Ecological reconstruction of fly ash and slag landfills in order to achieve ecological coherence between degraded ecosystems and Natura 2000 sites

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Abstract

Purpose. Main purpose is remediation of Bacau slag and fly ash landfill located in an ecologically sensitive area nearby Natura 2000 sites.

Research question is what kind of habitat restoration measures at the landfill site to improve the habitat quality of the area in order to improve overall connectivity between the Natura 2000 designated sites.

*Methods.*Heavy metals were determined in fly ash and slag using SRISO 11047-99 method. Soil samples were taken from three deep: 0-5 cm, 15-20 cm and 30-35cm from surrounding area. Heavy metals were doused with total forms atomic absorption spectrometry method. By multichannel gamma spectrometry were determined radionuclide's content of coal and its by-products.

*Result.*The values for heavy metals content obtained from soil sampled area compared with analysis of fly ash are higher than normal, but below the alert threshold for less sensitive soils (Cu, Cr, Ni, Zn, Pb). Assessment of the natural radionuclide concentrations in both the coal and the waste resulting from combustion within the limits of the literature cited is somewhat higher than the soil in the area.

*Conclusions.*Bacau slag and fly ash landfill's location between two Natura 2000 sites, on the Carpathian migratory corridor leads to necessity to be apply habitat restoration measures at the landfill site in order to improve the habitat quality of the area, thus favoring the presence of protected bird species, and at the same time to improve overall connectivity between the Natura 2000 designated sites.

Keywords: coal, fly ash, Natura 2000, green infrastructure.

1. Introduction

Fly ash and slag, a result of combustion of coal at high temperature, are non-hazardous industrial waste. Commercialization of the waste was attempted, but without success, so the only solution remained was disposal. Large area occupied by landfiil and usually placement in the riverbed of important rivers had a negative impact on the environment. Moreover, after Romania's Assecion to EU Natura 2000 sites were declared and some declered sites become nearby this kind of contaminated sites.

In Romania, around 6% of industrial landfills are located on the shores of some watercourses.

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Following alignment with European environmental rules were imposed and revising the current exhaust systems transport and storage of products resulting from the combustion of coal and some power plants have dropped the use of coal.
The Bacau slag and fly ash landfill's location in the Riverbed of the River Siret, near the three Special Protected Areas of Community importance: (1) ROSPA0063 *Buhusi-Bacau-Beresti* Lakes, consisting of five lakes on Bistrita and Siret River, (2) ROSCI0434 Middle Siret Valley extended in 2016 and (3) ROSPA0072 Middle Siret Valley where the Bistrita River basin merges with Siret River. This location in a ecologically sensitive area implies the need to remediate the contaminated site.

2. Material and methods

Study area. The slag and fly ash landfill is placed outside Bacau City. The landfill is located at 4 kilometers distance of the thermal power plant Bacau, eastward, in the Riverbed of the Siret River in a relatively flat area with an average altitude of 142.50 to 143.00 meters.
The slag and fly ash landfill began operating in the year 1986. Previously, the land was used as agricultural land. The area of the landfill consists of a mosaic of agricultural, aquatic and forest ecosystems.

The climate and natural phenomena. As regards the relief, the middle basin of the Siret River's climate varies greatly, both from north to south, and especially from west to east.

The middle Siret River Valley, which is the lowest stage of relief from the area, has a harsher climate in the floodplain and low terraces, totally different of the East and of the West regions.

The average annual temperature in the city of Bacau is 10ºC, the average for January being - 6ºC, and for July, + 20ºC. An absolute minimum value of -32, 5ºC was recorded in 1954, and an absolute maximum value of 38, 8ºC was recorded in 1952.

The average annual wind frequency shows a predominance of air movement from N, NW, and NE. Wind speed is generally higher during winter when cold air masses travel from the Siberian region. Average annual wind speed is below 6 meters / second.

In particular the Siret River Valley corridor generates channeling airflow, which highlights certain microclimate features during the year due to deviations from the mean air temperature, thermal inversions in winter and reduced rainfall.

Ground water is confined within the horizon of coarse gravel with boulders and sand, and a high permeability, its level being recorded at varying depths in the range of 1.5 - 3.5 meters. The vertical natural variation of this level can be regarded as minor, since it does not exceed 0.5 m.

Geology, seismicity. In terms of geomorphology, The Bacau Thermal Power plant is located on the main riverbed of BistritaRiver, mainly characterized by the presence of alluvial deposits with a thickness of 4 to 5 meters.The site where the Thermal Power Plant was built is classified as Grade 8 in seismicity.In the east (Totova Hills - Plateau of Barlad) towards the SE-NW direction soils mainly exist of cambic (leachate), gray and brown soils.Within the Siret and Bistrita Valleys extensive areas of marshy alluvial soil, in meadows, or cambics and grey soils on terraces are observed.The entire thermal power plant site is made up of alluvial deposits of 8-12 m thick, consisting of gravel, sand and boulders, which includes a layer of 8-12m of alluvial soils resting on a thin lens of sandy clay insulated

surfaces and low thickness, lens sandy clay, muddy.The hydrostatic level is located in permeable sand and gravel deposits at a depth ranging from 4.70 to 5.50 meters below the benchmark.

Soil. Hills with altitudes of 500-600 meters are bordering both sides of the Siret valley. These landforms have developed out of clay-alluvial soils classes. In some places, depending on the parent material eu-mesobasic brown soils were formed. Soil cover and relief differs throughout the study area due to environmental conditions.

Hydrology. The main rivers that drain the territory around the city of Bacau are Bistrita and Siret Rivers, the city is located on the right bank of the lower course of Bistrita River before the confluence with Siret River.

Annual and monthly rainfall varies quite importantly. In Bacau County the annual average quantities increase from 550 mm in the eastern region to 1000 mm on the western mountain peaks. Between these two extremes the average annual values lies between 600 and 800 millimeter.

Vegetation. The area of the landfill consists of a mosaic of agricultural, aquatic and forest ecosystems. Across the landfill surface, water meadows appear, aspen and alder, scatteredamong mesophilic pastures and crops are common, the most prominent crops being cereals and corn. Grasslands are well represented. The hills are covered with hardwood, especially beech.

On 1st of January 2007, Romania became a member of the European Union. The quality of a Member State implies both rights and obligations, including the declaration of Natura 2000 sites.

The declaration of Sites of Community Importance starting with 2007 placed the fly ash and slag landfill nearby (fig.1).

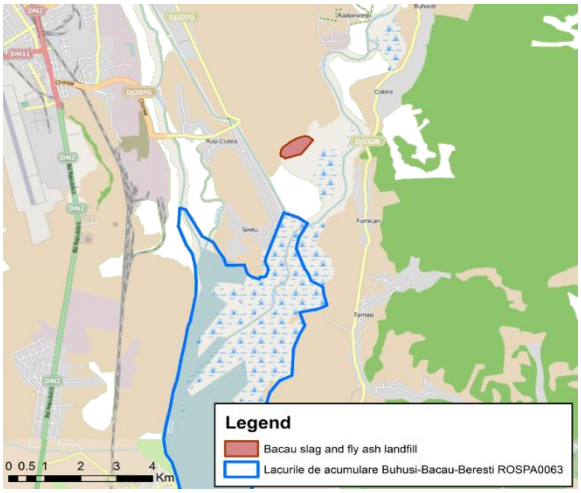

Fig.1 Location of fly ash and slag landfill (year 2007)

Fly ash and slag landfill is also located on the Carpathian migratory corridor (fig.2) In order to have long–term resilience to external threats; the species of conservative interest need to be able to circulate within the protected areas in the hydrographic subbasin Bistrita, in connection to the hydrographic basin Siret.

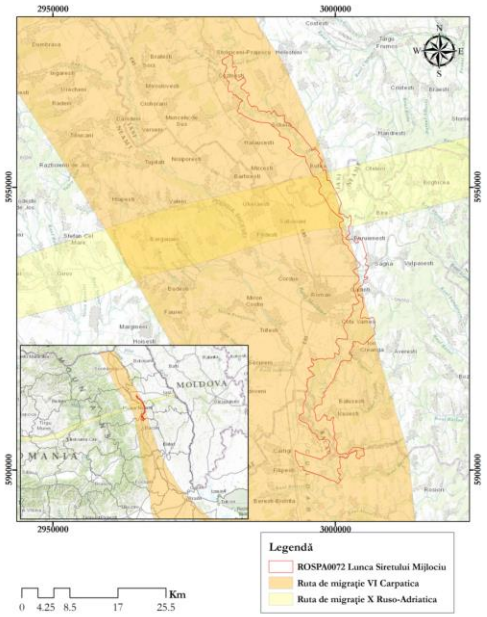

Fig. 2 Main migration routes crossing the Natura 2000 site ROSPA0072 *Middle Siret Valley*

Bacau slag and fly ash landfill fragments habitats which are the source of food and nesting for identified bird's species in the ROSPA0072, ROSPA0063. Some of these species are threatened and important EU species*: Cygnus cygnus, Sterna hirundo, Circus aeruginosus, Actitis hypoleucos.* According to the management Plans (*http://www.apmbc.anpm.ro*) for ROSPA0063 *Buhusi-Bacau-Beresti Lakes* and ROSPA0072 *Middle Siret Valley*, despite the presence of an impressive number of bird species of conservative value, as well as of a high percentage of natural and semi-natural ecosystems, the sites suffer from significant anthropic pressures that determine the existence of an unfavorable conservation state for the species of community interest. In 2016 new Natura 2000 site was declared ROSCI0434 Middle Siret Valley and the limit of the new site are at the landfill's limit.(fig.3)

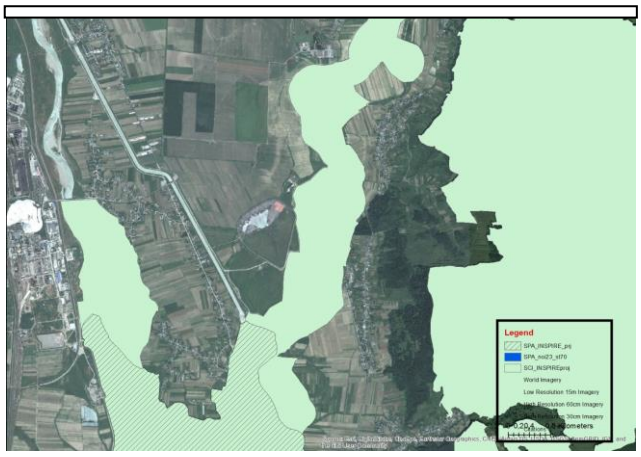

Fig.3 Fly ash and slag landfill, ROSPA0063, ROSCI0434 (year 2016)

Characteristic data of the landfill. [1]Type of landfill: Riverbed deposit (Siret River), current height: the average height of the dam base is of 5.00 meters, current volume: V = 3.37 million cubic meters, area: S = 46.77 hectares, number of compartments: 3.

The lignite provided by Oltenia basin contains sulphur in a ratio of 0.5-1.5%, 0.5-1% nitrogen and the amount of ash is 20-30%. Heavy metals were determined in fly ash and slag using SRISO 11047-99 method.

Soil samples were taken from three deep: 0-5 cm, 15-20 cm and 30-35cm from surrounding area. Heavy metals were doused with total forms atomic absorption spectrometry method.

Coal and its by-products have significant amounts of radionuclide's including uranium, thorium which is the ultimate source of the radioactive gas radon and thoron respectively. Radiation hazard from airborne emissions of coal-fired power plants have been cited as possible causes of health in environmental. By multichannel gamma spectrometry were determined radionuclide's content.

3. Results and discussion

Table 1 presents the higher heavy metal concentration values obtained from soil sampled taken at depths between 0-35 cm. from surrounding area compared with analysis of fly ash.

Table 1. The higher heavy metal concentration values (ppm)/ Analysis of samples of slag and ash (mg/kg d.m)

The cardinal direction	**Cu**	**Zn**	**Pb**	**Ni**	**Cr**	**Cd**
In site [2] (one year of operation)	25	66.5	25	30	22	0.85
In site (the closer)	21.81	60.3	5.30	29.43	19.52	<0.5
N(one year of operation)	42.5	121.5	48.5	60	30	1.4
N (the closer)	34.97	84.8	6.72	40.86	25.56	<0.5
Reference values	20	100	20	20	30	1
Sample (fly ash and slag)	53,8	89,5	7,50	63,80	50,96	<0.5

The values for heavy metals content are higher than normal, but below the alert threshold for less sensitive soils (Cu, Cr, Ni, Zn, Pb).
Assessment of the natural radionuclide concentrations in both the coal and the waste resulting from combustion within the limits of the literature cited is somewhat higher than the soil in the area, but below on annual average. The

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three compartments were covered with 30 cm of vegetative soil and **β global** radiation concentration values in the study area was within normal range from the previous years of the area (Table 2).

Table 2. **β global** radiation concentration values in the study area

The place of sampling	**β global radiation concentration values (**Bq/kg)
Compartment 1	327,1
Compartment 2	442,4
Compartment 3	252,8
Vegetation	329,0
Average annual vegetation	381,2
Soil	472,3
Average annual soil	528,4

4. Conclusions

The EU promotes green infrastructure to enhance Europe's natural capital. The Natura 2000 network constitutes the backbone of the EU green infrastructure.

Bacau slag and fly ash landfill is located between three Natura 2000 sites, in Bistrita and Siret River basins, but on top of that is also located on the Carpathian migratory corridor.

Remediation and ecological rehabilitation of the fly ash and slag landfill Bacau promotes favorable habitats to the birds of conservative interest, similar to those identified in ROSPA0063 *Buhusi-Bacau-Beresti Lakes* and ROSPA0072 *Middle Siret Valley* on the Carpathian migration corridor. Phytoremediation (phytostabilization) followed by revegetation applies to the fly ash and slag landfill Bacau in order to create habitats favorable for the birds of Community interest that come across Carpathians Migration Corridor, for instance*Cygnus cygnus, Sterna hirundo*, and at the same time to improve overall connectivity between the Natura 2000 designated sites.

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