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Formation of the Geometry of the Side Slopes from the Geotechnical Aspect for the Recultivation of the Degraded Area from Coal Mining

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ABSTRACT
The impact of coal exploitation on the geological layers of the earth is closely related to mining activities and this activity has been quite pronounced considering the topographical changes of the green space together with the vegetation that would directly affect the degradation of agricultural lands. The soil is the environmental medium with irreparable damages from the activity of coal exploitation for the location where the Sibovc mine is located, which is characterized by the physical disappearance of the pedological profile of the soil such as the ecosystem, etc. and that represents the most serious form of damage to her. The purpose and importance of this paper is the biological recultivation of the area degraded by coal exploitation, based on the height of the scale H and the angle α^o of the slope of the clay layers with the safety factor allowed for determining the humus layer for the cover of the degraded area, physical and chemical analyzes were performed based on the samples that were taken in the open profiles in the field, it was planned to plant saplings (trees) that will have a positive effect on the prevention of soil erosion, the enrichment of the air with O_2, the reduction of the amount of CO_2 in the air, the prevention of the distribution of dust in the environment, the size of the passage and from the geotechnical point of view, the prevention of humus soil landslides. The planned recultivation of the plot will start from the level of quota 570, 580 and 590 m, covering an area of about 17 hectares.

Keywords: slope geometry, degradation, recultivation of the area.

INTRODUCTION

As a result of the mining activity, there will be a large-scale impact on the environment. The study on the environment serves as a basic description of the effects that are expected to occur. Predictions of the effects on the environment present, above all, the concern in the sense of earth movement resulting in the loss of surface area and living space. During the operation of the mine, compared to the existing mines, a large void will be created. Since the filling of the areas with humus soils during coal exploitation will become parallel in time, which will enable the return of the areas to agricultural fields in a beautiful landscape according to the analyses and results of the soil.

Humus represents the friable part of the earth's crust, which represents the basis for the development of agriculture, because it is used for the cultivation of various plants. The creation of soil is a long process, because with the destruction of rocks and the conversion of the organic world into fine granular forms, the surface layer of arable land is created, the soils from the crushing – the alienation of rocks and from the dead organisms of the plant world and animals, the fertile soil layer, humus, is created. According to the Law on agricultural land (Law no. 02/L-26), humus must be conveyed / monitored before it is exploited. The special treatment of humus provides an important component for the re-cultivation of the finished parts of the mine by applying the inner fold. The degree of compaction of the humus is foreseen in the conveyances before this layer is excavated. This can be achieved through research on soil qualities, combining humus thickness analysis with qualitative sampling and analysis of this layer was an obligation from the energy corporation of Kosovo for the removal of the coal cover, the humus layer that was excavated was selected as separated part and are placed in the inner fold in the east side, in the levels 570, 580 and 590 m, space foreseen for the final recultivation of the area where the coal was exploited, as in Figures 1 and 2.

GEOGRAPHICAL POSITION

The area where it is planned to recultivate the land where the coal was mined is located within the active area of the Sibovc mine according to Figure 1. In the south of this area is the existing mine of Bardhi, in the west is Lagja Berisha (Grabovc), in the south-east is Mirashi - Hade village and to the north it is bordered by the Sibovc village, its extension towards the north is about 2 km.

STUDY AREA

The location where the re-cultivation of the area is planned covers an area of about 4.8 km^2 which is part of the Sibovc mine field where coal is mined to supply power plants for the production of electricity for the community in general. According to the geological map, the Kosovo

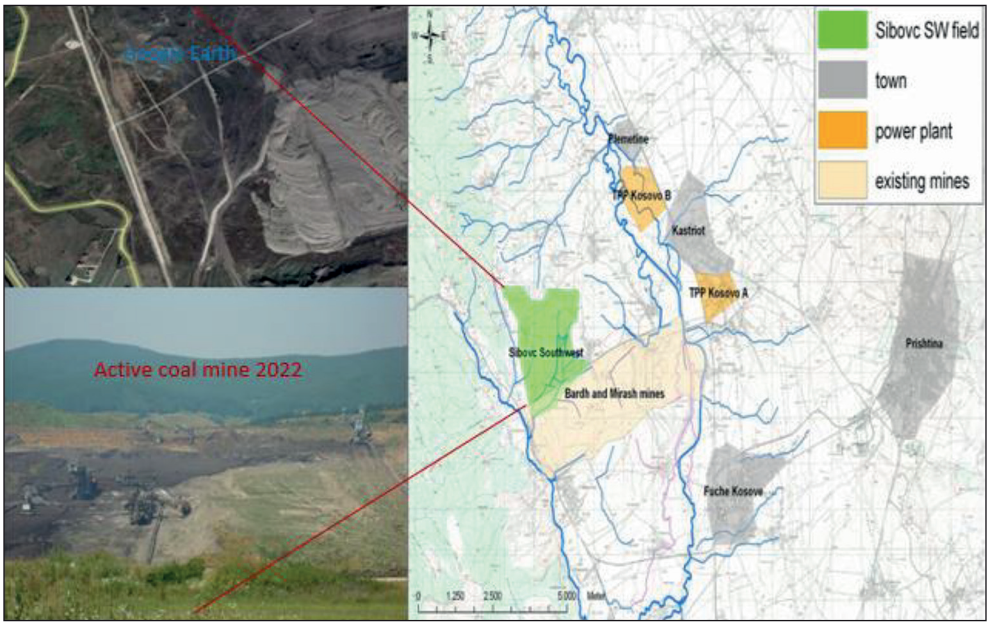

Figure 1. Geographical position of the mine where biological recultivation is planned

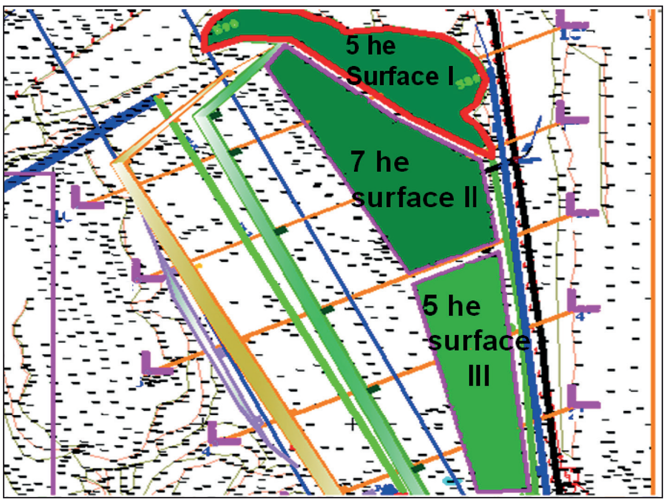

Figure 2. Map of the situation with the position of the profiles and the surfaces for recultivation

Basin is included in a tectonic area filled with Tertiary sediments, in the western part they are represented by Paleozoic rocks and in the east by Cretaceous sediments and in the upper part by the Quaternary (Elezaj & Kodra, 2008). Based on the geological-geomechanical drilling in the ceiling part of the coal, we have the presence of humus with a thickness of 1.20 m, yellow clay with an average thickness of 12 m and grey clay with an average thickness of 15 m, coal with an average thickness of 70 m and finally green clay.

After the completion of the folding operations, the area is planned to be filled with clay material for re-cultivation where it will be excavated with E-10B and E-9M rotary excavators and the material will be transported by means of conveyor belts to the designated areas for recultivation according to the situation map Figure 2:

- 5 ha – 1st Parcel
- 7 ha – 2nd Parcel, and
- 5 ha – 3rd Parcel

MATERIAL AND METHODS

For the realization of the works in the field, two methods were considered: In the first method, the map of the situation was taken as a basis, where 4 (four) profiles were analyzed according to Figure 2, comparing the change of the land from the existing state, (INKOS Institute, 2016) given the soil changes in function of the mining works in the Sibovc mine presented as in Tables 1, 2 and 3 according to the designed condition presented in Figure 3, Figure 4, Figure 5 and Figure 6 (Ahmeti. H, 2021) have been calculated profiles of soil layers with geo-mechanical parameters as in Table 4 by means of software programs according to GeoSlope 2021 and Slide V6, 2022, where the safety factor is derived according to geotechnical standards where the planting of different types is foreseen to the trees.

Realization and soil monitoring in the green belt area, according to the methodology, soil samples were taken from the pedological profiles (drilling), at every 30 cm depth, respectively at the 0–30 and 30–60 cm depth (INKOS Institute Laboratory, 2020).

The samples were prepared and analyzed according to the standard methodology approved by the World Organization of Standards (ISO), as well as the American Environmental Protection Agency (US-EPA), as shown in the table.

While from the aspect of geotechnical safety, the existing geomechanical parameters from the INKOS Institute presented in Table 4 were taken and the geological-geomechanical profile

Table 1. Soil changes due to mining operations in the Sibovc mine

Mining works carried out in the Sibovc mine	Characteristics of changes
GEOMECHANICS	
1. Removal of soil 2. Advancement of the working front 3. Terrain deformations 4. Internal folding of the soil	1. Change of terrain relief - damage to agricultural land - Meadow culture 2. Changing the geological structure of the soil masses, the physical-mechanical changes of the soil - the creation of stairs 3. Causing erosions - landslides of soil masses 4. Creation of new, final spaces for new cultivation

Table 2. Change in the area of agricultural land

Excavator Type	Character of works	Work front	The type of soil	Height [h]	Surface [m^2]
E - 9M	Excavation works	North	Hummus	~ 1 m	98,385.00
E - 10B	Excavation works	North	Hummus	~ 1 m	11,2887.00
Total damaged land expressed in surface area					∑ = 211,272.00

Table 3. Coal cover removal and extent of soil damage

Excavator type	Character of works	Parameters	Type of works	Soil type	Surface [m^2]	Volume [m^3]
E - 9M	Soil removal	H = 18 m	Construction of cascades	Fertile soil, yellow-ash clay	S = 98,385	V = 1,770,444
				Ash-yellow clay		
E - 10B	Soil removal	H = 18 m		Fertile soil, yellow-ash clay	S = 112,887	V = 2,031,966

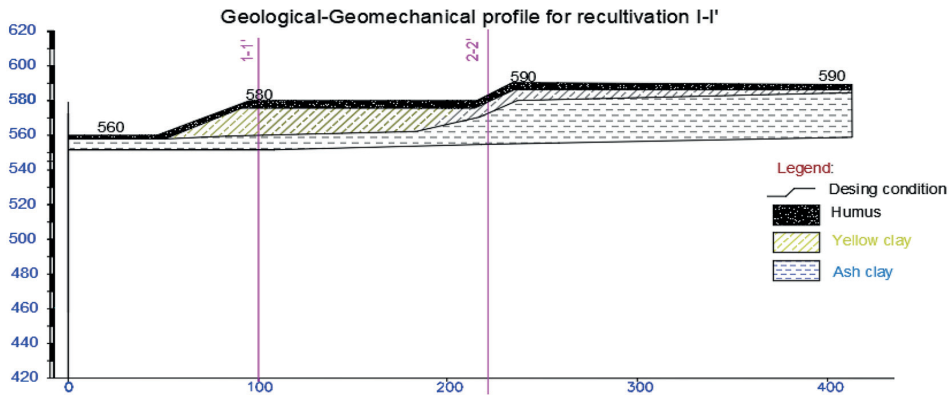

Figure 3. Profile I-I' geological-geomechanical profile for recultivation of the green belt

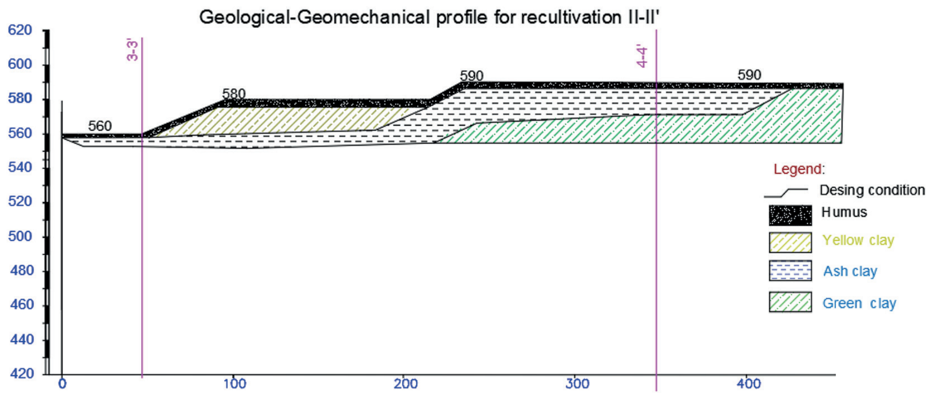

Figure 4. Longitudinal profile II-II' for the recultivation of the green belt

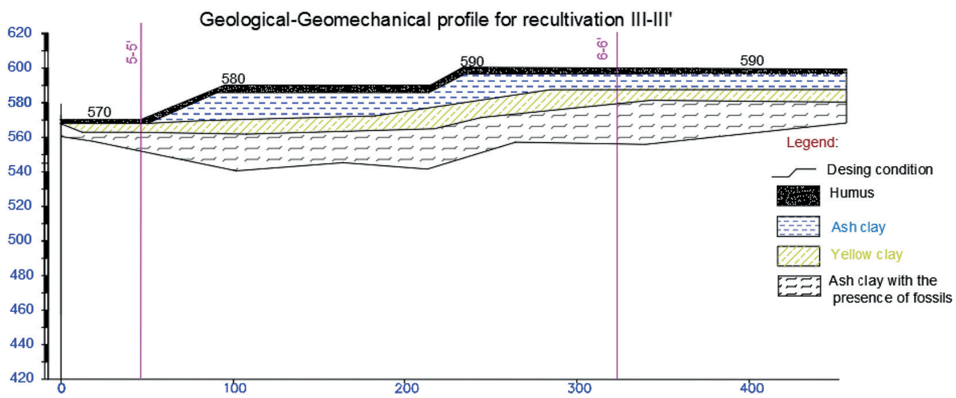

Figure 5. Longitudinal profile III-III' for the recultivation of the green belt

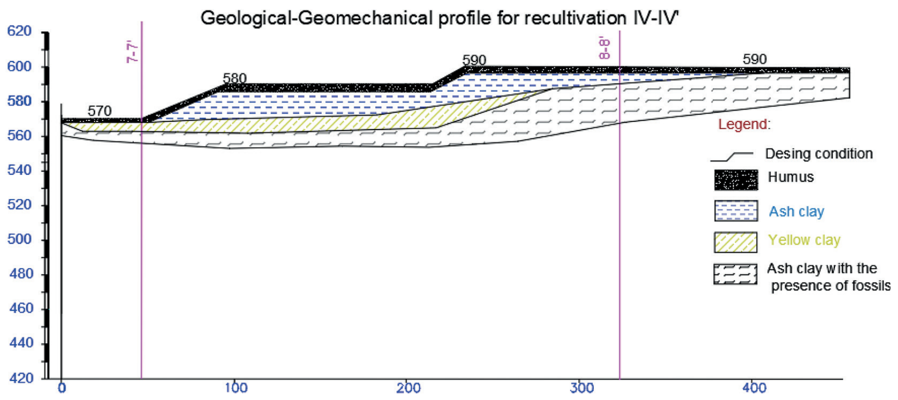

Figure 6. Longitudinal profile IV-IV' for the recultivation of the green belt

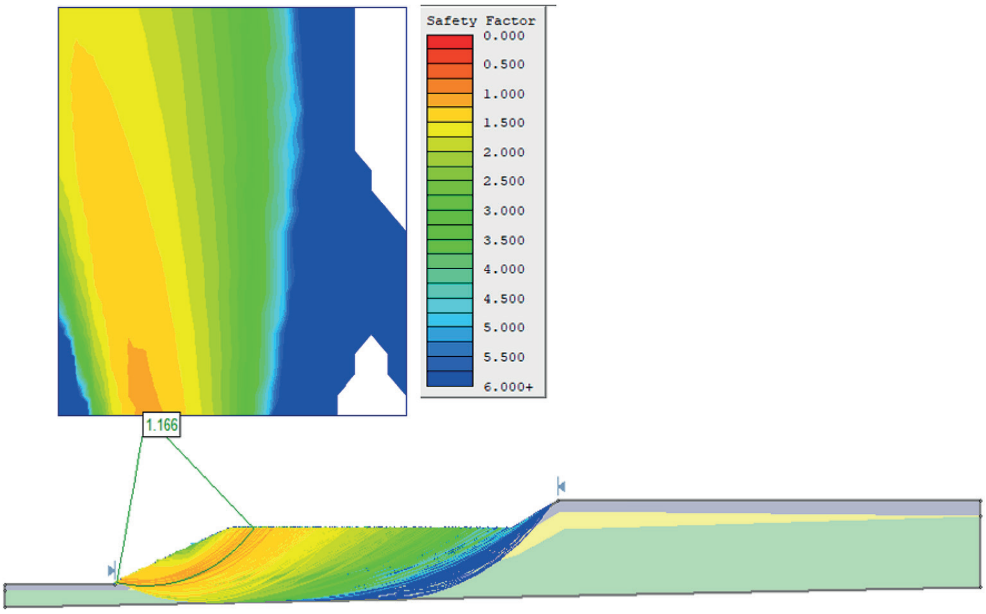

Figure 7. Calculation of the geometry of the slopes for the recultivation of the area with the allowed safety factor

was calculated with the safety factor F_S = 1.16 as in Figure 7 according to (Ahmeti, H. 2022; Braja M. Das, Khaled Sobhan, 2014) that the condition is met according to the geotechnical design norms for the recultivation of the area, the distance of planting seedlings and their types are presented in Table 7 (Arboit, M., & Betman, E. 2017; Muhlisin, J., Iskandari, B. & Martha, F. 2021; Almas, T. 2016; Arnberger, A. & Eder, R. 2012).

The second method: Analyses of physical and chemical parameters to determine the humus layer for recultivability such as: water pH, $CaCO_3$, organic matter, humus, N-total, nutrient elements P, K, Ca and Mg.

Physical parameters: hydroscopic moisture, specific gravity and granulometric composition; aqueous pH – electrometric method with a pH-meter from the aqueous extract in a soil-water ratio of 1:2; $CaCO_3$ – gasometrical method by determining the amount of CO_2 released during the action of 10% HCl solution – Scheibler's calcimeter; organic matter – two hours of burning at 360 °C; humus – the method of oxidizing organic matter with an acidic solution of $KMnO_4$; nutrient elements P, K from Amonacetate – EDTA extract, ratio soil extract 1:10; P – spectrophotometric method with molybdateammonium; K – flame photometer; Ca – flame photometer; Mg – AAS; hydroscopic moisture-gravimetric method drying at 105 °C for two hours of dried sample in air (10 days); specific gravity-gravimetric method with water pycnometer; granulometric composition – with sieves and pipettes, the method of sedimentation and dispersion with the 0.04 N solution of $Na_4P_2O_7 \times 10\ H_2O$.

Chemical parameters: Soil reaction characteristics (pH value), soil reaction (pH value), both active (pH in H_2O) and substitutive or physiologically active acidity (pH in 1M KCl), were determined by the electrometric method (potentiometric) in parallel with glass electrode and centron. Based on the pH values in KCl, the degree of reaction according to Scheffer – Schachatschabel can be determined, that is, the soil classes can be determined, according to Table 8.

Table 4. Geostatic parameters for calculation (INKOS Institute)

Lithological layer	φ [°]	C [kN/m²]	γ [kN/m³]
Humus	12.00	6.00	18.00
Clay with yellow color	14.10	7.50	17.40
Clay with grey color	15.00	9.00	19.20
Clay with green color	11.86	8.00	18.52

Organic matter content (% humus)

Determination of the amount of soil organic matter, namely humus, was carried out using the method according to Kotzmann. The method is based on the oxidation of organic matter with the solution of 0.1 M of $KMnO_4$, from which the total amount of organic matter, namely humus, is calculated based on the principle of calculation with the relevant coefficient (the amount of oxidized carbon CO_2 and the conversion of carbon C into humus).

Based on the humus content values, according to the method, soils can be classified into the following classes:
- weakly rich in humus (<2%);
- average rich (2–4%);
- rich (>4%).

Carbonate content (% $CaCO_3$)

The amounts of carbonates ($CaCO_3$) in the soil samples were determined by the volumetric method in a calcimeter. The method is based on the treatment of the sample with HCl and the volumetric measurement of the released CO_2 in the calcimeter according to Scheibler. The classification of soils by classes is presented in Table 9.

The easily usable amounts of phosphorus (P_2O_5) and potassium (K_2O) in the researched samples were determined by the AL method (Egner-Riehm). The method is based on the extraction of samples in AL (ammonium – lactate) solution. From the obtained extract, phosphorus was determined by the UV Spectrophotometry method by developing color with the ammonium molybdate complex, while potassium was determined by the Atomic Adsorption Spectrophotometry (AAS) method.

Physical parameters – granulometric composition (texture %)

The preparation of the sample was done by peptizing it with sodium pyrophosphate, while determining the fractions with the hydrometric method. Whereas, the classification of materials according to this property is based on the triangle according to Ehwald. The results are presented in Table 10.

ANALYSIS AND RESULTS

Based on the analysis and results, the number of seedlings for biological re-cultivation that are presented in Table 5 has been determined based on Equation 1 for the year (2022–2023) for the level of the land quota 570, 580 and 590 m, while types of trees are presented in Table 6 and in Figure 9 according to the geological – geomechanical profiles designed with safety factor F_S = 1.16 as in Figure 7 designation, age and size are shown in Table 7 and Figure 8.

The average values of the results for the chemical analyzes for the green belt are shown in Table 11 and their graphic presentation is shown in Figure 10, while the average value of heavy metals based on the profiles of the green belt are shown in Table 12, the presentation their graph is given in Figures 11 and 12.

$$N_{of} = \frac{\mathrm{S}}{\mathrm{a} \cdot \mathrm{b}} = \mathrm{seedlings/he} \quad (1)$$

Table 5. Number of plants for re-cultivation for levels (570, 580, 590 m)

Year	Level [m]	Area [hectares]	Number of plants [pieces]
2022–2023	570, 580 and 590	17	10,625

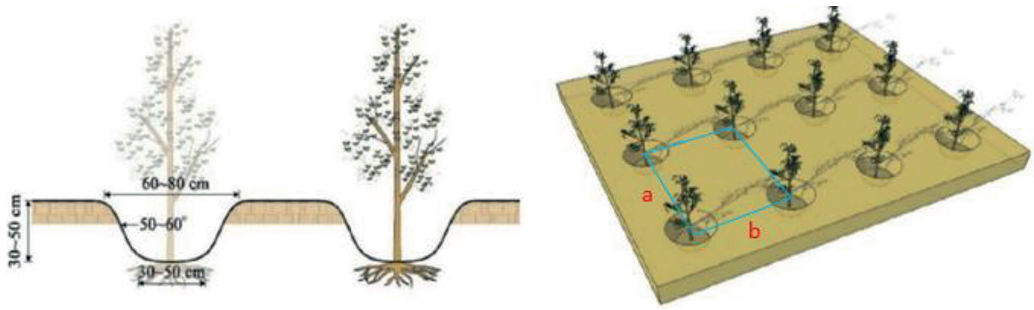

Figure 8. The appearance and dimension of the seedling position

Table 6. Types of saplings (trees)

Nr.	Designation	Unit	Quality	Age [years]	Size [cm]
1	Platanus orientalis L.	piece	Certified	3	225–230
2	Tilia SP	piece		3	225–230
3	Aesculus hippocastanum L.	piece		3	225–230
4	Populus nigra L.	piece		3	225–230
5	Robinia pseudoacacia	piece		3	225–230
6	Quercus petraea	piece		3	225–230

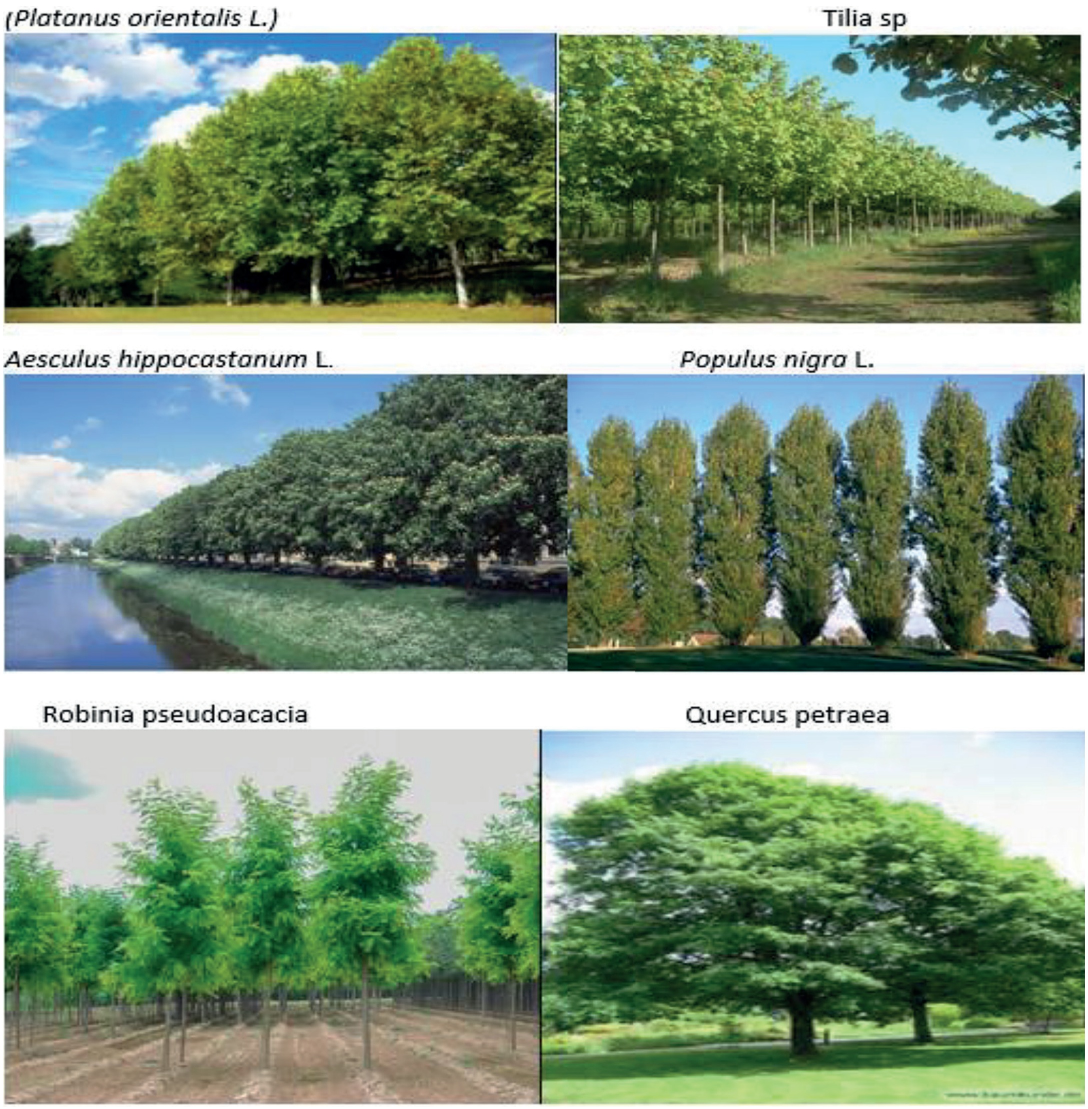

Figure 9. Biological recultivation

Table 7. Land class according to reaction rate

No.	Land class	Values [pH]
1	Very acidic	< 4.9
2	Weakly acidic	5.0
3	Neutral	7.0
4	Weakly alkaline	7.1–9.0
5	Very alkaline	> 9.1

Table 8. Land classification according to classes

No.	Land class	Class {%}
1	Very slightly carbonated	0.1–1.0
2	Slightly carbonated	1.0–5.0
3	Moderately carbonated	5.0–10.0
4	Quite carbonated	10.0–20.0
5	Very carbonated	20.0–50.0
6	Too carbonated	> 50.0

Table 10. Texture classification according to clay composition

Sandstones	Light sub-clay	Medium sub-clay	Heavy sub-clay	Light clay	Medium clay	Heavy clay
< 15 [%] clay	15–25 [%] clay	25–45 [%] clay	45–60 [%] clay	60–75 [%] clay	75–85 [%] clay	> 85 [%] clay

Table 11. Average values of the results for the chemical analyzes of the green belt

Symbol	P1 0–30	P1 30–60	P2 0–30	P2 30–60	P3 0–30	P3 30–60	P4 0–30	P4 30–60	Average
	Fir-tree		Catalapi		Ash-tree		Jasen Pendula		
EC	270	260	250	240	330	350	450	400	318.75
Chlorides	20.50	15.50	24.00	24.50	14.50	11.00	6.50	5.00	15.1875
Sulphates	200	280	160	120	270	310	325	415	260
pH (H_2O)	7.4	7.3	7.3	7.2	7.1	7.2	7.2	7.4	7.2625

Table 12. Average values of heavy metals based on green belt profiles

Symbol	P1 0–30	P1 30–60	P2 0–30	P2 30–60	P3 0–30	P3 30–60	P4 0–30	P4 30–60	Average
As	Fir - tree		Catalapi		Ash - tree		Jasen Pendula		
Cd	<0.1 ppb	<0.1ppb	<0.1ppb	<0.1pbb	<0.1pbb	<0.1pbb	<0.1pbb	<0.1pbb	
Cr	71.26	65.25	76.37	62.24	75.89	74.54	81.38	90.74	74.71
Ni	145.23	166.72	146.97	129.81	132.98	138.35	153.64	155.82	146.19
Pb	69.41	76.50	87.03	84.99	119.40	115.82	76.27	69.20	87.33
Zn	365.12	308.01	287.95	256.66	268.74	346.47	338.35	400.56	321.48

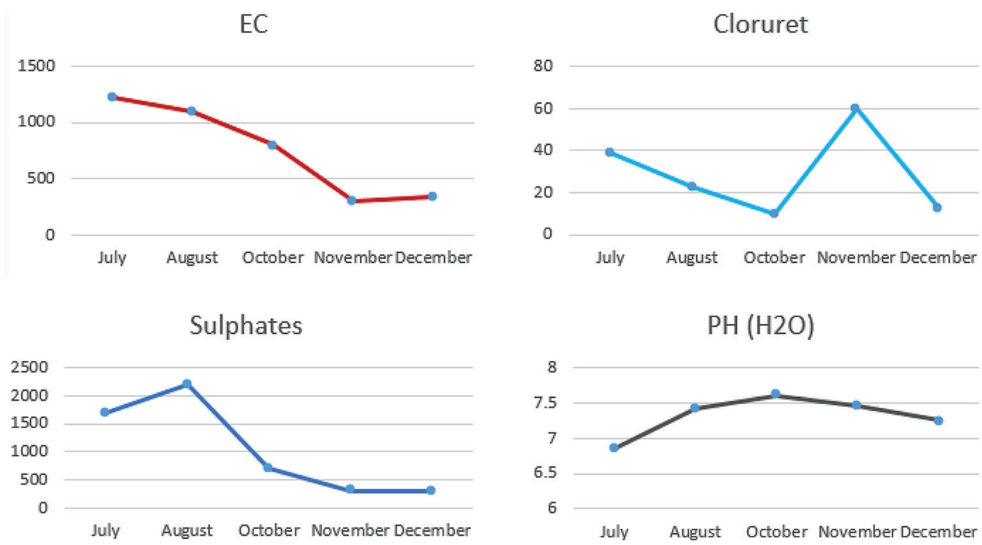

Figure 10. Graphic representation of chemical analysis for green belt

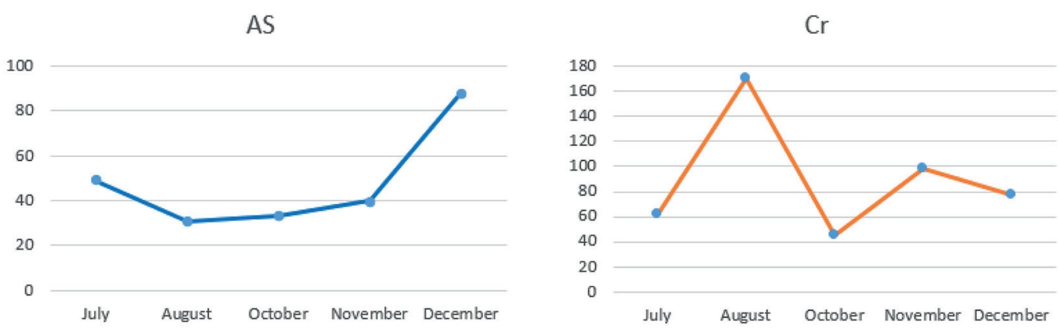

Figure 11. The average values of the content of heavy metals (AS; Cr) in the green belt according to the profiles

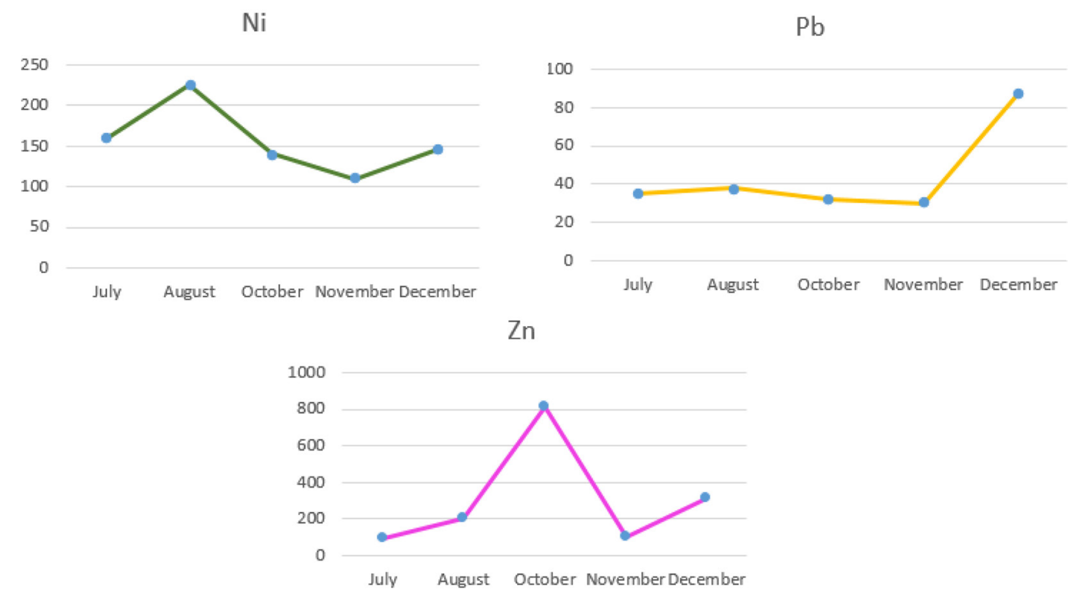

Figure 12. Average values of the content of heavy metals (Ni; Pb; Zn) in the green belt according to the profiles

CONCLUSIONS

The results of the chemical analysis of the soil samples are also followed by the Maximum Allowed Values (MAV) according to the Dutch List, which is currently the norm used by most EU countries, in the absence of an EN norm. As the majority of countries, even the Republic of Kosovo, does not regulate the Norm for the level of soil contamination with chemical elements, however, in our country with Administrative Instruction no. 02/2009 of 2009 and the latest Administrative Instruction no. 11/2018 of 2018, the aspect of the Maximum Allowed Level of Discharge and Distribution of Pollutants on the Land has been adjusted.

From the data presented in the monthly reports, we can conclude that the values of the active reaction of the soil (pH in H_2O) in all analyzed samples have shown values > 7.0, respectively according to the reaction they belong to the class of weak alkaline soils. The content of the amount of soluble ions (SO_4 and Cl) show high values and they are correlated with the high level of electrical conductivity (1370 µs/cm). Regarding the content of chemical elements that cause phyto and zoo toxicity, As, Cd, Cr, Ni, Pb and Zn, from the results obtained and their comparison with the values determined by the Dutch List, we can conclude that their amount in the analyzed samples are brought in the range from lower compared to the optimal values up to the interval between the optimal value and the level when it is necessary to take action to mitigate the contamination, except for the amount of Zn which in the samples of the depth 30–60 cm of the poplar and the samples of two depths of the Salix, Fir and Ash trees have exceeded the Maximum Allowed Values, in which case measures should be taken to mitigate the level of contamination with this chemical element.

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