

Assessment of gas emissions from oil mines in Romania

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Abstract. Methane is responsible for around 30% of the rise in global temperatures since the Industrial Revolution, and rapid and sustained reductions in methane emissions are key to limiting near-term global warming and improving air quality. The energy sector – including oil, natural gas, coal and bioenergy – accounts for more than 35% of methane emissions from human activity and has some of the best opportunities to cut these emissions. The annually updated Global Methane Tracker is an essential tool for raising awareness about methane emissions across the energy sector and the opportunities to bring them down [7,8,9]. In Romania, there is only one oil mine in operation, Sărata Monteoru, and two oil mines in conservation (Matița and Solonț). The purpose of these works is to establish the gas emissions regime (methane, its counterparts and carbon dioxide) and the calculation of gas emissions into the atmosphere at the Sărata-Monteoru and Solonț oil mines following their classification.

1 Introduction

The presence of methane gas and its counterparts in the atmosphere of the underground works of the Monteoru and Solonț Oil Mine was highlighted during the mine opening, preparation and exploitation of the deposit [1].

The extraction of crude oil at Sărata-Monteoru dates back to the middle of the 19th century, and was initially carried out with the help of short wells, in which the crude oil was collected by gravity drainage. As the crude oil reserve was depleted, the wells required gradual deepening, so some of them were dug to depths of approx. 300 m.

Starting from 1925, the exploitation of crude oil by mining methods was carried out, for which purpose a network of mining works was executed at the level of the horizon + 44 m and later they were extended to the level of the horizon - 25 m.

There are various oil mines in the world, but few are considered true "mines" in the classic sense of underground mining. Sărata Monteoru in Romania is home to such a mine, unique in Europe for its method of extracting oil through underground galleries. It is a tourist attraction, but also a historical site, dating back to 1874.

The Sărata Monteoru oil mine. It is considered unique in Europe due to the method of oil mining. It was functional until recently, but could not be visited.

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It was an ambitious project, started in 1925, for the extraction of oil through underground galleries.

Other oil extraction areas:

Although they are not mines in the classical sense, many countries have large oil reserves and extract them through drilling:

-Venezuela: Has the largest oil reserves in the world.

-Saudi Arabia: Is a major oil producer and exporter.

-Canada: Has significant reserves, especially in the tar sands, but extraction is more difficult.

-Iran: Another country with significant oil reserves.

-The United States: Has become the largest oil producer thanks to hydraulic fracturing and horizontal drilling technologies.

Note: Oil extraction is generally done through drilling, and mines are rather an exception.

2 Geological and mining data

The Sărata-Monteoru structure is the northeast periclinal termination of the anticlinal fold that develops between Tohani and Sărata-Monteoru over a length of approx. 23 km.

In the axial zone, in the Monteoru sector, the Sarmatian appears, consisting of sands, calcareous sandstones, limestones and gray marls, with important facies variations, over which follow the Meotian deposits represented by calcareous sandstones and alternations of sands, marly sands, marls and less often mistakes. The Pontian is made up of marls at the bottom and top and of sands in the middle part. Above the Pontian deposits, follows the Dacian consisting of sands interspersed with marls, clays and lignite layers.

The Levantian, placed concordantly over the Dacian, is composed of sands in the lower part and gravels, sands, marls and clays with cross-stratification in the upper part.

In terms of tectonics, the system of transverse and longitudinal faults divides the structure into tectonic blocks - 2 in the Meotian and 4 in the Sarmatian - and causes the whole structure to sink in steps towards the NE.

The Meotian crude oil accumulations are of stratiform type and are located in a structural trap, screened at the top by marls and laterally by tight faults.

The analysis of the geological documentation highlights the following important aspects regarding the stratigraphy, structure and type of the gas and oil collecting rocks and the surrounding rocks.

- the rock complexes collecting crude oil, mainly composed of sands and sandstones, are located in the Sarmatian and Meotian;

- the Meotian complex in block I - Sărata Monteoru mine sector - taken into account by increasing the final factor of recovery of crude oil from the deposit by tertiary methods, including mining, includes 7 complexes of porous - permeable rocks with 27 layers impregnated with crude oil, of industrial importance;

- most of the formations, both useful and sterile, are thin (77% with thicknesses below 5 m), and the distance between the complexes varies between 10 and 18 m, with the exception of complexes I (upper) and VII (lower) which are further apart (28 m between complex I and II, respectively 75 m between complex VI and VII);

- in the package of useful layers, barren rocks are represented by clays, marls and sands. Marls and compact clays appear in the roof of the productive complex.

- from a petrographic point of view, the structure of Sărata Monteoru is characterized by large variations in facies, in the lithological structure there are frequent transitions from one type of rock to another;

- the inclination of the strata determined on the cores varies between 300 and 550, with a tendency to increase with depth. The average inclination is 350;

- from a hydrogeological point of view, at the level of the Sărata Monteoru mine (+ 44 m), the water pressure is reduced as a result of the drainage of the layers with intermediate waters intercepted with the mining works.

The analysis of the physical-mechanical and physical-geological properties of rocks in the context of the mechanism of gas migration and the production of dynamic phenomena reveals the following:

- the high porosity (30%), shows the great possibilities of fluid storage by the collecting rocks;
- permeability reaching values of 1600 mD denotes a high filtering capacity. This shows that they can favor the migration of gas and oil towards the mining works excavated in such formations.
- sandstone-type rocks have high mechanical resistance, being similar from this point of view to those found in the Jiului Valley. The high permeability and the possibility of keeping the gas migration paths free for a long time favors their slow release.
- the clayey-marly type rocks have a low mechanical resistance and zero or very low permeability. As a result, they can constitute tight screens in the migration of gases but insufficiently resistant in conditions of increased pressure, consequently favoring the production of gas dynamic phenomena.

The geology at both oil mines is similar.

3 Current mining works

3.1 Current mining works executed at Sărata-Monteoru

Currently, the network of mining works of the Sărata-Monteoru oil mine (figure no. 1) consists of:

- two wells: well 50 - for extraction and well 42 - for aeration;
- directional galleries located at + 44 m and - 25 m horizons;
- two ventilation shafts between the horizons – 25 m and + 44 m;

The exploitation of crude oil is carried out, both by gravity drainage from the horizontal wells executed in the walls of the mining works, and in the air-lift system from the descending vertical wells, executed from the drilling chambers from the two horizons.

The crude oil is collected in a pool and then pumped to the surface. (Figure no. 1 Monteoru Oil Mine)

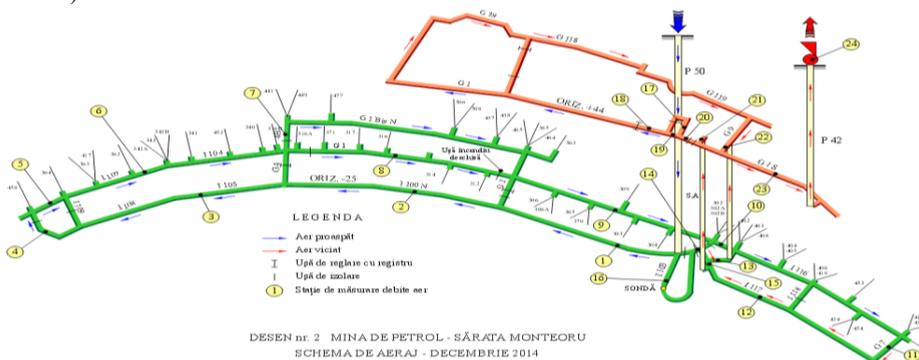


Fig. 1. Monteoru Oil Mine

3.2 Current mining works executed at Solont

A main fan station is used to provide general ventilation for the Solont Mine. This station is equipped with two identical ventilation units, one in operation and the other as a backup, in working condition.

The ventilation system is suction

The main ventilation station within the Solont Mine is located on the surface, at the base of gallery T1.(Figure no. 2 Solont Oil Mine)

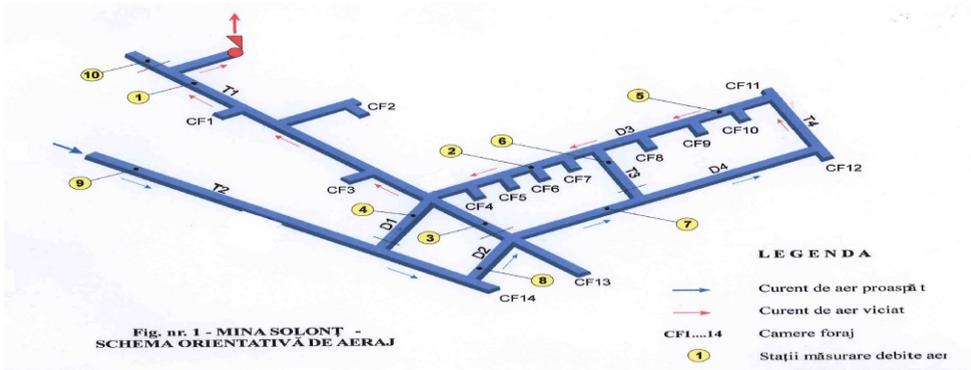


Fig. 2. Solont Oil Mine

4 Mine ventilation

4.1 Mine ventilation system Monteoru

The mine is ventilated in a suction system by means of a main ventilation installation, located on the surface (at the mouth of shaft no. 42).

The installation is equipped with two V 543-M-IQ type centrifugal fans, one of which is in operation and the other is spare. The nominal parameters of these fans are:

- flow rate 130.000 m³/h;
- depression 215 mm H₂O;
- speed 600 rpm.

The fans are driven by 2 identical electric motors of 160 kw at a supply voltage of 400 V.

4.2 Mine ventilation system Solont

The ventilation systems are equipped with a centrifugal fan type V 444/1, having the following technical characteristics:

- fan flow rate, QV = 90.000 m³/h;
- fan depression, Hv = 69 mm H₂O;
- speed, nv = 515 rot/ min

5 Specific measurements performed in underground mining works

In order to classify the mining works related to the Sărata-Monteoru oil mine and Solont oil mine from the point of view of gas emissions, INCD-INSEMEX Petroșani carried out measurements specific to oil mines during September 2023.

The qualitative and quantitative measurements of the underground atmosphere were carried out at the level of the network of mining works related to the mine, respectively at the horizon + 44 m and the horizon - 25 m. [2,3].

Through the measurements, the evolution of gas concentrations (methane and its counterparts and carbon dioxide) and the air flows circulated through the mining works were followed.

The circulated air flows and the value of the existing gas concentrations were determined, respectively measured:

- in the exhaust currents of the contaminated air from the mine;
- in the discharge currents of the stale air from the two horizons;
- in the air currents on the route of the mining works;
- in niches, at the level of the boreholes and in the borehole chambers;
- at the level of collecting basins.

The results of the specific measurements performed are presented centrally in table no.1 in Monteoru oil mine and no.2. in Solont oil mine.

Table 1. Specific measurements Monteoru

Nr. Stat	Place of measurements	Horizon	Q (m ³ /min)	The composition of the underground atmosphere				Remarks
				CH ₄ (% vol.)	% *LIE echiv.CH ₄	CO ₂ (% vol.)	O ₂ (% vol.)	
0	1	2	3	4	5	6	7	8
1.	Gallery G 1 S for pit 42	+ 44 m	1285	0,05	1	0,1	20,7	Exit General from the mine
2.	Gallery G 9	+ 44 m	761	0,075	1,5	0,1	20,8	Exit from the horizon
3.	Gallery G 103 A	- 25 m	SLM	0,1	2	0,2	20,7	The exit from the pools
4.	Gallery I 117	- 25 m	738	0,15	3	0,1	20,7	Exit General from the mine
5.	Gallery G 7	- 25 m	695	0,1	2	0,1	20,8	Exit from the horizon
6.	Gallery G I	- 25 m	308	0,1	2	0,1	20,8	Aeration undermine depression
7.	Gallery I 107	- 25 m	492	0,05	1	0,1	20,8	Aeration undermine depression
8.	Gallery G 9	- 25 m	-	1,75	35	0,1	19,2	Bottom of the bag

9.	Dead-end mine working 441 - 449	- 25 m	-	2	40	0,3	19,1	Bottom of the bag
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Table 2. Specific measurements Solont

Nr. crt.	Place of performance measurements	The composition of the underground atmosphere			Q (m ³ /min)	Remarks
		CH ₄ (LIE)	CO ₂ (%vol.)	O ₂ (%vol.)		
0	1	2	3	4	5	6
1.	Gallery T1, before fan duct	1	0,07	20,8	989	Main mine exit
2.	Gall. D3, after gallery T1	0	0,1	20,8	500	
3.	Gall. T1, before gallery D1	0	0,07	20,8	288	
4.	Gallery D1	0	0,05	20,8	201	
5.	Gall. D3, before gallery T3	0	0,1	20,8	295	
6.	Galeria T3	0	0,08	20,8	205	
7.	Gall. D4, before gallery T3	0	0,06	20,9	500	
8.	Gallery D2	0	0,07	20,9	788	
9.	Gallery T2	0	0,06	20,9	982	Fresh air intake
10.	Gallery T1	0	0,05	20,9	262	Short circuit

The measurements were made at the level of the wells during the extraction, both at the ceiling of the work and at their base, recording the highest value.

At the same time, in the work on: "Preliminary assessment of the degree of danger of gases, vapors and crude oil from petroleum structures, under exploration under the conditions of crude oil extraction through mining works", prepared by INCD - INSEMEX Petroșani, it resulted that for the existing deposit conditions in the Sărata-Monteoru oil structure and Solont oil mine, the existing degree of danger is characterized by:

- the danger of explosion of gaseous hydrocarbons and liquid hydrocarbon vapors present in the underground atmosphere;
- the risk of fire from liquid hydrocarbons entering the mining works.

The gas emissions released into the atmosphere by the ventilation stations at the two oil mines are included in Tables 3.

Table 3. Gas emission by the ventilation

Nr Crt	Mine	Air flow (m ³ /min)	Methane and homologs concentration (%LIE)	Methane equivalent emitted at the aeration station (m ³ /min)	Methane equivalent emitted at the aeration station (m ³ /year)	Methane equivalent emitted at the aeration station (kg/year)	Methane equivalent emitted at the aeration station (tone/year)	Production (tone/year)
0	1	2	3	4	6	7	8	9
1.	Monteoru	1285	1	0,6425	337.698	187,08	0,187	1.825
2.	Solont	989	1	0,49	257.544	142,67	0,142	60

The calculation of the total amount of methane released into the atmosphere was made by relating the absolute flow of methane recorded in the year 2024 to the density of this gas in relation to air ($q=0.554\text{kg/m}^3$).

6 Conclusions and proposals

The specialized research, observations and measurements carried out in the underground mining works related to the Sărata-Monteoru and Solont oil mine, during September 2023, led to the establishment of the following [4,5,6]:

- a) The analysis of the geological documentation, of the physical-mechanical properties of the rocks, of the gas migration mechanism in the mining works, reveals the following, the high porosity of the rocks, up to 30% of their volume, shows the great possibilities of fluid storage by the collecting rocks;
- b) The exploitation of crude oil is carried out, both by gravity drainage from the wells executed in the walls of the mining works, and in the air-lift system from the downward vertical wells, executed from the drilling chambers from the two horizons.
- c) Mine ventilation is carried out in a suction system by means of a main ventilation installation, located on the surface.
- d) The dangerous nature of the underground atmosphere at the Sărata-Monteoru and Solont oil mine, from the point of view of the production of gas and vapor explosions, is reflected by the low value of the lower limit of explosiveness - which varies from 0.8% to 3/ 4 %, i.e. between the values of the lower explosive limit of crude oil vapors and primary (well) gases.
- e) The most frequent form of gas release, encountered both during the execution of underground mining works and during exploitation, is the slow emanation of gases and vapors.
- f) Based on the results obtained, from the measurements and determinations made, of the assessment of the degree of danger presented by the gaseous, liquid and vapor hydrocarbons from the underground atmosphere, it is proposed to include the underground mining works related to the Sărata-Monteoru and Solont oil mine in the category of mines with: **FIRE DAMP REGIME of CATEGORY I** from the point of view of methane emissions and in **CATEGORY I** from the point of view of carbon dioxide emissions.
- g) From the analysis of the results obtained and presented in this work, the following can be deduced:
 - air flow rates had values of;
 - 1285 m³/min for the Sărata-Monteoru;
 - 989 m³/min for the Solont;
 - flow rates that satisfy the air requirements of the 2 mines.
- h) methane and homologs emissions into the atmosphere:
 - 0,187 (tone/year)for the Sărata-Monteoru oil mine,
 - 0,142 (tone/year) for the Solont oil mine
 - production:
 - 1825 tone/year t for the Sărata-Monteoru oil mine;
 - 60 tone/year for the Solont oil mine.

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