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Barbara Uliasz-Misiak*, Joanna Lewandowska-Śmierzchalska*, Rafał Matuła*

ECOLOGICAL RISK ASSOCIATED WITH THE ONSHORE HYDROCARBON DEPOSITS EXPLORATION

1. INTRODUCTION

The life cycle of oil or natural gas deposit begins with the discovery of accumulations of hydrocarbons for industrial use. The next steps are: exploration of the reservoir through drilling of boreholes to determine the geological characteristics and reservoir parameters and estimate its reserves, development of the field by wells drilling and completion of an exploitation installation. After the setting of the oil-mine begins operation stage thereafter oil-mine is closed and reclamation is performed. Each of the stages of the oil exploitation is associated with a different impact on the environment. The mentioned impact depends on the type and duration of the hazard or the size and sensitivity of the area where the danger is present.

Despite of the duration of the environmental impact of the different stages, direct impact mentioned works depends on the type of work performed and the size of the area, which may affected the geological works. The activities associated with the exploration of hydrocarbons usually affect environment from a few to several weeks. In the case of seismic surveys, they can have an impact on large area, the order of several – several tens of kilometers. During standard drilling, influence of industry is included on a much smaller area, a few of hundred square meters. Hydrocarbons production takes decades, and the operation may affect a larger area than in the case of drilling, in the range of 0.5–1 ha.

Exploration and exploitation of petroleum and natural gas like the other types of anthropogenic activities, should be carried out in such a way that the impact on the environment is small as possible.

* AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland

Negative impacts of oil exploitation on the environment may be associated with the routine work carried out on reservoirs or in case emergencies. For individual life stages of hydrocarbon deposits, an environmental impact of these two types of work is different. If the routine work related to the prospection of oil and natural gas are conducted in accordance with standards, because of the short their duration does not cause much of a threat to the environment. In contrast, the impact of routine work related to the extraction of hydrocarbons, due to the long exposure time, eg. Small outflows of gas valves, will have a much greater impact on the environment. In the event of an emergency at the stage of prospecting in the example. Eruptions during drilling, the threat to the environment is much greater than in the case of emergency situations in the exploitation of the reservoir.

The risks associated with seismic and drilling work and the impact on the elements of the environment we analyzed. Also has been estimated the frequency of adverse events. On this basis, based on a modified methodology, the preliminary analysis of the risks rated to environmental risks associated with the prospection of hydrocarbons was made.

2. SEISMIC SURVEYS AND ITS IMPACT ON ENVIRONMENT

Seismic method is an important tool for spatial recognition of the local geology. Seismic tests performed to identify the geological structure, particularly to indicate structures which may contain a hydrocarbon reservoir. Information on the construction of the resort lies in the time arrivals of seismic waves and the amplitude of the recorded signals. A common feature of all seismic methods is that they need a source of seismic waves (to be generated vibrations – sound waves). The source of seismic waves may be explosives (dynamite – explosive source) or vibrators (vibroseis method – vehicles with a mechanism to induce seismic waves).

Seismic research include four basic steps: design of measurement, performance (acquisition), seismic data processing and interpretation of seismic materials. In the design phase, seismic measurements is determined geological target and are selected optimal parameters ensuring proper subsurface imaging. This allows to describe the layout points excitation and collection, the type of seismic source, parameters of the signal source and parameter registration. The measurement of seismic waves involves the emission of seismic wave by the source seismic (explosives (dynamite – the source of explosive) or vibrators (method vibroseis – vehicles with a mechanism to induce seismic waves) at the point of excitation. Released waves propagating into the ground and bounce. The waves are reflected back on the surface, and then are recorded by vibration sensors disposed on the surface of collection points at different distances from the source. the signal received by the geophones by cables and acquisition, telemetric systems is transmitted to the recording apparatus.

The measurements are performed in a variant of seismic two-dimensional (2D seismic) or three-dimensional (3D seismic). 2D seismic surveys are carried out designed along straight lines, which are all points of excitation and measurement points. Obtained in this way a cross-section of the earth at the place where the works ware performed. A more technically advanced is 3D variant of seismic research. The method uses staggered receivers – linearly – a surfactant in relation to the respective excitation points spaced at a high density. Points excitation and detectors are spaced along the intersecting lines forming a network of registration. Seismic profiles can be created so as to cover the entire target area of research in order to allow proper measurement.

The third stage includes seismic processing of recorded data. The measured seismic data are redirected to the data center, where they are processed using specialized software. Processing leads mainly to obtain so called time sections and maps of depth domain. Fourth, the final stage of seismic covers the interpretation of seismic data. It is performed most often in the interactive interpretation systems on workstations. During interpretation, all available geological data are used from the area of research and seismic modeling tools to confirm the correctness of the interpretation. As a result of interpretation arises geological map of the substrate, indicating, for example, the potential locations of hydrocarbon reservoirs.

Seismic methods can cause environmental hazards associated with pollution of groundwater and surface water, emissions into the atmosphere, ground deformation, the negative impact on living organisms, noise, impact on landscape, seismic activity and traffic [1].

The scale of the environmental impact of conventional seismic survey is not large. Systematic development of instruments and measurement systems used for recording signals is important, not only because of the improvement of research methods, but also for the protection of the environment. The development of seismic surveys has meant of the reduction the time needed to carry out measurements shortly, and the data provided is more accurate, allowing for detailed mapping of complex geological structure. This improvement geological study, which also resulting in a decrease in costs and resources needed to carry them out. It also resulting in reducing the environmental impact of the research, including the reduction of air emissions coming from transport (reducing the time and traffic) and power generation [1].

The most serious threat to the environment which may cause the seismic work, is a violation of hydrogeological balance in the area of seismic activity. Detonations of explosives in shallow wells or excitation of seismic waves using vibrators can cause mechanical violation of geological structures involving the escape of mud or water self induced flows. It can also lead to disruption of water, lowering the groundwater or pollution as a result of the movement of water from various aquifers. The threat to water is particularly the case when in the area where research is carried out seismic are water points or source, usable aquifers at a small depth and found near aquifers containing water of differing quality or mineralization [2].

Other risks are associated with seismic including terrain deformation, periodic emissions of pollutants into the atmosphere and noise. A significant negative effect of seismic surveys is the destruction of vegetation, mainly crops, forest floor by working seismic crews setting out along the seismic profiles and by transportation along seismic lines [2].

Terrain deformation related to drilling and generating vibrations are usually small. It may happen when a breach of the mechanical structure of the soil will, even after quite a long time after the completion of the work, producing underground caverns, sinkholes and then as a result of the collapse of the ground over cavern. Generating seismic wave may also cause a faint but perceptible vibrations in the surface layers of the survey area [2].

Exhaust emissions or dust and noise are associated with high intensity traffic vehicle fleet during seismic surveys. They last only for a short time and are the most burdensome in the vicinity of the base transport time of the morning, when carried out simultaneous movement of many heavy vehicles. During the day, these vehicles are moving one by one and returning to the base gradually, and therefore related to the movement of their exhaust emissions, lifting dust from the area of travel and noise are generally small [2].

Proper leading of seismic requires spreading on the field a large number of geophones to record the seismic signal. This will cause: air emissions and noise from internal combustion engines of vehicles and vibrators, grubbing of trees and shrubs and disturbance of local habitats [2].

Damage to agricultural and forestry are linked to the destruction of vegetation as a result of drilling and traffic along the seismic profiles and access roads (mainly vibrators). As a rule, they are destroyed crops or forest floor in strips not exceeding 4 meters in width along the seismic profile, and in areas where drilling is carried out – on the surface of 40 m^2. Often it is necessary to also perform controlled clipping trees [2].

3. IMPACT OF DRILLING ACTIVITIES

After indicating by seismic a geological structure that could potentially contain an accumulation of oil or natural gas, in order to confirm the presence of hydrocarbons, an drilling activities are performed. First studies are carried out in order to design the borehole. Well location is based on the results of geological and geophysical researches. In addition to the drilling rig on the drilling site are located equipment for processing drilling fluid, power generators, cementing equipment and fuel and water tanks, social rooms, boiler houses, roads, installations for the collection, treatment and disposal of waste [1].

For drilling deep boreholes with depths from one thousand to a few thousand meters, the method of rotation is applied. At the bottom of the well rotates the drill, which molds the rocks. The drill bit connects to the drill string which is connected to the surface drive system, which introduces it into rotation. The drill string consisting of drill pipes used for pumping the drilling mud into the hole, and maintain the circulation of the mud during the drilling. Special mechanical device allows plunging and pulling the drill string. Ventured into the hole are also pipe lining protecting borehole wall, allowing you to dig the hole, sampling and measurements and research. Casing isolate drilled aquifers and oil and gas horizons. The last phase of drilling is particularly important because it determines the efficiency of obtaining a sufficiently large hydrocarbon production. During drilling may occur: a near wellbore formation damage, uncontrolled flow of reservoir fluids (water, oil or natural gas). Before operating, in order to increase hydrocarbon production are performed well stimulations such as hydraulic fracturing treatments and matrix treatments. After well completion on the bottom of the borehole is installed downhole equipment enabling the exploitation of oil or gas [1, 2].

Drilling may adversely affect the environment in two ways. Adverse events may be related to the operation of drilling rigs and drilling process for environmental emissions. This first type of threats can occur for a limited period of time (for several weeks). On the other hand introduced into the environment of waste water or waste may affect the water, soil or land for many years. As part of this activity can be isolated by routine work, which is usually in the case of drilling does not pose much of a threat to the environment or emergency events that may cause significant environmental damage.

Drilling rigs are localized in the areas of agriculture, forestry, sometimes in protected areas and their operation can lead to negative changes in all elements of the environment, which include [1, 2]:

- change the structure of the soil at the location of equipment and the necessary infrastructure, including, among others: warehouses, landfills, boiler, drilling, social rooms, access roads;
- suppression of vegetation due to the use of chemicals;
- contamination of soil, ground water or oil derivatives, materials for preparation of drilling muds or fluids treatment;
- contamination of surface water and/or groundwater by substances migrating from the area of drilling (pollution from drilling pits, as, domestic sewage);
- excessive water consumption for domestic purposes;
- atmospheric pollution (at local and global scale) as a result of the emission of gaseous and particulate pollutants from fuel combustion in diesel engines, boiler rooms, transportation and torches;
- noise emissions associated with the operation of equipment on drilling site.

Environmental hazards can also be caused by the drilling process and procedures conducted in the borehole, they include:

- contamination of soils and soil, surface water and/or groundwater contamination migrating from drill borehole (fluid reservoir, escaping mud or process fluids);
- changes in the hydrogeological conditions (uprising hydraulic contact between the levels of water-bearing);
- excessive consumption of water treatment technology, eg. hydraulic fracturing;
- atmospheric pollution due to emission of gaseous and particulate pollutants emitted during drilling;
- terrain deformation;
- noise emissions associated with certain treatments such technology.

The above-mentioned negative effects occur in a small area for a short period of time and for routine work is generally small-scale. In the majority they will not cause serious environmental damage. In case of emergency events, the situation is different. They cause significant environmental damage. One of the failures that pose a greater threat to the environment are eruptions of drilling fluid or formation fluids. The outflow of reservoir fluids under high pressure can cause a dangerous situation for the environment and human health. These include fires of oil and gas, and outflow of gas, oil, brine, or very toxic hydrogen sulfide. To extensive contamination of land, water and land and the destruction of vegetation may result in leakage of brine or oil or flush out the output. Particularly dangerous for human health and the environment are eruptions of fluid reservoir containing hydrogen sulphide [2, 3].

4. EVALUATION OF ECOLOGICAL HAZARD ASSOCIATED TO HYDROCARBON EXPLORATION

The risk is inextricably linked to any activities carried out by man. According to ISO/IEC 73 risk can be defined as a combination of the probability of an event and its consequences [ISO/IEC 73]. However, the concept of environmental risk there is no single universally applicable definition. According to the definition adopted by the EPA risk is the possibility of harmful effects on human health or ecosystems resulting from exposure to environmental stressors (https://www.epa.gov/risk/about-risk-assessment). Environmental risk has two components: a risk to human life and health and environmental risks [4, 5].

Ecological risk is defined as the probability of an event which causes environmental degradation and the related effects [6]. Events causing environmental degradation are characterized by uniqueness, randomness, multi-contesting and diverse effects.

On the significance of environmental damage affects a number of factors, which include: size, breadth, duration and type of adverse effects of pollution. In contrast, the likelihood of environmental damage depends inter alia on: the nature of the factor threatening the environment, the quantity or intensity of this factor, processes for its use and exploitation [6, 7].

In order to eliminate or reduce the risk to an acceptable level of the action is called risk management is performed. This is a combination of analysis (evaluation) of the risk and its control [5, 8]. Risk analysis provides all the information about the risks, and risk control is deciding what we want or what we can do with the risk [5, 9].

The risk assessment in environmental management involves four stages: defining the scope of the analysis, identification of risks, identify consequences and assessment of the likelihood of events with defined consequences [7]. The risk assessment is realized by qualitative and quantitative selection of the particular method, which depends on the availability and scope of information, knowledge of risk analysis methods and the knowledge and experience of persons conducting the analysis.

For the assessment of the risks associated with the search for hydrocarbons authors proposed qualitative method – preliminary analysis of threats. It involves the risk classification in order to determine which of them can be accepted due to the negligible probability of occurrence and potential threats. This method allows you to select the types of risk that should be the subject of further analysis [7, 10].

In order to assess the ecological risk work related to exploration of oil and natural gas (seismic and drilling) some works connected with was analyzed. Some aspects and impacts were underlined due to environment for which the risk was estimated by multiplying the weight of the likelihood of adverse events weights and consequences [1, 10].

From the statistics [11, 12] and risk analysis [1] for adverse events that may occur during seismic surveys and drilling works, suggested the probability of their occurrence can be described by the following weights:

- extremely rare – adverse events causing environmental hazards that occur in the oil industry very rarely, once every 10–20 years, weight – 1;
- rare – adverse events causing danger to the environment occur rarely in the oil industry, once every 5–10 years, weight – 2;
- occasional – adverse events causing environmental hazards present in the oil industry, not related to routine activities, once in 1–5 years, weight – 3;
- likely – adverse events causing environmental hazards present in the oil industry once or several times a year, weight – 4;
- highly likely – adverse events causing environmental hazards occurring in individual well surface repeatedly in the course of the year, weight – 5.

Based on the characteristics of seismic and drilling work, it was identified the following categories of adverse events consequences for the environment [1]:

- slight – events resulting negative impact on the environment having an immediate, but short-term impact on the environment, which are subject to natural remediation after a few days or weeks, events that can have a noticeable (eg. an increase in the concentration of air pollutants), but limited impact on environment, an example might be the use of drilling equipment with low efficiency, which can cause a temporary increase in the emission of pollutants into the atmosphere, after repairing the equipment level of pollution will return to the state before the incident in a matter of hours or days, weight – 1;
- noticeable – events: side effects resulting negative impact on the environment acting immediately or in the long term (weeks or months), mild, environmental remediation can occur naturally after a long period of time or will require physical intervention, these events could have a significant impact on the environment, an example it may be a small leak at the wellhead causing pollution of ground-water, weight – 2;
- significant – events resulting negative impact on the environment immediate and long-term (eg. a year), an event that will cause chronic, but not disastrous for the environment, example would be entering the reservoir waters contaminated with fracturing fluids into watercourses, it will cause an increase in the concentration of metals and radioactive elements in sediments and river, in the absence of intervention effect of such contamination will persist for several years, weight – 3;
- serious – events resulting in an immediate negative impact on the environment, both short-term (hours or days) and long term (weeks, months, or years), the effects of these events are removed within a few weeks after the incident occurred, these events will have large severity and cause the extinction flora and fauna and have a significant impact on ecosystems, an example of such an event can be a leakage of large amounts of raw chemicals into surface waters, causing serious effects on the aquatic environment, weight – 4;
- catastrophic – events resulting negative impact on the environment occurring immediately and for long-term (several years), the effects of the events will be severe and long-range, causing the extinction of flora and fauna or irreversible damage to the environment lasting for several years, these events also have the potential to damage natural resources almost by irreversible way, returning to the state before the event takes several years, an example may be contamination of groundwater on a large scale chemicals from the fracturing fluids, weight – 5.

The risk of adverse events during the seismic and drilling work was estimated by setting specific aspects of their impact on the environment and determining by the numerical value (Tabs 1, 2 and 3). According to the Regulation of the European

Parliament and Council Regulation (EC) No 1221/2009 of the environmental aspect is a component of activities, products or services of the organization that affects or may affect the environment. The same document also defines the concept of environmental impact, as well as any change in the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.

Table 1

Risk and influence on environment from seismic measurements

Environmental Aspect	Impact on the Environment	Probability	Conse-quences	Risk
Contamination of groundwater	Ground water can be contaminated by filtration rainfall containing substances derived from Base and Research seismic area. Disturbance of water and pollution as a result of their movement water from different aquifers horizons by mechanical violation of geological structures pulls in the escape of mud or artesian flow of waters, caused by the detonation of explosives in shallow wells or excitation of seismic waves using vibrators	1	3	3
Contamination of surface waters	Rinsing by heavy pollution from the base and the study area (sewage, oil, grease, fuel), leakage or spillage of potentially hazardous substances derived from seismic equipment and engines. The use of an invasive method which is dynamite effect on surface runoff	3	2	6
Emissions to air (local air quality)	Emissions gases and dust associated with high intensity traffic and vibrators during the work and the use of dynamite in shallow holes	5	1	5
Emissions to the atmosphere (global warming potential)	Along with the emission of gases, fumes and dust from motors and vibrators, to get into the atmosphere greenhouse gases that will contribute to climate change	5	1	5

Table 1 cont.

Environmental Aspect	Impact on the Environment	Probability	Conse-quences	Risk
Pollution of land	Rinsing by heavy pollution from land bases and research area (sewage, oil, grease, fuel or chemicals used to prepare scrubbers). Aspiration into the ground environment of large amounts of oils, lubricants, fuels or chemicals used to prepare scrubbers	2	4	8
Changes in the position of underground water	Lowering the groundwater table by mechanical violation of geological structures involving the escape of mud or self flow water, caused by the detonation of explosives in shallow wells or excitation of seismic waves using vibrators.	1	3	3
Terrain deformation	The creation of access roads to the test area. Grubbing land, in order to allow passage vibrators. Violation of the mechanical structure of the soil due to the drilling and to generate vibrations may produce underground caverns, sinkholes and then. Vibrations in the surface layers of the ground caused by the generation of seismic wave	5	2	10
Biodiversity	Disruption to the lives of protected species of animals. Interfering with the migration periods of birds. The disorder periods of breeding animals. Deforestation and other vegetation. The destruction of vegetation, mainly crops and forest floor along the seismic profiles and routes of transportation (mainly vibrators). Threats to living organisms associated with the leakage of different substances that get into the water-soil environment	4	2	8

Table 1 cont.

Noise	The noise associated with high intensity traffic, vibrators and generators. The highest continuous noise level is near the vibrators	5	2	10
Influence on landscape	Removal of vegetation, trees and other elements on the surface affects the landscape. It can cause damage to the local infrastructure and archaeological sites due to vibration. Compromised the structure of the surface layer of the ground during the creation of access roads or through the movement of vehicles off the roads in the area lead to scarring and increased erosion	3	1	3
Traffic	Local increase traffic because of the work of research.	4	1	4
Induced seismicity	Sources of acoustic waves (vibrators, explosives) can generate noise, disorder affecting the humans and wildlife.	5	1	5

Table 2

Risk and environmental impact of drilling activities

Environmental Aspect	Impact on the Environment	Probability	Conse-quences	Risk
Contamination of groundwater	Ground water may be contaminated by filtration rainfall containing substances resulting from drilling. Pollution levels of drinking water associated with leaky piping or cement. Leaky holes can provide a migration path for contaminations (drilling fluids, chemicals or cuttings) into aquifers	1	2	2
Contamination of groundwater (failures)	The outflow of the liquid treatment (anti-corrosion, biocides, anti-scaling) associated with a loss of tightness. In the case reservoir fluids eruption filtration to drinking water horizons	1	5	5

Table 2 cont.

Environmental Aspect	Impact on the Environment	Probability	Conse-quences	Risk
Contamination of surface waters	Rinsing by heavy pollution from drilling site (sewage, oil, grease, fuel or chemicals used for preparation of muds, liquids or cement). Leaks associated with improperly well completion	2	3	6
Contamination of surface waters (failures)	In the case of eruption entering the reservoir fluids to surface watercourses (runoff). Faulty wiring or drill equipment for the preparation of liquid treatment	2	5	10
Emissions to the atmosphere	Gas and dust emissions from the boiler, aggregates transport. The release of trapped gas, VOCs and dust from drilling. Emissions of greenhouse gases and gases escape from the flares	3	1	3
Emissions to the atmosphere (failures)	The outflow into the atmosphere of methane or hydrogen sulfide during the eruption	1	5	5
Pollution of land	Rinsing by heavy pollution from drilling site (sewage, oil, grease, fuel or chemicals used for preparation of muds, technological liquids or cement)	3	2	6
Pollution of land (failures)	Filtration into the ground large amounts of oils, lubricants, fuels or chemicals used for preparation of muds, technological liquids or cement	1	5	5
Changes in the position of underground water	Lowering the water table associated with excessive consumption of water for technological purposes	1	4	4

Table 2 cont.

Terrain deformation	Drilling boreholes can mechanically impair noticeably soil structure and surface area. They can be formed in a long period of time, underground caverns and cracks as a result of the collapse of the ground above the cavern. Collapse of the land surface after the completion of drilling	4	2	8
Noise	The noise associated with the traffic generators and devices. The highest level of continuous noise occurs in the vicinity of the drilling rig. High noise levels occur during the work, which are used for additional equipments, eg. during cementing	5	2	10
Biodiversity	Threats to living organisms mainly related to leaks of various substances that get into the water-soil environment	3	3	9
Influence on landscape	Drilling rig is a very common element in the industrial area of agricultural or forestry	4	1	4

Table 3
Categories and figures risk

Description of the risk	The numerical value	Category of risk acceptance
Small	up to 5	tolerated
Medium	6–12	controlled
Big	13–19	without acceptance
Very big	20–25	dangerous

5. CONCLUSIONS

Preliminary analysis of environmental risks related to the exploration of hydrocarbon reservoirs allowed the indication of the types of risks that differentially affect the environment.

Seismic cause ecological risk, for which the category of risk acceptance ranges controlled and tolerated. In terms of threats controlled seismic impact on the following environmental aspects: landscape, pollution and changing the location of groundwater, air pollution (locally and globally), traffic and seismic activity. Risk tolerance associated with seismic is a pollution of surface water and soil, noise, terrain deformation and impact on biodiversity.

Ecological risk estimates for seismic research indicates that there is no need to take action aimed at the reduction of this risk. Well-planned and carefully carried out with the use of modern technical means seismic surveys generally do not constitute a serious threat to environment, but it is possible to take actions that contribute to the preservation of the environment. Monitoring the water level in wells in the area, which will be conducted seismic work will allow the finding of a violation of hydrogeological balance and an indication of the scale changes occurring during seismic surveys.

During the work, it is important to use such methods to generate vibrations that the probability of disorders of ground water relations was as small as possible. The indication of the paths of heavy equipment movement, located on the grounds of possible low sensitivity to noise, dust and emissions minimize nuisances related to transport. Limiting the damage in agriculture and forestry is made possible by selecting such a deadline of the works, which will cause the least possible disturbance in the functioning of ecosystems and informing local community about the date of commencement of work, providing access roads sketches and profiles. This allows for proper planning of agricultural land and any gathering crops before the work begins. Well-planned and carefully carried out with the use of modern technical means seismic surveys generally do not constitute a serious threat to the environment. While decreasing the risks associated with the performance of very large number of exploration drilling during which interference in the environment is much deeper, and thus the potential danger of damage is higher.

Drilling cause environmental risks categorized as controlled and tolerated. In terms of the controlled risk, drilling impact on the following environmental aspects: landscape, pollution and changing the location of groundwater, air pollution (at local and global) and land. Risk tolerance associated with the work of drilling are similar as in the case of seismic pollution of surface water and soil, noise, terrain deformation and impact on biodiversity.

The ecological risk estimated for drilling work indicates that there is no need to take action to reduce this risk. However, some steps can be taken that will contribute to the preservation of the environment unchanged. These include the application of any rules according to mining operations.

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