Influence of Soil Forming Process on Element Content of Surface Soil in Yellow River Delta

Yunfeng Zhang [1], Qiang Jia [1, *], Houli Shi [1], Jitao Wang [1], Jianjun Shen [2, 3], Qing Cao [2, 3]

[1] Shandong 5th Geo-mineral Prospecting Institute, Taian, China

[2] College of Chemical Engineering and Safety, Binzhou University, Binzhou, China

[3] Binzhou Key Laboratory of Chemical Process Safety, Binzhou, China

* Corresponding Author Email: caoqing526@163.com

Abstract. In view of the abnormal areas of soil elements and organic pollutants found in the regional distribution, according to the previous sampling and testing results of surface soil, the abnormal areas in the investigation area of the Yellow River Delta were verified by the profile. Through sampling and testing, the vertical distribution of 12 elements, such As, Cr, etc., and the influence of soil forming process on 12 elements were analyzed, and the influencing factors of migration and transformation of heavy metal elements in topsoil were analyzed, which provided scientific basis for soil pollution and prevention.

Keywords: Yellow River Delta, Soil forming process, Elements, element migration

1. Introduction

In recent years, China's economic level has been significantly improved, which has promoted the process of industrialization development and increased the discharge of industrial "three wastes". The excessive use of agricultural chemicals in agricultural production has greatly exceeded the carrying capacity of the environment, and environmental pollution has become a global problem and attracted wide attention [1-3]. In the earth's ecological system, soil is an indispensable part and plays a significant role in the environment [2-4]. If the soil is polluted, it is more common to have heavy metal pollution in the soil, which is extremely harmful. It will not only harm the soil, but also affect the normal growth of crops in the soil, and heavy metal factors will transfer to crops, which will cause great damage to people's body [5,6]. At the same time, soil heavy metal pollution is difficult to repair, once the treatment is not good, it may lead to the soil can't be used. On the one hand, soil metal content is affected by soil parent materials, and on the other hand, human activities (agriculture, industry and transportation activities) also cause metal accumulation [7-11]. It is based on this realistic basis that the study of spatial distribution of soil metal pollution node plays an important role in soil pollution control.

In recent years, scholars at home and abroad collected soil samples from different regions and judged the threat of heavy metals in soil to public health based on health risk assessment indexes [12-15].The spatial distribution of different chemical elements in soil was studied, the surface soil samples were analyzed to determine the major and trace elements in soil, and the pollution degree of regional soil was assessed [16-18].The critical mass ratios of Cd, Cu, Pb and As heavy metals in soils of major types in China and the effects of regional differentiation of environmental capacity were studied by using correlation methods [19,20].Since then, more and more scholars have used multivariate statistical methods to study heavy metal elements in soil [21,22].

Many scholars have focused on the study of soil heavy metal pollution and weakened the influence of surface soil elements during soil formation. In this paper, a large-scale geochemical evaluation of land quality will be carried out to study the influence of soil formation process on surface soil element content.

2. Review of measurement methods and quality

2.1. Test area selection

In this survey area, the site selection is mainly from Binzhou City, which belongs to the hinterland of the Yellow River Delta. The terrain inclines from southwest to northeast, with a natural ratio of 1/7000. The altitude ranges from 14.5m to 6.5m, with the highest altitude of about 14.5m in the southwest and 9m to 10m in the northeast. Most areas in the territory have an altitude of about 11m.The Yellow River runs along its southern border, 10.5km in length. Longitudinally along the Yellow River to the Bohai Sea slightly inclined; Transversely, the main axis of the Yellow River flood plain is formed by the current Yellow River channel belt, which is slightly tilted outwards near the side and forms undulating terrain.

There is a certain connection between soil properties and soil-forming conditions. It is an important basis for soil judgment to comprehensively analyze the formation state and soil layer structure of soil and sort out the results. In view of the regional distribution of soil elements and organic pollutants abnormal areas found in the investigation, the horizontal and vertical soil profiles should be arranged to find out the genetic types and material sources of the anomalies. According to the surface soil test results, the anomalous regions in the Yellow River Delta were verified by section. The horizontal section is 10km and the vertical section is 10m.The horizontal section sampling was 10.2km and the vertical section sampling was 10.27m and the proportion was 102%.104 multi-objective geochemical horizontal profile soil sample collection record cards and 5 multi-objective geochemical vertical profile soil sample collection record cards were formed (100 samples were obtained).

2.2. Principles of sample layout

The soil profile is arranged from the background area through the area with relatively high value of elements, and at the same time, the profile is arranged through as many geological units (land use type or soil type) as possible, and the sampling points are appropriately selected on the horizontal profile to carry out soil vertical profile sampling synchronously. Soil horizontal section sampling interval of 100m; The depth of vertical soil profile collection is determined according to the following conditions.

(1) The investigation area was plain area, and the depth of soil horizontal profile was controlled at 20cm and that of soil vertical profile was controlled at 200cm.

(2) In the soil layer, there is a relatively clear section division, according to different levels of sample collection;

(3) Sampling was carried out at different density nodes based on the different spacing of soil sections.

2.3. Sampling method

(1) The collection and processing of soil horizontal profile survey were carried out in accordance with the collection method of surface soil.

(2) Soil samples from vertical profiles were collected after observation and recording of main profiles. In the vertical section of soil, Luoyang shovel was used for drilling and sampling, and the sampling depth was 2m (depending on the research purpose or whether the parent rock or underground water layer was reached). Soil profile sampling is taken every 20cm from top to bottom. About 1kg samples were collected from each layer. Design workload: 10m, the actual completed workload is 10m.

2.4. Sampling Record

Comprehensive arrangement of recorded data, sorting out the key points, a more detailed differentiation description of the key points, recorded in the soil profile record table, in addition to the number and text content, need to be filled in according to the standard of hierarchical differentiation according to the code. If the large and medium landform is "low hill", it is written as

"Bc”. When the description object requires multiple levels of standard description, use the + sign to combine them. In the soil surface structure, there are not only lumpy structures, but also granular structures, which can be written as "F+J". We strictly implement the technical requirements of 1:50,000 Land Quality Geochemical Investigation and Evaluation (Trial) and other related specifications.

2.5. Sample processing, processing and testing

After the samples are collected, they are dried by air in a ventilated and pollution-free room. After the dried samples are crushed, they are weighed and mixed after screening, and then they are packaged and stored. During storage, sunlight, high temperature, humidity and harmful gas pollution are avoided.

As, Cr, V, Ge, Cd, Hg, Cu, Co, Ni, Zn, Pb and PH were analyzed by X-ray fluorescence spectrometry (XRF), mass spectrometry (ICP-MS) and atomic fluorescence spectrometry (AFS), respectively. All the analyses and tests were carried out in accordance with the technical standards of Shandong Geological Survey: Technical Requirements for 1:50,000 Soil Quality Geochemical Investigation and Evaluation (Trial) and the multi-objective Regional Geochemical Investigation Specifications (1:250,000) of China Geological Survey [DD2005-01].

3. Influence of soil formation process on surface soil element content

The contents of As, Cr, V, Ge and other elements tend to increase with the deepening of soil depth, and the content of the topsoil layer is low while the content of the bottom soil layer is enriched. The soil forming processes affecting the content of these elements are mainly leaching process, podzolization process and rinsing process. In the process of soil formation, soluble salts and other weakly mobile substances (including clay minerals and organic compounds) are leached from the soil body or leached from the upper layer to the lower layer, so that these elements are lost from the topsoil layer and enriched in the bottom layer, forming the leaching process. In the leaching process, the minerals in the soil are destroyed, and the elements migrate chemically to form the deposition layer, and the silica remains on the surface, forming the gray leach layer (podzolic layer) and the deposition layer of iron, aluminum oxide and organic matter, which is the podzolic process in the process of soil formation. The rinsing process refers to the seasonal water stagnation in the upper layer, which causes the reduction of iron and manganese in the soil surface and lateral loss or downward deposition with water. Some iron and manganese nodules are formed in the dry season, gradually decolorizing the surface layer and forming the pale white slurry layer with the highest powdery sand content and poor iron and manganese content, also known as the white slurry process (See Figure 1).

The vertical distribution of Cd, Hg, Cu, Co, Ni, Zn and other elements decreased with the deepening of soil depth, and the contents of these elements were enriched in the topsoil layer and lower in the bottom soil layer. The soil forming processes that affected the contents of these elements were mainly the initiation process, salinization process and organic matter accumulation process. The formation process determines the initial accumulation of these elements on the surface, and the soluble salts in surface water, groundwater and parent materials accumulate in the surface or soil under intense evaporation to form a salinization layer, so that these elements are enriched in the topsoil layer and less in the bottom layer, which is the salinization process in the soil-forming process. Due to the influence of late biological factors, organic matter accumulates on the soil surface and forms dark humus layer or peat layer, which is the accumulation process of organic matter in the soil-forming process (see Figure 2).

The vertical distribution of Pb elements shows that the topsoil and bottom soil layers are enriched while the content of the core soil layer is low. The main soil forming processes affecting the content of Pb elements are initiation process and leaching process. The formation of soil has a certain evolution history, which is mainly a natural medium formed by the differentiation of underground bedrock and microbial action in the long geological activities. Soil parent material is

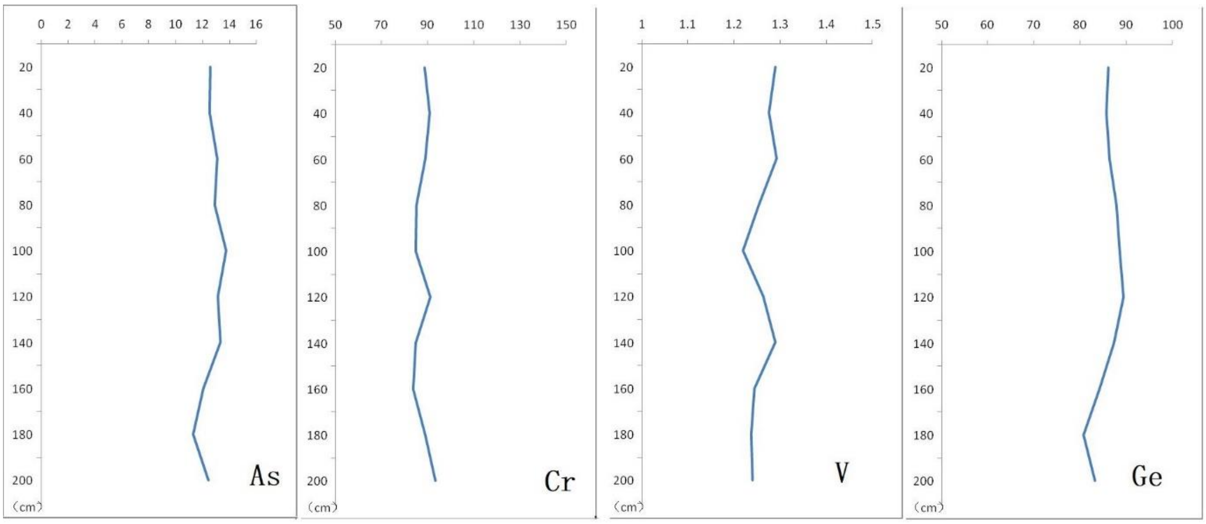

Figure1. Comparison between the distribution of As, Cr, V and Ge elements and the change of soil depth

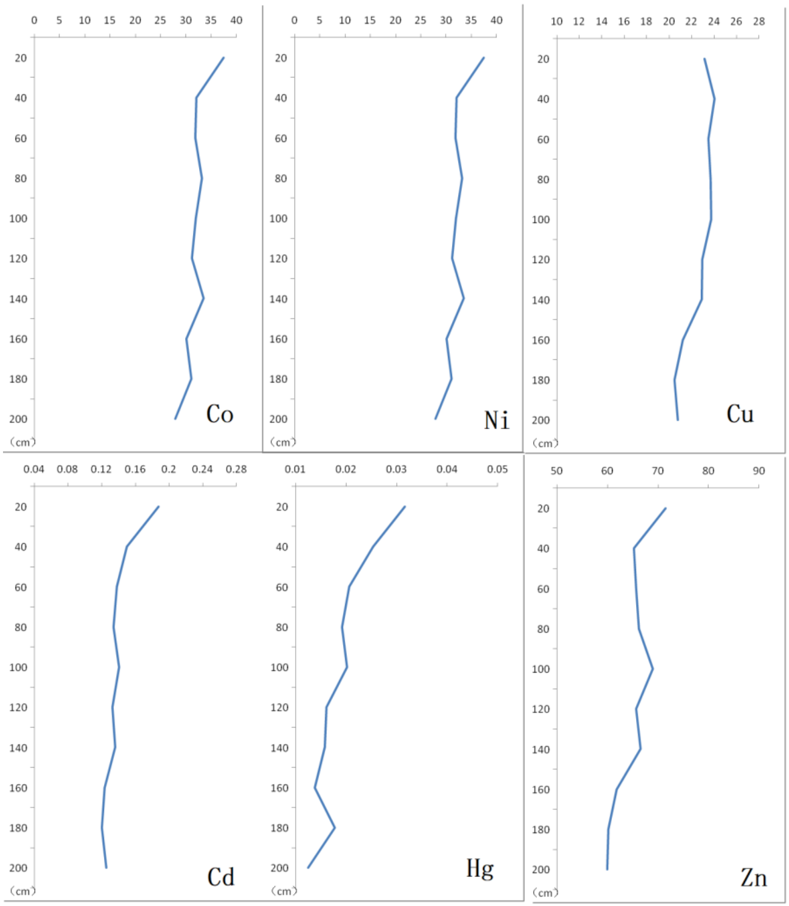

Figure 2. Comparison between the distribution of Co, Ni and other six elements and the change of soil depth

one of the most fundamental factors to control the mass fraction of soil elements, started in bare or weathering of borehole collapse on the raw, and biological accumulation, is the beginning of soil development, is the beginning of the process of soil into the process, again because of interference of biological, human activities such as factors, make the enrichment of the elements in the topsoil, through leaching process of late. Some of them are leached from the upper layer to the lower layer, resulting in a phenomenon of higher content in the top and bottom layers and lower content in the heart layer (see Figure 3).

PH value fluctuates unstable under the influence of soil alkalization, especially in the case of seasonal alternation, the accumulation of sodium ions or magnesium ions at the soil colloid exchange site forms the alkalization layer (or sodic layer). The larger the soil depth is, the larger the PH value will be, as shown in Figure 4.

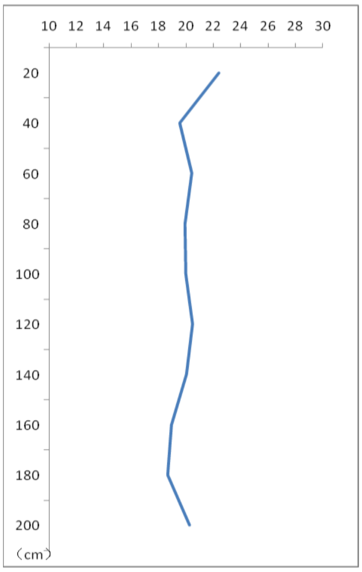

Figure 3. Comparison between Pb content distribution and soil depth change

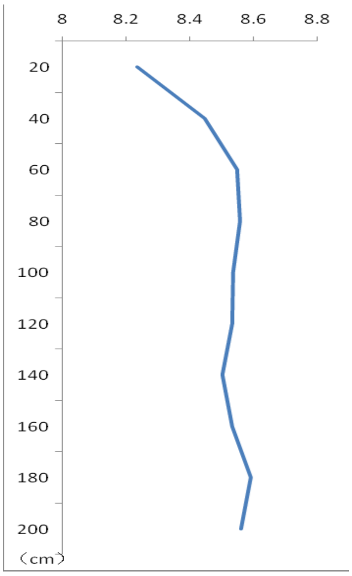

Figure 4. Comparison between PH content distribution and soil depth change

4. Speciation and distribution characteristics of heavy metals in soil and influencing factors of their migration and transformation

The manifestations of heavy metal elements in soil are more diversified, and the chemical morphology of heavy metal elements will be identical with that of different components. Heavy metal elements have a certain relationship with soil properties, pollution sources, climate environment, etc. To some extent, the content of heavy metal elements can reflect the differences in soil chemical properties, and also have a certain impact on the growth of plants. The results of investigation and analysis showed that the forms of heavy metals in soil could be classified as follows: water-soluble state, ion exchange state, carbonate bound state, humic acid bound state, iron-manganese bound state, strong organic bound state and residue state. The properties of heavy metal elements are different in different forms. Water soluble refers to the heavy metal ions in soil solution, which can be extracted by distillation or directly absorbed by plants. Under normal circumstances, the content of heavy metal ions in water soluble state is not high, so it is generally not suitable for separate extraction. The ion exchangeable state is the part that can be nonobligate adsorbed by soil colloid surface and can be replaced by neutral salt, and can also be easily absorbed by plant roots. Carbonate binding state is a very important form in calcareous soils. This state of heavy metal element is affected by soil condition factor is larger, the soil PH value change can affect change in the form of heavy metals, if increase the soil PH value, makes free of heavy metals into carbonate precipitation gradually, if the soil PH value is reduced, the deposition of heavy metals will be diluted, and then absorbed by plants. The binding state of iron and manganese oxides is absorbed by the obligate exchange position of iron and manganese oxides or clay minerals in the soil, which cannot be directly exchanged by neutral salt solution, but can only be replaced by metal ions with stronger affinity than the original. Such heavy metals are not easy to be released and absorbed by plants. Organic binding state refers to the combination of heavy metals with soil organic matter through chemical bonds, which also belongs to obligate adsorption. The residual state refers to the metal ions bound in the lattice of soil silicoaluminate minerals, which are difficult to release and absorb by plants under normal conditions.

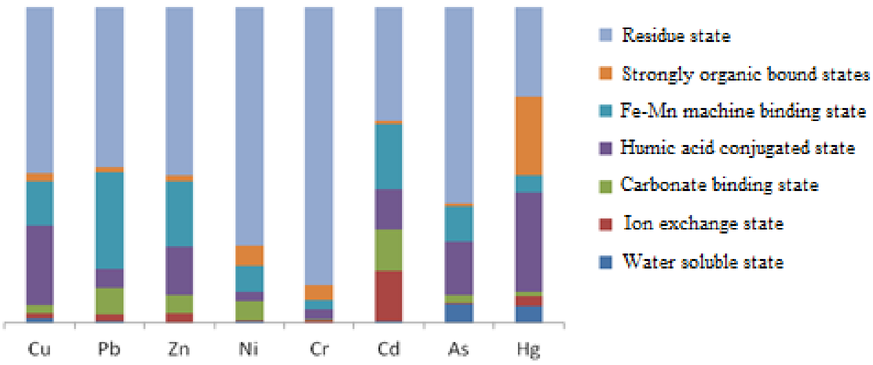

Figure 5. Proportion of heavy metals in topsoil

From the analysis of the collected samples within the regional scope, it can be seen intuitively from Figure 5 that the retained forms of heavy metal elements such as As, Cd, Cr, Cu, Hg, Ni, Pb and Zn in the soil are mainly residues. It is difficult to be absorbed and utilized by plants. The secondary forms of heavy metals such as As, Cu and Hg in soil are humic acid binding state, and the secondary forms of Ni, Pb and Zn in soil are iron and manganese binding state, which are difficult to be absorbed by plants.

5. Conclusion

The contents of As, Cr, V, Ge and other elements are low in the topsoil layer but rich in the bottom soil layer. Leaching, podzolization and rinsing processes affect the contents of As and other elements. The vertical distribution of Cd, Hg, Cu, Co, Ni, Zn decreased with the deepening of soil depth, and the contents of these elements were affected by the formation process, salinization process and organic matter accumulation process. The formation process and leaching process make the vertical distribution of Pb element more concentrated in the topsoil and bottom soil and less in the core soil.

Acknowledgements

The authors gratefully acknowledge the financial support from the Horizontal Fund Project of Binzhou University (BZU2020HXL037)

References

[1] Siegel F R. Environmental Geochemist of Potentially Toxic Metals. Berlin: Springer-Verlag Berlin Heidelberg, 2002, 15-42.

[2] Sun Tieheng, Zhou Qixing, Li Peijun. Pollution ecology [M]. Science Press,2002.

[3] Zhou Guohua, Dong Yanxiang, Liu Zhanyuan, et al. Temporal-spatial variation of elements in soils in the Hangjiahu area. Geology in China,2004,31:72-79.

[4] Yang Wencong, Qi Shihua, Xing Xinli. Spatial Distribution and Source Analysis of Heavy Metal Pollution of Soil in Daye City, Safety and Envionmental Engineering ,2020,27(4):121-127.

[5] Duan X C, Li P, Huang Y, et al. Geochemical characteristics and risk assessment of heavy metals in agricultural soils in Miyun district of Beijing. Geoscience, 2018,32(1):95-104.

[6] Wang Rui, Zhang Fenglei, Xu Shushu, et al. Method of Dividing the Value of Soil Heavy Metal Pollution Risk Screening: Using Cd as an Example. Environmental Science, 2019,40: 5082-5089.

[7] Yin Yimeng, Zhao Weituo, Huang Ting, et al. Distribution Characteristics and Health Risk Assessment of Heavy Metals in a Soil-Rice System in an E-waste Dismantling Area. Environmental Science, 2018,39(2): 916-926.

[8] Li Weidi, Cui Yunxia, Zeng Chengcheng, et al. Pollution Characteristics and Source Analysis of Heavy Metals in Farmland Soils in the Taige Canal Valley. Environmental Science, 2019， 40(11): 5073-5081.

[9] Qu Mingkai, Li Weidong, Zhang Chuanrong, et al. Source apportionment of soil heavy metal Cd based on the combination of receptor model and geostatistics. China Environmental Science, 2013,33(5):854-860.

[10] Cai Limei, Ma Jin, Zhou Yongzhang, et al. Heavy Metal Concentr ations of Agricultural Soils and Vegetables from Dongguan, Guangdong Province, China. Aata Geogyaphica Sinica, 2008, 63(9): 994-1003.

[11] Shu Xin, Li Yan, Li Feng, et al. Impacts of Land Use and Landscape Patterns on Heavy Metal Accumulation in Soil, Environmental Science, 2019,40(5): 2471-2482.

[12] Weigmann G. Heavy metal levels in earthworms of a forest ecosystem influenced by traffic and air pollution [J]. Water, Air and Soil Pollution.1991,57-58(1): 655-663.

[13] Taheri M, Mehrzad J, Afshari R, et al. Geogenic thallium and lead pollution in soils and potential risk of toxicity: A report from Iran[J]. Journal of Research in Medical Sciences,2015, 20(4):420-421.

[14] Muntean E, Muntean N, Miha iescu, T. Cadmium and lead soil pollution in Copsa Mica area in relation with the food chain[J]. Research Journal of Agricultural Science, 2010,42:731-734.

[15] Manceau A, Charlet L, Boisset M C, et al. Sorption and speciation of heavy metals on hydrous Fe and Mn oxides. From microscopic to macroscopic[J]. Applied Clay Science, 1992, 7(1-3):201-223.

[16] Sun Tianhe, Liu Wei, Jin Lijie, et al. Assessment of the heavy metal influential factors based on the multivariate statistical analysis—a case study of the urban and nearby areas of Pinyin County of Jinan, China. Journal of Safety and Environment,2021,21(2):834-840.

[17] Trajce Stafilov, Robert Sajn, Laura Ahmeti. Geochemical characteristics of soil of the city of Skopje, Republic of Macedonia， Journal of Environmental Science and Health. Part A, 2019, 54(10):972–987.

[18] Moataz K , Ahmed G . Assessment of Heavy Metals Contamination in Agricultural Soil of Southwestern Nile Delta, Egypt[J]. Soil and Sediment Contamination: An International Journal, 2018, 27(7):619-642.

[19] Rath D. S., Sahu B. K. Source and distribution of metals in urban soils of Bombay, India, using multivariate statistical techniques[J]. Environmental Geology, 1993, 22 (3):276-285.

[20] Garica R., Maiz I., Millan E.. Heavy Metal Contamination Analysis of Roadsoils and Grasses from Gipuzkoa (Spain) [J]. Environmental Technology, 1996, 17 (7):763-770.

[21] Chen Xiaochen, Cui Yanshan. Small-scale spatial distribution of heavy metals in urban topsoil: A case study in a small area near Shougang group. Journal of the Graduate School of the Chinese Academy of Sciences, 2010,27(2):176-183.

[22] Zhao Xiufang, Zhang Yongshuai, Feng Aiping, et al. Geochemical characteristics and environmental assessment of heavy metal elements in agricultural soil of Anqiu area, Shandong Province. eophysical and Geochemical Exploration, 2020,4(6): 1446-1454.