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ENVIRONMENTAL POLLUTION WITH GASEOUS POLLUTANTS IN THE OPERATION OF MINING MACHINES AT THE OPEN PIT[***]

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Abstract

Atmospheric pollution at the open pits depends on the annual production and intensity of emissions the harmful gases and dust, that is, development the individual phases in overburdening and obtaining the useful mineral resources. The gas and dust emissions at the open pits occurs as a consequence of technological processes aimed at obtaining the mineral resources, most often during loading and transport operations. In addition, the pollution also depends on the terrain configuration around the open pit and climatic parameters. Therefore, it can be considered that the entire area of the open pit is a source of environmental pollution. This paper will present the results of pollution level by gaseous pollutants at the open pit, caused by the operation of mining machines.

Keywords: *gaseous pollutants, combustion, mining machinery, environmental impact*

1 INTRODUCTION

Exploitation of mineral deposits can be done by the surface or underground works. The exploitation of mineral deposits at the open pits is done by the use of a discontinuous system in most cases, which consists of several production processes - operations [1]. Considering the physical and mechanical characteristics of the deposit, it is never possible to perform a direct excavation. Mainly, the basic operations of exploitation the mineral raw materials consist of: drilling, blasting, crushing, loading and transportation [2]. In addition to the mentioned basic mining works, the auxiliary works are also performed, which are always synchronized with the basic works.

Mining machinery is used to perform the basic mining works at the open pits: drills, excavators, trucks, bulldozers, graders and loaders [3].

The number and quantity of engaged mining machinery at the open pit depends on the designed system of exploitation of the mineral raw material, which is in

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accordance with the required capacity, physical and mechanical properties of the mineral raw material, structural parameters of the open pit and intended equipment for operation at the open pit [4,5].

In order to obtain the mineral raw materials, during the operation of mining machines at the open pit, the emissions of gaseous pollutants inevitably occur [6,7]. This most often happens during operations of loading and transport of mineral raw materials [8,9].

The intensity of pollution depends on the development of individual phases in the discovery and obtaining of useful mineral raw materials, on the configuration of the terrain around the surface mine and on climatic parameters [10]. Therefore, it can be considered that the entire area of the surface mine represents a complex source of environmental pollution.

This paper presents the results of pollution level with gaseous pollutants created during the operation of mining machines at the open pit for limestone exploitation.

2 CONCEPTS OF EXPLOITATION AT THE OPEN PIT

Exploitation of the limestone deposits is carried out by the open pit mining [11]. A discontinuous system of exploitation, consisting of several production operations, is applied.

Considering the physical and mechanical characteristics of limestone, the fragmentation is previously because a direct excavation is not possible. The blasted limestone is loaded into trucks and transported to the crusher. The auxiliary works are performed in synchronization with the basic works. The excavated humus cover is temporarily deposited on an internal landfill and subsequently used in recultivation after the end of exploitation.

The following mining machines are used to perform the basic mining works at the open pit: Atlas Copco ROC F6 drill, CAT 5080 hydraulic excavators, CAT773E trucks, CAT D9R bulldozer, CAT 12H grader and CAT 988H loader.

A discontinuous system of exploitation with the following technological phases is applied at the open pit: drilling, blasting, loading, transport and auxiliary works.

Drilling is performed with an Atlas Copco ROC F6 drill, with a drilling diameter of 90, 110 and 130 mm.

The blasted material is loaded with a Caterpillar 5080 hydraulic excavator with a normal bucket and CAT 988-wheel loader. The transportation of limestone, i.e. useful mineral raw materials, is done with the Caterpillar 773E trucks.

The entire mineral raw material from the open pit of the limestone deposit is treated as useful mineral raw material, without waste. The content of CaO is fairly uniform, and chemical composition of the mineral raw material is corrected by addition of marl and quartz sand.

The auxiliary works include the work site maintenance at the open pit and construction of a drilling platform, construction and maintenance of transport roads, maintenance of drainage facilities and maintenance of the open pit slopes, as well as the supply of machinery with fuel in the field. The following mining machines are hired for these works: Caterpillar D9R bulldozer, Caterpillar 12H grader and fuel tank truck.

The mining machines are supplied with fuel at the open pit from a gas station located outside the open pit. All vehicles except hydraulic excavators and bulldozers are supplied with fuel at the pump. The fuel is brought by tankers to the open pit and thus provides fuel for these mining machines.

3 EMISSIONS OF GASEOUS POLLUTANTS AT THE OPEN PIT

Gaseous polluting substances at the open pits are created as a result of technological processes [12-14] in order to obtain the useful mineral raw materials - limestone, during loading and transportation operations.

During drilling of boreholes, if the dedusting system is not working, the dust can enter the environment.

The open pit blasting is an occasional source of a dust-gas cloud emission. The length, width, height of the cloud, concentration and development of gases in the cloud at the open pit are affected by: the environment type, blasting methods, atmospheric conditions and quantities of explosives for one blasting.

The dust-gas cloud during blasting is created in three phases, as follows: by breaking out, that is, by being ejected from the borehole opening; by scattering, crushing, collapsing, launching and moving the mass and finally by knocking down and falling of the blasted mass; and under the effect of air shock waves and seismic earthquakes.

Upon explosive detonation, 50% of the gases created during blasting immediately go into the atmosphere, about 20% are absorbed by the crushed mass and about 30% fill the pores, cracks and empty spaces of the blasted material. The amount of gases, created during the open pit blasting, depends on the amount of explosives used.

The gaseous cloud moves in the prevailing wind direction. When the atmosphere is stable, the cloud constantly keeps rising and spreads the pollution with the air currents further through the atmosphere, and deconcentration of pollution occurs on that occasion. The impact on the environmental pollution in this situation is minimal.

Limestone is loaded with a diesel-powered hydraulic excavator and loader, with gaseous products entering the environment. During loading, the trapped gases are separated from the blasted mass and released, as well as the exhaust gases. According to the measurements, the gas emission at the open pit during the blasting operation is on average 0.25 m^3/s.

Limestone is transported by the diesel-powered trucks. During the transport of excavated mineral raw materials, the gaseous components of truck exhaust gases (carbon monoxide, nitrous gases and sulfur dioxide) reach the environment. The average gas emission for one truck according to the measurements is 0.42 m^3/s.

The diesel-powered bulldozer is used for auxiliary mining operations at the open pit. The average gas emission for the bulldozer is 0.26 m^3/s. In addition to the bulldozer, for auxiliary operations, a diesel-powered grader is also used, with the average gas emission of 0.09 m^3/s.

4 LEVELS OF ENVIRONMENTAL POLLUTION WITH GASEOUS POLLUTANTS DURING THE OPERATION OF MINING MACHINES

The level of environmental pollution with gaseous pollutants during limestone mining depends on: the intensity of emission the gaseous pollutants, climatic characteristics, terrain configuration, wind roses and protection measures taken in order to suppress or reduce the emission of gaseous pollutants during the technological operations and from degraded surfaces.

Mining machines at the open pit use a diesel fuel D2 in accordance with the standard SRPS B.H2.410/1.

During the operation of an internal combustion engine, oxygen from the air binds with hydrocarbons and other chemical compounds that make up a diesel fuel. The gas emission that occurs during the complete and incomplete combustion of fuel consists of the following components: CO, CO_2, C_nH_mO, C_nH_m, SO_2, NO, NO_2 and soot.

The concentration of gases at the open pit depends on the ratio of combustible components in the fuel, namely: carbon, hydrogen and sulfur, as well as on the corresponding fuel-air ratio.

With the fuel used, diesel D2, the sulfur concentration ranges up to one percent by weight, which is 500 ppm SO_2. The amount of air required to dilute these harmful components in the exhaust gases of an internal combustion engine depends on the concentration of those components.

In the case of liquid fuel D2, SO_2 is the dominant factor defining the required

amount of air for de-concentration of gases from the open pit atmosphere, because its value of the maximum permissible concentration (MDK) is equal to 4 ppm.

The environmental quality monitoring plan defines the frequency of monitoring and measurement and the type of pollutant to be measured.

Based on the known composition of the diesel fuel D2, the known engine power of mining machines and composition of the exhaust gases of these types of engines, concentration of the emission of polluting gaseous substances for all mining machinery at the open pit for obtaining limestone was determined to be 2.256 m^3/s representing an acceptable risk for the environment.

On the basis of the obtained value, that it expected an acceptable risk for the environment, there is a low probability of occurrence an environmental aspect that causes or can cause the environmental pollution with gaseous pollutants during the operation of mining machines at the open pit. [15-19]

Based on the obtained value, there are or may be small consequences for the environment. The consequences appear or may appear as an occasional pollution of the basic environmental factors that do not exceed the MDV and MDK values. The consequences of environmental pollution can be related to the level of the open pit.

Table 1 presents the average amount of exhaust gas emissions during the operation of mining machines at the open pit per one operation of the technological process. The total concentration of emitted polluting gaseous substances is 2.256 m^3/s.

Table 1 *Concentration of polluting gaseous substances at the open pit*

Type of equipment	Manufacturer	Type	No. of units	Total gas emission m^3/s
Drill	Atlas Copco	ROC F6	1	0.146
Hydraulic excavator	Caterpillar	5080	1	0.25
Loader	Caterpillar	988	1	0.25
Truck	Caterpillar	773E	3	1.26
Bulldozer	Caterpillar	D9R	1	0.26
Grader	Caterpillar	12H	1	0.09
Total			**8**	**2.256**

5 ENVIRONMENTAL PROTECTION MEASURES AGAINST THE NEGATIVE EFFECTS OF GASEOUS POLLUTANTS DURING THE OPERATION OF MINING MACHINES

The environmental pollution during exploration at the open pit results from the operation of engaged mining machines, as well as during blasting operations.

The environment quality in the vicinity of the open pit also depends on the environmental protection measures taken during the exploitation of mineral raw material - limestone.

Gaseous polluting substances, created by the operation of mining machinery and blasting operations at the open pit, diffuse together with the air currents into the atmosphere and are deconcentrated.

The environmental pollution with gaseous pollutants - exhaust gases such as CO, NOx, SO_2 from internal combustion engine machines, cannot significantly affect the environment because the gases diffuse.

The concentration of gases in the air is not expected to be higher than MDK in the environment. Therefore, no special protection is

foreseen, except for the regular maintenance and regular technical control the composition of exhaust gases from machines with the internal combustion engines, as well as the use of diesel fuel of a constant content.

Considering the expected level of acceptable risk, the mandatory protection measures that are taken are:

- Carrying out the periodical testing of the environment in order to control the realized effects of applied protection measures.
- Reduction the amount of gases during blasting is achieved when the impact cartridges are placed at the bottom of the bore hole, which affects the increased efficiency of blasting, and a smaller amount of gases is emitted.
- Mandatory use of the original explosive packages.
- Monitoring the concentration of gaseous substances in the air.

The owner of the open pit is obliged to monitor the indicators of emissions, that is, the indicators of the impact of activities on the environment and indicators of the effectiveness of applied measures to prevent the occurrence or reduce the level of pollution. The quality plan defines the frequency of measurements and type of pollutant to be measured.

6 CONCLUSION

Gaseous pollutants that occur at the open pits during the operation of mining machines arise as a consequence of technological processes aimed at obtaining the mineral raw materials, during blasting, loading, transport, crushing operations, as well as due to the effect of natural factors - terrain configuration, climate parameters, winds.

Mining machines at the open pit use a diesel fuel D2 in accordance with the prescribed standards. During the operation of an internal combustion engine, oxygen from the air binds with hydrocarbons and other chemical compounds, included in the composition of diesel fuel.

The concentration of gases at the open pit depends on the ratio of combustible components in the fuel, namely: carbon, hydrogen and sulfur, as well as on the corresponding fuel-air ratio.

Based on the known composition of diesel fuel D2, engine power of mining machines and composition of the exhaust gases of these types of engines, the concentration of emission the polluting gaseous substances for all mining machinery at the open pit for obtaining limestone was determined to be 2.256 m^3/s.

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