1.20E-14	2.60E-06	4.17E-14	1.99E-06	1.31E-14	1.99E-06
Ni	1.65E-15	2.84E-06	2.09E-14	2.84E-06	4.29E-16	2.18E-06	2.29E-14	2.18E-06
Cd	6.70E-17	2.27E-09	4.05E-16	2.27E-09	1.74E-17	1.74E-09	4.42E-16	1.74E-09
Pb	—	—	9.69E-17	9.69E-17	—	—	1.06E-16	1.06E-16
As	9.34E-15	7.68E-08	5.80E-15	7.68E-08	2.42E-15	5.89E-08	6.33E-15	5.89E-08
Hg	—	—	—	—	—	—	—	—
Total				5.52E-06				4.23E-06

4. Conclusion

The health risk evaluation results showed that both adults and children had a non-carcinogenic risk index of less than 1, meaning that the non-carcinogenic risk of heavy metals to the human body was small. Cr and Ni have certain carcinogenic risks, but they would not have unbearable effects on the human body. Skin contact was the main influence path of heavy metals, which was related to the occurrence characteristics of soil heavy metals in human living environment.

Acknowledgement

This paper has been supported by Construction of 3D visualization information system of Dawu Water Source Area in Zibo City(SDLR－2017－138).

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