



## ENVIRONMENTAL IMPACTS FROM THE HYDRO-FLOTATION OPEN WASTE-SITE “KISELICA” BY THE MINE “ZLETOVO”, PROBISHTIP, REPUBLIC OF MACEDONIA

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### SYNOPSIS

Within the intense mine exploitation (since 1945) and Pb-Zn ore preparation for further manufacturing, in the town of Probistip, an open waste-site for the hydro-flotation barren has been formed on a surface area of ~ 3,6 ha. Waste-site dust emission (composed by hazardous and toxic particles) from the oblique and horizontal waste-site surface became an unavoidable problem to the local and wider environment, especially pronounced during the dry and windy period.

In this paper we report on the mutual inter-relation among the dust chemical composition, dust particles grain size, the existent meteorological circumstances (stated as significant parameters) and the emission characteristics (quantity, quality, intensity) as well as the maximal distance ability of spreading in the environment from the hotspot

### INTRODUCTION

Atmospheric and ambient air emission often is result of anthropogenic activities. We report on environmental ambient air pollution (causes and repercussions) due to dry dust emissions from an open waste-site by the mine complex.

#### Site description

The waste-site “Kiselica” originally arose from the flotation barren water suspension (1:3), transported through an open channel from the section of flotation until the waste-site where the process of hydro-cycling was undertaken. The barren was deposited on the sand barriers, while theremain of the waste water is further

withdrawn through the drainage surface of the waste-site and the drainage channel directly to the final recipient - Kiselicka river.

The waste-site is of hilly type, with sand barriers on the left down-stream side of the Kiselicka river, located 2-3 km southern from the Probishtip town center. Actually the waste-site was formed in 1945, organized in 5 blocks (in nowadays functioning practically as two independent waste-sites) (Fig.1 and Fig. 2).



Figure 1. View on the waste-site “Kiselica” (block 4) near to Kiselicka priver



Figure 2. View on the oblique side of the waste-site “Kiselica” (block 5)

At the mine complex “Zletovo”, the primary pollution source is certainly the flotation waste-site “Kiselica”. Till now, the total amount of deposited waste material is 12,5 millions tons as flotation barren. On the waste-site numerous rare metals as

Ga (500 t), Mn (350.000 t) as well as very important metals, as Ge (5 g/t), U (10g/t), Au (0,3 g/t), Ag (12 g/t) etc. are deposited.

The main cause of environment pollution is the emission of dust particles containing heavy metals. Therefore, the waste-site "Kiselica" is the environmental threat by heavy metals spreading due to the winds movement especially characteristic for dry periods of the year. The pertinent data point that the dust emissions from the flotation waste-site are significant and we hope that our work would initiate further investigations.

### The heavy metals content in the flotation barren

According to as-performed investigations elevated concentration in As, Cd, Cu, Hg, Mn, Pb and Zn, were found in flotation barren sediment. The performed statistical analysis outlines their maximal, minimal and average values, including the value of standard deviation (STD) (Table 1).

**Table 1. The concentration of heavy metals in flotation barren sediment at flotation waste-site "Kiselica"**

Heavy metal	Maximal	Minimal	Average	STD
Al (%)	0,52	0,25	0,39	0,09
Sb ( mg/kg)	12,00	0,5	1,83	3,45
Cu (mg/kg)	709,00	50,00	267,92	198,49
Ba ( mg/kg)	1.560,00	322,0	703,8	387,27
Be ( mg/kg)	0,10	0,10	0,10	0,00
Bi ( mg/kg)	0,50	0,50	0,50	0,00
Zn ( mg/kg)	11.850,00	2.454,08	4.454,08	2.924,38
Cd (mg/kg)	36,00	4,00	15,92	9,81
Co (mg/kg)	11,00	3,00	8,17	2,52
Fe (%)	14,00	5,20	8,89	2,58
Mn (%)	7,90	0,53	3,84	2,10
Mo (mg/kg)	24,00	10,00	15,17	4,71
Ni (mg/kg)	11,00	3,00	9,08	2,15
Pb (mg/kg)	11.412,00	2.170,00	4.583,00	3.107,13
Ag (mg/kg)	38,00	7,00	18,08	9,96

Ti (mg/kg)	0,50	0,50	0,50	0,00
Ti ( mg/kg)	21,00	0,50	13,71	5,49
V (mg/kg)	24,00	19,00	20,92	1,44
Se (mg/kg)	0,30	0,30	0,30	0,00
Hg (mg/kg)	0,40	0,01	0,15	0,13
As (mg/kg)	460,00	110,00	266,50	107,53
Cr (mg/kg)	40,00	0,30	13,61	9,14

### Characterization of the wind parameters (direction and frequency)

The wind is a horizontal air movement caused by the air pressure difference in the region in the direction towards the air pressure decrease. Accordingly, the wind is very important climatic parameter giving the mark to the climatic peculiarities of certain regions.

In the Republic of Macedonia winds usually blow in the north quadrant, however, keeping the direction predominance for particular region (in dependence on the orthographic peculiarities), the direction change could happen. The wind direction in the northern quadrant towards the southern quadrant and contrary is always changeable as a result of existing orthographic conditions. However, predominant is the wind blowing in the valley along the river downstream as well as the mountain chains [1].

The region of Probistip is well known after “winds mixing”, especially pronounced in dry seasons of a year. Thus, often, very high whirlpool is generated. Actually, the wind from south (S) suddenly changes its direction to south-west (SW), than to south and south-east (SE). In the valley of the town of Kocani (Zletovsko Pole), as well as Krivo Palanecko Pole and then Kumanovo valley prevail winds from southern-west direction. The data for wind directions and speeds in the discussed region were obtained from the National Weather Service Synoptic Monitoring Network [5].

The wind direction and frequency is illustrated in Table 2.[5]

**Table 2. Average annual frequency of the wind in Probistip region (%) in different directions**

Wind Direction	N	NE	E	SE	S	SW	W	NW	C
%	86	105	59	85	69	198	63	45	310

On the base data presented in Table 1. we constructed the rose of winds shown in Figure 3.).

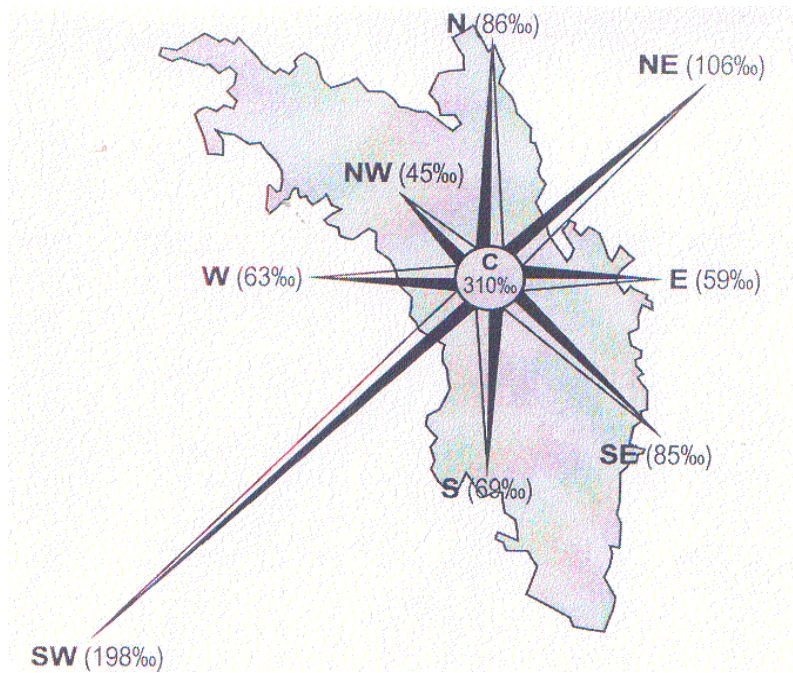


Figure 3. Wind rose with the frequency of silence

According to the data presented in Fig. 3, the greatest intensity could be considered in the case of the wind coming from SW (the frequency extent of 198 %), then the wind from NE (105 %). Wind coming from north within this region exhibits an average speed of 4-3 m/s, while the average annual speed is greater than 5m/s.

The weather situation characterized by the absence of wind is termed as “frequency of silence” that is an additional sign for the wind regime. Actually the wind frequency is directly dependent on the frequency in silence (higher or lower). In our case, the average annual frequency in silence of 310 %.

#### Physical and chemical characteristics of the flotation barren

By non-controlled deposition of the waste-material after the flotation stage at mine complex “Zletovo”, Probishtip, on the free space area along the Kiselicka river an accumulation of the quicksand was formed (initially). However, now it is a sediment accumulation. The consisting water in the barren was left to lie up in the sediment lake (blocks 4 and 5) that contributed to sterile conditions for flora and fauna development in this region.

The chemical characteristics of the barren materials are exposed in Table 3.

Table 3. Compositional characteristics of the barren material, “Kiserlica” waste-site / tailling

Element	Pb	Zn	Mn	Ge	U	S	CuO2	Fe2O3	Al2O3	SiO2

Abundance	0,29 %	0,35 %	0,39 %	5,00 g/t	10,00 g/t	3,22 %	50,12 %	13,50 %	10,20 %	50,00 %
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During the technological process of flotation concentration, different chemical compounds of inorganic and organic nature (such as alkali metal halides, di-tio-phosphates, poly-glycols) including the lime solutions (for the adjustment of technological water pH- value) as flotation reagents are used. Flotation agents undergo absorption on the barren particle surfaces, while a small part of them remains dissolved or/and dispersed in water.

The barren particles grain size distribution in samples taken from the dam at Kiselicka river is shown in Table 4.

**Table 4. The particle size distribution in the dust from the open waste- site "Kiselica"**

Particles size class (mm)	W (%)	R (%)	D (%)
-0,297 +0,208	26.1	26.1	100.0
-0,208 +0,147	23.1	49.2	73.9
-0,147 +0,104	26.1	75.3	50.8
-0,104 +0,074	11.6	86.9	24.7
-0,074 +0,053	3.9	90.8	13.1
-0,053 +0,037	2.3	93.1	9.2
-0,037 +0,020	2.7	95.8	6.9
-0,020	4.2	100.0	4.1

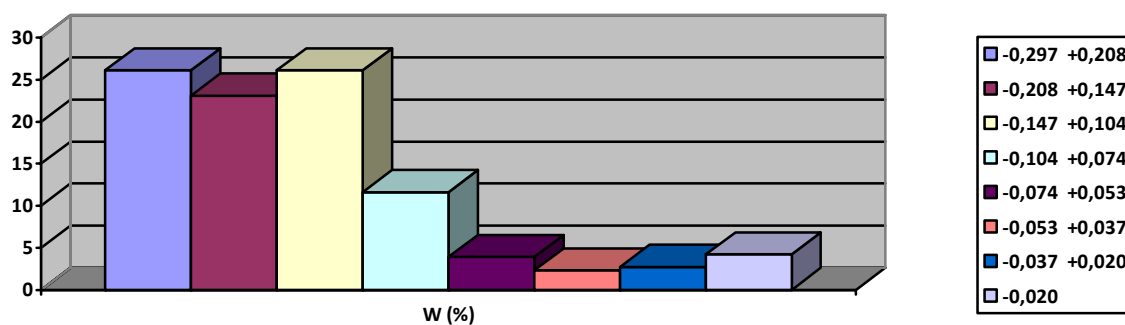
Where,

W - is the partial weight portion of separate narrow classes of granulation;

R - cumulative reminding on the sieve (if it is the first in the series);

D - cumulative dust amount under-sieve (if it is the last in series)

In Figures 4 and 5 the histogram of grain size distribution as well as the cumulative arithmetic curves (R and D) are presented, respectively.



**Figure 4. Histogram of the grain size of dust particles**

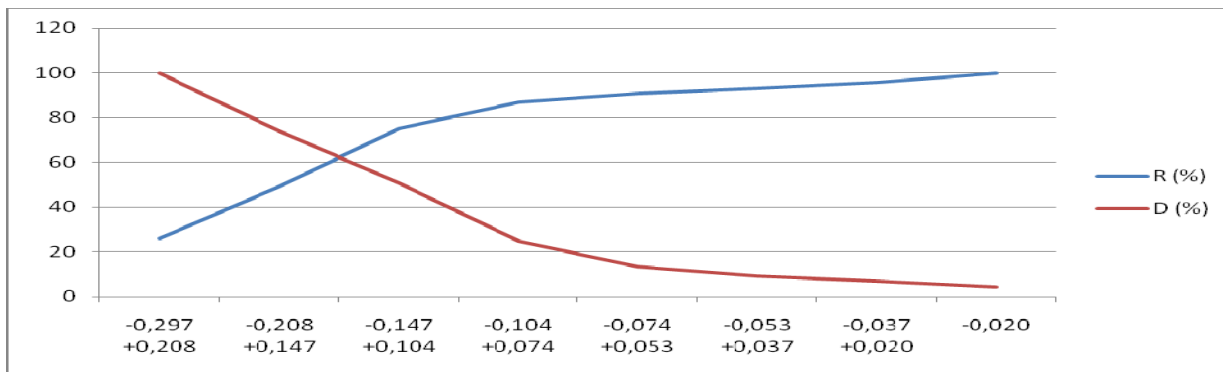


Figure 5. Cumulative Arithmetic Curve

**Environment pollution**

The emission of dust from the flotation barren waste-site depends obviously on the situation on the dam surface, meteorological circumstances as well as the dust particles grain size.

The dependence of the dust emission from the wind speed is presented in Table 5.

Table 3. Dust emission as function of the wind speed

Wind speed (m/s)	Emitted dust (g/s)
4	360
6	1.080
9	6.300

The particles final destination setting is a function of different transport phenomena as well as the particles size distribution as presented in Table 4.

Table 4. The particle spread in the environment

Class of particle grain size (mm)	Transport Distance (km)
-1,0 + 0,125	1 – 1,5
-0,125 +0,625	a few kilometers
-0,625 +0,312	> 300 km
-0,312 +0,0196	> 1.500 km
- 0,0196	Unlimited

It is clear that smallest particles could be found on the unlimited distance. Having in mind that particles obviously contain and heavy toxic metals, the impact to human population health in the region seems to be very serious threat shown in respiratory and other problems especially pronounced on children age.

In our work, the emission of hazardous toxic matters in Probishtip region has been monitored during the period between July - October of 2007. The results of the as-performed analyses on deposited species are presented in Table 5

**Table 5. Amount of deposited matters in dependence on seasonal variations (mg/m<sup>3</sup>/ day)**

Month	pH	S <sub>4</sub> <sup>2-</sup>	CaCO <sub>3</sub>	Insoluble	Pb	Zn	Cd
July- August	6,00	4,31	-	51,98	0,020	0,082	0,001
September	5,58	6,36	-	31,84	0,003	0,041	0,006
October	5,50	8,20	-	4,11	0,0001	0,0003	0
Average Value	5,83	6,29	-	29,31	0,008	0,041	0,002
GIV	-	-	-	450	0,25	0,40	0,005

## DISCUSSION

According to the Health Protection Program of the Republic of Macedonia, the Institution of Health Protection collects data about the health situation of population, however on not determined time intervals. Due to the lack of proper and appropriate equipment there is no permanent monitoring.

Two localities have been assigned as critical and these are just in the area of mining activities. The workers in the flotation stage (directly exposed to the influence) very often suffer from kidney illness due to the high Cd level in blood (> 1 mg Cd//100 ml) or even heavy intoxication, that point to the need of development of measures for professional occupational protection.

Continual monitoring of air quality does not exist. According to data from investigations in 2003 the sites where primary ore crushers are installed are proclaimed as the most threaten localities. The concentration (mg/kg dry mass) of heavy metals in dust as As: 165,85; Cd: 86; Cu: 354; Ni < 10; Pb: 15; Zn: 16 were registered.

As a second stationary air polluter the flotation barren waste-site was determined. In the period of high winds, huge fogs of dust are emitted in the ambient air. The previous investigations revealed the presence of Pb in the air was in the range between 0,8 – 18,15 µg/m<sup>3</sup> (while the macedonian standard prescribes the value of maximal allowed concentration- MAV- as 0,7 µg/m<sup>3</sup>). In regard to Zn the evident value was 0,5 – 35,6 µg/m<sup>3</sup>(not included in national standards for ambient air quality). The soot presence was registered in the range of 5-140 µg/m<sup>3</sup> (the Macedonian standard allows up to 50 µg/m<sup>3</sup>). This value exceeds the MAV 123 times/year which satisfies the EU standard showing the average concentration of soot between 34 – 51 µg/m<sup>3</sup>. Although the soot does not really generate problems on the site of waste-site "Kiselica" but the presence of heavy metals (Cd, Cu As, Pb and Zn) is if immanent amount.

## CONCLUSIONS

The fact is that the emission/ imission effects of the dust loaded by heavy toxic metals is obvious in the Probishtip region either on human population or the

environment as whole. The concentration of heavy toxic metals is elevated “downwind” that could be attributed to transport phenomena in high wind periods.

Classification of the existing heavy metals concentration data into wind direction and wind speed require long enough sampling records. The dependence of heavy metals on transport could be extracted from the climate record for heavy and winds.

A full quantification of dust particles loaded by heavy metals is rather unambiguous and robust task that needs continual monitoring and longer period of situation analysis.

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