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PROBLEMS RELATED TO OIL AND GAS MINING WASTE DEPOSITION IN VIEW OF LEGAL REGULATIONS**

1. INTRODUCTION

Oil and natural gas mining as well as any other type of mining and industrial activity have environmental impact in the course of which physicochemical properties and entire components of nature are changed. Exploration, recognition, managing and exploitation of hydrocarbons may results to change in environmental. Additionally, other environmental hazards may occur as a consequence of rapid events, failures or oil catastrophes causing various types of environmental transformations.

The causes and results of environmental changes caused by drilling activities have been presented in Table 1.

Apart from the negative environmental impact exerted by activities performed at the deposit, it is also improper waste management which creates a great hazard.

The main source of waste generation in oil and natural gas mining is the exploration, exploitation and production process. All those types of waste are classified according to the EU standards as exploitation waste.

The development of ecology and also changes in legal requirements obliges drilling companies to undertake activities aimed at environmental protection. Those measures should be oriented to the recognition of branch-specific hazards as well as elaboration and implementation of waste minimization methods as well as permanent perfecting and optimizing waste utilization technologies.

Improper handling exploitation waste materials may have serious environmental consequences, leading to irreversible ecological catastrophes.

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Table 1

Causes and consequences of environmental changes caused by drilling operations

Type of environmental transformation	Causes of environmental transformations	Consequences of environmental impact
Geomechanical transformations	Managing the area (rig, storages, access roads, social infrastructure, etc.) Drilling of rigs, Generated vibrations, detonations of explosives, e.g. when liberating seized liner, or perforation, Reservoir fluid eruptions beyond pipes and downhole, Lost circulations, Enhanced production, Storing of waste and hazardous materials	Landscape transformation, deformation of the terrain surface, Disturbing geological structures, Uncontrolled migration of reservoir fluid, Disturbed water relations, Production of underground cavities, trenches or cones on the surface, Change of soil air composition, Contamination of soil and water, Emission of hazardous substances to atmosphere
Water environment transformations	Managing the area (rig, storages, access roads, social infrastructure, etc.) Drilling of rigs, Reservoir fluid eruptions beyond pipes and downhole Lost circulations, Enhanced production, Storing of waste and hazardous materials. Break-downs and fires, Deposition of drilling waste and discharge fluids in pits, Discharge of reservoir and technological fluids	Destroyed draining systems, Changed level and contamination of surface- and groundwater, Qualitative changes of groundwater caused by interconnections between aquifers, Formation of fluid waste from the pits and piles, Lost circulations due to fracturing of impermeable rocks
Atmosphere transformations	Break-downs and fires, Operation of combustion engines, Natural gas eruptions, Boiler operation, Transport, Enhanced production, Completion of deposits, Re-entry, Tubing of wells	Noise emission, Increased air temperature, Emission of pollutions and dusts
Soil and vegetation transformations	Managing the area (rig, storages, access roads, social infrastructure, etc.) Drilling of rigs, Operation of rigs, Preparation of drilling muds, cement slurries and other technological fluids, Spontaneous outflow of reservoir fluids, Storing of waste and hazardous materials	Changes in landscape, deformation of surface area, Destruction of soil and vegetation, Contamination of surface with brines, oil products and chemicals, Change of state of composition of grounds ad their chemistry, Change of native flora. Overdensification of ground in the rig area
Marine environment transformations	Oil and gas eruptions and other drilling or machine break-downs, Oil fires, Break-downs of drilling platforms, tankers and undersea pipelines	Lowering solar exposition of marine water due to the presence of oil and ashes on its surface, Contamination of marine water with chemicals and oil products

This premise became a basis for introducing EU regulations about principles of managing waste produced in exploitation industry – Directive 2006/21/WE PE and Council of 15 March 2006 [15], which has been realized in Poland through the Act about exploitation waste of 10 July 2008 [16].

2. LEGAL REGULATIONS ON EXPLOITATION WASTE

The directive about managing exploitation waste has introduced standards common for all EU members, which according to the EU environmental policy determines principles of preventing or reducing negative consequences of managing exploitation waste, especially their influence on specific components of the environment. Exploitation waste should not be treated as streams of waste which were generated in the course of oil and natural gas exploration, exploitation and production, but also such which were indirectly related with those processes, e.g. food waste, waste oil, car-breaking, used batteries and light sources.

The directives, however, neither cover the issue of waste from marine exploration, exploitation and processing of raw minerals, nor water injection and re-injection of pumped out groundwater.

The directives discuss the methods of reducing the quantity of produced waste, rational managing of waste, and also neutralization of exploitation waste in especially prepared objects.

To assume the EU law about exploitation waste in Poland, a new normative act was worked out in the form of a detailed agreement on material law, which along with executive acts regulates issues related with exploitation waste in a complex way [6].

The Act of 10 July 2008 about exploitation waste has basic significance for units dealing with exploitation waste, including oil and natural gas mining waste.

This act is very important for the oil and natural gas mining sector as the amount of exploitation waste keeps increasing each year. This is connected with the increasing number of drillings performed.

According to statistical data of 2007 5007 mining plants were operational in Poland, in that 60 borehole mines exploiting oil, natural gas, sulphur, medicinal and thermal waters, coal-bed methane and underground gas storages [6]. In 2010 over 6,500 mining plants, in that 68 borehole plants, exploiting oil and gas, salt, sulphur, therapeutic water, coal-bed methane and also two underground gas storages (one under construction) as well as underground waste landfill were supervised by the State Mining Authority in Poland. It should be noted that six oil and natural gas hole mines comprise 76 oil and/or natural gas mines, 1 undersea mine and 7 underground gas storages [14]. It should be remembered that the number of mines specializing in hydrocarbon exploration and exploitation will successively increase in the coming years as a result of intensified exploration of shale-origin natural gas.

The act about exploitation waste is focused on prevention activities and also limiting their negative impact on the environment, human life and health. It obliges the entrepreneurs and state administrative organs to follow certain rules on behalf of correct management of exploitation waste. It specifies: the principles of managing exploitation waste and contaminated grounds; defines the licensing procedures related with exploitation waste management; establishes principles for a waste neutralization company, and procedures of preventing serious failures in objects dealing with utilization of exploitation waste of category A [16].

3. EXPLOITATION WASTE GENERATED BY OIL AND GAS MINING INDUSTRY

In the process of hydrocarbon exploration, exploitation and treatment of oil and gas to make them transportable, the following types of exploitation waste can be generated:

– solid waste, e.g.: cuttings, clay, barite, salt, cement and other;
– technological fluid waste, e.g.: drilling mud; sealing slurries, operation and post-operation fluids (acid solutions, emulsions, gels, microgels, surfactant solutions and other chemical compounds) and overpacker fluids (e.g. brines);
– reservoir fluid waste: reservoir waste – brine, oil-water emulsions and other oil-product compounds, acidic gases (hydrogen sulfide and carbon dioxide);
– waste coming from technological substances used for treating oil and natural gas for transport (glycol, methanol and other).

Exploitation of oil and natural gas is inevitably related with the production of waste frequently classified as hazardous and other than hazardous. The amount of produced waste can be reduced only by introducing novel treatment and managing techniques and technologies as well as by using environment-friendly materials and products for the technological processes.

Drilling exploitation waste can be neutralized in a number of ways. They can be generally classified as [7]:

– physical methods,
– chemical methods,
– biological methods,
– deposition in rock mass,
– processing and re-use.

Those methods have been known for years and applied in oil and gas mining, however managing waste from hydrocarbons exploration or prospecting and their processing still creates a serious problem. This results from the difficulties in working out an efficient and economic technology of managing exploitation waste. Owing to the good recognition of geological and reservoir conditions in the course of hydrocarbon exploration and exploitation, the waste storing underground creates greatest possibilities as far as liquid and liquefied wastes are concerned.

Literature provides plenty of various ways of depositing waste in the rock mass, e.g.:

– in abandoned underground workings and salt domes [1, 5, 9, 11],
– in closed vertical [3, 5] and horizontal [8] boreholes,
– in depleted hydrocarbon deposits [12, 13],
– in absorptive layers [10].

4. EXAMPLES OF UNDERGROUND STORAGE OF OIL AND GAS EXPLOITATION WASTE

Underground storages, having numerous advantages over their surface counterparts, play an important role in neutralizing exploitation waste. Underground storages contribute to reducing the risk of surface- and groundwater contamination; the surface of the terrain can be saved for other purposes, the environmental one including. In this option the safety and control of waste deposition is guaranteed, and isolation from the atmospheric phenomena and solar radiation provided. In constant temperature and humidity conditions the waste can be stored in an unchanged state for a very long time. Hazardous substances are stored underground as they need to be permanently insulated from the biosphere. Among the most favorable geological host layers are halite deposits (diapirs or beds), magma rocks (granite, basalt, tuff), complexes of certain sedimentary rocks (clayey rocks, anhydrites, some limestones).

The deposition of waste underground can be performed in workings of traditional underground mines, salt domes and special underground storages. Vertical or directional boreholes can be used for this purpose as well [3, 4, 8, 9].

In Poland the waste to be stored underground is injected to depleted hydrocarbon deposits. This operation is performed only on hazardous or neutral liquid waste from oil and natural gas exploration and exploitation. Other stored substances from hydrocarbon deposits are reservoir water and other unmentioned waste materials (this mainly refers to fluids used for natural gas drying and unregenerable methanol, and diethyleneglycol – DEG) [13].

The Polish Oil and Gas Mining (PGNiG) S.A. has three concessions for underground storing of liquid waste in fields: Borzęcin, Husów-Albigowa-Krasne and Świdnik.

Natural gas field Borzęcin is hosted by the Permian strata, accumulated in the Basic Limestone and in the onlying Rotliegendes strata in the central part of the Fore-Sudetic Monocline. The exploitation practice confirmed the existence of a hydraulic interconnection between those two stratigraphic horizons.

This field has a gas accumulation screen in the form of an onlying layer of Zechstein anhydrite limestone-saline sediments. It has a mass character and is limited from the bottom with underlying water at 1360 m of depth (originally 1380 m) [12]. The activity performed at deposit Borzęcin covers: natural gas exploitation, injection of liquid waste, injection of acidic gases [2].

One of the main reasons speaking for the selection of deposit Borzęcin as underground waste storage was the fact that injection of waste materials from sweetening installation has been practiced there since 1994. Among other arguments are:

- deposit is at the final stage of exploitation (end of exploitation has been scheduled for the year 2018),
- waste injection (through peripheral wells at the contour) will accompany simultaneous exploitation of natural gas,
- deposit has been very well recognized geologically,
- tightness and impermeability of deposit,
- existence of insulating layers, protecting against possible uncontrollable splitting of waste substances,
- existing surface equipment and utilities which can be used for waste injection.

There exist a concession and decision on waste codes by the Ministry of Environment Protection, which were issued for the deposition of waste in natural gas field Borzęcin. The concession covered the productive part of the natural gas field Borzęcin, where other than hazardous and neutral waste materials from exploration and exploitation of raw mineable materials, their exploitation and processing can be stored.

This refers to such wastes as:

– reservoir water contaminated with various substances during technological processes, significantly changing their composition, and thus questioning their re-injection to the strata as reservoir water,
– waste coming from oil and natural gas processing,
– liquids after acidification of reservoir rock,
– liquids used for gas cleaning and drying, containing methanol, glycol, amines, technological waters and drilling mud.

Natural gas field Husów-Albigowa-Krasne is connected with the autochthonous Miocene and is present in seven gas-bearing horizons deposited at a depth of 500–1000 m. Each of the horizons is isolated from the top and the bottom with clayey-shaly beds. Deposit water is injected to two horizons (VII and VIIa), having the most favorable geological and deposit conditions, and which are deposited at 900–1000 m and 940–1040 m of depth, respectively. The planned total injectable liquid waste is about 75.000 m^3 and the injection has been performed through one well (K-8).

Oil field Świdnik is deposited in the Upper Carboniferous sandstone at a depth of about 1083–1126 m. It was calculated that about 36.500 m^3 liquid waste can be injected to absorptive strata of the reservoir horizon. The waste is injected through two wells (Ś-13 and Ś-15). Additionally, an underground waste storage in depleted oil and natural gas field in the Permian (Upper Dolomite) is run at that area. It hosts waste from oil, natural gas and reservoir water exploitation and treatment.

5. FINAL CONCLUSIONS

1. All legal regulations about exploitation waste account for the specific character of mining waste and its environmental influence on nature and humans. Their basic aim was to work out specific regulations for a considerable group of waste. As a result, the landfills (piles) and also sediment pits and dams were included among the treatment objects.
2. The Law about exploitation waste differentiates between neutralization objects depending on the type of stored waste and the risk rate of the object itself. One of the most noxious rigors imposed on the proprietor is the necessity to possess a defined financial warrant before the construction of the object begins. The intention behind it was to increase the environmental safety of the object itself.

3. In the mining activity regions considerable amounts of exploitation waste are stored and neutralized. Incorrect handling may be environmentally hazardous and lead to dangerous and irreversible ecological catastrophes. This became a premise for introducing EU regulations about principles of managing exploitation waste (Directive 2006/21/WE PE and Council of 15 March 2006). On this basis the Polish act about exploitation waste of 10 July 2008 was worked out.
4. Polish mining is one of the biggest industrial sectors among the EU-member countries. It covers opencast, underground and borehole mining as well as processing of the mined raw material.
5. Special attention should be paid to the way in which gas field Borzęcin has been managed, especially the acid gases (carbon dioxide and hydrogen sulfide) injection process to underground gas storages. This solution is of great ecological value. This same meaning has been injection process in gas field waste water in gas field Husów-Albigowa-Krasne and oil field Świdnik.

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