# Distribution and risk evaluation of heavy metal in the soil of typical grassed swale

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**Abstract.** The concentration and distribution of Pb, Zn, Cu and Cr in the surface soil of three grassed swales located in the city of Beijing, Jiaxing and Shenzhen were studied in this paper. Evaluations on the risk of heavy metals were conducted based on the second level limit of soil environmental quality standard, using different indexes (i.e., single item, comprehensive items and potential ecological risk indexes). Results show that the concentration of Pb, Zn, Cu and Cr in all the soil samples is within the limit of second level of soil environmental quality standard of China, except the soil samples of the grassed swale from Shenzhen city. The result also shows that the concentration of the four kinds of heavy metals in the surface soil of grassed swales is linearly correlated with the depth of soil sampling points. In summary, ecological risk of heavy metals in the three grassed swales is slight.

## 1 Introduction

Grassed swale is a kind of engineering infrastructure with grass planted in the surface ditch. The purpose of this infrastructure is to collect and reuse of rain water. When the rain water flows through the swale, the pollutants in the runoff will be removed by the process of precipitation, filtration, infiltration, absorption and biodegradation. The grassed swale is generally applied in impervious road side and city park, etc. [1]. As a kind of typical runoff pollutants, heavy metals are trapped and accumulated in the surface soil of grassed swale with a potential risk to human health. Relevant investigation has been made in the surface soil of grassed swale in some countries. Beijing, Jiaxing and Shenzhen are the first batch of sponge cities in China. These three cities all experienced of water logging problem [2], thus rainwater utilization constructions in these cities are more common than elsewhere in China. As a kind of typical urban rainwater utilization engineering facilities easy for construction, grassed swales are applied in park and resident area in these three cities [3]. Heavy metal content is studied and risk assessment is carried out in the surface soil of three typical grassed swales located in Beijing, Jiaxing, and Shenzhen city. The result can be regarded as scientific basis for the prevention and control of heavy metal pollution in grassed swales.

## 2 Materials and methods

To ensure the typical of soil sample, the collection method of Simon T [4] is used in this study. Research results show that the top 30 cm soil is most vulnerable to heavy metal pollution [5]. Depth of grassed swale planting soil is also less than 30 cm in China according to our research.

### 2.1 Site description

Three typical grassed swales respectively locate in the Olympic Forest Park (116°23'3"E, 40°1'3"N, Beijing), Sunny Bay district (120°42'43"E, 30°44'57"N, Jiaxing) and Niushan park (113°57'11"E, 22°45'14"N, Shenzhen). The length of the three swales is all about 150 m. Beijing Olympic Forest Park was builted in 2008. It covers an area of 680 hectares with 478 hectares of green area, and 67.7 hectares of water surface. The annual average rainfall of Beijing is 600 mm. Jiaxing Sunny Bay district was built in 2012. The average annual rainfall of Jiaxing is 1169 mm. NiushanPark, a bright and high tech Industrial Park, is located in the southeast of Shenzhen City, which covers an area of 570 thousand square meters. The park was put into use in 2011. Shenzhen belongs to the subtropical monsoon climate, with an average annual rainfall of 1933 mm.

### 2.2 Sample Collection

Soil samples were collected from the top soil layer (30 cm) in the swales during the period from October to December in 2015. The distribution of sampling points of each grassed swale is shown in Figure 1. The three sampling points are arranged at both ends and the middle of each grassed swale. The soil samples of each sampling point were collected by 0-10cm, 10-20cm and 20-30cm depth using a stainless steel sampler. 27 soil samples were collected in each grassed swale. The samples were collected and stored in clean plastic bags with record of data, sampling points and other information. Then the samples were sent to the laboratory for further test.

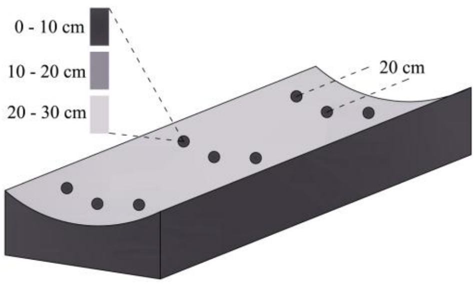


**Figure 1.** The distribution of sampling points.

### 2.3 Tests and Analyses

The collected soil samples (no less than 500 g) were air dried in natural condition indoor. Stones and debris in each sample were removed by hand. With the use of an agate mortar, the soil was sieved through a 2 mm nylon screen, and then filtered through a 0.15 m nylon screen[6]. Each tested sample is a mixture of samples from the same soil layer.

0.1 g soil was weighted by an analysis balance and dropped in a PTFE digestion tank. 5 ml Nitrate, 2 ml hydrogen peroxide, and 3 ml hydrofluoric acid were then added to the tank. All reagents are GR. Level. The tank was then put in the Topwave microwave for digestion. The tank was first heated to 150 degrees and kept for 20 min, then heated to 250 degrees and kept for 30min. When the tank was cooled down, the liquid in it was poured into 50 ml PTFE crucible. The liquid was heated on an electric hot plate (200 degrees) to remove the redundant acid in it. The final volume of liquid sample is 0.5 ml. The liquid was transferred to a 50 ml volumetric flask and set to 50 ml with deionized water. The contents of heavy metals were analyzed by flame atomic absorption spectrophotometer using Z-2010 HITACHI flame atomic absorption spectrometry. The correlation coefficient of the standard curve was no less than 0.9995.

10.0 g soil was weighted with an analysis balance and put into 50 ml high type beaker, adding 25 ml water. After sealing the container, the sample was stirred using the blender for 5 min, and the soil pH was measured with the FE20-K pH measurer after 2 h . This method was followed by NY/T 1377-2007 standard of China. Microsoft Excel 2003 and SPSS 17.0 software were used for data analyses.

### 2.4 Evaluation of heavy metal pollution

#### *2.4.1 Evaluation criteria*

The second level limit value of soil environment quality standard of China was applied as the evaluation criteria in this paper. This level of soil quality is basically does not cause damage and pollution to the plant and environment. The standard value of different metals is listed in Table 1.

**Table 1.** Second level limit metal value of soil environment quality standard [7] (mg/kg)

| Metal/pH | pH<6.5 | 6.5<pH<7.5 | pH>7.5 |
|---|---|---|---|
| Pb | 250 | 300 | 350 |
| Zn | 200 | 250 | 300 |
| Cu | 50 | 100 | 100 |
| Cr | 150 | 200 | 250 |

#### *2.4.2 Evaluation Methods*

Single factor index, comprehensive items and potential ecological risk indexes were applied to the risk evaluation. The single factor index method evaluates the ratio of tested value and relative standard limit value of pollutant. The calculation formula is as follows:

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

In the formula: $P_i$ represents to the single factor pollution index. $C_i$ represents to the content value of soil. $S_i$ represents to the criteria value. This evaluation method can evaluate the risk of pollution of single heavy metal in soil. Nemero comprehensive pollution index method is based on the single factor index. The calculation formula is as follows:

$$P = \sqrt{[(P_{imax}^2 + P_{iavg}^2)/2]} \tag{2}$$

In the formula, $P$ represents to the comprehensive pollution index. $P_{imax}$ represents to the largest single factor index value. $P_{iavg}$ represents to the average single factor index value. Table 2 shows the relation of $P$ value with soil quality.

**Table 2.** Comprehensive pollution index criteria [8]

| Level | Index Value | Soil quality |
|---|---|---|
| 1 | 250 | 300 |
| 2 | 200 | 250 |
| 3 | 50 | 100 |
| 4 | 150 | 200 |

Potential ecological risk index takes heavy metal content and its ecological effects, environmental effect and toxicological effect together into consideration. The calculation formula is as follows:

$$RI = \sum_{i=1}^{n} = \sum_{i=1}^{n} T_r^i \times P_r^i \tag{3}$$

*RI* represents to the potential ecological risk index value. $E_r^i$ represents to the single potential metal ecological risk value. $T_r^i$ represents to the coefficient of single metal (Pb=5, Zn=1, Cu=5, Cr=2[4]). $P_r^i$ represents to the single factor pollution index value. If the value of *RI* is less than 150, the ecological risk is slight. If the value of *RI* is between 150 and 300, the ecological risk is moderate. If the value of *RI* is beyond 600, then the ecological risk is serious [9].

# 3 Results and discussion

## 3.1 Heavy metal contents

The concentration of heavy metal in different level of soil is shown in Figure 2, 3 and 4. The maximum content of Cr, Cu, Zn and Pb in Olympic Forest Park is 126.3 mg/kg, 85.4 mg/kg, 230.3 mg/kg and 58.8 mg/kg, respectively. The maximum content of Cr, Cu, Zn and Pb in Sunny Bay district is 158.4 mg/kg, 85.2 mg/kg, 213.5 mg/kg and 23.6 mg/kg, respectively.

All the maximum values occur in the top 10 cm soil layer without exceeding the evaluation criteria, which actually means there is no heavy metal pollution in these two grassed swales caused by the four kind of heavy metals examined. The maximum content of Cr, Zn and Pb in Niushan Park is 124.6 mg/kg, 151.7 mg/kg and 144.6 mg/kg, respectively. Similarly, the maximum content of Cr, Zn and Pb occur in the top 10 cm soil layer without exceeding the evaluation criteria. Concentration of Cu in Niushan Park grassed swale is between 138.6-167.3 mg/kg, which greatly exceed the evaluation criteria and shows a heavy pollution condition. Data from Figure 4 also shows that basically, the metal concentration decrease along with the depth of soil. This phenomenon is due to the process of precipitation, filtration, infiltration and absorption by the grassed swale.

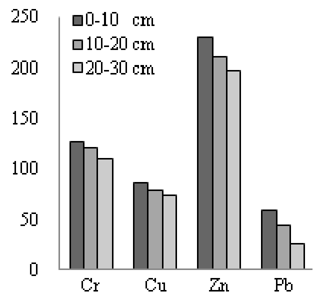


**Figure 2.** Concentration of Heavy metal in the soil of Olympic Park (mg/kg)

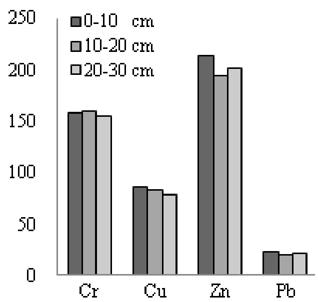


**Figure 3.** Concentration of Heavy metal in the soil of Sunny Bay (mg/kg)

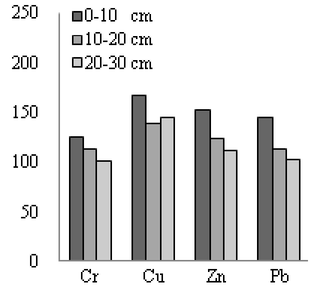


**Figure 4.** Concentration of Heavy metal in the soil of Niushan Park (mg/kg)

The background value of Pb, Zn, Cu and Cr of soil in Beijing is 24.6 mg/kg, 57.5 mg/kg, 18.7 mg/kg and 29.8 mg/kg, respectively [10]. The concentration of heavy metal all exceed this background value in the soil sample from Beijing. This indicates that the possibility of soil pollution still exits. According to the review of soil concentration in Beijing, Guo et al. believes that the main kind of heavy metal pollution in soils of Beijing is Pb, Zn, Cu and Cr, based on the background value [11]. In Jiaxing and Shenzhen city, there is no heavy metal background value data of soil until now. The static analysis results show that each of the heavy metal significantly associated with the other three metals at 0.01 level, so there is the possibility that the metal come from the same source. During the test we recognized that pH in the soil of Shenzhen grassed swale is less than 6, indicating that the soil is acidic, which is a vulnerable condition for heavy metal migration [12]. Besides, the annual rainfall in Shenzhen is larger than the other two cities, leading to a greater risk of heavy metal pollution. Besides pH, the organic matter in soil may also have an impact on the distribution of heavy metal in soil. The concentration of Zn in Shenzhen soil is significantly less than the other two cities, mainly because of the larger rainfall and the more chance of migration of Zn.

The standard of soil in China is founded in the last century, which is not strict enough. During the collection of soil sample, we found that the distribution of heavy metal in soil is not only associated with rainfall but also with the maintenance measure of grassed swale, such as irrigation and fertilization. Although the date of construction of these three grassed swale is different, they all perform well until now. Thus, the possibility of heavy metal pollution in grassed swale is low in short time. However, the long time performance of grassed swale in China is still unknown and need to be further investigated.

The concentration of Pb in Sunny Bay district is significantly less than the other two park. Probable reason for this is that the mobile population is larger in park than residential areas. The flush of rainwater in the surface soil is another factor of heavy metal distribution in soil, which can bring heavy metal in soil back into the rainwater. Compared with the results of heavy metal in soil of grassed swale besides traffic roads, heavy metal concentrations in these areas is lower, showing that road traffic is an important source of heavy metals in grassed swale soil. The concentration of Pb in the soil of Niushan Park is higher than the othe two areas. Laterite soil may be the cause of high concentration of Pb in the soil of ShenZhen.

### 3.2 Risk evaluation of heavy metal

The evaluation results of comprehensive index are showed in Table 3. Single factor index value of each kind of metal from Olympic Forest Park and Sunny Bay district is less than 1, which means a clean soil environment. Nemero comprehensive index value of this two areas is 0.7 or 0.8, within the range of level 2, which is a still clean state. Single factor index value of Cu in Niushan Park is between 2.9 and 3.3, with a comprehensive index value between 2.1 and 2.5. This shows that soil of grassed swale in Niushan Park is moderately polluted by Cu. The evaluation results of potential ecological risk is shown in Table 4. Potential ecological value of three areas is between 5.8 and 21.9, less than 40, which means that the ecological risk is slight.

**Table 3.** Evaluation results of Nemero Comprehensive pollution index criteria

| Depth/Site | Olympic Park, Beijing | Sunny bay district, Jiaxing | Niushan Park, Shenzhen |
|---|---|---|---|
| 0-10 cm | 0.8 | 0.8 | 2.5 |
| 10-20 cm | 0.7 | 0.7 | 2.1 |
| 20-30 cm | 0.7 | 0.7 | 2.2 |

The evaluation results of potential ecological risk is shown in Table 4. Potential ecological value of three areas is between 5.8 and 21.9, less than 40, which means that the ecological risk is slight. In fact, the ecological risk value is far low than 150. However, other kinds of heavy metal, such as Cd, Mn and Ni also can cause potential risk. This should be investigated in the following research.

**Table 4.** Evaluation results of potential ecological risk

| Depth/Site | Olympic Park, Beijing | Sunny bay district, Jiaxing | Niushan Park, Shenzhen |
|---|---|---|---|
| 0-10 cm | 7.6 | 6.9 | 21.9 |
| 10-20cm | 6.5 | 6.9 | 18.7 |
| 20-30cm | 5.8 | 6.9 | 18.5 |

## Conclusions

The concentration of the four heavy metal (Pb, Zn, Cu and Cr) in the surface soil of three grassed swales decrease with the soil depth. All the metal concentration in soil samples is in the second level limit of soil environment quality standard of china, except the Cu concentration of soil samples from Shenzhen city. The ecological risk of the soil in the three grassed swales examined is in low risk condition. Grassed swale has a significant performance without causing soil heavy metal pollution, at least in short time. However, the long term performance of grassed swale is still unknown and further study is needed. Distribution of heavy metal in soil of grassed swale is the result of natural rainfall and manual maintenance.

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