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Influence of Dust Emission Emitted from the Surface Quarry of Technical Stone on Air Quality

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ABSTRACT: The impacts of exploitation and processing of technical stone on the environment can have different levels of emissions and environmental devastation depending on the applied technological process for obtaining rock mass and production of stone aggregates, relief, climatic conditions, applied environmental protection measures and technological discipline. The primary impact of work processes on the environment during surface exploitation and processing of technical stone is manifested through emissions of mineral dust. In order to determine the impact of the exploitation of technical stone on air pollution, a dust emission calculation was performed according to the EPA methodology from an open pit mine that occasionally or never uses dust emission control during the process of production and processing of technical stone in order to assess its impact on air quality.

KEY WORDS: technical stone, dust measurement, dust emission, technological process.

1. INTRODUCTION

Technical stone is a mineral raw material obtained from sedimentary, magmatic and/or metamorphic rocks, which is used as a technical-construction stone. Unwanted effects on the environment during the surface explotation of technical stone occur:

- when opening a surface quarry,
- exploitation of the rock mass and
- by the production of stone aggregates.

Impacts on the environment during the exploitation of rock mass at the quarry are manfested through emissions: dust, noises, blasting effects, exhaust gases, waste production, ect. [1].

Quarry processes that emit dust into the environment are primarily the process of beneficiation of mineral raw materials (crushing and grinding) and grading on vibrating sieves. Also, dust emissions are generated when mineral raw materials are loaded into trucks, and when they are transferred to a crushing separation plant. The movement of trucks and other vehicles on the manipulative surface of the surface quarry, the disposal and storage of different fractions in the opet, and their exposure to the wind also leads to the emission of dust. Procedures of drilling mine wells that destroy the rock mass by pulverizing it into dust and blasting, whereby large quantities of mined material are blown into the enviroment. Dust emissions are mostly uncontrolled, which is why it is difficult to determine and balance them. Environmental protection trough leglal legislation becomes an important part of the economic and social development of the community, which manifests itself through the restructuring of business entities, the construction of transport infrastructure, the development of the enery sector, the development of scientific institutions and the new design of the tourist product through causing minimal damage to the environment. Currently, about 90% of the total production of aggregates in Europe comes from natural sources, from quarries and gravel pits. The remaining 10% of European aggregate production comes form marine deposits, recycling of industrial waste such as slag and ash, and recycling of construction waste.

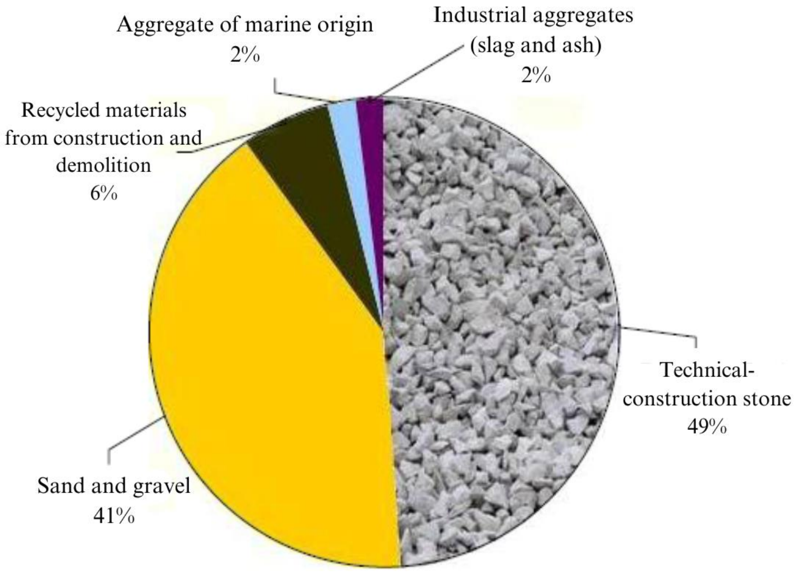

Figure no.1 Production and sources of stone aggregates in Europe

Total European demand for aggregates is 3 billion tonnes per year, according to UEPG statistics included in their 2010-2011 annual report. The aggregate sector achieves a total income of about 20 billion euros and an average consumption of 5.5 tons per year capita [2].

2. CALCULATION OF DUST EMISSION USING THE EPA METHOD FROM THE SURFACE QUARRY OF TECHNICAL STONE

Dust emission from surface quarry have the character of uncontrolled emissions that are impossible to measure using standard methodology and measuring equipment for emission measurement. For this reason, methodologies based on emission calculations are used for the assessment of emissions from surface quarrys, which take into account the key influencing factors on the level of emissions [3].

In Bosnia and Herzegovina, for the time being, no adequate methodology is used for the assessment of dust emissions at surface quarry for exploitation of mineral raw materials. The introduction and practical application of the considered methodology for estimating dust emissions, defined by the US Environmental Protection Agency (EPA) and supported by Canadian Environmental Protection Agency (EC) and the Australian National Pollutant Inventory (NPI), is a rational, constructive and economical solution which would ultimately lead to the adequate establishment of an environmental management system at surface mines.

The technical parameters for the calculation of dust emission from surface mining of technical stone is this paper were chosen based on empirical data, for an average surface mine in Bosnia and Herzegovina, which continuously uses equipment to control dust emmision durnig the entire period of explotation and processing in all technological processes which is „Kota" quarry near the town Vareš.

2.1. Location of the „Kota" limestone plant and plant near Vareš

The location of the surface mine „Kota" is about 3.0 km northwest of the town Vareš. The processing plant (seperation) and the quarries are connected to the asphalt road and the Vareš-Podlugovi railway via a good macadam road, the route of which goes over the liquidating mine, through which they exit to the main road and railway corridor. The distance between Vareš and Podlugovi is 25 km and from Sarajevo 50 km.

The first residential building is located at a distance of about 0.5 km from the locality itself, and the first inhabited place (Semizova Ponikva) at a distance of 2.0 km. The highest terrain elevation is 1,252.0 m, at the Stijene site, and the lowest is 1,007.0 m on the landfill plateau, where the seperation plant and accompanying facilities sof the industrial area are located.

Figure no.2 „Kota“ limestone quarry near Vareš

Figure no.3 Seperation plant for limestone processing „Kota“ near Vareš

2.2. Projected production capacity

The surface explotation of the technical imestone in the locality „Kota“ near Vareš is based on very favorable natural and created technical-technological and other conditions. The project solution for the exploitation of the limestone mineral raw material at the surface mine „Kota“ adopted the following parameters:

- number of working months in a year................N_{mj} = 9
- number of shifts per day..................................N_{smj} = 1
- number of working hours in a shift................ $N_{h/smj}$ = 10
- effective use of working time...........................k_v = 85%
- number of working days in a month................N_{rdmj} = 24

From the stated conditions, it follows that the annual fund of effective working time amounts to:

$T_g = N_{mj}$ x N_{smj} x $N_{h/smj}$ x N_{rdmj} x k_v = 9 x 1 x 10 x 24 x 0,85 = **1.836,0** h_{ef} /per year.

The designed hourly capacity of 150 tons/h_{ef} of the installed plant is realistic and confirmed in the trial operation of the plant, which was 140-170 tons/h_{ef}. The annual production capacity for the „Kota“ surface quarry is:

$Q_{annual}=T_g$ x $Q_{t/h}$=1.836,0 x 150,0=**275.400,00** (ton/year)

At the „Kota“ limestone surface quarry near Vareš, during the technological process of obtaining and processing technical stone, modern technology is used to correct dust emmisions from all technological processes.

2.3. Calculation of dust emission by technological processes

By applying the methodology of the US Environmental Protection Agency (EPA), it is possible to calculate dust emissions from all technological processes encountered during the explotation and processing of technical stone, as shown below.

2.3.1. Tailings removal

With the application of the equations of the American Environmental Protection Agency (EPA), it is possible to estimate the amount of dust emissions during the removal of tailings using the mining machinery of excavators and bulldozers, before other operations [4].

$$TSP = EF_{(TSP)} = \left(2{,}6 \cdot \frac{(s)^{1.2}}{(M)^{1.3}}\right) = \left(2{,}6 \cdot \frac{(0{,}75)^{1.2}}{(4)^{1.3}}\right)$$

$$PM_{10} = EF_{(PM10)} = \left(0{,}45 \cdot \frac{(s)^{1.5}}{(M)^{1.4}}\right) \cdot 0{,}75$$

$$PM_{2.5} = EF_{(PM2.5)} = \left(2{,}6 \cdot \frac{(s)^{1.2}}{(M)^{1.3}}\right) \cdot 0{,}105$$

Where:

M – average moisture content in the material (%)
s – content of fine particales in the material (%)
E_f – emission factor for corresponding dust particles (kg/h)

The emission factors for these activities can vary greatly depending on the content of fines in the material being removed, the moisture content, and therefore the estimation of emissions must be approached with caution.

2.3.2. Drilling mine boreholes

To estimate the emission rate of dust particles from the drilling od mine wells, use an equation tat depends on the total amount of demined material in the period for which the emission rate is estimated [5].

$$E = E_f \cdot Q$$

Where:

E – dust particle emission rate in units, kilograms during the year
Q – amount of all types of demined material during the year in tons

To estimate the emission rate of dust particles from the drilling of mine wells, an equation is also used, which depends on the total number of drilled mine wells in the period for which the emission rate is estimated.

$$E = E_f \cdot N$$

Where:

N – number of mine boreholes drilled during the year

2.3.3. Blasting of mine boreholes

Dust during blasting is created by the breaking and pulverization of technical stone by the action of the explosion in the mine boreholes.

The procedure refers to breaking and pulverizing both useful mineral substances and barren deposits that must be removed by blasting. The form for estimating dust emission from blasting is dependent on the size of the area being blasted, as well as the number of blasting operations during the year.

$$E = k \cdot N \cdot 0{,}00022 \cdot A^{1.5}$$

Where:

k – dimensionless particle size factor
N – number of explosions per year
A – area to be blasted in square meters

2.3.4. Gravitational transport of materials from floors

It is assumed that 70% of the material will need to be transported by gravity with an excavator or bulldozer, and approximately 1000 hours will be spent on these tasks. For a more precise assessment of dust emissions, use the form:

$$E = E_f \cdot T;$$

$$E_f = 2{,}76 \cdot k \cdot \frac{s^{1.5}}{M^{1.4}}$$

Where:

T – working time of the machinery in hours
k – aerodynamic partical size factor
M – average humidity of the material in percent (%)

2.3.5. Technological operations of material loading and unloading

The dust emission assessement is performed for all materials from the mentioned processes, both for the useful mineral substance and for the tailings. This procedute applies to process operations wherever there us a 'drop' of material which means that each 'drop' of material should be accounted for separately. To estimate dust emissions, a form is used that takes into account the mean wind speed at the location of the work, the moisture content of the material and an estimate of the total amount of material being manipulated.

$$E = E_f \cdot Q_m; \qquad E_f = k \cdot 0{,}0016 \cdot \frac{\left(\frac{U}{2{,}2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

Q_m – the amount of material for which the emission impact is determined, annually in tons
U – mean wind speed, meters per second

2.3.6. Crushing and screening operations

Crushed and sifted assessment is calculated for each crushing and sifting process. Primary secondary crushing and screening are calculated separately according to the following formula. The assessment of dust emission by one technological process (crushing or sieving) is determined according to a pattern that is a function of the dust emission factor and the total amount that is crushed or sieved [6].

$$E = E_f \cdot T_m$$

Where:

T_m – the total amount of processed material in this technological process during the year, in tons.

2.3.7. The impact of wind erosion on assortment landfills

The assessment of dust emission due to the impact of wind erosion on the landfill of assortments located on an opet surface is determined as the product of the emission factor and the area of the assortment.

$$E = E_f \cdot A_m$$

Where:

A_m – storage area, in square meters

For a more precise assessment of dust emissions from the influence of wind on landfills of the assortment, a form is used that takes into account the content of fine particles in the deposited material, the percentage of time during the year with wind greater than 5.36 meters oer second, the average number of days in the year when the landfill was drenched to a minimum of 0.000254 meters, as well as the surface of stocks exposed to the wind [7].

$$E = E_f \cdot A_m$$

$$E_f = 1{,}12 \cdot 10^{-4} J \cdot 1{,}7 \cdot \left(\frac{s}{1{,}5}\right) \cdot \left(365 \cdot \frac{(365 - P)}{235}\right) \cdot \left(\frac{I}{15}\right)$$

Where:

A_m – storage area, in square meters

J – aerodynamic particle size factor

s – average content of fine particles in the deposite material (%)

P – average number of days in the year when the landfill was drenched to a minimum depth of 0,000254 meters

I – percentage of time during the year with wind greater than 5,36 meters per second (%)

2.3.8. Truck transport on unpaved roads

To estimate dust emissions from truck transport on unpaved roads, a form is used that takes into account when calculating the dust emission factor, the average weight of the vehicle, the content of fine particles on the road surface, as well as the mileage of the vehicle on the specified road for which the emission estimate is determined.

$$E = E_f \cdot V$$

$$E_{f(TSP)} = 1{,}381 \cdot \left(\frac{s}{12}\right)^{0.7} \cdot \left(\frac{W}{3}\right)^{0.45}$$

Where:

V – vehicle mileage per year, kilometer

W – mean vehicle mass in tons

Reducing dust emissions from truck transport on unpaved roads can be achived in several ways. The equation for estimating dust emissions from unpaved roads indicates that a reduction in kilometers driven leads to a reduction in dust emissions. The speed and mass of vehicle moving along the specified route lead to a reduction or increase in dust emissions. The most commonly used way to reduce dust emissions into the air is wetting unpaved roads. Wetting can be with the addition of chemical agents or only with warer. The control of the efficiency of application of wetting unpaved roads is calculated using the following equation [8]:

$$C_f = 100 - \left(0{,}8 \cdot \frac{A \cdot D \cdot T}{I}\right)$$

Where:

C_f – control of the efficiency of moistening of road communication, in percentage

A – average annual evaporation, in meters

D – average number of vehicles per hour

T – time between two wettings, in hours

I – amount of water for wetting, liters per square meter

2.3.9. Wind impact on bare surfaces and macadam roads

The area of the macadam roads, as well as the bare surface of the surface mind technical stone, for which the calucaltion of the dust emission due to the influence of the wind will be made, is approx. 78,000.0m^2. The emission factor is a function on that terrain, the average wind speed, friction and the correction factor, which is a derived value [9].

$$E = k \cdot E_f \cdot A;$$

$$E_f = 2{,}814 \cdot (1 - v) \cdot \left(\frac{u}{u_t}\right)^3 \cdot C_{(x)};$$

$$u_t = u_t^* \cdot u^*$$

Where:

A – bare surface, as well as the surface of macadam roads on the mine, in (m^2)

v – amount of vegetation, dimensionless number (which ranges from 0,0-1,0)

u – mean wind speed, meters per second

u_t – limit wind speed, meters per second

$C_{(x)}$ – correction factor, dimensionless number

u_t^* – friction speed threshold, meters per second

u^* – the ratio of wind speed depending on the height of the surface roughness

The calculation of dust from surface quarry of technical rock „Kota" near Vareš with adequate application of dust emission control is shown in the following table (Table 1.), which is generated on an annual basis for a production capacity of 275,400t/y (approx. 100,000.0m^{3}h.m)

Table 1. Total calculation of dust emission with adequate application of dust emission control

Technological process	Dust emission (tons/year)		
	TSP	PM_{10}	$PM_{2.5}$
Tailings removal	0,0303	0,0031	0,0031
Boreholes drilling	0,5780	0,3030	0,3030
Miniranje dubBlasting of deep boreholes	3,8620	2,0080	0,1160
Gravitational transport of materials from floors	9,9020	4,6830	0,7090
Technological operations of material loading and unloading	1,3770	0,6330	0,0990
Crushing and screening operations	5,8740	0,8160	0,1340
The impact of wind erosion on assortment landfills	0,3440	0,1720	0,0680
Truck transport on unpaved roads	13,4100	3,4300	0,3400
Wind inpact on unpaved working roads and bare surfaces	14,7400	7,3700	2,9400
TOTAL DUST EMISSION (ton/YEAR)	**50,1173**	**19,4181**	**4,7121**

Furthermore, the calculation of dust emissions for mentioned quarry was carried out to the extent that it would not use continuous control of dust emissions (because most quarries in Bosnia and Herzegovina do not use measures to reduce dust emissions) during the technological process of production and processing of technical stone for the same annual production capacity and processing. The obtained values of dust emissions from all technological operations are presented in Table 2.

Table 2. Total calculation of dust emission using the EPA methodology without applying dust emission control

Technological process	Dust emission (tons/year)		
	TSP	PM_{10}	$PM_{2.5}$
Tailings removal	0,0303	0,0031	0,0031
Boreholes drilling	0,578	0,303	0,303
Miniranje dubBlasting of deep boreholes	3,862	2,008	0,116
Gravitational transport of materials from floors	9,902	4,683	0,709
Technological operations of material loading and unloading	5,508	2,532	0,396
Crushing and screening operations	19,580	2,726	0,446
The impact of wind erosion on assortment landfills	1,376	0,688	0,272
Truck transport on unpaved roads	111,735	28,623	2,828
Wind inpact on unpaved working roads and bare surfaces	21,060	10,530	4,210
TOTAL DUST EMISSION (ton/YEAR)	**173,6313**	**52,0961**	**9,2831**

3. CONCLUSION

The growinf trend of increasing the number of surface quarry of tecnological rock in Bosnia and Herzegovina leads to the emission of a large amount of dust into the atmosphere. Performing tecnological operations on surface quarrys such as drilling, blasting, material handling, processing, grading and transport are potential sources of air pollution with dust. Therefore, detailed studies of emission sources and quantification od emissions of pollutinf substances (especially dust) from surface quarrys for the explotation of mineral raw materials are needed.

In order to determine the impact od the explotation of technical rock on the state of air quality, a dust emission calculation was performed according to the EPA methodology for the „Kora“ quarry near Vareš, which has an annual production and processing of about 100,000m^{3}h.m of technical rock that implements dust emssion control and for the same quarry, a calculation of dust emission was made to the extent that it would not have used control measures.

By comparing the obtained results, it is evident that by controlling the dust emission generation measures from the surface quarry, the dust emissions can be reduced on an annual basis in a multiple amount. From the results of the calculation, it is evident that the largest amount of dust emissions on an annual basis is produced during the technolofical operaion of truck transport on unpaved roads, the impacht of wind on unpaved roads and the technological operations of crushing and screening.

The practical application of the considered methodology for the calculation of dust emissions in the air of the US Enviromental Protection Agency (EPA) is a rational, constructive and economical solution that woul ultimately lead to the adequate establishment of an environmental managment system at surface quaary for explotation of mineral resources in the territory of Bosnia and Herzegovina.

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