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Evaluation of Soil Heavy Metal Pollution in Urban Fringe of Small and Medium-Sized City in Northwest China

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Abstract

Soil environment directly affects the health of human settlements. With the gradual deepening of China's environmental protection work, people are more and more aware of the significance of soil pollution investigation and prevention. Cities are densely populated areas, and human activities are very complex. The pollution sources produced by various human activities directly or indirectly cause the accumulation of heavy metals in soil. In this study, Remote Sensing (RS), Geographic Information System (GIS) and questionnaire survey were used to identify the potentially polluted areas in the city. Through field sampling, the specific point pollution status is quantitatively analyzed. The average contents of Cr, Cd, Cu, Ni, Pb, Zn, As and Hg in 22 samples were 82.43, 1.76, 58.54, 42.00, 47.75, 317.22, 14.93 and 0.34 mg/kg respectively. The contents of Hg, Zn and Cu reached 5.46, 4.57 and 2.74 times of the soil background value respectively. The results of comprehensive pollution index showed that the content of heavy metals in soil of industrial land was significantly higher than that of other land types, and the potential pollution risk was higher. The results of this study provide data support for urban planning and environmental protection.

Keywords

Urban fringe; Industrial land; Soil pollution; Heavy metal.

1. Introduction

Since 1978, China's economy has grown rapidly and the level of urbanization has been continuously improved. The area of urban built-up area has increased from 7438 km^2 in 1981 to 58455 km^2 in 2018 [1], an increase of nearly seven times. By the end of 2019, the urbanization rate of China's resident population reached 60.60%, an increase of 1.02 percentage points over 2018. The urban resident population was 848.43 million, an increase of 17.06 million over 2018. Among them, the urbanization rate in the central and western regions increased by 1.20 and 1.16 percentage points respectively, significantly higher than that in the eastern region. At present, the development of urbanization in the central and western regions is faster than that in the eastern region, and the difference of urbanization level between regions is further reduced. The implementation of urban-rural integration development strategy has greatly promoted the formation and development of urban fringe, which has

become an important part of China's urban space [2]. Since the 18th CPC National Congress, the construction of ecological civilization has been promoted to a historic height, and the concept of ecological civilization has become the guiding concept of urban and rural construction. China has gradually abandoned the old model of energy consumption driven development of natural resources and advocated a new sustainable development model of "based on circular strategy, application of low-carbon technology, development of green economy and pursuit of ecological civilization" [3]. Urban fringe is the most active area of urban construction activities, and industrial development is the primary driving force of urban fringe construction. In addition, the economic development of urban fringe areas is often in the primary stage, and it is easy to embark on the road of sacrificing the ecological environment for economic development. Specifically, the leading industries have high environmental pollution and high dependence on energy, and the absence of environmental protection facilities such as sewage treatment and ecological protection belt directly leads to the destruction of ecological environment pollution. At the same time, the development of urban fringe provides a large number of employment opportunities and attracts a large number of migrant populations. Most of them choose to live in urban villages with low rent. Driven by interests, the villages expand disorderly, build against regulations and the environment is dirty, which threatens the ecological safety of urban fringe. The ecological problem of urban fringe has become one of the biggest obstacles to the implementation of new urbanization and Rural Revitalization Strategy, promoting poverty alleviation strategy and promoting the coordinated development of urban and rural areas. Facing the national strategic needs, it is imperative to solidly promote the multi-disciplinary integration research on the comprehensive treatment of urban fringe in China. It is urgent to carry out the research work on the identification, division, pollution investigation and evaluation of urban fringe in different types of regions, so as to realize the mode integration and path optimization of ecological construction of urban fringe.

The growth rate of urban scale in southern Shaanxi is slow, and its development direction is not clear or constantly changing. As a result, the newly added construction land is basically scattered in the edge areas of cities and towns. Affected by the boundary contour of land ownership, the boundary shape tends to be irregular, but it still grows in an extended way [4]. This way not only causes a waste of land resources, but also seriously intensifies the contradiction between environmental, social and economic development in urban fringe areas. Compared with other regions, southern Shaanxi is an economically backward region in Shaanxi Province, with a slow pace of urbanization. Urban development is obviously affected by natural factors such as vegetation, terrain and rivers. Less research has been carried out on urban scale and urban development boundary under resource constraints. In addition, according to the national main function zoning and the main function zoning of Shaanxi Province, southern Shaanxi is located in Qinba mountain area, a key ecological function area in China. The ecological resources are fragile and the environmental carrying capacity is low. Especially in the urban fringe, the ecological problems are prominent and the contradiction between urban and rural development is amplified, which seriously threatens the health of regional human settlements.

2. Materials and Methods

2.1. Research Areas and Sampling Points

Shangluo is located in the south of Shaanxi and belongs to the core area of Qinba mountain. This is the intersection area of North-South climate and an important water source of the "South-to-North Water Transfer" project. Shangluo has complex landform, with a forest coverage rate of 62.3%. From the perspective of the overall urban spatial structure, natural landscape has become the main limitation of urban spatial expansion. With the expansion of urban

construction land, the characteristics of urban space growing along the water system are very obvious. In 2010, the urbanization rate of Shangluo city was 36%, and by 2018, the urbanization rate has reached 47.12% [5].

The sampling points of the project are arranged by 3S technology combined with geographic information system (GIS), remote sensing (RS) and global positioning system (GPS). Through the collection of historical data and field survey, the suspected polluted areas in the study area are identified and the key areas are intensively screened. During sampling, the surface sundries were stripped, and the sampling depth was 0-20 cm. Taking the main urban area of Shangluo City as the object, mainly industrial land and residential land, 22 sampling points were selected. Three subsamples were collected at each sampling point and mixed into one sample, a total of 22 soil samples (Figure 1).

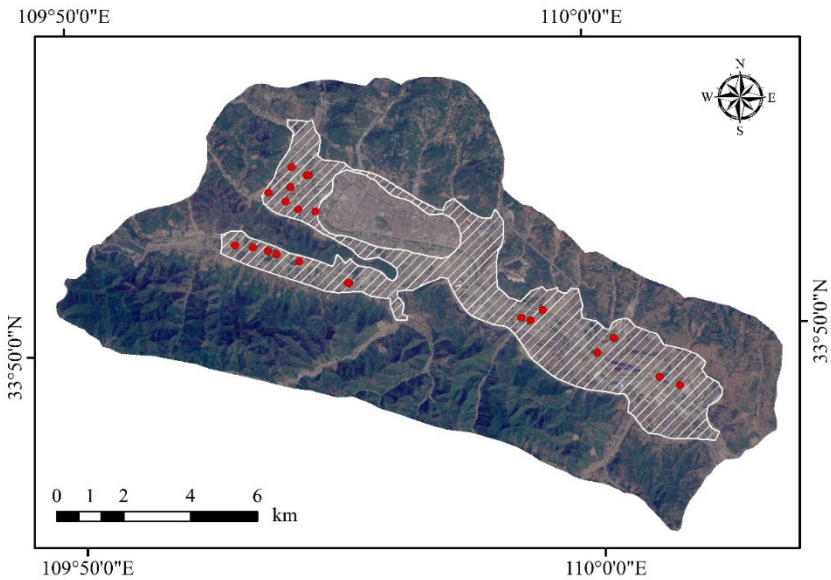

Figure 1. Research area and sampling points in Shangluo

2.2. Sample Collection and Analysis Methods

In this study, eight heavy metals Cd, Cr, Cu, Ni, Pb, Zn, Hg and as in soil were investigated and analyzed. first, The portable XRF instrument (sciaps, X-200) is used to screen the key areas, selecting the areas with high heavy metal content, collecting the soil samples of the area and send them to the laboratory for analysis. In the laboratory, the collected samples are air dried, roughly ground and finely ground to pass the nylon screen with an aperture of 0.149 mm (100 mesh). The instrument adopts inductively coupled plasma mass spectrometer ICP-MS (Agilent 7700e, Agilent), atomic fluorescence spectrometer (sk-2003az, jinsuokun), and the national standard soil sample is used for quality control in the process of determination.

In this study, the pollution index method was used to evaluate the pollution level, including single pollution index and Nemerow comprehensive pollution index. Single pollution index method is an important evaluation method of single factor index method. It is widely used in environmental pollution investigation and evaluation to scientifically evaluate a heavy metal element in soil. The calculation formula is as follows:

$$P_i = C_i / S_i \tag{1}$$

Where C_i is the measured concentration of heavy metals in soil, S_i is the evaluation standard or reference value of heavy metals in soil, and P_i is the single pollution index, The evaluation

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standard of soil heavy metals shall be in accordance with the standard for soil environmental quality control of soil pollution risk of construction land (GB36600-2018), and refer to the relevant values in the standard for soil environmental quality control of soil pollution risk of agricultural land (GB15618-2018).

Nemerow comprehensive pollution index method directly reflects the severity of comprehensive pollution by comparing and analyzing the maximum and average values of multiple factors.

$$P_c=\{[P^2_{imax}+P^2_{iave}]/2\}^{1/2} \quad (2)$$

Where P_{imax} is the maximum value of single pollution index; P_{iave} is the arithmetic mean of single pollution index and P_C is the comprehensive pollution index. According to the values of P_C, the degree of soil pollution is divided into five levels (Table 1).

Table 1. Nemerow pollution index levels

Level	P_c	Pollution Degree
I	$P_c \leq 0.7$	Clean
II	$0.7 < P_c \leq 1$	Slightly Polluted
III	$1 < P_c \leq 2$	Moderately Polluted
IV	$2 < P_c \leq 3$	Heavily Polluted
V	$P_c > 3$	Extremely heavily polluted

3. Results

The statistical results of laboratory analysis are shown in Table 2. The average contents of Cr, Cd, Cu, Ni, Pb, Zn, As and Hg in 22 samples are 82.43, 1.76, 58.54, 42.00, 47.75, 317.22, 14.93 and 0.34 mg/kg respectively. The contents of Hg, Zn and Cu reached 5.46, 4.57 and 2.74 times of the soil background value respectively. The soil contents of Cr, Ni and As are very close to the soil background value. The standard deviation (SD) of Zn was the largest among all varieties, reaching 406.35. The SD of As, Cd and Hg is less than 10, and the SD of Hg is the smallest, which is 0.51. Among the 22 samples, the coefficient of variation (CV) of Cu, Zn, Cd and Hg are greater than 100%, among which the CV of Hg is the largest, which is 148.93. It indicates that there are great differences in values and high dispersion among different samples. The CV of Ni is the smallest, which is 29.34, indicating that the values of different samples are close and the difference is small.

Table 2. Statistical results of soil samples

Elements	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
Mean	82.43	42.00	58.54	317.22	14.93	1.76	47.75	0.34
Median	76.66	39.25	41.88	124.97	13.51	0.31	29.41	0.13
SD	28.51	12.32	63.76	406.35	8.70	3.30	40.29	0.51
Min	50.11	25.55	17.53	62.57	0.82	0.05	15.78	0.00
Max	187.86	83.83	331.73	1664.19	45.62	11.55	180.60	1.74
CV%	34.59	29.34	108.91	128.10	58.24	187.20	84.37	148.93
Background Value	62.5	28.8	21.4	69.4	11.1	0.76	21.4	0.063

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From the perspective of different heavy metal elements, Pollution indices (P_i) of Cr, Cd and Zn are greater than 1, of which the average pollution index of Cd is the highest, reaching 5.87. The average pollution index of Pb is the lowest, only 0.12. From the perspective of different sampling points, the comprehensive pollution index of sampling points 16 and 18 is significantly higher than that of other points, reaching 380.33 and 334.94 respectively, belonging to heavy pollution, mainly due to the high content of Cd and Zn at this point. In general, the P_C of 11 points is less than 0.7. They are regarded as clean condition, accounting for 50% of the total; The P_C of two points belongs to slight pollution, accounting for 9.09% of the total; P_C in one point is moderately polluted, accounting for 4.55% of the total; P_C in one point is heavily polluted, accounting for 4.55% of the total; The P_C of 7 points belongs to extremely heavy pollution(P_C>3), accounting for 31.82% of the total.

In terms of the content of heavy metals in the samples in this study, there is an obvious pollution situation in the samples. From the perspective of spatial distribution, the pollution index of points 1-12 is significantly lower than that of points 13-22, which shows that the distribution of heavy metals in soil has the characteristics of agglomeration in space (Figure 2). Points 1-13 are located in the west of the study area, which is mainly the old urban area of Shangluo City, mainly including the main living areas of urban residents; Point 14-22 is located in the east of the study area, which is mainly industrial land, including scattered factories and centralized industrial parks.

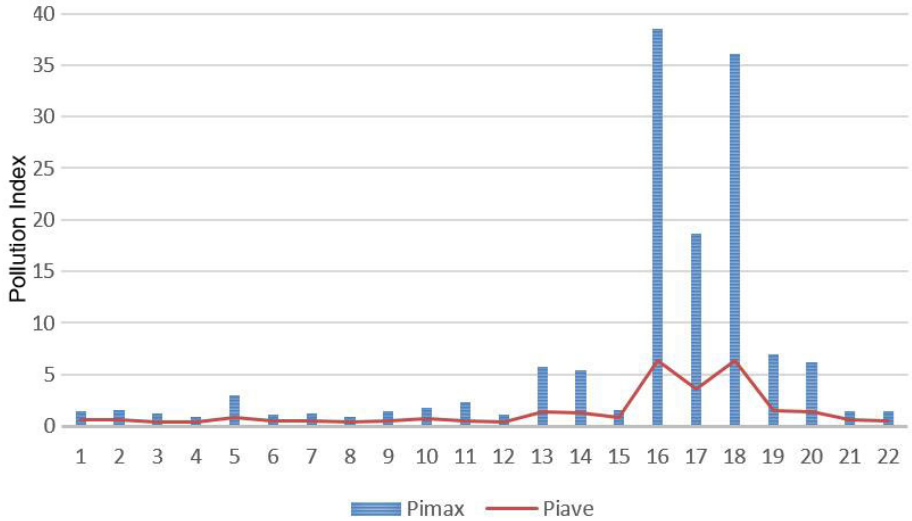

Figure 2. Pollution index results

4. Discussion and Conclusion

Due to the direct impact of human activities, urban soil pollution shows the characteristics of many kinds of pollution and complex pollution sources. In the 2014 report on China's soil pollution, it was pointed out that the soil heavy metal pollution of industrial land was serious [6]. With the expansion and development of the city, industrial land has gradually moved from the interior of the city to the suburbs, resulting in a large number of industrial land distributed in the urban fringe. These industrial activities directly or indirectly lead to the accumulation of heavy metals in soil, including the stacking of industrial raw materials, chemical reaction and so on. This study confirmed that there is a direct relationship between soil pollution and human activities. Industrial activities are the main cause of heavy metal pollution in urban soil. On the one hand, we need to pay more attention to the layout of industrial land to avoid direct harm to human body caused by industrial pollution; On the other hand, industrial production should be based on not harming the ecological environment. In the process of redevelopment and

utilization of industrial land, we must find out the soil pollution status, and timely control and treat the contaminated soil.

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