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RESULTS OF APPLICATION OF SOME NON-TRADITIONAL RESTORATION METHODS ON NORTH BOHEMIAN MINES LOCATIONS

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ABSTRACT

The importance of brown coal implies from the growing need of energy in the Czech Republic. It is nowadays a single significant fossil raw material, without which our state would become fully dependent on the import of energetic sources. More than 70 % of mined brown coal comes from the North Bohemian Basin these days. Open cast brown coal mining has lead to large damage on the landscape. That is why the reclamation work has become important on principle recently.

The difficulty of reclamation of North Bohemian localities consists in extremely unfavourable properties of rock strewn to the most of dump bodies. These rocks are mechanically unstable in the wind and water erosion and it gets undesirable, acidic characteristics as SO_3 and Al ions influence by weathering. Limitation of the influence of weathering, amendment of chemistry and physical composition of top rocks strata, and definition of the required amount of fertilizable rock have been successful in recent years as suitable methods have been used.

The presented article includes the characteristics of the important phytotoxic areas and the methodology of their reclamation mainly based on the application of suitable fertilizable rocks. Some tentatively used non-traditional methods were evaluated e. g. the application power plant stabilizer and ash. The paper assesses the success rate of the reclamation methods.

The results are documented with the long term monitoring of physical, mineralogical, chemical and pedological parameters of rocks in the testing areas.

Key words: non-traditional restoration methods, reclamation, application power plant stabilizer and ash.

RESULTADOS DE LA APLICACIÓN DE ALGUNOS MÉTODOS NO TRADICIONALES DE RESTAURACIÓN EN LOCACIONES MINERAS EN EL NORTE DE BOHEMIA

RESUMEN

La importancia del carbón marrón radica en la creciente necesidad energética que existe en la República Checa. En la actualidad es el combustible fósil del cual depende la nación, de lo contrario tendría que importar recursos energéticos. Más del 70% del carbón marrón mineral proviene de las minas del norte del Valle de Bohemia. La explotación de minas a cielo abierto ha causado serios daños en el paisaje. Debido a esto, el trabajo en recuperación de estas locaciones ha adquirido gran importancia recientemente.

La dificultad en la recuperación de las locaciones en el Norte de Bohemia radica en la existencia de propiedades extremadamente desfavorables en la roca que allí se encuentra expuesta a derrames. Estas rocas son mecánicamente inestables a la erosión por viento y agua, por lo cual adquieren características ácidas no deseables dada la influencia del SO_3 y del Al. A pesar de las limitaciones a causa de los procesos erosivos, el mejoramiento de las condiciones químicas y físicas de las capas superiores de roca y la determinación de la cantidad adecuada de roca fertilizante a utilizar, se han convertido en métodos exitosos y adecuados en los últimos años.

El presente artículo incluye las características de importantes áreas fitotóxicas y la metodología para su recuperación basada en la aplicación adecuada de rocas fertilizantes. Algunos métodos tentativos no tradicionales fueron evaluados, uno de ellos fue la aplicación de un poderoso estabilizante vegetal y cenizas. El artículo señala la rata de recuperación de los métodos. Los resultados fueron documentados a través del monitoreo a largo plazo de parámetros físicos, mineralógicos, químicos y edafológicos en rocas en las áreas de investigación.

Palabras clave: Metodos de restauración no tradicionales, reclamacion, aplicación de plantas estabilizadoras y cenizas

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INTRODUCTION

The North-Bohemian Basin area is known for its largest Czech brown coal deposit. About 50% brown coal reserves have been exploited in the North-Bohemian Basin by the mining company of Severoceske doly, a.s. (North Bohemian Mines, j.s.c.) today. The opencast mining of brown coal naturally led to vast landscape damages. Therefore reclamation work has acquired great significance. The specific feature of Severoceske doly, a.s. mining is the fact that the mining has been realized in two geologically absolutely different localities. This fact demands even rather different methods of reclamations.

The main problem at Doly Bilina localities is the occurrence of overburden rocks from the series of rocks of coal seams. These rocks are texturally light but large amounts of coal (cca 5 %) and sulphur (cca below 3 %) which makes the soil reaction extremely acid. If they appear on the surface of the dump, they create a phytotoxic area, reclamation of which requires special methods. Rocks from Doly Nastup Tusimice localities are more suitable to reclamation use, but texturally extremely heavy rocks with large fraction of physical clays appear there that can generate a sterile soil area. Their reclamation requirements are completely different from those on Doly Bilina phytotoxic areas. That is the reason of the application of some non – traditional restoration methods.

This report briefly summarises the experience in application of fertilizable soils, power plant stabilizer, power plant ash and aerial sowing of charlock. The results are documented by the monitoring of the physical, mineralogical and pedological parameters of rocks in testing areas.

PROPERTIES OF OVERBURDEN ROCKS IN OPENCAST MINES BILINA AND LIBOUS

The reclamation work methodology in the North Bohemian Basin is above all determined by the properties of overburden rocks which occur in the top horizon of the reclaimed sites.

The research of the rocks reclamation properties dealt with four current mining localities in the central part of the basin. It concerned the Bilina and Libous mines. This chapter states the stratigraphic status properties of these sites with respect to reclamation availability. The total status of the area of interest is shown in the FIGURE 1.

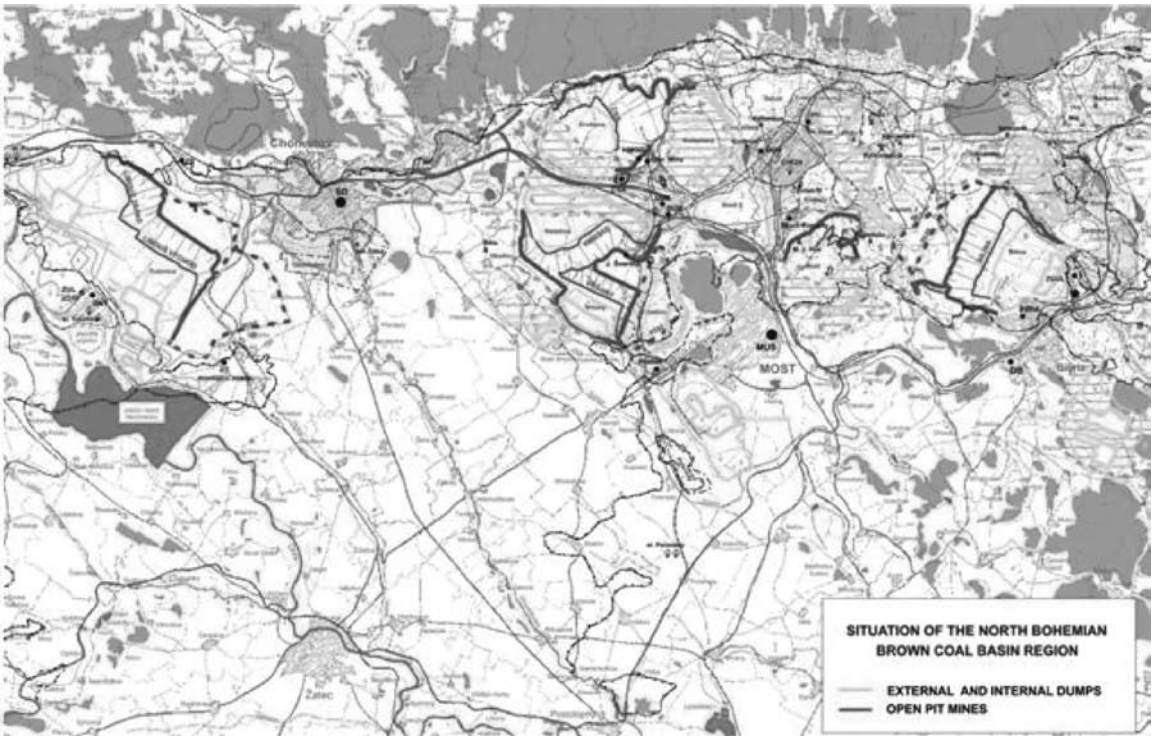

FIGURE 1. The situation of the North Bohemian Brown Coal Basin region

In the area of Bilina mine there are quaternary rocks well usable for reclamation. It concerns topsoil, loess and loess loams, which are selectively mined and used as fertilizable rocks.
Grey kaolinite and illite claystones which form the top horizon in a part of the area are also usable. Deeper deposited rocks of the delta sandy formation representing the biggest volume of overburden rocks are not usable from the reclamation perspective and the coal claystones from the seam formation can be rated as phytotoxic. The overburden cuts of the Bilina mine are shown in the FIGURE 2. In the Libous mine quaternary topsoil is selectively mined and deposited. Grey clay stones of the overburden massif are well usable for reclamation. The horizon of heavy clays structure on the head of the tertiary is the only exception.
Significant properties of typical overburden rocks of the open pit mines Bilina and Libous are mentioned in following TABLE 1.

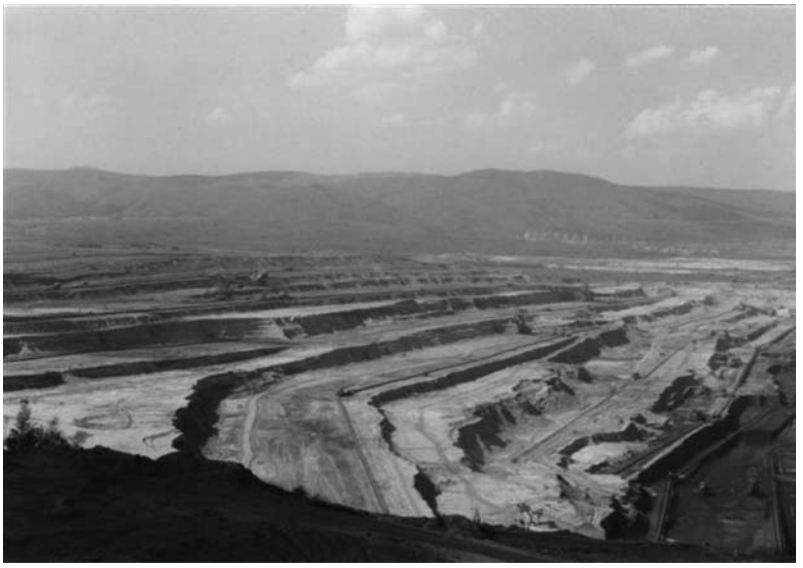

FIGURE 2. The overburden cuts of opencast Bilina mine

TABLE 1. Mineralogical composition and restoration useability of typice overburden rocks of North Bohemian Mines

Location	Stratigraphic horizon	Type of the rock	Restoration Useability	Mineralogy
Bilina mine	Quaternary deposits	Top soils, loess loams, loams, gravel sands	Perfect	Quartz, kaolinite, illite, dash of anorthoclase, calcite and montmorillonite
	„Libkovice“ overlying strata	Grey k.-I. Clays	Good	Quartz, kaolinite, illite, dash of siderite
	Sand-clay strata	Sandy clays, sands	Bad	Quartz, dash of kaolinite, illite, siderite
	Overburden rocks of coal bed	Sandy clays, sands, coal	Phytotoxic	Quartz, kaolinite, illite, dash of coal and siderite
Libous mine	Quaternary deposits	Loams, clay loams, gravel sands	Good	Quartz, kaolinite, illite, dash of anorthoclase and montmorillonite
	Overlying strata (top of the strata)	Yellow plastic clays	Bad	Quartz, kaol inite, illite, dash of montmorillonite, calcite and siderite
	Overlying strata	Grey k.-I. Clays	Good	Quartz, kaolinite, illite, dash of siderite

Loess, loess loams, alms and bentonites are used for the technical reclamation of the dumps the upper horizon of which is formed by phytotoxic rocks and the rocks with bad usability for reclamation (see TABLE 1.). The bentonites were stopped from applying with regard to high market price of the material.

After integrating the sites damaged with mining into the region ecosystem, the reclamation of opencast mines, inner dumps and the most important external dumps is crucial. While hydrological reclamation of the opencast mines has been only the subject of general studies, thanks to the application of new reclamation methods significant results were reached in the other localities. Some of them are presented in this report.

APPLICATION OF SOME NON–TRADITIONAL RESTORATION METHODS ON NORTH BOHEMIAN MINES LOCATIONS

The research of the possibilities of non-traditional restoration methods in North Bohemian Mines locations has ensued from the topical needs of the mining organisation. They mainly are the reclamation of sterile and phytotoxic areas, the elimination of erosion phenomena, and furthermore the preservation of remarkable ecosystems originating on dumps. This report briefly deals with the results of the applications of fertilisable rocks in Strimice location, the application of power plant stabilizer on Bilina internal dump, the application of power plant ash on Brezno dump and the foundation of areas for natural succession (development) in Radovesice location.

Strimice Dump Reclamation – Application of Bentonite

The Strimice dump reclamation was the first large reclamation event using up-to-date reclamation processes.

The dump is located to the South-East from the town of Most. It was formed in the years 1959-1973. The surface of the crown is 160 ha and the elevation reaches 330 meters above sea level. The original forestry reclamation took place in 1967. With regard to severe changes of the surface zone in the dump the planting virtually died out. At the same time a great impact of erosion effects came to light. Bentonites from the Cerný vrch mine were used for technical reclamation. The layer of the brought bentonite rocks was defined to 50 cm. Then agricultural reclamation in the dump plain with the total surface 89 ha was launched.

Success rate of the selected method was tested in the co-operation with the Bilina mines and the Research Institute for Brown Coal, j.s.c. Most. By sampling and analysing the samples from the Strimice dump the creation of a new soil profile was proved. That is divided into an upper layer consisting of topsoil (or the mixture of topsoil and bentonite), a middle layer consisting of bentonite (or the mixture of clay and bentonite) and the original material of the dump.

The upper layer consists, from the mineralogical viewpoint, of quartz, kaolinite, illite, montmorillonite. The mixture of spars, muscovite appears sometimes. The chemical status is quite friendly. The soil reaction is indifferent, the T absorption medium to high (according to the bentonite content), the content of calcite varies. The content of nitrogen is low, the content of humus is medium. The content of acceptable sustenance is low for phosphorus, medium to high for magnesium and potassium. Regarding the grain size the soils are quite coarse, sandy to loamy. They are suitable for reclamation.
The middle layer mostly consists of bentonite. In the mineralogical composition it corresponds to greater amount of montmorillonite.
The soil reaction is lightly alkaline, the T absorption is high (with growing amount of montmorillonite), the content of calcite is growing. The content of nitrogen and humus is low. The content of sustenance is slightly growing against the upper layer. From the grain size point of view the samples are lightly coarse, they correspond to sandy and loamy to loamy soils. The original material of the dump consists of yellow clays with the pieces of coal. These soils are extra severe for reclamation.

The results prove the success of the selected method of the Strimice dump reclamation. It is shown in the TABLE 2. With respect to current market price of bentonite it is not possible to apply this type of reclamation today.

The Strimice dump reclamation has been completed. At the crown of the dump an airport with ca 90 ha surface surrounded with agricultural reclamation serves to the Most citizens. On the slopes of the dump forestry reclamation with tourist trails (FIGURE 3.) were built.

TABLE 2. Properties of reclaimed soil profile

probe S1 -sample taking interval (m)	N (%)	Cox (%)	$CaCO_3$ (%)	pH /H_2O	Receivable nutrients (mg.kg^{-1})			Absorbing capacity mmol		(%)
					P	K	Mg	S	T	V
0.00-0.60	0.07	1.24	0.98	6.79	10	190	102	13.4	19.7	68
0.60-0.90	0.07	0.68	9.93	8.23	1	218	949	36.3	36.3	100
under 0.90	0.15	2.94	0.24	4.50	1	103	304	3.1	8.2	39

FIGURE 3. The restoration of dump surface (locality Strimice)

Bilina Internal Dump Restoration - Experimental Application of Power Plant Stabilizer

In the year 1999 an application of power plant stabilizer to various types of dump soil was tested in the inner dump of the Bilina mine. Extremely acid (sterile from reclamation perspective) coal clay stone from the coal preparation plant Ledvice was one kind which created a vast phytotoxic area in the dump. A stabilizer from the Ledvice power plant was used being the product of desulphurization. The target of the work is to consider possibilities to make technical reclamation of phytotoxic areas more efficient.

The value of the soil reaction in the water leaching amounted to 3.8 – 4.5 for the above stated coaly claystones. After applying 600 t/ha power plant stabilizer the soil reaction of the resulted mixture was about 9-10. Hereof the need to optimize the stabilizer dosage implied to reach the resulted mixture reaction of ca 6.5 – 7.5.

Within the scope of solution first samples of clean power plant stabilizer and coaly claystone were taken for which the value of soil reaction in water leaching was determined. Then a testing area of the size of 0.5 × 0.5 m was prepared, various amounts of stabilizer applied and the soil reaction of the mixture determined. The applied dosage of stabilizer was finally calculated per 1 hectare. The research results are shown in the following table No. 3. The changes in the soil reaction values of A - F mixtures have been verified after two years by another sampling and samples analysis. The results are stated in the TABLE 3. too.

The samples were taken immediately after the stabilizer was applied. The A-F mixtures were tested for the presence of risky trace elements the increased contents of which were not detected.

TABLE 3. Recommended Dosage of Stabilizer and Resulting Values of Soil Reaction (after application and after 2 years)

Sample	**Stabilizer dosage / 0.25 m² (kg)**	Stabilizer dosage/ 1 ha **(t)**	**pH/ H_2O -after application**	**pH/ H_2O -after 2 years**
Clean stabilizer	-	-	12,1	-
A	15	600	9.63	8.52
B	12.5	500	8.86	8.00
C	10	400	8.57	7.80
D	7.5	300	8.12	7.50
E	5	200	7.25	7.20
F	2.5	100	7.00	7.00
Coaly claystone	0	0	4.11	-

Within the scope of this experiment the mixtures of acid coaly claystone and power plant stabilizer corresponding the dosage of 600 t/ha to 100 t/ha were laboratory modelled. Then the soil reaction in the water extract was determined for these mixtures and other comparative samples of power plant stabilizer and coaly claystone. The results are stated in the TABLE 3. It shows that dosage 600 t/ha is already high and pH of the mixture is strongly alkaline. The optimal dosage ranges between 100 – 300 t/ha, the dosage of 200/ha can be recommended for the follow up application.

The experiment proved substantial improvement of sterile coal clay stones properties and the method is, because of great production of the stabilizer, very prospective. Before it is used in practice other, more extended tests in wider areas will be needed. Current status of the experimented area is shown in the FIGURE 4.

FIGURE 4. The experimental area after application of the power plant stabilizer

Brezno Dump Restoration - Experimental Application of Power Plant Ashes

The application of power plant ash from the Tusimice power plant was tested in the experimental areas of the Brezno dump. It concerns the dump of the Libous mine. The experimental areas were based on yellow overlying clays from the Libous mine.

These rocks are homogenous in principle and strongly viscid. With regard to extremely severe physical properties and water regime they are not suitable for reclamation. Kaolinite, montmorillonite, silica and quartz dominate in their mineral composition. From chemical status perspective they are carbonate-free, the soil reaction is usually lightly alkaline to lightly acid, the absorption capacity is usually high. The content of phosphor is quite low, the content of potassium is usually medium and the content of magnesium is high. From grain size perspective they are extremely fine grained and not suitable for reclamation. Their hydro-physical properties do not change in a longer period of time after embedded on the top of a dump. They create soil structure with permanently unfavourable infiltration properties.

The target of the experiment was to improve grain size composition of the upper layer in the experimental areas. Power plant ashes dosage of 200 t/ha was applied in the three 1 ha areas and embedded to the top layer with a plough. The grain size composition of the original yellow clays and the acquired mixtures of the samples taken were determined. We also defined the risky trace elements the concentration of which did not exceed legal limits.

During the grain size composition determination of the samples the combination of hydrometric test and grading analysis was used. The analysis results are stated in the following TABLE 4.

TABLE 4. Results of Grain Size Analysis of Yellow Clay before and after Power Plant Ash Application

Type of the rock	Grain size category I %	Grain size category II %	Grain size category III %	Grain size category IV %	Skelet %
Yellow clay	76	17	1	5	1
Mixture after ash application	56	28	2	10	4

Grain size category I -cut under 0.01 mm
Grain size category II -cut 0.01-0.05 mm
Grain size category III – cut 0.05-0.1 mm
Grain size category IV – cut 0.1-2 mm
Skelet - cut over 2 mm

Radovesice Dump Reclamation – Foundation of Areas Retained to Natural Succession

Natural succession retained areas on Bilina and Libous mines dumps emerges from the philosophy of Severoceske doly mining company locations reclamation. These areas have been founded in places where functional ecosystems began developing spontaneously under specific conditions, where a preservation and research of some biologic geologic and palaeontologic phenomena is needed, and where a future provision of access can be presupposed. The areas are selected after the research of the dump and it is decided of their establishment after the agreement of Severoceske doly, a.s. (mining company), VUHU, a.s. (Brown Coal Research Institute. j.s.c.), VUMOP (Research Institute for Melioration and Soil Preservation), and ZUP (University of Agriculture in Prague). The detailed research of the area is made for setting an introductive documentation after its establishment and input to SD mining company planning maps. This is the start of long time research of the territory evaluating its pedologic and biologic development. In this contribution the areas established on Radovesice dump are briefly characterised.

Construction of Radovesice dump started in 1964. It was situated into cadastral territory of villages Radovesice, Kostomlaty and Svetec. It has elongated form from south – east to north – west and its territory falls into highlands of Czech Middle – mountains. It is the most extensive up till now operated dump of Mines Bilina. The experiences gained at Střimice locality were utilized at its restoration.

At present time the forest restoration is mostly executed on the dump. With regard to dump extent, its significance and unfavourable character of majority of bulked soils, the preparation of dump surface with utilization of local marlites is performed according to methodics of Dr. Fisera (1990). Those form the geological surface of erosion valley in the underlaying strata of the dump Cermak (1998). The marlite excavation runs in direct nearness of the dump and this fact substantially

decreases the costs. With regard to the first very positive results it was decided to use this method on the whole dump surface (with exception of areas retained for natural succession).

Two relatively large areas determined for retaining to natural succession were selected after the thorough survey of not reclaimed part of the dump (about 670 ha) which consisted of field mapping, evaluating of upper soil profile by boring rod and laboratory analysis of selected samples. Dump exposure can be seen in FIGURE 5.

FIGURE 5. The situation of areas retained to natural succession

Succession area No. 1 with 32 ha was selected in the south part of the dump. Prevailing rock type is heterogeneous mixture of brown clay, grey clayeite and grey sandy clayeite with the increased amount of brown clay. Brown grey kaolinic illitic clays. Sandy rocks took significant part in the east of the area and shape its natural border. A series of natural water sheets and little marshes occur here.

Succession area No. 2 with 20 ha was selected in the north part of the dump. Prevailing rock type is heterogeneous mixture of brown clay, grey clayeite and grey sandy clayeite with the increased amount of brown clay, too. Brown grey kaolinic illitic clays. "Sandy dunes" shape southern border of the area. Two big natural water reservoirs and some little water sheets and marshes occur here. Some of the little water sheets changed to marshes during the year.

Comparision of the pedologic characteristics of the rocks of the dump areas reclaimed by the means of marls and the rocks of supposed areas retained to natural succesion are shown in following TABLES 5 and 6.

TABLE 5. Pedologic characteristics of upper horizon of the dump reclaimed by embedding marls and by hauling in topsoil.

sample taking interval (m)	N (%)	Cox (%)	$CaCO_3$ (%)	pH /H_2O	Receivable nutrients ($mg.kg^{-1}$)			Absorbing capacity mmol		(%)
					P	K	Mg	S	T	V
0.00-0.20	0.2	2.4	2.2	6.7	8	232	912	18	18	100
0.20-0.50	-	1.5	11.3	8.0	1	106	100	12	12	100
0.50-1.00	-	1.9	3.5	6.4	2	150	198	9	9	100

TABLE 6. Pedologic characteristics of upper horizon of the area retained to natural succession

sample taking interval (m)	N (%)	Cox (%)	$CaCO_3$ (%)	pH /H_2O	Receivable nutrients ($mg.kg^{-1}$)			Absorbing capacity mmol		(%)
					P	K	Mg	S	T	V
0.00-0.90	-	1.3	0.4	7.8	0	593	1736	13	13.5	96

Spontaneously originated little water sheets and marshes on succession area No. 1 (south part of the dump) are shown on FIGURE 5. Plant and animal genera composition were evaluated on both areas.

Both area are recommended to be retained to natural development without reclamation actions. The territory should be observed on and should served as a research area. Already by now the way in which some genera (mostly vegetable kingdom) adapt to the environment not too typical for them is interesting to observe. With respect to their localisation (see FIGURE 5.) both areas will serve as natural corridor for animals movement during necessary technical works in surrounding parts of the dump.

CONCLUSION

This paper briefly summarises the results of application some non–traditional restoration methods on North Bohemian Mines locations. Classical reclamation methods are compared using the application of fertilizable minerals with the methods of test use of power plant stabilizers and ashes.

First results show these methods could become a significant addition to the fertilizable minerals application in various localities. Therefore research work in this area will continue in the future. The application of power plant stabilizer into extremely acid phytotoxic minerals might be prospective and the application of power plant ash into heavy particle clays, too, when resolving the issue of embedding it into the top layer.

Foundation of two experimental areas on the not reclaimed part of Radovesice dump has a great significance for the research, preservation and future provision of the access of the ecosystems originating spontaneously on the dump.

The experiments prove the necessity of differentiated approach to the localities based on the consistent analysis of a certain site, the selection of suitable reclamation additive and ingenious concept of future locality use.

The results attained also prove that upon the knowledge of the transferred minerals properties and all natural relations of the area it is possible to find a solution which substantially eliminates impacts on the environment. Thanks to great research work and differentiated approach to the localities the North-bohemian dumps will gradually incorporate into the landscape of the Krusne hory mountain range.

The goal of the article is to briefe with the commencing of the solution of the task no. 105/06/0124 which deals with the research of the occurrence, characteristics, and possible applications of the natural claystone sorbents of the North Bohemian Basin.

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