IMPLEMENTATION THE FOREST AMELIORATION ON THE ALKALI METAL SLAGHEAP HILLSIDES

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The following article presents the selected partial results and other information gained from alkali metal slagheap reclamation, which was planned and realized using biological and technical methods. Out of the various possible methods, the method founded on restocking the area using the original technical method was chosen. This method is based on the reinforcement of the soil in the slagheap with acacia poles and its subsequent biological reclamation. This provides erosion control of the surface. The object integrated the slagheap into the environment and particularly optimised the depletion of CO_x immediately after it was emitted into the air. The sorts of trees and shrubs used in the restocking of the slagheap's slopes are described also with the partial results of the landslide tests done on the hillsides.

forest amelioration; slagheap reclamation; biological engineering revegetation

INTRODUCTION

After the Second World War industry developed very quickly in Europe. The more product produced the more waste was created. The inefficient technology used in production and the total unconcern to solve the problem of waste resulted in the devastation of the countryside and the adverse impact on the environment of people.

The increased interest in the environment, which has led to an increased demand for a sustained improvement in living conditions, has stemmed from this understanding of the world.

A concrete example of this development has been to solve the problem of alkali metal waste created by the production of aluminium.

Exhaust gases produced by manufacturing were released into the air in vast quantities while solid waste was stored in a slagheap. At present the area of the slagheap is around 45 ha and its height is almost 40 m.

Herbs, shrubs and trees cannot live on the slagheap which has a pH value greater than 9.5 and so the slagheap has been an eyesore and adulterated the environment.

The optimal solution is the revegetation of the slagheap and surrounding locality with middle height and higher trees, which are considered as the best measure to regenerate a devastated area and will make the fluent transition between the variant sorts of environment. This information was proved when the University of Agriculture in Nitra, Forestry Research Institute in Zvolen, ENVIGEO in Banská Bystrica and ARBOR in Senec test planted these sorts of trees in this slagheap in the period 1993–1996.

On the basis of the information about sludge bed reclamation (Žiar nad Hronom, Šala, Storage Plant Gabcíkovo in Slovakia, Chomutov and Alka in Hungary), three alternative reclamation projects were proposed. Alternative 1 – to accomplish reclamation only on the terraces of the treated part of the slagheap, alternative 2 – to accomplish reclamation on the terraces and locally also on the slopes and alternative 3 – to accomplish reclamation on the whole area.

With regard to the ecological and economic aspect of the owner's demands, we decided to realize the third alternative, using the original technical method. This method is based on the reinforcement of the soil in the slagheap with acacia poles and its subsequent biological reclamation. This provides erosion control for the surface, the object was to integrate the slagheap into the environment and particularly to optimise the depletion of CO_x immediately after it is emitted into the air.

MATERIAL AND METHODS

Goals of the project

The aims of reclamation of the treated part of the slagheap are:

- maximization of CO_x depletion
- elimination of solid emission entering the agro ecosystem, forests, and urban areas
- increasing the aesthetic aspect of the area
- preventing soil erosion on the slagheap
- decreasing rain water infiltration into the slagheap
- decreasing infiltration of alkaline water from the slagheap into the underground water table
- decreasing the infiltration and outflow of impure rain water, which will feed the planted shrubs + trees that have a high storage capacity for water
- decreasing the possible ecological risk.

Methodology and procedure

We would like to explain some of the terminology used in the project:

Forest amelioration – are biological and technical remedies to improve soil condition and water management of the area, to decrease soil erosion, to making the land wet, to increase production and the other functions of the forest. The purpose of the forest amelioration is to improve the location's conditions based on all kinds of afforestation, to plant out the forest shelter belt, to landscape the area, to make an erosion control plan, drainage of the roads, reclamation of the damaged and devastated areas and to improve the water management of the land to protect the lower parts.

Bench – purely horizontal area or slightly sloping area on the slagheap that originated from pouring and the storage of waste material (possible use in the future).

Reinforced slope – sloped area between two horizontal benches, resp. layers poured material on the slagheap. (The average distance between two benches is about 7 m, the average slope is about 40 degree.)

Topsoil – soil, where is enough organic matter to enable the forest trees and the plants to grow.

Slope reinforcement grid from thin acacia poles – wooden reinforcement device on the sloping surface of the slagheap, made from horizontally and vertically arranged stabilized poles from acacia trees. This grid is fulfilled with topsoil to a depth of 30 cm, where the trees proposed and agreed in the project are planted.

Revegetation – arrangement of vegetation on the slope or other area, sowing or planting of trees, shrubs and plants along with transported soil. Implementation of the technical measures is a part of revegetation.

Reclamation – wide-ranging reconstruction or adjustment of the whole shape, character or even the nature of the area damaged or devastated by industry or construction used to fulfil society's demand.

Clone – set of specimens from one kind of wood, propagated by cuttings.

Multiclone variety – specimens grown by crossbreeding similar types to get desired characteristics. The extent of the realized project is about 400 pages, for that reason only the basic ideas and selected methods are introduced into this article. The procedure of reclamation was divided into the following parts:

- demarcation of the treated area, division into sections
- comparing the treated area with an aerial photo and with the map, scale adjustment
- landslip stability computation, fluid penetration test
- proposal of the reclamation project – the basic recommendations of the reclamation process
- divide proposal of the treated area into the sections specified for afforestation
- detail planting plan specification
- management plan for the shrubs and trees, irrigation and field engineering.

RESULTS

Treated area

The treated area (slagheap and surrounding area influenced by seepage from the slagheap (Fig. 1) is located in the southeast of Žiarska Valley, in the alluvial plain of Hron. This area consists of Holocene alluvial deposits with a shifting character, mainly of clay-loamy to loamy soil. The prequaternary base consists of Pliocene sediments.

Alluvial soil, pseudogley and gley have developed from these sediments. Natural character of these soils has been changed by infiltration of alkalized rain water from the slagheap.

The first stage of reclamation was to analyse the actual character of the soil and inventory of the actual vegetation cover in the area. For this purpose the actual ground vegetation was sampled to specify its dry weight and to quantify the current resource of biomass, carbon and to determine the density of vegetation. At the same time the topsoil was sampled in all sections of the slagheap and also from the areas, where the land had been influenced by infiltration of alkalized rain water from the slagheap.

Localising the treated area was done by a combination of information from a topographical map in the scale of 1 : 25 000, the basic map of SR in the scale of 1 : 10 000 and information from aerial photos (ortophoto) of the slagheap. The system of S-JTSK coordinates was used. Topographical map in the scale of 1 : 25 000 in the system of S-42 coordinates was transformed for this purpose into S-JTSK by means of control points. For the process TopoL 6.004 software was used. The orthophotos were oriented with the map by means of control points and collinear and polynomic transformation, where the standard position error of the transformed photos was from 0.5 to 2 meters. With regard to different kinds of reclamation used, the treated area was divided into 5 sections (A–E). There was further discrimination in each section between benches and fill slopes. The area of each section was determined as the area of its normal projection. Possible mistakes arising from using this method should be considered particularly in reclamation in sloping areas. Item "number" means block identifier of each polygon in TopoL software.

By scanning the map was transformed into digital form and after that processed in the TopoL software. The link with the system of S-JTSK coordinates was made by dint of the net of coordinates with a spacing of 100 m.

Dividing the treated area into sections and their localization

Section "A" – area in the south east side in front of the slagheap horizontal between road made from box-frames and bottom of the slagheap

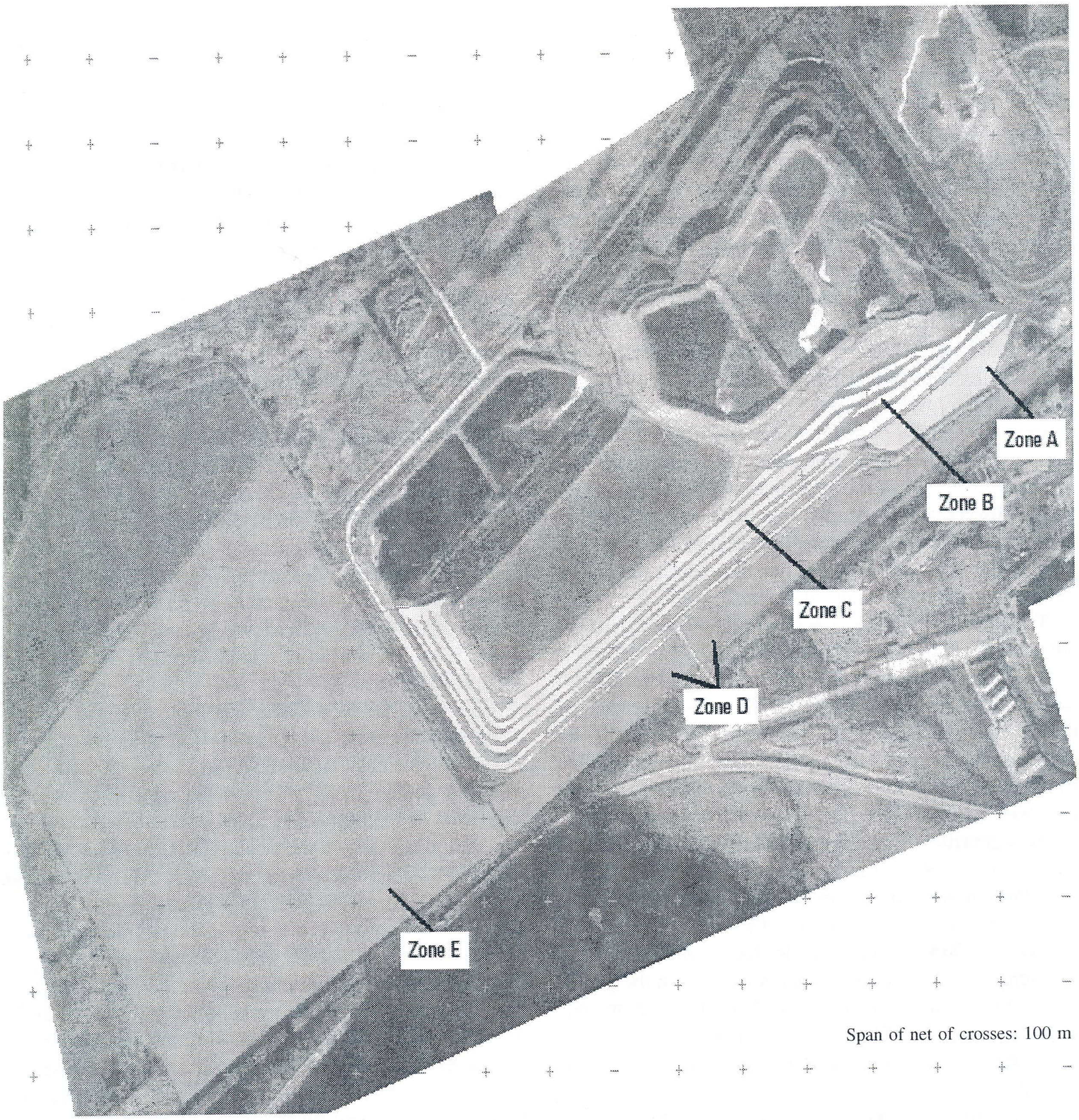


Fig. 1. Localisation of zones for reclamation

Section "B" – revegetated area on the south – eastern part of the slagheap, located on the right of the road crossing it.

Section "C" – south and west part of the slagheap located between the road made of box-frames and the bench nearest the top of the slagheap. Part of it is outside the fill slope of the drainage canal from the road made of box-frames.

Section "D" – horizontal area located between the road made of box-frames and the railway on the southern side of the slagheap.

Section "E" – cca 30 hectares of the earth to the west from the road made of box-frames. This area is waterlogged by the solution percolating from the slagheap and is covered by plants and shrubs.

Standard error m is defined as the square root of the sum of the square of all errors, divided by the number of measurements, in our case by the number of control points. On the map the standard error follows:

$m(x)$ = **0.111 m**

$m(y)$ = **0.069 m**

Small errors are caused by the press quality, made up of the map and distortion because of scanning.

The inner boundary of the subterranean sealing wall, marked on the map, is considered as the boundary of the slagheap in the digitalized polygon. The area of this polygon is:

P = 44.1549 hectares

If we will, for simplification, consider the slagheap as a rectangle oriented across the system of coordinates, with the lengths of side a_1 = 980 m and a_2 = 450 m, the resulted standard error of product $P = a_1 \times a_2$ is then possible to calculate as:

$$m_p = \pm\sqrt{\frac{(a_1^2 \cdot m_{(x)}^2 + a_2^2 \cdot m_{(y)}^2) + (a_2^2 \cdot m_{(x)}^2 + a_1^2 \cdot m_{(y)}^2)}{2}},$$

$$m_P = \pm 99.54 \text{ m}$$

Landslip stability in the section C_{2-3}

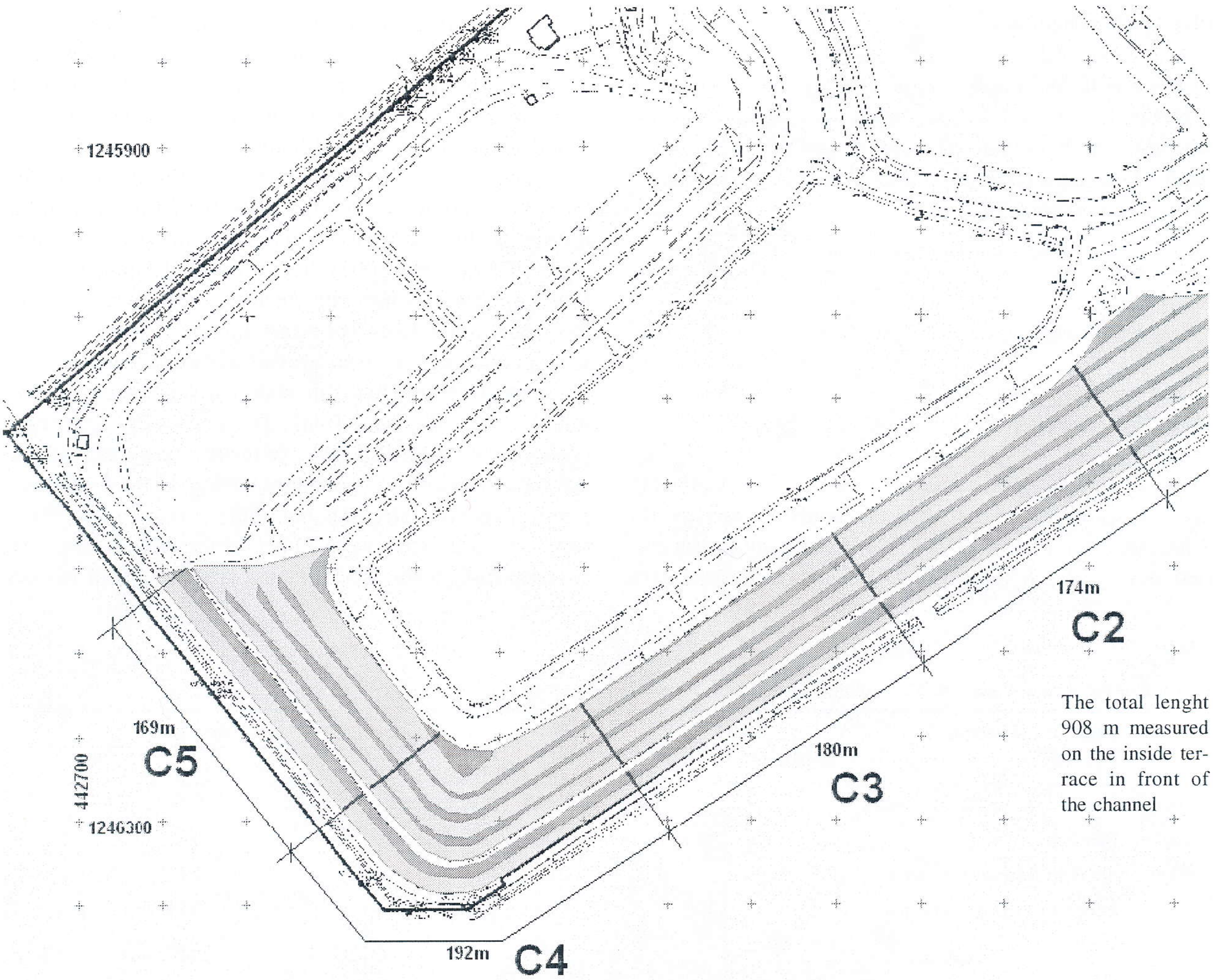
As a precaution the managers of the project decided to ask the specialist to compute the landslip stability for 2 hectares in the section C_{2-3}. An investigation was carried out by the EKOGEOS Company from Bratislava with the partnership of the Technical University in Bratislava. The results of this are guaranteed by an expert in this area – professor Hulla. Out of about 200 pages of the results of this investigation, only selected points are presented here:

According to the results from bibliographical researches, laboratory findings as well as fluid penetrant testing are big extremes in slagheap material properties there (Klč et al., 2002). To correlate the results from fluid penetrant testing with shearing strength parameters the information from specialist literature were used as well as information from Slovak technical standards.

Computing the landslip stability was made at two times – prolusion and final. The knowledge got from prolusion were used spatially to rectify the geodetic measurement and for fluid penetrant testing. In the final computing shearing strength parameters from these fluid penetrant tests that were close to the lowest shearing strength limit were used. In each profile the full respect

Division of the section C into parts according to the proposed kind of reclamation

Parts of the section C	Area in m^2	Area in ha
C1		
Slopes	5 633	0.56
Benches	2 208	0.22
Slope in front of the canal	1 042	0.11
Bench in front of the canal	1 117	0.11
Total	10 000	1.00
C2		
Slopes	6 059	0.61
Benches	2 050	0.20
Slope in front of the canal	875	0.09
Bench in front of the canal	1 016	0.10
Total	10 000	1.00
C3		
Slopes	6 158	0.61
Benches	1 765	0.18
Slope in front of the canal	976	0.10
Bench in front of the canal	1 101	0.11
Total	10 000	1.00
C4		
Slopes	5 541	0.56
Benches	1 648	0.16
Slope in front of the canal	1 648	0.16
Bench in front of the canal	1 163	0.12
Total	10 000	1.00
C5		
Slopes	6 295	0.63
Benches	1 504	0.15
Slope in front of the canal	1 687	0.17
Bench in front of the canal	1 115	0.11
Total	10 601	1.06



to the change of shearing strength parameters according to the depth got from fluid penetrant testing was given.

The biggest problem was found in influencing the slope stability between the second and third bench, where a new road was projected during the time of mechanization's operation and transportation of material. When testing we assumed a full Tatra 148 lorry i.e. x 50 kN on a contact area of 2 x 0.3 x 0.75 m. From the results of final computing it is possible to say:

- Vehicle movement on the brink of the current bench could threaten the landslip stability in places, where the degree of stability is around the minimum limit F = 0.94–1.04;
- After widening the third bench by 2 m and shifting the vehicle to its inner edge, the degree of stability could reach a value F = 0.94–1.04 in places with lower landslip stability;
- Using stone material under the box frames to stabilize the road could change the index F = 1.33–1.40;
- Another alternative, using three pole fences on the slope with the lower landslip stability index, will have the F = 1.16–1.25; but with the help of box frames we can obtain the value F = 1.46–1.62;
- In the parts with a higher landslip value of stability index it is possible to get a higher degree of stability in all kinds of loading.

Widening the third bench will increase the slope between the third and fourth bench as well. If the material of the upper slope has a landslip stability index close to the minimum limit ($\varphi = 28°$, c = 6 KPa, $\gamma = 16$ kN/m^3), the condition for its stability follows:

- The minimum stability value of F = 1.07–1.11 will have the slope above the fourth bench in profile PE-1 (pic. 4.39 part A of the investigation), so in a place totally not uninfluenced by the heavy transportation on the third bench and the steep slope between the third and fourth bench;
- With the same conditions in profile PE-2 the slip plane should intersect the bottom of the slope at the surface of the widened third bench (pic. 4.67) and value of F = 1.09 – 1.13. So in this case a little bit higher than in profile PE-1;
- Thanks to the better condition of material in profile PE-3 the slope above the canal is stable in all situations of the slip plane. The widening of the third bench and changing the slope will have a little influence on its stability.

It was considered to use a gabion to stabilize the third bench in proposal slagheap revegetation project. But we did not think it good to use it, because it increased loading of the nether slope about 24 kPa and required expanding expansion the third bench to 6 m and the slope between the third and fourth bench should be even steeper.

In respect of newly made land research and landslip stability computing it is possible to establish the conditions for revegetation the slope as follows:

- The third bench will be widened to 5 m, covered by the box-frames to make a road or the better quality of material should be used to make the surface of the road. The movement of Lorries and mechanization will be organized to drive as close as possible to inner slope.
- The slope between the third and fourth bench will be adjusted without the use of the gabion.
- The water level of the underground water table in test boreholes will be observed; if the water table level will reach the slip planes, it is not safe to continue working.
- The slagheap revegetation could be realized according to the project made by the Forestry Research Institute in Zvolen, Slovakia.

Slagheap reclamation process in section "C_{2-3}"

Fundamentals and basic methods of solution

The proposed bio-technical solution tries to improve and regenerate this area with a live ecosystem. This ecosystem will be put into technically well prepared, stabilized topsoil on the slopes and benches of the slagheap.

According to the atypical conditions of the treated area the project offers an unusual and original method to revegetate the slagheap's slopes, where the forest amelioration method, based on reforestation, is used. To support the reforestation, in other words the forest amelioration method, it is necessary to construct technical specific equipment to guarantee compatibility, connectivity and success of realization the technical procedure and revegetation methods. This is the difference between this project and standard construction project, because all construction works are used only as the support or part of the afforestation project. The final implementation of the project requires a lot of manual work, new atypical technological methods and regular testing of the new combination of partial technologies (K l č et al., 2003a).

To protect the topsoil, in the reclamed parts of the slagheap, from erosion or potential landslip a barrier from thin acacia poles is constructed on the surface. Compared to other biological material acacia wood is the proper material and has been proved over centuries. Acacia wooden is rot resistant therefore is efficient for a long time.

For organizational purposes the treated area C_{2-3} was divided into several parts – slopes S_{0-4}, benches T_{1-4}, a dike, and the canal and so on. These parts consider the basics for other computing and speculations.

Depth of the topsoil is on average about 30 cm on all slopes and benches (except bench no. 3) of the treated area. This depth is minimum soil necessary for successful afforestation. The necessary depth for grassing is about 15 cm on the slopes and plain of the dike.

For stability the soil need only start about 2 m above the drainage canal on the slopes S_{02} and S_1.

Basically it is recommended to minimize the ground shaping of the slagheap's surface and maximally to preserve the existing vegetation on the slagheap's slopes and benches.

Permanent access of this section will be guaranteed by making the third bench in the width of 5 m, with the regard to static computing made by the specialists. Surface of the road will be toughen by either second hand or new road box frames (permanent or provisional solution).

For revegetation the whole section C is recommended to keep the technique, that is mean to put the topsoil with benign conditions. This topsoil will be reinforced with thin acacia poles.

This topsoil will be put on the slopes and benches from the third bench using UDS lorry and on the slope S_1 from the second bench by hands using a mobile flumes made from PVC, or will be moved from embankment using UDS lorry. This system will ensure access to shift the topsoil in the whole section C_{2-3} and the need of making other access will be excluded (K l č et al., 2003b).

Basic recommendations for completion

The topsoil should have the following conditions:

- Appropriate granularity and structure,
- Sufficient amount of organic matter,
- Reasonable supply of nutriment,
- Acceptable level of toxicology.

For these general conditions to be done the substrate can consist of the following materials:

- Mould (even with lower quality) from overburden removed by construction, if the construction has been an area not so far from the treated area;
- Mixture of materials with a higher amount of organic matter (for example sediment from the sewage disposal plant and material with lower soil quality;
- Bottom sediments from water reservoir.

According to the current possibilities, even from an economic point of view, the likeliest alternative is a mixture of soil from the dumping ground located close to the treated area and substrate with a higher amount of organic matter (for example peat or compost). It is proposed in the project to mix a fertilizer Vitahum with the soil at the rate 1 : 2. It is also possible to use other topsoil with a sufficient amount of organic matter, for example soil mixed with manure, with putrid bio waste or with humus (K l č et al., 2003b).

According to a soil analysis the grain size and mechanical properties of the soil from the dumping ground found near the state road is not appropriate: high amount of clay (according to the grain size analysis the soil is loamy-clayey to clayey, the clay content is more than 35%). Related to this property the adhesive power, plasticity when wet is high and when dry is hard making cracks. The chemical properties of the soil are also not appropriate. The soil is a little bit alkalized (pH 7.2–7.7) and has less than the average amount of organic matter and nitrogen. The content of the main nutrients is good, except for phosphorus; also the relative content of boron is less. But it is presumed that there is heterogeneity of material in the dumping ground. Without any improvement this soil material is unsuitable for use especially as a substrate for trees or as a material with lower slope stability. But mixed with an adequate amount of Vitahum it is sufficient. From practical point of view it is important here an adequate of wetness, so that materials will mix well.

Recommended method of preparing soil substrate:
- To deliver soil from a heap near SlovAlco factory to the mixing place;
- To deliver fertilizer Vitahum, manure from PD Slaská or another kind of fertilizer from other sources to the mixing place;
- Put both components into layers and mix using machines;
- Mix soil substrate with Vitahum at the rate of 2 : 1.

Making access to section C_{2-3} and adjusting the third bench for delivering poles and soil substrate by lorries and reinforcement of such:
- To connect access to section C_{2-3} to the constructed road (section C_1 access)
- Earthmoving works-digging the earth from the bottom of the slope and putting it back on the bench, making the slope;
- The final width of the third bench will be 5 m;
- To lay detritus on the surface of the third bench and compact this surface;
- To make provisional or permanent stabilization of the surface in the third bench with road box frames;
- To make reinforcement props from thin acacia poles, so that after laying the soil substrate on the slope the upper part of the prop should protrude 2–3 cm above the surface
- To lay the soil surface from the third bench on other benches and slopes;
- To afforest the prepared slopes and benches according to the plan;
- To ensure irrigation of the afforested areas by sprinkler vehicle from the third bench or from the pipe placed near section C.

Thin acacia poles:
- It is recommended to use acacia poles as the assortment "mine poles" with the following dimensions (length of 4m, the average diametre of 10 cm, mass 0.0314 m3);
- Pegs from acacia wood should be 80 cm long with a diameter of 8 cm;
- The pegs should be sunk into the earth to half of its length.

Afforestation project

When choosing the wood species the most important reasons were biological quality, facility to grow in bad conditions, speed of growth in the first few years, facility to survive in competition with other plants as well as the ability to enrich the soil with organic waste, possibly in symbiosis with nitrificative germ. Because of the bad local conditions, it is not practicable to use native kinds of wood only, but also allochtonous kinds as well as selected clones or multiclone varieties of other wood species where most of them already have been successfully used for revegetating sterile soils.

The aim of afforestation of the slagheap is to use more varieties of wood species that will be both height and spatial differentiated, to reach not only a functional but also an aesthetical solution. Therefore more varieties of shrubs as well were used.

According to the bad local conditions and presumptive losses a planting space of 1 x 1 m was used.

The treated area was divided into 11 sections and for each a separate planting project with specific planting space was employed. The main wood species was Robinia pseudacacia, which was combined with other kinds of wood species. Special part of this afforestation project was also a timetable of caring for the plants, refill plans and irrigation plans for the future.

Total caring of plants and reclaimed area

It is necessary to manage the care of the plants on the reclaimed area in the future until they are able to compete with the wild animals. As well as this, the unpredictable extreme weather or other situations could require other proceedings. Inevitably the different kinds of wood planted will have to replace those which died and the grass between the wood will have to be mowed to a radius of 0.30 m. Protection for animals will be provided by repellents and it will be necessary to form the shape of quickly growing species of wood and taking their branches off.

In the period from the first until the third year after planting it is necessary to irrigate the plants, especially if the amount of rain will be not enough for their growth and survival. Irrigation will be ensured by sprinkler vehicle from the third bench or from the pipes used in present time to sprinkle the slope from dustiness.

CONCLUSIONS

We have summarized the methods used for reclamation of 2 ha slagheap in the article. Because of special conditions in the slagheap we think this solution is just one of many possible solutions. But it is realistic and also included this time, is what is better for the environment than just to have long speeches about how to do it. The realization was limited by the budget of investor and also by other limits. But we are open to discuss other attempts and proposals and we hope the reclamation is finished as soon as possible, no matter if using this or another method.

A lot of technical and ecological measures have been made to treat the slagheap, such as building up the scumboards, repumping and returning the percolated polluted water from the slagheap back to the reservoirs on the top, building up the irrigation system to decrease the amount of dust when the surface of the slagheap is dry, realizing partial reclamations and ameliorations as well as supporting the cooperation with the research organisations to find the solution to treat the slagheap and others.

It will also be necessary to ask for financial assistance from MŽP SR as well as the EU in the future, because it will be very difficult for the investor to finance the reclamation in an increasing horrible ecological situation. The slagheap is like a time bomb for the future if there is a flood in the Hron river, there would be a wide ecological, economic and other disasters.

We appreciate the attempt of the investor to treat and to help to remove this old ecological burden with his own properties. If the partial solution, described in the article, stands the test of time, it will not be economically very demanding but efficient and useful for almost the whole surface of the slagheap. This method is the "open method", meaning it is possible to be modified, for example with the method of overlaying the slagheap with plastic foil.

Another possible use and reclamation of the slagheap is to construct an airport on the top or to construct a multifunctional sports precinct and to revegetate the remaining area.

The priority for the future is to change the method of production of aluminium with the minimization of the creation of the waste. The slagheap is also a possible dump of material for the future when the new production technology of production is used. To move the sludge into the abandoned mines near this factory is not possible from an economic point of view at this time.

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Využitie lesníckych meliorácií na skládke alkalických kalov.

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V príspevku sa uvádzajú vybrané parciálne výsledky a získané poznatky z biologicko-technickej rekultivácie navrhnutej a vykonanej na skládke alkalických kalov. Z viacerých alternatívnych postupov sa dohodol postup celoplošného ozelenenia (zalesnenia haldy s originálnym technickým riešením). To bolo založené na armovaní pôdneho substrátu žrďovými oporami z tenkej agátovej guľatiny s následnou biologickou rekultiváciou riešenej časti. Tým sa zabezpečila protierózna úprava povrchu terénu, zjednotil sa tento objekt s okolitým prostredím a hlavne sa v optimálnej miere zabezpečila implementácia spotreby oxidov uhlíka CO_x z ovzdušia už pri zdroji jeho emanácie do ovzdušia. Popisujú sa dreviny a kry využité při zalesňovaní svahov haldy a parciálne výsledky zo skúšok stability vykonaných v predmetnej zóne haldy.

lesnícke meliorácie; rekultivácia skládky; biologicko-technické rekultivácie

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