Revista Minelor – Mining Revue
ISSN-L 1220-2053 / ISSN 2247-8590
vol. 28, issue 1 / 2022, pp. 66-72

EVALUATION OF AIR POLLUTION AS A RESULT OF COAL EXPLOITATION IN ROŞIUŢA COAL PIT

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DOI: 10.2478/minrv-2022-0006

Abstract: *The polluting activity carried out by the coal exploitation in Roşiuţa coal pit has effects on the environment and the main pollution sources of the atmosphere are: suspended powders, particulate matter and burning gases. The pollutants contain substances with different degrees of toxicity. Through the measurements performed "in situ", for the dust concentration at different points, it was found that the indices of the maximum concentration (MC-mg/m^3/air), on the mining areas, were according to the legislation in force. At some points, the dust concentration is higher, but as the distance increases, the pollution is no longer felt, so it can be noticed that the lignite exploitation has a local influence.*

Keywords: *air pollution, coal pit, sterile dump, coal yard, Roşiuţa*

1. Introduction

Roşiuţa mining perimeter is located in the North of Oltenia, on the territory of Gorj County, occupying the Northeastern side of Motru mining basin under the administration of Roşiuţa Mining Exploitation, within Motru Coal Mining Exploitation.

The appearance of the relief is given by the alternation of high profile isolated hills and dividing valleys that widen in the confluence area, giving the appearance of a small depression (confluence between Ploştina Creek and Motru River, confluence between Peşteana Creek and Motru River).

The average altitude of the relief is between 200-300 m and the highest being Pâlvei Peak of 415 m to the North-East of Roşiuţa village, Motru town being located at an altitude of 185 m. The lowest elevation is 171 m in Meriş meadow located upstream of Broşteni commune. The whole relief is given by the high peaks in the North East sector with a rounded appearance and the valleys that widen towards the confluence.

It should be noted that in the last 40-45 years, all these landscapes have undergone an increasingly strong anthropogenic pressure, some of which are in advanced stages of degradation.

Geological research undertaken in the North-Western part of Oltenia in the period 1950-1960 highlighted the existence of important lignite reserves in the meadow area of Jiu, Jaleş and Tismana, located at a shallow depth, with average discovery reports of 2 - 3 m^3 / ton, possibly capitalized by up-to-date mining works.

2. Areas with the highest risk of air pollution and pollution sources

The change of air quality, caused by coal exploitation in Roşiuţa coal pit, materializes through the increase, in certain areas, of the concentration of particulate matter resulting from machinery operations. The most important areas where pollution can be noticed are:

- Excavation areas;
- Sterile dump areas;
- Discharge points of the front lanes on the connecting lanes;
- Distribution nodes;
- When dumping the coal in the coal yard and its shipment;
- On the roads towards the coal pit.

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Another potential source of air quality deterioration is the self-ignition of coal from deposits. Due to incomplete combustion, carbon dioxide and small amounts of sulfur dioxide, light hydrocarbons - toxic substances whose concentrations do not usually exceed the permitted limits, are released into the air. Oxidation of stored coal results in a loss of calorific value relative to the fuel mass [1].

Atmospheric emissions from Roşiuţa coal pit are of two categories: emissions from combustion processes and direct emissions from technological processes (table 1).

a) Emissions from combustion processes come from:
- Mobile sources (vehicles, means of transport);
- Surface sources (excavators).

b) Emissions from technological processes come from three sources:
- Mobile sources (conveyor belts);
- Surface sources (excavators);
- Fixed sources (coal deposits).

Table 1. Sources of air pollution related to the studied area

Process phase	Type of emission source	Emission
Car traffic	Ground linear with undirected emissions	Flue gases from daily traffic on site (transport vehicles)
Coal excavation and sterile	Ground surface with undirected emissions	Flue gases from the construction machinery (front excavators)
		Particulate matter due to coal excavation and sterile dumping
Coal transport and sterile	Ground linear with undirected emissions	Particulate matter due to coal and sterile transport
Coal and sterile storage	Ground surface with undirected emissions	Particulate matter due to coal and sterile storage

The main sources of air pollution caused by mining exploitation may be considered: fixed equipment according to the “Continuous flow extraction technology with high capacity equipment” and mobile equipment related to:
- Material processing at working points;
- Discontinuous flow operation with classic equipment and car transport;
- Development and strip superstructure;
- Development and superstructure of technological and access roads;
- Rehabilitation works / machinery operation;
- Landscaping.

2.1. Fixed equipment

The coal exploitation in Roşiuţa coal pit is the main source of air pollution with dust. Also, it can be noticed the low mechanical strength and low humidity (in the summer) of friable rocks, which lead to dust making. The areas of dusty air pollution are:

a) Rotor excavator working area

In the case of the cross-sectional block excavation method in the forward direction, during the cutting operation, bucket spillages, on the excavator belt number 1 and further in the lane relay until the discharge on the main flow strip, a large amount of dust. The flocculation of the deposited dust is influenced by meteorological causes, the quantity and quality of the excavated rocks, the distance from the emissary, so that the pollution from the neighboring areas can be temporarily important [2].

Other sources of dust are the falling rocks on the slope during the mining works, the material from buckets on the belt and crushing lumps.

Excavation area is relatively isolated from the human settlements (the households of Runcurelu village located in the Northwestern limit of the excavation works will be relocated).

b) On the way of conveyor belt

Dust is formed when the coal is discharged from one lane to another. The high concentration of dust made by coal transport is influenced by:
- Low humidity;
- Low rain;

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- High transport speed;
- The height of fall on the pick-up belt.

These areas are far away from villages, except for the route of sterile transport lanes in the inner dump corresponding to Lupoaia mining perimeter and the coal transport route located in the Western side of the perimeter, at least 200 m from the inhabited area of Roşiuţa village.

c) Discharge at production points (concentration of production)

There is also the concentration of production of all technological lines in the flow, in the distribution node, which increases the concentration of dust. These areas are far away from villages.

d) In the coal yard

The coal yard serving the coal pit is located near the main road. The coal, to the distribution node is transported on the transport circuit consisting of conveyer belts located on the floor of the coal pit as well as on the bench which connects the distribution node and the excavation bench.

The coal is transported on the tap line, from the distribution node, consisting of conveyor belts in fixed construction, to the coal yard, located in the Western side of the coal pit at about 50-100 m from the coal yard of Roşiuţa village.

The coal is dumped in the coal yard by ASG and KSS type machines and the shipment to the loading point is made by KSS type machine.

In addition to the factors listed above that lead to the formation of dust, there is also the taking of coal from the conveyer belt and its discharge from about 5-10 m high. The monitoring of the air quality indicators carried out by Gorj and Mehedinti Environmental Protection Agencies in the adjacent area to the coal yard reflects exceeding values of the maximum allowed concentrations for sediment dusts and particulate matter.

e) Sterile dump

During the analyzed period, the sterile dump is made in the inner dump of Roşiuţa mining perimeter, the inner dump of Lupoaia mining perimeter and the outer dumps of Valea Ştiucani, Valea Potângu and Valea Cireşului.

According to the working norms, the excavation, transport and dump installations used in Roșiuța mining perimeter must be equipped with mobile installations for spraying the access areas during the summer, when the dust concentration increases.

2.2. Mobile equipment

Suspended powders, particulate matter and burning gases are the main pollutants. Dust is formed in the case of the material and spare parts supply at the working point on the technological flow with cars, on the access roads to the coal pit, which if not sprayed with water is a danger to the health of the staff who work in the area.

Table 2. Emission agents for the main elements of the flue gases

No.	Pollutant	Measure unit	Emission factor
1	NOx	g/kg of diesel	48.8
2	NM-VOC		7.08
3	CH_4		0.17
4	CO		15.8
5	NH_3		0.007
6	N_2O		1.3
7	PM		5.73
8	Cadmium	μg/kg of Diesel	0.01
9	Copper		1.7
10	Chrome		0.05
11	Nickel		0.07
12	Selenium		0.01
13	Zinc		1
14	Benz - a - anthracene		80
15	Benzo (b) - fluoranthene		50
16	Dibenzo (a, h) anthracene		10
17	Benzo (a) pyrene		30
18	Chrysene		200
19	Fluoranthene		450
20	Phenanthene		2500

Emissions of dust and gases specific to the machinery activity are assessed by the consumption of fuels and the area on which these activities take place (pollutants, particulate matter and sediments). It is estimated that air pollution in the activities of refueling, maintenance and repair of means of transport is reduced and can be neglected. The mobile equipment involved in the coal exploitation will generate emissions like: NOx, SO_2, CO, CO_2, CH_4 and NMVOCs.

According to the simple methodology, the following emission factors, presented in the tables 2, 3 and 4, can be applied to the analyzed situation:

For the transport activity performed with transport equipment larger than 3.5 tons and using Diesel fuel, the emission agents are presented in the tables below.

Table 3. Emission agents

Emission agent	NO_X	CH_4	VOC	CO	N_2O	PM	CO_2
gr / km	10.9	0.06	2.08	8.71	0.03		800
gr / kg of Diesel	42.7	0.25	8.16	34.2	0.12	4.3	3138
gr / MJ	1.01	0.006	0.19	0.80	0.003		73.9

Table 4. Emission agents for heavy metals in flue gases

No.	Pollutant	Measure unit	Emission agent
1	Cadmium	μg/kg of used Diesel	0.01
2	Copper		1.7
3	Chrome		0.05
4	Nickel		0.07
5	Selenium		0.01
6	Zinc		1

Mobile emission sources like diesel engines which produce exhaust gases in the atmosphere contain the whole complex of pollutants specific to the internal combustion of diesel: nitrogen oxides, non-methane volatile organic compounds, methane, carbon oxides, ammonia, heavy metal particles, polycyclic aromatic hydrocarbons and sulfur dioxide.

The complex of pollutants emitted into the atmosphere through the exhaust gases contains substances with different degrees of toxicity. Thus, in addition to common pollutants (NOx, SO_2, CO, particles), there are substances with carcinogenic potential highlighted by epidemiological studies conducted under the auspices of the World Health Organization [3], namely: cadmium, nickel, chromium and polycyclic aromatic hydrocarbons (PAHs).

It is also noted the presence of nitrous oxide (N_2O) - a substance incriminated in the depletion of the stratospheric ozone layer - and methane, which, together with CO_2 have global effects on the environment, being greenhouse gases. The amount of pollutants emitted into the atmosphere by machinery depends mainly on the following factors:

- Engine type;
- Engine power;
- Fuel consumption per unit of power;
- Machine capacity;
- Age of engine / machinery.

Pollutant emissions decrease the more advanced the engine performance, the trend in the world being the manufacture of engines with the lowest possible consumption per unit of power and with the most restrictive control of emissions. Moreover, these two elements are reflected in the dynamics of both EU and US legislation in the field. For the conveyance, the above assessments regarding the correlations between the pollutant emissions and the technological level of the engine, the fuel consumption per unit of power or per 100 km, the age of the vehicle are also valid.

The equipment (excavator, bulldozer, front loader, and tractor) moves over short distances in the work area and there is an even distribution of emissions across the work areas. Maximum pollutant concentrations are achieved within this area. Dispersion studies completed with measurements show that, outside this area, the concentrations of air pollutants are substantially reduced. Thus at 20 m outside this strip the concentrations are reduced by 50% and at over 50 m the reduction is 75%. Along the transport route, the distribution of pollutants is considered uniform. From a chemical point of view, the dispersion is the result of the reactive characteristic of the air under the influence of solar radiation, atmospheric humidity, variability of thermal

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regime and turbulent phenomena through which the air is contacted with the soil and water surface, generating additional chemical interactions [4].

The resulting emissions have a strictly local effect in the area of the work fronts with effect within the perimeter of the coal pit, where the provisions of STAS 12574/87 "Air in protected areas" do not apply.

2.3. Coal ignition

Coal ignition is a process of slow oxidation in contact with air, being an exothermic phenomenon that can affect coal yards and outcrops in the coal pit. The observations made over time on the coal yards in the mining perimeters of Oltenia region regarding the behavior of the stored coal, led to the conclusion that the time interval favorable to self-ignition is from 30 to 90 days from the date of storage. Oxidation is rapid during this period and later the coal tends to stabilize its oxidation rate at a lower level. At the same time, it was found that the spontaneous oxidation of coal takes place in five distinct stages:

- Up to 48.7 ° C, the coal slowly absorbs oxygen from the air. The temperature continues to rise and when it reaches 76.6 ° C, favorable conditions for self-ignition occur in a time interval of approx. 72 hours;
- Oxygen absorption increases with stack temperature up to a range of 100-137.7 ° C;
- At 137.7 ° C, the carbon dioxide is removed with water vapor;
- The elimination of carbon dioxide continues to a temperature of 232.2 °C, at this temperature the coal ignites spontaneously;
- At 366.6 ° C the coal begins to burn.

The oxidation process, in addition to the appearance of fire nuclei, results in gaseous emissions of methane, ethane, carbon monoxide, sulfur dioxide, nitrogen dioxide, hydrochloric acid and polycyclic aromatic hydrocarbons. In order to be able to remove this undesirable phenomenon, it is necessary to know a series of aspects, among which the essential ones are both the properties and composition of the stored coals and the environmental factors. The environmental factors that have a greater or lesser influence on the quality parameters of the stored coal for a certain period of time are:

- Air temperature;
- Ground temperature (at the surface of the deposits);
- Relative humidity of the air;
- Atmospheric pressure;
- Wind action;
- Meteorological phenomena (fog, precipitation, snow layer thickness).

The characteristics of coals that show a strong tendency to self-ignite are:

- High oxidation characteristic rate;
- High friability;
- The presence of finely divided pyrites.

3. Particulate matter and field sampling

Dust is released from the starting point of the cutting operations by the excavator in the coal pit, the dumping of the material from the buckets on the belt conveyor and the dumping from one conveyor to another, in the relay of belts transporting waste and coal. Dumping the sterile in the dump from heights exceeding 20 m, the fall from the height of the material on the arm of the dump machine favors the formation of dust.

Through the measurements performed "in situ" (figure 1), for the dust concentration from different points (figure 2), it was found that the indices of the maximum concentration (MC-mg/m^3/air), on mining areas, were according to the legislation in force (table 5). At some points, the dust concentration is higher, but as the distance increases, the pollution is no longer felt, so the lignite extraction activity has a local influence.

Table 5. Particulate matter

No.	Sampling point	Results [g/m^2/month]				Maximum allowed value	Standard of reference
		Month					
		February 2021	March 2021	April 2021	May 2021		
1	sample point 1	28.77	35.29	28.68	24.38	17 g/m^2 / month	STAS 12574/1987
2	sample point 2	15.96	9.25	10.84	14.37		
3	sample point 3	20.70	8.33	10.75	14.93		

Revista Minelor – Mining Revue
ISSN-L 1220-2053 / ISSN 2247-8590
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Figure 1. Location of Roșiuța coal pit and sample points

There are also other activities which produce dust, like coal dumping in coal yards, shipping and loading into wagons.

During the use of the access roads in the coal pit, for the materials and spare parts supply at the working points, the conveyance forms dust as well.

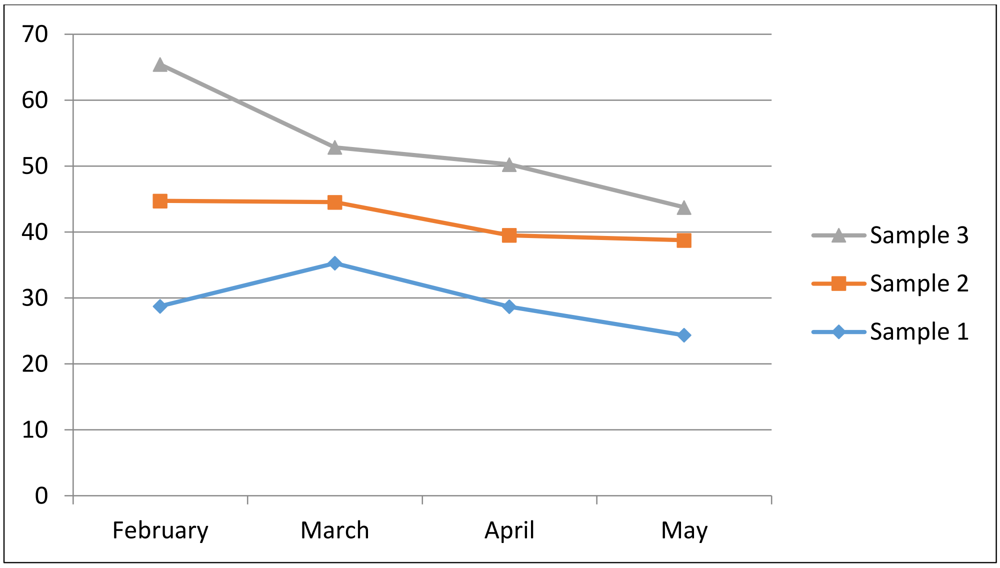

Figure 2. Particulate matter (g/m^2/month)

The emissions resulting from the exploitation of lignite in Roşiuţa I perimeter have a local effect in the area of the work fronts [5], inside the coal pit perimeter, where the provisions of STAS 12574/87 and O.M. 592/2002 replaced by Law no. 104/2011, only from the activity of coal storage and dispatch results exceeding the maximum allowed concentrations for sediment and particulate matter in the inhabited area.

4. Conclusions

The pollution produced on the environment by the coal exploitation in Roşiuţa coal pit is significant, with effects on the whole environment, including the human community. The environment protection actions and ecological restoration of waste lands in the works carried out in the coal pit area have the role of controlling and limiting the negative effects to ensure the restoration of bad lands to the natural conditions before mining.

The effects of the change in air quality, caused by the coal exploitation in Roşiuţa coal pit, can be noticed through the increase, in some areas, of the dust concentration, gas and smoke resulting from the development of the coal pit technology. Considering the technological process of coal exploitation, the sources of air pollution can be considered as the fixed equipment and mobile equipment.

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Dust is formed in the case of the material and spare parts supply at the working point on the technological flow with cars, on the access roads to the coal pit, which if not sprayed with water is a danger to the health of the staff who work in the area. The main pollutants are: suspended powders, particulate matter and burnt gases.

Emissions of dust and gases specific to machinery activities are assessed by the consumption of fuels and the area on which these activities take place (pollutants, particulate matter and sediment).

Mobile emission sources, regardless of their type, run on diesel engines, the exhaust gases in the atmosphere contain the whole complex of pollutants specific to the internal combustion of diesel engines: nitrogen oxides, non-methane volatile organic compounds, methane, carbon oxides, ammonia, heavy metal particles, polycyclic aromatic hydrocarbons and sulfur dioxide.

The main pollutants emitted into the atmosphere by the transport activities contain elements with different degrees of toxicity. Thus, in addition to pollutants like NOx, SO_2, CO and particles, there are elements with carcinogenic potential highlighted by epidemiological studies conducted by the WHO, namely: cadmium, nickel, chromium and polycyclic aromatic hydrocarbons.

Through the measurements performed "in situ", for the dust concentration from different points, it was found that the indices of the maximum concentration (MC-mg/m^3/air), on mining areas, were according to the legislation in force. At some points, the dust concentration is higher, but as the distance increases, the pollution is no longer felt, so the lignite extraction activity has a local influence.

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