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Use of underground space for the storage of selected gases (CH_4, H_2, and CO_2) – possible conflicts of interest

Introduction

The underground space has been used by people since ancient times. Initially, it was used as a shelter (caves) and for exploration and the exploitation of mineral resources and groundwater. The development of mining enabled the rock mass to be used for other purposes, such as transport, infrastructure, the storage of liquids and gases, substances, and waste (Przybycin et al. 2011; Evans et al. 2009).

The limited land space and the safety of storage are the reasons for using underground structures. This is the case with shelters, data systems (e.g. documents, films, photographs), computer systems, etc. The most shallow facilities, offices and storage sites, are usually built up to about 10 m BGL (below sea level) (Figure 1). Social facilities (cultural and recreational spaces, railway, and subway stations) are located up to a depth of 20 meters. Industrial

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facilities (factories and storage sites) are located up to a depth of 30 m. Transport infrastructure (tunnels, parking lots, waste processing plants, or fuel tanks) is typically built at a depth of 40 m. The exploitation of mineral resources and groundwater and underground storage of fuels, natural gas, carbon dioxide, and radioactive or hazardous waste is carried out at greater depths (250–3000 m BGL) (Uliasz-Misiak and Przybycin 2015; Nordmark and Peira 2003; Evans et al. 2009). One of the ways of using the rock mass is underground storage of waste and substances in natural pores, crevices, rock caverns, and mining excavations. Natural gas, liquid fuels, carbon dioxide, heat energy, hydrogen, and others are stored underground.

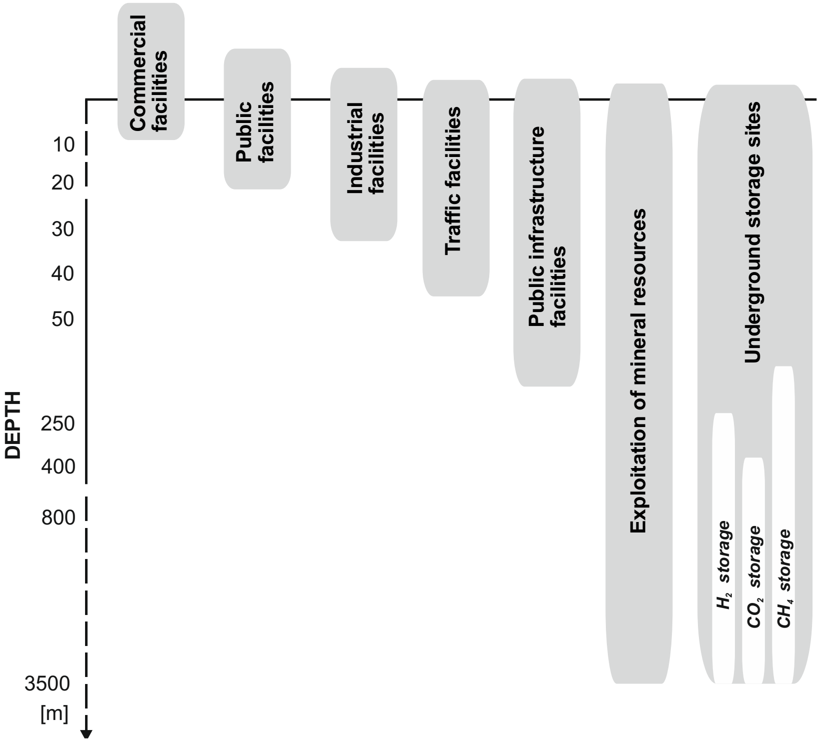

Fig. 1. The use of the rock mass depending on the depth (based on Przybycin et al. 2011, amended)

Rys. 1. Sposoby wykorzystania górotworu w zależności od głębokości

The analysis of the literature underlines the need for the rational management of underground space, especially when the rock mass can be used for various purposes (the storage of substances, exploitation of raw materials or water, etc.). Taking the current status and the future of rock mass development into account, a guideline for the development of the underground space use in Poland was proposed (Uliasz-Misiak and Przybycin 2016). The authors discussed the actions in the field of valorization and protection of geological structures, highlighting their significant and growing importance to the national economy. In addition, the implementation of legislation regarding rock mass management was proposed.

An urgent need to coordinate the use of underground and above-ground spaces was expressed by Bartel and Janssen (2016). The authors emphasized the need for strategic and comprehensive spatial planning of land development and the rock mass. This is the way to avoid future conflicts between stakeholders. In order to ensure the best use of underground space, it should include procedures for designating areas for certain purposes.

A comprehensive planning of the subsurface use (e.g. for various forms of energy storage) was presented by Bauer et al. (2013). The methodology they proposed was based on the detailed characteristics of underground storage sites and the phenomena that take place within them. The mentioned methodology allows us to assign specific energy storage methods to appropriate geological structures below the earth's surface.

Island power systems and dispersed energy consumers in poorly developed areas, combined with a large, usually dominant share of renewable energy sources, create new opportunities and challenges for energy storage. However, this requires an assessment of the power supply systems and the planned use of underground space (Erdinc et al. 2015; Tarkowski and Uliasz-Misiak 2003).

The development of underground space is extremely important for the expansion of large urban centers. Delmastro et al. (2016), discussing the energy supply to cities, suggested the simultaneous use of both above-ground and underground space. They emphasized that this approach can affect city livability and improve public health. Carneiro et al. (2019) indicated restrictions regarding the use of underground space related to environmental conditions, security, and social aspects.

The rational management of underground space, especially when it can be used for various purposes, requires a comprehensive approach. It should include procedures for determining areas for certain purposes, the development of the rock mass, and land surface development, especially in areas of large urban agglomerations. This, in turn, should translate into the security of human activities in various areas and enable us to avoid conflicts between entities interested in using the same underground space, rational management of the rock mass and raw materials. The question of demand and sustainable use of underground space has recently received more and more attention. The possibilities of using it for the storage of industrial gases – CH_4, H_2, and CO_2 are discussed by the authors. To meet the needs of various entities interested in the raised issues, the use of the rock mass was presented in the context of its usefulness for the storage the discussed gases and the legal aspects of such activities. Attention was drawn to the possible conflicts of interest that may arise when using the same underground space for different purposes.

1. Experience in the field of underground gas storage

Rock formations are suitable for the storage of large amounts of fluids with limited or minimal environmental impact. The large-scale gas storage for energy applications in various forms allows for their better integration with renewable energy sources (Blacharski et al. 2017; Hache and Palle 2019; Haghi et al. 2018; Hosseini and Wahid 2016; Mah et al. 2019), balancing energy supply and demand (Abdin et al. 2019; Aneke and Wang 2016; Tagliapietra et al. 2019), increasing the energy security, and better management of the energy network (Azzuni and Breyer 2018; Blanco and Faaij 2018; Peng et al. 2016). The storage of gas enables the transition towards a low-emission economy (Ma et al. 2018; Parra et al. 2019; Samsatli S. and Samsatli N.J. 2019; Sgobbi et al. 2016) as it allows significant amounts of carbon dioxide to be trapped (Murray et al. 2008) and the use of "clean" fuels such as hydrogen.

A specific rock formation may be suitable for various forms of underground energy storage. Therefore, there is a competition for the use of underground space for energy storage. The question arises: which technology to choose, which one is the most suitable for the geological formation under consideration? Matos et al. (2019) suggested that numerous factors should be taken into consideration, including: reservoir geology, reactivity of the storage site (deposit and the overlying formation) to the injected fluid, energy density, technology efficiency, sustainable underground space planning, etc. Furthermore, underground space planning should take the state of land development in the underground storage area and both technical and environmental factors determining the safety of gas storage into account. Carneiro et al. (2019) discussed the methodology and results of studies aimed at identifying geological formations suitable for the large-scale storage of renewable energy in Portugal.

The main stored products include fossil fuels (natural gas and crude oil) and their products (fuel, liquefied gas), and, more recently, compressed air or hydrogen. The petroleum industry has many years of experience in natural gas storage, both in porous formations and salt caverns (Gąska 2012; GWPC-IOGCC 2017; Yucekaya 2013). The intensive development of the technology for the underground storage of natural gas began after the Second World War and was associated with the inability to meet the demand for natural gas supplied by pipelines. For several dozen years, the oil industry has routinely injected liquids into rock formations, reservoir waters, or acid gases (H_2S and CO_2) (Tarkowski and Stopa 2007; Uliasz-Misiak and Chruszcz-Lipska 2017). In 2018, there were 662 underground natural gas storage sites (with a capacity of 421 billion Nm ^{3}) worldwide. Most storage sites were located in depleted hydrocarbon reservoirs – 73.4% (486 sites), salt caverns – 15% (99 sites), and aquifers – 11.6% (75 installations) (Figure 2). While most of the gas is stored in depleted hydrocarbon deposits (79% of global working gas volumes), salt caverns account for about a quarter of the global deliverability (Cornot-Gandolphe 2019).

In 2020, there were 7 natural gas storage facilities in Poland, located in the Polish Lowlands, the Carpathians, and the Carpathian Foredeep. Most of them are located in depleted hydrocarbon deposits, two in salt caverns leached in salt domes (Mogilno storage site) and in a bedded salt deposit (Kosakowo storage site). The active capacity of all gas storage facili-

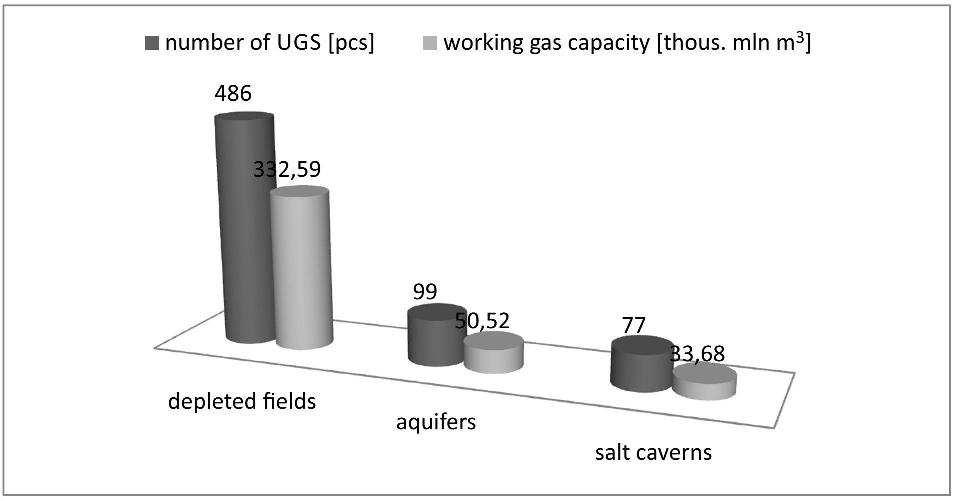

Fig. 2. Underground natural gas storage sites in the world in 2018 (based on Cornot-Gandolphe 2019)

Rys. 2. Podziemne magazyny gazu na świecie w 2018 roku

ties in Poland is 3174.80 million m^3 (PGNiG 2020). By 2030, it is assumed that the storage capacity of underground facilities will be expanded to a minimum of 43.8 TWh (Ministry of Climate and Environment 2020). One of the planned underground gas storage facilities will be the Damasławek storage facility located in the salt formation. Where approximately 1,000 million m^3 of natural gas will be stored in 20 salt caverns (GAZ-SYSTEM SA 2016).

The practical experience with hydrogen storage is still limited. The experience in the field of underground storage of natural gas can be transferred to the other gases under consideration; however, the specificity of hydrogen requires research and testing before this technology is implemented on an industrial scale. The first salt caverns for the storage of pure hydrogen were built near Teesside, United Kingdom, in the early 1970s and are still operational. The stored gas contains 95% H_2 and 3–4% CO_2. Three more caverns were built in the USA in the 1980s and at the turn of the 21st century in Texas (operated by Praxair and Conoco Philips). These caverns are used in the petrochemical industry (Crotogino et al. 2018; Pottier and Blondin 1995). In Europe we also have experience in the storage of hydrogen-carbon oxides mixtures (town gas). This gas contains 50–60% hydrogen, the remaining gases are: carbon oxides (15–20%), methane (10–20%), and trace amounts of nitrogen. It is used for heating and lighting purposes. The salt cavern facility in Kiel (Germany), the aquifer gas storage reservoir in Lobodice (Czech Republic), or Beynes storage unit (France) can all serve as examples (Panfilov 2016).

Injecting CO_2 into reservoir rocks is a practice that has been used for several dozen years in the petroleum industry for enhanced oil recovery (CO2-EOR) or the enhanced production of coal bed methane (ECBM) (ways of using carbon dioxide). Industrial-scale CO2-EOR projects have been implemented since the mid-1970s, and in 2017 there were 166 such projects worldwide (IEA 2019). We have less experience with CO_2 injections into deep, unexploited coal seams for enhanced coal bed methane (ECBM) recovery, e.g. micro-pilot tests in Alberta (Canada Burlington project, San Juan Basin, USA), the RECOPOL project (Poland), or the Qinshui Basin project (China) (Liu et al. 2017). The use of the rock mass for the geological storage of CO_2 (Carbon Capture and Storage – CCS) is now considered as an option to reduce the anthropogenic emissions of this gas (Bachu 2008; Holloway 2005). Currently, there are numerous research and industrial installations for the underground storage of carbon dioxide worldwide, including: Sleipner – in the North Sea, Snøhvit – in the Barents Sea, In Salah in Algeria, or Weyburn (Canada). The CO_2 storage at the Sleipner (1 million tons of CO_2 per year) and Snøhvit fields is carried out using a brine aquifer; in the In Salah storage site carbon dioxide is stored in a natural gas reservoir; in the case of the Weyburn field, a carbon dioxide injection was used to increase oil recovery (Aminu et al. 2017; Metz et al. 2005).

2. Geological and reservoir aspects of underground storage of CH_4, H_2, and CO_2

The use of geological structures in porous rocks (aquifers, oil and gas reservoirs) or caverns leached in salt deposits is considered for the storage CH_4, H_2, and CO_2. The former occur naturally as geological traps in which hydrocarbon reservoirs were accumulated or in the form of elevated anticlinal structures in aquifers. The latter were created as a result of human activity (Ebigbo et al. 2013; GWPC-IOGCC 2017; Kruck and Crotogino 2013; Wójcicki et al. 2014).

A detailed analysis of the geological and reservoir conditions for underground storage of CH_4, H_2 and CO_2 in porous and salt rocks takes the characteristics of reservoir rocks, overburden, and interlayers of other non-salt rocks and their properties that affect the behavior, storage capacity, rock tightness, and the operation of an underground storage facility into account. The factors that have the greatest influence on gas storage are the most important ones. They primarily concern the tightness of the underground storage facility (Liu et al. 2015; Teodoriu and Bello 2020; Verga 2018; Wang et al. 2019), geochemical interactions with reservoir fluids and the rock matrix (Crotogino et al. 2018; De Silva et al. 2015; Henkel et al. 2014; Tarkowski and Wdowin 2011; Yekta et al. 2018), microbiological interactions (Bordenave et al. 2013; Hagemann et al. 2016; Hemme and van Berk 2017; Panfilov 2010; Tarkowski et al. 2009; Toleukhanov et al. 2015), and aspects related to the economics of the project (e.g. the amount of working gas and cushion gas) and storage efficiency (Kruck and Crotogino 2013; Matos et al. 2019).

The security of underground storage of CH4, H_2, and CO_2 is the main issue considered when selecting underground storage sites. This is related to the efficiency of underground gas storage or the losses associated with the gas leakage. The lack of gas migration confirms the tightness of the underground storage facility and its proper operation (Amid et al.

2016; Tarkowski and Stopa 2007; Verga 2018). The quality and tightness of the cap rock is particularly important when choosing a geological structure for an underground hydrogen storage facility. This gas, due to its specific physico-chemical properties, is characterized by the highest mobility and permeability. Hydrogen was found to diffuse fastest from the rock matrix towards the Earth's surface (Abdalla et al. 2018). The storage of this gas is the most difficult. Therefore, the greatest restrictions should be used when choosing a storage location. The most suitable conditions for hydrogen storage can be found in salt caverns (Karnkowski and Czapowski 2007; Kruck and Crotogino 2013; Tarkowski and Czapowski 2018). The depleted natural gas reservoirs have good tightness (Wei et al. 2016; Chen 2015), which confirms its natural accumulation. The tightness of oil storage sites is variable (better for methane and carbon dioxide, worse for hydrogen). In the absence of natural gas in an oil field, there is no certainty as to the natural tightness of the reservoir. Additional tests are required to confirm the tightness. In the case of aquifers, their tightness must be confirmed by a detailed analysis. The presence of low permeability rocks in the overburden does not fully guarantee the tightness of the storage site and the occurrence of faults may be a serious problem.

The exploration of individual geological structures (aquifers, oil and gas reservoirs, or caverns leached within salt formations) is variable. Generally, the depleted hydrocarbon reservoirs have the most favorable geological and reservoir characteristics; locally, the degree of exploration is the highest in exploitation areas of rock salt deposits. Identifying the areas for underground storage facilities at aquifers requires expensive analysis. Usually, aquifer structures have the greatest storage capacity; however, they are not always the key parameter determining the suitability of the structure for storage. When it comes to hydrocarbon reservoirs, their storage capacity is determined by the size of the reservoir and its depletion. When it comes to salt caverns, the storage capacity is equal to the size of the leached salt cavern.

Geochemical and microbiological interactions of the discussed gases with the underground environment, namely rock matrix and reservoir waters, are of great importance and should be considered when choosing storage locations. The above mentioned interactions can have both positive and negative effects, i.e. improve or deteriorate reservoir parameters of both the underground storage site and sealing rocks of the poorly permeable overburden. In the case of underground storage of carbon dioxide, these interactions mainly affect aquifers and depleted hydrocarbon reservoirs and are conditioned by the reactivity of the rock matrix with the gas dissolved in water. In depleted hydrocarbon deposits, the interaction of the stored hydrogen with carbon dioxide may result in the formation of methane (Ebigbo et al. 2013; Shi et al. 2020), which, in some cases, can be seen as a positive aspect of the storage. The reactivity of rock salt, with the exception of thin interlayers of clay rocks, is low. The solubility of the considered gases in water is varied, but negligible in the case of hydrogen. It is the highest for carbon dioxide, which has a positive effect (mineral sequestration) on the efficiency of its storage. Microbiological interactions are particularly important in porous rocks, as they can lead to the deterioration of rock reservoir parameters or the clogging of the gas injection /collection system.

When analyzing other aspects related to the storage of CH_4, H_2, and CO_2, attention should be paid to the economic side and technical conditions of the construction and operation of the discussed sites. The adaptation of depleted hydrocarbon reservoirs for underground gas storage is less expensive than the use of aquifers or leached salt caverns. In the case of the storage in depleted oil or gas reservoirs, it is possible to use the existing infrastructure. Storage facilities in salt caverns occupy a smaller area than other types storage sites, which makes them easier to monitor and operate; in addition, their construction time is shorter. The brine produced during leaching is a significant problem, as it must be removed in an environmentally friendly manner or used for industrial applications.

3. Conflicts of interest related to underground gas storage in Poland

The underground space is owned by the state, and its use should be regulated by law for the purpose of rational, balanced, and safe use. Thus, the most important regulations are those that enable us to protect these places against threats resulting from improper management and exploitation of the rock mass and allow their use in accordance with the energy policy of the state. The mentioned regulations must meet the needs of companies dealing with gas and waste storage, stakeholders interested in renewable energy sources, energy companies, including those producing renewable energy, petrochemical plants, and transport companies.

Underground gas storage involves numerous aspects, ranging from whether a given gas is perceived as a raw material or a substance, through the transport of gas to an underground storage facility, storage, and ending with many years of responsibility for an underground storage facility after the end of gas injection.

Nowadays, more and more people realize that human activities are causing climate change on a global scale. Without limiting this impact, and therefore without changes in sectors responsible for CO_2 emissions (energy, transport, etc.), many environmental changes are inevitable. Societies are increasingly willing to adapt to change, although they are far from being aware of the need for change, wanting them, and agreeing that these changes have a direct impact on our situation. The awareness of the process and the safety of underground gas storage, combined with the common knowledge about climate change and the need to combat it, should translate into greater public acceptance for the underground storage of carbon dioxide, methane, and hydrogen.

3.1. Conflicts related to the use of the rock mass

In Poland, activities related to the prospecting, exploration, and exploitation of mineral deposits and underground storage of substances are regulated by the Geological and Mining Law (Act of June 9, 2011 – Geological and Mining Law 2011), as amended) and by regulations of the Minister of the Environment. The underground storage of substances, including gases, requires a license to be granted by the Minister of the Environment for a limited period of time, not less than 3 years and not more than 50 years. The concession entitles you to conduct economic activity in the designated area. Operating without a license is illegal and has criminal consequences.

The license is granted for activities "proposed" by the entrepreneur, e.g. mining, exploitation of thermal waters, or underground storage of substances. The decision shall define the scope of the license. Therefore, at the licensing stage, various ways of using the same geological structures should be taken into account, and the license should be issued for priority activity from the point of view of the licensing authority (Uliasz-Misiak and Przybycin 2016).

Due to the favorable geological conditions (the occurrence of thick sedimentary rocks), the storage of H_2 (Tarkowski 2017, 2019; Luboń and Tarkowski 2020; Lewandowska-Śmierzchalska et al. 2018; Lankof and Tarkowski 2020) and CO_2 (Marek et al. 2011; Tarkowski and Uliasz-Misiak 2006; Tarkowski et al. 2009; Šliaupa et al. 2013) in the Polish Lowlands is currently being considered; the storage of natural gas is already being implemented (Czapowski 2019; Gąska 2012). Structures considered as potential storage sites for carbon dioxide, hydrogen, and natural gas are typically anticlines where reservoir layers form aquifers in Lower Cretaceous, Lower Jurassic, or Lower Triassic rocks. At the same time, they are most suitable for the extraction of thermal waters. In such a case, the creation of an underground storage facility, in accordance with the Geological and Mining Law, could prevent the use of these waters. A conflict of interest may also arise in the case of using salt domes as gas, fuel, or hazardous or radioactive waste repositories. The Polish Lowland is prospective for the exploitation of conventional and unconventional deposits of hydrocarbons and other minerals, the exploitation of which may interfere with other ways of developing the rock mass.

In addition to the above-mentioned problems related to the possibility of using geological structures in various ways (carbon dioxide, hydrogen or natural gas storage), there may be conflicts related to the use of rocks within the same formation but at different depths. In the same location, but at different depths, conditions may allow for both underground storage and the exploitation of mineral resources.

3.2. Spatial planning conflicts

Conducting an effective economic and ecological policy requires rational use and the shaping of space by public authorities, i.e. an appropriate spatial policy. One of its main elements is determining the way of land development. In this regard, in Poland, spatial development plans (and, in their absence, land use plans) prepared on a commune, poviat, or voivodeship scale are one of the main tools of this policy (Nowak 2019). These documents determine land development conditions and take the areas of mineral deposits occurrence (Spatial Planning and Land Development Act 2003) into account. These provisions do not take the regulations on rock mass management into account (Uliasz-Misiak and Przybycin 2016). The existing regulations only apply to the exploitation of minerals and the underground storage of substances and waste disposal (Act of June 9, 2011 – Geological and Mining Law 2011).

Land use plans and spatial development plans should ensure the rational management of environmental resources. The spatial development plans should take mineral deposits and the needs of their exploitation into consideration. The spatial development plans do not take the spatial development of the subsurface, and thus the ways of using geological structures into account (Uliasz-Misiak and Przybycin 2016).

Therefore, the management of the rock mass is part of the broadly understood protection of deposits, understood as the protection of areas against such development that would prevent access to the deposit (Nieć 2008; Uliasz-Misiak and Winid 2012). In this regard, the resolution of the Council of Ministers on the National Spatial Development Concept 2030 indicates that the state policy should ensure the protection of mineral deposits against irrational and illegal exploitation. It also states that it is necessary to introduce legal provisions and the protection of mineral deposits and the possibility of using them in accordance with the utility value on the basis of the exploitation plans for individual mineral deposits prepared by the Minister of Investment and Economic Development. According to this document, the plans should constitute the basis for issuing a license for underground gas storage, and potential concession areas are to be included inthe spatial development plans (National Spatial Development Concept 2030 2012).

3.3. Conflicts related to environmental protection

In areas protected by the Nature Conservation Act, restrictions on activities related to underground gas storage, depending on the type of area, may apply. The most restrictive restrictions related to business activities, including bans, apply in national parks and nature reserves. It is not possible to carry out activities related to the exploitation of minerals and the underground storage of substances in the areas mentioned. Less restrictive regulations apply in natural landscape parks and nature parks. It is forbidden to implement projects that may have a significant negative impact on the environment, except for those for which the preparation of an environmental impact report is not obligatory, and the environmental impact assessment procedure has shown no adverse impact on the landscape park (Nature Conservation Act 2004). In addition to the bans listed in the Act, national and natural landscape parks may have additional restrictions and prohibitions included in protection plans. There are no bans on Natura 2000 sites and the protection system is more flexible. Within the Natura 2000 site, however, investments that are harmful to the environment are prohibited (Uliasz-Misiak and Winid 2012).

The protection plans for national and natural landscape parks identify the existing and potential internal and external threats and define the methods of their elimination or reduction (Gawroński 2002; Radecki 2007; Stachowski 2008). The plans prepared for landscape parks take the requirements for mining activities into account, including: the range and scale of extraction, duration, and exploitation methods (Radwanek-Bąk 2007). Including activities related to the underground storage of gases is not required.

3.4. Social acceptance issues

The issue of social acceptance of the storage of CH_4, H_2, and CO_2 (Clarkson 2013; Evensen and Brown-Steiner 2018; Teodoriu and Bello 2020) requires further legislation. The storage of natural gas, carried out for several decades by oil companies, does not raise major social concerns. The abovementioned companies have developed methods of solving problems with local communities. We already have significant experience with social acceptance for the underground storage of carbon dioxide (L'Orange Seigo et al. 2014; Roberts and Mander 2011; Tcvetkov et al. 2019), unlike in the case of underground hydrogen storage (Zaunbrecher et al. 2016). For example, the results of carbon capture and storage (CCS) for Germany were presented by: (Arning et al. 2019; Braun et al. 2018; Dütschke et al. 2016), for Poland (Tarkowski et al. 2014), for China (Chen et al. 2015). The growing social awareness of climate change is also associated with the need to acquire alternative energy sources (including the production and extraction of methane and hydrogen) and the fact that the energy source itself must also be stored somewhere. This should translate into greater social acceptance for both underground storage of carbon dioxide and hydrogen. This is further supported by the fact that, according to Roberts and Mander (2011), understanding the significance and seriousness of decisions makes it easier to accept a given solution. This also applies to the underground storage of gas.

Conclusions

The use of the rock mass in the context of its suitability for the storage of CH_4, H_2, and CO_2 was presented. Possible conflicts of interest related to the use of geological structures, spatial planning, nature protection, and social acceptance, which may arise in the case of using the same underground space for the storage of various gases, were indicated (Figure 3).

The storage of CH_4 has been carried out since the beginning of the 20th century, the injection of CO_2 for various purposes has been used for several decades in the oil industry (for over 20 years as an option to reduce the anthropogenic emissions of this gas). The underground storage of H_2 is carried out in only a few industrial installations. The experience gained from underground natural gas storage can be transferred to the storage of other gases. Limited experience with hydrogen storage and its specific properties will require extensive research before wide-scale implementation of the technology.

Fig. 3. Conflicts of interest related to underground storage of natural gas, carbon dioxide, and hydrogen

Rys. 3. Konflikty interesów związane z podziemnym magazynowaniem gazu ziemnego, składowaniem dwutlenku węgla i magazynowaniem wodoru

Geological and reservoir conditions are crucial when selecting structures (aquifers, oil and gas reservoirs, or salt caverns) for the storage of CH_4, H_2, and CO_2. These factors have the greatest impact on gas storage, ensuring the safety of underground storage and the absence of undesirable geochemical and microbiological interactions with the fluids and the rock matrix. Economic aspects and the associated storage efficiency should also be taken into consideration.

Underground storage of CH_4, H_2, and CO_2 may cause conflicts related to the use of the same geological structures, land use, and nature protection in the area of activity. The lack of regulations setting priorities in the development of the rock mass may result in the use of the same geological structures for various purposes (exploitation of minerals, storage of various gases, etc.).

The introduction of appropriate provisions concerning spatial development would enable the sustainable management of the rock mass. At the same time, it would facilitate decisions on how to manage the site at different levels of decision-making.

Failure to include other methods of rock mass development than the exploitation of mineral deposits in the legal regulations on protected areas and nature conservation plans may prevent the creation of underground storage in structures located in selected protected areas.

The awareness of the technology and the safety of underground gas storage, combined with common knowledge about climate change and the need to combat it, should translate into greater social acceptance for the underground storage of CO_2 and H_2. Many years of experience of oil companies in the field of storage of CH_4 will be helpful in this regard.

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USE OF UNDERGROUND SPACE FOR THE STORAGE OF SELECTED GASES (CH_4, H_2, AND CO_2) – POSSIBLE CONFLICTS OF INTEREST

Keywords

underground gas storage, methane, hydrogen, carbon dioxide, conflict of interest

Abstract

The rational management of underground space, especially when used for various purposes, requires a comprehensive approach to the subject. The possibility of using the same geological structures (aquifers, hydrocarbon reservoirs, and salt caverns) for the storage of CH_4, H_2 and CO_2 may result in conflicts of interest, especially in Poland. These conflicts are related to the use of the rock mass, spatial planning, nature protection, and social acceptance.

The experience in the field of natural gas storage can be transferred to other gases. The geological and reservoir conditions are crucial when selecting geological structures for gas storage, as storage safety and the absence of undesirable geochemical and microbiological interactions with reservoir fluids and the rock matrix are essential. Economic aspects, which are associated with the storage efficiency, should also be taken into account.

The lack of regulations setting priorities of rock mass development may result in the use of the same geological structures for the storage of various gases. The introduction of appropriate provisions to the legal regulations concerning spatial development will facilitate the process of granting licenses for underground gas storage. The provisions on area based nature protection should take other methods of developing the rock mass than the exploitation of deposits into account. Failure to do so may hinder the establishment of underground storage facilities in protected areas. Knowledge of the technology and ensuring the safety of underground gas storage should translate into growing social acceptance for CO_2 and H_2storage.

WYKORZYSTANIE PODZIEMNEJ PRZESTRZENI DLA MAGAZYNOWANIA WYBRANYCH GAZÓW (CH_4, H_2 I CO_2) – MOŻLIWE KONFLIKTY INTERESÓW

Słowa kluczowe

dwutlenek węgla, metan, wodór, konflikt interesów, podziemne składowanie/magazynowanie

Streszczenie

Zarządzanie podziemną przestrzenią, szczególnie gdy można ją wykorzystać w różnych celach, wymaga kompleksowego podejścia do problemu. Możliwość wykorzystania tych samych struktur geologicznych (poziomów wodonośnych, złóż węglowodorów oraz kawern solnych) do magazynowania CH_4, H_2 i CO_2 może skutkować konfliktami interesów szczególnie w warunkach polskich. Konflikty te są związane z wykorzystaniem górotworu, planowaniem przestrzennym, ochroną przyrody, społeczną akceptacją.

Doświadczenia w magazynowaniu gazu ziemnego można przenieść na magazynowanie pozostałych gazów. Przy wyborze struktur geologicznych na magazyny gazów, uwarunkowania geologiczno-złożowe będą w największym stopniu wpływać na ich magazynowanie. Bezpieczeństwo magazynowania oraz brak niepożądanych oddziaływań geochemicznych i mikrobiologicznych z płynami złożowymi i matrycą skalną będą istotnymi czynnikami. Należy także uwzględniać aspekty ekonomiczne i związaną z tym efektywność magazynowania.

Wskazano, że brak regulacji prawnych ustalających priorytety w sposobie zagospodarowania górotworu będzie skutkował konkurencją w wykorzystaniu tych samych struktur geologicznych na magazyny różnych gazów. Wprowadzenie do uregulowań prawnych dotyczących zagospodarowania przestrzennego terenu odpowiednich zapisów ułatwi wydawanie koncesji na podziemne magazynowanie gazów. Nieuwzględnienie w przepisach dotyczących obszarowych form ochrony przyrody innych sposobów zagospodarowania górotworu niż eksploatacja złóż może przeszkodzić w zakładaniu podziemnych magazynów w obszarach chronionych. Znajomość technologii i zapewnienie bezpieczeństwa podziemnego magazynowania gazów powinny się w praktyce przekładać na coraz większą społeczną akceptację dla magazynowania CO_2 oraz H_2.