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KATEDRA EKOLOGIE

RESTORATION OF ASH-SLAG DEPOSITS EMPHASIZING THEIR IMPORTANCE FOR ENDANGERED ORGANISMS

BAKALÁŘSKÁ PRÁCE

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I am declaring this work to be done independently. All of the sources and literature used in this work are properly cited with full reference to source.

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Abstract

Ash-slag deposits present significant anthropogenic sites in landscape. Due to their negative effects on human health and environment, a rapid reclamation of these sites is preferred. As several recent studies reveals, this process destroys habitat surrogates for many endangered species colonizing these sites. This thesis review the technical aspects and risks of ash-slag deposits in the Czech Republic and confront it with the reviews of the recent biodiversity surveys. The compromises between technical and ecological restoration approaches are possible, for responsible planning, however, a complex research is highly necessary.

Keywords

ash-slag deposits, postindustrial sites, artificial biotopes, habitat restoration, landscape conservation, reclamation

1. Introduction

Industrialization of the Czech Republic and whole of Europe mainly during 20th century has caused major changes in the landscape and altered its usage. Some of the most important changes were connected with means of raw materials extraction and processing.

Mineral resources extraction process has a rich tradition throughout the history of these landscapes, but is always connected with significant changes in influenced area. Mining operation has caused pollution and contamination of surrounded landscape both in the present and the past. Previously unknown coal surface mining changed entirely many large regions of the Czech Republic. Newly formed electric industry has added to these changes. A main effect of its production comes from the burned coal. Apart from the required thermal energy, other byproducts are produced. Ash and slag represents the solid part.

The ash and slag removed from the smoke has to be stored. For this purpose each coal power plant and coal heating plant has at least one ash sedimentary basin or ash deposit site adjoined to it. The amount of these sites in the Czech Republic and almost no data available, including the exact number and area of these sites, call for more attention. Due to negative effects of this substance on human health are these sites considered as purely negative. In the view of recent biodiversity surveys, this view might shift in the near future.

2. Aims

- To review actual situation of ash depositing in the Czech Republic
- To review the role of postindustrial sites in landscape
- To summarize available surveys of fauna and flora of ash-slag deposits and evaluation of their potential for biodiversity conservation
- To determine possible conflicts between conservation and technological approaches to ash deposits reclamation

3. Industrial sites in landscape

3.1 Historical background and effects on the European landscape

"During the 19th century, European industrial revolution started by acceleration of heavy industries. This revolution is seen as the process of change from an agrarian, handicraft economy to one dominated by industry and machine manufacture, which began in England in the 18th century and from there spread to other parts of the world. The main features involved were technological, socioeconomic, and cultural progress. Changes came in various ways. New basic materials like iron and steel. New energy sources in form of coal, petroleum, electricity and also machines providing energy, for example steam engine or internal combustion engine. New machines, that permitted increased production with a smaller expenditure of human energy. Also new organization of work, known as the factory system, which meant increased division of labour and specialization of function. Development came in transportation and communication and played also a major role. These technological changes made possible a tremendously increased use of natural resources and the mass production of manufactured goods." (Encyclopædia Britannica)

With industrial revolution agriculture has changed as well. Traditional farming has been slowly abandoned and subsequent farming and forestry intensification took its place. This era also started major changes in society structure and land usage. Previously landscape had been composed fine-grained mosaic of areas with different use. With growing industry, farming and forestry, these units became larger and previous landscape structure was suppressed. This landscape homogenization and utilization is a key factor in biodiversity conservation (Konvička et al. 2005).

With growing industrialization, and electric energy consumption, many coal power plants were built (e.g., www.cez.cz). Industrial production reached its peak production in the 60's and 70's of the 20th century (Stuczynski et al. 2009). In Czech Republic there has been a time lag and this peak was reached a decade later in 80's of 20th century. This peak had also effect on pollution. Level of the technologies used at that time and lack of regulation resulted in soil and water pollution. Also growing number of sites needed to store waste from this production is connected to this growth.

3.2 Postindustrial sites

Postindustrial sites are providing non-forest biotopes created by anthropogenic disturbance. These sites, such as brownfields, quarries, sand pits, dumps, and the ash-slag deposits, have been long seen as purely negative for nature conservation. In the light of new findings, this view has been rapidly shifted. It has been repeatedly evidenced that quarries (e.g., Tropek & Konvička 2008), sand and gravel pits (e.g., Řehounková & Prach 2006), brownfields (e.g., Eyre et al. 2003) and other postindustrial sites are hosting many endangered species, which are disappearing from the common landscape.

In quarries dimension stone or gravel and crushed rock are mined. The quarrying technique is drilling and blasting the rock with explosives to break stone walls. The broken stone is then crushed into smaller pieces and separated into fractions (Encyclopædia Britannica). The quarries are characterized by large amount of barren rock. It has been shown that sites both in operation or abandoned are hosting about 50% of the butterfly species in the Czech Republic, including endangered both in the Czech Republic and Europe. (Beneš et al. 2003). The conservation potential was described by TROPEK et al. 2010 on vascular plants and various groups of arthropods. Their data clearly shows significantly higher amount of endangered species on the spontaneously developed sites in comparison with the sites technically reclaimed. These sites are inhabited by number of endangered spiders (Tropek & Konvička 2008) or wild bees (Krauss et al. 2010)

A sand or gravel pit is used for surface extraction of sand and gravel. They are built mostly in area of alluvial floodplains of large watercourses and are created by removing ground and/or minerals covering future site. The mining operations are usually done above ground water level or below. Due to high level of groundwater penetration the area is transformed permanently to a pond in case of mining below groundwater level. Abandoned sand pits are playing a vital part in landscape. Their usage ranges from sites of relaxation for people to supplementation of biotopes, such as inland sand dunes and riverside gravel beds, lost from common landscape. (Konvička et al. 2005). As open sands are one of the most endangered habitats through Europe, these sites provide suitable conditions for specialized psammophilous species. Studies done on sites include plants (Řehounková & Prach 2006) or bank swallows (*Riparia riparia*) (Heneberg 2009).

The brownfields are created by decline in industrial production, which has been caused by economic and technological changes after the peak of production in the 60s and 70s of the 20th century. The prevailing factors to indicate site as a brownfield are: The sites in question have been affected by the former uses of the site and surrounding land and are derelict and underused. A contamination problem, real or perceived, is present. The site is located mainly in developed urban area. An intervention is required to bring them back to beneficial use. This new phenomena in landscape already occupies land up to 0,5 % of total area of the country. In the Czech Republic alone estimated area of the brownfield land is expected around 30 000 hectares spread over 10 000 potential sites (Oliver et al. 2005). Not much is known about communities inhabiting these sites, but study on beetles has also shown number of endangered species which might be showing future conservation interest (Eyre et al. 2003).

Ore sludge deposits are made of waste sludge produced during ore processing and are concentrated mainly in ore excavation areas. The only systematic surveys of their biodiversity involve plants (Vaňková & Kovář 2004), lichens (Palice & Soldán 2004) and fungi (Kubátová et al. 2002). A survey of spiders implies a great potential for specialists of open sands on these sites (Řezáč 2004). Nothing is known about other groups colonizing these sites.

Soil dumps are anthropogenic sites created by deposition of material left over from mining operations. This material is not containing economical levels of mined resources, but might contain traces of it. These sites provide suitable conditions for spontaneous succession. Again, many endangered species are found at these sites. (Prach et. al 2010)

3.3 Changes in land use

The land has undergone significant changes since the industrial revolution (Table 1). The decrease of arable land is caused by many factors. Since the amount of land available is constant, the growth of other areas has taken over parts of arable land area. Productivity of agriculture has risen (e. g. Van Zanden 1991), so even though the population has grown, the amount of land tilled could drop. This feature is common through the whole Europe. Well known factors causing this are mechanization, fertilization and application of industrial methods to the food production process.

The built-over area increase is again linked both to growing industry and growing need for accommodation of the population. The increase in required accommodation space is more rapid than population growth (e.g. www.czso.cz) , because it has been connected to demographical and socio-economical changes. With better economic situation, population can afford bigger living space. Also stepping away from multigenerational accommodation added to this phenomenon.

The rising forest cover is less known factor. These figures are showing that forest cover has grown by almost 16%. (Bičík et al. 2001) One of the factors affecting this trend is rising use of coal, which has superseded wood's previous function as the energy source.

The growth of water area between years 1948 and 2000, which is almost 78%, was caused, among other factors by huge dam building projects of second half of 20th century as well as hydric recultivations. These actions resulted in destruction of natural river beds and valleys, as same as the natural river dynamics.

The massive growth in other areas is documenting the growth of surface mining as well as other postindustrial sites. The northwestern part of the Czech Republic was the most affected by this growth. Many of the surface mines are located in this region.

	Land type	1845	1948	1990	2000	% change 1845-2000
	Arable land	37 974,9	39 341,8	32 323,8	30 824,0	-18,8%
	Permanent cultures*	899,3	1 494,6	2 355,8	2 364,2	162,9%
	Meadows	7 330,0	7 177,1	5 717,2	6 743,3	-8,0%
	Pastures	6 381,4	3 034,1	2 567,2	2 867,4	-55,1%
1	**Agricultural land resources ****	*52 585,6*	*51 047,6*	*42 963,9*	*42 798,9*	*-18,6%*
2	**Forest area**	22 761,2	23 826,7	26 287,6	26 372,9	15,9%
3	**Water area**	1 130,3	896,7	1 559,2	1 593,5	41,0%
4	**Built-over area**	462,5	849,2	1 252,9	1 305,2	182,2%
5	**Other areas**	1 814,2	2 248,6	6 798,2	6 794,9	274,5%

* includes meadows, gardens, vineyards and hop-gardens

** Sum of the arable land, permanent cultures, meadows and pastures

Table 1: Changes in land use 1845-2000 in km^2 (lucc.ic.cz/lucc_data/)

4. Ash-slag deposits

4.1 Composition, depositing and use of fly ash

Fly ash is the finest residue of coal burning with particles up to 1 mm in diameter. It is separated from the smoke to prevent its release into the atmosphere. In power plants and coal heating plants, electrostatic separators are used for this separation. Slag is a residue of impurities contained in the coal, which remains in the cauldron and has to be removed (www.cez.cz). The ash and slag produced in the burning process is considered and treated like industrial waste, but it could be also seen as byproduct.

Chemical composition of the separated byproducts and their physical properties depend mainly on the method of burning and the type of coal. Almost each power plant has different source of coal, so chemical properties on every site are significantly different (http://waste.fce.vutbr.cz/). The ash produced in pulverized burning is created in temperatures ranging from 1350°C to 1600 °C for black coal burning and from 950°C to 1250 °C for brown coal burning. Solid waste from this process consists of about 75% of fine ash and 25% of rough ash with slag (Medvecová and Mužík 2003). The ash produced from fluid burning is created at lower temperatures, around 850 °C. The resulting chemical (Table 2) and physical composition is affected by this. In the fluid burning, calcite is added as a sorbent of sulphure dioxide. As a result, ash from the fluid burning contains not only remnants of burned coal, but also of reacted calcium sulfate and burned lime.

The burning type	SiO_2	AL_2O_3	Active CaO	Free CaO	MgO	TiO_2	Fe_2O_3	SO_3	Na_2O	K_2O
Pulverized	52,22	28,01	3,09	-	1,38	2,37	9,66	0,6	0,51	1,59
Fluid	42,34	19,44	18,21	2,58	2,49	1,55	5,79	5,26	0,37	1,41

Table 2: Average chemical composition of ash (Medvecová and Mužík 2003)

The separated ash is stored as a hazardous waste. Formerly it had been transported as a hydrated mixture into sedimentary basins, where it was stored. The mixture of ash and slag with wastewater was pipelined to the basins where it could sediment. Most of the water repeatedly circulated between the power plant and its sedimentary basins, some of it, however, often escaped to adjoining areas. As a result, it negatively affects ground water quality in the vicinity, both quantitatively (rising water level and flooding of some areas) and qualitatively (chemical pollution) (Anonymous 1986). Recently, a different method is preferred. Ash is mixed with calcium sulfate remaining from a flue-gas desulphurization and transported by trucks or by a special belt conveyor designed to reduce the dustiness during the transport. A hydration of the ash and calcium sulfite mixture leads to its chemical stabilization, providing wind and water erosion prevention.

The ash has many uses, so storage without further use should be considered as redundant. The ash can be used in the building industry in concrete and mortar making, aeroconcrete and other variations of building blocks production or additive in bitumen construction membranes. In stabilized form it could be used in road and railroad building as well as filling material for technical reclamation of other anthropogenic sites. The calcium sulfate is used mostly as a material for production of plasterboards (or drywall), aeroconcrete or cement. It can also play a role in desalination as an agent for boron removal (Polat et al. 2004). Even though it can be used in these ways, about 80 % of approximately 10 million tons produced annually is not and is stored instead. (Medvecová and Mužík 2003).

4.2 Locations of the ash-slag deposits

Each power plant, heating plant and almost each bigger factory burning any solid fuel has its own ash-slag deposit and bigger plants have usually several of them. The exact number of the deposits in Czech Republic is, however, unknown and needs further survey. The most comprehensive available data comes from the Czech ministry of agriculture, although it does not cover by far all of the sites (Fig. 1, Table 3) Even the principal operator of the coal power plants in Czech Republic, ČEZ, a. s., do not provide any useful data as it proclaims not having any comprehensive database. This data lack calls for further survey, as the future research potential of these sites is enormous. Additionally, as old sites are being filled to its capacity, there will be a demand for new deposit sites increasing a pressure to the landscapes.

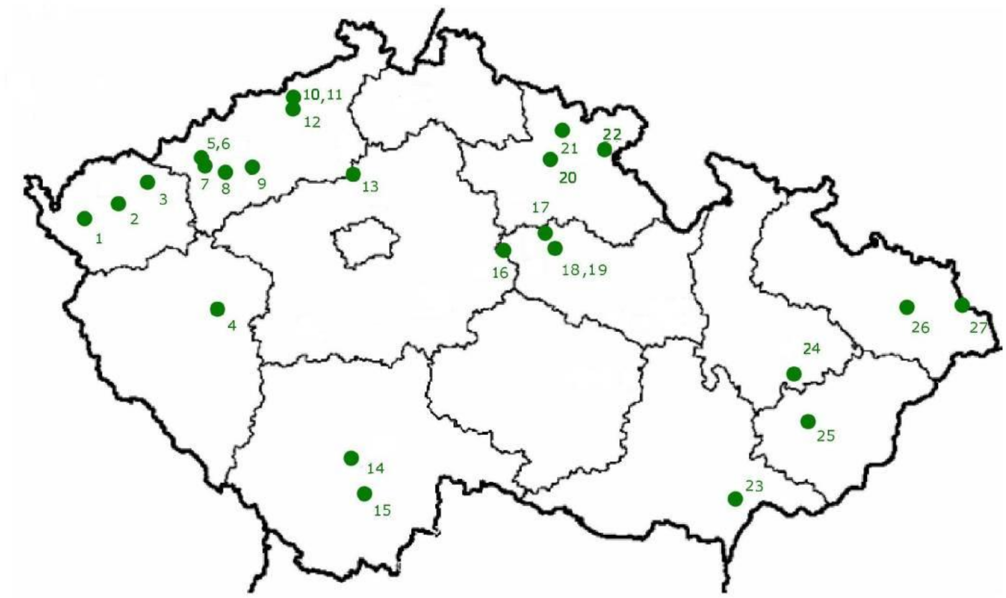

Fig. 1: The location of sedimentary basins in the Czech Republic from the data of Ministry of agriculture 2009. These are the only available data at this time, however, the location of several sites was not possible to gain from any available source. Description of the sites is in Table 3

No. in Fig. 1	The nearest town with extended competence	The deposit's name	No. in Fig. 1	The nearest town with extended competence	The deposit's name
1	Sokolov	Silvestr	15	Č. Budějovice	Hodějovice
2	Sokolov	Vřesová	16	Přelouč	Chvaletice I
3	Ostrov	Odkaliště II.	17	Pardubice	Semtín
4	Plzeň	Božkov	18	Pardubice	Dříteč
5	Kadaň	Prunéřov A III	19	Pardubice	Bukovina n. L.
6	Kadaň	Ušák	20	Dvůr Králové N. L.	Odkaliště IV
7	Kadaň	Tušimice	21	Trutnov	Debrné
8	Chomutov	Vysočany	22	Náchod	Dolní Radechová
9	Louny	Třískolupy	23	Hodonín	Zbrod
10	Ústí n. L.	Nová pop. skládka	24	Přerov	Odkaliště A, B
11	Ústí n. L.	Stará pop. skládka	25	Zlín	Odkaliště Bělov
12	Ústí n. L.	Barbora III	26	Paskov	Mezideponie pop.
13	Mělník	Panský les	27	Třinec	Lištná
14	Č. Budějovice	Triangl			

Table 3: The deposit's names and location of the nearest town with extended competence (Ministry of agriculture 2009)

Fig. 2: An example of ash-slag deposit in this case Přelouč – Chvaletice (Foto: Robert Tropek)

5. Health and environmental aspects

5.1 Health risks

The main reasons for careful ash depositing and subsequent reclamations of these sites are serious health risks for humans caused by it. In vitro studies showed, that coal fly ash, independent of type of coal burning, origin or type of precipitation from the smoke, exerts cytotoxicity (Borm 1997). Due to similar physical properties of the particles it is compared to silicon dioxide. In this study, coal fly ash is shown as less toxic than pure silicon dioxide, which is a basic component of soil, sand, granite, and many other minerals. The size of the particles is linked to human respiratory problems such as silicosis (e.g., Collins et al. 2005). Both in vitro and in vivo studies indicated slight differences in impact on health between various types of coal fly ashes (Borm 1997). Also carcinogenic effects of coal dust have been observed. (Finkelman et al. 2002) These effects might be connected with ash particles as well. Radioactivity in the ash particles is not a major concern, as its levels are within those of ordinary rock and soil.

Most of the sedimentary basins are situated in lowlands near rivers due to economy of transport both coal and water to the power and thermal plants. This puts them into regions with high population densities and agriculture production. Therefore, it is necessary for ash deposit sites to be secured from erosion (mainly aeolic) and the material leakage to surrounding areas.

Recently, few studies indicates that this environmental risks does not threaten at least some plants and animals in such life threatening way. Accumulation of heavy metals in some plants from environment does not reach toxic levels (Brieger 1991, Gupta 2008). Also the experiments with corn growing have shown ash deposits as a suitable site for plants (Petříková 2002). Findings summarized in the next chapter show large populations of some organisms inhabiting the ash-slag deposit sites. This is an indicator of conditions suitable, sometimes preferred, for some species, in many cases endangered or even critically endangered.

5.2 Recent biodiversity surveys of ash-slag deposits

Any studies of plants and animals colonizing the ash-slag deposit are still very scarce. The first more complex surveys of the communities of the ash-slag deposits were carried out in the Eastern and Southern Bohemia (see below). Among the best surveyed taxa are vascular plants (Vaňková & Kovář 2004), macromycetes (Soldán & Palice 2004), hymenoptera (eg. Halada 2010, Tropek et al. unpublished data) or beetles (Mertlík 2011). All of these authors have found significant number of endangered species present on the studied sites.

The deposit České Budějovice – Hodějovice (Loc: 48°57'18.600"N, 14°30'52.000"E) has been active since 1982. This site is currently not in use, the only active part is a reserve basin for eventual crisis situations. As RAUCH et al. 2010 has shown, this site is vegetated by spontaneous succession and is hosting various aquatic and non-aquatic plants and woody species. Endangered bitter herb (*Centaurium erythraea*) has been found there. The sedimentary basin is known to host 40 species of specially protected vertebrates, mainly several specially protected reptiles and amphibians, such as fire-bellied toed (*Bombina bombina*), protected by European legislation, have been also found. It is also the only known site in the Southern Bohemia, which was colonized by an endangered tiger beetle *Cicindela arenaria viennensis*, specialized to declining biotope of open sands, and a rove beetle *Scopaeus minutus*, a rare species of open habitats. Also HALADA 2010 has shown this site to host 40% of cuckoo wasps (Chrysididae) known in the Czech Republic. Many of which are endangered, critically endangered and two species considered extinct (*Chrysis graelsii sybarita* and *Chrysis iris*). Reclamation of the site was planned by draining and completely covering by topsoils. After initiative from local entomologists and the Calla NGO, two smaller sites have been left unreclaimed and should serve as a refuge for endangered species. Future disturbations are planned to maintain and/or restore the open character of the site. As this site has become the centre of interest, it might become a valuable place for a further study.

On the Přelouč – Chvaletice (Loc: 50°1'40.000"N, 15°26'8.500"E) deposit, located in a former pyrite mine, the hydrated mixture was deposited since 1970's and ceased in 1990's when commercial use for ash produced in power plant Chvaletice has been preferred. Since the time, the site has been drained and is being gradually reclaimed. Larger areas of the deposited substrate have been exposed as draining continued. This provided opportunity for psammophilous communities, especially insects. RAUCH et al. 2010 has described formation of vegetation cover and succession taken place early on with assistance of lichen and moss like purple horn toothed moss (*Ceratodon purpureus*) and different species of Cladonia. Vascular plants are represented by annual plants such as lentil vetch (*Vicia tetrasperma),* and rich cover of expansive plants, such as wood small reed (*Calamagrostis epigejos)* and common reed (*Phragmites australis)*. These species have gradually grown and created more compact cover. Woods have flourished since early succession stage. The most common are silver birch (*Betula pendula),* European aspen *(Populus tremula)* and willows (*Salix* sp.), which have created larger units as well. Numerous arthropod species on this site are psammophilous specialists, which have lost almost all of the suitable biotopes in throughout the Central Europe. These inhabit only non-reclaimed areas of site. Special nets were used for stabilization of the substrate. These nets did not left enough free space in between to allow colonization. Significant species found at site also include *Cerceris rybyensis, Cicindela arenaria viennensis, Halictus subaureatus, Hedychridium krajniki, Myrmeleon formicarius, Oepodia caerulescens, Oxybelus argentatus* and others. Vertebrates can be represented by *Coronella austriaca, Natrix natrix* or *Pseudepidalea viridis*.

The grayling (*Hipparchia semele*), a butterfly with one of the most significant decline of localities inhabited by this species, was the target of thorough study performed on settling basin Tušimice (Loc: 50°22'22.064"N, 13°20'40.749"E) done by ČÍŽEK et al. 2010. This study suggests that the settling basin provides the last larger refuge for this species. Small populations are found along the adjacent Ohře river, but population from the sedimentary basin is apparently the source population for the whole area. This study also shown preferences of *Hipparchia semele* on this site: a mosaic of disturbed sites with very sparse vegetation cover and solitary trees are used for reproduction, ruderalized sites are used for adult feeding, higher barren places are used by males to guard their territories and low grass covered spots provide place for resting and basking. Apart from *H. semele,* an endangered silver-spotted skipper (*Hesperia comma*) has been also found there (Tropek, pers. comm.).

Similarly to the other sites, further study is necessary as no other biological survey was done there.

The deposit Pardubice – Bukovina nad Labem (Loc: 50°7'3.16"N, 15°49'44.467"E) provides another important refuge for psammophilous species. MERTLÍK 2011 has found several endangered psammophilous beetles there. Biotope of tiger beetle *Cicindela arenaria* within this site is formed by fine particles of floated ash and sludge. Two click beetles, *Cardiophorus asellus* and *Dicronychus equisetioides*, were found in two areas of ash sediments. The site is also very important refuge for psammophilous wild bees and wasps. There were found several endangered species, including several critically endangered ones. Two of them (*Mimumesa littoralis*, *Nysson hrubanti*) are even considered as extinct in the Czech Republic (Tropek & Černá, pers. comm.). Indicator of a negative relation of the technical reclamations and endangered communities could be critically endangered grayling (*Hipparchia semele*). This site had been the only remaining locality in the Eastern Bohemia, but as reclamation proceeds, number and size of areas suitable for this species had decreased, until it reached a critical limit and *H. semele* became extinct in that part of the Czech Republic.

6. Reclamation

6.1 Legal issues

The legislation of the Czech Republic demands immediate reclamation of affected site (law no. 334/92 which replaced the previous law no. 53/66). According to §4 of this law, immediately after license for non-agricultural use of land is expired, such landscaping has to be performed so the area in question could be reclaimed and capable of performing another function in the landscape according to the reclamation plan.

The previous law is supplemented by the ordinance of the Ministry of environment (no. 13/1994), which addresses conditions of reclamation, such as the requirement of a reclamation journal, used for recording of measures completed and in progress, and the content of soil landscape reclamation plan. This plan contains five parts. The technical part, in which the amount of removed soil and its planned use has to be specified. This part also contains the future plans and means of landscaping, soil dump sites, preparation for “biological” reclamation, water regime alterations, ameliorative measures and road building on site. The second part is “biological”, which is specifying ameliorative sowing measures, intensity of fertilization and the aim of reclamation. The third part is a schedule of planned technical and “biological” reclamation measures. The fourth contains a budget of the reclamation measures. And the last one provides maps with the marked measures from the parts 1 to 3 before and after the reclamation including a connection with the surrounding terrain.

Only after reclamation is finished, and the land is taken over by its owners or leaseholders, the obligation of paying the fees for removal from the agricultural land fund would be canceled. These laws are connected mostly to reclamation of post mining sites. In some sites this reclamation includes filling with stabilized mixture of ash and energetic gypsum.

Ash deposits are being treated as a building and are affected by law no. 183/2006. This law requires the reclamation to be included in the land-use planning and requires a building permission from the concerned municipality.

6.2 Technical reclamation

The aim of any reclamation is to return the so-called basic ecological function to the landscape and to reduce any possible negative impact on the population health within the area. Technical reclamation is very expensive process, which include complex landscape-forming technological intervention. Technical reclamation has very rich history. First school of reclamation was established as early as 1960’s in northwestern part of the Czech Republic (www.czechcoal.cz). This process has three stages. First part of reclamation covers the buildings and machines removal. In addition, all of the unfilled spaces and other irregularities are leveled off. The aim of this most important stage is securing the site against future negative effects on surrounding area and environment. In case of the ash-slag deposits, these might include leaking, dusting, leaching and following erosion or pollution of surface water.

In the second stage the heavy machinery is needed in large scale. During this stage, the landscape is formed by covering the underlay with soil and other inert materials transported from nearest possible locations located in the most economically accessible distance due to the large volumes of material needed to be moved. The final layer is formed by topsoil.

The final stage is called "biological". Its purpose is to "restore" the ecological functions. The type of "biological" reclamation can be sorted by the resulting land use to forestry reclamation (a production forest planting), agricultural reclamation (an arable field creating), hydric reclamation (water filling) and reclamation for other purposes (such as airfields, golf courses etc.). The prevailing type at many ash-slag deposits is the forestry reclamation (www.cez.cz). The main disadvantage of technical reclamation is its demand for fast revitalization and acceleration of natural succession processes resulting in unstable ecosystems.

There are some sites recently reclaimed by this method. One example of agricultural reclamation is the ash-slag deposit Vysočany (Loc: 50°23'16.568"N, 13°31'26.037"E), which was filled with hydraulically transported ash from power plant Tušimice 14 km west from the site. The forestry reclamation can be seen on site Mělník (Loc: 50°24'2.196"N, 14°22'57.731"E), where a production forest has been planted in rows on reclaimed ash-slag deposit. An example of possible other use is near Dříteč (Loc: 50°6'19.939"N, 15°49'43.822"E). This site was technically reclaimed and golf course was built on created space. No studies have been conducted on these sites.

6.3 Ecological restoration

Recently different approach is being put into attention. Instead of pure technical reclamation, use of natural succession, both spontaneous and directed, is slowly being preferred. For the negative aspects of ash-slag deposits such as dustiness, fast technical reclamation was the only option in the effort to protect human health and surrounding area (www.cez.cz). But as recent findings are showing populations of endangered species, preservation of habitats suitable for these species should be taken into an account (Rauch et al. 2010). After the technical reclamation is finished, the resulting increase in nutrients and radical change of the habitat conditions often result in extinction of all the endangered species previously inhabiting the site.

Recently, biotechnological approaches are relatively common alternatives. Relatively frequent is dumping of industrial wastes from paper mills or wastewater sludges, which provides missing nutrients and significantly accelerate the succession (Rauch et al. 2010). Dustiness can be also prevented by application of stabilization nets. Due to high levels of some heavy metals, selected plant species (*Sida cardifolia* and *Chenopodium album*) can be used to cumulate them in their biomass removable from the deposits (Gupta & Sinha 2007). Interesting study comes from JUWARKAR & JAMBHULKAR 2008, comparing several biological interventions of possible restoration. In this case farmyard manure was applied (50 tones on hectare) on the studied site and selected plants (*Azadirecta indica, Cassia saemea, Eucalyptus hybrida, Pongamia pinnata, Emblica officinalis, Tectona grandis, Annona squamosa, Dendrocalamus strictus* and *Delbergia sisso*) inoculated by mycorrhizas to help them in reducing the stress conditions on the deposit, were planted. This action dramatically improved the physical properties of the ash, the most significant were increasing of water holding capacity, increasing of nutrients availability, and declining of heavy metal content in comparison to untreated plots.

This approach, aimed at succession acceleration, is a valid alternative to technical reclamation. When the method is carefully chosen according to specific site conditions, this restoration should rapidly and suppress the health risks with significantly lower costs. On the other hand, it has the same impact to the psammophilous communities and have to be combined with spontaneous succession and small-scaled blocking of succession on the barren substrate for maintaining the conservation potential of the site (eg. Konvička et al. 2005).

The ecological restoration should take into an account the conditions on site before restoration and attempt to minimize the impact of technical reclamation. One of main goals should be preservation of habitat mosaic and disturbative elements to avoid homogenization of resulting site, the target habitat should be small-scaled barren ash plots imitating the open sands.

7. Thesis proposal

As this thesis has shown, the lack of any comprehensive data on the exact number, size, location and structure of material stored in ash-slag deposits through the Czech Republic is great. On the other, the data should be necessary for future restoration planning. This might be one of the main goals of further author's research. Additionally, as amount of new biodiversity surveys of the deposits will increase, it will be very useful to gather them and confront with restoration proposals.

8. Conclusion

In light of the new data being slowly gathered, the previous purely negative view on postindustrial sites, such as ash-slag deposits, quarries, and sand pits, is being shifted. Technical reclamations cause total annihilation of endangered psammophilous species inhabiting these sites. As findings in chapter 5.2 indicate, unreclaimed ash-slag deposits provide habitat for many endangered species, including critically endangered ones and even some considered as extinct in the Czech Republic. As these deposits fine-grained substrate's susceptivity to aeolic erosion, possible leaks and other environmental impacts on surrounding landscape and negative effect of these particles on human health, some kind of reclamation is necessary. Due to expected number of these sites, their location mostly in industrial centers or in vicinity of agglomerations (both means higher density of human population and impoverished landscape) and their slowly discovered function as sites supplementing rapidly declining sandy habitats, their role in biodiversity conservation might unfold as very significant. For the similarity of this fine-grained ash substrate with sand, some psammophilous and other xerothermophilous specialists colonize it. Further complex research is highly needed in many fields to connect the scarce data and preliminary results.

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