The impact of EXtreme weather events on MINing operations

TEXMIN

European Commission

Research Fund for Coal & Steel

Gas emissions form closed mine in light of climate change

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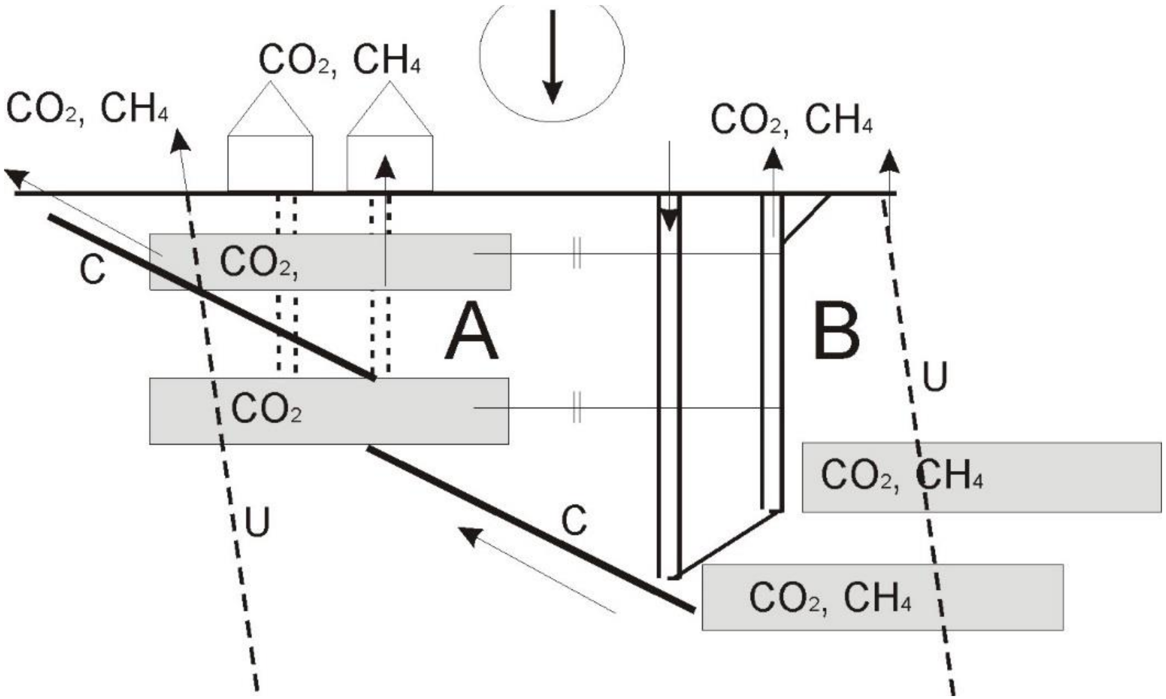
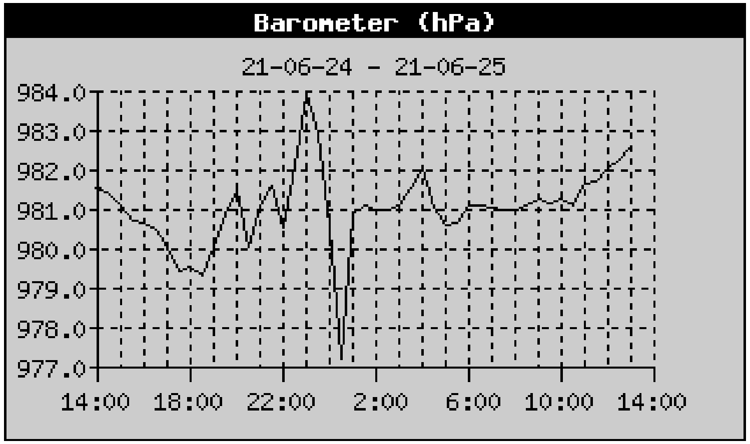
The process of gas emissions from an abandoned mine

pressure drop





An extreme pressure drop recorded during the duration of TEXMIN project

Climate change is likely to result in a **greater intensity and frequency of storms associated with deep low-pressure systems** (Falarz 1997; Ustrnul & Czekierda 2000; Trepińska, 2007). Barometric pressure drops will increase in frequency and magnitude during severe weather events. In addition, a greater number of days with a low pressure are also expected.

These more extreme atmospheric events and, consequently, deeper pressure drops could lead to more gas emissions from underground mines (Lagny et al., 2013; Wrona et al., 2016a). Future projections of maximal pressure tendency for Polish territory can be computed based on e.g. (Falarz, 1997; Bielec-Bąkowska, 2007; Koźmiński & Michalska, 2010).

Maximal 24h pressure changes (drops) over the period 1986-2007 varied during the winter between 966.1 hPa and 1049.4 hPa, (**3.47 hPa/1h**), and during the summer between 990.7 and 1031.5 hPa (1.7hPa/1h) (Falarz, 1997; Koźmiński & Michalska, 2010). There were 23 days of the year with intense low pressure (pressure in the center of a baric system was from 945 hPa to 985 hPa) and 11 days with strong high pressure (pressure in the center of a baric system was from 1040 hPa to 1050 hPa (Bielec-Bąkowska, 2007). A detailed analysis for southern Poland (near The Upper Silesia Region) has been conducted by Falarz (Falarz, 1997). **Considering the Kraków area, she stated that in the future a significant pressure drop of 4 hPa/1h or even 5 hPa/1h should be expected at least once every 2 years, mainly in January. Once in every 10 years the pressure drop could exceed 5 hPa/1h, also in January.**

Connections between the tasks on gas emissions from a closed shaft being performed by SUT

In situ measurements (task 2.2 + task 2.3)

validation

The models (task 3.3)

Excpected extreme weather event

MAXIMAL variation of pressure, temperature and wind speed
according to the results from WP1
and additional literature studies

safe distance from the shaft being closed:

- measured (task 2.3)
- forecast (task 3.3)

a factor for **gas hazard evaluation** (task 4.1.2)

An example of
a map of a gas hazard
for a post-mining area

The results of measurements (Tasks 2.2 + 2.3)

The measurements were divided into two groups:

- G1 - measuring of gas emitted through the emission point – temperature,

velocity, gas concentrations (carbon dioxide, oxygen, methane and carbon monoxide).

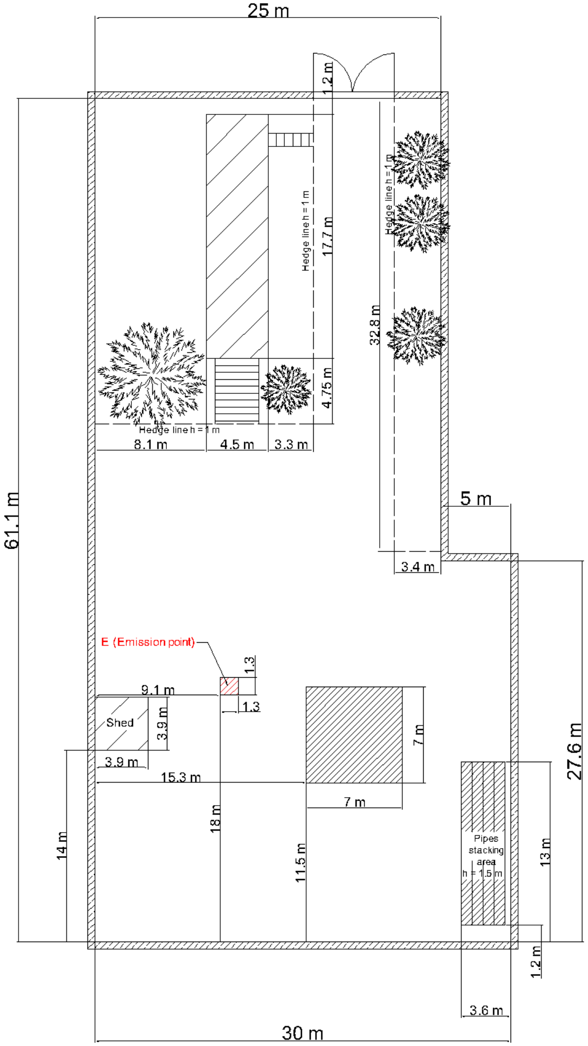
- G2 - measuring of carbon dioxide and oxygen concentration in vicinity of

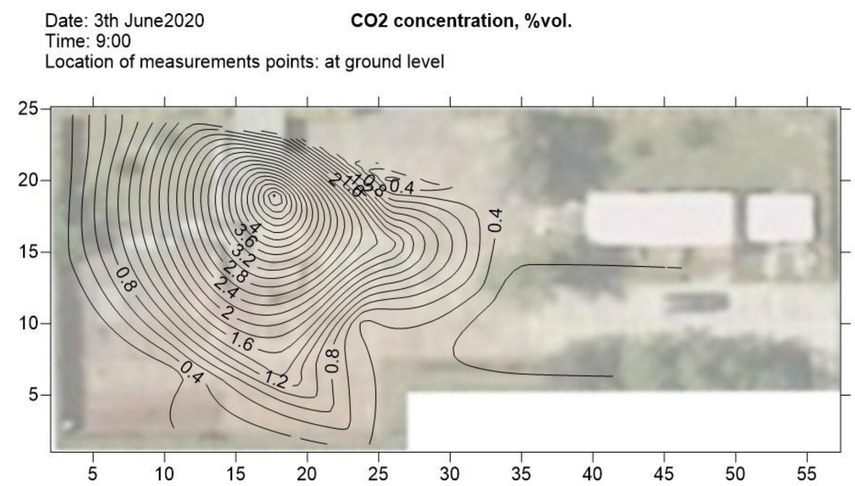
II shaft at two levels – ground level and 1 meter above the ground.

In addition following data in vicinity of II shaft was gathered:

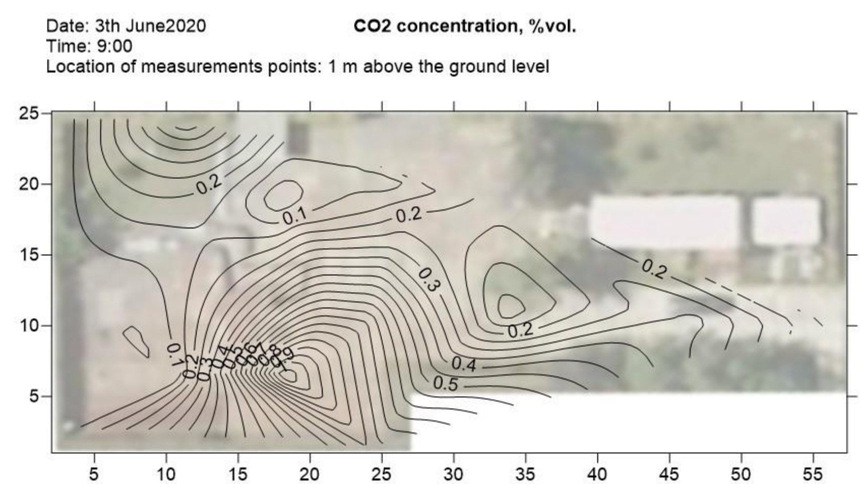
- temperature of atmospheric air (ambience),
- wind speed,
- wind direction.

The results of measurements (Tasks 2.2 + 2.3)



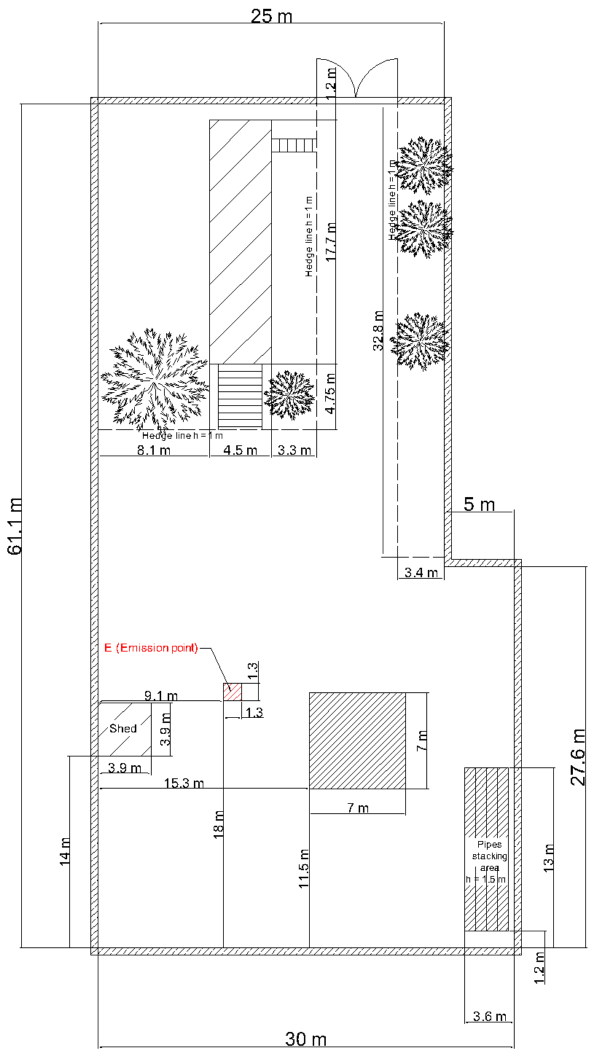


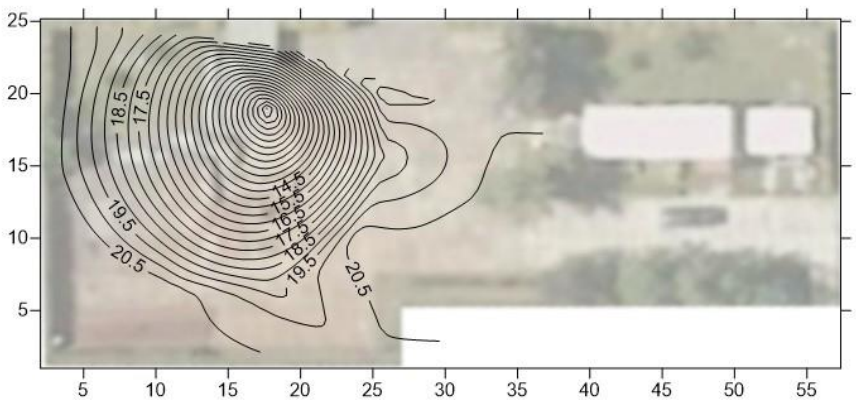
CO_2 ground level, 03.06.2020, 9:00 AM



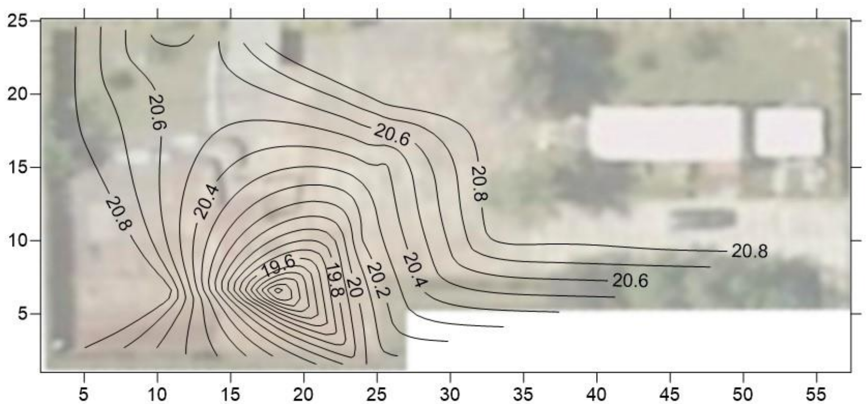
CO_2 1m, 03.06.2020, 9:00 AM

The results of measurements (Tasks 2.2 + 2.3)



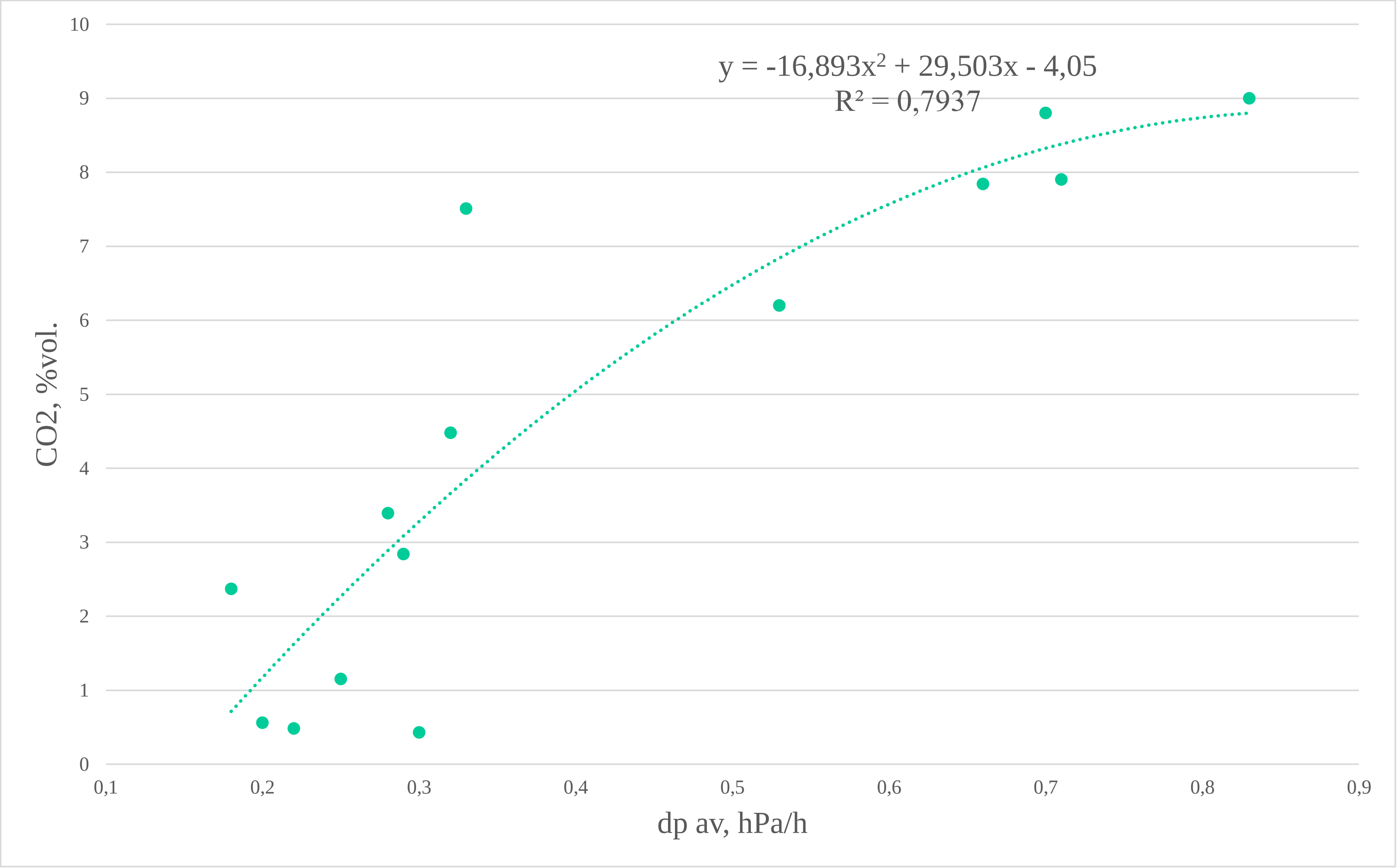


O_2 ground level, 03.06.2020, 9:00 AM



O_2 1m, 03.06.2020, 9:00 AM

The results of measurements (Tasks 2.2 + 2.3)



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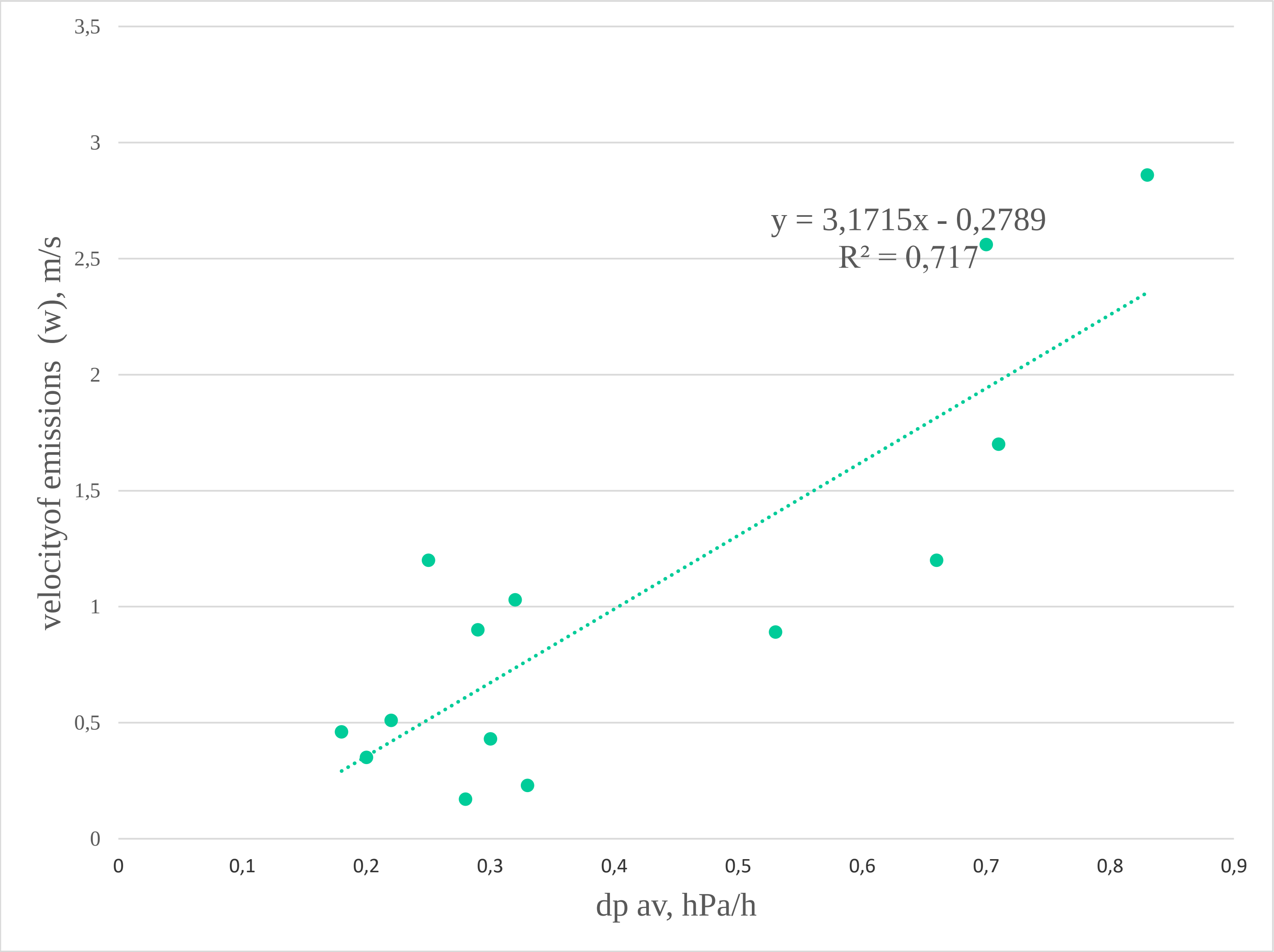

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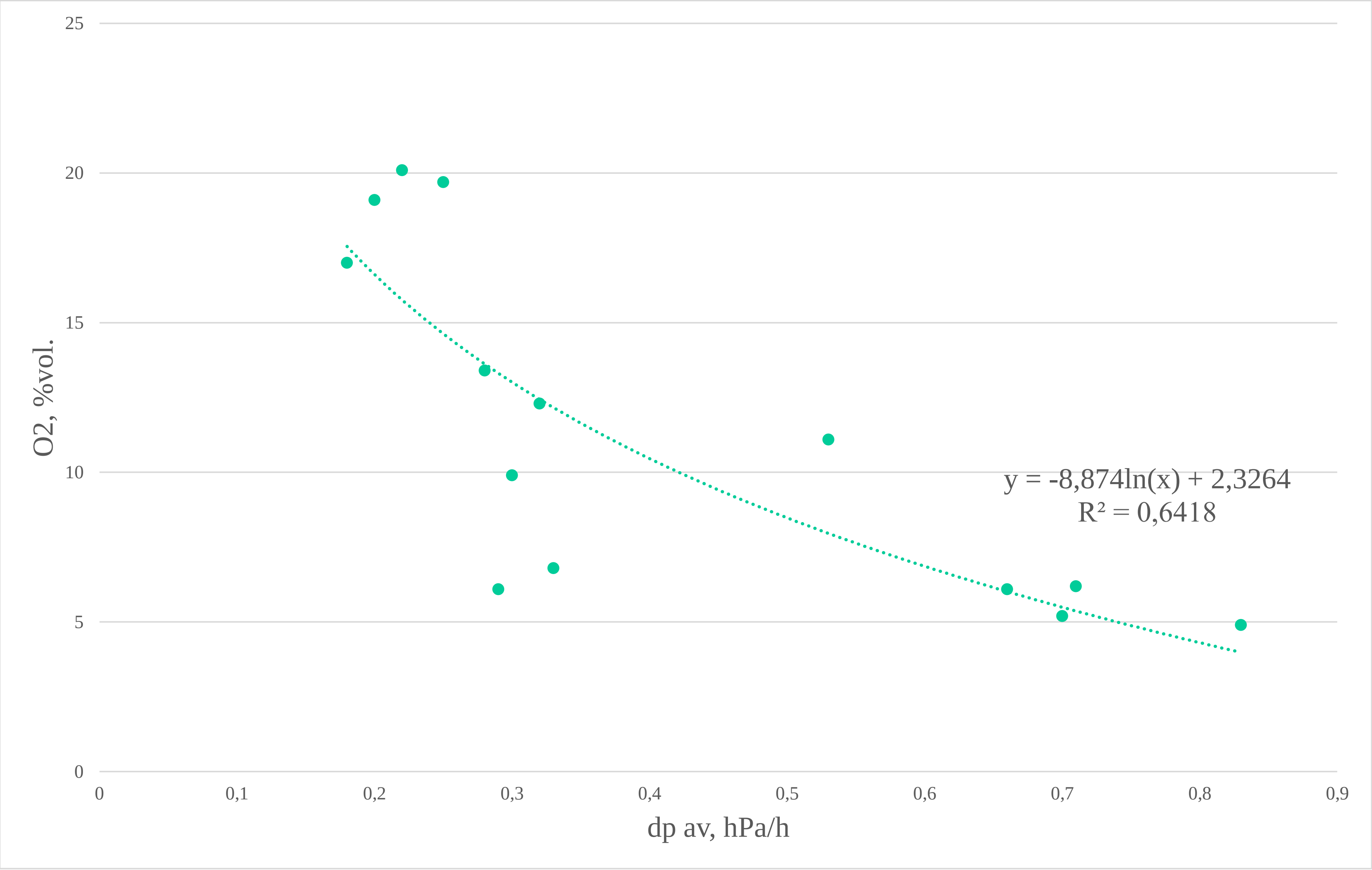
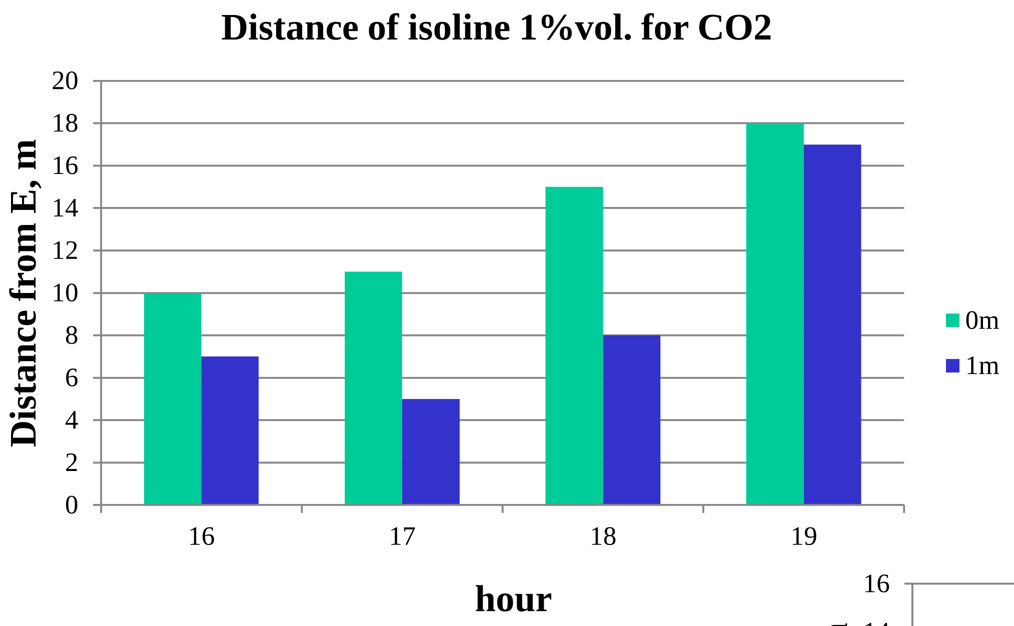
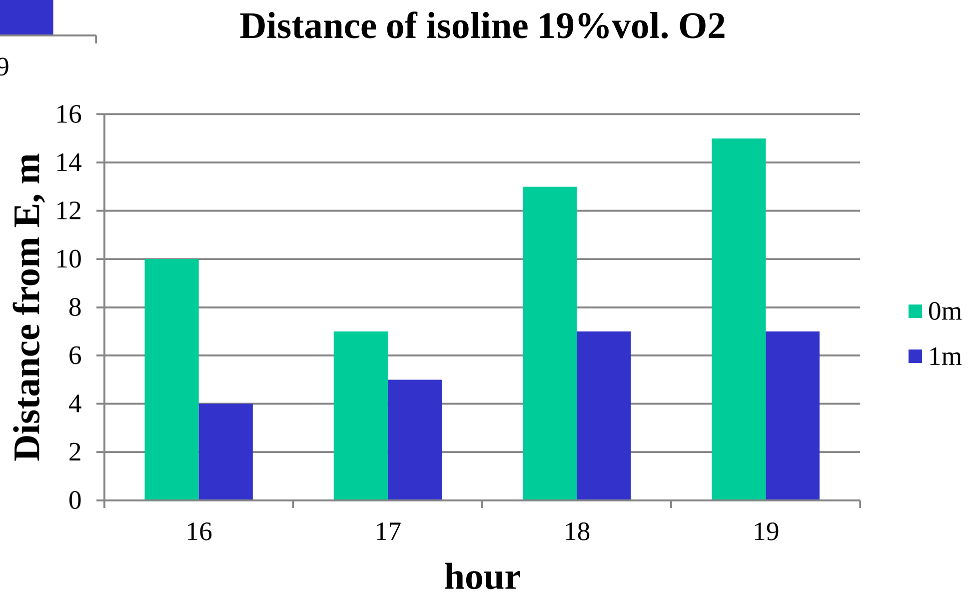


An example of the changing distance of the gas concentration isoline from the emission point during the pressure drop





CH_4 and CO were NOT detected (but it must be mentioned that according to literature studies these gases can be expected in other post mining regions or even in tested region in the future). The highest value of CO_2 concentration in emitted gases was 9.0% vol. and the highest gas emission velocity from the shaft was 2.86 m/s. The lowest oxygen value in the emitted gases was 4.9% vol. it was found when the mean negative value of the baric trend was -0.83 hPa/h.

It was found that the process of gas emission from closed mines is subject to inertia, which can be observed during very dynamic weather phenomena (e.g. an extreme weather event). The period of atmospheric pressure increase does not always mean a safe gas situation in the vicinity of the shaft, as stated on August 22, 2020, the emission of gases from a closed shaft may persist even an hour after the baric tendency has changed from negative to positive.

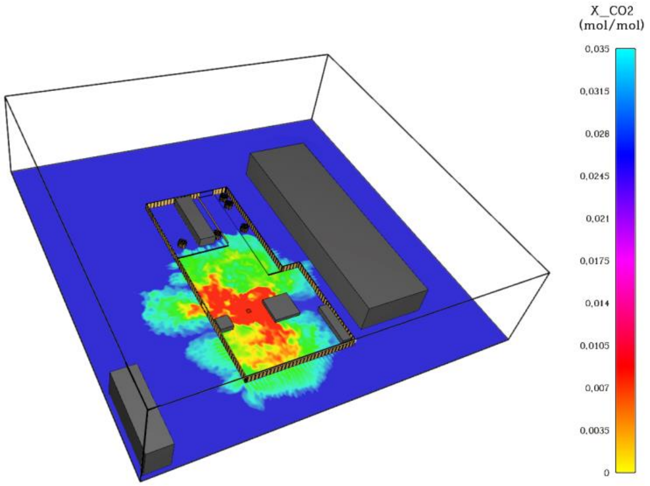
Analysing variation of gas distribution around the shaft II during a pressure drop it can be stated that in the measuring area, an increased concentration of carbon dioxide and a reduced oxygen concentration were found up to the border of the area, i.e. at a distance of 40 m from the emission source.

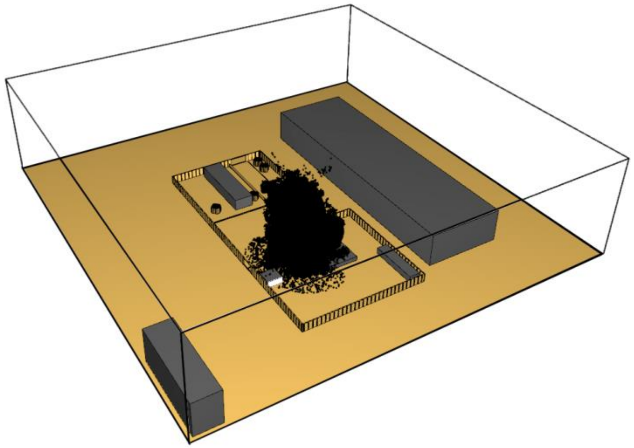
The results indicate that both the overall mean value of the baric tendency and its type have an impact on the values of the measured parameters (emission velocity, gas concentrations), but the hourly pressure changes may cause some additional fluctuations.

Numerical modeling (Task 3.3)

Two tools were in use:

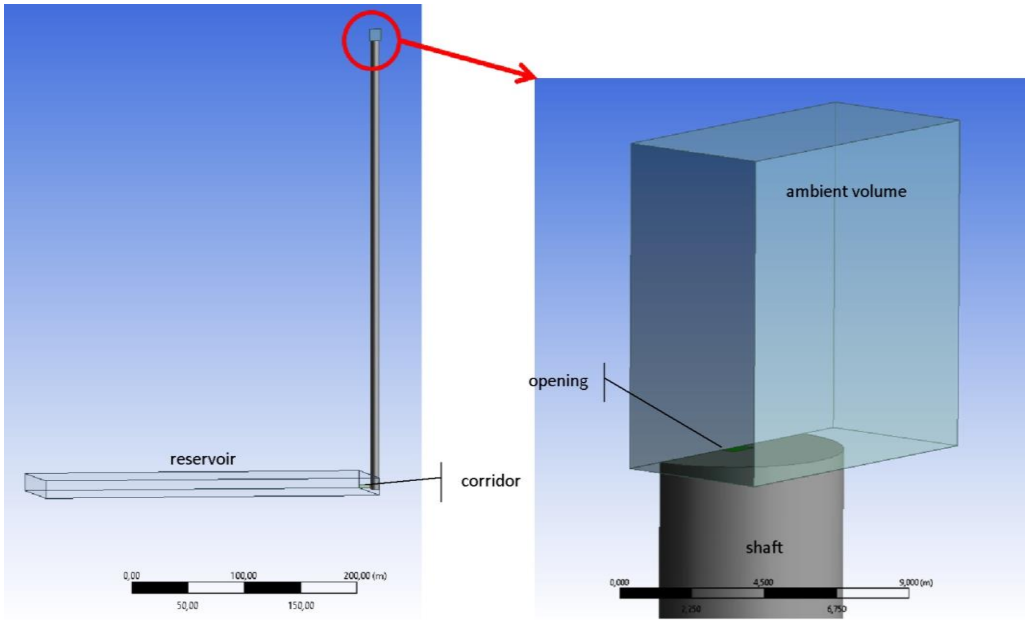
- Ansys Fluent
- FDS (Pyrosim)



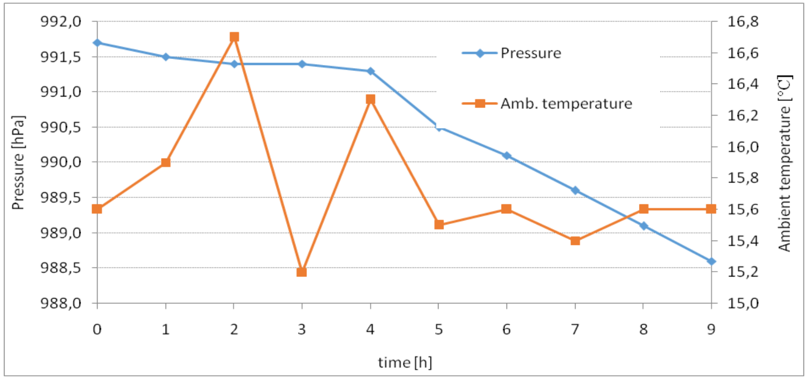


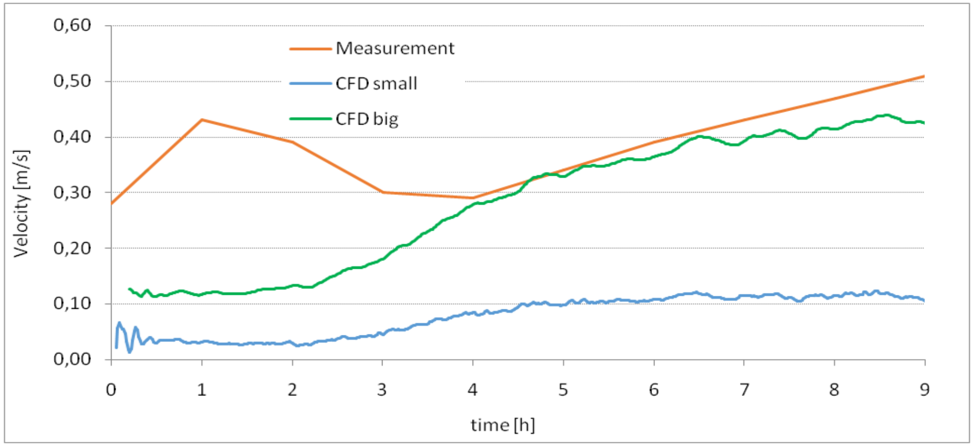
Numerical modeling (Task 3.3)

Ansys Fluent



Validation

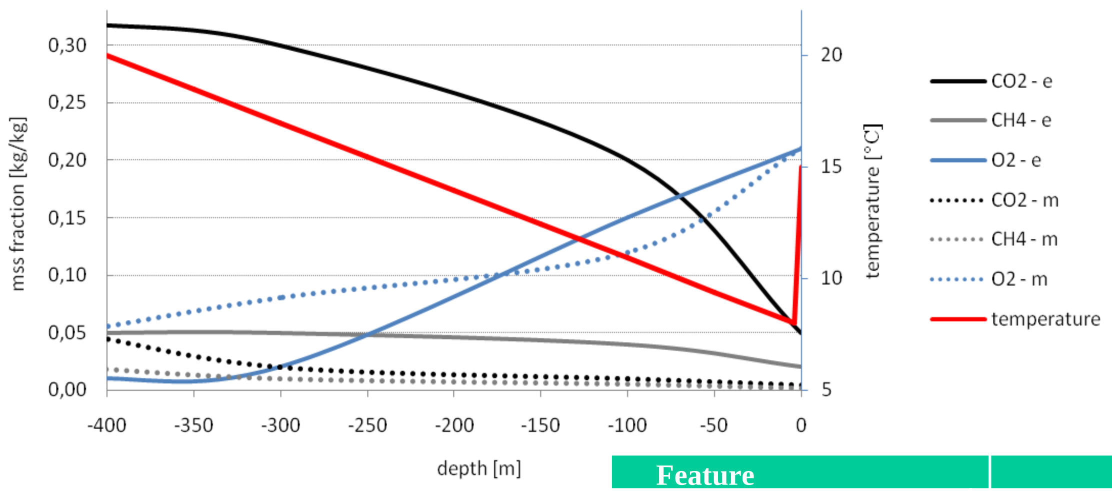




Examined cases - variants

Case	Excavation	Barometric tendency [hPa/h]	Gases mixture	Sand plug
1	large	3.5	E	sand
2	large	3.5	M	gravel
3	large	7.0	M	gravel
4	large	7.0	M	sand
5	large	7.0	M	fine sand
6	small	3.5	E	sand
7	medium	3.5	E	sand
8	medium	3.5	M	gravel
9	medium	7.0	M	gravel
10	small	3.5	M	gravel
11	small	7.0	M	gravel
12	small	7.0	M	sand
13	small	7.0	M	absence
14	medium	7.0	M	absence
15	large	7.0	M	absence

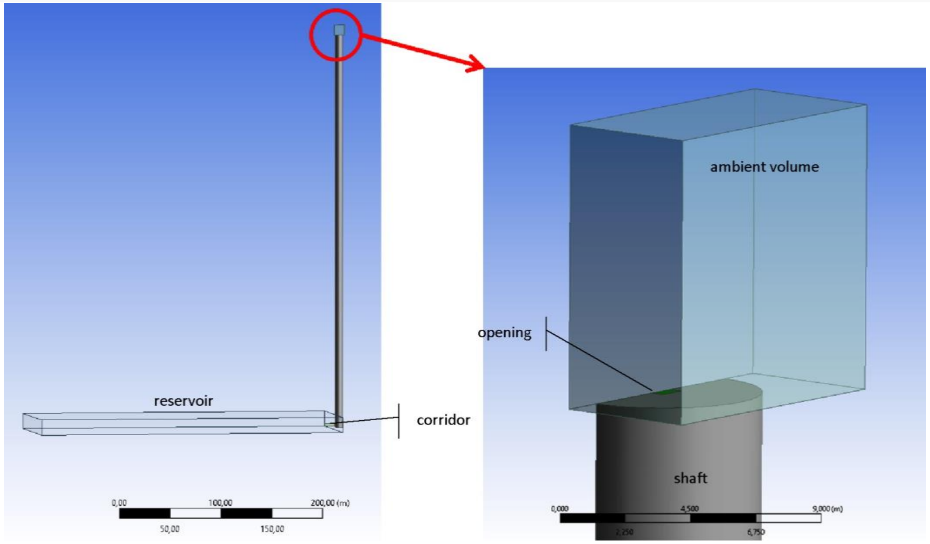
Numerical modeling (Task 3.3)

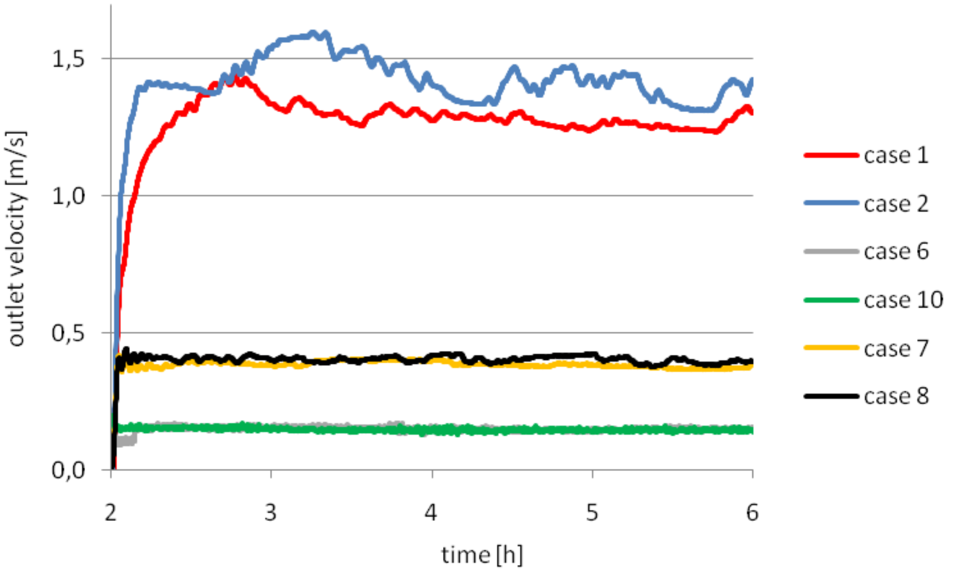


Initial compound of gases mixture (e – estimation, m – measurement) and the temperature distribution

Feature		Value
Turbulence model		k-epsilon realizable
Fluid material		Mixture: air, methane, carbon dioxide (ideal gas)
Operating pressure		98700 Pa
Gravitational acceleration		9.81 m/s^2
Solver		Pressure based
Pressure / velocity coupling		Simple
Under-relaxation factors	Pressure	0.4
	Momentum	0.5
	Energy	0.95
	Others	Default
Time step		1 s

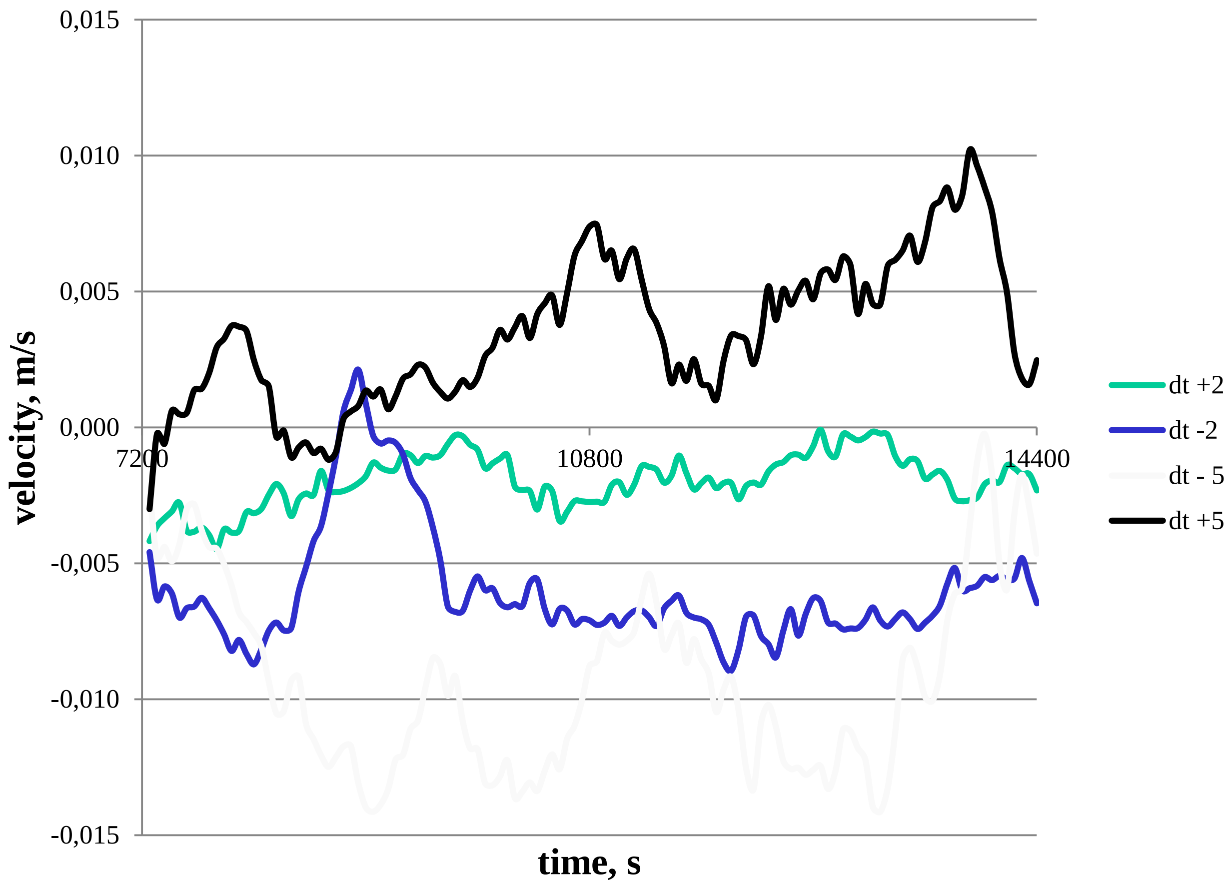
Numerical modeling (Task 3.3)





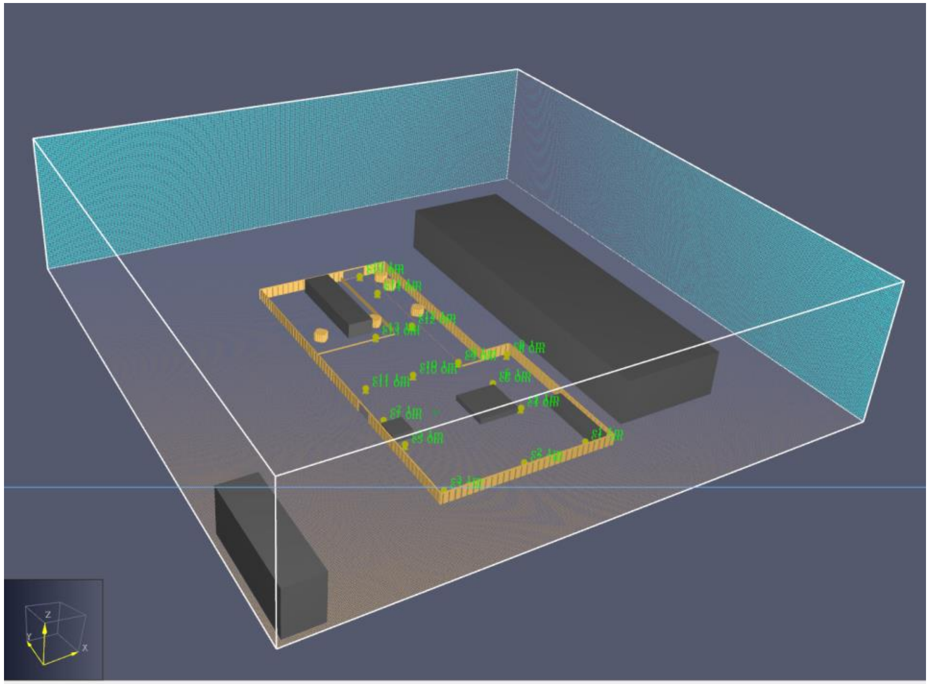
Numerical modeling (Task 3.3 and 2.2)

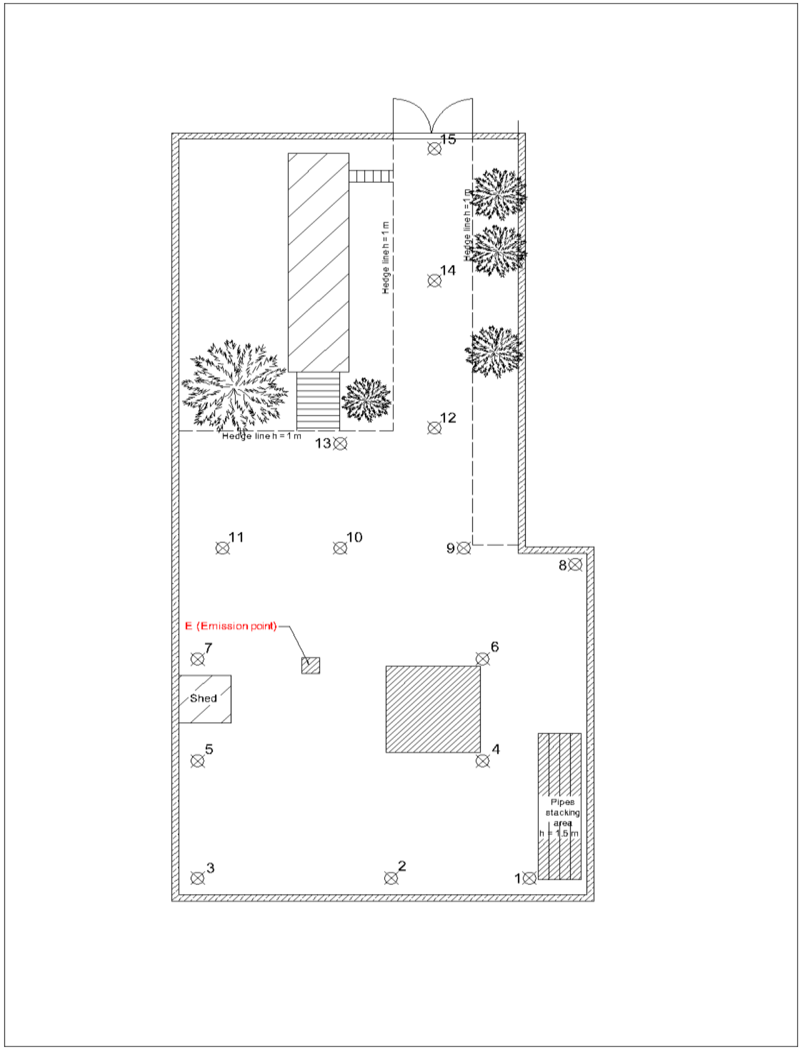
The influence of temperature increase on gas emissions velocity



Numerical modeling (Task 3.3)

FDS/PYROSIM





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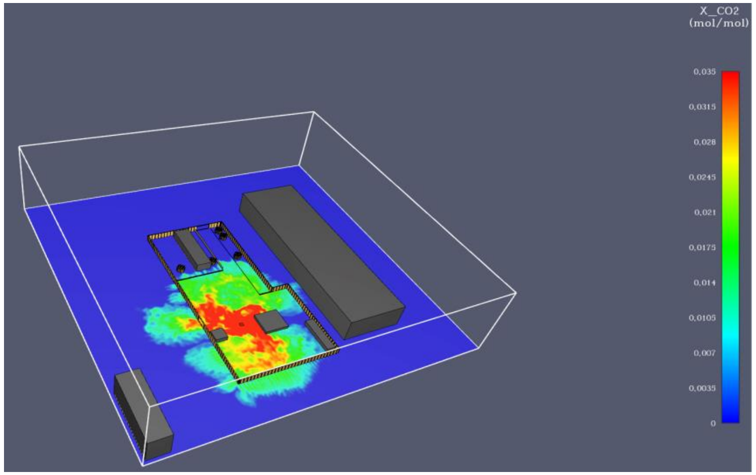
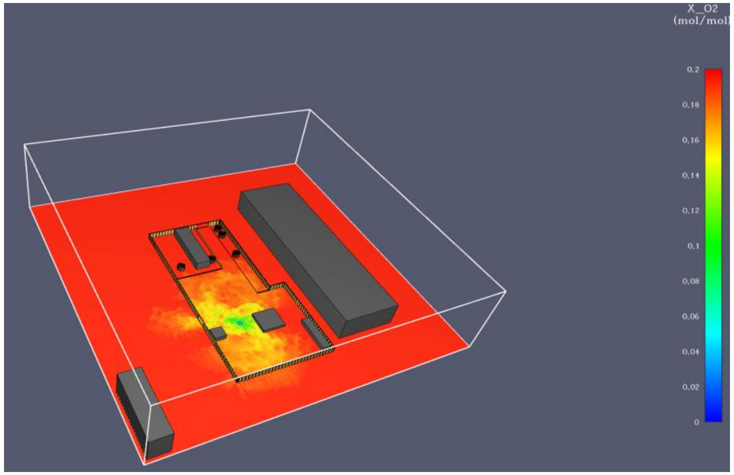
The models (3.3)





- Lack of wind contributes to the maintenance of an increased concentration of emitted gases in the vicinity of the liquidated shaft, the range of the zone with increased concentration of emitted gases, which may pose a threat to people, **is about 25m**.

- The wind significantly dilutes the pollutants emitted from the abandoned shaft, but causes hat the range of the emitted stream of gases **to exceed 50 m** in the direction of the wind.

A method to determine gas hazard at the surface of a post-mining area (4.1.2)

The method is based on key questions

Part A	
1. Has a mining area been established in the area?	If YES, go to 2, If NO, end of the procedure – no gas hazard
2. Has there been, is or is mining operation in the given mining area?	If YES, go to 3, If NO, end of the procedure – no gas hazard
Part B	
3. Is the decommissioned shaft located within 50 m from the building?	0/1
3a. Is the liquidated shaft located within 10 m from the building?	0/1
4. Is the fill level lower than the clearing level? (When the shaft is located more than 50 m - value 0, if the backfill level cannot be determined - value 1.)	0/1
5. Is there a former shallow mining area of one coal seam under the facility?	0/1
5a. Was more than one coal seam mined under the facility in the former shallow exploitation area?	0/1
6. Is the thickness of the overburden less than 100 m?	0/1
6a. Is the thickness of the overburden less than 50 m?	0/1

The method is based on key questions

7. **Is the time from shaft decommissioning less than 30 years?** (In the case of an active shaft take 1,in the absence of information, count the time since the closure of the mine to which the shaft belonged)	0/1
7a. Is the time from shaft decommissioning shorter than 5 years? (In the case of an active shaft take 1, in the absence of information, count the time since the closure of the mine to which the shaft belonged)	0/1
8. Is there a fault line up to 50 m from the facility that reaches the carbon roof?	0/1
8a. Is there a fault line up to 10 m from the object up to the carbon ceiling?	0/1
9. Has there been no reconstruction of the underground water table so far? (return to first status) (When it is not known, fill 1)	0/1
SUM:	

The evaluation of the result and the gas hazard categories resulting from the sum of the points are presented below:

11 - 12 points -	very endangered area, category 6.
9 - 10 points -	significantly endangered area, category 5.
7 - 8 points -	medium risk area, category 4.
6 - 5 points -	moderate risk area, category 3.
4 - 3 points -	low risk area, category 2.
1 - 2 points -	slightly endangered area, category 1.


100
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G1
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G2
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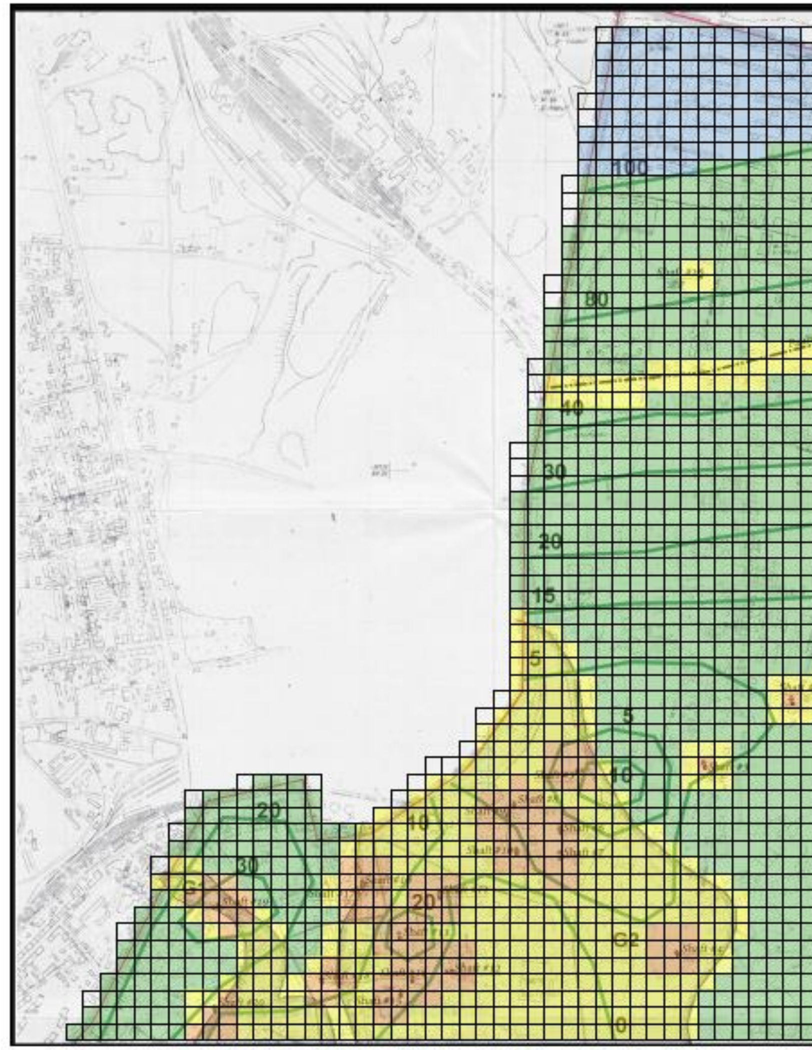
1:5000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Mitigation means

Gas hazard category	Planned facility	Existing facility
6 very endangered area	Consider a different location	Consider resettlement of residents
5 significantly endangered area	In order to determine in detail possible methane emission to the surface, determine the methane content of the seams in a given mining area. Use gas barriers in the ground, waterproofing the floor slab, drainage of the rock mass, design a gas monitoring system with automatic ventilation, take measurements of gas migration towards the surface.	In order to determine in detail possible methane emission to the surface, determine the methane content of the seams in a given mining area. Apply drainage and sealing the rock mass, design a gas monitoring system with automatic ventilation, carry out measurements of gas migration to the surface, conduct an information campaign among the local population.
4 medium risk area	Apply floor slab sealing, rock mass drainage, design a gas monitoring system together with automatic ventilation, consider, conduct gas migration measurements towards the surface.	Consider draining and sealing the rock mass. Apply gas monitoring along with a ventilation system and alarm.
3 moderate risk area	Consider floor slab sealing, rock mass drainage and designing a gas monitoring system with automatic ventilation. Recommend periodic measurements of gas concentrations.	Consider using gas monitoring with ventilation and alarm facilities. Perform periodic measurements of gas concentrations.
2 low risk area	Recommend the subsequent user to conduct periodic measurements of gas migration towards the ground surface in a given place.	Perform periodic measurements of gas migration during periods of strong barometric decreases.
1 very low risk area	No recommendations	No recommendations

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