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ASSESSMENT OF DUST EMISSION AT THE LIMESTONE OPEN PIT "MILOJEVIĆ BRDO"[**]

Abstract

The basis of emission assessment at the Open Pit "Milojević Brdo" is to define the dust distribution depending on the wind influence and dust emitters. This paper presents the data for equipment engaged at the open pit. Through an analytical approach, the total emission of dust emitted by the mining equipment and aeolian erosion in the area of the open pit was determined. The results of this analysis represent a prediction of the state of dust impact on the environment during the exploitation process at the open pit.

Keywords: *dust emission, maximum allowed concentration, emission limit value, open pit mining*

1 INTRODUCTION

The Open Pit "Milojević brdo" of limestone as a technical-building stone is located in the southwest of Čačak on the northwestern slopes of the Jelica Mountain. The exploitation life of the surface mine is 42 years. The maximum annual exploitation capacity is 150,000 tons. The exploitation takes place discontinuously at the Open Pit "Milojević brdo". The exploitation consists of: preparatory work, drilling and blasting, gravity transport, loading of blasted material, crushing and classification (obtaining the final products), loading of final product.

2 MATERIAL AND METHOD OF OPERATION

The production of mineral resources is usually associated with the management and manipulation of significant quantities of materials not found in the other industrial areas. In addition to the significant consumption of energy necessary in the production of mineral raw materials, there are also significant impacts on the environment, i.e., the environmental factors of exploitation [1].

The European Environment Agency (EEA) estimates that 80-90% of the urban population in Europe is currently exposed to the particulate matter and ozone levels that are higher than recommended by the World Health Organization (WHO) [2]. This is particularly pronounced in the areas with a high intensity of industrial activity, as it is the case at the open pits.

Considering the mining equipment and technological units at the Open Pit "Milojević brdo", it can be concluded that the impact of individual mining operations is

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different when talking about local or general dust emissions. Table 1 shows the impact of individual operations as well as the assessment of percentage participation of the certain technological operations [3].

Table 1 *Review the impact of individual operations as well as an assessment the percentage participation of the certain technological operations*

Technological operation	Nature of pollution	Share in air pollution (%)
Drilling of boreholes	Local	5
Blasting	Wider zone	15
Gravity transport	Local	15
Limestone loading into the crusher	Local	5
Primary crushing	Wider zone	15
Final product loading	Local	10
Auxiliary works at the landfill	Local	5
Eolian erosion	Wider zone	30

Dustiness in the surroundings of the working equipment is intensively changed with the humidity, but the indicators of this impact are strongly related to the type of rock material in which the mining works are performed.

As an intensive pollutant, there is the raising of deposited dust - "eolian erosion", which on average produces about 30% of the total pollution, and it is possible that it is significantly more. This situation occurs at wind speeds greater than 2 m/s. The emission of individual work tools is of an experimental nature, and is usually calculated separately for each type and the obtained value is marked with N0 (mg/s).

$$N = N_0 \exp(\alpha \frac{Q - Q_0}{Q}), \text{(mg/s)}$$

For a point source, the intensity of release of harmful substances into atmosphere of the open pit can be determined by the relation:

$$I = Q * N, \text{ (mg/s)}$$

Intensity of release the harmful substances for several different sources, and in relation to the open pit:

$$E = \Sigma I_u + \Sigma I_s \text{ , (mg/s) respectively}$$

$$E = \Sigma I_t + \Sigma I_e + \Sigma I_P + \Sigma I_s, \text{ (mg/s)}$$

The total intensity of release the harmful substances (dust or gases) of one group of sources also depends on the simultaneous operation of these sources. For the corresponding point sources, the total intensity is:

$$IT = \Sigma A_i K_i I_{ti} \text{ , (mg/s)}$$

If the work of source is variable in intensity, then the coefficient is:

$$K_i = \frac{A_i (I_{max} - I_{mi})}{A_0 * I_{max}}$$

The dust emission (E) resulting from the "eolian erosion", the surface of exposed, blasted or deposited materials of different grainsize distribution and humidity on the surface, can be calculated:

$$E = E_s F, \text{ (mg/s)}$$

During the technological process, the following emitters can be present at the same time Table 2:

Table 2 *Type of dust emitter*

Type of dust emitter	Total emission (mg/s)
One drilling rig	600
Bulldozer (gravity transport)	1500
One excavator (loading to the crushing plant)	1000
One excavator (loading to the crushing plant)	1000
"Eolian Erosion"	5160
Total superimposed emission in the process of exploitation	**9.260**

Suppression of dust during the operation of mining equipment at the open pit can be successfully carried out by wetting the blasted mass in the summer, watering of roads and effective maintenance of dedusting devices during drilling of bore holes. Applying the complex protection measures, the stated total dust emission from the open pit can be reduced by up to 90%. Then the dust immission from the open pit in the most unfavorable case for the environmental protection would amount to: **E=926 (mg/s).**

This data was used to calculate the impact of open pit dust on the environment. An increased presence of dust is expected only in extremely dry periods. It can be objectively said that the the case of simultaneously operation of all machines is technologically practically impossible, so the calculation refers to the most unfavorable conditions of dust impact.

Assessment of dust emission in the mineral processing process

During the technological process of mineral processing, the sources of air pollution with suspended particles are:

Dotted

- Loading of out-of-mine limestone into a mobile crusher
- Dumping place from crusher to the mobile screen
- Loading of finished fractions into transport vehicles,

Linear

- belt conveyors on a vibro screen,

Superficial

- open landfills of finished fractions +0 - 63 mm, 31.5 - 63 mm and 0 - 31.5 mm.

The assessment of this emission is a function of wind speed, material properties, grain size distribution, and surface area of the open landfill of finished products. The primary sources are technological equipment and machinery in operation, and the secondary sources are all active surfaces (open landfills and internal roads), which, under the impact of wind, emit the floating fractions from deposited dust into the air. Calculation of the total emission assessment is done according to the methodology of comparison with similar plants for crushing and sieving and the results are given in the following Table 3.

Table 3 *Results of assesmeng calculation of the total emission*

Dust source	Concentration (mg/m^3)	Emission (mg/s)
Loading basket of the primary crusher	100	50
Primary crushing	100	200
Conveyor belt from the crusher to the vibro screen	300	230
Vibro screen	100	2,500
Transporters for finished aggregates	100	230
TOTAL	**700**	**3,230**

Assessment of the total dust emission when there is no dust removal system is: 3,230 mg/s. This emission can be reduced by up to 95% of the total emission applying the technical protection measures, such as dry dusting or sprinkling with water, belt conveyors and spillways, covering with removable vibro screen covers, etc.). In that case, the dust emission from the mineral processing process would amount to: **Er≈ 150 (mg/s).**

The assessment of emissions from the open landfills is a function of wind speed, material properties, grain size distribution and surface area of the open landfill, so here the emission can be assessed on the basis of the following relationship:

$$E = Es \times F = 2 \times 240 = 480 \text{ (mg/s)}$$

(Es = 5 mg/sm^2 at V = 4 m/s)

Assessment of this emission is given only at a wind speed of 4 m/s, at higher speeds the emission rises sharply. As informative data, the emission at a wind speed greater than 15 m/s is given, but it is noted that this type of emission is very rare, and that it does not have a decisive impact on air pollution in the environment: Es > 500 mg/cm^2.

Dust emissions from the open landfills can be reduced up to 20 times applying the technical protection measures, such as wetting or covering with a demountable cover. In that case, this emission would amount to:

E = 480/20 = 24 (mg/s), at V = 4 (m/s)

The total dust emission from the exploitation and preparation of limestone would amount to

E (dedusting+preparation) = 926 mg/s + 150 mg/s + 24 mg/s = **1100 (mg/s)**

3 RESULTS AND DISCUSSION

Introduction of the system of environmental standards (ISO 14000) implies the development of an environmental protection management system as a means of achieving and systematically controlling the level of performance in the area of environmental protection [4].

The maximum concentration of dust is located on the axis of the main direction of wind blowing, and at a point at a distance X (m) from the source, it can be determined by the formula:

Depending on the pattern of air flow in the pit, which depends on the pit configuration, the direction and speed of wind, the dust concentration at the edge of pit will also depend.

Thus, the formulae for its determination are given in the literature:

at flow scheme:

$$C_{xl} = \frac{10\Sigma q_i}{\Psi x_{sk}\ L_k W_s} + C_0\ , (mg/m^3)$$

at recirculation scheme:

$$C_{xl} = \frac{15\Sigma q_i}{\Psi x_{sk}\ L_k W_s} + C_0\ , (mg/m^3)$$

The dust sedimentation outside the pit is carried out on the wind axis on the surface that has the shape of a rectangle with surface, (P = 1m * x). Lateral scattering of dust, depending on the turbulence coefficient Ψ, is not significant, so the equation of surfaces on the wind axis can be observed in the shape of a rectangle of length, x. The total dust sedimentation from the pit edge to the isoline of the natural dust background of the area (C_o = 0.01 mg/m^3), is obtained by the formula:

$$I = \frac{(C_{sl} - C_0) W_s\, F3600 * 24}{I_i}\ , (m),$$

If this formula is saved by the rectangle length x, in the wind direction, the range of immissions of the certain given values, I_i, within the zone from the dust source to the isoline of natural concentration background. This gives the range points, x_i, of the certain sizes of occasional emissions, I_i, which, when connected with lines for various wind directions, represent the dust isolines around the pit contour:

$$I = \frac{(C_{sl} - C_0) W_s\, 3600 * 24}{I_i}\ , (m),$$

How much the air pollution will be in a certain direction during the year depends on the amount of wind in that direction.

On the basis of the percentage of wind frequency, f, that is, the number of days d, of wind blowing in certain directions in a year, the isolines of average daily emissions for a year can be determined by the formula:

$$x_i = \frac{(C_{sl} - C_0) W_s\, F3600 * 24F}{I_i}\ , (m),$$

F = d_f/365

The upper values of the average immissions of the total precipitable substances for populated areas are 450 (mg/m^2/day) for one day, and 200 (mg/m^2/day) for a calendar year, determined by the Regulation on Amendments to the Regulation on Monitoring Conditions and Requirements for the Air Quality ("Official Gazette of RS", Nos. 11/2010, 75/2010 and 63/2013) [5].

When it comes to the data on frequencies and wind speeds according to the sides, the data from the meteorological station Kraljevo was used.

Based on the analyzed data from the meteorological station, the predominant wind direction is west (200‰) and east (172.8‰), then northwest (137.0‰) and south (123.3‰). Winds blow most rarely from the north (65.8‰).[6]

From the downloaded data for wind speed and wind frequencies according to the world standards, the following calculations can be made:

- dust emission range for dangerous concentrations above MDK (*maximum allowed concentration)*,
- range of occasional daily GVI (*immission limit value)*
- range of mean annual GVI

Based on calculations, the range of air pollution concentrations in the vicinity of the Open Pit "Milojević brdo" above MDK and GVI is given in Table 4.

Table 4 *Range of concentrations of air pollution concentrations in the vicinity of the Open Pit "Milojevića brdo"*

Ord. No.	Name of size and units	N	NE	E	SE	S	SW	W	NW
1	Mean speed, W_s (m/s)	1.44	1.16	2.44	2.68	1.56	1.34	2	2.44
2	Frequency of wind direction, (‰)	65.8	68.5	172.6	117.8	123.3	115.1	200.0	137.0
3	No.of days per annum, 18	24	25	63	43	45	42	73	50
4	Coefficient Ɣ	0.655	0.537	1.075	1.176	0.705	0.613	0.890	1.075
5	L_t, (m)	264	378	284	235	264	378	284	235
6	X_{sk}, (m)	284	235	264	378	284	235	264	378
7	C_0, (mg/m^3)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	q, (mg/s)	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
9	C_{xl}, (mg/m^3)	0.388	0.497	0.087	0.081	0.311	0.334	0.147	0.103
10	Range X(m) C>0,12	**344**	**443**	**70**	**64**	**273**	**294**	**124**	**85**
11	Range X(m) C>0,07	41	56	22	14	62	62	46	21
12	Range, l 100, (m)	**470**	**488**	**162**	**164**	**405**	**375**	**237**	**196**
13	Range, l 200, (m)	235	244	81	82	203	187	118	98
14	Average annual. L 100, (m) ann.	**30.9**	**33.4**	**28.0**	**19.3**	**50.0**	**43.1**	**47.3**	**26.9**
15	Average annual L 200, (m) annum	15.5	16.7	14.0	9.7	25.0	21.6	23.7	13.4

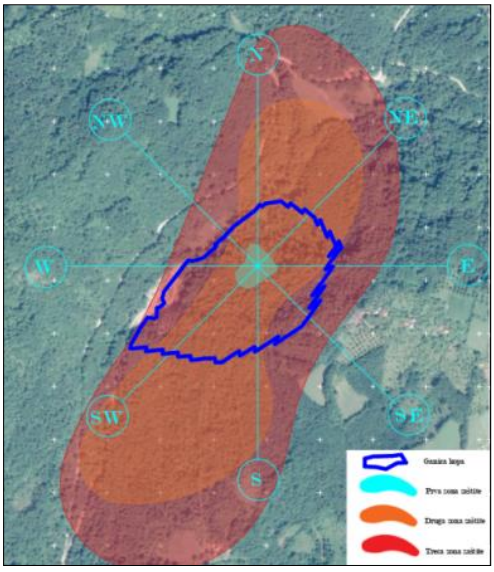

Figure 1 *Interpretation the range of air pollution concentrations in the vicinity of the Open Pit "Milojević brdo"*

The following can be seen from Table 4 and Figure 1:

The first protection zone (marked in blue) refers to the range of average annual permissible values of total sediments. The range of the average annual permissible values of the total precipitation amounts to the maximum of 50 m with a southerly wind, directed to the north, then 47.3 m with a westerly wind, directed to the east, and 43.1 m with a southwesterly wind, directed to the north-east. Other ranges of the average annual permissible values of the total sediments have significantly lower values. These ranges are located within the limits of the exploitation field.

The second protection zone (marked in orange) refers to the range of occasional permissible values of the total sediments; its greatest width is 488 m toward the southwest when the northeast wind blows. The next range of occasional daily permissible total precipitation values of 470 m is when the north wind blows.

The range of harmful concentrations of the total suspended particles above MDK on certain profiles depends on the direction and speed of wind with constant dust emission and reaches a the maximum value of 443 m when the wind blows from the northeast. When the calculated values for all wind directions are combined, an isoline is obtained, which is marked in red in Figure and refers to the range of air pollution concentrations of the total suspended particles above MDK. It is also **the third dangerous zone** of the soil around the open pit.

4 CONCLUSION

In order to establish the functional dependence of dust distribution in the area of the open pit and its immediate surroundings as a function of the input parameters, it is necessary to view the entire system as dynamic, which requires a conti-nuous monitoring of the input parameters and the results of dust measurement in the specific area. In this way, it is possible to form a model of impact on the environment quality.

This paper presents one approach to the model of distribution the dust particles in the area of impact the mining works at the Open Pit "Milojević brdo". The ultimate range and spatial distribution of dust emission is determined on the basis of the main impact factors, namely:

-dust emissions,
-distances from the place of emission,
- speed and direction of air currents.

The model for predicting the concentration and spread of dust in the function of mentioned parameters determines the degree of impact the mining operations on the environment in the vicinity of the open pit and determines the type and extent of protection measures required to reduce this impact to the permitted limits.

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