Evaluation of Hazard of Mine Gas emissions at the Surface

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Abstract

The paper presents principles of the method of measuring the concentration and the flow rate of gas emitted from various underground spaces by new evaluation criteria, however mainly from the point of view of consequences of risks associated with gas emissions in semiclosed and closed spaces, in areas affected by the mining of mineral raw materials or mining claims already abandoned.

The paper gives the information about the objectives and principles of the method of measuring the concentration and the flow rate of methane contained in gases emitted from various underground spaces. The method is based on methane emissions in closed and semiclosed spaces in abandoned areas or those affected by mining operations or in mining areas closed in the past.

Key words*: gas emissions, concentration and the flow rate.*

Introduction

As shown by experience in already closed mining districts, the gas that is released and that accumulates in the spaces of worked-out underground mines has tendency to find a pathway to the surface. This phenomenon is dangerous especially in built-up areas where structures and the basement are in contact and in the case of sewerage systems and utility lines, where explosive or choking gases may accumulate in structures and after initiation their explosion or oxygen displacement from the atmosphere may occur and the irrespirable atmosphere may be created.

After the completion of mining activities in the mines of the Ostrava region, the cubic capacity of underground empty spaces is about 30 million m3. In the mentioned spaces, the gas emission capacity is estimated at 120 000 m3 CH4 per day.

The explosion of a gas mixture may take place only if the concentration of methane contained in the mixture corresponds to the explosion range and if there is initiation, i.e. energy is supplied to trigger the chemical reaction – explosion. This initiation in connection with structures can be induced especially by electrical equipment, open fire, or mechanical sparks, or in another way.

In various countries of Europe, accidents associated with surface gas emissions were registered in the past (Germany - Aachen, Bochum, Belgium – Lyon area, France – North and Lorraine Coalfields, England – Nottingham area).

In the Czech Republic these problems are now highly topical in the Ostrava part of the Coalfield and in the area of the Orlová municipal district and are connected with the closure of almost all underground coal mines. As for emergency situations, I give the following incidents in the Ostrava Basin as examples (methane explosion in the canteen of the former Salma-VD Hugo Mine in the year 1996; gassing by the emitted methane in the area of pedestrian subways, so-called Frýdlanské mosty, in the year 1996; methane explosion in a two-family house at Na Vrchu in the Ostrava-Hrušov municipal district in the year 1999 and since the year 2001 frequent and recurrent mine gas emissions in the TJ Slovan game area, the forest park, the surroundings of the old built-up area at Orlová).

Hazardous situations were caused by the following events:

- By the accurate emanation and concentration of mine gas via direct communication between old underground workplaces and the surface (mine holes, fissure, crack…)
- By gas accumulation in semiclosed and closed spaces (cellars and ground floors of dwellings and structures, buried services, sewerage systems, and others)
- By closing spaces with gas emissions (e.g. by the basement slab in the case of buildings or by the closing concrete plug in the case of shafts backfilled).

Objectives and Principles of Methane Emission Evaluation

Simple measurements of gas contents in the atmosphere may be sufficient for risk detection and estimation for concentrated emanation or accumulation of gas in the closed environment.

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Solving is more complicated in the case of emission dispersion in the field, because the occurrence of a measurable content of gas in soil is not always equivalent and the existence of the flow is not always really significant. In addition, some gases, especially CO2 and methane can be naturally present in soils.

For these methods of measurement used originally for wastes and contaminated soils, uses have been found quickly in the areas with the finished mining of coal.

As far as the quantitative and qualitative measurements of gas emissions from soils are concerned, any reliable and verified method for measuring the flow rates of gases emitted at the surface was not known in the past. That is why methods for this kind of measurement have been developed and verified. One of these methods is the application of the accumulation chamber, produced by the French research institute Ineris. This method was employed when dealing with the task of ČBÚ Praha (Czech Mining Office in Prague) titled in English "Dynamics of Emitted Gases" that had been assigned to our Institute of Mining Engineering and Safety of the Faculty of Mining and Geology of VŠB – Technical University of Ostrava and that dealt with the measurement of emitted gases in the Orlová urban conglomeration.

A means to study the intensity of gas emissions at the surface is the determination of the volume flow rate of the emitted methane per unit of land surface. The basis of measurement is to find the course of the increase in the methane concentration in the accumulation chamber put on the surface of the studied area, and thus to assess risks of concentrated emanation and accumulation of gas in the closed environment.

The measured quantity is the volume flow rate of methane given in units of cm3 of the gas emitted from the surface of 1 m2 per 1 minute, i.e. cm3/m2/min. Because it is the quantitative method, the volume flow rate may be measured by its use, and not the concentration of emitted gas that is a criterion for the atmogeochemical method of so-called methane screening.

Technical parameters of the accumulation chamber device developed at Ineris, France are as follows:

Chamber volume:	30 l
Dimensions:	0.7 x 0.7 m
Analyzer sensitivity:	1 ppm
Detection limit:	0.005 cm3/min/m2
Measurement range:	0.05-4 000 cm3/min/m2
Measuring time:	1-3 min

Fig. 1 Measuring device (evaluation unit + recording unit)

Measurement Goal

Hazards and dangers of uncontrolled surface emissions of mine gases from the underground are determined by direct in situ measurements of the following:

- CH4 and CO2 concentrations in the soil air,
- the amount of CH4 and CO2 emitted at the surface, emission intensity,
- CH4 and CO2 concentrations in construction works, underground structures, sewerage systems, or utility lines.

The assessment of the hazard of mine gas emissions on lands is carried out with the aim to assess technically potential mine gas emissions in structures from the point of view of detection and prevention. This is done on the basis of the measurement and evaluation of the concentration of mine gases in the soil air or the intensity of mine gas emissions and the evaluation of other indicators and characteristics affecting mine gas emissions at the surface, such as the pressure and composition of gases and their changes in connection with changes in the barometric pressure, the geological structure of the overlying rocks, soil permeability, etc.

The necessity of measuring the gas flow rate has resulted from experience that in many cases, the content of methane in soil is high (CH4 concentration determined by the methane screening method) and the flow rate is low, and vice versa. Measuring the flow rate of the gas emitted at the surface supplies another piece of information about gas emissions that cannot be provided by measuring the concentration of gas in soil. Both the measurements form a set in which they complement each other.

If it is necessary to measure total emissions from a certain area, measurements are taken at points placed on the square grid with spacing adequate for accuracy required. Further, point measured values are interpolated and extrapolated by using special methods for the compilation of a map of total flow rates, a map of values, etc.

The device and the method are protected by the European patent No. 96-05996 of the year 1996 titled "The Measurement of Surface Gas Flow".

The whole device consisting of the measuring chamber, the analyzer with the recording unit, connecting hoses and the power generation unit was put into a car (see Fig. No. 1).

For the measurement itself the chamber is provided with a sharp edge that runs into the soil and thus any exchange of gas with the surrounding is prevented, or in the case of a hard bed, a sealing cushion is used.

The atmosphere is exhausted from the chamber by the pump into the analyzer and returns into the chamber so that conditions for gas emissions could not be changed. The condition is that the composition of the measured gas cannot be changed by analysis. The analysis of gas is made continually and its results are then recorded by the recording unit. On the basis of steepness of the curve, the gas flow rate at the surface will be evaluated. The whole measurement lasts about 1-3 min.

Protocol for Measurement

The result of field measurements is Protocol for Measurement with the following data:

- what was measured (volume flow rate, concentration of gas - CH4,CO2)
- date of measurement and the measuring device used
- the method of recording the result of measurement (CH4 concentration in the accumulation chamber in ppm, measurement of time in min for particular points of measurement in the area assessed)
- where the measurement was carried out (place, owner, parcel number, structure number, street, municipality)
- barometric pressure (hPa), temperature – outdoor (°C)
- protocols for measurements must be stored for 3 years as a minimum
- measurements can only be taken by trained technicians, the interpretation of results can only be done by mining engineers experienced in the area of degassing who are accredited by the supreme mining authorities (Czech Mining Office, District Mining Office).

Evaluation of Results

The computer calculations of measurements are performed by using the program MS Excel.

This computer program was developed at VŠB – Technical University of Ostrava. For practical applications it is available for the other users on CD-ROM.

What is very advantageous is the graphical evaluation of the area of interest by plotting measured values into the map in a form of isolines, or into the relief-map – see Fig. No. 2. To process the results of measurements, software Surfer, Atlas should be used preferentially.

Conclusion

The assessment of risk of mine gas emissions at the surface by measuring emission intensity by means of the accumulation chamber is, in comparison with the methods used in the Czech Republic so far, advantageous especially thanks to the fact that any surface degradation and any disturbance to plant root systems do not occur and the risk of damage to utility lines (electro-communication cables, water mains, gas mains) is eliminated.

As for the future, this method could be employed in the construction sector in foundation engineering for new structures and in the improvement of existing structures in regions with mine emission hazard in areas with finished coal mining and also for increasing the safety of citizens living and moving in these regions.

With reference to the fact that measuring the intensity of mine gas emissions is a quantitative method, it is very suitable to tie up this measurement with the atmogeochemical measurements (qualitative measurement) made in the same time period.

Remark. The concentration of gas in the soil as such does not mean that the gas will be emitted at the surface. Soil permeability and changes in the barometric pressure play an important role in this case.

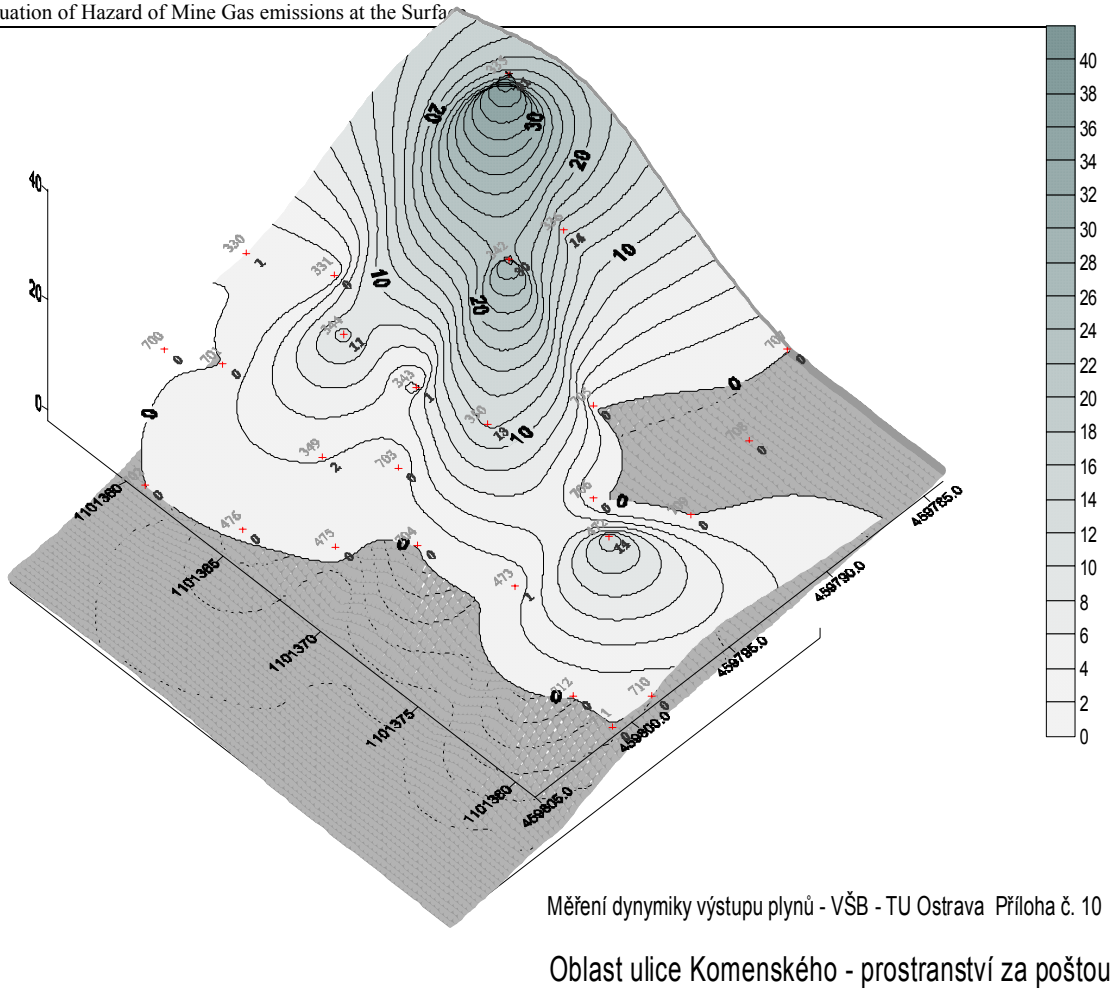

Fig. 2 Form of processing the results of measurements in 3D format. Measuring the dynamics of gas emissions – VŠB – TU Ostrava Area of Komenského street – area behind the post office

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