ZHANG MIN
YANG WU
and
MAO KAINAN

Study on the heavy metals in soil in different functional zones of Ereen

Using plasma emission spectrometer and atom atomic fluorescence spectrometry analysis and the heavy metals of the soil samples, which are scientifically collected in business zone, living zone, agricultural zone and industrial zone of Ereen. The results show that different functional zones of Ereen present different distribution characteristics of heavy metals in soil, As, Cd, Cu, Hg , Zn of industrial zone and Cd in business zone, living zone and agricultural zone are all exceed the national soil environmental quality standards. The content of heavy metals in upper soil is higher than in the subsoil in the study area, which shows that artificial external pollution input potential influence on the soil of Ereen. Agricultural zone of Ereen is less pollution, industrial zone is polluted seriously, commercial and residential both achieve the moderate pollution, thus should strengthen scientific control and governance.

Keywords: *Ereen, different functional zones, heavy metals, distribution characteristics.*

1. Introduction

Because heavy metal is toxic, non-biodegradable and biological availability, the pollution of heavy metal in soil has attracted much attention. It will cause potential impact on water, air, animals and plants if heavy metal enrich in soil, and eventually harm human body directly or indirectly. A large number of studies show that in areas where the content of heavy metal in soil is high, the content of heavy metals in earthworms is also high. The adverse effects of heavy metals on human body mainly include: damage the skeleton, circulation, nerve and endocrine system, change the epithelial tissue sensitivity and immune mechanism, cause cancer, etc. The sources of heavy metals in soil can be divided into natural source and anthropogenic source. In the process of natural soil formation, the heavy metals in rock will redistribute in soil under the physical, chemical and biological effects, which are also known as the background value of soil. At present, the heavy metals in soil mainly comes from human activities, such as mining activities, industrial production, agricultural activities and life emissions. The process of migration behaviour of heavy metals in mining, transportation, use, and waste disposal has been widely studied. Wang studied the heavy metals in soil and plants around the mines, the result shows that the content of heavy metals in plants around mines is higher than other areas [19]. Wu analyzed the distribution characteristics of heavy metals in the soil of typical industrial cities in China, and put forward scientific pollution control measures [20]. Therefore, it is urgent and realistic to study the distribution characteristics and environmental assessment of heavy metals in soil.

The Ereen is located in north-central Mongolia approximately 42 km to SW from the centre of Mandal Soum, Selenge province and 140 km to NNW of Ulaanbaatar, capital of Mongolia. The Dzüünharaa, one of the largest stations on the Trans-Mongolian Railway is located 35km to the north. The main towns in the area are served by good infrastructure including power, water and communications. With the population explosion, the development of urbanization and industrialization, the urban ecological environment of Ereen faces a great challenge; the urban environment problems are increasingly concerned by society. At present, the current situation of heavy metal pollution in soil of Ereen was studied, but the research on soil pollution of different functional zones is limited. Therefore, this study collects soil samples systematically in industrial zone, living zone, business zone and agricultural zone of Ereen, study on the distribution characteristics of heavy metals in soil in different functional zones and evaluate environmental status of soil in different functional zones to provide an important theoretical reference for urban soil environmental protection and management.

2. The general situation and research methods

2.1 Basic situation of Ereen

Ereen deposit is located near to the principal gold deposit in the district, Gatsuurt mine, developed by Centerra Gold Corporation. The Sujigtei fault separates Devonian rhyolites (which host Ereen) in the west from Palaeozoic granites in the east. Therefore, certain Gatsuurt ore controlling features could be similar to Ereen ore-controlling factors. Stratigraphic section of the Ereen area is consecutively represented by

Dr. Zhang Min, Dr. Yang Wu and Dr. Mao Kainan, School of Resources and Environmental engineering ,Guizhou Institute of Technology, China, 1st Caiguan Road, Yunyan District, Guiyang City, Guizhou province. 774762582@qq.com

Cambrian-Ordovician Kharaa group formation, Ordovician-Silurian Undur formation, Silurian Mandal group formation, Devonian Uaan Undur formation, Jurassic-Cretacious Ajnai white fracture formation, lower Cretacious Shariin Gol formation, Quaternary Holocene sedimentary formation. Plutonic rocks are spread moderately in the project area. From the previous research the following groups of plutonic rocks were identified on the basis of the geologic-structural location, stratigraphy deposition and border relation towards each other, petrography, and petrochemical characteristics.

1. Medium late Ordovician Boroo river formation
2. Late Ordovician Ikh Tashir formation
3. Medium Devonian rock formation
4. Permian Guadeloupian small Khentii formation
5. Early Triassic Tukhum formation

2.2 Sampling and testing

According to the respective external environment and the characteristics of different functional zones, using the method of diagonal points collect soil samples, each sample area select 10 sampling points, and in accordance with the 0~20cm and 20~40cm to layered soil profile collection, totally collect 80 samples. According to the CulterLs230 and main soil texture classification standards in China, the soil texture of the samples is distinguished. Takes samples back to the lab, then dries naturally, excludes plant residue and gravel, uses agate pot body for grinding over 100 mesh to prepare for analysis. PH value, soil density, organic matter, total nitrogen and available phosphorus were determined according to the national standard method, the basic properties can be found in Table 1.

As a pretreatment, dispels the soil sample with nitric acid-perchloric acid-hydrofluoric acid mixture liquid. The contents of Cd, Cu, Cr, Pb and Zn are tested by plasma emission spectrometer (ICP-OES), As and Hg are analyzed by atomic fluorescence analyzer (AFS). In the process of analysis, uses blank sample and national soil standard sample to ensure the accuracy of digestion and analysis. The recovery of the elements in the experiment is 95.7%~104.2%.

2.3 Soil environmental quality assessment standard

In order to evaluate the quality of soil environment in different functional zones, this study analyzes the soil environment of the study area by using the single factor index evaluation method, environmental pollution comprehensive index method and Nemero's comprehensive index method [4].

(1) Single factor index evaluation method

$$PI = C_i / S_i$$

Fig.1 Regional geology of Bayangol terrain

Type: PI for pollution index of pollutant i, C_i for the actual content of pollutants i, S_i for the soil evaluation standard.

(2) Soil environmental pollution comprehensive index method

$$P_T = \sum_{i=1}^{n} P_i W_i , \quad \sum_{i=1}^{n} W_i = 1$$

Type: P_T for soil environmental quality comprehensive index with weight, P_i and W_i for pollution index and the weight of pollutant i respectively.

(3) Nemero's comprehensive index method

$$P = \sqrt{\frac{P_i^2 + P_{i\max}^2}{2}}$$

Table 1: The basic properties of the soil in different zones (0-20 cm)

Functional zones	pH	Soil density (g/cm^3)	Organic matter (g/kg)	Nitrogen (g/kg)	Available p (mg/kg)
Business	5.89	1.56	36.8	2.56	54.7
Living	5.85	1.25	37.5	2.38	53.2
Agricultural	5.67	1.53	48.7	3.45	88.5
Industrial	6.47	1.63	44.9	2.76	62.4

TABLE 2: THE CONTENT AND POLLUTION INDEX OF SOIL HEAVY METAL IN DIFFERENT FUNCTIONAL ZONES (mg/kg)

Heavy metal	As	Cd	Cr	Cu	Hg	Pb	Zn
Business	17.7 ±3.9	0.59±0.33	89.8±19.5	36.9±13.2	0.28±0.22	81.3±23.8	149±59
Pollution index	0.59	1.97	0.75	0.74	0.93	0.33	0.75
Living	23.4 ±4.7	0.98±0.47	92.4±23.7	39.4±16.7	0.29±0.24	127±26	171±48
Pollution index	0.78	3.27	0.77	0.79	0.97	0.51	0.86
Agricultural	20.1±5.8	0.36±0.21	79.3±31.6	33.2±15.3	0.16±0.11	94.0±34.2	120±34
Pollution index	0.67	1.2	0.66	0.66	0.53	0.38	0.6
Industrial	72.4±18.6	1.44±0.59	107±37	190±42	1.11±0.56	203±54	245±68
Pollution index	2.41	4.8	0.89	3.8	3.7	0.81	1.23

Type: P for soil pollution ecological risk index, P_i and P_{imax} for the average pollution index and the largest pollution index of pollutant I respectively.

3. The results and discussion

3.1 CONTENT OF SOIL HEAVY METALS IN DIFFERENT FUNCTIONAL ZONES

The content of soil heavy metals in different functional zones can be seen in Table 2. The Table 2 shows that the enrichment of heavy metals in different functional zones showed different characteristics. As (72.4 mg/kg), Cd (1.44 mg/kg), Cr (107 mg/kg), Cu (190 mg/kg), Hg (1.11 mg/kg), Pb (203 mg/kg) and Zn (245 mg/kg) in industrial zone are much higher than living zone, agricultural zone and business zone. The difference is mainly caused by emissions of pollutants in the industrial production. The enterprises in Shifeng area are mainly smelting plant, steel mill and glass foundry, etc. These industries need to burn a lot of coal in combustion process, a large number of heavy metals from coal will be separated into the atmosphere, thus the soil in industrial zone have enrichment heavy metals[8,9,17-19]. Through the comparison of different functional zones, the contents of Cd, Cr, Cu, Hg and Zn are industrial zone > living zone > business zone > agricultural zone, while As and Pb are industrial zone > living zone > agricultural zone >downtown. In general, the industrial zone shows a big difference in soil heavy metals compared to other areas, while the differences of heavy metals in the living zone, business zone and agricultural zone are not obvious.

3.2 THE ECOLOGICAL RISK OF HEAVY METALS IN DIFFERENT FUNCTIONAL ZONES

Through the study on the content of heavy metal in soil, it can provide main data for the evaluation of soil pollution status and predict the ecological risk of soil pollution, thus provide an important reference on preventing soil pollution and protecting ecological environment and human health. Therefore, according to the secondary standard of "National soil environmental quality standard" (GB15618-1995), in this paper, the status of soil pollution is evaluated qualitatively. In the secondary standard, the content of As, Cd, Cr, Cu, Hg, Pb, and Zn are 30 mg/kg, 0.3 mg/kg and 120 mg/kg, 50 mg/kg, 0.3 mg/kg and 250 mg/kg and 200 mg/kg when pH is below 6.5. Comparing heavy metals in soil of the study area with the national soil secondary standard, heavy metals (except Cd) in business zone, living zone and agricultural zone are lower than the secondary standard, while heavy metals (except Cr and Pb) in industrial zone are higher than that of the secondary standard.

The pollution risk index of soil pollutants in different functional zones can be calculated according to the single factor index evaluation method. Table 2 shows that As, Cd, Cu, Hg and zinc exceed bid in industrial zone, Cd exceeds bid in business zone, living zone and agricultural zone, and other elements are within the scope of the standard. Cd is the most serious pollution element in Ereen, its pollution index reached 4.80 in industrial zone, followed by living zone, business zone and agricultural zone with pollution index 3.27, 1.97 and 1.20 respectively. Hg is close to the standard in business zone (0.93) and living zone (0.97), which has potential pollution risk and should monitor the content dynamic variation characteristics constantly.

3.3 THE VERTICAL DISTRIBUTION CHARACTERISTICS OF HEAVY METALS IN SOIL

The pollution index of heavy metals in the upper soil (0~20 cm) and subsoil (20~40 cm) can be seen in Fig.2. In Fig.2, different functional regions show the same characteristics, that is, the upper soil pollution is heavier than the subsoil. Illustrate that the main source of heavy metals in soil in Ereen is human input, instead of endogenous mineral decomposition. These heavy metals were enriched in the surface soil under the action of nature, then into the subsoil in leaching process.

3.4 THE DISTRIBUTION CHARACTERISTICS OF DIFFERENT FUNCTIONAL ZONES

3.4.1 Determination of the weight of evaluation index

Taking the secondary standard of national soil

Table 3: Comprehensive index of soil environmental quality in different functional zones of Ereen

	As	Cd	Cr	Cu	Hg	Pb	Zn	Composite
Business	0.081	0.543	0.053	0.186	0.19	0.013	0.016	1.081
Agricultural	0.092	0.331	0.047	0.167	0.109	0.015	0.013	0.773
Living	0.107	0.901	0.055	0.199	0.197	0.02	0.019	1.497
Industrial	0.33	1.325	0.064	0.958	0.753	0.031	0.027	3.487

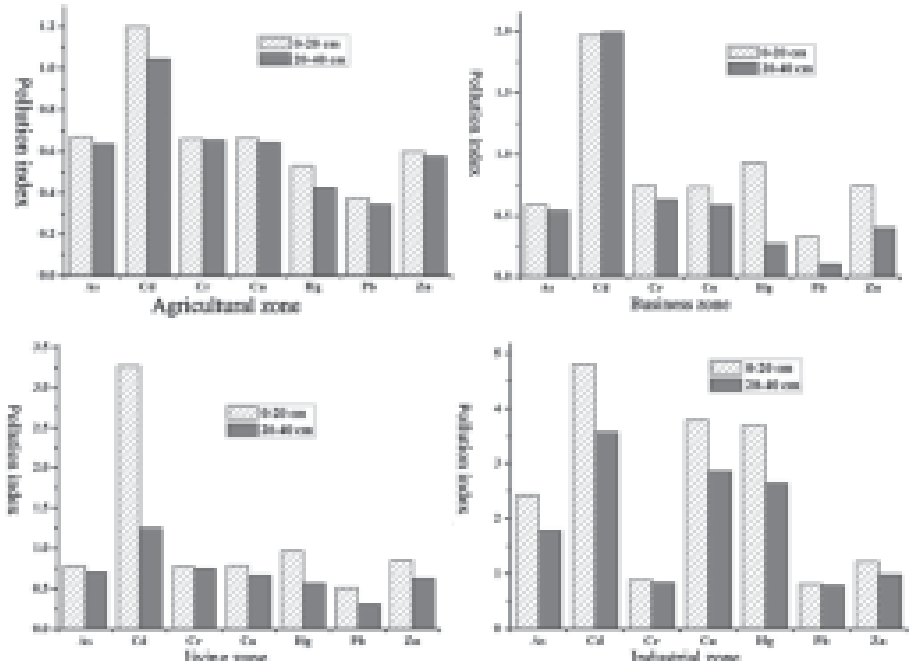

Fig.2 The vertical distribution characteristics of soil heavy metals

environmental quality standard as the evaluation standard, obtains the pollution index of heavy metals in soil in different functional zones of Ereen. Using the factor analysis of SPSS16.0 to analyze the pollution index, we can get the contribution rate and cumulative contribution rate of the principal component of the heavy metal. The calculation results show that contribution rate of the first, second, and third principal components in Ereen are 87.35%, 11.46% and 1.09% respectively. According to the contribution rate of the first principal component, the load of the heavy metals can be calculated, it can be known that the factor loadings of As, Cr, Cu, Hg, Cd, Pb and Zn are 1.176, 2.371, 2.165, 1.748, 0.332, 0.614 and 0.186. Based on the load of each factor in the first principal component, the effect of different heavy metals in soil can be evaluated, and the weight of the different heavy metals can be determined. The calculation result shows that the weight of As, Cd, Cr, Cu, Hg, Pb, and zinc are 0.137, 0.276, 0.071, 0.252, 0.203, 0.039 and 0.021 respectively. It can be found that Cd, Cu, and Hg have a great influence on the soil environment quality of Ereen. Therefore, only soil multi factor analysis can reflect the soil environmental quality scientifically.

Table 4: Classification standard of Ecological risk assessment

Classification	P comprehensive	Pollution levels
1	P comprehensive≤1.3	Non-pollution
2	1.3<P comprehensive≤2.7	Lower
3	2.7<P comprehensive≤7	Moderate
4	P comprehensive >7	Severe

3.4.2 Comprehensive evaluation of soil environmental quality (Table 3)

The comprehensive index model of soil environment quality can synthesize the pollution index of heavy metals in soil in different functional zones of Ereen, thus obtains the soil environment of different functional zones. According to the calculation result, the soil environmental quality comprehensive index of business zone, agriculture zone, living zone and industrial zone is 1.081, 0.773, 1.497 and 3.487, respectively. It is obvious that the soil environmental quality of industrial zone is the worst, followed by business zone and living zone, soil environmental quality of agricultural zone is relatively better.

3.5 Ecological risk assessment of different functional zones

Take the secondary national soil environmental quality standard as the evaluation standard, according to Nemero's comprehensive index method, evaluate the risk index of the upper soil in different functional zones. Through calculation, the ecological risk index of soil environment in business zone, agricultural zone, living zone and industrial zone is 2.86, 1.16, 3.15 and 12.6 respectively. The results show that industrial zone is polluted heavily, business zone and living zone are polluted moderately, and agricultural zone without contamination. Because industrial enterprise in Ereen is mainly for smelting, steel mills, glass factory, chemical plant, boiler plant, etc. These enterprises emit a large number of harmful substances to atmosphere during the process of production, which is an important source of soil pollution in industrial zone. There are a large number of people and motor vehicles in business zone and living zone, causing large exogenous waist and off-gas emissions [2, 18]. The harmful substances in the wastes will enter the soil under the action of natural conditions (weathering, leaching, etc.), thus causing soil pollution.

TABLE 5: ECOLOGICAL RISK INDEX IN DIFFERENT FUNCTIONAL ZONES OF EREEN

	As	Cd	Cr	Cu	Hg	Pb	Zn	Risk index
Business	0.279	0.93	0.354	0.349	0.441	0.154	0.352	2.86
Agricultural	0.165	0.296	0.163	0.164	0.132	0.093	0.148	1.16
Living	0.319	1.338	0.315	0.323	0.396	0.208	0.35	3.25
Industrial	1.724	3.428	0.637	2.714	2.643	0.58	0.875	12.6

7. Conclusion

(1) Through the analysis of heavy metals in soil in different functional areas of Ereen, the contents of heavy metals in different functional areas have different characteristics, and the contents of Cr, Cu, Cd, Hg and Zn show that industrial zone > living zone > business zone > agricultural zone, while As and Pb show that industrial zone > living zone >agricultural zone > business zone.

(2) According to the single factor evaluation of soil in different functional areas, Zn, Cu, Cd, Hg and As in the industrial zone of Ereen exceed bid, and Cd in commercial zone, living zone and agricultural zone all exceed bid, other elements are within the scope of the standard. The enrichment of As, Cd, Cu, Hg and Zn in soil may have a potential impact on plants and human beings.

(3) The content of heavy metals in the upper soil are higher than in the subsoil in all functional zones, which indicates that the input of external artificial pollution is the main source of soil pollution in Ereen.

(4) According to Nemero's comprehensive index method, industrial zone of Ereen is polluted seriously, commercial zone and living zone both achieve.

References

1. Chen, Z. Q., Ai, Y. W. and Fang C. et al. (2014): "Distribution and phytoavailability of heavy metal chemical fractions in artificial soil on rock cut slopes alongside railways [J]." *Journal of Hazardous Materials*, 2014, 273: 165-173.
2. Ha, H., Olson, J. R. and Bian, L. et al. (2014): "Analysis of Heavy Metal Sources in Soil Using Kriging Interpolation on Principal Components [J]." *Environmental Science and Technology*, 2014, 48: 4999-5007.
3. Bech, J., Poschenrieder, C. and Llugany, M. et al. (1997): "Arsenic and heavy metal contamination of soil and vegetation around a copper mine in Northern Peru [J]." *Science of the Total Environment*, 1997, 203: 83-91.
4. Fryer, M., Collins, C. D. and Ferrier H. et al. (2006): "Human exposure modelling for chemical risk assessment: a review of current approaches and research and policy implications [J]." *Environmental Science & Policy*, 2006, 9: 261-274.
5. Shao, X. X., Huang, B. A. and Zhao, Y. C. et al. (2014): "Impacts of human activities and sampling strategies on soil heavy metal distribution in a rapidly developing region of China [J]." *Ecotoxicology and Environmental Safety*, 2014, 104: 1-8.
6. Lough, G. C., Schauer, J. J. and Park, J. S. et al. (2005): "Emissions of metals associated with motor vehicle roadways [J]." *Environmental Science & Technology*, 2005, 39: 826-836.
7. Querol, X., Fernandezturiel, J. L. and Lopezsoler, A. (1995): "Trace-Elements in Coal and Their Behavior during Combustion in a Large Power-Station [J]." *Fuel*, 1995, 74: 331-343.
8. Singh, G. and Paul, B. C. (2001): "Assessment of groundwater quality impacts due to use of coal combustion byproducts to control subsidence from underground mines [J]." *Environmental International*, 2001, 26: 567-571.
9. Wang, X. M., Zhou, C. C., Liu, G. J. and Dong, Z. B. (2013): "Transfer of Metals from Soil to Crops in an Area near a Coal Gangue Pile in the Guqiao Coal Mine, China [J]." *Analytical Letters*, 2013, 46: 1962-1977.
10. Wu, G., Wu, J. Y. and Shao, H. B. (2012): "Hazardous Heavy Metal Distribution in Dahuofang Catchment, Fushun, Liaoning, an Important Industry City in China: A Case Study [J]." *Clean: Soil, Air, Water*, 2012, 40: 1372-1375.