METHODS OF LANDSCAPE RESEARCH
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ENVIRONMENTAL IMPACTS OF AN OPENCAST MINE

key words: landscape protection, opencast mine, settling dust, wind, land-use, analytical measures, cluster analysis, discriminant analysis, Hungary

INTRODUCTION

Dust loading of the air appears to be an ever increasing environmental problem at more and more places worldwide. Dust pollution is high primarily in large industrialised cities and along busy roads, however, significant dust load can be expected in the environments of intensively cultivated agricultural lands and opencast mines. This paper investigates the dust load of an opencast perlite mine in the Zemplén Mountains in the north-eastern part of Hungary (Farkas, 2005). Within the area of the mine at Pálháza a grinding factory operates also presenting a source of potentially significant dust pollution. Regarding landscape protection it is important to know the exact quantity with which these activities contribute to the load of the environment. To understand the processes operating in a landscape – here the dust pollution – it is essential to study the role of the landscape forming elements. There is no other significant source of pollution in the surrounding of the mine as the nearest larger pollution sources are found in Kosice, 30 km away from the area of the mine (Burčík, Hronký, 1999) and the effect of these on the study area is negligible. On the other hand we had exact data on the development of the landscape forming elements therefore the study area is excellent for clearing the above questions. The actuality of the study is that the region – thanks to its excellent conditions – is becoming a dynamically developing tourist destination nowadays (Karancsi, 2006) therefore it is highly important to decide whether the operation of the mine endangers the tourist attraction of the region or not.

MATERIALS AND METHODS

In order to study the settling dust load 22 dust traps were established in an area of 3 km radius around the perlite mine covering evenly the study are (fig. 1). Dust traps were created according to the Hungarian Standard 21454-1:1983. The collection of dust samples were carried out at a monthly rate between July 2004 and July 2006. Through laboratory analyses the amount of the unsolvable and the solvable dust fractions were determined and these together present the settled quantity (Mersich, 1994; Balázs Fülöp, 2003).

For the analytical examinations dust samples were digested with 20 ml of 65% (m/m) HNO_3 heated on hot plate to 80 °C. After the evolution of NO_2 fumes had ceased, the mixture was evaporated almost to dryness and mixed with 5 ml of 30% (m/m) H_2O_2. The mixture was again evaporated to dryness. The samples were diluted to 10 ml by adding 0.1 mol.dm-3 nitric acid. The concentration of Al, As, Ba, Cd, Co, Mn, Ni were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) using a Thermo Iris Intrepid II XSP instrument. Concentrations of elements in dust were expressed as mg/kg dry weight.

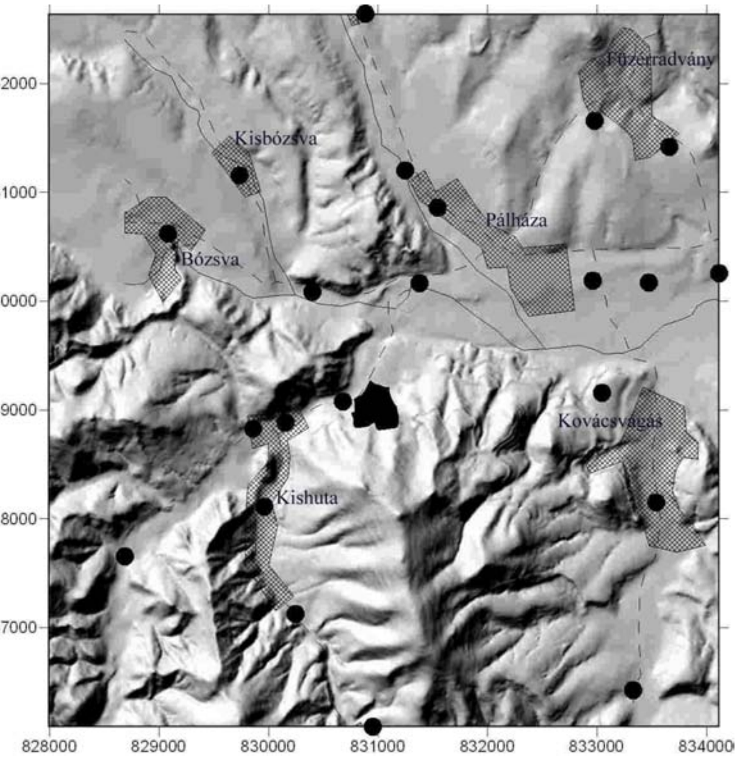

Fig. 1. Shadow relief map of the study area (dots mark the position of the dust traps in the vicinity of the perlite mine).
Source: *compiled by the authors.*

The evaluation of the spatial distribution of the dust load was made with relations to the meteorological data. Meteorological data were produced by an automatic meteorological station established 1 km to the North from the quarry within the study area. Besides the meteorological parameters that influence the spatial distribution of the settling dust the most (wind velocity, wind direction, amount of precipitation) the station recorded temperature, moisture and sun radiation every 10 minutes. Data regarding wind conditions were measured at an elevation of 4 metres. Land-use was examined on the basis of the database of the Corine Land Cover 50.

RESULTS AND DISCUSSION

Natural conditions of the area

Considering the spatial distribution of the settling dust originated from the mine primarily the relief and meteorological conditions have significant roles, however, apart from these several factors influence the pattern of dust load. Among others, land cover also significantly influences the spreading of the dust load. The tree crown – especially after crown growth – presents an effective filter in forested areas as it impedes the transmission of dust for large distances. Significant amount of dust may be blown into the air from agricultural lands especially when cultivation or harvesting is carried out in dry weather. Geological conditions have a smaller role, however, the aerodynamics of the perlite dust produced by the excavation and grinding is greatly dependant on the chemical and physical properties of the given rock. Hydrological conditions have a subordinate role considering dust loading. Its effect is reflected in that the micro-climate is wetter in the environment of streams thus soil dries less easier and dust also gets into the air less easier.

Due to their dominant role the relief, meteorological and land-use conditions are outlined in the followings.

Relief conditions

Relief significantly influences the spreading of pollutions therefore we analyse the relief conditions of the environment of the mine. The mine itself was created in the northern side of the Som-hill having an elevation of 500 m. The excavation zone starts at 165 m and reaches up to 275 m. The opencast mining started from 1958 produced a 500-600 m wide scar while the overburden material builds up new hills in the eastern southeastern side of the mine. In the northern foreground of the mine the basin hilly region of the Upper Hegyköz dissected by wide valley with a dire-ction of North-South and the intermittent flat intervalley ridges is found. The Upper Hegyköz itself is surrounded by 500-700 m high mountains that have some effect on the air-flows even though they lie several kilometres from the study area. West and East of the mine the valley of the Bózsva stream widening towards the East is found. To the southwest the valley of the Kemence stream is found narrowing near the mine down to a width of 60-70 m, however, it becomes 300 m wide gradually towards the southwest. Southeast of the mine the wide valley of the Hosszú stream is running towards the South.

Meteorological conditions

First, the pattern of the wind direction frequencies is studied. The measuring station recorded the wind directions at an elevation of 4 m by 22,5°. Regarding the whole time of the examinations the northern winds were the most frequent (18.3%) (fig. 2). If NNE and NNW winds are counted in almost 40% of the study time northern winds were blowing. Besides northern winds southern (S, SSE, SSW) ones can be considered as frequent with 22%. Similar results were gained by studying the monthly average of the wind direction frequencies. No significant deviation was experienced among the months as northern winds dominated in every month. These frequency results show good correlation with the literature (Wantuchné Dobi, 2005). As for frequency maximums, northern winds reach their maximum in the autumn months when they approach 50%. Southern winds reach their maximum in the summer months when 25% is exceeded by their frequency.

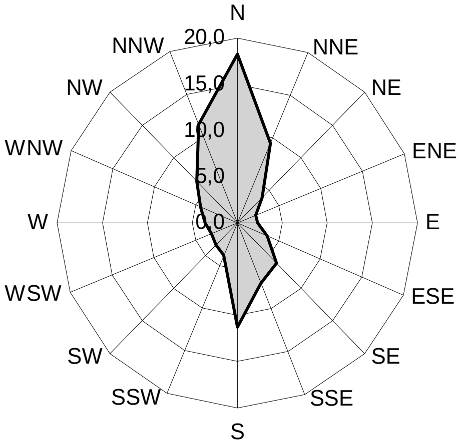

Fig. 2. The pattern of the wind direction frequencies based on the mean of the measurement results through a two-year long study time period.
Source: *compiled by the authors.*

Apart from wind direction, wind velocity also has significant influence in the pattern of dust pollution. The stronger are the winds blowing the larger is the distance dust grains can reach in the air and the larger dust grains are drifted by the wind. Fig. 3 shows that the monthly average wind velocities measured at a height of 4 m were higher between February and July significantly (0.72-0.94 m/s) than between August and December when the monthly averages varied between 0.37-0.51 m/s.

In 2005 on the basis of the data of the 10 minute measurement periods wind velocities were varying between 0 and 5 m/s. The rate of the completely windless periods was the highest between August and December. In December wind was not blowing at all in one third of the month while the rate of the completely wind free periods stayed under 20 % in the Spring and Summer months and not even reached 10 % in February. The frequency of the stronger winds was largest between February and July as the rate of winds stronger than 1 m/s frequently exceeded 25 %.

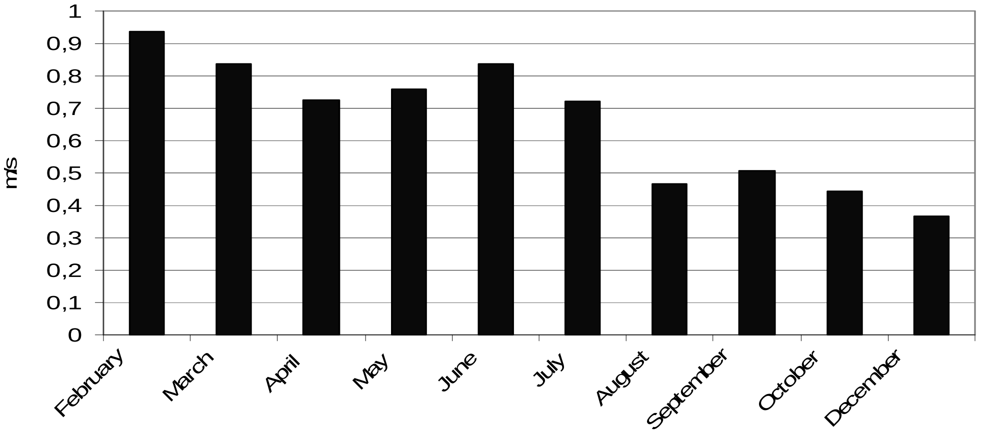

Fig. 3. Monthly average of wind velocities in 2005 February, March, April, May, June, July, August, September, October, November, December. ***Source:*** *compiled by the authors.*

It is also interesting that how the wind direction is drawn in the case of the stronger winds as the dust loading of the air can be significantly increased by stronger winds and dust particles may reach larger distances from the pollution sources. The frequency of winds stronger than 2 m/s was examined. The results proved that northern winds are dominating in most of the months – even in the case of the stronger winds.

Besides winds precipitation has important roles as well in the pattern of dust pollution. From the wet surface – due to the wetter environment – dust is not taken from the surface. From the wetter surface dust does not reach the air. Thus the dust reaches not the air producing less dust load for the air. The moisture of the surface depends on the amount of precipitation and its distribution in time and the infiltration and evaporation rates. Evaporation is influenced primarily by the temperature of the air. The warmer is the air the more intense is the evaporation and the quicker the surface becomes dry releasing dust into the air easier. It can be concluded from the above that the warmer summer period holds better conditions for dust pollution than winter.

Studying the variation of the precipitation it can be detected that very small amount of precipitation fell in January, March, October and November in 2005 while the summer months prone to dust pollution were wetter (fig. 4.). Based on the distribution of the precipitation within the months it was stated that the conditions of dust pollution were not good in the summer period as the surface was wet for a long time. Dry periods were longer in the autumn but the rate of evaporation was less due to the smaller temperature as regarding the 170 watt/m^2 radiation value in July it was only 81 watt/m^2 in October and even only 39 watt/m^2 in November.

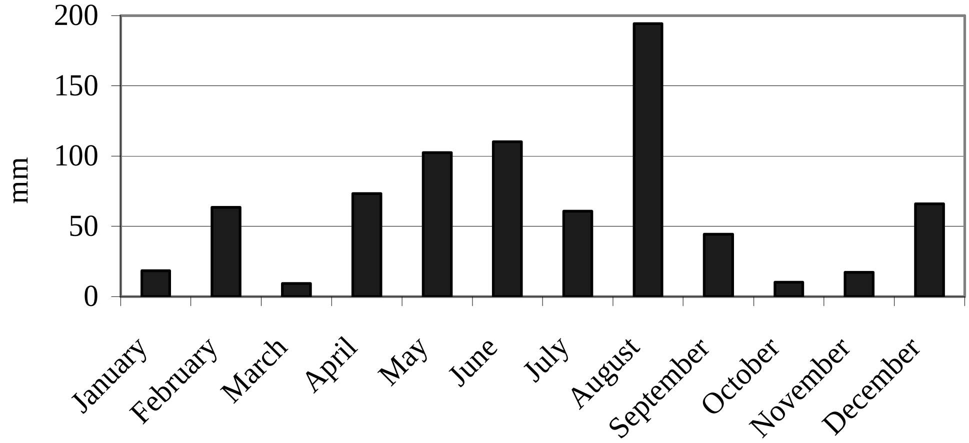

Fig. 4. The amount of precipitation in the study area in 2005. ***Source:*** *compiled by the authors.*

The land-use in the surroundings of the perlite mine

Land-use was studied on the basis of the database of the CORINE LAND COVER 50 (fig. 5.).

It is visible that primarily forest is found in the surroundings of the perlite mine (47.2% deciduous forest and 6.1% pine forest) with a relatively high rate of arable land (21.9%) especially in the areas North of the mine.

Besides forest and arable land shrubs (8.4%) and pastoral lands (7.5%) worth mentioning. The rate of the other land-use areas is not significant.

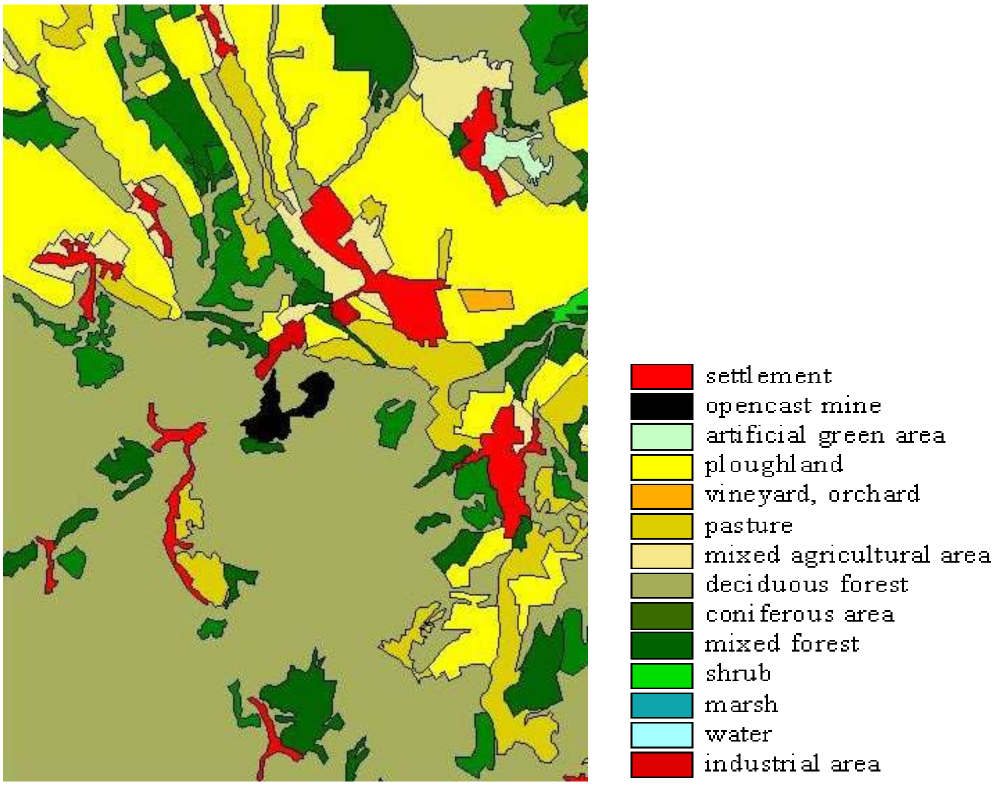

Fig. 5. Land-use in the surroundings of the mine. (Source: CLC 50). ***Source:*** *compiled by the authors.*

Considering the spreading of the dust from the mine it is beneficial that there are large areas of continuous woodlands impeding strongly the spreading of the dust over large distances. *Figure 5.* shows that the vicinity of some of the dust traps is covered by extensive arable lands from where significant amount of dust may get into the air in the course of cultivation or in dry time periods.

SPATIAL AND TIME VARIATIONS OF THE DUST LOAD

Settling dust in the study area can be originated from several sources. The most significant of them is the mine as large amount of dust is released into the air through explosions related to the opencast mining, through the deposition of the overburden and through the grinding of the perlite. Apart from the mine we have to count with the dust from the cultivation works, furthermore traffic and private heating contribute to the dust pollution of the air.

Studying the wind conditions it was revealed that northern winds dominate in the area which is a fortunate condition regarding dust load as the 500 m high mass of the Som Hill is situated South of the mine blocking the way of the winds blowing towards the South. Moreover, the surface of the Som Hill is covered by forest further impeding the transport of the dust. The relief barrier presented by the Som Hill diverts the winds towards the southwest into the valley of the Kemence stream and towards the southeast into the direction of the Hosszú stream. Fortunately extended woodlands are in the way of the winds presenting a filtrating effect which is advantageously the most effective between May and September when dust loading would be the most intense.

The health limit for settling dust is 16 g/m^2/30 days. In the study time dust exceeded this limit only in the case of the dust trap found nearest the mine in a distance only 100 m. Even in those months when dust values stayed below the limit this trap showed the largest amount of dust. The high values can be explained undoubtedly by dust from the mine (fig. 6). It can be stated that the dust coming from the mine settles within a few hundred metres from the mine except for the dry windy periods when dust reaches greater distances. In such weather conditions values around 10 g/m^2/30 days were measured in an area of 1.5 km around the mine. In some cases other measurement points showed values near the limit but in these cases the dust was not produced by the mine but rather dust originated from the cultivation of the agricultural lands. This is proved also by that these traps were established next to arable lands and higher values occurred in the time of cultivation otherwise they showed lower values for settling dust.

The fact that the lowest values of settling dust is measured in the stations situated most away from the mine and that greater values are gained nearer the mine suggests that the mine presents a clear load for its environment. With the help of the map in fig. 6 we have counted the average amount of the settling dust in zones with different distances from the mine (tab. 1).

It is visible that the rate of the average settling is lower than 3 g/m^2/30 days in the zone most distant from the mine 2-3 km away within the study area. In the zone 1-2 km away from the mine 3.4 g/m^2/30 days was measured and within 1 km from the mine a significantly higher value of 5.4 g/m^2/30 days were measured. In the station situated closest to the mine – only 100 m – the average value of the settling dust is almost 9 g per month in an area of 1 m^2.

Studying the variation of the amount of the settling dust in time it can be stated that values are higher in the summer half year at most of the measuring stations (fig. 7).

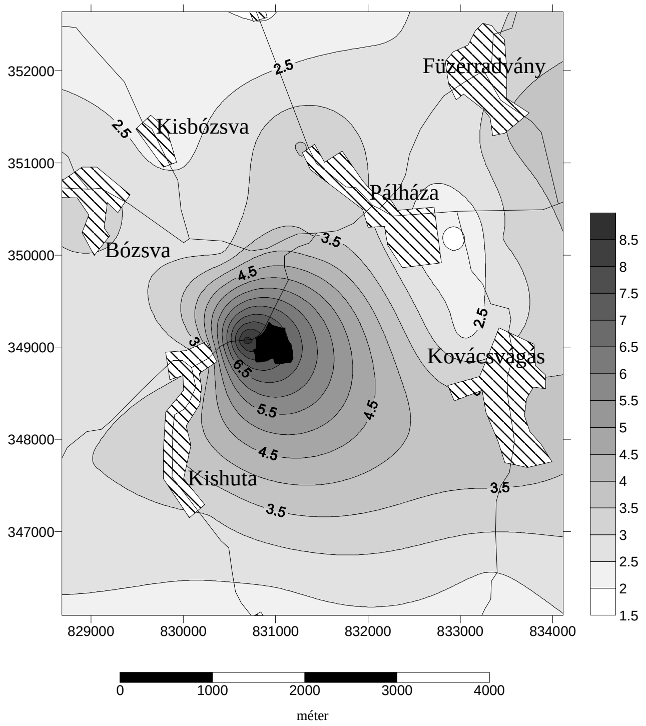

Fig. 6. Spatial distribution of the settling dust (g/m²/30 days). On the basis of the average values related the time of the complete investigation. (The black spot is the area of the mine).
Source: *compiled by the authors.*

Tab. 1. The amount of settling dust in the environment of the mine. On the basis of the map (fig. 6) constructed from the two-year data of the 22 measuring station.

	Drawn from the centre of the mine		
	Within a circle with a radius of 1 km	1-2 km zone	2-3 km zone
minimum value (g/m²/30 days)	2,8	2,2	1,8
maximum value (g/m²/30 days)	8,8	5,1	4,1
average (g/m²/30 days)	5,4	3,4	2,9

Source: *compiled by the authors.*

In this period 75% of the measuring stations expressed average values over 3 g/m²/30 days while in the winter half year the rate is less than 20%.

Larger differences between the summer and the winter half years is experienced at sites where the dust trap is close to arable lands because the majority of the cultivation works take place in the summer period. Especially the dry windy periods produced greater values. The loading of the mine is continuous throughout the year as the excavation is continuous as well. This is reflected in the data of the stations situated near the mine as here the relatively high average values of 8 g/m2/30 days were determined in both time periods.

ANALYTICAL STUDY OF THE DUST SAMPLES

After studying the quantitative parameters of the dust load we carried out the analytical examination of the dust samples. We studied what kind of measure does the dust originated from the mine influence the element contents of the dust samples from different sampling points on. At first we carried out cluster analysis based on the studied element (Al, As, Cd, Co, Ba, Mn, Ni) concentrations in dust samples. As the result of the analysis the sampling points were classified into four clusters (fig. 8). The fact that the sampling points near the mine, which are loaded by dust at the biggest rate and the sampling points far from the mine belong to the same (fourth) cluster shows us that in point of the studied elements the mine has a significant effect to the dust element contents. At the same time the points belong to the first and third clusters form well separated units, which suggests that another effect irrespectively of the mine influences the analytical composition of the dust samples.

The confidence level of the cluster analysis was tested by disrcriminant analysis. Altogether we got three functions, from which two were significant ($p<0.05$). First function explains 88.9%, second 80.6% of the total variance of the dependent variables (namely the 4 clusters). First two functions explain 96.2% of the total variance. Third function is not significant and has small effect on the total variance (3.8%) with small eigenvalue (which is the 1/20 and 1/10 of the first two ones respectively).

The Pearson correlation coefficient structure matrix (tab. 2) shows the significance of the investigated elements and it can be seen the dominance of Ni, Mn and Ba.

It is proved by the standardized canonical discriminant function coefficients eigenvalues as well. Ba belongs to the 3rd function and so it was omitted from the evaluation.

Classification results show 100% accuracy with the original values and 68% with cross-validation technique. So the group membership can be predicted from the above mentioned elements with that precision.

Fig. 9 shows the discriminant scores of the first two functions. The group centroids are clearly separated. There are significant differences in both dimensions. In the first dimension the 3rd cluster, in the second dimension the 2nd cluster have the highest values. Ni has larger effect on Cluster 1, and Mn on Cluster 2.

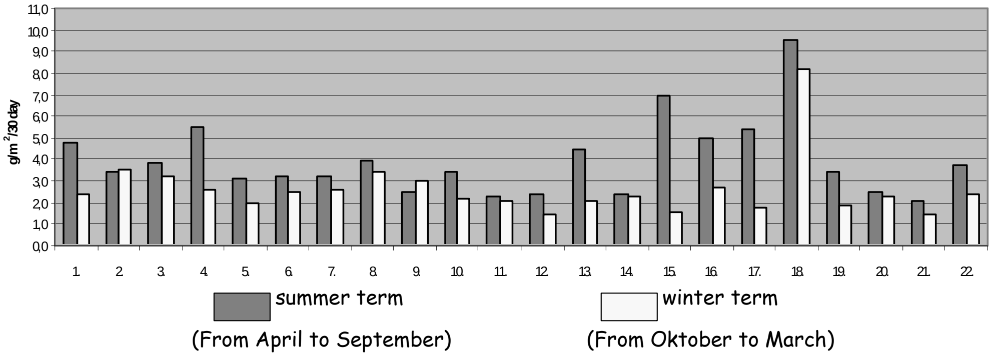

Fig. 7. Average values of the amount of the settling dust in the case of 22 measurement stations in the summer and the winter half year relating to the complete study time. ***Source:*** *compiled by the authors.*

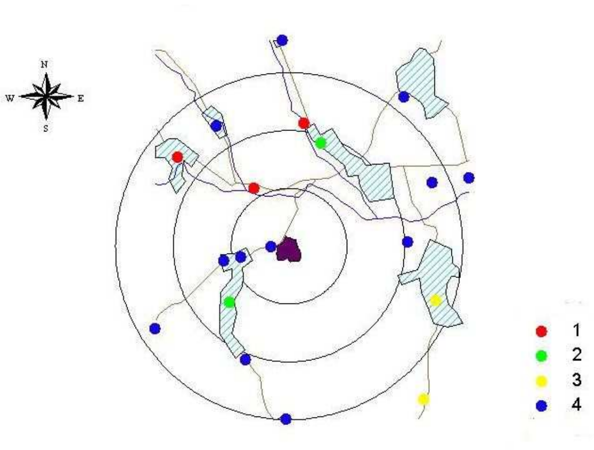

Fig. 8. The result of the cluster analyses by the studied elements. ***Source:*** *compiled by the authors.*

CONCLUSION

The paper investigated the pollution effect of the perlite mine at Pálháza in the 3 km vicinity of the mine. It was concluded that significant dust load can be expected only in the immediate surroundings of the mine. There were measurements of dust amounts greater than the value of the health limit in the sever hundred metres vicinity of the mine but 1 km away from the mine there were no values greater than the limit experienced, however, the effect of the mine is detectable but this presents no significant dust load. On the basis of the above mentioned it can be stated that the mine causes more serious dust load in its immediate vicinity and it does not endangers the development of the tourism in larger distances.

Tab. 2. The Pearson correlation coefficient structure matrix.

	Function		
	1	2	3
Ni	.881(*)	.192	-.009
Mn	.145	.752(*)	.365
Al	.098	.459(*)	.335
As	-.017	.389(*)	.314
Ba	.143	.315	-.769(*)
Cd	.111	-.010	.367(*)
Co	.008	.085	-.127(*)

Source: *compiled by the authors.*

Regarding the variation of the dust load in time, it was determined that the amount of the settling dust is significantly larger in the summer half year and greatest dust load occurs in the dry and windy periods. On the base of the analytical composition of the dust samples the sampling points can be classified into four different groups (clusters). On the major part of the sample area can be detected the mine's significant effect to the element content of the dust.

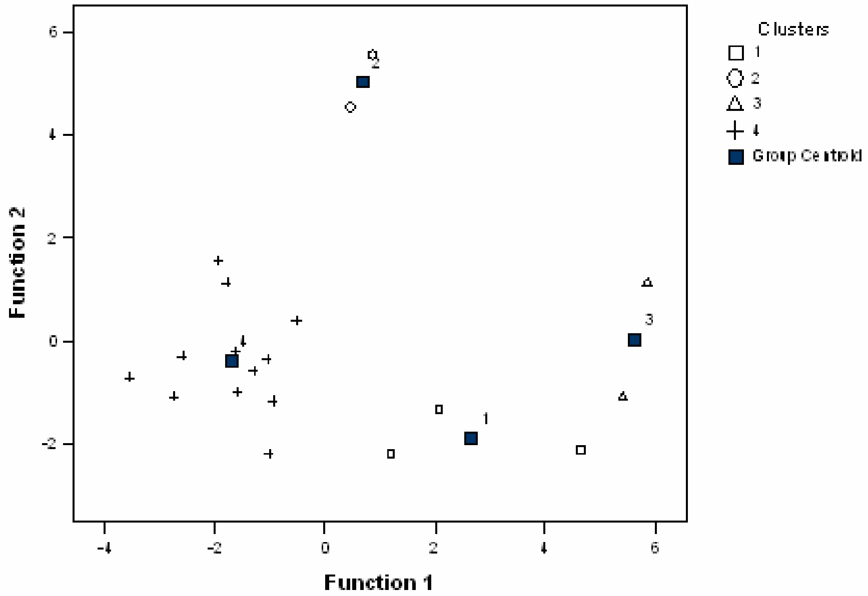

Fig. 9. Scatterplot of the canonical discriminant functions. ***Source:*** *compiled by the authors.*

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SUMMARY

An opencast mine may cause negative effects in many ways. Landscape scarrings of opencast mines are harmful in aesthetic respect, engines, machineries and periodic blastings may cause notable noise loading which are injurious even if these mines are situated far from the settlements because the noise from the mines may disturb animals living in the surrounds (Kerényi, 1995, 2003, Barótfi, 2000). Besides the listed impacts the dust accompanied to the opencast mining cause the most significant load to the environment of these mines. In this study, the extent of dust loading is examined in the case of a North-Hungarian perlite mine. Milling of the exploited perlite is carried out in the milling plant located within the area of the mine in Pálháza which cause additional dust loading. Settling dust loading was studied by 22 measurement stations within a distance of 3 kilometres from the mine, during the installation of which even cover of the study area was aimed. Gathering of the dust samples were carried out monthly from August 2004 to July 2006 thus we have a two-year database. During the laboratory tests, the amount of insoluble and soluble dust fractions, altogether making up the total amount of settled dust, was determined respectively. In addition to the meteorological parameters having the most influence on the spatial distribution of the settling dust (i.e. wind velocity, wind directions and the amount of precipitation, air temperature, humidity and irradia-tion) that is why an automatic meteorological station was installed in the proximity of the mine, i.e. within the study area. It gave us the necessary meteorolo-gical data during the examination.

Knowing that the most significant dust loading derives from the opencast mine we can not forget that periodically during the agricultural seasons from the arable lands and during the heating seasons through the chimneys additional dust might get into the dust-traps. To determine the origin of the dust in each dust-trap the dust samples were analytical examined as well. By the chemical composition of the samples we could find out how big roles the pollution sources outside the opencast mine played and hereby we could detect how significant the dust loading originated from the perlite mine is in its environment.