Characteristics and Potential Ecological Risks of Heavy Metal Pollution in Surface Soil Around Coal-fired Power Plant

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Characteristics and potential ecological risks of heavy metal pollution in surface soil around coal-fired power plant

Abstract: The concentrations of heavy metals (As, Cd, Cr, Cu, Hg, Mn, Pb and Zn) in surface soils in the area surrounding a coal-fired power plant in China were measured, the distribution characteristics of heavy metals in different wind directions were analyzed, and the pollution degree of heavy metal in soil was evaluated. The soil around the power plant is generally polluted by heavy metals, and the degree of pollution is heavy pollution and moderate pollution. The potential ecological hazard of heavy metals in soil is moderate or slight. The values of Nemerow index and potential ecological risk index are different among different directions and different distances from the power plant. Cd, Hg and As are the mainly contributors for the potential ecological risk. The results revealed that wind direction is important for the distribution of heavy metal around coal-fired power plant. The study can provide a theoretical basis for the prevention and management of soil heavy metal pollution around coal-fired power plant.

Key words: Coal-fired power plant, Surface soil, Heavy metal, Spatial distribution, Environmental risk

1. Introduction

As an important medium of material and energy exchange in ecological environment, soil can provide the environment and nutrition for the growth of plants and microorganisms (Adediji et al. 2020; Olatunde et al. 2020). With the development of economy and society, soil environmental quality is increasingly affected by human activities, including intensive industrial and agricultural activities (Chai et al. 2021), and attracted widespread attention (Wu et al. 2021). Heavy metals have stable chemical properties, high toxicity and long incubation period, and the soil pollution process of heavy metals is characterized by concealment, long-term and irreversibility. Soil heavy metal pollution can cause changes in soil composition, structure and function, inhibit crop root growth and photosynthesis, resulting in crop yield reduction or even crop failure (Kouchou et al. 2020; Wang et al. 2021). Meanwhile, it will lead to the accumulation of heavy metals in plants, and eventually enter the human body through the food chain, which posing a serious threat to human health, including lung cancer, bonefractures, kidney dysfunction, and may cause impairments in cholesterol, liver function, nervous, and endocrine systems etc. (Hu et al. 2020a; Hu et al. 2020b). The recovery of soil from heavy metal pollution is difficult for the non-biodegraded of heavy metal, which has become a serious problem in the world (Wang et al. 2020). Soil pollution of heavy metals has attracted extensive attention of society and academia.

The heavy metal pollution of thermal power plants mainly comes from coal combustion (Oral et al. 2019). The emission of heavy metals and their compounds in coal may lead to potential ecological environment impacts including air, water and soil through the medium of flue gas, ash, waste water (Burachevskaya et al. 2019; Zhao et al. 2018). Fly ash particles in the flue gas emitted from coal-fired power plants through chimneys become a major source of environmental pollution due to their migration range and particle size (Burachevskaya et al. 2019; Ćujić et al. 2016). Heavy metals in the atmosphere enter the farmland soil through dry and wet deposition, causing the increase of heavy metals content in the soil (Ćujić et al. 2016; Ćujić et al. 2017; Zhang et al. 2017). A large number of studies have reported heavy metal pollution in the surrounding soil caused by coal-fired power plants (Burachevskaya et al. 2019; Deng et al. 2014; Fu et al. 2019; Tang et al. 2012). Huainan is a typical mineral resource-based city in East China and an important

base for the development of heavy industry in East China. The installed capacity of thermal power generation in Huainan City is 14.343 million kilowatts in 2019. Although the coal-fired power plants have implemented ultra clean emission facilities, the heavy metal pollution accumulated by long-term emission in the past has not been effectively controlled(Zhao et al. 2018). Meanwhile, most of the research on heavy metal pollution in soil environment of Huainan City is concentrated in the surrounding mining areas, and the soil heavy metal pollution around coal-fired power plants in this area needs further study. It is necessary to conduct a systematic study on the heavy metal pollution in the soil around a power plant to provide useful information for the rational utilization and pollution control of the soil around the power plant.

In order to understand and evaluate the pollution status of heavy metals in the soil around the power plant, according to the fan-shaped sampling principle of point source, soil samples were collected from the surrounding area of Pingwei coal-fired power plant, which was built in 1984. Single factor pollution index method, Nemero pollution index method and potential ecological hazard index method were used to comprehensively analyze and evaluate the environmental quality, heavy metal pollution degree and potential ecological risk of the soil. The results are important for clarify the agricultural risk of the surrounding area and provide an important scientific basis for the rational use of land resources, improve the ecological security level of soil environment around the power plant, prevent and control soil heavy metal pollution, protect the health of urban people. Meanwhile, it also provides a reference for the supervision of environmental pollution caused by point source pollution in other similar areas and the ecological restoration of soil around a power plant.

2. Materials and methods

2.1. Study area and soil sampling

The power plant is located in Pingwei Town, Panji District, Huainan City. The area where the power plant is located is plain with flat terrain, inclined from northwest to southeast, belonging to warm temperate semi humid monsoon climate. The annual dominant wind direction is northeast wind, and the secondary dominant wind direction is east wind. The annual average wind speed is 2.2m/s. The soil around the power plant is farmland, and there are no other pollution sources around the power plant.

Twelve soil samples were collected from 500, 1000 and 1500 m away from the chimney of the power plant at the angle of 45 ° between the upwind (northeast), downwind (southwest), downwind (due West) and downwind (due south) of the dominant wind. 8 control samples in agricultural land were collected in the area far away from the power plant (Fig. 1). There is no potential pollution source in the sampling area of the control samples. According to the Sample collection specification of Technical rules for monitoring of environmental quality of farmland soil(NY/T359-2012), the stainless steel soil sampler was used to collect soil samples. Double sampling was conducted for each sample, and 0-20 cm topsoil was collected by plum blossom sampling method. The mixed soil samples were collected at each sampling point and transported back to the laboratory without damage and pollution. Sampling records shall be made in detail. The sampling was carried out in August 2019.

2.2 Sample analysis and quality control

The soil samples were pretreated according to Technical specification for soil environmental monitoring (HJ/T 166-2004) . After removing the gravel and plant residues, the samples were placed in a cool place for air drying, grinding, passing through 100 mesh sieve and dry storage.

The contents of Cu, Zn, Cd, Pb and Cr were determined by inductively coupled plasma spectrometer (Thermo, ICP-AES), As was determined by ultraviolet spectrophotometry (Agilent Cary 3500), and Hg was determined by cold atomic absorption spectrometry (Aula254-gold). Standard addition recovery and repeated measurement were used for quality control. The recovery of each element ranged from 93.5% to 105.6%, and the deviation of repeated measurement ranged from 0.1% to 9.5%. The analysis figures were drawn with Origin 9.0, and the related statistical analysis was carried out with SPSS 19.0.

2.3 Evaluation method

2.3.1 Single gene index method

Single gene index method is used to evaluate the pollution degree of a heavy metal in soil, which can reflect the average pollution level of each heavy metal in soil comprehensively. The calculation formula is as follows:

$$P_i = C_i / C_{i0} \quad (1)$$

Where P_i is the pollution index of heavy metal i in soil; C_i is the measured concentration of heavy metal i (mg/kg), C_{i0} is the background value of heavy metal i in soil of Anhui Province (mg/kg). The grading criteria are shown in Table 1.

2.3.2 Nemero pollution index method

Nemero pollution index method is a multi-factor environmental quality index method considering the maximum value, which reflects the comprehensive pollution of heavy metals in soil. According to the following formula:

$$PI = \sqrt{(P_{max}^2 + P_{ave}^2) / 2} \quad (2)$$

where PI is Nemero pollution index; P_{max} is the maximum value of single factor index of heavy metals; P_{ave} is the average value of single factor index of heavy metals. The classification standard of Nemero pollution index method is shown in Table 1.

2.3.3 Potential ecological hazard index method

The potential ecological hazard index proposed by Hakanson (Lars and Hakanson 1980) can reflect the impact potential of heavy metals on the ecological environment comprehensively. The calculation formula is as follows:

$$RI = \sum E_r^i \quad (3)$$

$$E_r^i = T_r^i C_f^i \quad (4)$$

$$C_f^i = C_0^i C_n^i \quad (5)$$

where RI is the sum of all heavy metal risk factors in sediment; E_r^i is the potential ecological hazard index of heavy metal i , T_r^i is the toxicity coefficient of heavy metal i , the toxicity coefficients of As, Mn, Cd, Cr, Cu, Pb, Zn and Hg were 10, 1, 30, 2, 5, 5, 1 and 40. C_0^i is the content of heavy metal.

RI was adjusted according to the grading standard of literature (Lü et al. 2019). According to Hakanson's first grading value 150 divided by the total toxicity coefficient 133 of eight pollutants (PCB, Hg, Cd, As, Pb, Cu, Cr and Zn), the RI grading value of unit toxicity coefficient is 1.13; the RI grading value of unit toxicity coefficient is 1.13 multiplied by the total toxicity coefficient 94 of eight heavy metals in this study, and the integer value is obtained $RI=106$ (First level limit), and the remaining limit values of each level can be obtained by multiplying the upper limit value by 2. The RI classification standard is shown in Table 1.

3 Results and discussion

3.1 Characteristics of heavy metal in the selected soil

The average pH value of soil samples was 6.88 (6.42-7.68). The concentrations of heavy metals in the soil around the power plant are shown in Table 2. The concentration range for each metal was: 62.58 to 142.37 mg/kg for Cr, 12.39 to 30.49 mg/kg for Cu, 355.24 to 499.32 mg/kg for Mn, 8.22 to 10.98 mg/kg for Pb, 46.39 to 97.29 mg/kg for Zn, 0.004 to 0.0361 mg/kg for Hg, 13.27 to 17.91 mg/kg for As, 1.65 to 3.66 mg/kg for Cd. The order of average content is: Mn > Cr > Zn > Cu > As > Pb > Cd > Hg. The average contents of As, Mn, Cd, Cr, Cu, Zn and Hg exceeded the background values of soil in Anhui Province. Comparing the concentrations and background level of heavy metals with the soil of unpolluted sites in the area can characterize the impact of human activities (Hu et al. 2020b). The average concentration of Cr in the soil around the power plant is 1.7 times of the background value, and the average concentration of Cd is 2.9 times of the background value. The concentration of Cd in two samples exceeded the risk screening value (0.30 mg / kg) of $6.5 < \text{pH} \leq 7.5$ specified in GB 15618-2018 standard for soil pollution risk control of agricultural land, with an average exceeding multiple of 1.18. Compared with the research reports on the soil around other coal-fired power plants at home and abroad (Table 4), the average concentrations of Cd and Hg in the soil around the power plant are lower than those reported in the literature. It may be due to the different composition and amount of coal used in different power plants, which leads to some differences in the concentrations of heavy metals in the soil around the coal-fired power plants.

3.2 Distribution of heavy metals in different wind directions

The distribution characteristics of heavy metals in soil of different wind directions around the coal-fired power plant are shown in Figure 2. The contents of Cr, Cd, Hg and As in the soil around the coal-fired power plant showed obvious spatial distribution differences in different wind directions, which are consistent with the distribution characteristics of point source of pollutants, and consistent with the conclusion of many studies, the distribution pattern matched the predominant wind directions. Some similar researches confirmed that the maximum heavy metals contents in the soils around power plants within or close to the predominant wind direction (Ćujić et al. 2016; Ćujić et al. 2017; Dragović et al. 2013; Tanić et al. 2018). Previous studies have shown that coal-burning power plant is one of the main sources of Hg emission (Perez et al. 2019; Rodríguez Martín and Nanos 2016). The observed trend of Hg content in four wind directions of coal-fired power plant are found, the soil in the upwind direction of dominant wind (northeast direction) is the smallest, and the downwind direction of active wind (southwest direction) is the largest with the highest at 1000m. The element diffuses with the downwind direction of air pollutants, and finally slowly settles in the southeast direction of the power plant through the atmosphere (Keegan et al. 2006; Rodríguez-Iruretagoiena et al. 2015). The concentration gradually decreases with the increase of the distance from the power plant, which is consistent with the conclusion of some literatures (José et al. 2013; Perez et al. 2019; Rodríguez Martín and Nanos 2016).

3.3 Single factor index and Nemerow pollution index

The classification results of soil single factor index and Nemerow pollution index around power plant are shown in Table 5. It indicated that the soil around the power plant is generally polluted by heavy metals, and the degree of pollution is heavy pollution and moderate pollution. With the long-term coal combustion of the coal-fired power plant, the heavy element of As, Cd and Pb with high volatility in the selected soils are higher than the control point, and the content

distribution is different in various wind directions.

From the single factor index, the P_i of each heavy metal is 0.58-7.4, and that of the control point is 0.28-1.43. Among them, the P_i of Cd ranged from 1.8 to 7.4, ranging from slight pollution to heavy pollution, with the maximum value at 1000 m downwind of the dominant wind and the control point of light pollution (1.1). The P_i of As at 1000 m downwind of the dominant wind and 500 m downwind of 45° of the dominant wind are 2.72 and 2.55, respectively, belonging to moderate pollution, with the control point of slight pollution 0.9; The P_i of Hg at 1000 m downwind of the dominant wind with a highest value of 2.07, which belong to moderate pollution, and the control point is clean (0.97); the other five heavy metals are no pollution or slight pollution (0.76 ~ 2.27) in each sampling point, and the control point is clean or slight pollution (0.32 ~ 1.43).

According to Nemero pollution index, the PI of dominant downwind direction, sub-dominant downwind direction, and downwind direction of dominant wind 45 ° angle are 2.01, 1.70 and 1.67, respectively, which belonged to moderate pollution, slight pollution, slight pollution, respectively. PI of dominant upwind direction is 1.41, which belonged to slight pollution. The PI of control point is 1.02, which belonged to slight pollution. Although the pollution level is slight pollution, but the values of PI are different. The pollution degree is as follows: dominant downwind direction > sub-dominant downwind direction > downwind direction of dominant wind 45° angle > dominant upwind direction > control point.

3.4 Potential ecological hazard index

The potential ecological hazard index of heavy metals in the soil around the power plant is shown in Table 5. The potential ecological hazard of Cd and Hg in the soil around the power plant is moderate or strong. According to the potential ecological hazard index of heavy metals, the E_r^i of Cd at the dominant downwind wind, sub-dominant downwind direction and downwind direction of dominant wind 45° angle of 1000 m were 222, 129 and 141, which is a very strong ecological hazard. The control point is a moderate ecological hazard (34); The E_r^i of Hg at 1000 m downwind of the dominant wind is 83, which is a strong ecological hazard; the E_r^i at 500 m of sub-dominant downwind direction and downwind direction of dominant wind 45° angle are 63 and 65, respectively, which belong to strong ecological hazard. The control point is a moderate ecological hazard (39); the other six heavy metals are slight ecological hazards (7-27).

According to the comprehensive potential ecological hazard index of heavy metals, the RI of dominant downwind direction, sub-dominant downwind direction are 293 and 218, respectively, which belonged to strong ecological hazard. The RI of downwind direction of dominant wind 45 ° angle and dominant upwind direction are 210 and 155, respectively, which belonged to medium ecological hazard. The RI of control point is 96, belongs to slight ecological hazard. The contribution of different heavy metals to RI is different, and Cd, Hg and As are in the top three. and the contribution rate of Cd and Hg is 60.3% at downwind of the dominant wind. Lǔ et al. reported that Cd, Hg and As contribute to 81.2% of the potential ecological hazards in Anhui (Lǔ et al. 2019).

3.5 Correlation analysis of heavy metals

Correlation analysis is widely used to identify the sources of heavy metals in soil. The results of Pearson correlation analysis are shown in Table 6. The Pearson correlation matrix of heavy metals and soil properties is presented in Table 4. There is obviously positive correlation ($P < 0.01$) with correlation coefficients higher than 0.4 between the following heavy metals: As vs. Pb

(0.761), Hg (0.773), Cd (0.896); Hg vs. Pb (0.639), Cd (0.782). The strong correlation among elements indicates that As, Hg, Cd and Pb around the coal-fired power plants may have the same migration pathway, or have the same pollution sources, showing a trend of compound pollution(Ćujić et al. 2017; Rodriguez Martin and Nanos 2016). There is a significant negative correlation between Mn vs. Cr(-0.634), Cu(-0.447), which indicates that the source of Mn is different from other heavy metal elements. It may come from geological weathering, which is greatly affected by the parent material, but relatively less affected by the external environment(Hao et al. 2017).

3.7 Cluster analysis of heavy metals

The cluster analysis of eight heavy metal elements is carried out by using the method of inter group average for variable standardization and the distance measurement using the square Euclidean distance. The similarity of data can be reflected by the distance between data, and the understanding of different sources of heavy metals can be obtained. The agglomeration schedule of HCA is presented in the dendrogram (Fig. 3). The results show that As, Cd, Hg and Pb are associated within one cluster in the soil around the power plant. These elements have similar behavior, both in their distribution in raw coal and soil around the power plant(Dragović et al. 2013). Second cluster consisted of Cu and Mn. Third cluster consisted of Cr and Zn. In the soil of control point, Cr, Cu, Zn, As, Cd, Hg and Pb are clustered into one group, while Mn is a self-contained one. Mn is among the most abundant trace elements in the Earth's crust and usually used as a marker element of soil natural source, which is less affected by external interference, and mainly affected by geological weathering and soil forming process(Tanić et al. 2018).

4 Conclusion

The concentration range for each metal is: 62.58 to 142.37mg/kg for Cr, 12.39 to 30.49 mg/kg for Cu, 355.24 to 499.32 mg/kg for Mn, 8.22 to 10.98 mg/kg for Pb, 46.39 to 97.29 mg/kg for Zn, 0.004 to 0.0361 mg/kg for Hg, 13.27 to 17.91 mg/kg for As, 1.65 to 3.66 mg/kg for Cd. The order of average content is Mn > Cr > Zn > Cu > As > Pb > Cd > Hg. The contents of Cr, Cd, Hg and As in the soil around the coal-fired power plant showed obviously spatial distribution differences in different wind directions.

From the single factor index, the P_i of each heavy metal is 0.58-7.4, and that of the control point is 0.28-1.43. Among them, the P_i of Cd ranged from 1.8 to 7.4, ranging from slight pollution to heavy pollution. The PI of dominant downwind direction, sub-dominant downwind direction, and downwind direction of dominant wind 45 ° angle are 2.01, 1.70 and 1.67, respectively, which belonged to moderate pollution, slight pollution, slight pollution. PI of dominant upwind direction is 1.41, which belonged to slight pollution. The PI of control point is 1.02, which belonged to slight pollution. Although the pollution level of heavy metals in different wind directions is the same, the value of PI is different. The pollution degree for different wind directions is dominant downwind direction > sub-dominant downwind direction > downwind direction of dominant wind 45° angle > dominant upwind direction > control point.

The RI of dominant downwind direction, sub-dominant downwind direction are higher than other wind direction with values of 293 and 218, respectively, which belonged to strong ecological hazard. The contribution of different heavy metals to RI are different. The results of correlation analysis and cluster analysis show that the heavy metal pollution around the power plant is mainly caused by coal-fired emissions, and Mn may be caused by geological reasons.

The study helps to better understand and evaluate the distribution and pollution status of

heavy metals in the surface soil around coal-fired power plants, and emphasizes the need for further research on human and environmental health. It can also provide a reference for the soil environmental control in the study area, and also affords a useful lesson for the reasonable utilization and pollution control of the soil around the power plant in other similar areas.

CRedit authorship contribution statement

Yunhu Hu: Writing - original draft, Writing - review & editing. **Mu You:** Supervision, Visualization, Methodology. **Guijian Liu:** Supervision, Writing - review & editing. **Zhongbing Dong:** Project administration, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- Adedeji OH, Olayinka OO, Tope-Ajayi OO, Adekoya AS (2020) Assessing spatial distribution, potential ecological and human health risks of soil heavy metals contamination around a Trailer Park in Nigeria Scientific African 10 doi:10.1016/j.sciaf.2020.e00650
- Burachevskaya M et al. (2019) Study of copper, lead, and zinc speciation in the Haplic Chernozem surrounding coal-fired power plant Applied Geochemistry 104:102–108 doi:10.1016/j.apgeochem.2019.03.016
- Chai L, Wang Y, Wang X, Ma L, Cheng Z, Su L (2021) Pollution characteristics, spatial distributions, and source apportionment of heavy metals in cultivated soil in Lanzhou, China Ecological Indicators 125 doi:10.1016/j.ecolind.2021.107507
- Ćujić M, Dragović S, Đorđević M, Dragović R, Gajić B (2016) Environmental assessment of heavy metals around the largest coal fired power plant in Serbia Catena 139:44–52 doi:10.1016/j.catena.2015.12.001
- Ćujić M, Dragović S, Đorđević M, Dragović R, Gajić B (2017) Reprint of "Environmental assessment of heavy metals around the largest coal fired power plant in Serbia" Catena 148:26–34 doi:10.1016/j.catena.2015.12.018
- Deng S et al. (2014) Emission characteristics of Cd, Pb and Mn from coal combustion: Field study at coal-fired power plants in China Fuel Processing Technology 126:469–475 doi:10.1016/j.fuproc.2014.06.009
- Dragović S, Ćujić M, Slavković-Beškoski L, Gajić B, Bajat B, Kilibarda M, Onjia A (2013)

- Trace element distribution in surface soils from a coal burning power production area: A case study from the largest power plant site in Serbia *Catena* 104:288–296 doi:10.1016/j.catena.2012.12.004
- Fu B, Liu G, Mian MM, Sun M, Wu D (2019) Characteristics and speciation of heavy metals in fly ash and FGD gypsum from Chinese coal-fired power plants *Fuel* 251:593–602 doi:10.1016/j.fuel.2019.04.055
- Hao Y, Li Q, Pan Y, Liu Z, Wu S, Xu Y, Qian G (2017) Heavy metals distribution characteristics of FGD gypsum samples from Shanxi province 12 coal-fired power plants and its potential environmental impacts *Fuel* 209:238–245 doi:10.1016/j.fuel.2017.07.094
- Hu B et al. (2020a) Current status, spatial features, health risks, and potential driving factors of soil heavy metal pollution in China at province level *Environ Pollut* 266:114961 doi:10.1016/j.envpol.2020.114961
- Hu Y, He K, Sun Z, Chen G, Cheng H (2020b) Quantitative source apportionment of heavy metal(loid)s in the agricultural soils of an industrializing region and associated model uncertainty *J Hazard Mater* 391:122244 doi:10.1016/j.jhazmat.2020.122244
- José et al. (2013) Source Identification of Soil Mercury in the Spanish Islands *Archives of Environmental Contamination & Toxicology*
- Keegan TJ et al. (2006) Dispersion of As and selected heavy metals around a coal-burning power station in central Slovakia *Sci Total Environ* 358:61–71 doi:10.1016/j.scitotenv.2005.03.020
- Kouchou A, Ghachtouli NE, Duplay J, Ghazi M, Rais N (2020) Evaluation of the environmental and human health risk related to metallic contamination in agricultural soils in the Mediterranean semi-arid area (Saiss plain, Morocco) *Environmental Earth Sciences* 79
- Lars, Hakanson (1980) An ecological risk index for aquatic pollution control. a sedimentological approach *Water Research*
- Lǚ Z, Zhang J, Zou T, Liu K, Wang M, Zhang H (2019) Characteristics and evaluation of heavy metal pollution in soil around coal-fired power plants *Journal of Environmental Engineering Technology* 9(6):720–731 doi:In Chinese, abstract in English.
- Olatunde KA, Sosanya PA, Bada BS, Ojekunle ZO, Abdussalaam SA (2020) Distribution and ecological risk assessment of heavy metals in soils around a major cement factory, Ibese, Nigeria *Scientific African* 9 doi:10.1016/j.sciaf.2020.e00496
- Oral R et al. (2019) Soil pollution and toxicity in an area affected by emissions from a bauxite processing plant and a power plant in Gardanne (southern France) *Ecotoxicol Environ Saf* 170:55–61 doi:10.1016/j.ecoenv.2018.11.122
- Perez PA, Hintelmann H, Lobos G, Bravo MA (2019) Mercury and methylmercury levels in soils associated with coal-fired power plants in central-northern Chile *Chemosphere* 237:124535 doi:10.1016/j.chemosphere.2019.124535
- Rodriguez-Iruretagoiena A et al. (2015) Fate of hazardous elements in agricultural soils surrounding a coal power plant complex from Santa Catarina (Brazil) *Science of The Total Environment* 508:374–382 doi:10.1016/j.scitotenv.2014.12.015

- Rodriguez Martin JA, Nanos N (2016) Soil as an archive of coal-fired power plant mercury deposition J Hazard Mater 308:131-138 doi:10.1016/j.jhazmat.2016.01.026
- Rodríguez Martín JA, Nanos N (2016) Soil as an archive of coal-fired power plant mercury deposition Journal of Hazardous Materials 308:131-138
- Tang Q, Liu G, Yan Z, Sun R (2012) Distribution and fate of environmentally sensitive elements (arsenic, mercury, stibium and selenium) in coal-fired power plants at Huainan, Anhui, China Fuel 95:334-339 doi:10.1016/j.fuel.2011.12.052
- Tanić MN, Ćujić MR, Gajić BA, Daković MZ, Dragović SD (2018) Content of the potentially harmful elements in soil around the major coal-fired power plant in Serbia: relation to soil characteristics, evaluation of spatial distribution and source apportionment Environmental Earth Sciences 77 doi:10.1007/s12665-017-7214-4
- Wang Y, Duan X, Wang L (2020) Spatial distribution and source analysis of heavy metals in soils influenced by industrial enterprise distribution: Case study in Jiangsu Province Sci Total Environ 710:134953 doi:10.1016/j.scitotenv.2019.134953
- Wang Y, Guo G, Zhang D, Lei M (2021) An integrated method for source apportionment of heavy metal(loid)s in agricultural soils and model uncertainty analysis Environ Pollut 276:116666 doi:10.1016/j.envpol.2021.116666
- Wu J, Zhou Q, Huang R, Wu K, Li Z (2021) Contrasting impacts of mobilisation and immobilisation amendments on soil health and heavy metal transfer to food chain Ecotoxicol Environ Saf 209:111836 doi:10.1016/j.ecoenv.2020.111836
- Zhang Y, Shang P, Wang J, Norris P, Romero CE, Pan W-p (2017) Trace element (Hg, As, Cr, Cd, Pb) distribution and speciation in coal-fired power plants Fuel 208:647-654 doi:10.1016/j.fuel.2017.07.064
- Zhao S et al. (2018) Emission characteristic and transformation mechanism of hazardous trace elements in a coal-fired power plant Fuel 214:597-606 doi:10.1016/j.fuel.2017.09.093

Fig. 1 Sampling sites of soil around the coal-fired power plant and control points.

Fig. 2 Concentrations of the heavy metals in soil from different distances of the power plant.

Fig. 3 Cluster analysis of heavy metals dendrogram in soil samples surrounding the coal-fired power plant.

Figures

Figure 1

Sampling sites of soil around the coal-fired power plant and control points. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Concentrations of the heavy metals in soil from different distances of the power plant.

(a) Power plant

(b) Control point

Figure 3

Cluster analysis of heavy metals dendrogram in soil samples surrounding the coal-fired power plant.

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