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# METHANE EMISSION MEASUREMENTS ALONG UNDERGROUND GALLERIES OF COAL MINE

The article shows the results of research on methane concentration changes along mine galleries. The experiment was conducted in a longwall area mined using a U-type system, and the results were obtained in situ. The main goal was to measure methane concentration by function of gallery length and dividing segments of methane data into segments, which ultimately enabled separate analysis of these methane data. The analysis led to the diagnosis of methane hazard through the detection of exceedance of the assumed tolerance area.

**Keywords:** methane concentration measurements; segmental measurements; U-type system; experiment; individual methanometer; methane hazard assessment; detection of methane emission sources

## 1. Introduction

Methane emission from exhaust shafts of coal mines is an important issue from a law point of view, and emission limits are imposed on mining companies in advance. These restrictions are dictated by environmental protection considerations, which are reflected in initiatives of the EU and international organisations (CCAC, UNFCCC, IPCC) [1]. Methane emission from underground mines is a natural consequence of drilling headings and mining longwalls, also after exploitation areas like goaf, transport of excavated coal and unused, isolated excavations. A great part of total methane emissions are longwall areas [2].

Other principal but fundamental reasons for methane emission monitoring are safety issues for the mining crew and all mine works. Methane concentration measurements are responsibilities

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arising from safety prevention and maintenance needs. They are one of the most crucial ventilation measurements [3]. Stationary methanometers and anemometers connected to the gasometry system are commonly used for methane concentration monitoring [4]. Individual hand-held methanometers are used to assist in the monitoring process.

Methane concentration measurements are used to monitor the safety state by controlling methane concentration in designed places. The measurement is compared with the permissible methane concentration level, which may differ depending on the nature of the place and the legal provisions in force in a given country. In Polish law, for maingates, the maximum amount of $CH_4$ concentration in ventilation air is 1%. At tailgates, this amount is 2%. From a safety point of view, it is important to continuously monitor methane concentration, particularly in longwall areas, where the methane concentration values can change rapidly [5-8]. Measurements along the galleries may indicate places of potential hazard due to high methane emission or local methane accumulation [6,9]. Properly conducted prevention of methane hazards should avoid accumulations and counteract high methane concentration in ventilation air [10,11].

There are more and more attempts to develop innovative solutions using artificial intelligence, expert systems and wireless sensor networks [9,12-19]. The development of cutting-edge solutions for the mining industry is aimed at reducing and avoiding human risk. These solutions significantly facilitate the transfer of measurement data and the combining of these data with the measurement location. Simultaneous acquisition of location and value of methane concentration allows recognition of methane emission intensification places and finally much better recognition of methane hazard [20,21].

## 2. Methane concentration measurements along an excavations

The segmental approach to methane concentration measurements and methane hazard detection differs significantly from routine ventilation measurements. Routine measurements of methane concentration, which are in the area of methane prevention, focus on point measurements relating to designated places, while in segmental measurements, the continuity and linearity of the path increase between locations are important. Measurements along excavations can be performed by, in principle, every crew member who will be equipped with a methanometer with the ability to record the measurement location. As the worker moves, the methanometer measures and analyses data. To maintain the repeatability of the crossing route, it is divided into sections that can be analysed separately by collecting records of measurements performed by different people. The method of sectional methane hazard detection is described in more detail in [20].

### 2.1. Measurement location

The experiment was carried out in one of the underground coal mines in Poland. For the experiment, the longwall no. 31 was selected. This longwall was mined in seam 405/3 and qualified for the third methane hazard category. The longwall was ventilated using a U-type ventilation system. In the tailgate, the Φ1000 mm ventilation pipeline was installed, which delivered fresh air to the longwall outflow.

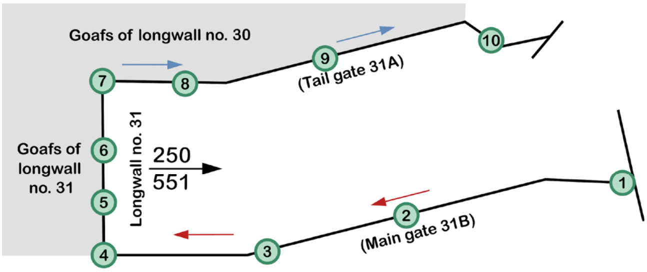


Fig. 1. The longwall no. 31 area. The drawing was prepared using seam 405/3 map

On the schematic drawing of the discussed area (Fig. 1) numbers from 1 to 10 show the location of arbitrarily placed reference nodes, which were the segment endings. The arrows point out an airflow direction.

### 2.2. Equipment used in the experiment

Measuring instruments made at the Strata Mechanics Research Institute of the Polish Academy of Sciences were used to perform the measurements. They were Metanoanemometers SOM 2303 [22]. Before the experiment, methane sensors were adjusted and calibrated using certified calibration mixtures. The instrument indications were also checked after the experiment, with no significant deviations found. The accuracy of methane sensors for the range 0%-2% is 0,1% V/V. Time constant T90 was below 3 s.

## 3. Methodology

The group of four people in the measuring team was divided into two teams, 2 people each. Both teams will start from the safety stopping point located in the tailgate (refer to Fig. 1, point 10). The experiment was divided into 2 stages. Each stage consisted of a passage along the maingate, the longwall and the tailgate. Stages were synchronised at the end of the main and tailgate near the safety stop, where the teams waited for the end of the first part of the experiment. Teams were waiting for all members and a signal to start the second stage.

The route of the passage for team no. 1 is shown in the figure (Fig. 2).

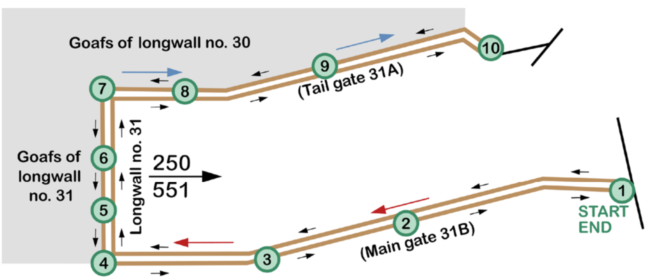


Fig. 2. The longwall no. 31 area with the passage route of the team no. 1

The route of the passage for team no. 2 was shown in the figure (Fig. 3)

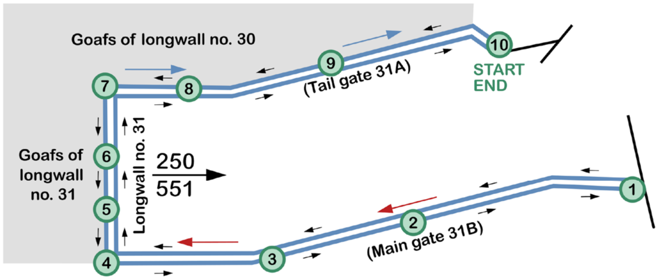


Fig. 3. The longwall no. 31 area with the passage route of the team no. 2

The passage through the maingate, then through the longwall and finally return through the tailgate was a complete first stage. In the second stage members went in the same way, but in opposite directions to fill up the route (Figs. 2, 3). Each member went alone, separated by a few minutes in distance from others. In the first stage, it was 5 minutes, and in the second stage, the distance was extended to 10 minutes.

After completing the measurements, the data were received from instruments and divided into segments by using node locations and entering and leaving the time of each segment. The data was aggregated and analysed. The data aggregation consisted of combining methane concentration recorded values with segments and nodes. Finally, chosen and interesting segments were compared.

## 4. Results

Instantaneous values of methane concentration for one passage started from the tailgate was shown in the figure below (Fig. 4)

The chart (Fig. 4) details the longwall and main/tailgates and marks the characteristic points (reference nodes) from 1 to 10, which are the ends of the measurement segments. The range of changes in methane concentration along the entire route was insignificant – 0.65% in total. Changes in concentration and trends can be observed along segments. Passing through the ventilation doors separating fresh and used air can be seen as a sudden and step change in methane concentration.

Then, following the longwall gallery for the first 200 m shows no tendency. A slight increase is noticeable in the next 200 m segment, i.e. in segments 9-8. The maximum values were measured near the intersection of the longwall with the tailgate. At the same time, the methane concentration measurement data showed the greatest variability at this location, which was caused, on the one hand, by the presence of a source of methane emissions from the goaf and on the other hand, by the inflow of fresh air from the ventilation tube. The formation of an air-methane mixture appears itself in significant variance in the results.

The methane concentration in the longwall showed a decreasing trend towards the inlet. The graph in Fig. 4 displays ripples and an increase in concentration in the central region of the

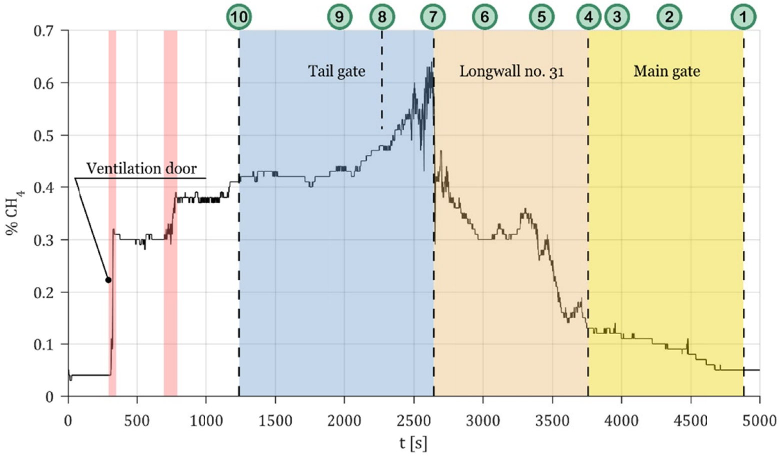


Fig. 4. Experimental data. Methane concentration over the time while the team passage the route. Route: Tailgate 31A – longwall no. 31 – Maingate 31B. Points from 10 to 1

longwall, which could be due to the presence of the shearer. The maingate also shows an increasing tendency of methane concentration towards the longwall, however, the range of concentration changes in this gallery was small – up to 0.1% $CH_4$. After division into segments, 72 methane concentration records were obtained. The segments with the highest concentrations were selected for analysis, i.e. segments located in the longwall 5-6, 6-7.

In further analysis, a tolerance area for methane concentration changes was created for each analysed segment. The tolerance area was created based on the selected series by performing a transformation on it. Due to uncertainty in determining the location and measuring methane concentration, each point on the data series was given a tolerance range. The uncertainty in determining the position increases with distance from the reference nodes, reaching the highest value in the centre of the segment. The uncertainty of methane concentration measurement is constant and results from the accuracy of the sensor and its calibration method. Taking all these uncertainties into account, the maximum tolerance values for methane concentration changes are determined for each metre of the segment (Ostrogórski, 2022). The set of charts below contains all data series of the analysed segment and the limits of the tolerance area.

The methane concentration level remained below the upper limit of the tolerance area, resulting in a low methane hazard level (see Fig. 5). The methane concentration series, despite low values, showed significant variability in methane concentration. This translates into the shape of the tolerance upper limit line, which depends on the choice of the reference series. In this case, this series was the course with the lowest recorded concentrations.

The graph (Fig. 6) shows segmental registrations for the last section of the longwall. Near 60 m from the segment's beginning, the methane concentration exceeded the upper tolerance limit, which resulted in a high hazard level being indicated. The fact is that the methane concentration did not even exceed 0.7% at the outlet from the longwall, which probably would not have caused any concern among the crew and supervisors, but the large variability of the concentration resulted in a temporary exceedance of the tolerance limit, which should be understood as a warning signal – a high level of methane hazard.

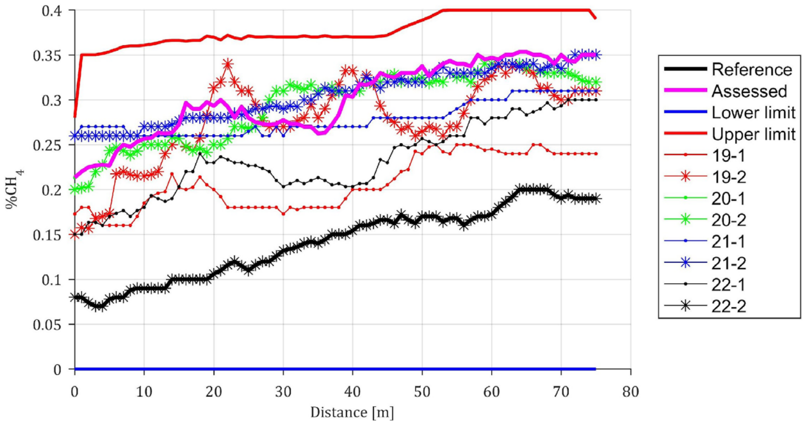


Fig. 5. Experimental data after division into segments and area of methane concentration tolerance. Data for segment 5-6

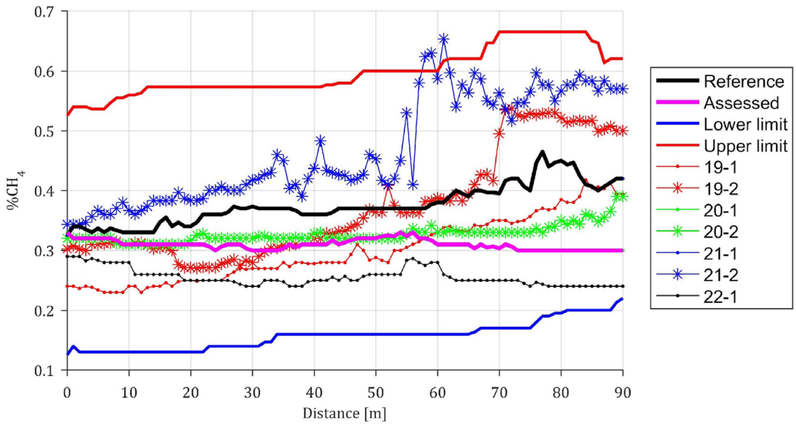


Fig. 6. Experimental data after division into segments and area of methane concentration tolerance. Data for segment 6-7

# 5. Summary and conclusions

Measuring methane concentration along mine galleries may be a useful supplementation to actual methane hazard detection routines by detecting emission sources. Methane concentration patterns illustrating the concentration distribution along galleries require division into segments within which comparisons can be made and the nature of changes assessed. The method of segmental methane concentration measurements allows the determination of methane concentration tolerance limits based on one of the previously recorded data series. Exceeding the upper limit is a criterion for assessing the hazard due to a significant change in concentration values compared to the current values. The analysed methane concentration patterns for the longwall on the segment between powered roof supporting sections 50 and 100 were within the concentration tolerance range, and no increased level of hazard was found. At the end segment of the longwall for the series marked with the symbol "21-2", in relation to the "20-1" series, the system would indicate a high level of hazard because the concentration values exceed the upper tolerance limit. However, for the series which was currently assessed (Fig. 6), the hazard level was low because the entire series is below the upper tolerance limit.

The method of measuring methane concentration in a mining excavation presented in the article, together with the analysis of the hazard level, extends the generally accepted framework for analysing the issue. The analysis of data obtained from segmental measurements is more sensitive to small, unnoticeable changes in concentrations under operating conditions, which can be considered a kind of indicator parameterizing the current methane hazard status.

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