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Methodology of Restoration Research in Czech Republic

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***Abstract*—**Restoration research has become important on principle recently in Czech Republic. The reason is simple. 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. Reclamation of phytotoxic areas is one of the serious problems in the North Bohemian Basin. It mainly concerns the areas with the occurrence of overburden rocks from the coal bed enriched with coal. The presented paper includes the characteristics of the important phytotoxic areas and the methodology of their reclamation. The results are documented with the long term monitoring of physical, mineralogical, chemical and pedological parameters of rocks in the testing areas.

***Keywords*—**Brown coal, dump, methodology, restoration.

I. Introduction

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. Contemporary range of deprived country does not correspond to present and future measure of exploitation. It is the burdensome heritage of past extensive and centrally planned mining. That is why the reclamation work has become important on principle recently. Environment protection and people's health by variant bulk are used at natural geological environment. The results were evaluated complexly after last sample taking.

Mining of brown coal is run in four mining locations. They are geologically different and the parameters of mining coal are quite different too. This requires a little bit different methodology of both extraction and reclamation.

The difficulty of reclamation of North Bohemian localities consists in extremely unfavourable properties of rock strewn to the most of dump bodies. These are series of rock of overlaying formation and those of coal bed. The most used materials are sands, kaolinite – sands and kaolinite – illite sands. Coal, siderite and pyrite are adultered to the dump rock. This rock is mechanically unstable in the wind and water erosion and it gets undesirable, acidic (almost toxic) 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.

Reclamation of phytotoxic areas is one of the serious problems in the North Bohemian Basin. It mainly concerns the areas with the occurrence of overburden rocks from the coal bed enriched with coal. We can cope with less frequent issue of acid mine waters mainly in reclaiming the areas at the exposure of a coal bed. The phytotoxicity of the stated locations is given, apart from the increased content of sulphur, mainly by extremely acid soil reaction which poses higher requirements to the reclamation methodology. The areas on the surface where extremely heavy grain yellow clays occur are a totally specific case.

The presented paper 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.

II. History of Reclamation Works in Czech Republic

The history of brown coal mining in the region is already hundreds years old. This fact is documented by records in chronicles dating back to the 15th century. Mining in tens collieries and also first small open – pit mines started to work in the break of the 19th – 20th century. It is clear that this intensive mining operation brand enrolled for history of reclamation. These ones commenced, not only for the region of the North Bohemian Brown Coal Basin, but also for all Bohemia, as early as in the year 1908. In this time a reclamation branch – office of the Land Agricultural Board was established in Duchcov. The area of 448 ha was recuperated from the total number of 3372 ha of devastated soil, according to this board at the time. The recuperated area was altogether [1].

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A systematic development of reclamation works in the North-Bohemian Brown Coal District (know as "SHR") started in the 50ies. The agricultural and reclamation plant of SHR was established in Teplice, in the year 1957. The first reclamation works -General of SHR- was compiled in Banske projekty Teplice (the Mining Projects company in Teplice) in the year 1959. National enterprise of SHR -Rekultivace v Teplicich- made the reclamation works. After that the company of Banske stavby Most (Mining Constructions in Most) and later also the company of Rekultivacni vystavba Most (Reclamation Construction Most) continued in this work.

More demanding technical alterations were not performed until the 60ies. Effects of old mining were disposed together with disposal of rare coal-mine spoils of small open-pit mines. Predominantly amelioration trees were planted out. Technical preparation of the reclamation operations started already in the 70ies. The terrain was prepared prior to biological reclamation. Fertilizable soils were filled in and drainage was performed. Small and medium-sized open-pit mines gradually finished operation, after 1970. A big open-pit mines was opened. The number of areas abandoned from mining operation was still increasing year by year. Gradual reclamation of these areas started. The reclamation activites got a new dimension since the 80ies. Extensive areas of mine dumps have entered to reclamation works. The reclamation of high mine dumps bodies created a new problem. Selective mining and depositing of utilizable soils commenced at that time. Changes were implemented into the technology of reclamation works [2].

III. Application of Some Experimental Restoration Methods on North Bohemian Localities

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 and the application of power plant stabilizer on Bilina internal dump. Next examples (the application of power plant ash on Brezno dump and the foundation of areas for natural succession in Radovesice location) will be presented in an oral speech.

IV. Strimice Dump Restoration-Application of Bentonites

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. 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 reclamation. It is shown in the Tables I and II.

TABLE I
Properties of Reclaimed Soil Profile

-sample taking interval (m)	N (%)	C_{ox} (%)	$CaCO_3$ (%)	pH /H_2O
0,00-0,60	0.07	1.4	0.8	6.8
0,60-0,90	0.06	0.6	9.9	8.2
under 0,90	0,01	4.8	0.1	3.9

TABLE II
Properties of Reclaimed Soil Profile

-sample taking interval (m)	receivable nutrients ($mg.kg^{-1}$)			absorbing capacity mmol (%)		
	P	K	Mg	S	T	V
0,00-0,60	10	180	105	13	19	68
0,60-0,90	1	222	996	33	33	100
under 0,90	1	100	189	4	8	50

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 were built.

V. Radovesice Dump Restoration-Application of Marles

Construction of Radovesice dump started in 1964. It was situated into cadastral territory of villages Radovesice, Kostomlaty and Světec. 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 Bílina.

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 experimental methodology. Those form the geological surface of erosion valley in the underlaying strata of the dump. 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 [4].

The preparations of dump surface, melioration and restoration works are executed gradually, after finishing – bulking of technical parts of the dump. The basic significance has the shortening of interval bulking – restoration, because it means shorter time of erosion of original material of dump surface. Oxidation of pyrite and decay of clay minerals are low. Melioration of surface of Radovesice dump begins with bringing 0,3 m marlites for determined area and ploughing with plough into the depth 0,5 – 0,7 m. With regard to compactness of dump, stone character of marlites and required depths of ploughing these works are technically the most difficult moment of restoration. By the ploughing the dump materials will again get on surface, these are again carried by 0,3 m marlites and ploughed into depth 0,7 – 1,0 metres. So they enter into the mixture the originally ploughed – in marlite and the final mixture is gained with real depth 0,6 – 1,0 metres (see Fig. 1).

Properties of arising rooting horizon are runningly followed up. At present research of experimental areas runs and various quantities of marlites are applied by various way (with ploughing-in and without ploughing-in) or with cover by other soils. The decreasing of quantity of backfilled marlites was proposed about one third on the base of this research [5].

According to geological descriptions, original material of dump is formed by clays, sands and sandy clays. The mineralogical analysis gives evidence about presence of quartz, kaolinite, illite. The traces of siderite are occuring here. The characteristic parameters of these rocks are high content of quartz, low contents of calcite, magnesite, nitrogen, acceptable nutrients and the low values of sorption capacity. Their restoration utilization is very low.

Marls and marlites used at restoration are formed by the mixture of calcite, quartz, illite and kaolinite. The granularity is influenced by the calcite content and the significant share gravel to stones forms at fresh marlites. The content of calcite fluctuates between 40 – 55%. Soil reaction in water leach is slightly alkaline, the values of sorption capacity and acceptable nutrients are low.

The arising rooting horizon is as a rule formed by the mixture of disaggregating or plastic marls and marlites, clays and loams. This group of rocks is the result of restoration works and from that reason many samples of this type were taken here. The values of sorption capacity increased to 14 – 18 mmol/100 g soil. The granularity analysis proves the presence of gravel composed from the fragments of marlites and basalts. The content of calcite is sufficient, with depth it decreases as a rule. Very significant soil reaction in water leach is mostly slightly alcaline what proves by evidence the action of marlites in depths to one meter and it means the possibility of elimination of presupposed acid precipitations.

It is possible using the mentioned methodics to protect erosion effects such it came in the first stage of restoration of Radovesice dump. It can be proved in the following Tables III and IV. The sample No. 1 forms the grey – brown marl loam, sample No.2 is formed by grey marl with fragments of marlite and sample No. 3 is formed by grey - brown dump clay and fragments of coal mass.

Fig. 1 Anthropogenic soil profile on the surface of Radovesice dump

TABLE III
Properties of Reclaimed Soil Profile

-sample taking interval (m)	N (%)	C_{ox} (%)	$CaCO_3$ (%)	pH /H_2O
0,00-0,20	0.12	2.1	2.1	6.6
0,20-0,50	-	0.9	12.4	8.0
0,50-1,00	-	1.3	3.4	5.9

TABLE IV
Properties of Reclaimed Soil Profile

-sample taking interval (m)	receivable nutrients ($mg.kg^{-1}$)			absorbing capacity mmol (%)		
	P	K	Mg	S	T	V
0,00-0,20	8	232	912	18	18	100
0,20-0,50	1	106	100	12	12	100
0,50-1,00	2	150	198	9	9	100

VI. Bilina Internal Dump Reclamation-Application of Power Plant Stabilizer

In the year 2005 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. The used stabilizer is the product of desulphurisation in Ledvice plant. It contains $CaSO_3$ (cca 50%), $CaCO_3$ (cca 25%), $Ca(OH)_2$ (cca 20%), and others less significant components [3]. Dangerous contents of risky trace elements were not found out. It is very alcalic, that is why the possibility was tested of its application on extremely acidic phyto-toxic area of coal claystones.

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 x 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 V. 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 Table V 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 V
DOSAGE OF STABILIZER AND RESULTING VALUES OF SOIL REACTION

sample	stabilizer dosage/1ha (t)	pH/H_2O -after application	pH/H_2O -after 2 years
clean stabilizer	-	13.0	-
A	600	9.7	8.6
B	500	8.9	8.0
C	400	8.6	7.7
D	300	8.1	7.5
E	200	7.3	7.2
F	100	7.1	7.0
coaly claystone	0	3.8	-

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 Table V. 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.

VII. CONCLUSION

The North Bohemian Brown Coal Basin is today the greatest coal deposit in the Czech Republic. Big volumes of stripped rocks and the extent of areas designated for reclamation require the application of new, efficient reclamation methods.

The application of fertilizable minerals remains the basic methods of technical reclamation proving its success at the localities of Strimice, Radovesice and the inner dump of the Bílina mine. But the first attained results of the research prove that some new progressive methods can become a significant complement of this method. Application of power plant stabilizer into extremely acid phyto-toxic minerals in Bílina Mines could be a prospective method where some non-traditional erosion control measures applied well.

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 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 conclusions stated in this article are documented with the results of samples taken in Strimice, Radovesice, internal dump Bílina.

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 Krusné hory mountain range.

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