Contents of heavy metals in urban parks and university campuses

Yong Zhang1, 2, *, Qian Chen1

1School of Resource, Environmental and Safety Engineering, Hunan University of Science and Technology, Xiangtan, China
2College of Resources and Environmental Sciences, Hunan Normal University, Changsha, China

*Corresponding author e-mail: 292278@qq.com

Abstract. Because the city park has become an important place for people's daily leisure, and the university campus is one of the most densely populated areas of the city, their environmental pollution is critical for the health and safety of the residents. In this paper, two kinds of evaluation methods were used to evaluate the content of Cu, Zn, As and Pb in soils of city parks and university campus in Xiangtan. The results showed that only Juhuatang Park was a non-polluted area, and the other 7 sampling sites were lightly polluted; Analysis shows the heavy metal contents of soil in city parks are closely related to vehicle emissions, agriculture and irrigation, combustion of household waste, living area and commercial shops, the use of fossil fuels, industrial waste gas and waste residue and other human activities.

1. Introduction
Soil heavy metal pollution means that the content of heavy metals in soil increases and exceeds the background value of the soil due to the continuous expansion of human production and living activities [1]. With the continuous improvement of the level of urbanization in China, the urban population has increased significantly. Urban parks have become an important place for people's daily leisure, and the university campus has developed into one of the most densely populated areas of the city. With the increase of population density and the rapid development of industry and agriculture, etc., the soil in the city parks and the university campus may be polluted by heavy metals in varying degrees, and then affect people's health through the air, water, and other media. Therefore, it is becoming more and more important to study the heavy metal contents of soil in urban parks and university campuses and assess the risk of heavy metals.

Previous studies have shown that the soil in the urban parks, such as Shenzhen, Beijing, Shanghai, Baotou, Harbin, Guangzhou, etc., suffered a certain degree of heavy metal pollution [2-6]. The analysis and evaluation of 7 kinds of heavy metals in 8 parks in Nanning show that the potential hazard index for Nanning was 22.22, and reached a mild ecological risk level. Among them, the most serious environmental hazard is heavy metal Pb [7]. Yu Cong carried out the research on heavy metal content and risk evaluation in Pudong New Area of Shanghai and found the soil in the park green space had been polluted by some heavy metals [8]. However, as a small and medium-sized city, the content and assessment of soil heavy metals in Xiangtan area are extremely lacking, especially for that
of the urban parks and university campuses. During the rapid development of Xiangtan, the environmental requirements of urban residents are also rising. City parks have become the essential factor of people's daily life; at the same time, university campus usually is not only an important part of city green space, but also an area with highest population densities in a city, so it also needs a high-quality environment. Therefore, through the study of the heavy metals in the urban parks and university campuses of Xiangtan City, we can provide the decision-making basis for improving the soil environment quality and improving people's daily living environment.

The analysis and evaluation of 7 kinds of heavy metals in 8 parks in Nanning show that the potential hazard index for Nanning was 22.22, and reached a mild ecological risk level. Among them, the most serious environmental hazard is heavy metal Pb [7]. Yu Cong carried out the research on heavy metal content and risk evaluation in Pudong New Area of Shanghai and found the soil in the park green space had been polluted by some heavy metals [8].

2. Materials and methods

2.1. Research area overview
Xiangtan is an important industrial city in Central China and located in the north of the Tropic of Cancer (111°58′–113°05′E, 27°20′55″–28°05′40″N). The area of Xiangtan City reached 5015 Km². As of 2015, the green coverage rate of Xiangtan reached 40.42%, and per capita public green area is 10.05m² [9]. To alleviate the heavy metal pollution of the soil, the Xiangtan municipal government has intensified its management of the contaminated areas [10].

2.2. Sample collections and methods
In March 2017, the samples of surface soil in Huxiang Park (HXP), Juhuatang Park (JHTP), Yuetang Park (YTP), Baishi Park (BSP), HPP (HPP), Yuhu Park (YHP), Xiangtan University (XTU) and Hunan University of Science and Technology (HNUST) were collected respectively. 2-5 samples were collected in each region, and 23 samples were collected (Figure 1).

![Figure 1. Distribution of sampling sites.](image)

2.2.1. Sampling and processing. 2-5 sampling sites were sampled at random in each sampling area, and GPS is used to locate each site. Firstly, remove the litter on the surface of the soil, and then use the ring-knife to pick up the surface soil and put in the self-sealing bag. In the laboratory, using quarter
division method, one of the samples was taken and ground through 100 mesh screens. Finally, the ground samples are enclosed in the self-sealing bag.

2.2.2. Experiment. Using EPX-50 mobile X ray fluorescence spectrometer, which is made by Innov-X Company of the United States, the contents of different heavy metals were measured for each soil sample. EPX-50 has the advantages of convenient portability, high safety, high accuracy, easy to use and easy to operate. Meantime, the instrument does not damage the sample and can be measured repeatedly.

2.3. Data processing and methods
There are many evaluation methods for heavy metal pollution, and the most commonly used methods include Single Factor Index, Nemerow Index, Pollution Load Index, Geo-accumulation Index, etc. [11]. In this paper, Single Factor Index and Nemerow Index are selected to evaluate the heavy metal pollution of soils in Xiangtan.

2.3.1. Single Factor Index. The Single Factor Index is mainly used to assess the risk of a kind of heavy metal pollution. Its expression is:

\[ P = \frac{P_i}{P_s} \]  

In the formula (1), \( P_i \) is the measured concentration of pollutant \( i \); \( P_s \) is the environmental quality index of \( i \) in soil pollutant. If \( P \leq 1.0 \), it shows the content of this heavy metal is within its background value, and the soil is not contaminated; If \( P > 1.0 \), it shows the content of this heavy metal has exceeded its background value, and the soil is contaminated; the greater the value of \( P \) is, the higher the degree of soil contamination is [13]. Soil background values used in this study are shown in table 1. Because soils in Hunan are mainly acid red soils, the second level standard values are selected as the background values in this study.

| Heavy metal elements | Natural background value | Second level standard value | Third level standard value |
|----------------------|--------------------------|----------------------------|----------------------------|
| Cu                   | 35                       | 50                         | 400                        |
| As                   | 100                      | 200                        | 500                        |
| Zn                   | 15                       | 30                         | 30                         |
| Pb                   | 35                       | 250                        | 500                        |

Note: the reference standard is the "soil environmental quality standard of People's Republic of China national standard". In table 1, the pH value of the soil corresponding to the second level standard value is PH<6.5, and the pH value of the soil corresponding to the third level standard value is PH\(\geq 6.5 \) [12].

2.3.2. Nemerow Index. The Single Factor Index can only evaluate the pollution situation of a kind of heavy metal. If comprehensive pollution status of several heavy metals is needed to be evaluated, Nemerow Index will be a good choice [3]. The expression of Nemerow Index is:

\[ I = \sqrt{\frac{(\bar{P})^2 + (\text{max} \ P)^2}{2}} \]  

In the formula (2), \( \bar{P} \) is the mean of individual pollution index, \( \text{max} \ P \) is the maximum of the single pollution index, and \( I \) is the soil comprehensive pollution index. If \( I \leq 1 \), it indicates no pollution; If
1≤I≤2, it indicates a slightly polluted; If 2<I≤3, it indicates a moderate pollution; If I>3, it indicates a severe pollution [3].

3. Results and analysis

3.1. Single Factor Index

3.1.1. Partition evaluation of Single Factor Index. In order to visually compare the extent of heavy metal pollution in each district, the average value of each heavy metal in each district was used as the measured values to calculate the Single Factor Index (Figure 2).

From Figure 3, it can be seen the Single Factor Index of As is greater than 1 in a number of research areas, and the results indicated these districts had been contaminated by As. The Single Factor Index of As is as follows: XTU, BSP, HNUST, HPP, HXP, YHP, JHTP, YTP. Sources of As are mainly pesticides and chemical fertilizers. In fact, XTU is situated on the outskirts of the city and has a large number of farmlands nearby. Therefore, the content of As is higher.

In the study areas, all Single Factor Index of Pb is no more than 1, which showed no pollution by Pb. From high to low, the Single Factor Index of Pb is YHP, HPP, JHTP, XTU, HXP, BSP, HNUST and YTP. The higher Single Factor Index of Pb is directly relative to its location (city center) and a long history, which led to the development of the surrounding greenhouse agriculture, and traffic is also developed. Similarly, only the Single Factor Index of Cu in YHP exceeded 1 among the 8 research areas. However, the Single Factor Index of Cu in YTP and BSP was 0.9 and nearly reached the critical value. Similar to Pb, the Single Factor Index of Zn did not exceed 1 in all sampling areas. However, from high to low, the Single Factor Index of Zn is different from that of Pb, and as follows: YHP > HPP > HXP > JHTP > XTU > YTP > HNUST > BSP.

Previous studies have shown that Zn and As mainly come from the use of chemical fertilizers, sources of Pb are mainly traffic pollution, and the sources of Cu are mainly industrial emissions [14]. In conclusion, the regional differences of heavy metals are directly related to their probable sources.

3.1.2. Single Factor Index of each sampling point. For the Single Factor Index at each sampling point, the Single Factor Index of As was almost high at all sampling sites (except for individual sampling points, such as 3 and 21), which means As is the main component of heavy metal pollution of soils in Xiangtan urban parks and universities. Comparatively, Pb has the lowest values of Single Factor Index, and all values are below 1.

From the Single Factor Index of four heavy metal elements, about 1/2 of the values are between 1 and 2, which indicates that part of the soil in urban parks and university campuses were polluted, but the pollution degree is light. Pollution degree of four kinds of heavy metal elements is As > Cu > Zn > Pb.

More than half of the Single Factor Index of As is between 1 and 2, which indicates most sampling sites are slightly polluted by As; Expect the contamination of Zn at the sample point 21, the remaining sample sites were not contaminated by Zn;
Although the Single Factor Index of Cu at the sample point 21, 20, 15, 13 and 6 exceeded 1, but the values of the rest sample points were less than 1, which indicates that the Cu distribution is very uneven, and there was no pollution in most places; Of all the 23 sample sites, no Single Factor Index of Pb exceeded 1, which indicates that the soils in all sample sites were not contaminated by Pb.

3.2. Evaluation of Nemerow Index

Of all the eight study area, only the Nemerow Index of JHTP is less than 1 (I=0.92), which indicates although this region has not been contaminated by heavy metals, it is already relatively near to the level of mild pollution. The Nemerow Index of the other study areas was between 1 and 2 and belongs to light pollution. Among them, the Nemerow Index of HPP is the highest (I=1.906), which is close to moderate pollution. Pollution degree of heavy metals is as follows: YHP > XTU > BSP > HPP > HNUST > HXP > YTP > JHTP (Figure 3).

![Figure 3. Nemerow Index of different research areas.](image)

The heavy metals of soil not only come from agricultural fertilization and industrial emissions, but also come from the heavy metals of the atmosphere, which mainly comes from industrial production and a lot of harmful gases and dust containing heavy metals produced by automobile tire wear and automobile exhaust emissions [15]. The sources of heavy metals in soil are widespread and come from lots of different ways.

The Nemerow Index showed YHP had the highest degree of heavy metal pollution. YHP, which is located at the center of Xiangtan City, was one of the first batches of old parks of Xiangtan. Its agricultural development, industrial development, and traffic development made it turn into one of the most serious pollution areas. XTU is accompanied by numerous farms and covered by densely industries nearby. In addition, one of main transportation lines also passes here. These may cause the high content of heavy metals in the soil. BSP is located in the old city center of Xiangtan city. Heavy metals pollution of soil has reached a slight degree. The combined effects of automobile exhaust emission and the combustion of fossil fuels in living quarters and commercial areas are the main reason. HPP is adjacent to the Xiang-Qiang Railway, faces the main traffic routes into the city center, and has a large number of farmlands nearby. Therefore, soil heavy metals may originate mainly from automobile exhaust emissions and agricultural activities. HXP (I=1.3), YTP (I=1.06), and JHTP (I=0.9) belongs to the new urban area. The soil heavy metal pollution in these areas is relatively light, or even not. HXP, the largest city park, is located at the center of the new city. Without a doubt, the construction of the new urban area has the greatest impact on the soil heavy metals. JHTP and YTP have a low level of heavy metal pollution. Even so, pesticide and irrigation will still be an important factor affecting the soil heavy metal contents.

4. Conclusion

Through the analysis and evaluation of the heavy metal contents of the surface soil in the eight research areas, we can draw the following conclusions:

1. From the spatial distribution point of view, Xiangtan city park and university campuses were polluted by Cu, Zn and As at different degrees, but most of them are just mild pollution. However, all study areas were not polluted by Pb.
(2) Numerical Index analysis showed that: except JHTP, which is not polluted, the pollution degree of soil heavy metal in other areas is: YHP > XTU > BSP > HPP > HNUST > HXP > YTP > JHTP.

(3) Pollution status of soil heavy metals in Xiangtan city parks and university campuses is closely related to human activities. Heavy metal pollution of the old district is higher than that of the new district; taking the city center as the starting point, the pollution gradually decreases along with the increasing of the distance from the city center; The closer to the industrial and agricultural areas is, the more serious the pollution is, and vice versa.

Acknowledgments
This work was financially supported by Study on the Changes of Land Use and Landscape Pattern and Ecological Safety of River-Lake adjacent areas (2011RS4013).

References
[1] Chen Huaiman, Environmental Soil Science, Advance in Earth Sciences, 6 (1991) 49-51.
[2] LI Yumei, LI Haipeng, ZHANG Lianke, JIAO Kunling, SUN Peng, WANG Weida, Contamination and Health Risk Assessment of Heavy Metals in Soil Surrounding an Aluminum Factory in Baotou, China, Environmental Monitoring in China, 33 (2017) 88-96.
[3] SHANG Erping, ZHANG Hongqi, YANG Xiaohuan, XU Erqi, XIAO Linlin, DONG Guanglong, Assessment of soil heavy metal of paddy field in four provinces in southern China, Acta Scientiae Circuitantia, 37 (2017) 1469-1478.
[4] SHI Gui-tao, CHEN Zhen-lou, XU Shi-yuan, et al., Characteristics of Heavy Metal Pollution in Soil and Dust of Urban Parks in Shanghai, Environmental Science, 28 (2007) 238-242.
[5] SHI Gui-tao, CHEN Zhen-lou, WANG Li, et al., Heavy Metal Pollution and the Ecological Risk in Dust of Shanghai Urban Parks. Urban Environment & Urban Ecology, 19 (2006) 40-43.
[6] Lin Wen, Li Jiyue, Su Juan, Study on Urban Forest Soil Heavy Metal Pollutions in Guangzhou, Guangdong Forestry Science and Technology, 28 (2012) 25-29.
[7] Mo Liping, Lin Qing, Xie Xiaocang, et al., Soil heavy metal contents and potential ecological risk assessment of park green space in Nanning, Journal of Guangxi Teachers Education University (Natural Science Edition), 28 (2012) 1-4.
[8] YU Cong, YIN Shan, Zhou Pi-Sheng, et al., Distribution Characteristics and Assessment of Heavy Metals in City Park, Journal of Environment and Health, 25 (2008) 891-894.
[9] Brief introductions of Xiangtan County, Huxiang Forum, 6 (2006) 2.
[10] JIA Wei-tao, LV Su-lian, FENG Juan-juan, et al., Restore Heavy Metal Contaminated Soil with Energy Plants, China Biotechnology, 35 (2015) 88-95.
[11] Fan Shuanxi, Gan Zhuoting, Li Meijuan, et al., Progress of Assessment Methods of Heavy Metal Pollution in Soil, Chinese Agricultural Science Bulletin, 26 (2010) 310-315.
[12] State Environmental Protection Administration, Soil environmental quality monitoring standard (HJ / T 166 - 2004), (2004) 25-27.
[13] SHI Zheng-jun, WU Chong, LU Ying, Comparative Study on Soil Heavy Metal Content of Urban Green Ground Near Parks and Roads in Shenzhen City, Chinese Journal of Soil Science, 38 (2007) 133-136.
[14] BAI Shi-qiang, LU Sheng-gao, Analysis and Evaluation on Concentration of Heavy Metals in Soils of Industrial Area and Suburb Cropland of Luoyang City, Journal of Agro-Environment Science, 26 (2007) 257-261.
[15] Wang Hongmei, Study on the law of heavy metals migration in activated sludge system, China University of Geosciences (Beijing). (2006)