Seasonal Variation of Heavy Metal Distribution in Soils around Erdenet Mining Area, Mongolia

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Abstract

The objective of this study is to investigate seasonal variations of heavy metals in surface soils of Erdenet mining area and to assess the soil environmental quality. After appropriate preparation, all surface soil samples were analyzed for major and heavy metals by X-Ray Fluorescence (XRF) Spectrometry. Soil texture, conductivity (EC), pH, total organic carbon (TC) and nitrogen (TN) contents were also measured. The enrichment factor (EF) was estimated to assess the level of the contamination and the possible anthropogenic impact in soils from the mining activity. The EF_{soil} for Cu, As and Pb were in the highest values around industrial areas, indicating that around mining area surface soils were highly enriched by those elements. From the results of correlation analysis, it was observed different types of correlations between soil-heavy metal and soil-season. This study showed that environmental assessment around mining area give a serious attention to local government and responsible environmental regulation bodies.

Keywords: Seasonal variation, Heavy metals, Soil, mining, Contamination

1. INTRODUCTION

Mining of minerals and metals is important in all industrialized and developing countries. In the past century, much of mining has concentrated on the extraction of metals (M.N. Rashed, 2010)

Erdenet is second largest industrial and mining city with 100 thousand populations in Mongolia, which is located in the northern part of the country, it lies in a valley between the Selenge and Orkhon rivers about 400km northwest of Ulaanbaatar, the capital city. The city was built in 1975 to exploit Asia's largest deposit of copper ore and has the fourth largest copper mine in the world. The "Erdenet Mining Corporation" is a joint Mongolian-Russian venture, and accounts for a majority of Mongolia's hard currency income. Erdenet city is divided into three distinct urban zones, the ger district (Mongolian traditional nomadic housing), the residential zone and the industrial zone. The residential zone is itself divided into 6 districts while a 7th is under planning. Around 50% of the 110,000 inhabitants of the city still live in gers while the rest live in the old "Russian" apartments. Erdenet has two coal powered power stations with one dedicated to the operations of the mine while the other operates for the benefit of the city. Many research groups are working under the environmental situation of the Erdenet city. Ganbold G. et al. (Ganbold et.al., 2006) analyzed by INAA method 39 elements in soil and river silt samples from polluted area and river around Erdenet town. The results of this study were show that water around Erdenet city is polluted by the industrial liquid waste from the Erdenet Mining Corporation. The Erdenet mine in north central Mongolia is one of the largest porphyry copper- molybdenum deposits in East Asia (Dejidmaa et.al., 1998). The ore is mined from an open pit, and

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copper (Cu) and molybdenum (Mo) are concentrated using mostly flotation and partly solvent extraction and electro-winning (SX/EW) methods. Residues (tailings) are pumped to a tailings dam where the fluids are allowed to drain and evaporate. They may be subject to wind erosion because of the low precipitation and high evaporation rates in the semi-arid Erdenet area.

The purpose of this study is to provide (i) to investigate contamination level around industry and industrial areas areas by using surface soil analysis; (ii) to assess the environmental pollution effect to the non-industrial or residential area; (iii) to estimate the seasonal variation of heavy metals on environment; (iv) to do correlation analysis between analyzed characteristics.

2. EXPERIMENTAL

2.1. Study area

The study area, Erdenet mining industrial area is located in the northern part of the Mongolia at the distance about 400km northwest from the capital city Ulaanbaatar of Mongolia (north latitude 49.1°, east longitude 104.1°), where the "Erdenet Mining Corporation" is a joint Mongolian-Russian venture is conducted. Erdenet city is divided into three distinct urban zones, the ger district (Mongolian traditional nomadic housing), the residential zone and the industrial zone. The residential zone is itself divided into 6 districts while a 7th is under planning. We divided sampling site into the residential and industrial areas. Sampling was carried out between March 2011 and December 2011.

2.2. Sampling

The sampling location points are sketched in the map of Fig.1. To provide a satisfactory geographical and human activity representation of the site, the sampling area for surface soils was subdivided into four areas: residential area (R), industrial areas (IA1, IA2, IA3); which represents the influence of mining activity.

Twenty soils were sampled by hand auger from the ground surface (0.2-10 cm) just to avoid the effect of elements migration with the wind. The soil samples were air-dried and sieved by 2mm sieve prior to chemical analysis.

2.3. Analytical methods

The chemical properties of soil samples were investigated by using the standard methods of analytical chemistry. Soil pH was measured by glass electrode of pH-meter (Toko, TPX-90i, Japan) in water and in 1M-KCl using soil to solution ratio of 1:2.5, respectively. Electrical conductivity (EC) was measured by conductivity meter (Horiba, EC-51, Japan) in the suspension with soil to water ratio of 1:5. The TC and TN content were analyzed using a CN analyzer. Texture was investigated by using the pipette method (ISO, 2001). Elemental analysis of soil samples was carried out by X-Ray Fluorescence (XRF) Spectrometry.

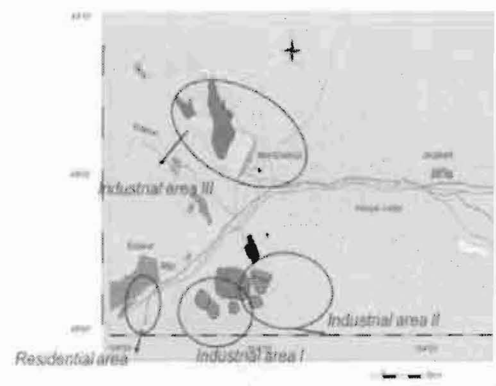

Fig.1. Sampling area

The relationship between metal concentrations in soil samples for four seasons was tested by Pearson correlation coefficients (r). Coefficients of correlation were calculated at the significance level $P \leq 0.05$.

3. RESULTS AND DISCUSSION

Soil pH and moisture contents are given in Fig 2. The content of moisture was higher in spring season for industrial area III.

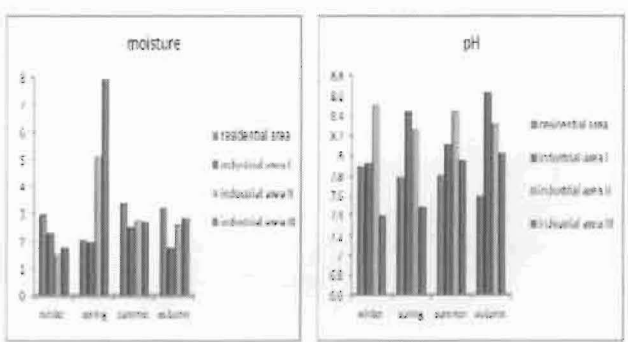

Fig 2. The pH and EC contents for studied areas

The results showed slightly alkaline values varying from 7.45 to 8.62. The ratio of total carbon and nitrogen (C/N) varied from 13.5 to 44.4. The relative percentage of clay, silt and sand in the soils were in the range 0.53 - 27.57%, 10.89 - 38.18%, and 41.85-78.57%, respectively. Almost soils were classified as clay and silty clay loam. The soil samples in this study showed alkaline pH and high Ca content, suggesting that considerable amount of $CaCO_3$ might be present in these soils. The alkaline pH of the soils in the study area and high content of calcium play an important role in metal stability, in such a way that there is no transfer of soluble heavy metals and they are being only mobilized in particulate form. Consequently, the decreases in pH mobilize significant amount of the metals which are present in these soils since carbonates are one of the major sinks for heavy metals (Li X .and Thornton I. 2001). The behavior and bioavailability of the heavy metals in soil is primarily controlled by pH. Figure 3 shows concentrations of Cu and As in different sites of the studied areas. In the industrial areas, however, the average concentrations of Cu was extremely higher than the world average of 90 mg kg^{-1} respectively, reported by Bowen (Bowen, 1979). The As content was for studied areas varied from 12 to 56 mg kg^{-1} which higher lower than world average of 35 mg kg^{-1}. Soil texture has a major influence on trace metal concentrations, with heavy textured soils higher concentrations of Cd, Co, Cr, Cu, Ni and Zn then light soils having higher Pb concentrations than other soils (Zhao F.J. and Grath S.P.Mc 2007). A major source of the heavy metals in the gold-mining area is oxidation of sulphide minerals since most of the metals are known to occur mainly as sulphides and associated with gold-ore. In the process of ore crushing and other mining activities these heavy metals can be released in the environment.

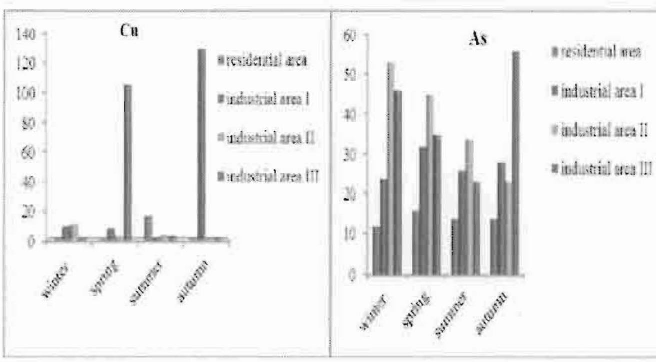

Fig 3. The Cu and As contents of soil samples for studied areas.

The highest content of Cu and As was in autumn around the industrial areas I and III, respectively.

Finally, we used enrichment factor (EF) to assess the level of the contamination and the possible anthropogenic impact in soils from the mining activity. To identify anomalous metal concentration, geochemical normalization of the heavy metals data to a conservative element, such as Al, Fe, and Si were employed. Several authors have successfully used iron to normalize heavy metal contaminants (Mucha A.P., et al., 2003; S.R.Oliva et al. 2007). In this study iron was also used as a conservative element to differentiate natural from anthropogenic components. The enrichment factor of soil (EF_{soil}), is relative abundance, with regards to Iron, of one element (M) in a soil compared to its relative abundance (M/Fe) in control site: $EF_{soil}=(M/Fe)_{soil}/(M/Fe)_{control}$. The EF_{soil} for Cu, As and Pb were highest values around industrial areas, indicating that around mining area soil were highly enriched by those elements.

More interesting information has been deprived from correlation analysis between contents of determined elements for different studied areas. The considerably significant high correlation was observed between As-Cu for industrial area II and III (r = 0.927) which reflects the presence of heavy metals in the minerals in soils of these areas. .

4. CONCLUSION

The surface soil samples in this study showed alkaline pH and high Ca content, suggesting that considerable amount of CaCO3 might be present in these soils. The soil of industrial areas is polluted by heavy metals such as Cu, As and Pb. The highest content of Cu and As was in autumn around the industrial areas I and III, respectively. The significant correlation was observed between As-Cu for industrial area II and III (r = 0.927) which reflects the presence of heavy metals in the minerals in soils of these areas. This study showed that environmental assessment around mining area give a serious attention to local government and responsible environmental regulation bodies.

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