Recovery of degraded and transformed ecosystems in coal mining-affected areas

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Deliverable 3.3

Assessment of rehabilitation techniques for waste heaps

Authors

Assoc. Prof. Barbara Stalmachová, VŠB-TU Ostrava (Czech Republic)

Dr. Hana Švehláková, VŠB-TU Ostrava (Czech Republic)

Assoc. Prof. Jiří Kupka, VŠB-TU Ostrava (Czech Republic)

Dr. Jana Nováková, VŠB-TU Ostrava (Czech Republic)

Assoc. Prof. Hana Vojtková, VŠB-TU Ostrava (Czech Republic)

Dr. Pedro Riesgo Fernández, University of Oviedo (Spain)

Dr. Gregorio Fidalgo Valverde, University of Oviedo (Spain)

D. Juan José Álvarez Fernández, HUNOSA (Spain)

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Executive summary

Within this Deliverable, the assessment of rehabilitation techniques for waste heaps in Figaredo Mine and in the Ema-Terezie mine dumps complex was developed.

Regarding Figaredo Mines, in the first place, water analyses were collected every month since February 2020 till October 2020 above the waste dump, in the waste dump and below the waste heaps. Soil analysis was developed at a place that was already restored. These analyses allow estimating the contribution of the waste heap to water characteristics as well as the presence or not of anomalous metal concentrations and the pH of the waste heaps.

In the second place, an above-ground vegetation comparative assessment at Figaredo Mine was developed in order to determine the degree of vegetal development of the restored waste heaps. Two field visits to Figaredo Mine were developed: the first on February the 2nd, 2020, and the second on November the 11th, 2020.

Hydroseeding was considered as the first necessary step after the slope stability works. Optimal components of the sowing were established together with the optimal herbaceous seed's composition, as well as the optimum distribution of plantation species and density.

Regarding Ema-Terezie mine spoil dump, research has been focused on the evaluation of individual ecological factors that affect both the reclamation methods used and the subsequent development of vegetation, fauna and soils in dumps after mining activities.

To achieve these goals, the following aspects were analysed: hydrological properties of the area affected by the Burňa stream and the former Trojice coke plant; development of soils on Ema dumps (non-reclaimed dump, affected by burning), Terezie dump (forest reclamation), Petr Bezruč (forest reclamation with mosaics of high herb meadows); character and development of vegetation vegetation, including phytocenological evaluation, evaluation of the occurrence of rare and endangered plant species, occurrence of invasive plant species; zoological evaluation (species composition, focusing mainly on invertebrate species, rare and endangered species); and microbiological evaluation focusing on soil development.

1 Introduction

Within Task 3.3, rehabilitation techniques in waste heaps will be assessed. For this purpose, water analysis and soil characterization campaigns, together with an assessment of vegetation, will be developed in the waste heaps of Figaredo Mine and in the Ema-Terezie mine dumps complex, providing data about their behaviour in order to determine which rehabilitation practices allow successful environmental and vegetal developments.

Also, and complementing the previous research, a comparative assessment of above-ground vegetation in the dumps will be carried out on selected areas in the waste heaps of Figaredo Mine and in the Ema-Terezie mine dumps complex, according to the following criteria:

1. Reclamation - spontaneous succession.
2. Forest biotopes - treeless biotopes
3. Biotopes on the plane - biotopes on the slope - biotopes on the foot of slope.
4. Wet biotopes - dry biotopes.

VŠB lead this task, based on its previous experience on this field, with the cooperation of HUNOSA and UNIOVI regarding the work to be done at the waste heaps of Figaredo Mine.

The results from this task will be considered for the formulation of alternative land rehabilitation and ecological restoration actions, in order to generate scenarios.

2 Water and soil analysis at Figaredo Mine

Figure 1 presents the location of the water and soil samples that were collected in Figaredo Mine till November 21st, 2020.

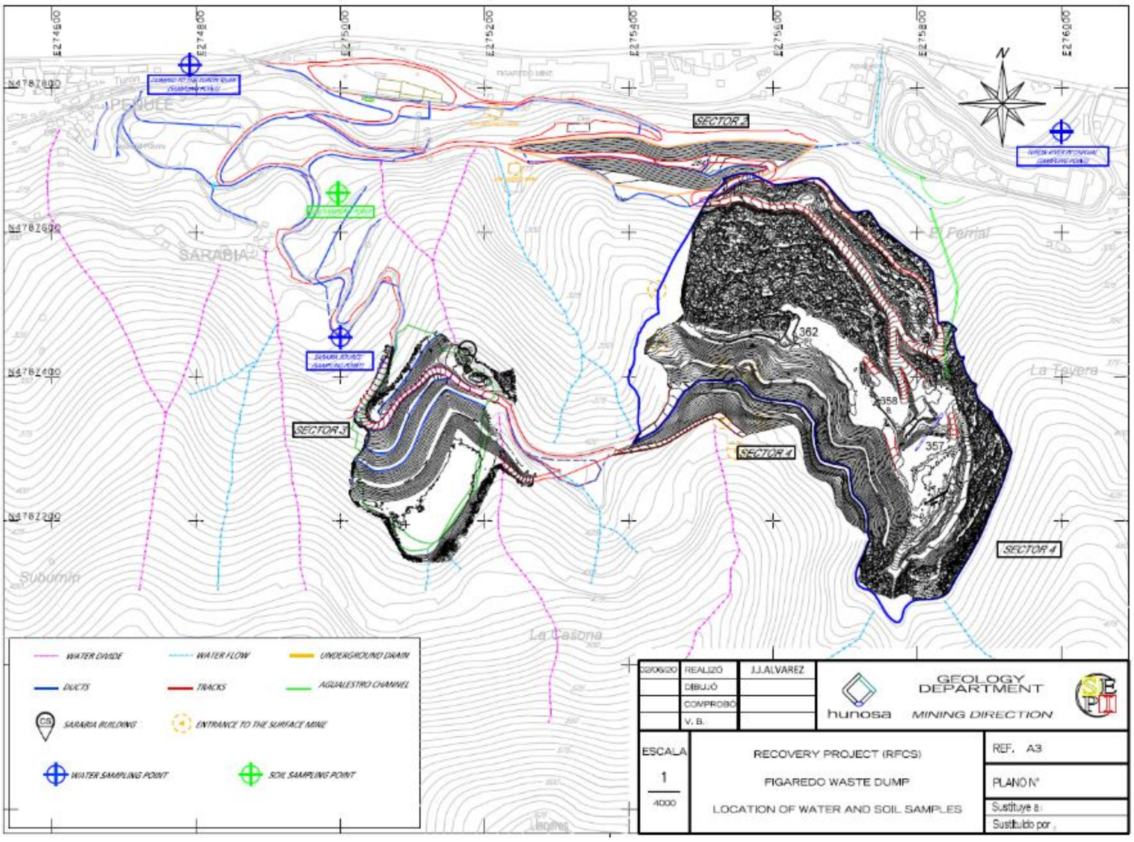


Figure 1. Location of water (in blue) and soil (in green) samples in Figaredo Mine

The soil sample for the analysis was taken in Sector 1, which was restored in 2009. Figure 2. Place where soil sample was taken in Sector 1

Water samples for the analysis were collected very month since February 2020 till October 2020 at three different points:

1. Water samples above the waste dump, in the Turón river, in the town of Cabojal, situated in the upper right side of Figure 1 (in blue).
2. Water samples taken in the Sarabia spring (Figure 3), in Sector 1 of the waste dump, situated in the lower left side of Figure 1 (in blue).
3. Water samples below the waste dump, also in the Turón river, situated in the upper left side of Figure 1 (in blue).

Figure 2. Place where soil sample was taken in Sector 1

Figure 3. Sarabia spring in Sector 1

2.1 Soil analysis

Presents the soil analysis developed on June the 2nd, 2020, in Sector 1 that was restored in 2009.

Table 1. Soil analysis in Figaredo Mine on June the 2nd, 2020

Variable	Value	Variable	Value
Clay	25%	Lime	20.0%
Sand	55%	Magnesium (Mg) (change)	1.78 meq/100 g
Arsenic (As)	<0.01 mg/kg	Manganese (Mn)	33.6 mg/kg
Sulphur (S)	<0.01 mg/kg	Organic matter (Walkey-black)	9.17%
Boron (Bo)	1.32 mg/kg	Mercury (Hg)	<0.01 mg/kg
Cadmium (Cd)	<0.01 mg/kg	Nitrogen (N)	0.326%
Calcium (Ca) (change)	8.13 meq/100 g	Nickel (Ni)	<0.01 mg/kg
Cationic exchange capacity (CEC)	12.3 meq/100 g	Plumb (Pb)	<0.01 mg/kg
Total carbonates ($CaCO_3$)	22.3%	Potassium (K) (change)	0.74 meq/100 g
Copper (Cu)	12.3 mg/kg	Relation C/N	16.3
Chrome (Cr)	<0.01 mg/kg	Texture	sandy clay loam
Assimilable phosphorus (P)	48.7 mg/kg	Zinc (Zn)	26.7 mg/kg
Iron (Fe)	52.3 mg/kg	pH (1:25 m/v)	7.9
Humidity	11.2%	pH in ClK	6.21

2.2 Water analysis

2.2.1 Analysis of water samples above the waste dump

Table 2 and Table 3 present the analysis of the water samples above the waste dump, in the Turón river, in the town of Cabojal, situated in the upper right side of Figure 1.

Table 2. Analysis of water samples above the waste dump (1 of 2)

Variable	27.02.2020	26.03.2020	28.04.2020	29.05.2020
pH at 25ºC	8.2	8.3	8.2	7.8
Conductivity (25ºC) (µS/cm)	871	710	350	784
Suspended solids (mg/l)	<5	<5	<5	<5
Total dissolved solids (mg/l)	660.7	508.3	250.6	561.3
DQO (mg/l O_2)	<25	<25	<25	<25
DBO_5 (mg/l O_2)	<25	<25	<25	<25
Sulphates (mg/l SO_4^{2-})	220	185	49	150
Chlorides (mg/l Cl^-)	7.1	14.2	21.3	14.2
Ammonium (mg NH_4^+/l)	0.12	0.49	0.14	<0.10
Nitrates (mg/l NO_2^-)	<5	<5	<5	<5
Nitrites (mg/l NO_3^-)	0.093	<0.033	<0.033	0.034

Table 3. Analysis of water samples above the waste dump (2 of 2)

Variable	25.06.2020	29.07.2020	20.08.2020	29.09.2020	28.10.2020
pH at 25ºC	8.1	8.2	8.1	8.4	8.1
Conductivity (25ºC) (µS/cm)	836	945	999	689	587
Suspended solids (mg/l)	<5	<5	<5	<5	<5
Total dissolved solids (mg/l)	634.1	716.8	757.8	493.3	420.2
DQO (mg/l O_2)	<25	<25	<25	<25	<25
DBO_5 (mg/l O_2)	<25	<25	<25	<25	<25
Sulphates (mg/l SO_4^{2-})	112	116	160	96	92
Chlorides (mg/l Cl^-)	14.2	7.1	7.1	14.2	14.2
Ammonium (mg NH_4^+/l)	0.1	0.11	<0.10	0.1	0.12
Nitrates (mg/l NO_2^-)	<5	<5	5.8	<5	<5
Nitrites (mg/l NO_3^-)	0.068	0.035	0.06	<0.033	<0.033

2.2.2 Analysis of water samples on the waste dump

Table 4 and Table 5 present the water samples taken in the Sarabia spring, in Sector 1 of the waste dump, situated in the lower left side of Figure 1.

Table 4. Analysis of water samples in Sector 1 of the waste dump (1 of 2)

Variable	27.02.2020	26.03.2020	28.04.2020	29.05.2020
pH at 25ºC	8	7.5	7.7	7.7
Conductivity (25ºC) (µS/cm)	4840	4750	4610	4690
Suspended solids (mg/l)	<5	<5	<5	<5
Total dissolved solids (mg/l)	3671.4	3603.1	3496.9	3557.6
DQO (mg/l O_2)	<25	<25	<25	<25
DBO_5 (mg/l O_2)	<25	<25	<25	<25
Sulphates (mg/l SO_4^{2-})	2750	135	2600	2400
Chlorides (mg/l Cl^-)	7.1	14.2	21.3	14.2
Ammonium (mg NH_4^+/l)	<0.10	0.8	<0.10	<0.10
Nitrates (mg/l NO_2^-)	<5	<5	<5	<5
Nitrites (mg/l NO_3^-)	<0.033	<0.033	<0.033	<0.033

Table 5. Analysis of water samples in Sector 1 of the waste dump (2 of 2)

Variable	25.06.2020	29.07.2020	20.08.2020	29.09.2020	28.10.2020
pH at 25ºC	7.6	7.9	7.4	7.7	7.5
Conductivity (25ºC) (µS/cm)	5210	5370	5440	5110	4580
Suspended solids (mg/l)	<5	<5	<5	<5	<5
Total dissolved solids (mg/l)	3952	4073.4	4626.4	3876.2	3474.1
DQO (mg/l O_2)	<25	<25	<25	<25	<25
DBO_5 (mg/l O_2)	<25	<25	<25	<25	<25
Sulphates (mg/l SO_4^{2-})	1250	2900	3000	2675	2650
Chlorides (mg/l Cl^-)	14.2	21.3	21.3	14.2	14.2
Ammonium (mg NH_4^+/l)	0.15	<0.10	<0.51	0.25	0.16
Nitrates (mg/l NO_2^-)	<5	<5	6.2	<5	<5
Nitrites (mg/l NO_3^-)	<0.033	<0.033	<0.033	<0.033	<0.033

2.2.3 Analysis of water samples below the waste dump

Table 6 and Table 7 present the water samples taken below the waste dump, also in the Turón river, situated in the upper left side of Figure 1.

Table 6. Analysis of water samples below the waste dump (1 of 2)

Variable	27.02.2020	26.03.2020	28.04.2020	29.05.2020
pH at 25ºC	8.2	8.2	8.3	7.9
Conductivity (25ºC) (µS/cm)	844	689	349	757
Suspended solids (mg/l)	<5	<5	20.8	<5
Total dissolved solids (mg/l)	640.2	493.3	249.9	542
DQO (mg/l O_2)	<25	<25	<25	<25
DBO_5 (mg/l O_2)	<25	<25	<25	<25
Sulphates (mg/l SO_4^{2-})	200	135	48	140
Chlorides (mg/l Cl^-)	7.1	14.2	21.3	14.2
Ammonium (mg NH_4^+/l)	0.12	0.24	0.16	<0.10
Nitrates (mg/l NO_2^-)	<5	<5	<5	<5
Nitrites (mg/l NO_3^-)	<0.033	<0.033	<0.033	<0.033

Table 7. Analysis of water samples below the waste dump (2 of 2)

Variable	25.06.2020	29.07.2020	20.08.2020	29.09.2020	28.10.2020
pH at 25ºC	8.1	8.2	8.1	8.3	8.1
Conductivity (25ºC) (µS/cm)	796	933	989	674	574
Suspended solids (mg/l)	<5	<5	<5	<5	<5
Total dissolved solids (mg/l)	569.9	707.7	750.2	482.5	410.9
DQO (mg/l O_2)	<25	<25	<25	<25	<25
DBO_5 (mg/l O_2)	<25	<25	<25	<25	<25
Sulphates (mg/l SO_4^{2-})	110	118	160	90	92
Chlorides (mg/l Cl^-)	14.2	14.2	7.1	7.1	14.2
Ammonium (mg NH_4^+/l)	0.11	<0.10	<0.10	<0.10	<0.10
Nitrates (mg/l NO_2^-)	<5	<5	6.2	<5	<5
Nitrites (mg/l NO_3^-)	<0.033	<0.033	<0.033	<0.033	<0.033

3 Above-ground vegetation comparative assessment at Figaredo Mine

In order to determine the degree of vegetal development of the restored waste heaps, two field visits to Figaredo Mine were developed within the RECOVERY project. The first on February the 2nd, 2020, and the second on November the 11th, 2020.

3.1 Sector 1

Restoration of Sector 1 took place in 2009 by means of slope stability works, in order to achieve the final slope configuration (Figure 4). On the other hand, Figure 5 presents the NW-SE final profile of Sector 1.

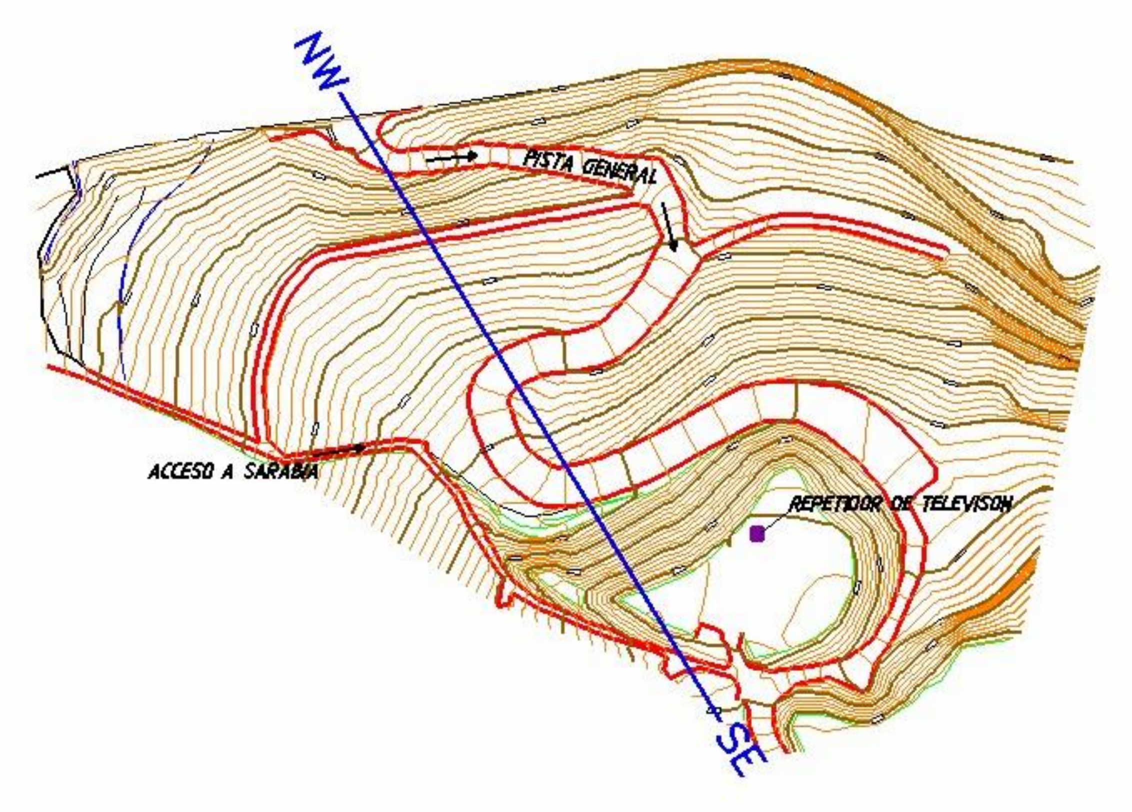


Figure 4. Final slope configuration of Sector 1

Regarding the hydrology of the restored area, it was considered as the basic principle of action that runoff from the upper part of the dump will be led, through the ditches to be made on the service track of the dump itself, towards the outer plaza of the Figaredo Mine, in order to be finally dumped into the river Turón after being decanted in the rafts located near the pit of the mine, at the bottom of the waste heap.

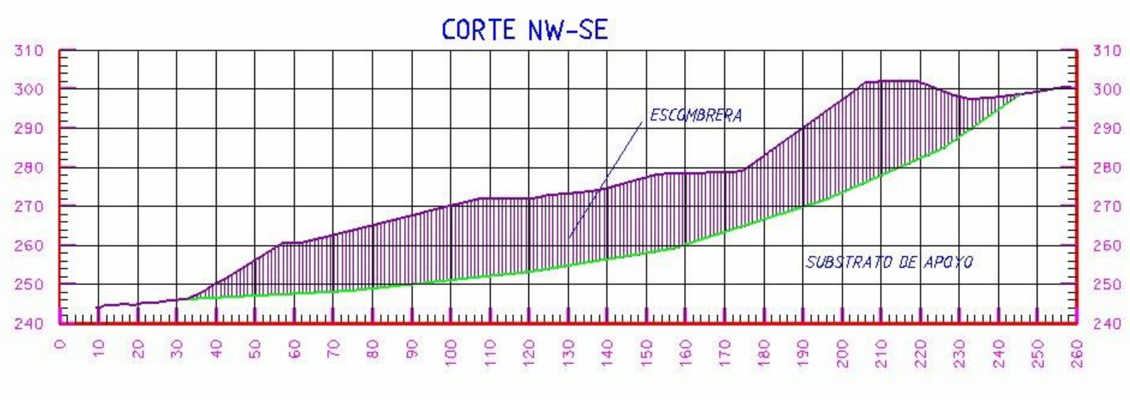


Figure 5. NW-SE slope profile of Sector 1

After this actuation, and in order to promote the germination of herbaceous plants, the entire surface of the restored slopes was covered with a layer of topsoil of approximately 25 cm thick. Topsoil came from external stockpiles, and it was spread and refined to prepare the surface of the slope for the sowing phase.

The sowing was carried out with herbaceous species selected considering the characteristics of the terrain (slope, orientation, etc.) and the specific qualities of the different species (rapid germination, vigorous rooting, etc.). The sowing methods were hydroseeding on slopes and manual sowing on platforms with less than a 5º slope.

The components of the sowing and their proportions are presented in Table 8.

Table 8. Components and dosage of the sowing in Sector 1

Component	Dosage (Kg/ha)
Mulch	200
Stabilizer	35
Seeds	150
Inorganic fertilizer NPK (8-24-16)	100
Organic amendment (worm humus)	240

The mulch serves as protection to the soil and to the seeds that are deposited on it. The stabilizers are organic materials applied in aqueous solution that, penetrating into the ground, contribute to agglomerate particles, improving the overall structure of the soil. Fertilizers and organic amendment are used due to the lack of structure of the soil and the possible loss of nutrients from the applied topsoil layer. Finally, the seeds used are presented in Table 9.

Table 9. Seeds composition in Sector 1

Seeds	Percentage
Lolium perenne	25%
Lolium multiforme	15%
Dactylis glomerata	12%
Festuca rubra	10%
Agrostis stolonifera	8%
Trifolium repens	15%
Vicia sativa	6%
Lotus corniculatus	9%

Figure 6 presents a berm in Sector 1, and Figure 8 and Figure 8 present two details of the vegetation in the berm. Figure 9 presents a view of Sector 1 from the pit area at the bottom of the dump.

Figure 6. Berm in Sector 1

Figure 7. Detail of vegetation in the berm in Sector 1

Figure 8. Another detail of vegetation of the berm in Sector 1

Figure 9. View of Sector 1 from the pit area

It has to be noticed that several areas which were not restored developed trees due to the proximity of a non-exploited area with trees (Figure 10).

Figure 10. Non-restored area near Sector 1

3.2 Sector 2

3.2.1 Hydroseeding in Sector 2

Sector 2 underwent hydroseeding in November 2016. The components of the sowing and their proportions are presented in Table 10Table 8.

On the other hand, the herbaceous seeds composition are shown in Table 11, and the bush seeds composition are presented in Table 12.

Figure 11 presents the results before and six months after the hydroseeding process (May 2017). Figure 12 presents the state of sector 2 in February 2020 and Figure 13 the state in November 2020.

Table 10. Components and dosage of the hydroseeding in Sector 2

Component	Sowing (Kg/ha)	Cover (kg(ha)	Total (kg/ha)
Mulch	900	720	1620
Stabilizer	22	18	40
Herbaceous seeds	295	0	295
Bush seeds	5	0	5
Inorganic fertilizer	700	0	700
Organic amendment (compost)	0	225	225
Slow release fertilizer	120	0	120

Table 11. Herbaceous seeds composition in Sector 2

Herbaceous seeds	Percentage	Herbaceous seeds	Percentage
Festuca rubra	9%	Trifolium repens	9%
Lolium perenne	23%	Lolium multiflorum	19%
Trifolium pratense	4%	Festuca Ovina	9%
Medicago sativa	2%	Festuca arundinacea	9%
Melilotus officinalis	4%	Dactylis glomerata	12%

Table 12. Bush seeds composition in Sector 2

Bush seeds	Percentage
Fraxinor excelsior	100%

Figure 11. Hydroseeding results after six months in Sector 2 (Nov. 2016 – May 2017)

Figure 12. Sector 2 in February 2020 (3 years and 3 months after the sowing)

Figure 13. Sector 2 in November 2020 (four years after the sowing)

3.2.2 Plantation in Sector 2

After a trial in 2017, plantation in Sector 2 was developed in April 2018 with a density of 250 trees/ha, totalizing 406 trees. The plantation was adapted to the orography of the land, being distributed over the entire surface in the most suitable areas for planting.

Table 13 presents the different plants that were used in Sector 2 as well as their heights. The species used stand out for their low mortality rate, being ideal for implantation in the waste dump. They can adapt to all types of terrain and their soil requirement is much lower than that of others.

The planting holes were sanitized, and topsoil was added. Trees were planted with tree guards and a protective net (Figure 14).

During the first months of the plantation, maintenance works and irrigation were developed. Later, an annual maintenance was also developed.

Table 13. Plants used in Sector 2

Species	Percentage	Height	Units
Fraxinus excelsior	36%	1.25 m	146
Betula alba	36%	1.25 m	146
Acer pseudoplatanus	20%	1.25 m	81
Ilex aquifolium	8%	20-25 cm	33

Figure 14. Tree guard and protective net

Figure 15 and Figure 16 present the state of different plants in February 2020 and November 2020.

Figure 15. Sector 2 in February 2020

Figure 16. Sector 2 in November 2020

3.3 Sector 3

3.3.1 Hydroseeding in Sector 3

Hydroseeding of Sector 3 took place in November 2016, October 2017 and April 2018, using the same components and seeds than in Sector 2. Figure 17 presents the previous stage in November 2016, and the results achieved in April 2018.

Figure 17. Sector 3 in November 2016 and in April 2018

Another view of Sector 3 is presented in Figure 18.

Figure 18. Another view of Sector 3

The top part of Sector 3 was hydroseeded on February-March 2020 (Figure 19), and after nine months the state of development is presented in Figure 20.

Figure 19. Top of Sector 3 in February 2020

Figure 20. Top of Sector 3 on November 2020

Finally, Figure 21 presents the hydroseeding projection in Sector 3.

Figure 21. Hydroseeding projection

3.3.2 Plantation in Sector 3

Plantation in Sector 3 took place in April 2018, with the same density and proceedings than in Sector 2. Table 14 presents the plants used in Sector 3.

Table 14. Plants used in Sector 3

Species	Percentage	Height	Units
Fraxinus excelsior	35%	1.25 m	128
Betula alba	35%	1.25 m	128
Acer pseudoplatanus	15%	1.25 m	55
Ilex aquifolium	15%	20-25 m	55

Figure 22, Figure 23, Figure 24 and Figure 25 present trees of each of the species that were planted in April 2018, in November 2020, a little more than two years and a half after the planting took place.

Figure 22. Acer pseudoplatanus in November 2020, Sector 3

Figure 23. Ilex aquifolium in November 2020, Sector 3

Figure 24. Betula alba in November 2020, Sector 3

Figure 25. Fraxinus excelsior in November 2020, Sector 3

3.4 Sector 4

Sector 4 is undergoing exploitation nowadays in order to valorize the coal content of the waste heaps Figure 26.

The proceedings and methods used in the restoration of Sector 4 were the same than in the other sectors, except the use of coconut mesh in the areas with a steep slope (Figure 27).

Figure 26. Exploitation of Sector 4 in November 2020

Figure 27. Sector 4 in October 2016 and in April 2018

4 Reclamation techniques on Ema – Terezie mine spoil dump complex

Being a significant dominant of the city, the mine spoil dump Ema – Terezie complex represents the largest conical dump in the urban area of Ostrava. It is an old dump complex formed by closed mines Ema, Trojice, Terezie and Petr Bezruč. The dump was declared as the cultural monument. Ema is located in the cadastral area of the Silesian Ostrava. It borders the built-up area (Na Najmanské, Vozačská, Miloše Svobody and Obvodní streets) in the east and northeast, former Petr Bezruč mine in the north and northwest, and Trojické údolí with the former Trojice coke plant in the southwest. The area is ca. 32 ha. The original terrain is descending to the southwest, balanced by thick layers of backfill, that form the body of the dump.

Natural Conditions

According to the regional geomorphological classification (T. Czudek, 1973), the mine spoil dump Ema – Terezie complex belongs to the outer part of the Western Carpathians, concretely the Ostrava glacigenic basin in the system of outer Carpathian depressions. The morphology of the dump terrain is adapted to the original shape of the Trojické údolí. The current appearance of the dump Ema is the result of landscaping in the axis of this valley.

Trojické údolí represents an approximately 1200 m long depression. Burňa stream, which joins the river Ostravice approximately 600 m from the western border of the area (below Bohumínská Street), flows across the axis of the valley. It is oriented from northeast to southwest. The altitudes range from about 234 m above sea level in places under the base of the dump to about 323 m above sea level at the highest peak of the dump. The original bottom of the valley, and thus also the bed of the Burňa stream, is situated below the level of the dump surface and it is piped. The end of Trojické údolí and the source of the stream Burňa are located about 200 m below the southwestern foot of the two heaps system, where the heap Ema (the dump structure of the former mine Trojice) forms a significant landscape feature. The piping of the Burňa stream takes place through the area of the former Trojice coke plant and ends in the northwestern outcrop of the area. The stream enters the surface near the supporting wall above Těšínská Street and forms an extensive wetland. The stream is further diverted below street level and piped again.

The geological structure of the studied area is complex and variable in the horizontal direction. It can be characterized as follows: Geologically, the oldest unit of the area are coal-bearing carbon rocks. They are deposited very shallowly below the surface throughout the territory. They occur in the form of weathered eluvium. The southern and southeastern slopes of Trojické údolí are built mainly by rocky outcrops of the Carboniferous (so-called carbon window - a geological situation, where the stratigraphic interface between the carbonaceous bedrock and the upper clay cover layer is missing, and Paleozoic rocks rise directly to the surface). On these rocks (outside the area of the carbon window) is deposited a monotonous complex of gray-green calcareous clays, the so-called Ostrava slings of Miocene age. However, the occurrence is not continuous, and the clays cover only the northern parts of the area. The Neogene is missing around the valley and was probably eroded by the activity of a watercourse. The Quaternary overburden is represented by several stratigraphically, genetically and lithologically different sediments. The stratigraphic sequence begins with the sediments of the Saale glaciation, which is widespread throughout the whole area. These are alternating sands and clays with considerable facial variability. Another layer unit is loess loam, preserved only on the northern and northeastern edge of the studied aerea. In the lower parts of the slopes, they are usually replaced by deluvial clays. Alluvial clays form a cover of younger erosion furrows, opening into the Trojické údolí. The main geological element, modeling the original natural shape of the valley to its current form, is a thick layer of backfill formations, reaching a thickness of several tens of meters (central cone of the dump).

History of the Dump Formation

The mine spoil dump Ema – Terezie complex forms a complex of dumps of the former mines Ema, Trojice, Terezie and Petr Bezruč ("dump Ema"), historically even older mining works. It is one of the oldest dumps in the Ostrava region, which has been in operation since 1920. The dump was declared as the cultural monument.

Morphologically, it is a slope dump combined with a conical dump. The slope of the dump is only partially developed because it was poured gradually, after partial landscaping of the original subsoil. The original configuration of the terrain surface is now undetectable.

Considering the original, mainly manual, mining method of high-quality coal seams, the percentage of deposited tailings was not very large once. However, the gradual mechanization of mining increased the volume of deposited material. The tailings were stored in a cartridge and transported to the dump Ema by the carriage lift.

The Ema dump is situated in a mining area that has been used for a long time. The existence of the mining works in its subsoil allows the possibility of communication between them and the dump. In addition to carbonaceous rock, an undetectable amount of construction, municipal and household waste was deposited here. Immediately after the war, rubble from bombed-out houses was deposited at the foot of the dump. According to the testimony of witnesses, wood sawdust was also poured on the dump as well as washery dirt from treatment plant with a grain size of 0-200 mm, which in some places amount to approx. 15% of the volume.

Thermal processes, including open fires, have been taking place here for decades with varying intensity. Repeated attempts to rehabilitate the central cone were not effective.

An example from the 1960s is the operational attempt to rehabilitate existing thermal processes associated with the prevention of the formation of new deposits of thermal activity, which consisted of the combined pouring of waste material and power plant fly ash.

The area of Ema was also negatively affected by the close connection with the adjacent dump of the Trojice mine, which probably ignited due to the high content of combustible substances in the tailings. It was rehabilitated in 1977. The method of surface grooving of the heap surface was chosen as the technology. A suspension of power plant fly ash and water was washed into the excavated grooves. This created a sealing barrier against the transfer of the fire of the deposited material to the adjacent Ema dump. The solution of the infusion on the north-western slope of the dump was also significant. There was a danger of a possible spread to the old dump in the mine Petr Bezruč. This problem was solved in 1982 by the OKD emergency commission. A method of sprinkling insulating strips on the slope of the dump was designed and implemented. The technological procedure consisted of regular putting of power plant fly ash in layers subsequently covered by a layer of washery dirt with a guaranteed and controlled content of combustible substances (a total of 50 thousand of m^3 was transferred to this locality). An insulating divide was created between the old dump and the Emma dump. Pre-designed reclamation works were subsequently carried out in this area.

Evident thermal processes in the dump are currently taking place at the southwest part of the slope of the central cone in a strip 7-12 m wide (area of the former cable car). The affected part has an area of about 2000 m^2 and there are open vents for hot gaseous combustion products. The reclamation of the perimeter ring, flattening of the slopes and afforestation was realized so far.

Technical Parameters of the Dump

Dump volume: total complex approx. 8 million m^3

Area: 32 ha

Operating hours: 1920 - 1995

Transport technology: narrow-gauge track, ring around Ema- cars and tractors.

Ema by a skip lift along the sloping, cable car from the Trojice Mine

Shape: conical with an irregular panel surface at the foot of the cone

At present, the land on which the Ema dump is located, is owned by RPG RE Land, s.r.o. (parc. Nos. 510/1, 510/2, 510/4 and 2413).

The dump is managed by the state enterprise DIAMO.

Thermal Activity

At present, the manifestations of thermal processes are visible at the dump, in the 7 - 12 m wide strip, just before the top of the central cone at southwest slope. There are open cracks in the soil cover - vents with hot gas outlet with a strong aromatic odor. Thermal activity was registered at the dump from about the 1960s with breaks to the present. The content of combustible substances was analyzed from the samples (see the examination of the area). It ranges between 6 – 22 %, which is enough to continue thermal processes in terms of the possible origin and development of endogenous fire. Atmoscreening, performed on the dump, indicated the content of CH_4 in the soil air at the level of the lower sensitivity limit of the analyzer. The concentration of CO_2 ranges from 0.2 to 2.6 % in the soil air and up to 9.7 % in places of open vents (see the examination of the area). The maximum concentration of CO, measured in the probes, was 95 ppm and the maximum concentration of CO, measured in the open vent was 1306 ppm. It can be considered as a dangerous concentration. The results of the implemented atmoscreening and thermoscreening and the manifestations on the soil cover indicate the ongoing burning in a large part of the dump. Temperature, measured in the probes at a depth of 1 m, ranges from 17 - 21.8 ºC with maxima in open vents (65.4 - 67.1 ºC). Ongoing thermal processes in the deeper parts of the dump on the south-eastern slope of the central cone are indicated by not very significant, but observable slight increase in temperature at the places of increased CO contents.

Landscape Recultivation Methods on the mine spoil dump Ema – Terezie complex

The area of the dump Ema - Terezie complex is divided into three segments in terms of the use of reclamation techniques (see Fig. 28):

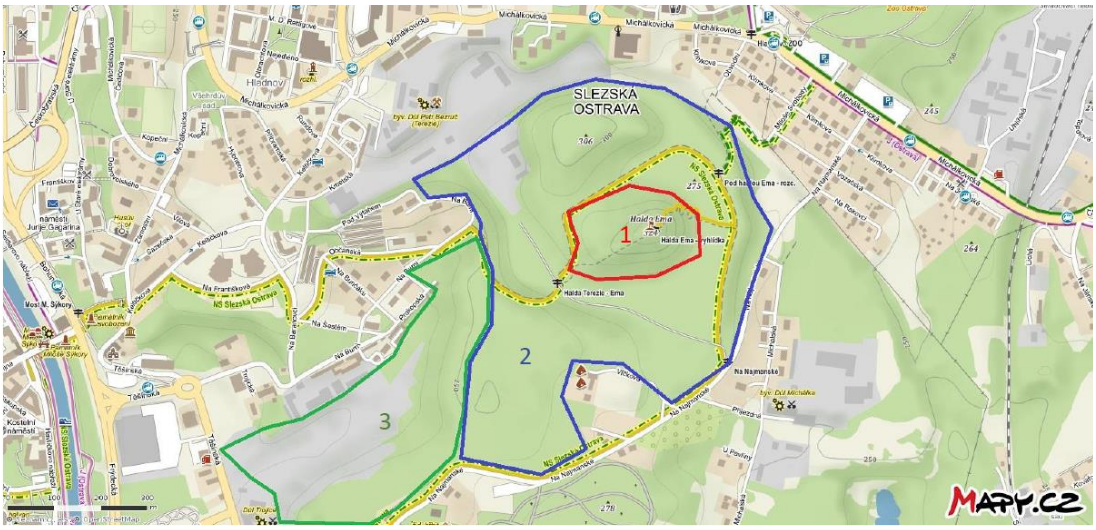


Figure 28. Mine spoil dupm Ema – Terezie complex - segments of reclamation

1. Ema conical dump - segment 1

Reclamation techniques used: spontaneous succession

Species composition of woody plants: *Betula pendula (92 %), Populus tremula (5%), Cerasus avium + Quercus robur + Quercus cerris juv. + Sorbus aucuparia (3%).*

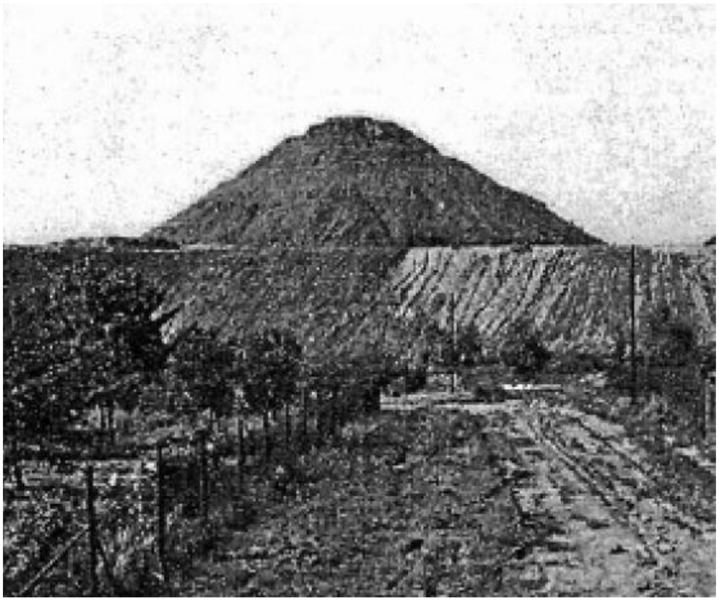


Figure 29. Dump Ema - the end of the 60s of the 20th century (Havrlant, 2003)

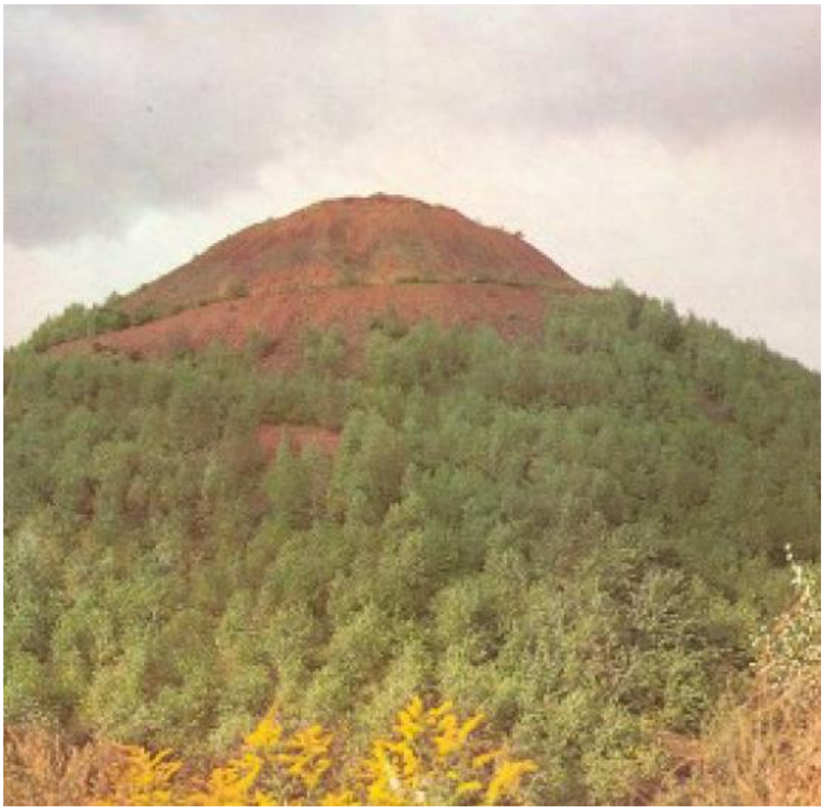


Figure 30. Dump Ema 1974 (Klát, 2010)

Figure 31. Dump Ema 2014 (Stalmachová, 2014)

2. **Tabular dump Terezie and Petr Bezruč – segment 2**

Used reclamation techniques: forest reclamation with a mosaic of high-herb and grass segments

Commencement of reclamation works: 1975

Completion of reclamation works: 1995

Species composition of woody plants: *Acer platanoides, Acer pseudoplatanus, Amorpha fruticosa, Carpinus betulus, Cornus mas, Crataegus laevigata, Forsythia intermedia, Lycium barbatum, Picea pungens, Populus tremula, Quercus robur, Robinia pseudoacacia, Sorbus aucuparia, Tilia cordata, Viburnum opulus.*

Spontaneous spread of diaspores from the environment enriching the species composition:

1. *Quercus cerris* (source: Ostrava Zoo),
2. *Populus alba* (source of anemochorous spread of seeds from Central Moravia through the Moravian Gate),
3. *Betula pendula* (anemochoric seed spread)
4. *Cerasus avium* (zoochorous seed spread)
5. *Larix decidua* (anemochoric seed spread)
6. *Populus x euroamericanus* (anemochoric seed spread)
7. *Populus tremula* (natural forest regeneration)
8. *Rosa* sect. *caninae* (zoochromic seed spread)
9. *Salix capraea* (anemochoric seed spread)
10. *Sambucus nigra* (zoochorous seed spread)

Figure 32. Dump Terezie – Petr Bezruč, 2019 (Stalmachová, 2019)

3. **Flat dump and area of the former Trojice coke plant - segment 3**

Used reclamation techniques: spontaneous succession - forest with representation of high-herb segments of vegetation

Species composition of woody plants: *Acer platanoides, Acer pseudoplatanus, Betula pendula, Cerasus avium, Populus tremula, Quercus robur.*

The Trojice coke plant was active from 1846 to 1983. The abandoned area is currently forested, with a mosaic-like occurrence of high-herb segments. The state enterprise DIAMO is preparing to rehabilitate the coking plant complex and the former Trojice Mine in Silesian Ostrava. In the future, there should be family development or forest reclamation with landscaping. Currently, the area is infested with a number of substances that could contaminate the nearby river Ostravice. The underground is mainly products of coking, tars, polyaromatic hydrocarbons, phenols, cyanides, lead and mercury, there are approximately 160,000 tons of undesirable substances. Estimates of the costs of cleaning a seven-hectare area are around one billion crowns. The work will last three years; the state should pay for it.

Figure 33. The area of the former Trojice coke plant (Stalmachová, 2019)

Figure 34. The area of the former Trojice coke plant (Stalmachová, 2019)

According to the intervention intensity in the restoration process of the landscape affected by man, we can identify four categories of post-industrial vegetation - I. retention, II. adjustment, III. complementation, IV. negation.

I. retention- wilderness

Wilderness refers to places that are completely left to nature and its succession. These are localities where nature can take care of "itself" - without human intervention. Such areas are located mainly in more remote parts of industrialized areas or in places, where the developmental stage is botanically or zoologically valuable and the intervention would be disruptive.

II. adjustment- - leaving the succession to vegetation with access to space

This type of vegetation is formed by natural succession, but there is a disturbing element of human intervention. These interventions in the natural development of vegetation are expected to intensify the use of space in the area by humans. It is therefore a controlled succession, which represents the development of vegetation with the inputs of a foreign factor (starting the process, directing in the desired direction). This method is used to develop plant communities in the area in the shortest possible time to achieve the desired properties. The most frequently used methods of controlled succession include the introduction of plant material and various methods of stand maintenance (mulching, barking, mowing). The given type of industrial vegetation management will find application both in more remote areas of the industrially influenced landscape and in areas transformed into parks if the rule of access to the basic network of roads or footpaths is observed.

III. complementation - preservation of segments of post-industrial vegetation and completion with new compositional elements

Spontaneous vegetation is in contrast with the conventional plantings. Natural vegetation is subordinative to the design of the creator, who only uses its attractiveness and wildness to complete his purpose. Care for vegetation elements is more intensive, e.g., trimmed hedges, flower beds. In many ways, such a landscape resembles the conventional nature of public space. It is suitable mainly in areas with a presumption of higher intensity of use.

IV. negation - ignoring existing vegetation, its destruction and creation with new elements

Vegetation, created by natural succession, is completely replaced by new plantings. This type is located especially near objects that have undergone conversion or in areas, where new construction has taken place on the brownfields area (Ostravské městské lesy a zeleň, 2011), (Walker, 2003).

Using the above identification system of post-industrial vegetation, we can evaluate individual segments:

1. Segment - Conical dump Ema: category I - wilderness - birch stand with the occurrence of fruiting deciduous trees on burnt, red-colored tailings. On the northwest slope, there are combustion gas outlets inside the dump.

2. Segment - Tabular dump Terezie - Petr Bezruč: category II - adjustment - in the 1970s forest reclamation using mostly deciduous tree species, spontaneously inhabited by zoochorically and anemochorically spreading species (see species composition above). The species composition basically corresponds to native species, with isolated plantings of ornamental trees (*Amorpa fruticosa, Robinia pseudoacacia* and others, see species composition above). Now a non-intervention area with tourist use.

3. Segment - The area of the former Trojice coke plant: current state - wilderness, interventions are planned, which can be classified in category III (in the case of forest reclamation), or category IV. - negation (in the case of future implementation of family development. At present, it is not possible to specify the category in more detail, due to the fact that the Government of the Czech Republic has suspended all remediation activities.

5 Water analysis in the Ema-Terezie mine dump complex

5.1 The water analyses of the surface water, in the basin of the river Burňa

The whole territory is made up of a complex of dumps, the former mines Sv. Trojice, Ema and Petr Bezruč (former name of the Terezie Mine).

Contamination of territory

Regime of analyses: September 2019 – September 2020, surface water sampling, once a month, simple, point sampling according the Czech norms.

Monitoring profiles – 4 profiles of the Burňa river basin. The number of the hydrological order of the river basin, respectively the watercourse is 2-03-01-0830-0-00.

- Stream Burna discharge
- Burna pool
- Cooling canal
- Earlier wetland

Figure 35. Earlier wetland

Figure 36. Burna pool

Figure 37. Stream Burna discharge

Figure 38. Cooling canal

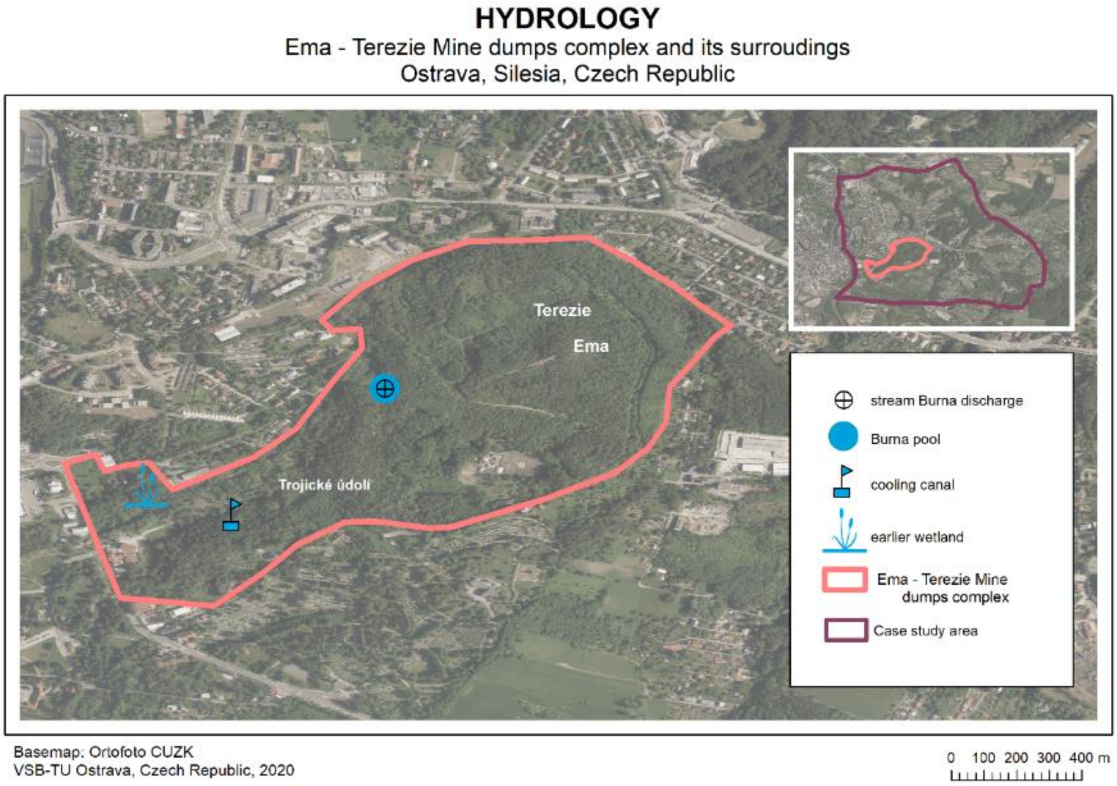


Figure 39. Situation map

Selected monitored parameters:

Basic physical and chemical parameters as: CON (Conductivity), pH, t (temperature), 02 (dissolve oxygen), CODCr (Chemical oxygen demand by Cr), BOD (Biochemical oxygen demand), TSS (Total suspended solids), TDS (Total dissolved solids), NO3 (Nitrates), NO2 (Nitrites), NH4 (Ammonium ions,) Cl (Chlorides), SO4 (Sulphates), (Ptotal) Phosphorus total.

Toxic metals: Pb, Hg, Cd, Cr, Cu, Zn, Ni

Strategic metals: Mn

The main contaminants are PAU, NEL, C10-40, Pb, ammonium ion (presentation ppt - Company G Consult, 2014).

Results of analyses Stream Burna discharge and Burna pool

The profile Cooling canal, was not contaminated, it was only a surface water seepage, and the extreme values of the (minimum) box plot corresponded to the profile without any contamination. And the profile earlier wetland was destroyed, meliorated, for construction purposes and the extreme values of the (minimum) box plot corresponded to the profile without any contamination.

Higher concentrations of pollution were in the parameters: Chemical oxygen demand by Cr (CODCr) , Total suspended solids (TSS), Total dissolved solids (TDS), Ammonium ions (NH4), Sulphates (SO4).

The measured values of the analyses were evaluated according to the valid Czech legislation.

The value of permissible surface water pollution (p) according to Government Regulation No. 401/2015 , valid in the Czech Republic, is set as an annual average. For limit (p) nitrate nitrogen is determined, the NO3 value must be stoichiometrically converted, (kNO3 = 0.2259). For limit (p) ammoniac nitrogen determined, the NH4 + value must be stoichiometrically converted (kNH4 + = 0.2299). Government Regulation No. 401/2015 on indicators and values of permissible pollution of surface water and waste water, particulars of permits for discharge of waste water into surface water and to severage, sensitive areas.

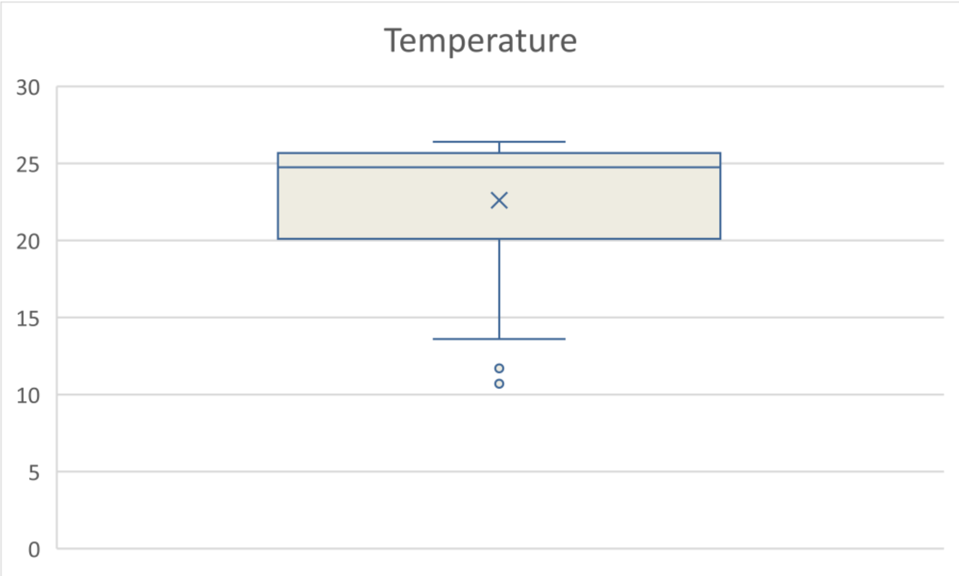


Figure 40 Box plot of temperature

Limit p, according the Czech legislation, is maximal 29

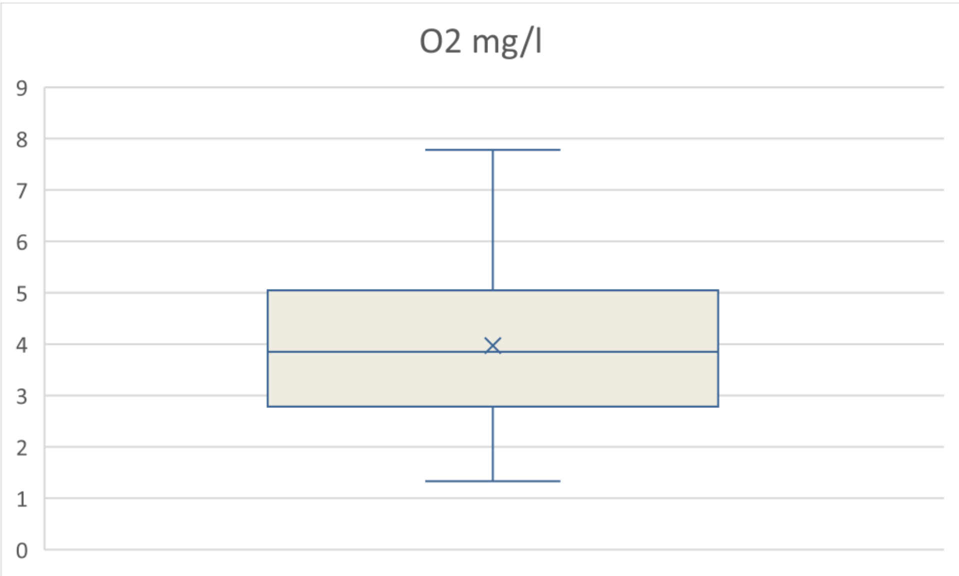


Figure 41 Box plot of Oxygen

Limit p, according the Czech legislation, is more than 9 mg/l

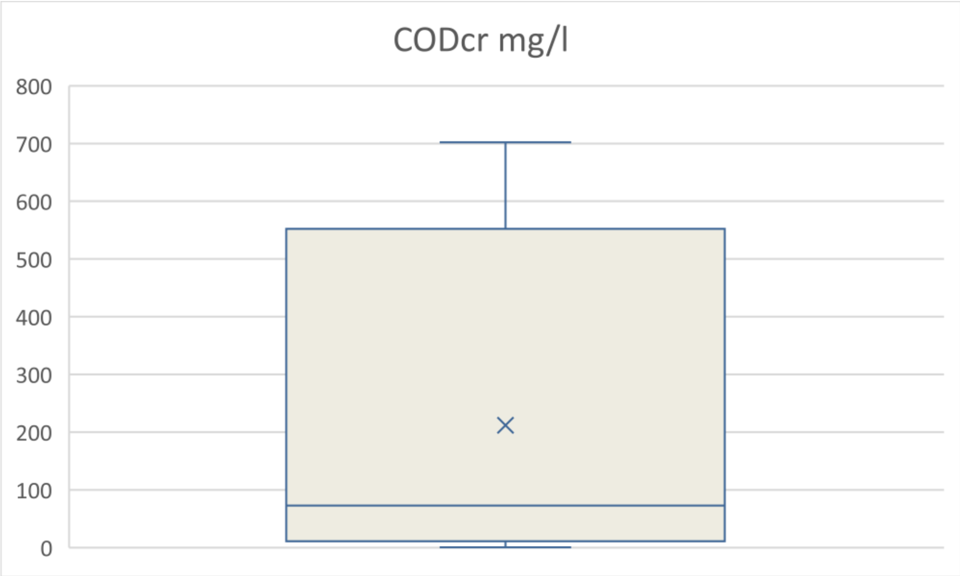


Figure 42 Box plot of CODCr

Limit p, according the Czech legislation, is 26 mg/l

Figure 43 Blot box of BOD

Limit p, according the Czech legislation, is 3,81 mg/l

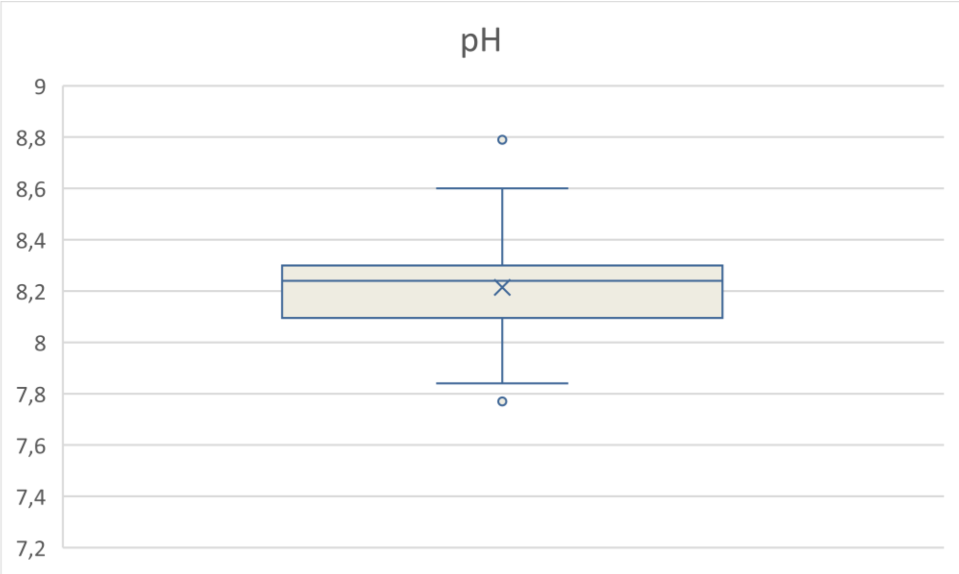


Figure 44 Box plot of pH

Limit p, according the Czech legislation, is 5-9

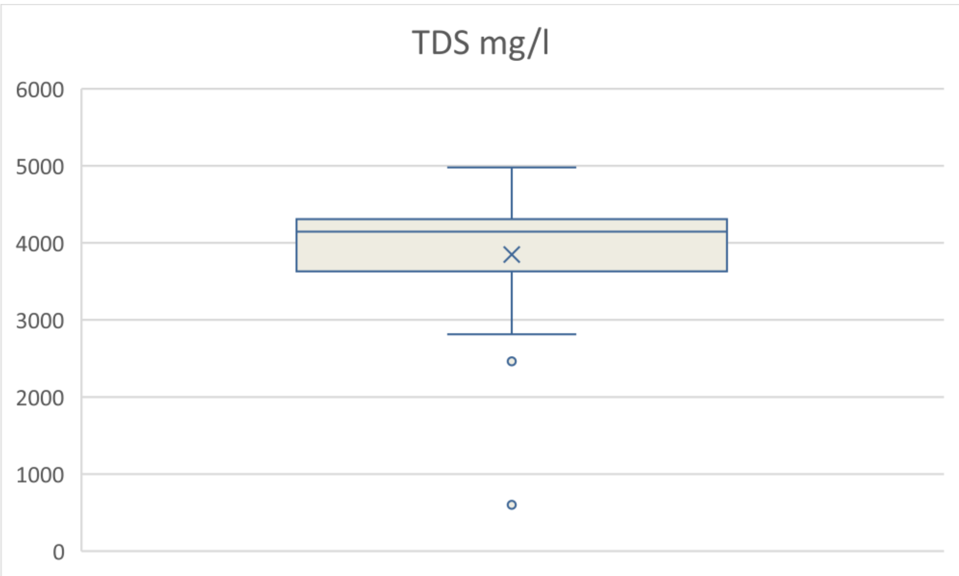


Figure 45 Box plot of TDS

Limit p, according the Czech legislation, is 750 mg/l

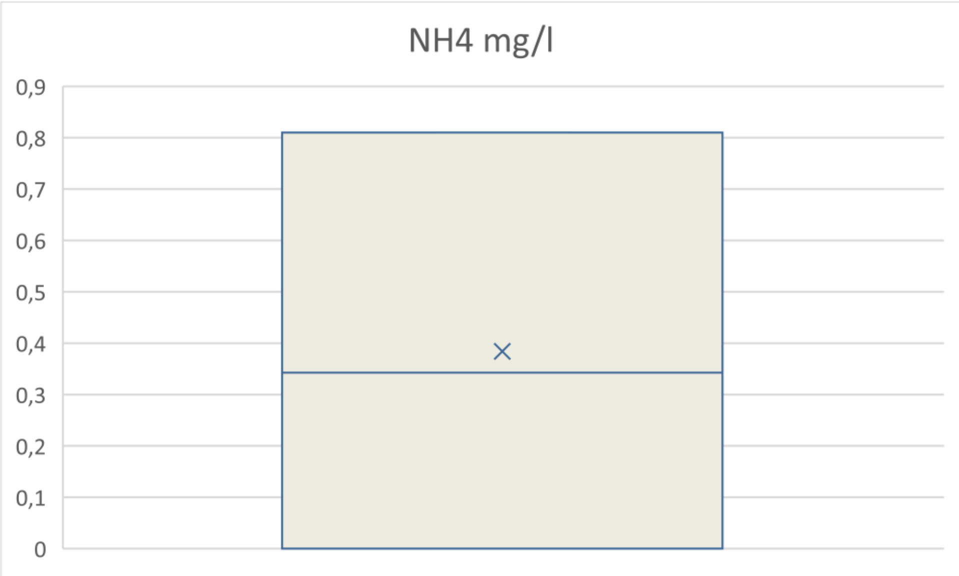


Figure 46 Box plot of NH_4

Limit p, according the Czech legislation, is 0,231mg/l. For limit (p) ammoniac nitrogen determined, the NH4 + value must be stoichiometrically converted (kNH4 + = 0.2299)

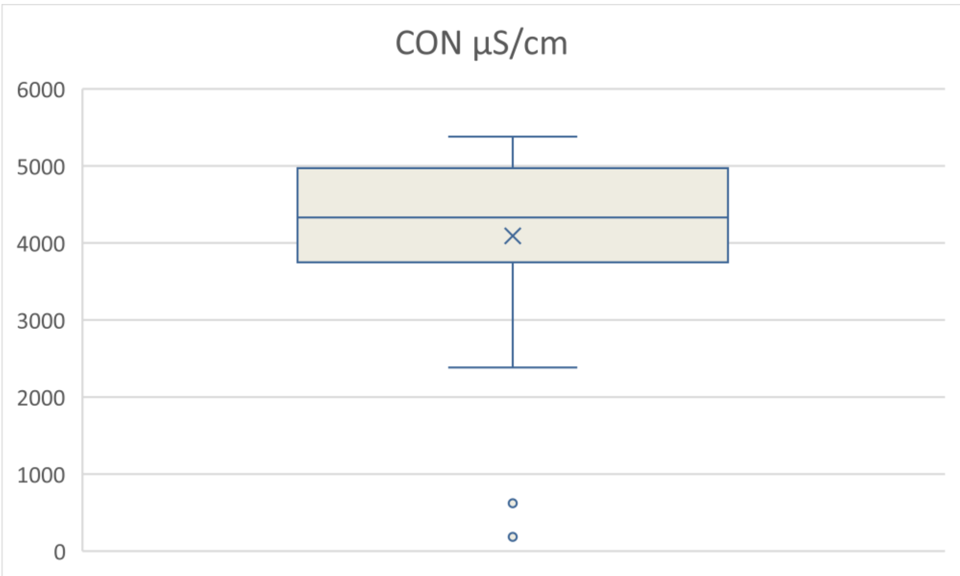


Figure 47 Box plot of CON

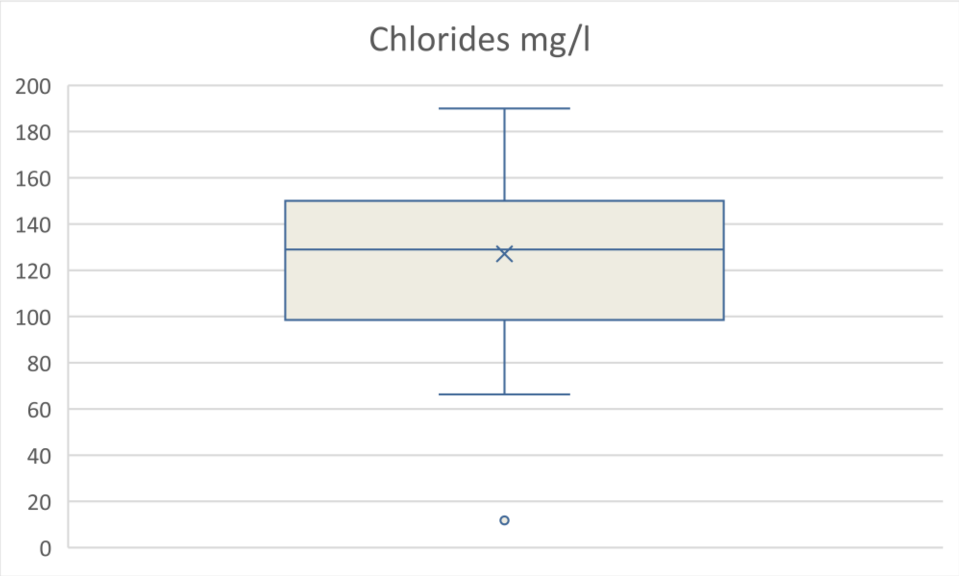


Figure 48 Box plot of Chlorides

Limit p, according the Czech legislation, is 150 mg/l

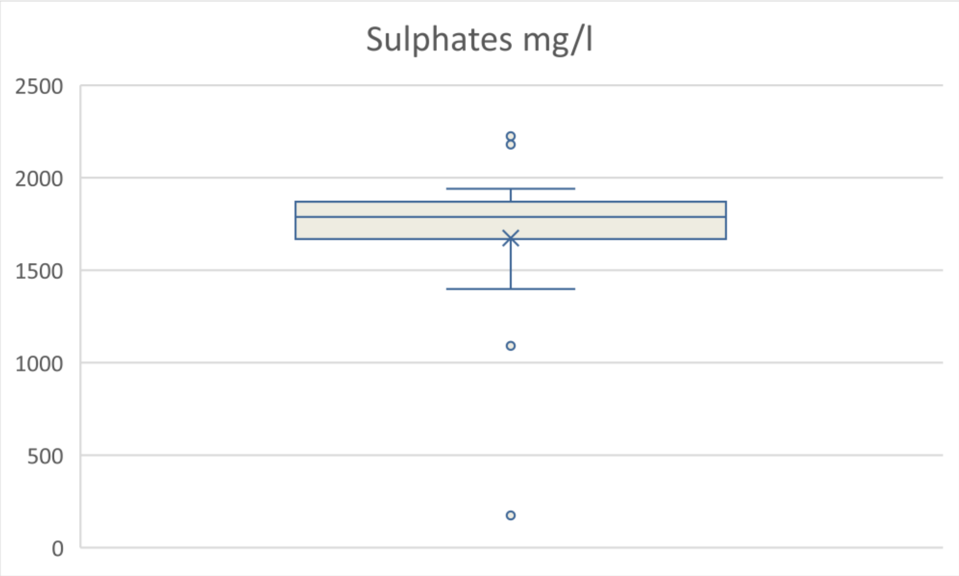


Figure 49 Box plot of Sulphates

Limit p, according the Czech legislation, is 200 mg/l

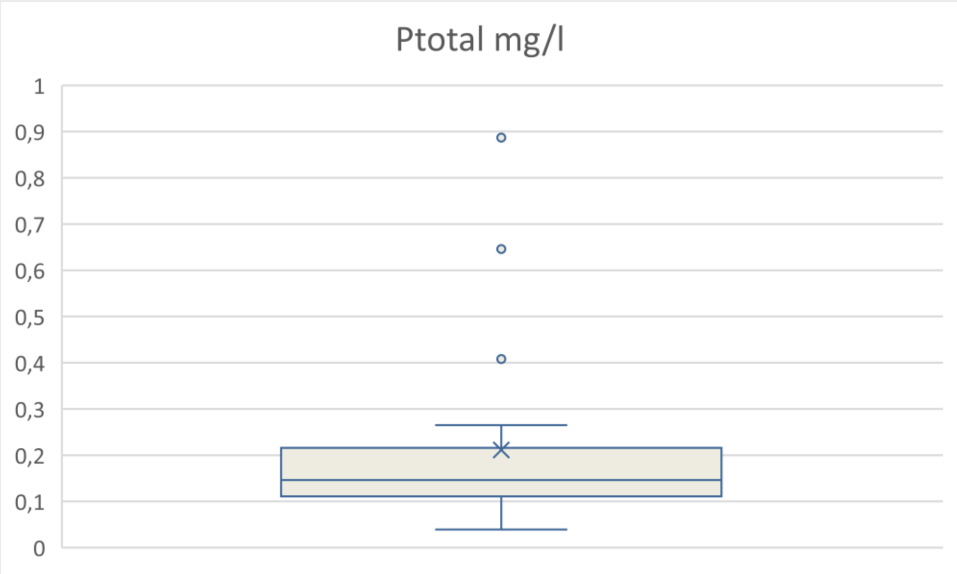


Figure 50 Box plot of Ptotal

Limit p, according the Czech legislation, is 0,15 mg/l

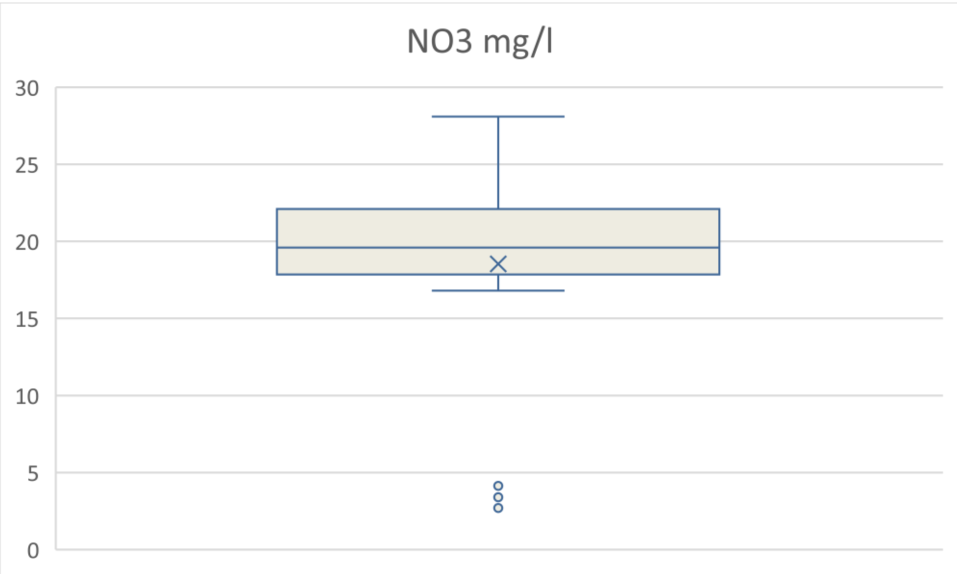


Figure 51 Box plot of Nitrates

Limit p, according the Czech legislation, is 5,41. For limit (p) nitrate nitrogen is determined, the NO3 value must be stoichiometrically converted, (kNO3 = 0.2259)

Hydrogeological well – only 1 sample, November 2019

Pb µg/l	Cd µg/l	Cr µg/l	Cu µg/l	Ni µg/l
111	5	<5	49	10

Zn mg/l	Fe mg/l	Mn mg/l	Na mg/l
0,50	443	16	436

Measurement uncertainty: 20%. It´s usually determine the elements on the method ICP MS (inductively coupled plasma mass spectrometry), which has a higher sensitivity. At the method AAS (atomic absorption spectrometry), everything was below detection. The elements Pb, Cd, Cr, Cu, Ni were measured by method ICP MS, and elements Zn, Fe, Mn, Na by method AAS.

There are contamination of Pb (limit 7,2), Cd (limit 0,3), Cu (limit 14), Zn (limit 0,092), Fe (limit 1), Mn (limit 0,3), Na (limit), according the Czech legislation.

These results are from two profiles as Stream Burna discharge and Burna pool.

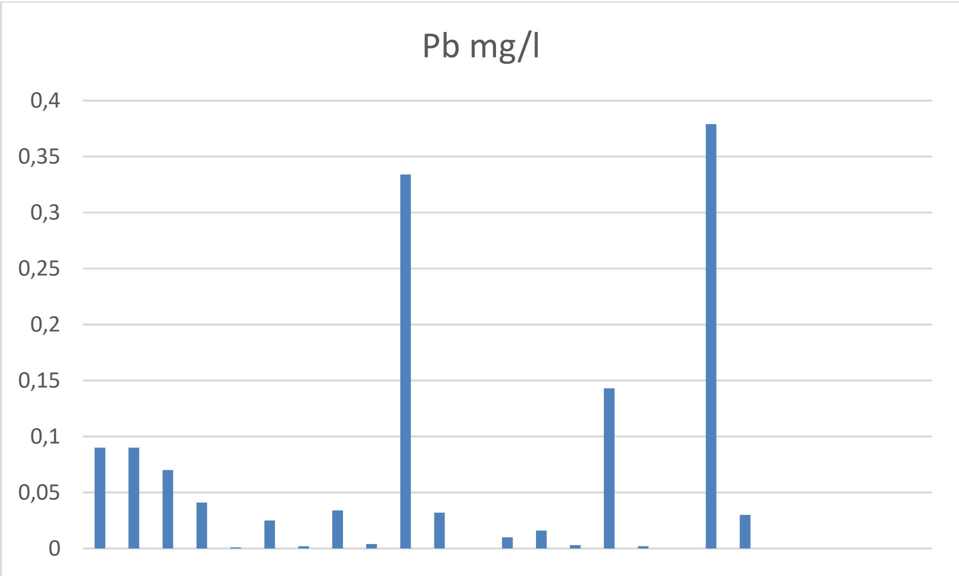


Figure 52 Value of measurement Pb

Limit p, according the Czech legislation, is 7,2 µg/l….. 0,0072 mg/l

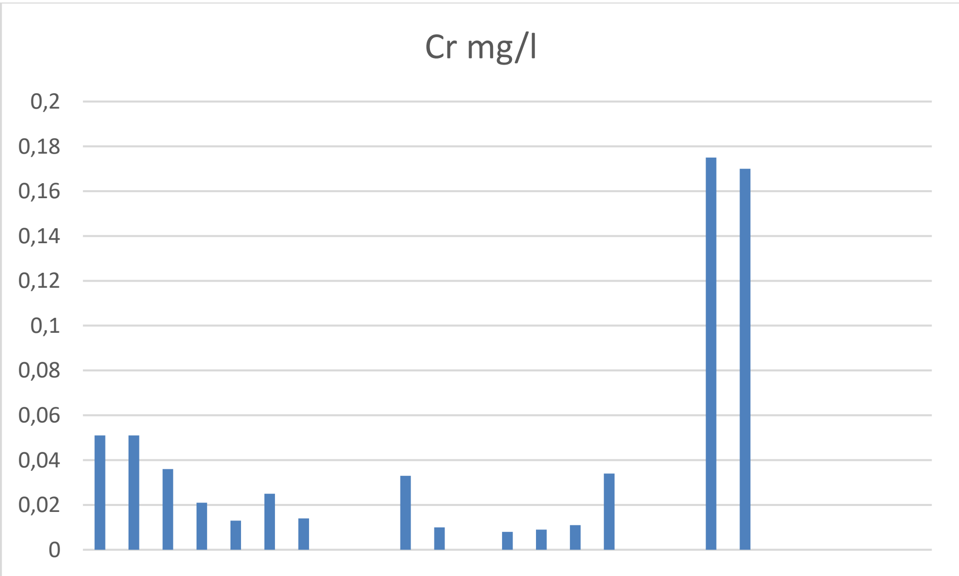


Figure 53 Value of measurement of Cr

Limit p, according the Czech legislation, is 18 µg/l….. 0,018 mg/l

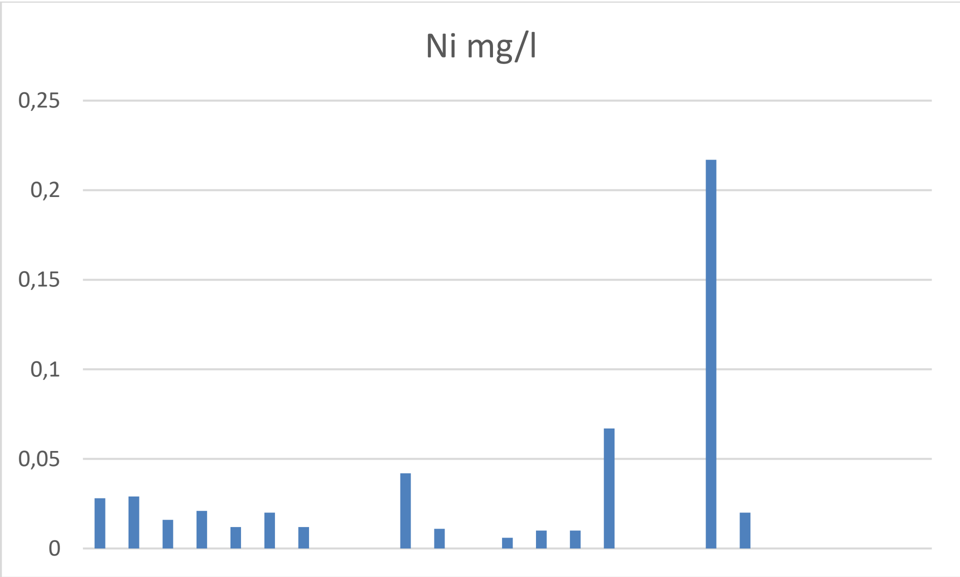


Figure 54 Value of measurement Ni

Limit p, according the Czech legislation, is 20 µg/l….. 0,020 mg/l

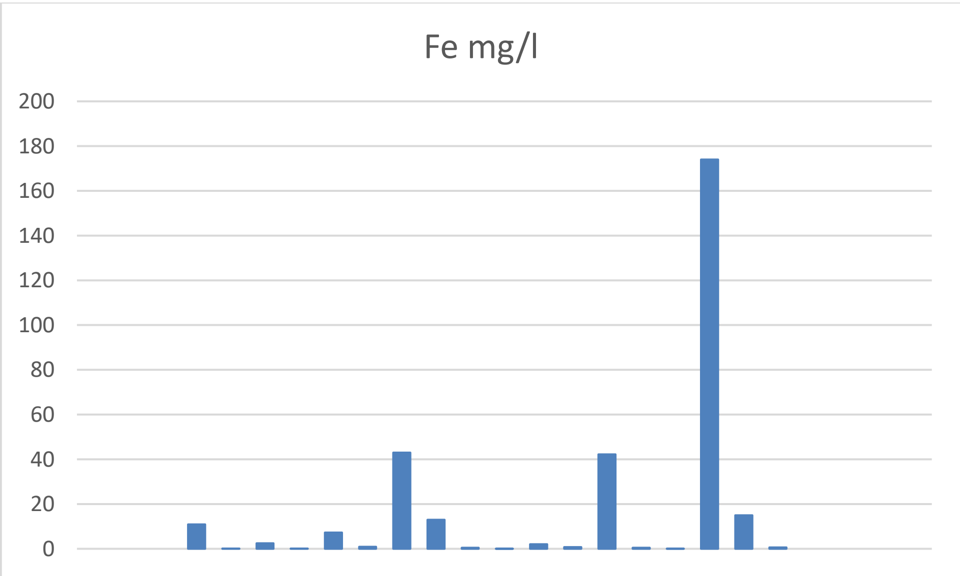


Figure 55 Value of measurement of Fe

Limit p, according the Czech legislation, is 1 mg/l

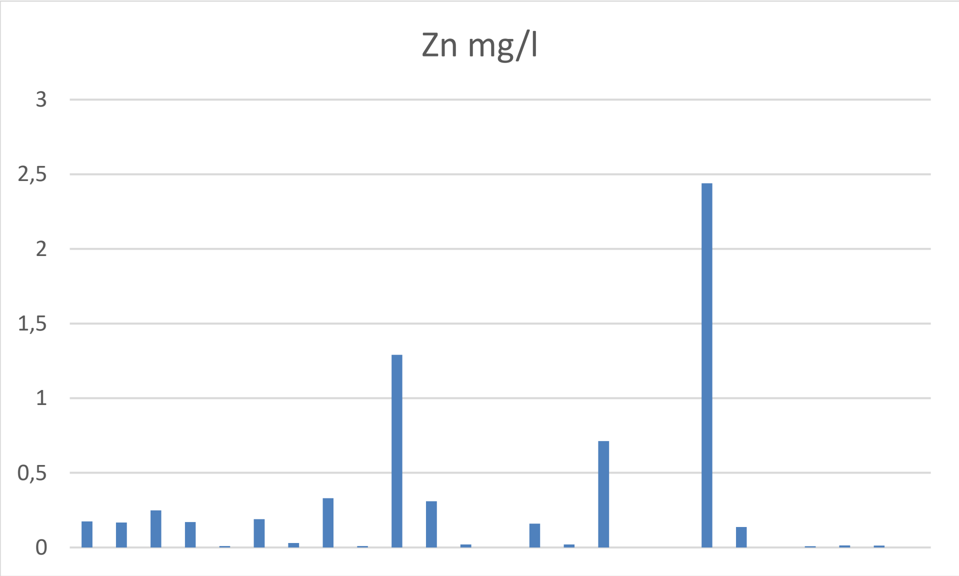


Figure 56 Value of measurement Zn

Limit p, according the Czech legislation, is 92 µg/l..... 0,092 mg/l

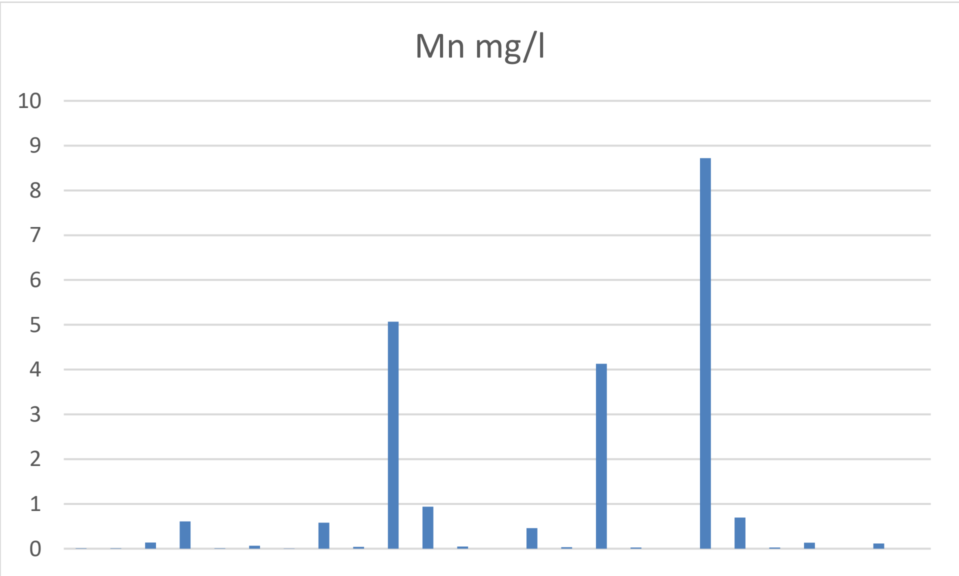


Figure 57. Value of measurement of Mn

Limit p, according the Czech legislation, is 0,3 mg/l

There are contamination of Pb, Cr, Ni, Fe, Zn, Mn.

Fe sulphide naturally weathers by oxidative processes. It´s present in the dump as pyrite. So we can speak in part of natural deposition.

We can talk about occurrence of pseudo-groundwater body, perched ground water in dumps. Dumps makeup of the fragments of brick, concrete, cinder, ash, clay, demolition of the coking plant Sv. Trojice, after the World War II bombing, demolition debris and scree.

Carbon rocks are: algae limestone (organ genic, composed of skeletal elements of plants and animals, secreting CaCO3. Examples are biohermic and biostromic limestone such as reef, coral, late grass, algae crinoid etc. Other layers - clays, claystone's, calcaneus clays, gravels (G Consult, 2014).

Migration of contaminants according to the permeability of the solids, in the unsaturated zone, above it with low permeability clay, creating the assumption of suspended aquifers, subsurface water almost in the surface layer… than the slope. The problem of NELs (non-polar extractable substances or hydrocarbons, fats, oils, chlorinated non-polar organic substances) their sorption to sediments.

Design of remediation measures Continuous pumping of water from excavation pits, their cleaning at the decontamination station and back seeping into the infiltration drain.

Backfill of excavation pits with inert material in layers with compaction. Final coarse landscaping to the proposed level with overlaid reclamation layers (G Consult, 2014).

6 Soil survey at the spoil dump-fields of Ema-Terezie complex

The soil survey was carried out at fifteen sampling sites in the area of interest (Terezie – Ema spoil dump field, Petr Bezruč spoil dump field and Trojice valley) and samples were analyzed by WD-XRF spectrometry (Tab. 5.1; Fig. 21). The predominant soil type (soil-forming substrate) in the area of interest is Anthrosol (skeletal and urban).

Table 15. WD-XRF analyses of soil-forming substrate Ema – Terezie complex

Element	Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sc	$mg.kg^{-1}$	10	13	20	9	11	11	13	12	20	20	~	21	19	15	20
V		67	96	119	58	66	74	80	68	119	127	59	121	105	91	141
Cr		96	84	109	113	98	121	82	80	111	132	66	123	106	276	121
Co		~	10	13	10	10	10	13	~	14	~	~	14	12	10	12
Ni		25	36	41	22	33	36	35	30	47	36	24	46	43	47	52
Cu		55	48	45	12	17	18	26	19	47	58	14	37	48	38	71
Zn		322	85	121	33	51	65	68	61	108	124	38	127	93	88	125
As		~	~	~	10	10	11	11	~	17	226	~	14	11	17	39
Rb		54	72	154	58	76	77	97	75	165	162	59	157	159	170	191
Sr		113	297	118	49	82	65	74	63	153	168	42	109	108	121	183
Zr		201	226	216	170	429	248	311	280	198	192	164	182	176	193	227
Ba		772	603	738	308	452	415	527	546	658	1425	326	849	613	816	1047
Pb		98	44	50	16	24	26	29	27	48	253	14	46	42	37	39

The values were compared with the preventive values of the content of risk elements for farmland (Statutory Decree No. 153/2016 Coll., Table No.1). According to Statutory Decree No. 153/2016 Coll. it was only possible to compare the levels of elements: V, Cr, Co, Ni, Cu, Zn, As and Pb. At the sampling site No.15 the preventive values were exceeded for a total of six risk elements: V, Cr, Ni, Cu, Zn and As. According to Statutory Decree No. 153/2016 Coll. the average values only two risk elements were exceeded (As and Cr). Contamination by As and Cr is probably caused secondarily (Fig. 19).

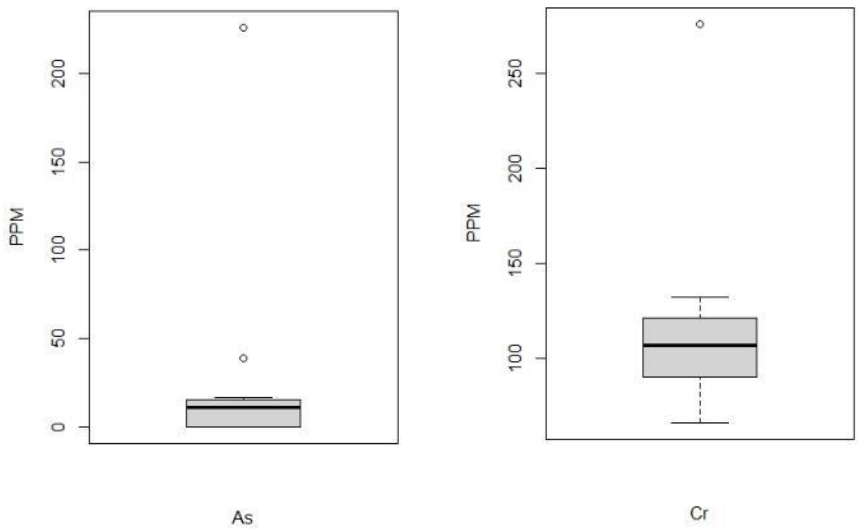


Figure 58. Box plot of As and Cr concentration in the soil-forming substrate

Strontium and especially barium have been shown to be present at higher concentrations (Fig. 20). A higher concentration of these elements is typical for this area.

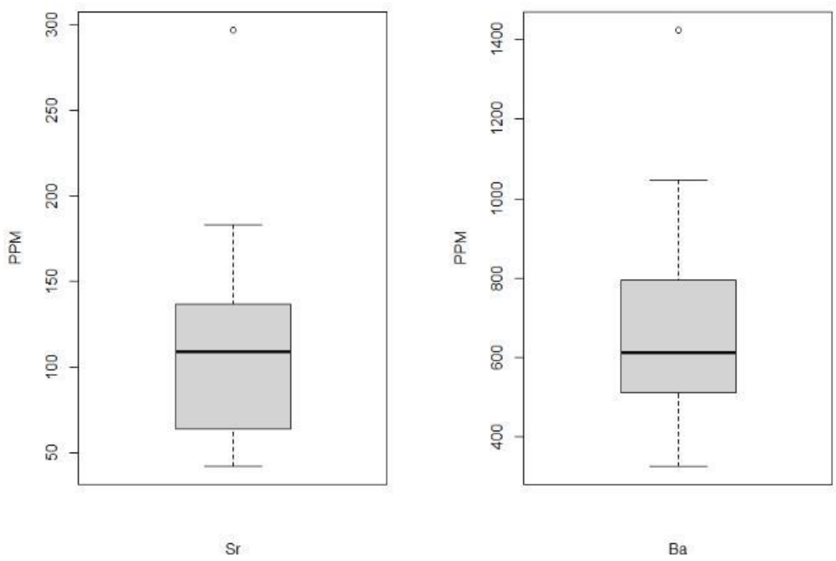


Figure 59. Box plot of Sr and Ba concentration in the soil-forming substrate

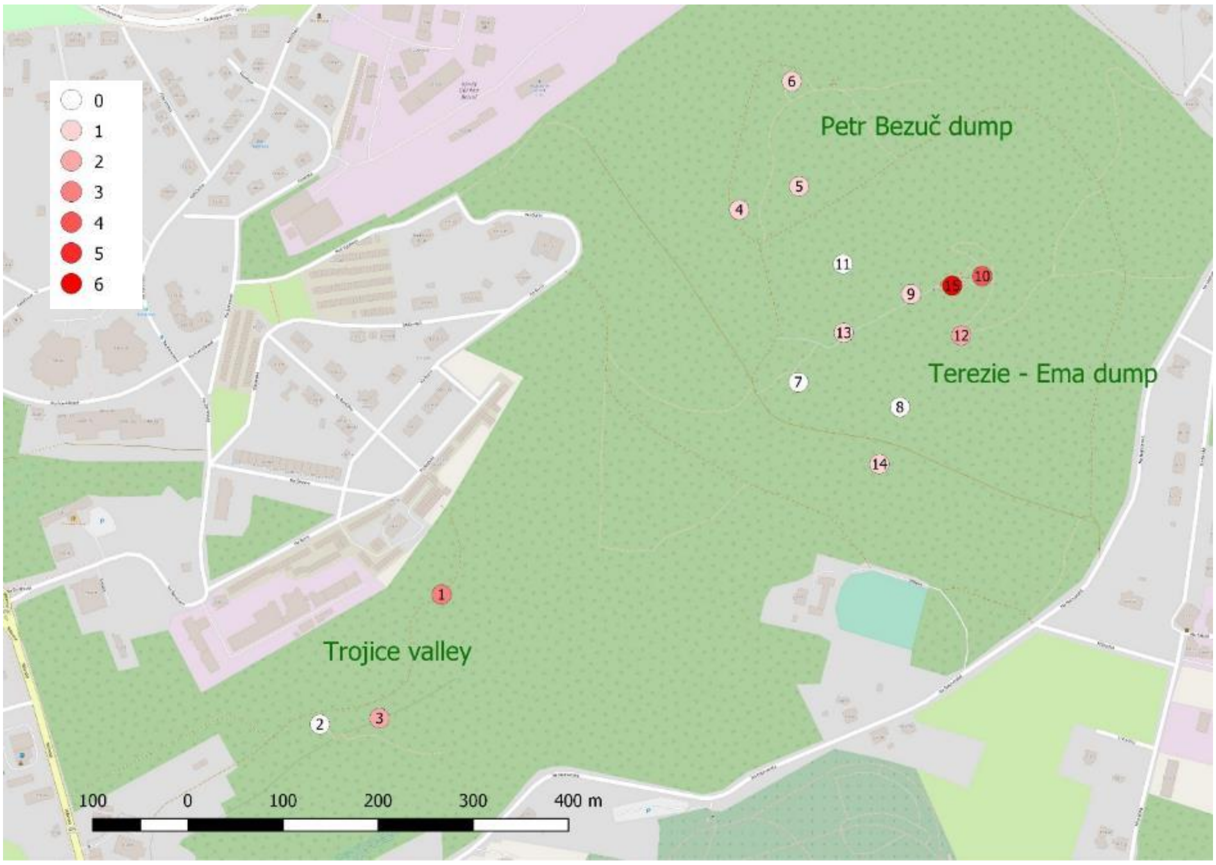


Figure 60. The map with the location of the soil sampling sites in the territory of interest. The color saturation of the symbols corresponds to the number of elements (V, Cr, Co, Ni, Cu, Zn, As and Pb) whose values were exceeded on the sampling site.

7 Baseline mapping – Botanical and Phytosociological analyzes in mine spoil dump Ema – Terezie complex

Characteristic of model territory

Ema Mine Heap

It is part of the mine heaps complex including mine heap Ema, Terezie and Petr Bezruč located in Silesian Ostrava. The area of the complex is 22 hectares, altitude approx. 312 - 315 m above sea level, the year of foundation 1920. Ema is still a thermally active cone mine heap, forest reclamation was started in 60´s except the top, the most thermally active part. However, most of forest stands come from the spontaneous dispersion of seeds, mainly Birch (*Betula pendula*), Poplar (*Populus tremula*) and Willow (*Salix caprea*) (Koutecký, 2011). Research of this mine heap included its central conical unreclaimed part and reclaimed areas in the south and south -east parts of the so-called Trojice Valley formed by the Trojice mine heap (IMGE, 2000).

Number of Phytosociological reléves: 16 (FE1 - FE16)

Position of the phytosociological reléves see in Figure 1.

Terezie – Petr Bezruč Mine Heap

The Terezie mine heap was founded in 1920 (IMGE, 2000). Since the age of 60, with the exception of the northern slope, it has been continuously reclaimed. Afforestation took place here until 1995. Between 2004 and 2005 an intensive pruning was carried out on the northern slope of Terezie, which disrupted the growth of the tree layer (Koutecký, 2011). The mine heap Petr Bezruč is one of the flatter mine dumps and encircles the Terezie and the Ema. Forest reclamation was carried here.

Number of Phytosociological reléves: 9 (FB1 – FB9)

Position of the phytosociological reléves see in Figure 1.

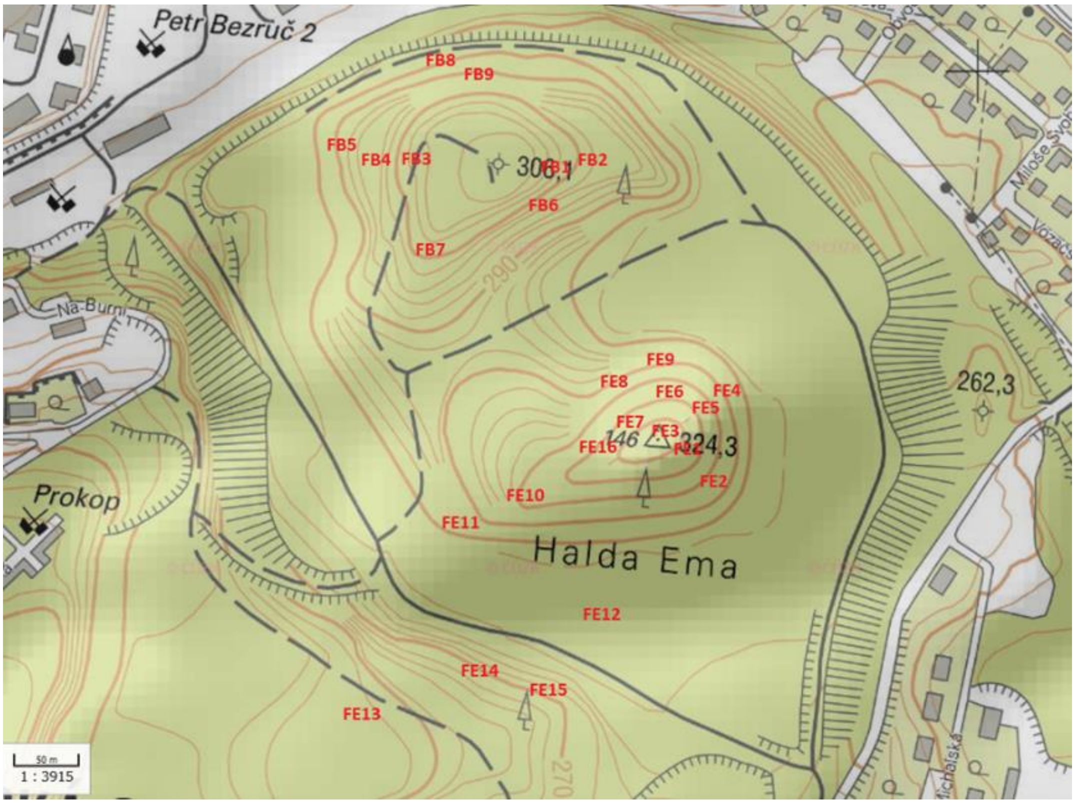


Figure 61. Position of reléves in Ema, Terezie and Petr Bezruč mine heaps

7.1 Methods

Floristic and phytosociological survey

Phytosociological research was carried out according to the rules of the Zurich - Montpellier School (Braun - Blanquet, 1964). The first were orienteering terrain observation to determine the basic physiognomy of vegetation and the character of relief. In the flatter parts of the heaps, reléves had the shape of 100 m^2 squares. On slopes and terraces, the shape of a rectangle was chosen as the more suitable one to maintain the recommended area. Phytosociological survey was performed at available slopes and exposures. Every species found was recorded in phytosociological tables during the season.

In 2020 and 2021, phytosociological research will be extended to other areas, especially in the Trojice Valley.

Twenty-five phytosociological reléves were performed on the monitored mine dumps. Reléves were situated to include basic habitats - forest communities and tree -

less areas, slopes/exposures and plateaus. Consideration was also given to reclamation or succession of mine dumps areas. The identification of plant communities in the habitats of the mining landscape is quite difficult in the traditional classification concept because there are diagnostic species usually miss and generally species composition changes rapidly. Therefore, their classification cannot be considered to be quite accurate and alternatives are listed for individual phytocoenoses.

Reléves description – Mine Heap Ema

FE1: tree- less, slope, SE exposure, succession, FE2: forest, slope, SE exposure, succession, FE3: forest, plateau, succession, FE4: forest, slope, NE exposure, succession, FE5: forest, slope, NE exposure, succession, FE6: forest, slope, N exposure, succession, FE7: forest, slope, E exposure, succession, FE8: forest, slope, NE exposure, succession, FE9: forest, slope, N exposure, succession, FE10: forest, slope, W exposure, reclamation, F11: forest, plateau, reclamation, F12: forest, plateau, reclamation, F13: forest, plateau, reclamation, F14: forest, slope, SW exposure, reclamation, F15: forest, slope, S exposure, reclamation, F16: tree- less, slope, SW exposure, succession

Reléves description – Mine Heaps Terezie – Bezruč

FB1: forest, slope, E exposure, reclamation, FB2: forest, slope, E exposure, reclamation, FB3: forest, slope, W exposure, reclamation, FB4: forest, slope, W exposure, reclamation, FB5: forest, slope, W exposure, reclamation, FB6: tree - less, slope, SW exposure, reclamation, FB7: tree - less, plateau, reclamation, FB8: forest, slope, SE exposure, succession, FB9: tree - less, slope, SE exposure, succession.

Diversity

Species diversity was expressed by the Shannon-Wiener diversity index H 'and evenness E (Begon et al, 1997).

$$H' = -\sum_{i=1}^{S} P_i . \ln P_i$$

p_i... relative abundance of species

s ... number of species in the community

The relative representation of the species in the sample is determined by evenness E, where:

$E = H' / H'max = H' / \ln S$

The aggregate data (area, slope, exposure, altitude, H´, E) for all reléves are shown in the header of the phytosociological tables (see Table 1, 2). Reléves with a Shannon - Wiener index above 2.5 (mean diversity boundary) and an evenness above 0.9 are indicated in red.

Origin of species

The species were categorized according to Pyšek et al (2012) and pladias.cz databases:

a) Indigenous (native) species - a species that has evolved in the Czech Republic during evolution, or has arrived here without human contribution.

b) Archaeophyte - an alien species introduced in the Czech Republic by man between the Neolithic and the year 1500.

c) Neophyte - an alien species introduced in the Czech Republic after 1500.

d) Invasive species - non-native species (archaeophytes or neophytes), which are able to uncontrolled spread over considerable distances from their origin population and suppress native species. Invasive species were categorized according to Pergl, 2016.

Rare and endangered species

Endangered species were classified on the basis of:

a) Affiliation to specially protected species in according with Annex II of Decree 395/1992 Coll. (Act No. 114/1992 Coll.): critically endangered species, severely endangered species, endangered species.

b) Affiliation to national threat categories according with the Red List of Vascular Plants of the Czech Republic (Grulich, 2017).

c) Affiliation to international IUCN categories according with the Red List of Vascular Plants of the Czech Republic (Grulich, 2017).

7.2 Results

Table 16. Phytosociological reléves Ema mine heap

	FE1	FE2	FE3	FE4	FE5	FE6	FE7	FE8	FE9	FE10	FE11	FE12	FE13	FE14	FE15	FE16
E3																
Ulmus glabra														2		
Tilia cordata											2	3		2	2	
Sorbus aucuparia					+		+	+	+	1						
Robinia pseudoacacia													2			
Quercus rubra									r	1		r				
Quercus robur	+	r						r	1				2		2	
Prunus avium			r			r			r			1	1			
Prunus cerasus									r							
Populus tremula		1	1	+	r	2										
Fraxinus excelsior													2	2	3	
Fagus sylvatica		r						r					2		2	
Betula pendula	+	2	3	2	2	2	2	2	1				1	2	2	
Acer campestre														1	2	
Acer platanoides									r		+		2	2		
Acer platanoides juv.								r	+	1	1	2	+	+		
Acer pseudoplatanus		+					+				3		3	4		
Acer pseudoplatanus juv.					+		+	+	r	1	1	2	+	+		
Aegopodium podagraria												1	2	2		
Aesculus hippocastanum													2	1		
E2																
Syringa vulgaris	+															
Symphoricarpos albus											+	+				
Sambucus nigra									+			3	2	2	1	
Sambucus racemosa									r							
Prunus serotina											+					
Rosa sect. canina	+	r	r				r			+	1	+			1	
Rubus caesius	1				r								1			
Rubus idaeus										r	+	r				r
Prunus padus												r				
Ribes uva crispa														1		
Ligustrum vulgare	r									r			2	1		
Forsithia x intermedia													1			
Crataegus monogyna	r	r								1		+	2			

Cornus alba	+	r				+		+					1	2		
Cornus sanguinea										1	+					
Corylus avellana							+	+					2	r		
Corylus colurna								r								
E1																
Achillea millefolium	1														2	
Allium stipitatum						r										
Alliara petiolata													2			
Alopecurus pratensis	+	+														
Anthriscus sylvestris												r				
Artemisia vulgaris		r	r													
Athyrium filix-femina									+				1		2	
Aster lanceolatus																2
Betula pendula juv.			r	+	r		+	r	r							r
Calamagrostis epigejos	2	+	4		2			+	+	+			+			
Calystegia sepium											r	r				
Carex hirta											r					
Carex pallescens					r						+					
Carpinus betulus juv.											r					
Circaea lutetiana											+	1				
Cirsium arvense			r													
Conyza canadensis			+							1						2
Crataegos monogyna juv.											+					
Crepis biennis	r	r	2	2	1	r	+	r	+				r			
Dactylis glomerata										+			+	r	3	
Digitaria sanguinalis	1															
Dryopteris filix-mas							+	+	1		+		2	1	1	
Duchesnea indica											1					
Epilobium ciliatum		+				+	r	+								2
Erigeron annuus	1	+		1	+				+	1	1			2		+
Eupatorium cannabinum		+	r	r	+		+		+				+			
Fagus sylvatica juv.								r	r							
Festuca pratensis								r								
Festuca rubra										1		+			+	
Festuca sp.														+		
Ficaria verna												+	2	3		
Fragaria vesca	1							r	+	+	1					
Fraxinus excelsior juv.												+	r	r	r	
Galeopsis speciosa	r	r					r							+		

Galinsoga parviflora	r	r														
Galium album											+	1				
Galium aparine										2	+	+	2	2	2	
Geranium robertianum									1							
Geum urbanum					r						1		2	2	+	
Glechoma hederacea											1					
Hacquetia epipactis															2	
Hieracium bauhini				r			r									
Hieracium pilosella	r			r												
Holcus lanatus																
Hypericum perf.							r			1						2
Chenopodium botrys																r
Impatiens parviflora											r	r	+			
Lamium album															2	
Lamium purpureum										+						
Lapsana communis			1			1	+	r	+						2	
Lathyrus vernus															2	
Leucanthemum vulgare			r									+				
Lysimachia nummularia													3			
Oenothera biennis	+	+														
Oxalis acetosella		+														
Parthenocissus inserta													2			
Picris hieracioides		+				+	+						r			
Plantago lanceolata												r				
Plantago major												r	r			
Poa annua					+											
Poa compressa											r			r		
Poa nemoralis	r	+	3	+	1	+	+	r	+	1			+	r	1	
Poa pratensis	1	+			2		r		+	2	+	r	1	+	1	1
Poa trivialis																2
Populus tremula juv.	r		r			+			+	r						
Pulmonaria officinalis		r														
Pyrola minor								+								
Quercus petraea juv.				r	+		r	r	+							
Quercus robur juv.	r	r			r	r	+		+			r	+		+	r
Quercus rubra juv.		r	+		+		+	r	r	1	r		r			
Ranunculus repens										2						
Reynoutria japonica												2		3		
Robinia pseudoacacia juv.			r												2	

Rumex obtusifolius													1	2	2	
Senecio ovatus											+					
Senecio vulgaris	r															
Inula conyzae											1	1				
Solidago canadensis	1	+	+				+	+	+	2		1	3	2	1	
Sorbus aucuparia juv.								r	r	1		+	2			
Stellaria graminea		r														
Symphytum tuberosum		+								r		r				
Tanacetum parthenium	+	r	+	r		r	r	+	r	+						
Taraxacum sect. ruderalia		+	+		+			r	r	+	r	r	+		2	r
Tilia cordata											2	3		2	2	
Tilia cordata juv.											+	1		+		
Torilis japonica		r	r													
Tussilago farfara		+		+	+		+	+	+							
Urtica dioica										1			3	2		
Veronica chamaedrys															2	
Vicia cracca										r		+				
Viola rechenbachiana													r	1	1	
Area m^2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Slope dg.	38	33	0	39	36	31	30	28	33	15	0	0	0	28	15	32
Exposure	SE	SE	no	NW	NW	N	E	NE	N	W	no	no	no	SW	S	SW
Altitude masl	320	290	324	304	310	309	310	306	301	305	280	277	257	263	273	307
H	3	3.2	1.9	1.9	2.5	2	2.9	2.9	3.4	3.1	2.8	2.7	3.3	3	3.1	2
E	0.9	0.9	0.6	0.8	0.8	0.8	0.9	0.9	1	0.9	0.8	0.8	0.9	0.8	0.9	0.8

Table 17. Phytosociological reléves Terezie – Bezruč mine heap

	FB1	FB2	FB3	FB4	FB5	FB6	FB7	FB8	FB9
E3									
Tilia cordata	1	+					2	2	
Sorbus aucuparia	+	+							
Robinia pseudoacacia								1	
Quercus robur	+						+	+	
Prunus avium		r							
Prunus domestica	r								
Populus tremula	3	2					1	+	
Juglans regia								+	
Fraxinus excelsior		+				1	+	1	
Carpinus betulus								r	
Betula pendula	r		1			+	1	r	
Alnus glutinosa	r								
Alnus incana		r			1				
Acer campestre								+	
Acer negundo						r			
Acer platanoides								2	
Acer pseudoplatanus		+	3	2	2	+	2		
E2									
Rosa sect. canina	+			+		r	+		
Rubus caesius						r			+
Prunus padus	r	r							
Ligustrum vulgare	r								
Cornus alba	+								
Cornus sanguinea		+					1	1	
Corylus avellana	r					r	r		
Crataegus leavigata	+						r		
Sambucus nigra								+	
E1									
Aegopodium podagraria					1				
Achillea millefolium	+						+		1
Alliara petiolata								r	
Anthriscus sylvestris		+	r	+					
Artemisia vulgaris						r			+
Athyrium filix-femina	r	r							
Betula pendula juv.							r		
Calamagrostis epigejos	+	+			r	1			
Carpinus betulus juv.	r							r	
Cirsium vulgare				R					
Crepis biennis	r		+		r	r			
Dactylis glomerata			+			+			
Dryopteris filix-mas		+	+	+			r	1	+
Erigeron annuus	+	+		R	+	r	2	+	1
Eupatorium cannabinum		r							
Festuca rubra	r	r		R					
Fragaria vesca		+				+		1	1

Fraxinus excelsior juv.		+	+		r			1	
Geranium robertianum								3	1
Geum urbanum		+	+	+	r		r	2	
Glechoma hederacea		+							
Hieracium bauhini		r							
Hypericum perforatum	+								
Impatiens parviflora		r	+	R					+
Juglans regia juv.	r								
Lamium purpureum								+	
Lapsana communis				R				1	
Lolium perenne				R					
Medicago lupulina	+								
Melica uniflora	+								
Poa annua									2
Poa compressa	+								1
Poa nemoralis		r		+	+		1		
Poa pratensis	1		1			+		1	
Populus tremula juv.									+
Quercus robur juv.	+	+	+		r		+		
Quercus rubra juv.						r	+	1	
Reynoutria x bohemica					2				
Reynoutria japonica				1	3	1			
Robinia pseudoacacia juv.					r	r	+		
Rumex obtusifolius									+
Senecio jacobaea						+			
Senecio ovatus			r						
Solidago canadensis	2	1	1	+	1	2	3	1	2
Solidago gigantea						1			
Sorbus aucuparia juv.	+	+		R		r	+		
Stellaria media				+					+
Symphytum tuberosum				R		r			
Tanacetum vulgare								r	
Tilia cordata juv.				+		+			
Trifolium pratense							+		
Urtica dioica				+				+	
Verbascum phlomoides									+
Veronica persica								r	1
Vicia cracca	r	r	1				r		r
Vicia sepium						+			
Acer campestre juv.								r	
Acer platanoides juv.						1		1	
Acer pseudoplatanus juv.	2	1	1	1	+	1	2		1
Area m^2	100	100	100	100	100	100	100	100	100
Slope dg.	25	10	23	24	25	19	0	29	29
Exposure	E	E	W	W	W	SW	no	SE	SE

Altitude masl	303	299	300	295	290	299	280	277	284
H´	2.60124	3.04821	1.85133	2.64194	1.82411	2.95338	2.46128	2.95563	2.5831
E	0.7575	0.91477	0.68364	0.8819	0.6912	0.90647	0.77446	0.8607	0.89369

The origin of plant species

Most of species on monitored mine dumps are native, accounting for over 70% of all determined plants (Ema 73%, Terezie - Bezruč 79%). This is followed by a group of non-native species, of which neophytes predominate (Ema 16% and Terezie -Bezruč 14%). Archaeophytes constitute the least numerous species.

Rare and endangered plant species

Rare and endangered species were found only on the Ema mine heap. *Hacquetia epipactis* and *Pyrola minor* belong to indigenous species, *Chenopodium botrys* is an archaeophyte (see Table 3).

Table 18. Rare and endangered species

Species	Red list – Czech republic	Red list - IUCN	Act No. 114/1992	occurrence
Hacquetia epipactis	C4a - rare	LC – least concern	No protected	Ema
Pyrola minor	C3 - endangered	NT - near threatened	No protected	Ema
Chenopodium botrys	C3 - endangered	NT - near threatened	No protected	Ema

Invasive plant species

An overview of invasive species is given in Table 3, which corresponds to the division of invasive species into Black List (BL), Gray List (Gl) and Watch list (WL) (Pergl et al, 2016).

The percentage of the invasive species of all categories in reléves is 13% in Ema and in Terezie Bezruč mine heaps.

Table 19. Invasive plant species

Species	Category*	Occurance	Origin
Aster lanceolatus	BL2	Ema	neophyte
Solidago canadensis	BL2	Ema, Terezie - Bezruč	neophyte
Solidago gigantea	BL2	Terezie - Bezruč	neophyte
Robinia pseudoacacia	BL2	Ema, Terezie - Bezruč	neophyte
Parthenocissus inserta	BL2	Ema	neophyte
Quercus rubra	BL2	Ema	neophyte

Prunus serotina	BL2	Ema	neophyte
Symphoricarpos albus	BL2	Ema	neophyte
Acer negundo	BL2	Terezie - Bezruč	neophyte
Reynoutria japonica	BL2	Ema, Terezie - Bezruč	neophyte
Reynoutria x bohemica	BL2	Terezie - Bezruč	neophyte
Conyza canadensis	BL3	Ema	neophyte
Cirsium arvense	BL3	Ema	archaeophyte
Galinsoga parviflora	BL3	Ema	neophyte
Erigeron annuus	GL	Ema, Terezie - Bezruč	neophyte
Impatiens parviflora	GL	Ema, Terezie - Bezruč	neophyte
Duchesnea indica	GL	Ema	neophyte
Juglans regia	GL	Terezie -Bezruč	archaeophyte
Aesculus hippocastanum	WL	Ema	neophyte

* category according to Pergl et al (2016): BL2 (Black list 2: mild to massive environmental impacts, species highly dependent on human activities), BL3 (Black list 3: mild to massive environmental impacts , current distribution corresponds to spontaneous spread and unintentional introduction by man), GL (Gray list: Currently limited environmental impact), WL (Watch list: warning list)

Phytosociological communities

Tree - less communities

Communities with dominant Wood small reed (*Calamagrostis epigejos*) - ***Calamagrostis epigejos* [*Convolvulo - Chenopodiea*]** Kopecký, Hejný, 1992, Reléves: FE1

Communities with dominant Canadian goldenrot (*Solidago canadensis*) - **[*Convonvulo - Melilotion*]** Višňák, 1991, Reléves: FB9

Communities with dominant Panicled aster (*Symphyotrichum lanceolatum*) - ***Asteretum lanceolati*** Holzner et al. 1978 , Reléves: FE16

Forest communities

Communities with dominant European white birch (*Betula pendula),* Reléves: FE2, FE3, FE4, FE5, FE6, FE7, FE8, FE9

Communities with dominant Linden (*Tilia platyphylos, Tilia cordata*) and Maples (*Acer pseudplatanus, Acer platanoides*) - ***Tilio platyphylli-Acerion*** Klika 1955, Reléves: FE10, FE11, FE12, FE13, FE14, FE15, FB1, FB2, FB3, FB4, FB5, FB6, FB7, FB8

Communities with with dominant Knotweed ((*Reynoutria japonica, Reynoutria sachalinensis, Reynoutria x bohemica*), with dominant Red Oak (*Quercus rubra*), with occurrence Black Locust (*Robinia pseudoacacia*) and with occurrence Blue Spruce (*Picea pungens*) were also recorded.

Diversity index

The average Shannon - Wiener index H ´ recorded at the Ema - Terezie - Bezruč mine dump complex reached the values: x̄ = 2.7, Me = 2.9. The absolute highest H´ = 3.4 was calculated for the phytocenological reléve FE9 (forest - slope - succession). The average and maximal evenness E of species abundance reaches the values x̄ = 0.84, Me = 0.86, max = 0.98.

The H´ values of recultivated (x̄ = 2.7, Me = 2.8) and succession areas (x̄ = 2.6, Me = 2.7) do not differ much, however, it is clear that it is slightly lower for succession areas. In the case of evenness, its values reach essentially identical values for recultivated (x̄ = 0.8, Me = 0.8) and (x̄ = 0.8, Me = 0.9) areas and areas leave to spontaneous succession (x̄ = 0.8, Me = 0.9) . Thus, it can be said that reclamation (and the associated financial demands) does not have a significant effect on the species diversity of plants in the complex of Ema - Terezie - Petr Bezruč dumps. However, our and other researches (Švehláková, 2019, Koutecký 2011) on other Ostrava mine dumps show that the reclaimed areas are significantly species-richer than the areas left to succession, and Ema is a bit of an exception in this.

8 General zoological survey at the spoil dump-fields Ema - Terezie

A total of 227 species of animals were recorded in the area of interest (Terezie – Ema spoil dump field, Petr Bezruč spoil dump field and Trojice valley) and in the wider area as part of a general zoological survey (Fig. 23 and Fig. 24).

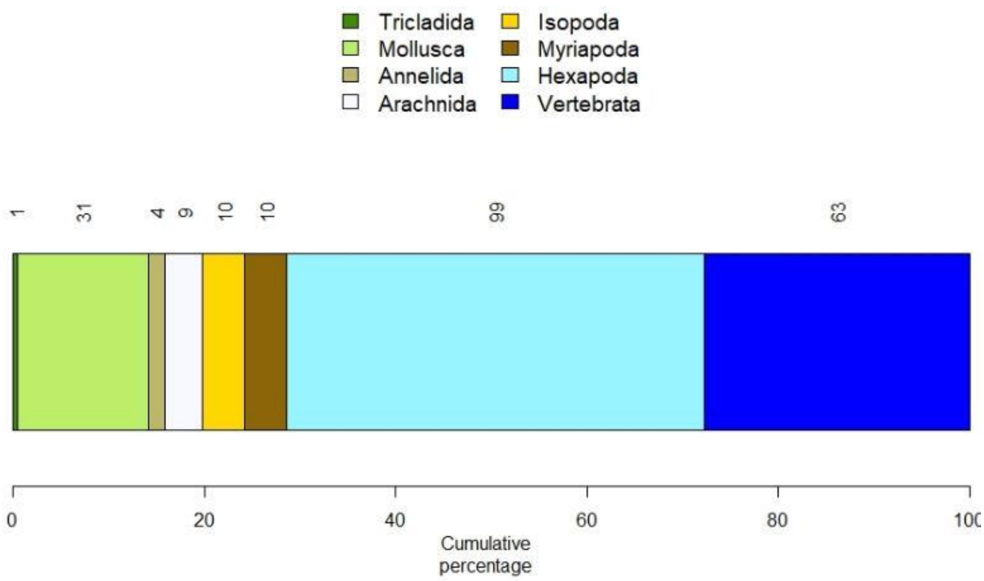


Figure 62. The diagram of selected taxonomic groups of animals in the results of the general zoological survey in the area of interest and in the wider area (absolute and relative abundance)

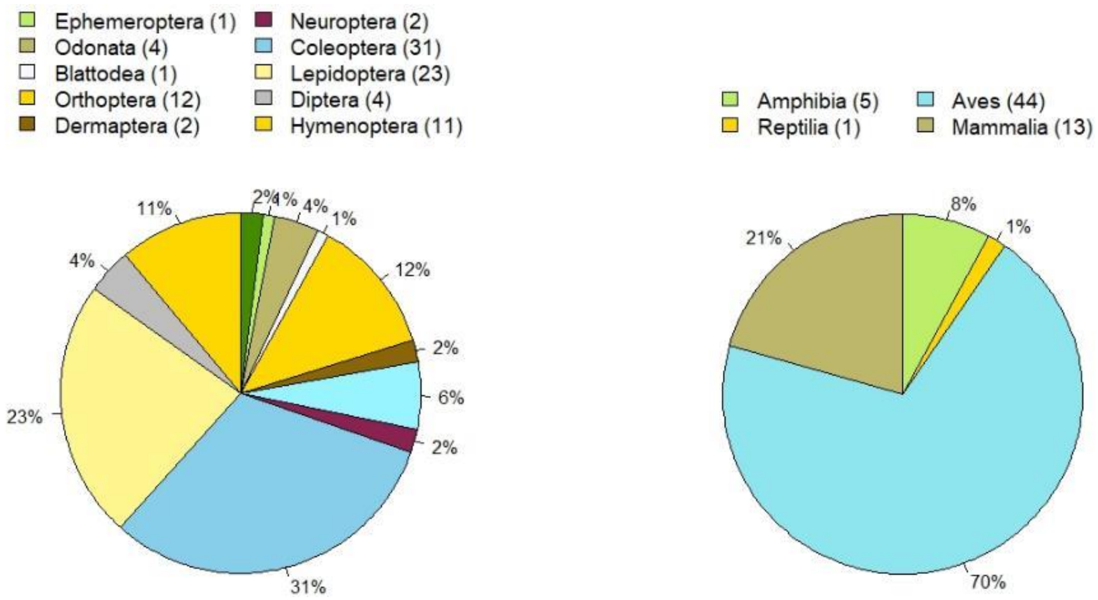


Figure 63. The diagram of taxonomic groups of Hexapoda and Vertebrata in the results of the general zoological survey in the area of interest and in the wider area (absolute and relative abundance).

Among the recorded species, there are a total of 21 species that are classified as specially protected species or are listed in some endangered categories in the red lists. For research purposes, these species were divided into three categories: priority species, interest species and other species. This classification is based on the nature of their occurrence in the area of interest and their ecological links. An overview of priority species, interest species and other species is given in Tab. 7.1. and the occurrence of priority species in the territory of interest in Fig. ZX.

Table 20. Overview of specially protected species (according to Annex No. III to Decree No. 395/1992 Coll.) or species listed in the red lists (according to Farkač et al. 2005 and Plesník et al. 2003) found in the general zoological survey in the area of interest and in the wider area in 2020

Species	§	IUCN	Category
Bombina cf. *bombina*	O	VU	priority species
Lacerta agilis	SO	NT	priority species
Rhinolophus hipposideros	KO	LC	priority species
Androniscus roseus	-	NT	interest species
Arion circumscriptus	-	NT	interest species
Bufo bufo	O	.	interest species
Oxychillus glaber	-	NT	interest species
Ardea cinerea	-	NT	other species
Bombus pascuorum	O	.	other species
Bombus terrestris	O	.	other species
Carabus irregularis	O	NT	other species
Charadrius dubius	-	VU	other species
Cicindela campestris	O	.	other species
Delichon urbica	-	NT	other species
Hirundo rustica	O	.	other species
Hyla arborea	SO	NT	other species

Laciniaria plicata	-	NT	other species
Larus ridibundus	-	VU	other species
Lepus europaeus	-	NT	other species
Papilio Machaon	O	.	other species
Pelophylax esculentus	SO	NT	other species
Sciurus vulgaris	O	.	other species

Explanation: "§" - the degree of protection; "KO" - critically endangered species; "SO" - a highly endangered species; "O" - endangered species; "-" - the species is not particularly protected; "IUCN" - category of threat; VU - Vulnerable; NT - Near Threatened; "." - the species is listed in the red list in a lower category than the above

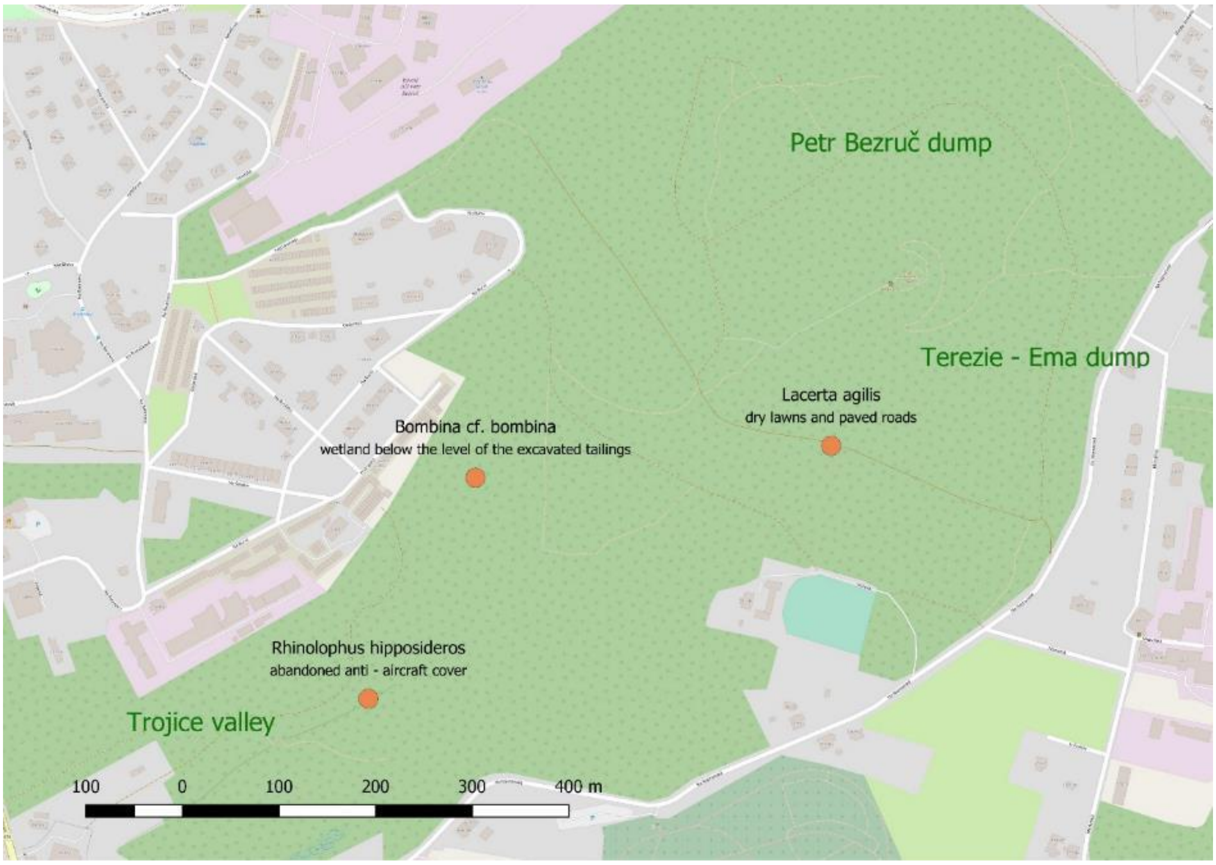


Figure 64. The map indicating the occurrence of priority species in the territory of interest

Figure 65. The fire-bellied toads (Bombina bombina) and the lesser horseshoe bat (Rhinolophus hipposideros) are so-called priority species

9 Specialized zoological survey at the spoil dump-fields Ema - Terezie

For specialized zoological survey was chosen three groups of animals: terrestrial isopods, millipedes and land snails. The specialized zoological survey was carried out at fifteen sampling sites in the area of interest (Terezie – Ema spoil dump field, Petr Bezruč spoil dump field and Trojice valley) (Fig. 27). A total number of 33 species were found in all 282 determined specimens.

Land snails

A total of 132 land snails representing 20 different species were recorded (Tab. 8.1). The most frequent species in the area of interest was *Fruticicola fruticum.* The most dominant species were *Fruticicola fruticum* and *Trochulus hispidus*.

Table 21. Overview of found species of terrestrial snails (Gastropoda) in 2020 and their frequency (F) and dominance (D)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	F (%)	D (%)
Aegopinella nitens	3	2	1	~	~	~	~	~	~	~	~	~	~	1	~	26.67	5.30
Alinda biplicate	2	1	1	1	~	~	~	~	~	~	~	~	~	1	~	33.33	4.55
Arion circumscriptus	~	~	1	~	~	~	~	~	~	~	~	~	~	~	~	6.67	0.76
Arion distinctus	2	1	~	~	~	1	~	~	~	~	1	1	~	1	~	40.00	5.30
Arion vulgaris	3	2	2	~	1	2	1	1	~	~	1	~	~	2	~	60.00	11.36
Cepaea hortensis	3	1	~	~	~	~	~	~	~	~	~	~	~	1	~	20.00	3.79
Cochlicopa lubrica	2	1	~	~	~	1	~	~	~	~	~	~	~	2	~	26.67	4.55

Discus rotundatus	~	1	~	~	~	~	~	~	~	~	~	~	~	1	~	13.33	1.52
Fruticicola fruticum	4	1	1	1	~	2	~	1	1	~	2	3	2	2	1	80.00	15.91
Helix pomatia	1	~	~	~	1	~	~	1	~	~	1	~	~	1	~	33.33	3.79
Laciniaria plicata	6	1	~	~	~	~	~	~	~	~	~	~	1	~	~	20.00	6.06
Limax cinereoniger	1	~	1	1	~	~	1	1	~	~	~	~	~	1	~	40.00	4.55
Limax maximus	1	~	~	~	~	~	~	~	~	~	~	~	~	~	~	6.67	0.76
Monachoides incarnatus	1	~	1	2	1	~	1	1	~	~	~	~	~	2	~	46.67	6.82
Oxychilus draparnaudi	2	~	~	~	~	2	~	~	~	~	~	1	~	~	~	20.00	3.79
Oxychilus cellarius	~	1	~	1	~	~	~	~	~	~	~	~	~	~	~	13.33	1.52
Cepaea nemoralis	~	2	~	~	~	~	~	~	~	~	~	~	~	~	~	6.67	1.52
Semilimax semilimax	~	~	2	~	~	~	~	~	~	~	~	~	~	~	~	6.67	1.52
Trochulus hispidus	5	2	3	2	1	~	1	~	~	~	~	2	1	3	~	60.00	15.15
Boettgerilla pallens	~	1	~	1	~	~	~	~	~	~	~	~	~	~	~	13.33	1.52

Terrestrial isopods

A total of 122 terrestrial isopods representing 7 different species were recorded (Tab. 8.2). The most frequent and dominant species in the area of interest were *Porcellio scaber* and *Armadillidium vulgare.*

Table 22. Overview of found species of terrestrial isopods (Oniscidea) in 2020 and their frequency (F) and dominance (D).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	F (%)	D (%)
Androniscus roseus	~	2	3	~	~	~	~	~	~	~	~	~	~	~	~	13.33	5.81
Armadillidium vulgare	7	4	3	2	~	1	1	~	~	1	~	2	2	3	1	73.33	23.26
Cylisticus convexus	~	~	~	~	~	~	~	~	~	~	~	1	2	~	~	13.33	3.49
Oniscus asellus	1	~	4	~	~	2	~	~	~	~	~	~	~	3	~	26.67	10.47
Platyarthrus hoffmannseggii	18	~	7	~	~	~	~	~	~	~	~	~	~	8	~	20.00	17.44
Porcellio scaber	7	5	1	2	3	2	3	1	2	1	1	4	2	2	1	100.00	34.88
Porcellium collicola	3	~	~	~	~	~	~	~	~	~	~	~	~	4	~	13.33	4.65

Millipedes

A total of 21 millipedes representing 6 different species were recorded (Tab. 8.3). The most frequent and dominant species in the area of interest were *Blaniulus guttulatus* and *Polydesmus inconstans.*

Table 23. Overview of found species of millipedes (Diplopoda) in 2020 and their frequency (F) and dominance (D).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	F (%)	D (%)
Blaniulus guttulatus	3	~	1	1	~	~	~	~	~	~	~	2	~	~	~	26.67	33.33
Cylindroiulus latestriatus	~	~	2	~	~	~	~	~	~	~	~	~	~	~	~	6.67	9.52
Glomeris pustulata	~	~	3	~	~	~	~	~	~	~	~	~	~	~	~	6.67	14.29
Julus scandinavius	~	~	2	~	~	~	~	~	~	~	~	~	~	~	~	6.67	9.52
Polydesmus inconstans	1	~	2	1	~	~	~	~	~	~	~	1	~	1	~	33.33	28.57
Choneiulus palmatus	~	~	1	~	~	~	~	~	~	~	~	~	~	~	~	6.67	4.76

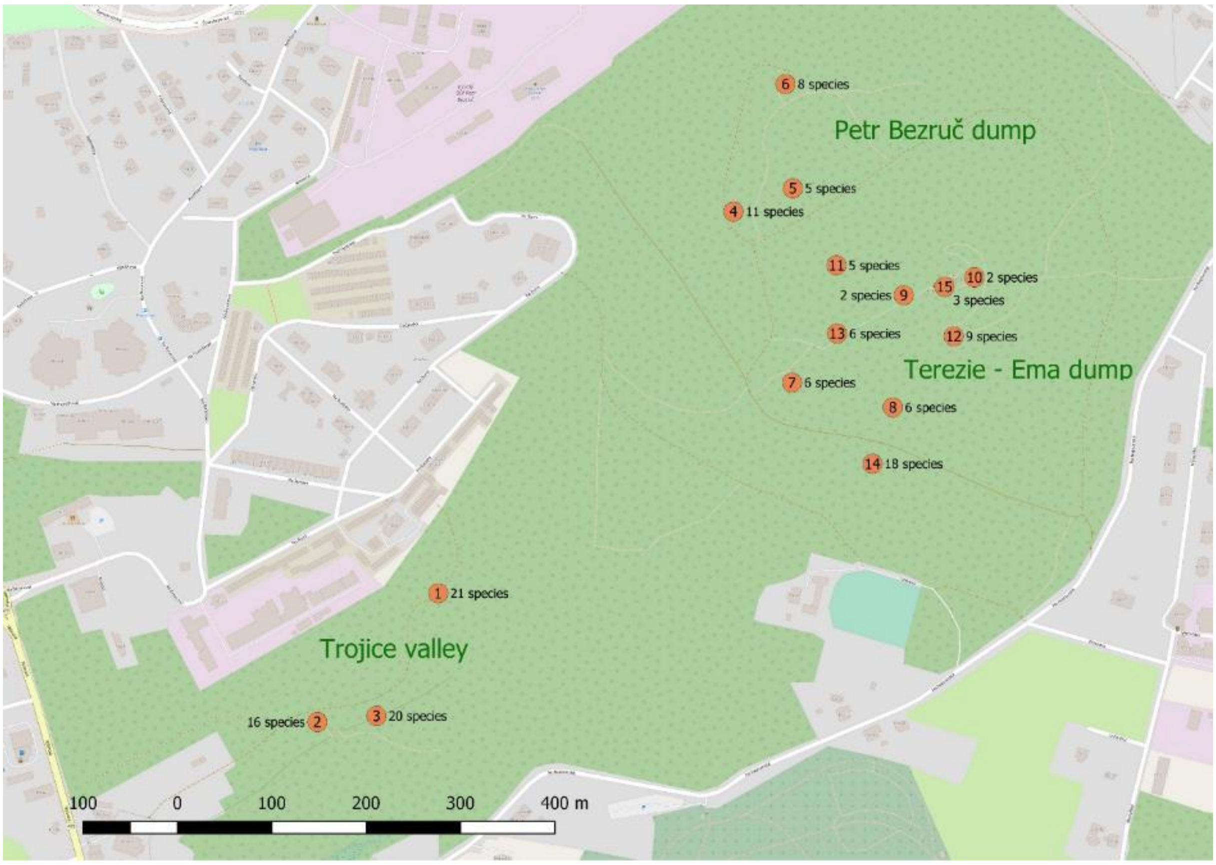


Figure 66. The map with the location of the sampling sites in the territory of interest and with indicating the total number of species found during the specialized zoological survey.

Figure 67. Semilimax semilimax is associated with damp habitats, mainly in forested valleys in hills. Common in Czech Republic.

Figure 68. Rounded snail (Discus rotundatus) lives in woodland and scrub habitats and it is commonly found also in synanthropic habitats in cities.

10 Microbiological survey on Ema – Terezie dump complex

The microbiological part of the project was focused on microorganisms as indicators of biogeochemical processes in soil substances of areas of interest. This year, this work was directed to the territory of the Ema dump. It has previously been shown that the study of microbiota is of great importance for the biological characteristics of the area, because microorganisms significantly affect the production functions of soil ecosystems.

Changes in the activity of microorganisms are considered as very sensitive indicator of anthropogenic influence, such as pollution due to mining and industrial activities.

Contamination of the environment leads to stress, which acts on soil microorganisms. Only populations and communities that are able to adapt to changed environmental conditions survive these changes. The response to the environmental stress, more precisely disturbance, which leads to a dislocation of the ecological balance in the community of microorganisms is usually a reduction in the diversity of individual physiological groups of microorganisms. Therefore, in the environment of heaps and sludge ponds, the genetic diversity of microorganisms is significantly reduced, which results in a reduction in taxonomic diversity. Long-term surviving microorganisms in an environmentally disturbed environment are then considered highly specialized because they have increased physiological and metabolic adaptability. This disturbance very often becomes the basis of selection in diversity, leading to the formation of microbiota with high resistance. The aim of the microbiological part of the project is to obtain a comprehensive view of the Ostrava sites with environmental burdens using soil microbiota indicators, which show the severity of environmental risks and the importance of their solution.

In 2020, the Ema dump was evaluated. In order to obtain the most accurate information on the condition of the microbiota in-situ, a number of tests had to be performed at different levels, as the environmental factor is not defined by a single parameter, but is a complex set of interactions at the level of physical, chemical, biochemical and biological properties, which complement each other. Given that, each analytical method has its limits, there is no single common property that can sufficiently assess the effect of anthropogenic factors on the microbiota.

An important indicator of the health condition of the ecosystem is primarily microbial respiration and total microbial biomass, which is related to the ability to decompose xenobiotic substances. The basic characteristics of the autochthonous microbiota were monitored in the samples of technogenic substances of the selected locality of the Ema dump, which were assessed during the evaluation of the microbiota, in particular:

- total soil microbial biomass
- microbial activity (basal (CO2B) and potential (CO2P) respiration)

- abundance of microorganisms
- diversity of microorganisms.

The biomass of microorganisms was determined in the soil samples taken by a fumigation extraction method, which also includes microbial biomass, which occurs in the soil environment very often bound in the form of a biofilm, for example in soil particles and aggregates; biofilms tend to be part of the plant rhizosphere and can also be part of the soil skeleton. The fumigation extraction method was performed according to the ČSN EN ISO 14240-2 methodology as a basic parameter for the evaluation of microbiota activity. Another part of the microbiological study was the analysis of the cultivable components of the soil microbiota with the identification of significant representatives. Based on previous studies, actinomycetes and microscopic filamentous fungi are the most resistant microorganisms to the contamination; due to thermal activity of the monitored area, a significant proportion of thermoresistant microscopic fungi was also assumed in the diversity of microorganisms. (This part of the project is still ongoing – for isolates that could not be identified using phenotypic identification, molecular-genetic method using ITS parts of the genome are now being continued). The basic identification of microorganism isolates was performed using the CENIII and FF biochemical tests of the modern BIOLOG^{TM} MicroStation test system (Biolog, USA), which is a part of the microbiological laboratory at VŠB – TU Ostrava.

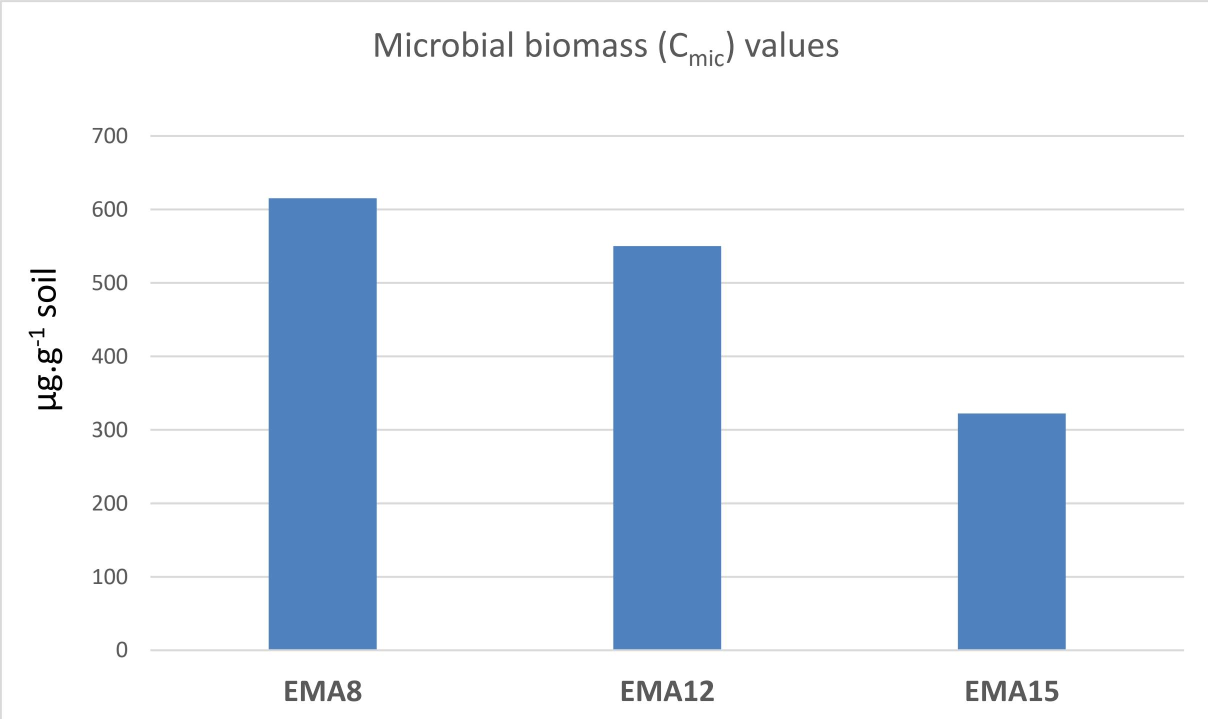
Results:

The basic parameters of the indigenous microbiota at the sampling sites (EMA8, EMA12, EMA15), which is represented by microbial activity based on basal respiration (CO_2B) and potential respiration (CO_2P), are given in Tab. 9.1:

Table 24. Designation of samples

Designation of samples	EMA8	EMA12	EMA15
Number of samples	5	5	5
Carbon without fumigation (μg.g^{-1} soil)	67,44	55,70	28,21
Carbon with fumigation (μg.g^{-1} soil)	615,36	550,36	322,29
Max (μg.g^{-1} soil)	656,63	621,25	324,56
Min (μg.g^{-1} soil)	535,55	515,13	309,19
Median (μg.g^{-1} soil)	634,64	532,23	319,58
CO_2-B (%)	23,81	20,09	10,91
CO_2-P (%)	94,24	76,33	42,14

Microbial biomass (C_{mic}) values were determined using the fumigation-extraction method:



The microbiota in the samples of soil substrates from the areas of the Ema dump can be assessed as relatively poor with a dominance of only a few genera. Of the microscopic fungi, species of the genus *Aspergillus*, *Penicillium*, *Eupenicillium*, *Fusarium*, *Altenaria*, *Geotrichum* and *Trichoderma* were the most abundant, while *Eupenicillium brefeldianum*, *Eupenicillium pinetorum* and *Nesoartorya fischeri* are typical representatives of thermoresistant microscopic fungi.

From the group of bacteria, the genus *Pseudomonas*, *Arthrobacter*, *Bacillus*, *Cupriavidus*, *Staphylococcus* and some others were the most represented.

At present, laboratory experiments associated with the genotypic identification of microorganisms using ITS regions of the genome are still ongoing.

Based on the conducted phylogenetic analysis, the isolated bacterial strains were composed of four phylum and were represented by this phylum in technogenic soils: *Firmicutes* (63 %), *Actinobacteria* (26 %) *Proteobacteria* (7 %), and *Bacteroidetes* (4 %). The strains of *Proteobacteria* and *Firmicutes* were present in all studied substrates, the species of genus *Bacillus* accounted for the major part of cultivable bacteria in most of the samples. Smaller part of the cultivable bacterial community was represented by strains of *Actinobacteria* and *Bacteroidetes*.

Isolates that could not be identified by phenotypic identification are now to be identified by the molecular genetic method of conventional ribotyping.

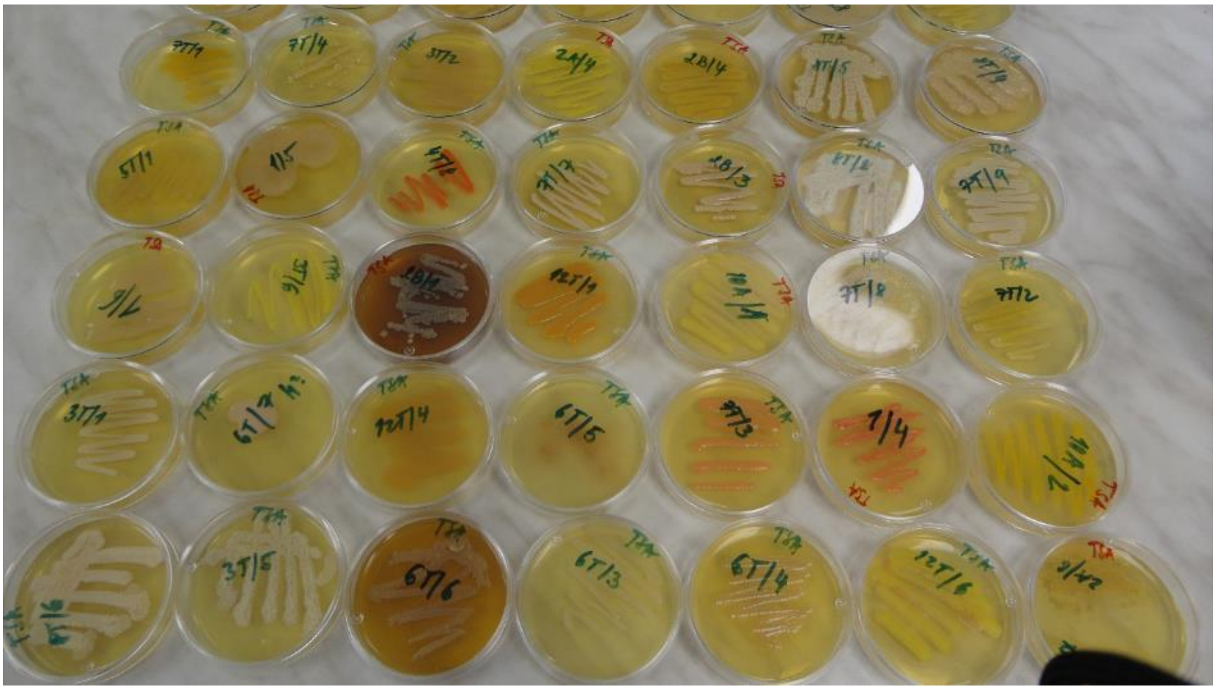


Figure 69. Isolation of bacterial microorganisms and preparation for their identification

Figure 70. Temperature measurement at the sampling point

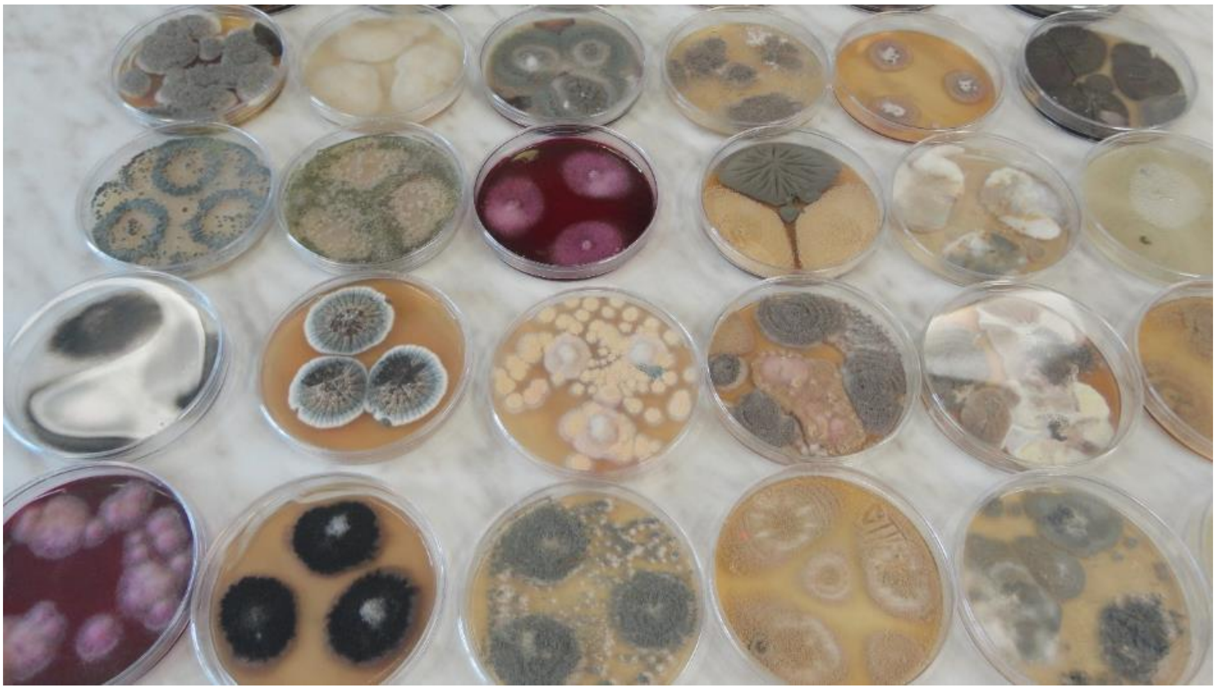


Figure 71. Preparation of microscopic fungi isolates for identification

11 Conclusions and lessons learnt

Research has been focused on the evaluation of individual ecological factors that affect both the reclamation methods used and the subsequent development of vegetation, fauna and soils in dumps after mining activities.

The area of the Ema - Terezie mine spoil dump complex was evaluated:

- Hydrological properties of the area affected by the Burňa stream and the former Trojice coke plant. The profile Cooling canal was not contaminated, it was only a surface water seepage. Higher concentrations of pollution were in the parameters: Chemical oxygen demand by Cr, Total suspended solids, Total dissolved solids, Ammonium ions and Sulphates.
- Development of soils on Ema dumps (non-reclaimed dump, affected by burning), Terezie dump (forest reclamation), Petr Bezruč (forest reclamation with mosaics of high herb meadows). According to Czech average values only two risk elements were exceeded (As and Cr). Contamination by As and Cr is probably caused secondarily.
- Character and Development of vegetation, including phytocenological evaluation, evaluation of the occurrence of rare and endangered plant species, occurrence of invasive plant species. Most of species on monitored mine dumps are native, accounting for over 70% of all determined plants. This is followed by a group of nonnative species, of which neophytes predominate. Archaeophytes constitute the least numerous species. Rare and endangered species were found only on the Ema mine heap. The percentage of the invasive species of all categories in reléves is 13% in Ema and in Terezie Bezruč mine heaps.
- Zoological evaluation (species composition, focusing mainly on invertebrate species, rare and endangered species). A total of 227 species of animals were recorded in the area of interest (Terezie – Ema spoil dump field, Petr Bezruč spoil dump field and Trojice valley) and in the wider area as part of a general zoological survey. Among the recorded species, there are a total of 21 species that are classified as specially protected species or are listed in some endangered categories in the red lists.
- Microbiological evaluation focused on soil development and on microorganisms as indicators of biogeochemical processes in soil substances of areas of interest. The microbiota in the samples of soil substrates from the areas of the Ema dump can be assessed as relatively poor with a dominance of only a few genera.

The area was divided regarding the evaluation of reclamation techniques into three segments: Segment 1 Ema conical dump, segment 2 Tabular dump Terezie and Petr Bezruč and segment 3 Flat dump and area of the former Trojice coke plant.

The vegetation and ecosystems of individual segments were evaluated, and these were included in the following categories of post-industrial vegetation:

1. Conical dump Ema: category I - **wilderness** - birch stand with the occurrence of fruiting deciduous trees on burnt, red-colored tailings. On the northwest slope, there are combustion gas outlets inside the dump.

2. Tabular dump Terezie - Petr Bezruč: category II - **adjustment** - in the 1970s forest reclamation using mostly deciduous tree species, spontaneously inhabited by zoochorically and anemochorically spreading species (see species composition above). The species composition basically corresponds to native species, with isolated plantings of ornamental trees (*Amorpa fruticosa, Robinia pseudoacacia* and others, see species composition above). Now a non-intervention area with tourist use.

3. The area of the former Trojice coke plant: current state - **wilderness**, interventions are planned, which can be classified in category III (in the case of forest reclamation), or category IV. - **negation** (in the case of future implementation of family development. At present, it is not possible to specify the category in more detail, since the Government of the Czech Republic has suspended all remediation activities.

Regarding Figaredo mine, water and soil analysis were developed during 2020. Water samples were collected monthly above the waste dump, in the waste dump and below the waste dump, and it was possible to observe that there were almost no changes in the analysis made above and below the waste dump. Soil samples in the waste dump present some anomalous metal concentrations and a pH of 7.9.

On the other hand, and after several trials, hydroseeding was considered as the first necessary step after the slope stability works. The optimal components of the sowing in kg/ha are mulch (1620), stabilizer (40), herbaceous seeds (295), bush seeds (5), inorganic fertilizer (700), compost (225) and slow-release fertilizer (120).

The optimal herbaceous seeds composition in percentage was Festuca rubra (9%), Trifolium repens (9%), Lolium perenne (23%), Lolium multiflorum (19%), Trifolium pratense (4%), Festuca Ovina (9%), Medicago sativa (2%), Festuca arundinacea (9%), Melilotus officinalis (4%) and Dactylis glomerata (12%). The bush seed composition should be Fraxinor excelsior (100%).

Plantations should be made with a density of 250 trees/ha, with species that should stand out for their low mortality rate, being ideal for implantation in the waste dump. They should adapt to all types of terrain and their soil requirement is much lower than that of others. Planting holes should be sanitized, and topsoil should be added. Trees should be planted with tree guards and a protective net. During the first months of the plantation, maintenance works, and irrigation should be developed. Later, an annual maintenance should also develop.

An optimum distribution of plants are: Fraxinus excelsior (35%), Betula alba (35%), Acer pseudoplatanus (15%) and Ilex aquifolium (15%). All plants should ideally be at least 1.25 m high, except Ilex aquifolium that could be planted with only 20-25 cm high.

The lessons relevant to RECOVERY from the assessment of rehabilitation techniques for waste heaps can be summarised as follows:

1. Water and soil analyses allow estimating the contribution of the waste heaps to water and soil characteristics in order to design remediation measures if necessary in the case of water, and to determine the predominant soil types (soil forming substrate) together with the anomalous metal concentrations.
2. Above-ground vegetation comparative assessments, including when necessary phytocenological evaluation, evaluation of the occurrence of rare and endangered plant species, and occurrence of invasive plant species, according to the different reclamation techniques, allow evaluating the individual ecological factors that affect both the reclamation methods used and the subsequent development of vegetation.
3. Finally, the evaluation of a zoological evaluation (species composition, focusing mainly on invertebrate species, rare and endangered species), and a microbiological evaluation focusing on soil development, can help complementing the understanding of the biological characteristics of the area, as well as understanding the response to the environmental stress, more precisely disturbance, which leads to a dislocation of ecological balances.

12 Glossary

CLC - CORINE Land Cover

CORINE - Coordination of information on the environment

EEA - European Environment Agency

GIS - Geographic information system

HUNOSA - Hulleras del Norte S.A.

UNIOVI - University of Oviedo

References

BEGON, M., HARPER, J.L., TOWNSEND, C.R.,1997: Ekologie – jedinci, populace a společenstva. Vydavatelství Univerzity Palackého, Olomouc, 628 pp. In Czech.

BRAUN – BLANQUET, J., 1964: Pflanzensoziologie: Grundzüge der Vegetationskunde. 3. neubearb. und wesentlich vermehrte Aufl. Wien: Apringer-Verlag. 631 pp.

GRULICH, V., CHOBOT, K. (eds.), 2017: Červený seznam ohrožených druhů České republiky. Cévnaté rostliny. Red List of Threatened Species of the Czech Republic. Vascular Plants.178 pp.

HAVRLANT, Miroslav. Historie a současnost Ostravských hald báňského průmyslu. Vlastivědné listy Slezska a severní Moravy . 29, 2003, Sv. 1. In Czech.

IMGE, 2000: Kompletní dokončení ARS v ostravské části OKR. Ms., dep. in: OKD – o. z. IMGE, Ostrava. In Czech.

KLÁT, Jaroslav. Dokumentování důlních památek v Ostravě. Buletin SDMG.2010. In Czech.

KOPECKÝ, K.; HEJNÝ, 1992: S. Ruderální společenstvo bylin České republiky. Praha: Academia. 128 stran. ISBN 80-200-0175-1. In Czech.

KOUTECKÝ, T., 2011: Hodnocení lesnických rekultivací a spontánní sukcese na antropogenním reliéfu v okolí Ostravy. Disertační práce. Brno, Mendelova univerzita v Brně, Lesnická a dřevařská fakulta, 121pp. In Czech.

PERGL J, SÁDLO J, PETRUSEK A, LAŠTŮVKA Z, MUSIL J, PERGLOVÁ I, ŠANDA R, ŠEFROVÁ H, ŠÍMA J, VOHRALÍK V, PYŠEK P, 2016: Black, Grey and Watch Lists of alien species in the Czech Republic based on environmental impacts and management strategy. NeoBiota 28: 1–37.

PYŠEK, P., DANIHELKA, J., SÁDLO, J., CHRTEK, J. JUN., CHYTRÝ, M., JAROŠÍK, V., KAPLAN, Z., KRAHULEC, F., MORAVCOVÁ, L., PERGL, J., ŠTAJEROVÁ, K., TICHÝ, L.:2012: Catalogue of alien plants of the Czech Republic (2nd edition): checklist update, taxonomic diversity and invasion patterns. – Preslia 84: 155–255

ŠVEHLÁKOVÁ, H. Půdní semenné banky posttěžební krajiny Horního Slezska [online]. Ostrava, 2019 [cit. 2020-12-07]. Dostupné z: http://hdl.handle.net/10084/138579. Disertační práce. Vysoká škola báňská - Technická univerzita Ostrava.

VIŠŇÁK, R., 1991: Společenstva s celíkem kanadským (*Solidago canadensis* L.) v antropogenní krajině. Preslia 63: 291–304. In Czech.

WALKER, Lawrence R. Primary succession and ecosystem rehabilitation. Cambridge: Cambridge U/niverstity press, 2003. ISBN 0-521-80076-5.