Soil environmental issues of coal-mining in Baganuur and Nalaikh, Mongolia

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Abstract. This study focuses on the environmental issues of mining (related) activities in Mongolia, with a focus on soils in the coal mining areas of Baganuur and Nalaikh. Besides the ecological components (including erosion), also the socio-economic conditions are of importance for the derivation of recommendations for a better understanding and management of Mongolia's environment.
The soil features in both research sites are generally good, heavy metal concentrations are within the guidelines, accept for Arsenic (As) showing increased values. The Geoaccumulation index and the Surface enrichment factor indicate no major influence of mining activities on the soil quality around the mining.
However, soil erosion increases near mining sites, which can have a negative impact on soil quality. Studying the long-term effects of mining on the soil and environment in Mongolia is one of the country's most important concerns. In this context, the aspect of rehabilitation in mining areas is becoming more and more important in Mongolian society. Ecological and especially geotechnical recommendations for the management of Baganuur's and Nalaikh's environment are of importance for the stakeholders.

Keywords: Coal mining, Rehabilitation, Soils, Erosion, Arsenic

1 Introduction

1.1 State of the art

The mining industry plays a crucial role in Mongolia's economy, with coal being the country's most important raw material. About 23% of Mongolia's GDP depends on coal exports. Mongolia has more than 300 known coal deposits with estimated geological coal resources of 150 billion tons, of which about 20 billion tons have been explored [1]. Among the coal deposits, the largest known coal mine in Mongolia is Erdenes Tavan Tolgoi with 6.4 billion tons of coal reserves, followed by Shivee-Ovoo mine with 646 million tons and Baganuur mine with 600 million tons of reserves [10].
Although mining is the most important economic factor in Mongolia, it is also the main cause of increasing environmental problems such as soil pollution, air pollution, white dust, soil erosion, land degradation and water pollution. In recent years, there has been increasing concern about the impact of mining on the environment and human health

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in Mongolia. Studies on environmental issues related to mining have already been conducted in Mongolia's largest mining areas. Mining-related pollution has been linked to bioaccumulation in plants and various species of wildlife and livestock and leads to an increase in public health problems [4, 11]. Due to massive expansion of soil erosion and transportation for mining production, soil degradation is a serious problem in the country, and few studies have been conducted to define soil erosion and soil degradation in Mongolia [7, 5, 3, 15].

Therefore, the environmental problems caused by mining in Mongolia remain the main issue and should be studied in more detail. In addition, the study and monitoring of the long-term effects of mining on the soil and environment in Mongolia is crucial. The aspect of rehabilitation of mining areas is becoming more and more important in Mongolian society. In Mongolia, rehabilitation concepts for the larger mining areas are regulated in the country's mining and environmental laws and regulations and are being implemented in some mining areas. However, such concepts are not available for smaller mines and especially for ninja mines such as Nalaikh, although the necessity is given and generally accepted. Therefore, an appropriate rehabilitation concept and regulation is also needed for small mining sites, which should be investigated in further studies. The main objective of this study is to summarize the current state of the environment, especially the soil, related to the coal mining sites in Baganuur and Nalaikh.

1.2 Study sites

The study area is one of the largest open pit mines in Mongolia and its surroundings in Baganuur, and the Nalaikh mining license area (abandoned mine site).

1.2.1 Nalaikh coal mine

The Nalaikh mine is located about 40 km east of Ulaanbaatar (see Fig. 1). It was established in 1922 and was the first industrial mining operation in Mongolia. The former mine was closed in 1990. In large parts outside the areas marked in Fig. 1, grazing takes place, within the Mining Licence Area (marked in red) there is no other land use than mining.
Coal reserves are estimated at about 24 million tons. In recent years starting in 2000, many small artisanal mines operated by private companies and people (ninja miners) at shallow depths to provide good-quality coal to customers in Nalaikh District and Ulaanbaatar City [1]. During the peak winter season, up to 2.000 "ninja miners" worked in about 300 pit holes. Nalaikh coal accounted for about 70% of the 1 million tons of coal burned each year in UB's Ger District. However, during this time, there were a number of deaths and injuries at the Nalaikh mine due to unsafe operations. In the last three years, the illegal Nalaikh mines has been closed and some of the degraded areas have been filled with coal ash, and some degraded areas are now becoming landfill sites in the Nalaikh district.

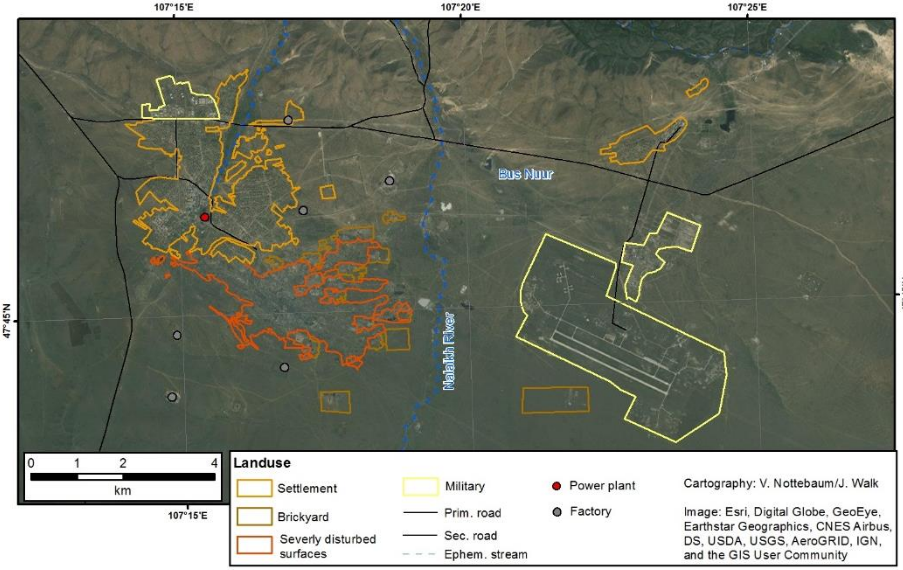

Fig. 1. Nalaikh coal mining licence area (red marked). [11]

1.2.2 Baganuur coal open-pit mine

Baganuur coal mine is located about 130 km from the city of Ulaanbaatar (see Fig. 2). The mine was established in 1978 and is one of the most important mines in Mongolia, providing most of the coal needed in the central region of Mongolia for use in thermal power plants, which supply the country's main electricity needs, and about 70% of the coal needed to run the power plants in Ulaanbaatar city [2]. In this study a total of 48 soil samples were collected from the top layer of the soils around the mining sites (Fig. 2). The samples show that the soil texture in this area is mainly sandy.

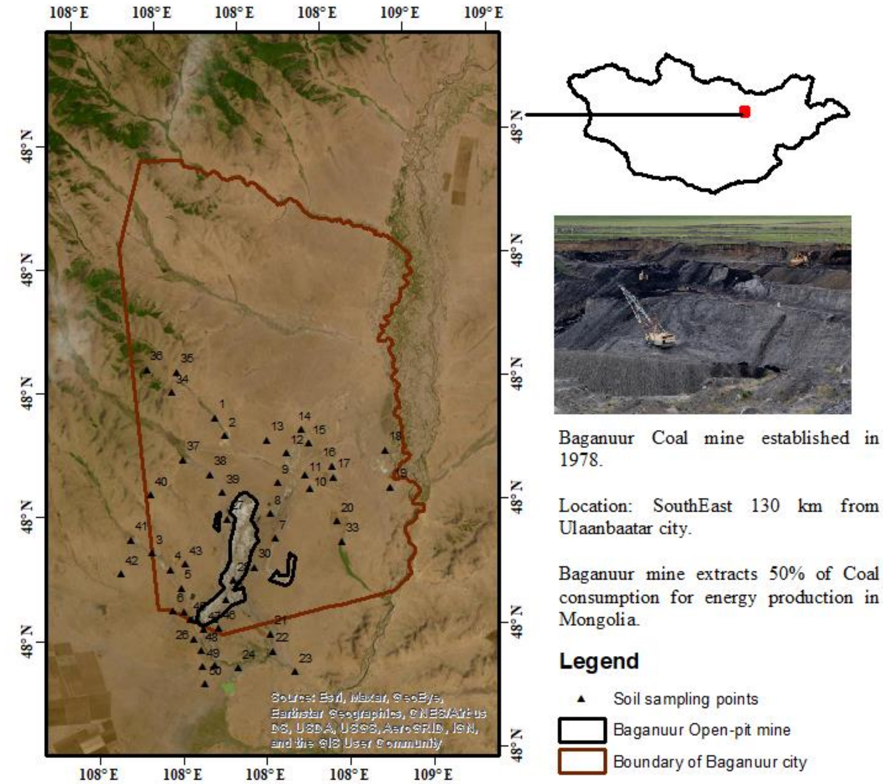

Fig. 2. Baganuur Open-pit mine and soil samplings locations. [15]

2 Data and methods

In Nalaikh a total of 28 topsoil sampling sites were described and sampled mainly in October 2018, with an analytical focus on heavy-metal distribution. Sampling took place in 2 depths (0-5 cm and 5-15 cm), in order to calculate several indices like Surface enrichment (SE) or Geoaccumulation index (I_{geo}). Several soil catenas were sampled Using the NW-SE catena as an example, an aeolian distribution of the heavy metals was assumed according to the main wind direction.
In the Baganuur research site soil samples (48 locations) were collected to determine soil texture and organic matter content. Satellite images (Landsat 4-5, Landsat 7-8) as well as Digital Elevation Models (DEM) were used to define Normalized Difference Vegetation Index (NDVI).

Soil quality analysis was defined based on the geoaccumulation index (I_{geo}) using the following equation:

$I_{geo} = \ln(C)$ (1)

$C = value/ (reference (8,6) * 1,5)$

>2 moderate - heavily contaminated; >1-2 moderate contaminated; >0-1 not - moderate contaminated;

<0 not contaminated

The Surface enrichment (for arsenic) factor is calculated using the following equation:

$SE_{As} = topsoil / subsoil$ (2)

where, topsoil: 0-5 cm; subsoil 5-15 cm

$0.5 \leq EF \leq 1.3$ As concentration may come entirely from natural processes; $EF > 1.3$ a significant portion of As was delivered from anthropogenic sources/ activities

The estimation of soil loss was calculated based on monthly rainfall and vegetation data using the following equation by Schmidt et al. 2019.

$$A_{month} = R_{month} \times K \times LS \times C_{month} \times P \quad (3)$$

where, A_{month} – monthly describes soil loss in t ha^{-1} $month^{-1}$; K-soil erodibility factor (MJ mm ha^{-1} h^{-1} $month^{-1}$) (calculated based on Soil texture, Organic matter); LS-Topographic steepness factor (calculated based on DEM); C_{month}-Land cover management factor (calculated based on vegetation index-NDVI); P-the support and conservation factor (not influential, P=1).

3 Results and discussion

3.1 Nalaikh

The soil samples show a silty-sandy texture. pH value range between 5.42 and 8.67 in the upper topsoil (0-5 cm), in the lower topsoil (5-15 cm) the highest pH value reaching 9.19. The natural (undisturbed) soils are mostly Kastanozems, which are of a good to very good quality.

The heavy metal contents of all samples were below the MNS [8]. As some publications of coal mining areas discuss elevated arsenic concentrations and since Nalaikh coal also has comparably high arsenic levels, further focus of the heavy metal calculations (Surface enrichment SE, Geoaccumulation I_{geo}) is on spatial distribution patterns of arsenic in soils and sediments.

The results of I_{geo} values of Nalaikh soils and sediments as well as SE_{As} values in topsoil samples are shown in Fig. 3.

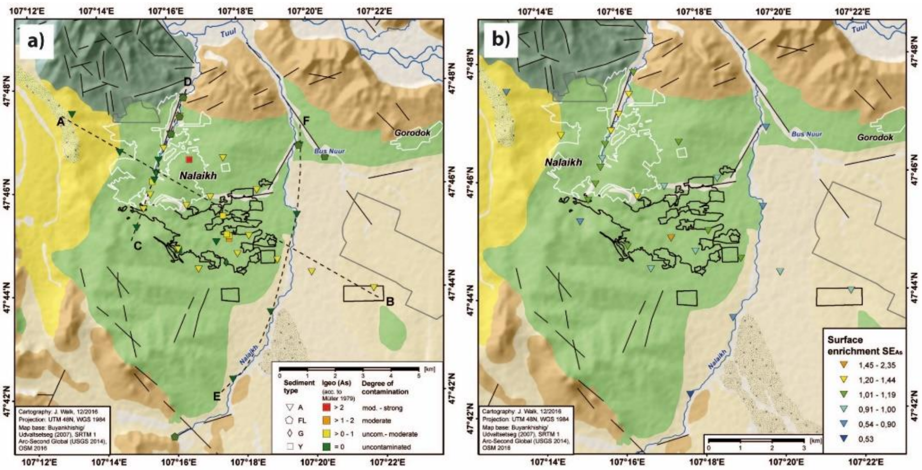

Fig. 3. Results of I_{geo} and SE in Nalaikh; a) I_{geo} values, b) SE values calculated from two depths (0-5, 5-15 cm). Dashed lines indicate cross sections. [11]

According to I_{geo} [9], especially the samples from the mining area and the urban area of Nalaikh show uncontaminated to moderately contaminated soils and sediments (Fig. 3a). Along the Nalaikh River, the results show no downstream trend. Samples outside populated areas have mostly uncontaminated values, while contaminated to moderately contaminated topsoils occur near the mining area. This indicates a general accumulation of As in the soils around the area of mining activities. The NW-SE transect (A-B) follows the main wind direction. A slight increase in As concentration and corresponding I_{geo} can be seen as the transect crosses the Nalaikh urban area and the adjacent mining area. Soils along the Nalaikh River generally do not show systematic accumulation of As.

In and around Nalaikh, As enrichment in soils and sediments can be considered low and without serious threats to the environmental compartments. However, geoaccumulation and surface enrichment confirm distribution mainly to the southeast from Nalaikh, along the main wind direction. This suggests an aeolian distribution pathway between a source (city of Nalaikh, power plant, ger settlements, mining area) and the depositional areas to the southeast.

3.2 Baganuur

In the Baganuur area, the soil texture was generally defined as sandy soil, and only a few soil samples were loamy and sandy loam. Based on the soil samples, 92% of the area is sand and 8% is loamy sand and sandy loam. Regarding the results of heavy metals in Baganuur, Zn and As in Baganuur are above the maximum values for these metals specified in the Mongolian soil quality standard [8]. Soil erosion estimation was used to illustrate the rate of soil loss during periods of high and low rainfall (see Fig. 4).

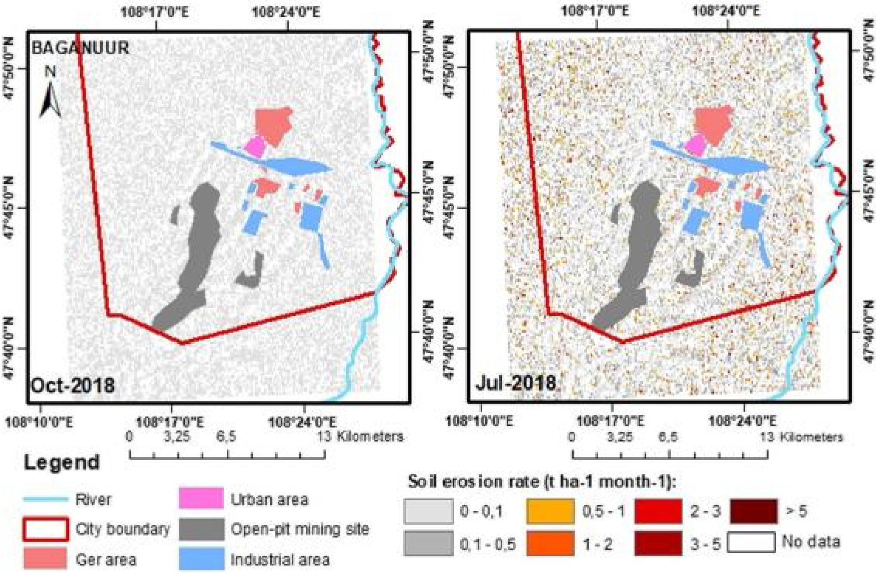

Fig. 4. Soil loss during the high and less precipitation month. [15]

In recent years, soil erosion and degradation in Mongolia have increased due to climatic factors and anthropogenic influences, with mining being one of the main contributors. For example, increased erosion potential has been detected in and around the Baganuur coal mine. In the Baganuur mining area, however, surface runoff flows from the northwest to the southeast through the open-pit mining area. It continues to flow into the Kherlen river and therefore poses a risk of pollution. The southern part of the Baganuur open-pit mine borders the town of Bayandelger city (soum), where livestock and agriculture are practiced. There is a high risk of soils and river pollution due to soil erosion and sediment transport from the mining sites. This may further adversely affect the health of local people, livestock and wildlife. Therefore, further studies need to be conducted to determine heavy metal contamination of soil and water along the surface runoff and sediment accumulation around the mining areas.

4 Conclusion

Soil analysis in the project areas focuses on heavy metal content, additional soil features were analyzed. In general, there is little ecological impact of the mining activities on the environment in Baganuur and Nalaikh. Erosional processes should be critically monitored since they have a high potential for pollution.

Anyway, ecological and especially geotechnical recommendations for the management of Baganuur's and Nalaikh's environment are of importance for the stakeholders. However, such recommendations should not only be derived from a consideration of environmental issues alone, but should also consider the socio-economic (including legislation) and technical conditions in the study area in order to give recommendations for a better understanding and management of Mongolia's environment.

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