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Michał Maruta

ORCID: 0000-0002-1642-8189
AGH University of Science and Technology in Krakow

THE POTENTIAL USE OF A DRÄGER X-AM 8000 PORTABLE MULTI-GAS DETECTOR FOR MONITORING EXPLOSIVE GASES IN THE AREA OF HISTORICAL OIL AND GAS FIELDS IN THE PODKARPACKIE REGION

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Abstract: The oldest oil basin in the world is located in the Polish Carpathians. Former mines, often abandoned, have become technical monuments. The growing popularity of industrial tourism in the world and in Poland attracts more and more tourists who want to "find oil" on their own. In most cases, these are abandoned crude oil and natural gas fields, with such places associated with the risk of poisoning, ignition or explosion of escaping gases from unprotected crude oil fields or borehole outlets. The article also highlights the heritage of oil mining in the Polish Carpathians and related cultural routes. The author focuses on the issue related to the occurrence of the hazard zone of hydrogen sulphide poisoning or methane explosion in the sites of old oil fields. It presents the possibility of using the Dräger X-am 8000 portable multi-gas detector as a personal device for monitoring the concentration of gases and vapours considered toxic and/or explosive, such as methane or hydrogen sulphide. It also proposes the use of the Dräger X-am 8000 multi-gas detector, which in combination with the Dräger X-site Live real-time area monitoring module, can serve as a mobile system for short- or long-term monitoring of the above-mentioned zones.

Keywords: Methane exhalation, hydrogen sulphide, hand-dug wells, industrial heritage tourism, Dräger X-am 8000

1. Introduction

Tourism is becoming a mass phenomenon, one which can almost be considered universal, and which is developing dynamically [1–3]. Furthermore, there is an increasing specialization of tourism, with technical monuments becoming tourist attractions. The division of tourism related to industry can be found in the work of M. Kronenberg [1], he distinguishes between:

- industrial tourism,
- tourism in post-industrial areas,
- industrial heritage tourism.

In reference to the rich heritage of the oil industry, new cultural routes are being created in the area of the Polish and Ukrainian Carpathians and existing ones are being modernized. They are located mainly in the Podkarpacie, Małopolska and Western Ukraine provinces [2, 4–9].

The most important of them include:

- The Jasło – Lviv Cross-Border Oil Trail,
- Carpathian-Galician Oil Trail,
- The World Cradle of Oil Mining,
- Following the footsteps of giant extinct mammals, earth wax, crude oil and salt.

It is worth remembering that contemporary responsible management of non-renewable energy sources requires reaching back to the 19th and 20th century history and the beginnings of oil and gas extraction.

The Carpathian oil and gas area is located in the central and eastern part of the Polish flysch Carpathians. The oil industry in Poland was initiated by hand-dug wells – known as dug pits, wells, and dug pits [10, 11]. Their location (Fig. 1) is the place of the primary, natural oil spill and/or exhalation of natural gas to the earth's surface.

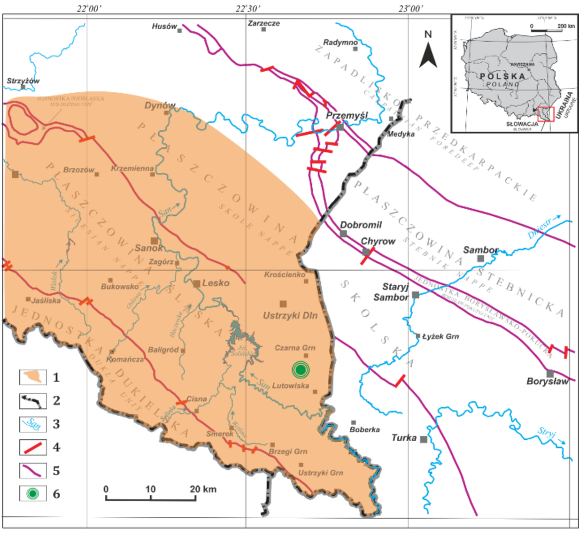
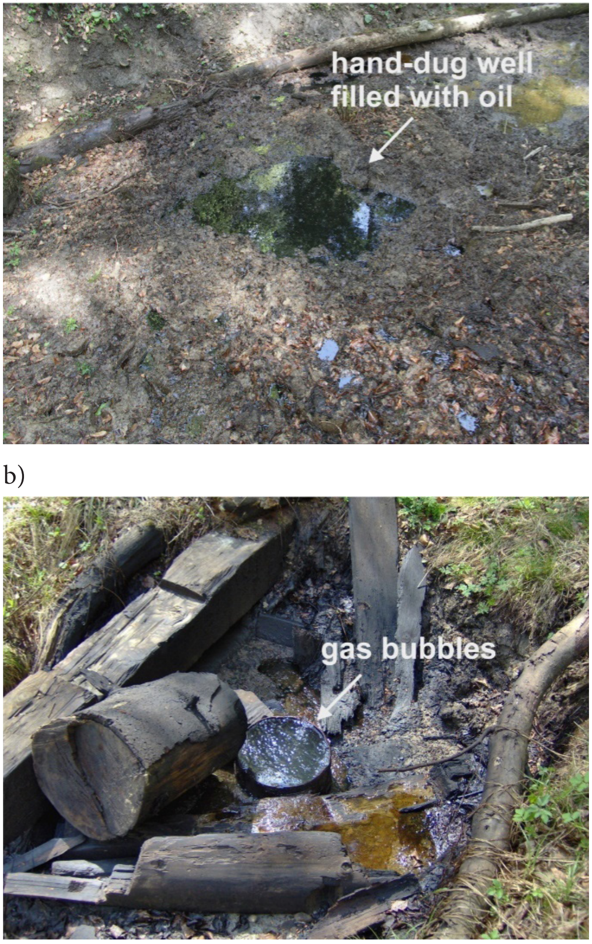


Fig. 1. The area of old hand-dug wells in the Polish Carpathians: 1 – range of the area of old mining pits occurrence, 2 – state borders; 3 – major rivers; 4 – faults; 5 – overthrusts, 6 – location of hand-dug well in Polana Ostre [12 – modified]

2. The risk associated with the exaltation of the gases in place of an old, abandoned oil and natural gas fields

Natural surface occurrence of oil and gas was known here already in the Middle Ages. The Polish geologist Stanisław Staszic, in his book *About Earthborn of the Carpathians and other mountains and Polish plains* [13] mentioned a black smudge of oil from the rocks [10, 14].

Old, abandoned oil and gas fields are becoming increasingly popular among tourists. Of these, the most interesting are the places where crude oil is available at one's fingertips and where the exhalations of natural gas are also visible (Fig. 2). Such places are often unmarked and unsecured [5–9, 15–18].


a)

b)

Fig. 2. An example of an old hand-dug set near Polana Ostre village: a) visible outline of the walls of the old hand-dug filled with oil; b) open outlet of the borehole with visible bubbles of methane [19 – modified]

Most often they have the form of hand-dug wooden wells or left-over boreholes (Fig. 3) [11, 19]. Oil was also obtained by collecting it from the water surface and digging shallow pits in the ground where it could accumulate.

According to the applications of the indigenous inhabitants of the Bieszczady Mountains, the number of such places may exceed 250 [17, 19].

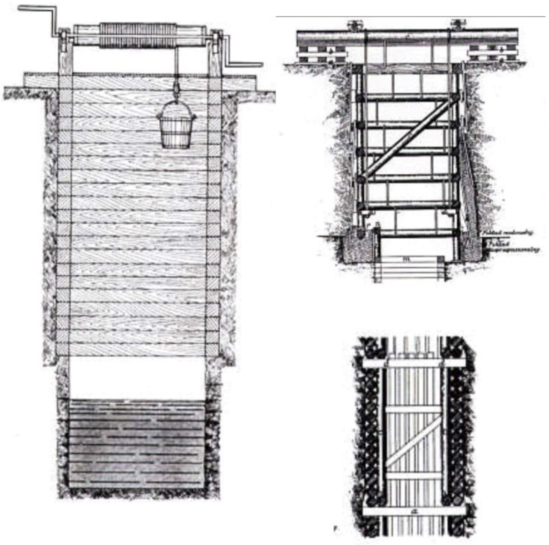


Fig. 3. Cross section of a hand-dug well with winch, timber lining [20 – modified]

The places of crude oil outflow and natural gas exhalation are also interesting from the scientific point of view, as evidenced by numerous articles and scientific studies [11, 12, 21–25].

The presence of volatile hydrocarbons within such facilities poses a serious risk of methane explosion, while hydrogen sulphide poisoning is also dangerous to the health and life of people residing there [11, 12].

In order to reduce the risk of ignition and/or explosion of methane or poisoning with hydrogen sulphide, people living in the potentially dangerous zone are obliged to be equipped with gas detectors, automatic notifying them of hazards by means of light and sound signals. Among these tools is the Dräger X-am 8000 [26, 27], which is portable and can at the same time measure the concentration of seven gases, including hydrogen sulphide and methane [26–28].

The occurrence of an explosion hazard generated while in the immediate vicinity of the excavation's outlet or an inactive borehole is related to the explosiveness of the air-gas mixture. Methane belongs to the gases whose emissions can be hazardous to human health and life [29, 30]. Methane is a flammable gas that reacts with oxygen, and the chemical reaction produces a flame accompanied by large amounts of heat. The ignition initiator for methane is, for example, a spark or a flame. The combustion is explosive when the concentration of methane in the air is between the lower and upper explosive limits [31].

The explosion limits expressed by the content of Methane in a mixture with air at a temperature of 20°C and a pressure of 1 bar are [31]:

- 5% vol./vol. Methane – lower explosive limit (LEL),
- 15% vol./vol. Methane – upper explosive limit (UEL).

Ignition of methane may occur spontaneously if the temperature of its mixtures in the air reaches 537°C at a pressure of 1 bar [31, 32].

Methane is a colourless, odourless, and tasteless gas that is lighter than air. It burns with an almost colourless flame with a blue halo [31–33].

Methane is not a toxic gas. This gas in high concentration has a suffocating effect on the respiratory system and displaces oxygen. Poisoning with this gas can even lead to unconsciousness, and in low concentrations it can cause narcotic effects [31–33].

Another gas that may appear in the air while in the immediate vicinity of the shaft exit or inactive borehole is hydrogen sulphide. This gas is classified both as to explosive gases and toxic. Exceeding the permissible concentration level may have a negative influence on human health and life [31, 32, 34].

Hydrogen sulphide is a colourless gas with a strong odour of rotten eggs, when the gas concentration exceeds 0.18 mg/m^3 [34]. When concentration of the gas ranges from 1400 to 2800 mg/m^3, it may stop respiratory processes [34].

Hydrogen sulphide is a flammable and explosive gas. The explosive limits of the gas in the air mixture are given below [34]:

- 4.3% vol./vol. hydrogen sulphide – lower explosive limit (LEL);
- 45% vol./vol. hydrogen sulphide – upper explosive limit (UEL).

The self-ignition temperature of hydrogen sulphide in the air mixture is 290°C [34].

3. The Dräger X-am 8000 portable gas multi-detector. Features and types of sensors compatible with it

The Dräger X-am 8000 (Fig. 4) portable gas multi-detector is ATEX-certified. This means that it can be used in an area where an explosive mixture of gases, vapours or oxygen can be generated temporarily or continuously. This explosion hazard area is classified as zone 0 [26–28].

Fig. 4. List of the basic features in Dräger X-am 8000 [28 – modified]

The Dräger X-am 8000 is a modern multi-gas detector with a build-in, high performance pump for a simultaneous and continuous monitoring of up to seven gases [26–28].

The detector has five slots into which four types of sensors can be installed as required, including dual-use sensors. The device can be armed with the following sensors [26–28]:

- infrared,
- photoionization,
- catalytic,
- electrochemical in XXS version for measuring oxygen and toxic gases.

Thanks to this, it is possible to select from the pool of 42 sensors those corresponding to the current needs in an easy way. In total, it makes it possible to measure the concentrations of 124 gaseous substances [26–28, 35].

The device is also equipped with a Bluetooth module that allows X-am 8000 to communicate with other systems or mobile devices with a dedicated application. This enables online data exchange or reading of measured values away from the gas sampling point [27, 28, 35].

Infrared (IR) sensor – principle of operation

The gas sample is transferred to the measuring cuvette by diffusion or a pump. The infrared emitter produces broadband radiation that passes through the window into the cuvette, where it is reflected by mirrors and passes through another window, hitting the dual detector. The dual detector consists of a measuring detector and a reference detector. If the gas mixture contains, inter alia, hydrocarbons, then some of the radiation is absorbed and the measuring detector produces a reduced electrical signal. The signal from the reference detector remains unchanged [27, 35, 36]. The DrägerIR sensor principle is presented in Figure 5.

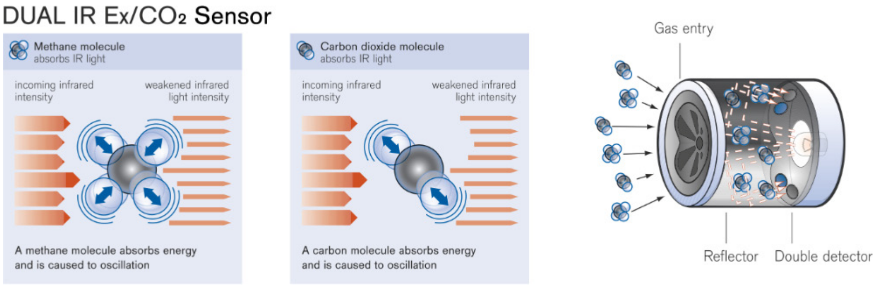


Fig. 5. Principle of infrared Dräger sensor [27 – modified]

Photoionization detector (PID) – principle of operation

Gas particles are detected if, under the influence of radiation emitted by the UV lamp, are ionized, i.e. the ionization energy is lower than the energy emitted by photons. The presence of ionization products is recorded by an electrometer. The resulting ions recombine [27, 33, 35, 36]. The Dräger PID sensor principle is presented in Figure 6.

Electrochemical sensor – principle ofoperation

The basic principle of an electrochemical sensor is that at least two electrodes (the measuring electrode and the counter electrode) are in contact with each other in two ways: first, through an electrically conductive medium (electrolyte), and second, through an external electrical circuit (electron conductor). The electrodes are made of a material with catalytic properties, thanks to which chemical reactions take place in the so-called three-phase zone [27, 35, 36]. The Dräger Electrochemical sensor principle is presented in Figure 7.

Catalytic bead sensors – principle of operation

A small coil made of platinum is embedded in a porous ceramic bead with a diameter of less than 1 mm [27, 35, 36]. A current flows through the platinum coil, heating the pellistor above 100°C. When temperature of the pellistor will increase in the presence of flammable gases, it contains a suitable catalytic material, which leads to causes the resistance of the platinum coil to such an increase. This change in resistance can then be evaluated electronically. For combustion, pellistor uses oxygen from the ambient air [27, 35, 36]. This sensor works on the basis of the catalytic bead principle. A second pellistor is used with almost the same structure in order to eliminate changes in the ambient temperature. The second pellistor does not react to gas. Coupled by a Wheatstone bridge, the two pellistors then form a sensor circuit, which is largely independent of the ambient temperature, and which can detect the presence of flammable gases and vapours [27, 35, 36]. The Dräger Catalytic bead sensor principle is presented in Figure 8.

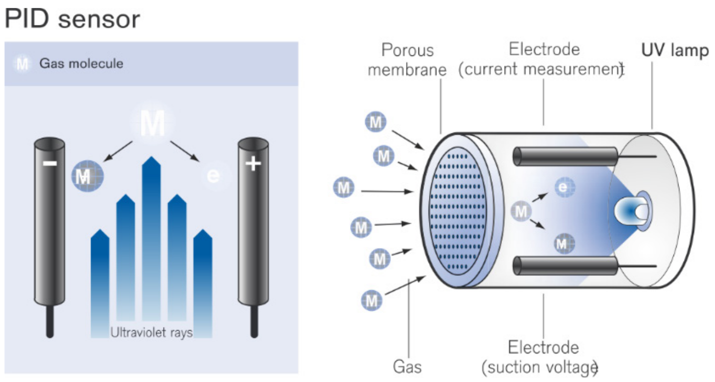


Fig. 6. Principle of photoionization detector – Dräger (PID) sensors [27 – modified]

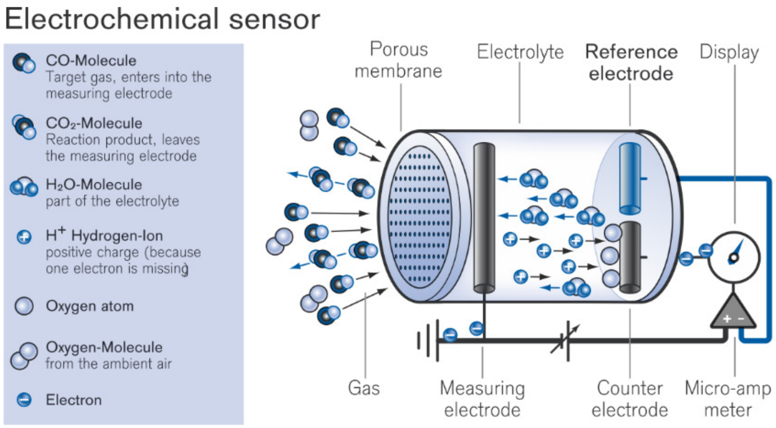


Fig. 7. Principle of electrochemical Dräger sensor [27 – modified]

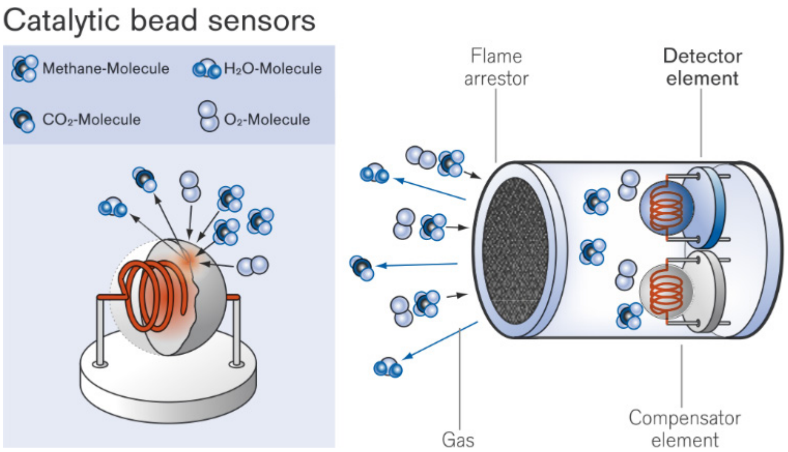


Fig. 8. Principle of catalytic bead Dräger sensors [27 – modified]

4. Use of the Dräger X-am 8000 for monitoring a gas mixture in the air within old oil and gas fields

In places where abandoned crude oil or natural gas fields occur, people there come into contact with liquids or gases classified as dangerous to human health or life and these substances can also pose a risk of ignition or explosion. At the time when work is performed in this area, in accordance with Polish law, the area should be marked, properly secured, and monitored [33, 37–39]. In this case, the most effective, also in economic terms, type of monitoring is mobile monitoring.

The Dräger X-zone 8000 multi-gas detector can successfully perform this function and, in combination with the dedicated Dräger X-site Live set (Fig. 9), it is a tool for real-time monitoring of a potentially hazardous area for human life and health. The advantage of this combination is that the Dräger X-site Live kit weighs just over 10 kg and is the size of a suitcase. In addition, Dräger X-site Live is equipped with a mobile device through which one can observe the current indications of the gauges and reconfigure it [35, 40].

Fig. 9. Dräger X-site Live set contents [40 – modified]

In addition to the designated slot for the Dräger X-zone 8000 multi-gas detector, there are communication modules inside the case: GSM, GPS, Wi-Fi and Bluetooth. This enables real-time transmission of measurement data to any place on Earth [40]. Also in this way, the device transmits information about the existing threat to life or health. When one of the sensors registers the exceedance of the permissible value for each of the tested substances, the message about the danger is automatically sent to all active users who are in the monitored zone and remotely supervising the work. In addition to electronic notification, the Dräger X-zone 8000 and the Dräger X-site Live kit emit a warning flashing light, an audible alarm signal and vibration via the Dräger X-zone 8000 multi-gas detector [27, 28, 35, 40].

The oil and gas industry also uses radiation generators and radioactive sources. The radioactive materials used may also pose a potential threat to the natural environment and to humans [40, 41]. For radiation protection, Dräger X-site Live is also equipped with a gamma detector with an alarm set at 50 μm/h (0.5 μSv/h). The measurement takes place in two seconds [40].

5. Conclusions

Old and abandoned oil and gas fields, in the form of pits and unprotected borehole outlets, may pose a risk of poisoning by escaping gases or lead to the ignition or explosion of methane.

The Dräger X-am 8000 portable multi-gas detector can be used to detect both toxic and explosive gases in the air.

Thanks to their mobility and technical parameters, the Dräger X-am 8000 together with Dräger X-site Live can be used for continuous and periodic monitoring of concentrations of up to 7 gases simultaneously, including explosive gases such as Methane and toxic gases such as e.g. Hydrogen sulphide.

Dräger X-am 8000 together with Dräger X-site Live can be used to monitor the concentration of gases in potentially explosive zone 0 during tourism or when carrying out, inter alia, research and inventory work related to zone protection.

Using communication modules in the Dräger X-site Live wireless hazardous area monitoring station, conditions in the workplace can be remotely monitored by the controllers.

Recognition of technical objects as monuments of a bygone era, appreciation of their cultural and artistic values contributes to the emergence and development of industrial tourism.

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References

[1] Kronenberg M.: *Wpływ zasobów dziedzictwa przemysłowego na atrakcyjność turystyczną miasta. Przykład Łodzi*. Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2013.

[2] Kruczek Z., Kruczek M.: *Post-industrial Tourism as an Opportunity for Revitalising the Environment of the Former Oil Basin in the Polish Carpathian Mountains*. Polish Journal of Environmental Studies, vol. 25, iss. 2, 2016, pp. 895–902.

[3] World Tourism Organization: *International Tourism Highlights*. UNWTO, Madrid, Spain, 2019, pp. 1–24. DOI: https://doi.org/10.18111/9789284421152.

[4] Augustyn B.: *Pamięć krajobrazu – przeszłość zapisana w teraźniejszości*, [in:] *Bojkowszczyzna zachodnia – wczoraj, dziś i jutro*, ed. J. Wolski, Vol. 2. Polska Akademia Nauk, Instytut Geografii i Przestrzennego Zagospodarowania im. Stanisława Leszczyckiego, Warszawa 2016, pp. 65–83.

[5] Karpacki Trakt Naftowy. https://www.gorlice.pl/pl/333/0/karpacki-trakt-naftowy.html [16.06.2021].

[6] Kruczek Z.: *Rola turystyki w zachowaniu dziedzictwa przemysłu naftowego w Polskich Karpatach*. Turystyka Kulturowa, vol. 3, 2019, pp. 33–52.

[7] Małopolski Szlak Naftowy. http://szlakimalopolski.mik.krakow.pl/?szlaki=szlak-naftowy [16.06.2021].

[8] Odkryj Podkarpackie. https://podkarpackie.eu/turystyka/muzeum-przemyslu-naftowego-i-gazowniczego-w-bobrce/ [16.06.2021].

[9] Towarzystwo Opieki nad Zabytkami – Oddział Bieszczadzki. http://www.tonzbieszczadzki.pl [16.06.2021].

[10] Cząstka J.: *Z dziejów górnictwa naftowego w Bieszczadach*. Nafta, vol. 6, 1961, pp. 173.

[11] Lipińska E.J.: *Places of natural flow of oil and natural gas emissions in Podkarpackie*. Infrastructure and Ecology of Rural Areas, vol. 1, 2010, pp. 13–24.

[12] Sechman H., Dzieniewicz M.: *Pomiary emisji metanu w wybranych rejonach polskich Karpat Zewnętrznych*. Geologia, vol. 35, iss. 41, 2009, pp. 129–153.

[13] Staszic S.: *O Ziemiorództwie Karpatów i innych gór i równin Polski*. W Drukarni Jego Ces. król. Mości Rządowei, Warszawa 1815.

[14] Maruta M., Mirek-Jonkicz E.: *The „Rock oil" at your fingertips: hydrocarbons' signs at the surface in the Polish Carpathians Area*. Mineralia Slovaca, Geovestník, vol. 43, iss. 2, 2011, pp. 183.

[15] *Jak zostałem szejkiem bieszczadzkim*. https://zyciejestpiekne.eu/jak-zostalem-szejkiem-bieszczadzkim [16.06.2021].

[16] Nowiny24: *W Bieszczadach tryska ropa*. https://nowiny24.pl/w-bieszczadach-tryska-ropa/ar/c3-6010223 [16.06.2021].

[17] *Przewodnik po Bieszczadach „Nieodkryte Bieszczady istnieją naprawdę"*. https://wydawnictwo.lesneoko.com [16.06.2021].

[18] Twoje Bieszczady. http://www.twojebieszczady.net/piesze/kopalnia_ropy.php [16.06.2021].

[19] Kuśmierek J., Dzieniewicz M., Sechman H., Machowski G., Czwarkiel P., Maruta M., Ozimek K., Pałkowska K., Pasternacki A.: *Studium geologiczno-naftowe wycieków węglowodorów w rejonie Karpat.* Stowarzyszenie Naukowo-Techniczne Inżynierów i Techników Przemysłu Naftowego i Gazowniczego, Archiwum KSE AGH, Kraków 2007 [unpublished].

[20] Muzeum naftového dobývání a geologie z.s. http://muzeumropy.cz [16.06.2021].

[21] Guzy P., Pietrzycki D., Świerczewska A., Sechman H., Twaróg A., Góra A.: *Emission measurements of geogenic greenhouse gases in the area of "Pusty las" abandoned oil field (Polish Outer Carpathians)*. Journal of Ecological Engineering, vol. 18, iss. 4, 2017, pp. 100–109.

[22] Kuśmierek J., Machowski G.: *Wycieki ropy naftowej w obszarze wschodniej części Karpat polskich i ich znaczenie prognostyczne*. Prace Instytutu Nafty i Gazu, vol. 150, 2008, pp. 247–250.

[23] Maćkowski T., Kuśmierek J., Reicher B., Baran U., Kosakowski P., Łapinkiewicz A.P., Machowski G., Papiernik B., Szczygieł M., Zając A., Zych I.: *Dwuwymiarowe modele termicznego przeobrażenia materii organicznej i ekspulsji węglowodorów w transgranicznej strefie Karpat polsko-ukraińskich*. Geologia, vol. 35, iss. 4/1, 2009, pp. 191–222.

[24] Maruta M., Sala D.: Naturalne wycieki ropy naftowej a środowisko naturalne w Karpatach – wstępne wyniki badań, [in:] *Interdyscyplinarne zagadnienia w górnictwie i geologii*, red. J. Drzymała, W. Ciężkowski, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2013, pp. 119–127.

[25] Sechman H., Guzy P., Kaszuba P., Wojas A., Machowski G., Twaróg A., Maślanka A.: *Direct and indirect surface geochemical methods in petroleum exploration: a case study from eastern part of the Polish Outer Carpathians*. International Journal of Earth Sciences, vol. 109, 2020, pp. 1853–1867, DOI: doi.org/10.1007/s00531-020-01876-y.

[26] Dräger: *Measurement strategy: Dräger X-am 8000 with PID-Sensor*; Dräger Safety AG & Co. KGaA, Lübeck, Germany, 2017, pp. 1–4.

[27] Dräger: *Dräger Sensor*® & *Portable Instruments Handbook*. 4th ed., Dräger Safety AG & Co. KGaA, Lübeck 2018.

[28] Dräger: *Dräger X-am® 8000 Multi-Gas Detector*. Drägerwerk Safety AG & Co. KGaA, Lübeck 2021.

[29] Kissell F.N.: *Handbook for Methane Control in Mining*. Information Circular/2006, NIOSH – Publications Dissemination, Cincinnati 2006.

[30] Solecki T., Macuda J.: *Metody wykrywania i identyfikacji substancji ropopochodnych w środowisku gruntowo-wodnym*. Wiertnictwo, Nafta, Gaz, vol. 21, iss. 1, 2004 , pp. 325–332.

[31] Krawczyk M.: *Analityka procesowa – wybuchowość mieszanin gazowych, czujniki chemiczne do pomiaru wybuchowości. Wykład*. Gdańsk 2003 [unpublished].

[32] Safety Data Sheets. https://przemysl.air-liquide.pl/en/resources/safety-data-sheets [16.06.2021].

[33] Smolarz A.: *Diagnostyka procesów spalania paliw gazowych, pyłu węglowego oraz mieszaniny pyłu węglowego i biomasy z wykorzystaniem metod optycznych*. Politechnika Lubelska, Lublin 2013.

[34] Stetkiewicz J.: *Siarkowodór. Dokumentacja dopuszczalnych wielkości narażenia zawodowego*. Podstawy i Metody Oceny Środowiska Pracy, vol. 4 (70), 2011, pp. 97–117.

[35] Dräger: *Portable gas detectors – Product overview*. Dräger Safety AG & Co. KGaA, Lübeck 2020.

[36] Dräger: *Wprowadzenie do detekcji gazów*. Dräger Safety AG & Co. KGaA, Lübeck 2016.

[37] *Obwieszczenie Ministra Gospodarki, Pracy i Polityki Społecznej z dnia 28 sierpnia 2003 r. w sprawie ogłoszenia jednolitego tekstu rozporządzenia Ministra Pracy i Polityki Socjalnej w sprawie ogólnych przepisów bezpieczeństwa i higieny pracy*. Dz.U. 2003, nr 169, poz. 1650.

[38] *Rozporządzenie Ministra Gospodarki z dnia 25 kwietnia 2014 r. w sprawie szczegółowych wymagań dotyczących prowadzenia ruchu zakładów górniczych wydobywających kopaliny otworami wiertniczymi*. Dz.U. 2014, poz. 812.

[39] *Rozporządzenie Ministra Gospodarki z dnia 8 lipca 2010 r. w sprawie minimalnych wymagań, dotyczących bezpieczeństwa i higieny pracy, związanych z możliwością wystąpienia w miejscu pracy atmosfery wybuchowej*. Dz.U. 2010, nr 138, poz. 931.
[40] Dräger: *X-site Live – Wireless hazard area monitor*. Drägerwerk Safety AG & Co. KGaA, Lübeck 2021.
[41] International Atomic Energy Agency (IAEA): *Radiation protection and the management of radioactive waste in the oil and gas industry*. Safety Reports Series, No. 34, International Atomic Energy Agency, Vienna 2003.