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Environmental consequences of oil and gas extraction on the example of the Bytkiv-Babchenskyi Oil and Gas Field

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Abstract. Most technological processes create an anthropogenic burden on the environment, and the oil and gas industry is no exception. Due to oil and gas production in the Bytkiv-Babchenskyi Field area, there is gas pollution in the territory of Pasichna and Bytkiv settlements, oil leaks to the surface, however, it is necessary to strive to minimise the negative impact and preserve the environment. The purpose of the study was to conduct a comprehensive analysis of the ecological state of the atmosphere, soils, hydrosphere and technogenic physical fields (radiation, noise, vibration, electromagnetic) near various oil and gas production facilities of the Bytkiv-Babchenskyi Field to determine the man-made impact of the oil and gas production process. The following methods were used: observation, measurement of environmental indicators, meteorological and physical field parameters, and laboratory analysis methods. A wide range of modern instruments was used, which allows for rapid analysis and determination of physical field parameters. In the laboratory, a more detailed analysis of water and soil samples was carried out using physico-chemical methods of analysis.

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The determined chemical, physico-chemical indicators of water quality, the content of volatile organic compounds and polyaromatic hydrocarbons complied with the regulatory standards. Among the toxic elements, strontium was detected, the content of which did not exceed the maximum permissible concentration. In terms of salt content, the hydrocarbonate water is slightly mineralised. The soils are low-saline with a neutral pH of the soil solution. The content of mobile iron, phosphorus, and nitrogen compounds is very low, low, and medium, respectively, and organic matter is very high. It was established that the parameters of anthropogenic physical fields do not exceed the permissible standards. The results of the study showed that the technogenic impact of the oil and gas production process on the air, water bodies and soils is within the permissible limits. The practical significance of the results obtained is the comprehensive monitoring of the state of natural objects throughout the year, which is important for oil and gas industry professionals when assessing the environmental impact of oil and gas production facilities and developing environmental protection measures

Keywords: oil and gas industry; man-made physical fields; physical and chemical research; gas pollution; atmospheric air; soils; hydrosphere objects

Introduction

Oil and gas companies are among the main polluters of the environment. This is due to the hydrocarbon production process itself, as well as to their primary preparation, transportation and processing. Pollution occurs both during the technological process and in the event of emergency situations. Emergencies are the most dangerous, as a large area of land is contaminated in a relatively short amount of time, which loses its ability to recover for a long period of time. The main causes of emergencies are salvo emissions, fires and damage to pipelines. The main sources of environmental pollution at oil and gas production facilities are production and injection wells, reservoir pressure maintenance pumping stations, group installations, individual well assemblies and other industrial oil and gas production facilities, which are characterised by their density across the entire oil and gas field. Environmental problems are caused by a number of factors – natural, technological and even historical – which cannot be separated from each other and which, to some extent, are interrelated and have mutual cause and effect. Therefore, the emergence and development of environmental problems begins with the first attempts to extract oil and gas.

As noted by J. Lubas (2021), oil and gas production in the Carpathian Region began at the end of the eighteenth century and was uncontrolled, and 1853, according to O. Gvozdevich (2021), is the year of foundation of the Galician oil industry. The problem of old oilfields is primarily related to abandoned wells, which, for example, according to J.P. Williams *et al.* (2020), number several million in the United States and up to 400,000 in Canada, and are a source of constant hydrocarbon gas emissions. T.M. Yatsyshyn *et al.* (2022) found that there are also abandoned wells of the old stock in the Carpathian Region, and environmental pollution is associated with methane emissions, which is also a greenhouse gas. In addition, data on the location of a significant number of wells drilled during the Austro-Hungarian Empire and Poland from the nineteenth century to 1939 has been lost in most cases. Therefore, the presence of old oil and gas wells in the study area can be considered the first cause of man-made environmental impacts.

The emergence of environmental problems is caused by the peculiarities of the geological structure of the Carpathian Region, the complexity of which is noted in the research of S. Wolkowicz *et al.* (2020). The presence of a significant number of tectonic faults causes the emanation of hydrocarbon gases, oil and formation water leaks to the surface under the influence of reservoir pressure. This is the reason for the natural pollution of the Bytkiv-Babchenskyi Oil and Gas Field. However, the tectonic processes that are intensively occurring in the Carpathian Region can also cause a violation of the wellbore integrity. This issue is especially relevant for the old well stock, where the leakage of old casing may occur due to the cementing technology used at the time. L. Bilous (2021) studied the historiography of environmental problems that arise at oil and gas production facilities on the example of the Boryslavnaftogaz Oil and Gas Production Division. It is noted that many scientists have studied the complex negative impact of the development and operation of the Boryslav oil field on all ecological systems and their components – atmospheric air, soil, water and biological resources. On the other hand, the territory of the Bytkiv-Babchenskyi Field is characterised by a fairly dense location of all oil and gas production facilities. For example, there are only about 600 wells in the field, more than 70% of which are not in operation for various reasons.

The Bytkiv-Babchenskyi Oil and Gas Field is located in the Nadvirna oil and gas production area of the Carpathian Region, which is one of the oldest oil fields not only in the Carpathian Region but also in Europe. The region is characterised by complex geological and tectonic conditions, and oil and gas production leads to intensification of fracture formation in rocks and increased migration of hydrocarbons from the subsoil. The territory of the Bytkiv-Babchenskyi Field is a densely populated area of Ivano-Frankivsk Region with a population of over 20,000 people. There are also six nature reserve sites, and some species of animals are protected under the Convention on the Conservation of Wild Flora and Fauna and Natural Habitats in Europe. The importance of conducting studies of the anthropogenic impact of oil and gas production facilities on environmental components is also related to the fact that

the Bytkiv-Babchenskyi Field is located in a densely populated area. The main settlements within its boundaries are Bytkiv, Markova, Maniava, Babche, Lukavets, Molodkiv, Sokolovytsia, Postoiata, Pasichna, Pniv, Bilozoryna. The Bytkiv-Babchenskyi Field has 6 objects of the nature reserve fund: Skit-Maniava forest reserve of national importance; Debrytsia protected tract; Syniachky protected tract; Hlybokyi protected tract of local importance; Komarnyky protected tract of local importance; Boiarske protected tract of local importance (The nature reserve fund..., 2023). Therefore, it seems important to determine the extent of the environmental impact of hydrocarbon production. The purpose of the study was to observe and assess changes in the quality indicators of the environment in the area of influence of oil and gas production facilities located in the Bytkiv-Babchenskyi Field.

Literature Review

The history of the oil and gas industry in the Carpathian Region is an important historical aspect in shaping the current environmental problems of the oil and gas industry. Oil production in Galicia began in the mid-nineteenth century. In 1854, the Mining Statute was adopted, which allowed oil production by private individuals, as indicated in their research by V.S. Biletsky *et al.* (2019). However, the first well in Ivano-Frankivsk Region was drilled in Kolomyia district in 1872, and in Prykarpattia in 1861 in the Boryslav. The intensive production of hydrocarbons, primarily oil, is evidenced by the fact that in 1909, oil production in the Boryslav oilfield district accounted for 5% of global production. This significant development of the oil and gas industry necessitated the construction of pipelines. The first oil pipeline was built in 1886, and the first gas pipeline in 1912. As early as 1932, there were seven companies producing oil and gas in Galicia, transporting oil and gas raw materials through their own pipelines.

The Bytkiv-Babchenskyi Oil and Gas Field is located in the Podkarpatska oil and gas bearing region of the Nadvirna oil and gas production area, with an area of over 16,000 hectares, as noted by M. Vul (2003). Development of the field began in 1860. The field belongs to the Berehove section of the Carpathians and a group of folds in the central part of the Boryslavsko-Pokutska zone, and oil and gas condensate deposits are associated with the Deep Fold. The study of the geological and tectonic conditions of the field formation is important in terms of environmental issues, especially those of natural origin. The field area is located within the Nadvirna seismogenic zone, which is part of the Boryslavsko-Pokutska structural and facies zone of the Internal Zone of the Fore-Carpathian Trough, overlain by the thrust of the Skiba Zone of the Carpathians and where the Nadvirna moral and neotectonic node is located, as described in the collective monograph edited by M. Malovanyi (2020). The Bystrytsko-Nadvirna Fault is a deep tectonic fault, which is regional in nature and is located outside the study area. The fault is a zone of subparallel faults such as dip-slides, the amplitude of which in the near-surface geological horizons ranges from the first metres to several tens of metres, while with depth it increases to 50-100 m and more. The fault zone is 100-200 m wide. V. Shlapinskyi (2018) pointed out that the geological structure of the territory is complex, with numerous structural faults. The horizontal displacement of identical folds can reach 10 km, and the amplitude of vertical displacement is 1.5-2 km.

The presence of tectonic faults causes emanation of hydrocarbons to the surface at all oil and gas fields in the world, especially in the territory of old oil fields with abandoned oil and gas wells. Since the study area is densely populated and oil and gas production facilities are located in the territory of settlements, assessing the level of air pollution in the areas where they are located is an important area of research into the environmental impact of oil and gas production. M.J. Munawar *et al.* (2022) emphasised that the main air pollutant is not only hydrocarbon gases, but also hydrogen sulphide. Not only natural gases, but also oil and produced water move through tectonic fractures under the influence of reservoir pressure. Therefore, in oil and gas production areas with complex geological and tectonic structure, oil and reservoir fluids leak to the surface. A significant number of such manifestations in Prykarpattia are associated with the Boryslav oil and gas condensate field, where the city of Boryslav is a man-made environmental disaster, as described in the research of many Prykarpattia scientists since the 70s of the last century. V. Filipovych *et al.* (2020) found that the area of methane pollution due to natural methane leakage in Boryslav is 20 km^2.

E. Ivanov *et al.* (2020), studying the problem of gas pollution in Boryslav and uncontrolled leakage of formation water, determined that natural pollution of the territory is superimposed on man-made pollution, which is associated with the improper arrangement of oil and gas production facilities. The consequences are the contamination of soil and hydrosphere. Therefore, it is necessary to take into account not only the quality composition of oil, but also the landscape of the territory, which will directly affect the degree of pollution of natural objects and the development of degradation processes. According to the research of M. Pavliuk *et al.* (2021), the oil of the Bytkiv-Babchenskyi Field is classified as light oil, as its density ranges from 750-800 kg/m^3. The average light hydrocarbon content is 10-20%, and the aromatic group composition is aromatic. Oil may contain an increased sulphur content of 1-8%. The Bytkiv-Babchenskyi Field is subject to significant anthropogenic impact. There are also oil and gas discoveries in the study area, especially in the settlements of Bytkiv and Pasichna. Thus, the Bytkiv-Babchenskyi Oil and Gas Field is located in an area with a complex geological and tectonic structure with a widespread network of tectonic faults, which causes natural emanation of reservoir gases and oil to the surface. This results in natural gas pollution of the study area and the presence of soils contaminated with oil and formation water.

Materials and Methods

To determine the anthropogenic impact of the oil and gas production process on the territory of the Bytkiv-Babchenskyi Field, eight objects were selected, seven of which are wells and one group unit. The objects are located in different parts of the field, including in the territory of settlements, covering the maximum area of the Bytkiv-Babchenskyi Field. Because of the martial law in the country, it is impossible to provide a map of the study area with oil and gas production facilities. Since oil and gas production facilities are strategic objects of Ukraine, this article does not identify well numbers and group units. The observations were carried out in 2022-2023. To optimise the field studies, oil and gas facilities were divided into two groups: Group 1 is represented by facilities 1-4, Group 2 is represented by facilities 5-8, where the studies were conducted quarterly in 2022 and 2023, respectively. At each of the oil and gas production facilities, the state of environmental components – atmospheric air, water bodies and soils, and anthropogenic physical fields (noise, vibrating, radiative and electromagnetic) – was studied. Quarterly measurements made it possible to observe and assess changes in environmental quality indicators at the Bytkiv-Babchenskyi Field to determine the impact of oil and gas production facilities on the environment.

The atmospheric air studies were conducted in accordance with Article No. 29 of Law of Ukraine No. 2707-XII (1992) and Procedure for State Monitoring in the Field of Atmospheric Protection (2019). Observations were carried out in accordance with the requirements of the Generalised List of Maximum Permissible Concentrations (MPCs) and Tentatively Safe Exposure Levels (SELs) of Harmful Substances for the Water of Fishery Reservoirs (1991); Methodological Guidelines "Justification of Estimated Safe Exposure Levels (SELs) of Chemical Substances in the Atmospheric Air of Populated Areas" (2004); Hygienic Regulations No. 156/34439 (2020); and Hygienic Regulations No. 157/34440 (2020). The study was conducted in open areas that are well ventilated from all sides at a height of 1.5 m above the ground. When assessing the impact of oil and gas production on the air, the location of the study site was considered and the main meteorological factors such as temperature, relative humidity, wind speed and illumination were determined. The soil cover in the study area of the Bytkiv-Babchenskyi Field is homogeneous, and during the observation period (2022-2023), no accidents occurred, and no oil and formation fluids were recorded on the daylight surface from oil and gas production facilities. Therefore, a visual examination of soil samples and pH determination was carried out around each of the study sites. However, two sites were selected to control pollution, in the vicinity of oil and gas production facilities 2 and 3, from which soil samples were collected for physical and chemical analysis. Sampling and preparation for physical and chemical analysis was carried out in accordance with the regulatory documents (DSTU ISO 10381-1:2004, 2004; DSTU ISO 10381-2:2004, 2004; Environmental protection…, 2005).

According to DSTU 4287:2004 (2004), the maximum area of representativeness of a sampling point for a pollution examination in mountainous areas is 3 ha. The sampling points were selected to avoid the influence of extraneous factors that could affect the results and should not be sampled closer than 50 m from them. In this case, such factors included the roads of the settlement and forest belts. There were no areas of vegetation with a sharp difference from the background in the sampling area. At each of the two study sites of the Bytkiv-Babchenskyi Field, one combined soil sample was collected, consisting of a set of individual point samples combined in proportion to the area of the study site of 100×100 m around the oil and gas production facility. Soil sampling was carried out to determine the general quality of the soil, which does not require regular testing and can be carried out at certain (irregular) intervals. To assess the overall quality of the soil, the following factors were investigated: hydrogen ion exponent, hydrolytic acidity, mass fraction of organic matter, ammonia nitrogen, nitrate nitrogen, mobile phosphorus and iron compounds, exchangeable calcium, exchangeable magnesium, amount of absorbed bases, mass concentration of water-soluble sulphates. Since the study was conducted to determine the overall quality of the soil, soil samples were taken from a depth of 10-20 cm and are classified as spatial samples.

In 2022, water quality in the Bystrytsia Nadvirnianska River was monitored in the settlements of Bytkiv and Pasichna, as these settlements are heart to a significant number of oil and gas production facilities. Water samples were collected and analysed in accordance with the following regulatory documents: DSTU ISO 5667-6:2009 (2009); Procedure for Checking, Taking Water Samples and Conducting Their Analysis (2019); Environmental Quality Standards (ENSs) for Determining the Chemical State of a Surface Water Body (2019); and Hygienic Regulations No. 524/37860 (2022). In the Bystrytsia Nadvirnianska River in the settlements of Bytkiv and Pasichna, a simple water sample was taken, which is obtained by a single water intake for further chemical and physicochemical analysis. In addition, a 4-in-1 autonomous portable water laboratory AZ-8603 (AZ-Instrument, China) was used to perform proximal analyses of the following indicators at the sampling site: hydrogen ion exponent, salinity, dissolved oxygen, and temperature. The chemical and physicochemical indicators of water and soil pollution were determined in the water monitoring laboratory of the Western Region of the Dniester Basin Water Resources Administration, accredited in accordance with DSTU EN ISO/IEC 17025:2019 (2019). To study the impact of anthropogenic physical fields around 1-8 oil and gas production facilities of the Bytkiv-Babchenskyi Field, electromagnetic and radioactive radiation was measured to determine radionuclides, noise and vibrating characteristics during the technological blowing-out process of well and operation of the Pumpjack. Regulatory documents were used to analyse the study results: DSP 173-96 (1996); DSN 239-96 (1996); DSN 3.3.6.039-99 (1999); and DBN V.1.1-31:2013 (2013).

The equipment used in conducting field research of the impact of oil and gas production facilities on environmental components was purchased under the international project HUSKROUA/1702/6.1/0022CRIMIGE Regional Centre for Training and Monitoring of the Environmental Impact of Electrical Installations (2020) and equipment of the certified Educational and Scientific Laboratory "Physical and Chemical Methods of Environmental State Research" (2023) of the Department of Ecology of the Ivano-Frankivsk National Technical University of Oil and Gas (Certificate of Technical Competence No. IF 447 of 31.03.2023). The equipment allowed for a wide range of environmental studies (the country of manufacture of most devices is Germany): determination of meteorological parameters (air temperature, humidity, wind speed, illumination); air pollution (content of fine particles PM2.5-10, concentration of carbon monoxide and formaldehyde, dew point temperature); water pollution (dissolved oxygen, pH, mineralisation); measurement of electric and magnetic fields, extended and long-term recording of all important parameters; noise measurement; vibration frequency measurement. The equipment allowed to determine the radiation background and identify radionuclides with an indication of the category to which they belong in accordance with the requirements of the International Atomic Energy Agency, including industrial radionuclides (^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{152}Eu and ^{241}Am) and natural radionuclides (^{40}K, ^{226}Ra, ^{232}Th, ^{238}U and decay products). AZ-8603 autonomous portable water laboratory (4 in 1) was used in the research. Oximeter/pH meter/conductometer/salinity meter was used. ET-965 multifunctional device for assessing meteorological parameters was utilised to identify air temperature, humidity, wind speed, illumination. Air quality analyser CEM DT-9881 was used for determining the content of fine particles (dust), concentration of carbon monoxide and formaldehyde, dew point temperature. Electromagnetic radiation analyser NFA-400 is designed to measure the electrical and magnetic components, with the range of magnetic flux density measurement from 0.1 to 9.999 nT. Frequency analyser NFE-35C is designed to detect pulsed sources of electromagnetic radiation. Radiometer SPEKTRA MKS-11GN was used – a highly sensitive search dosimeter with the ability to computer plot the obtained spectra and record observation points on the map. Vibrometer PCE-VT 3700S was also utilised. Thus, the surveys were conducted with modern European equipment and in accredited laboratories, which confirms the reliability of the results obtained.

Results and Discussion

The main natural component that is adversely affected is atmospheric air. The process of oil and gas production at the Bytkiv-Babchenskyi Field is accompanied by emissions of pollutants into the air from the system of collection, treatment and transportation of well products from the field, which is represented by group units, a thermochemical unit and individual well collections. There is also a natural migration of gas from oil and gas-bearing formations to the Earth's surface, which is associated with the widespread development of fractures. This is the main reason for the gas pollution in the Pasichna and Bytkiv settlements. Meteorological and air pollution parameter studies were conducted near 8 oil and gas production facilities of the Bytkiv-Babchenskyi Field, some of which are shown in the photo (Fig. 1).

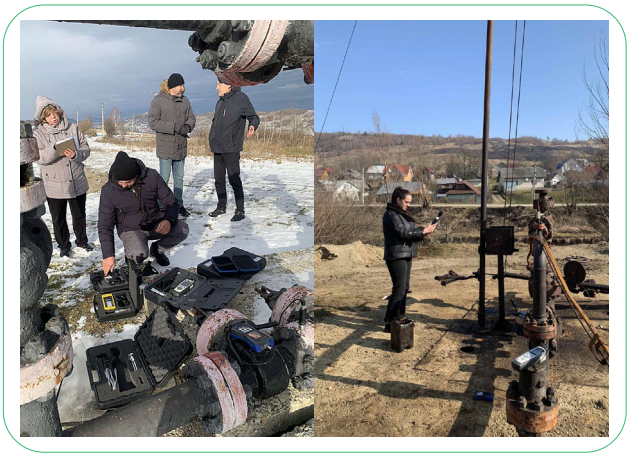

Figure 1. Conducting field research
Source: created by the authors

The main results of the field research of air pollution from oil and gas production facilities at the Bytkiv-Babchenskyi Field in 2022-2023 are presented in Table 1 and Table 2.

Table 1. Results of the study of air pollution from oil and gas production facilities at the Bytkiv-Babchenskyi Field, 2022

Indicator name	Oil and gas production facilities at the Bytkiv-Babchenskyi Field															
	Facility 1				Facility 2				Facility 3				Facility 4			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Air temperature, °C	+3.7	+20.4	+28.9	+0.8	+3.8	+20.5	+31.8	+0.9	+3.8	+20.2	+29.6	+0.2	+3.8	+22.5	+33.1	−0.9
Relative humidity, %	50.4	38.3	46.4	89	50.4	38.3	38.7	90.4	50.4	36.7	42.7	87	50.4	38.1	38.7	94.0
Wind speed, m/s	2.5	5.5	0.1	1.0	2.6	6.0	0.0	1.1	2.6	6.2	0.1	1.9	2.3	5.8	0.1	1.6

Table 1. Continued

Indicator name	Oil and gas production facilities at the Bytkiv-Babchenskyi Field															
	Facility 1				Facility 2				Facility 3				Facility 4			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Illumination, lux	0.54	10.5	12.8	0.21	0.47	10.9	33.3	0.27	0.51	10.7	36.2	0.45	0.54	10.8	38.7	0.24
CO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCHO	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0
PM0.5-2.5	0.0	4	5	34	0.0	4	4	25	3	21	24	17	0.0	33	3.7	31
PM2.5-10	0.0	10	11	61	0.0	11	10	54	21	53	67	32	0.0	64	10	63

Source: created by the authors

Table 2. Results of the study of air pollution from oil and gas production facilities at the Bytkiv-Babchenskyi Field, 2023

Indicator name	Oil and gas production facilities at the Bytkiv-Babchenskyi Field															
	Facility 5				Facility 6				Facility 7				Facility 8			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Air temperature, °C	−3.2	+21.7	+28.9	23.3	−3.0	+21.7	+28.9	23.5	−2.1	+21.9	+28.9	23.5	−3.0	+21.9	+28.9	23.5
Relative humidity, %	65.7	37.1	46.4	58.7	63.3	37.1	46.4	60.0	57.1	38.5	46.4	60.0	62.7	38.5	46.4	60.0
Wind speed, m/s	0.8	0.3	0.1	0.6	1.5	0.3	0.1	0.8	1.3	0.1	0.1	0.2	1.7	0.1	0.1	0.2
Illumination, lux	1.7	9.7	12.8	0.31	1.7	9.5	13.1	0.3	3.3	10.8	14.1	0.2	3.3	11.5	15.2	0.28
CO	0.0	0.0	0.0	0.0	0.001	0.001	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCHO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PM0.5-2.5	5	4	5	3	3	2	2	2	9	9	8	7	4	4	5	3
PM2.5-10	8	8	11	9	9	8	8	9	17	15	15	12	8	8	10	7

Source: created by the authors

Thus, the results of the studies carried out in 2022-2023 on the state of atmospheric air near oil and gas production facilities in the vicinity of oil and gas production facilities in the Bytkiv-Babchenskyi Field show the following carbon monoxide emissions at most facilities are absent or do not exceed the MPC; the presence of formaldehyde in the air recorded near some facilities does not exceed the permissible hygienic standards; dust particles of PM 2.5-10 prevail in the air, which is associated with meteorological factors. O. Romaniuk (2023) described in detail the environmental impacts of oil and gas production and the problem of gas pollution in settlements on the example of Boryslav. S.N. Riddick *et al.* (2020) focused on methane air pollution in the areas of oil fields, which is especially relevant in the territory of old oil fields, where there are many abandoned wells. M. Gålfalk *et al.* (2021) proposed to explore such areas using unmanned aerial vehicles with CH_4 gas detectors, which allows to map CH_4 concentration and wind speed with an accuracy of 0.84 parts per billion/s and 0.1 m/s, respectively, and is especially important in complex landscapes. P.M.B. Saint-Vincent *et al.* (2020) and A. Townsend-Small & J. Hoschouer (2021) have shown that gas concentrations are also affected by the season, so it is important to conduct continuous monitoring of well emissions throughout the year. In their research, J. Jońca *et al.* (2022) proved the influence of meteorological factors on the conditions of concentration and dispersion of hydrocarbon gases in the territory of oil fields. L. Makarenko (2024) showed that an increase in humidity reduces PM 2.5 pollution, while PM 10 pollution increases. And the pollution rate is largely influenced by the air exchange process. M. Hu *et al.* (2021) established a direct correlation between meteorological factors and the degree of air pollution.

Thus, most studies of the impact of oil and gas production on the air are related to the emanations of hydrocarbon gases, primarily methane. However, no studies have been conducted on the presence of other gases, such as formaldehyde and carbon monoxide, at oilfields. The results of the research show the presence of these gases near oil and gas production facilities, which requires further more detailed observations. However, the use of unmanned aerial vehicles with gas detectors is only appropriate when mapping areas with abandoned wells that may be a source of CH_4. Researchers have shown the influence of seasonal factors on the concentration of both methane and PM particles in the air. The study confirms the research of other scientists on the impact of meteorological parameters on the concentration of PM2.5-10. During the monitoring of water bodies, express analysis was used using the AZ-8603 autonomous portable water laboratory (4 in 1) oximeter/pH-meter/satellite/TDS (Fig. 2). The results of the observations are presented in Table 3. For chemical analysis of water samples collected in the Bystrytsia Nadvirnianska River near Site 7, the Water Monitoring Laboratory of the Western region of the Dniester Basin Water Resources Administration determined the mass concentration of elements, chemical and physicochemical indicators of water quality, and examined the content of volatile organic compounds, polyaromatic hydrocarbons, heavy metals, pesticides, pharmaceuticals, and elemental composition of water (Fig. 3).

Figure 2. Rapid water analysis
Source: created by the authors

Table 3. Results of rapid analysis of water samples from water bodies

Indicator name	Bystrytsia Nadvirnianska River near Site 6	Bystrytsia Nadvirnianska River near Site 7	Hygienic water quality standards	Code of regulatory documents
Hydrogen index, pH	6.4	7.0	6.5-8.5	DSTU 4077-2001 (2002)
Mineralisation, mg/dm^3	51.5	478	1,000	DSPN 2.2.4-171-10 (2010)
Dissolved oxygen, mg O_2/dm^3	30	12	> 4.0	DSTU ISO 5813:2004 (2004)
Temperature, °C	12.2	13.4		

Source: created by the authors

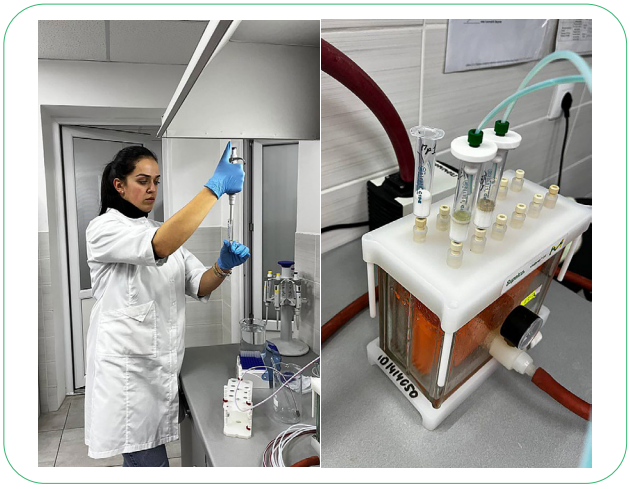

Figure 3. Sample preparation and analysis of water samples in the certified laboratory of the Dniester Basin Water Resources Administration
Source: created by the authors

The following conclusions can be drawn based on the results of the water sample analysis. In terms of salt content, the water is slightly mineralised, the water hardness is 4.7 mg-eq/dm^3 with an upper limit of 7.0 mg-eq/dm^3, the calcium content is 71 mg/dm^3, the bicarbonate content is 305 mg-eq/dm^3, and the water is bicarbonate. Chromatographic tests from the List 45+ according to the Law of Ukraine No. 45 (2017), the water sample contained volatile organic compounds such as benzene, dichloromethane, hexachlorobutadiene, and the concentrations of these pollutants did not exceed environmental quality standards. The content of biogenic elements, namely nitrogen, which is present in the form of inorganic compounds – ammonium ions, nitrate ions, is very low, and the content of phosphorus, in the form of orthophosphates and nitrites, is not detected, the concentration of biogenic elements is insignificant. The elemental composition is characterised by the presence of argentum, iron, manganese, nickel, molybdenum, potassium, sodium, zinc, vanadium, phosphorus, sulfur, titanium, lithium, stibium, barium, selenium and boron,

which are detected in insignificant concentrations that do not exceed the MPC, and therefore can be considered as trace elements. Among the toxic elements, strontium was detected in the water sample, with a content equal to the MPC. Toxic metals – cadmium, lead, arsenic and mercury – are absent. According to the results of chemical and physico-chemical indicators, the water is clean. The studies have not revealed any negative impact of oil and gas production facilities on the hydrosphere.

Research on the Bystrytsia Nadvirnianska River is related to the following main areas. A. Mkrtchian & I. Kovalchuk (2023) established the regularity of seasonal differentiation of the influence of certain factors and landforms on the temperature regime of the river. O.V. Lototska & V.O. Prokopov (2021) studied the water quality indicators of the Bystrytsia Nadvirnianska River within the Cherniiv Village of the Ivano-Frankivsk territorial community by such indicators as dissolved oxygen, ammonium ion, phosphate ion, chemical oxygen consumption, biochemical oxygen consumption, iron and manganese content, which correlates with the studies of the Bystrytsia Nadvirnianska River within the settlements of Pasichna and the southern part of Bytkiv. Since the oil and gas production facilities of the Bytkiv-Babchenskyi Field are located near the Bystrytsia Nadvirna River with its numerous tributaries flowing through the territory of the settlements, the study of water quality indicators is important to prevent possible pollution of water bodies. However, no studies have been conducted on the impact of oil and gas production facilities on water quality indicators within the Carpathian Region. There is also no information on seasonal fluctuations in the physicochemical and chemical parameters of water. Therefore, research in terms of monitoring the chemical and physicochemical water quality indicators of the Bystrytsia Nadvirnianska River within the impact of oil and gas production in the Bytkiv-Babchenskyi Field is relevant both from a practical and scientific point of view.

Visual examination of soil samples collected around oil and gas production facilities 1-8 showed that the soils are of the sod type with a low percentage of mechanical fractions. The soils are of the accumulative type, formed under unfavourable conditions by the humus-accumulative (sod) soil formation process. According to the results of the laboratory tests, it was found that the soils at the Bytkiv-Babchenskyi Field are characterised by very high and high organic matter content, with the content of 6.40% and 4.97% respectively, and high and medium levels of the sum of absorbed bases, the content of ammonium and nitrate nitrogen is medium, the content of mobile phosphorus compounds is low and medium, and the content of mobile iron compounds is very low. The low content of water-soluble sulphates is positive and indicates low soil salinity. The reaction of the soil solution is close to neutral. The pH value of the soil in the express analysis was in the range of 6.8-8.0. There are fluctuations in the pH value around oil and gas production facilities within ± 0.5, which is most likely due to the shape of the relief. No oil contamination of soils around oil and gas production facilities is observed. For the purpose of controlling the physical and chemical characteristics of the soil, samples were taken in the vicinity of oil and gas production facilities 2 and 3. The results of the physical and chemical studies are presented in Table 4.

Table 4. Results of physical and chemical studies of soil samples collected near oil and gas production facilities 2 and 3

Indicators	Results of soil examination near oil and gas production facilities	
	Object 2	Object 3
Hydrogen pH, pH units	5.72	6.45
Hydrolytic acidity, mmol/100 g of soil	2.92	1.98
Mass percentage of organic matter, %	4.97	6.40
Mass proportion of ammonium nitrogen, mg/kg soil	13.4	13.0
Mass proportion of nitrate nitrogen, mg/kg soil	10.0	5.0
Mobile phosphorus compounds (Kirsanov), mg/kg soil	70	37
Exchangeable calcium, mmol/100 g of soil	10	12.2
Exchangeable magnesium, mmol/100 g of soil	2.9	3.2
Sum of absorbed bases, mmol/100 g of soil	13.3	15.8
Mass concentration of water-soluble sulphates, mg/kg soil	21	31
Mobile iron compounds, mg/100 g of soil	0.52	0.48

Source: created by the authors

The studied soil samples are characterised by very high and high organic matter content, with values of 6.40% and 4.97% respectively, and high and medium levels of total absorbed bases. The soil solution reaction (pH) is neutral

and close to neutral. The content of ammonium and nitrate nitrogen is average and almost the same in both samples. However, these samples have low to medium levels of mobile phosphorus and very low levels of iron compounds. The content of water-soluble sulphates is also low, which is positive and indicates low soil salinity. The main areas of research on soil pollution and degradation in the areas of oil fields are the effects of oil pollution, the study of the processes of chemical elements migration in soils, bioindication and bio-reclamation. V. Lopushniak & H. Hrytsuliak (2021) in their research on the territory of the oil and gas pipeline in Bytkiv Village, Nadvirna District, concluded that heavy metals contained in oil that falls on the surface are migrating in the soil-plant system. E.C. Nwadibe *et al.* (2020) investigated the effects of soil contamination by crude oil and its impact on microbial activity, and H. Gao *et al.* (2022) on the soil ecosystem. Changes in the physical and chemical properties of soils will also affect the quality of vegetation. Research by L. Yuan *et al.* (2022) on vegetation degradation due to oil impacts near wells showed that such a negative impact is observed at a distance of up to 40 m from the well and that the number of plants and their resilience decrease. As noted by O. Orlov & M. Rahulina (2023), the soils of the Bytkiv-Babchenskyi Field area are diverse in origin and properties, and are characterised by a diverse soil cover. The conditions of relief influence on soil cover formation were studied by A. Yavorska & Z. Pankiv (2022) and Z. Pankiv & P. Honcharuk (2023). B. Karpinskyi (2023) stated that no studies have been conducted in the Carpathian Region to determine the level of soil oil contamination due to filtration processes. The results of the study by A.V. Pukish *et al.* (2021) on soil contamination by hydrocarbons in the process of oil and gas production show that there are changes in the physical, chemical and mechanical properties of soils. This results in a decrease in water permeability and moisture capacity, as well as deterioration of aeration and temperature balance. The research has established a correlation between salinity types and the concentrations of phosphorus and alkaline-hydrolysed nitrogen, phosphorus, potassium and humus. Ya. Semchuk *et al.* (2021) studied the impact of oilfields on the pollution of groundwater, surface water, and soil by formation water. According to the scientists, the consequences of such pollution can have a greater negative impact than the penetration of oil into the soil. V. Sierohlazov & V. Yurchenko (2021), based on the results of microbiological and hydrochemical studies of produced water from oil production facilities, established the conditions for the development of sulfate reductions, as well as the dependence of dissolved oxygen and hydrogen sulfide. Also, as a result of formation water reaching the surface exposed during oil and gas production, soil salinisation occurs. It was found by R.C. Dalal *et al.* (2021) that increased mineralisation can lead to instability of organic carbon and nitrogen in soils.

The main areas of research into the impact of oil and gas production on soils are the migration of chemical elements and their influence on the condition, diversity and resilience of vegetation. Other studies focused on oil contamination of soils and its consequences. A relevant area of research is the impact of formation water on the soil cover, which leads to geochemical anomalies, soil salinisation and soil degradation. However, an important and unexplored area of research is the development of soil degradation processes, which can be caused by various mechanical or physical factors that destroy the integrity of the soil cover. This process is not so pronounced in time compared to the consequences of direct oil or highly mineralised formation water entering the surface. To do this, it is necessary to begin by determining the main physical and chemical parameters of soils near oil and gas production facilities. No such studies have been conducted on the impact of oil and gas production facilities on the soil cover in the Carpathian Region, and in particular the Bytkiv-Babchenskyi Field. The study of the impact of anthropogenic physical fields in the vicinity of oil and gas production facilities included the determination of electromagnetic, noise, vibration and radiation field parameters. The results of the study of anthropogenic physical fields in the vicinity of oil and gas production facilities at the Bytkiv-Babchenskyi Field are presented in Table 5.

Table 5. Results of measuring anthropogenic physical fields in the vicinity of wells

Quarter	Noise field	Vibration field	Radiation field		Electromagnetic field			
	Noise, dB	Vibration, μm	Radiation background, μSv/h	Radionuclides	The electrical component,V/m	Magnetic component, mG		
						X	Y	Z
Site 1								
III	45	25.1	0.07	not detected	48	44	0.7	–
IV	52	28.7	0.07	not detected	43	96	102	73
Site 2								
III	50.8	25.0	0.08	Ra^{226}	0.9			
IV	47.3	24.5	0.08	Ra^{226}	1.0	48	52	56
Site 3								
III	53.8	51.3	0.07	not detected		102	96	37
IV	72.1	96.1	0.09	not detected	49.6	155	193	119

Table 5. Continued

Quarter	Noise field	Vibration field	Radiation field		Electromagnetic field			
	Noise, dB	Vibration, μm	Radiation background, μSv/h	Radionuclides	The electrical component, V/m	Magnetic component, mG		
						X	Y	Z
Site 4								
III	44.1	28.7	0.07	not detected	14.9	137	482	91
IV	50.4	24.1	0.07	not detected	15.1	161	515	135
Site 5								
III	64.8	43[1]/34[3]/24[4]/23[5]	0.07	Ra^{226}	1.1	360	238	960
IV	67	41.5	0.08	Ra^{226}	1.1	149	155	167
Site 6								
II	36[1]/65[2]/43[4]	26[1]/36[3]/34[4]/27[5]	0.1	not detected	2.6	42	34	42
IV	40	29	0.1	not detected	2.0	37	39	41
Site 7								
II	74[1]/56[2]	23.0	0.09	Th^{228}, Am^{241},	1.9	92	80	75
IV	70[1]/60[2]	164[1]/71[3]/65[4]/44[5]	0.09	Cs^{137}, Ir^{192}	1.7	87	85	77
Site 8								
II	50.3	23.0	0.08	Co^{60}, Cs^{137}, Mo^{99}, Th^{232}, I^{213}	1.1	155	161	215
IV	51	24[1]/23[3]/23[4]	0.08	Co^{60}, Cs^{137}, Mo^{99}, Th^{232}, I^{213}	1.1	151	158	203

Note: [1] – normal operation mode; [2] – during well blowing, pressure 85 atm; [3] – at a distance of 1 m; [4] – at a distance of 2 m; [5] – at a distance of 3 m

Source: created by the authors

During the radiation field survey, a spectrum of radionuclides was recorded at each monitoring point. The results of radiation field observations at the monitoring point near facilities 6 and 7 of the Bytkiv-Babchenskyi Field are presented in Figure 4 and Figure 5.

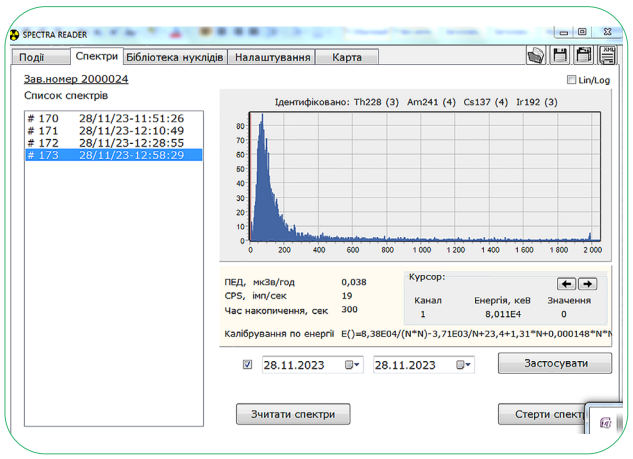

Figure 4. Spectra of radionuclides in the vicinity of the Site 6

Source: created by the authors

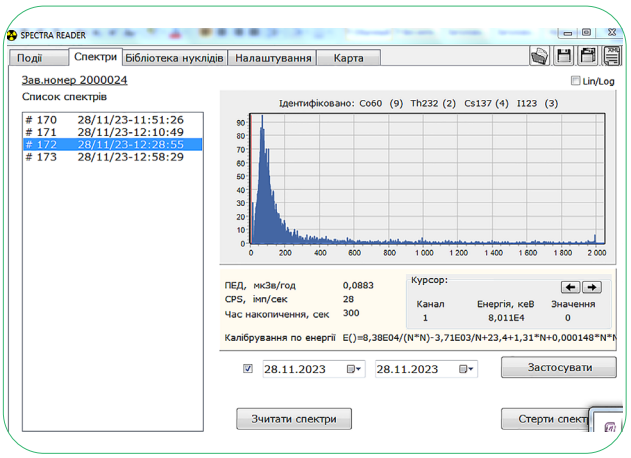

Figure 5. Spectra of radionuclides in the vicinity of the Site 7

Source: created by the authors

Thus, based on the results of studies of anthropogenic physical fields near oil and gas production facilities in 2022-2023, the following conclusions were drawn. The radiation background is in the range of 0.07-0.1 μSv/h, which did not exceed the permissible standards, and there

was no anthropogenic radiation field in the study area. Noise pollution around the well was in the range of 36-72 dB, reaching its maximum value near the production wells, which is associated with the operation of the rocking machine and well blowdown. Vibration pollution near the wells had minimum values in the range of 23-29 microns, and the maximum value was reached near the production wells due to the operation of the rocking machine, but at a distance of 3 m the vibration reached a value of approximately 23 microns; the vibration level did not exceed the permissible standards, and an increase in vibration was also observed during well blowdown. The level of electromagnetic field did not exceed the permissible standards, and in most cases was generated by power lines passing through the study area; the oil and gas production facilities themselves are not sources of electromagnetic anthropogenic physical fields. Technogenic physical fields, namely vibration and noise, generated by the oil and gas production process have a local minor impact on environmental components.

Therefore, environmental problems arising in the area of oil and gas production may be of natural and man-made origin. The field development process may provoke an aggravation of the environmental situation due to the natural processes of hydrocarbon emanation, due to the tectonic structure of the Bytkiv-Babchenskyi Field. The study of the consequences of negative impact on environmental components is especially relevant in connection with the nature reserve fund objects located on the field development territory or in the immediate vicinity of the field, as well as due to the location of oil and gas production facilities in the territory of settlements. All components of the environment are subject to technological impact. The main areas of research into the environmental impact of oil and gas production facilities are related to air emissions, pollution of water bodies and soil with oil and highly mineralised reservoir water. Many research papers by scientists from neighbouring countries that were mentioned above have been devoted to such studies. However, it is the comprehensive monitoring of the environmental situation near oil and gas production facilities that is important. Certain technological processes of oil and gas production, such as well blowout or operation of a rocking machine, create a certain man-made impact due to the formation of artificial physical fields (acoustic, vibration and radiation) around such facilities. The parameters of such fields, their distribution and impact on various natural components have not been studied. The obtained research results have shown their importance and prospects for further study of the impact of oil and gas production processes and facilities on the environment.

Conclusions

Based on the results of the atmospheric air condition research in the vicinity of oil and gas production facilities located on the Bytkiv-Babchenskyi Field territory, it was established that carbon monoxide emissions near Object 6 exceeded the established standards. The presence of PM 2.5 (10) dust particles in the air is related to meteorological factors. Soils at the Bytkiv-Babchenskyi Field are characterised by a high content of organic matter. The low content of water-soluble sulphates indicates low soil salinity. The reaction of the soil solution in the rapid analysis was in the range of 6.8-8.0. There was a fluctuation in pH around oil and gas production facilities within ± 0.5, which is most likely due to the relief shape. No oil contamination of soils was observed. According to the results of chemical and physicochemical parameters, the water in rivers and streams is clean. Concentrations of volatile organic compounds did not exceed environmental water quality standards, the content of biogenic elements was very low, phosphorus content was not detected, water hardness was 4.7 mg-eq/dm^3, and the water was hydrocarbonate with a calcium content of 71 mg/dm^3.

In the vicinity of the oil and gas production facilities, the authors conducted studies of man-made physical fields: radiation, noise, vibration and electromagnetic. The research results showed that the radiation background was within 0.07-0.1 μSv/h and did not exceed the permissible standards; noise pollution around the well was within 36-72 dB, vibration pollution near the wells had minimum values within 23-29 microns, and the increase in noise and vibration fields is associated with the operation of the rocking machine and well blowdown, the level of electromagnetic field did not exceed the permissible standards, and its parameters are associated with power lines. Thus, no negative impact of oil and gas production facilities on natural objects in the territory of the Bytkiv-Babchenskyi Field was detected.

Analysing the results of the research on the impact of oil and gas production facilities on environmental components and taking into account the main areas of scientific research on related issues, the following recommendations can be made for planning research areas: man-made physical fields, namely noise and vibration, require a larger-scale research to reasonably assess the impact of the oil and gas production process as a possible negative factor; the impact of man-made physical fields arising in the course of relevant oil and gas production operations on flora and fauna; gas pollution from abandoned wells in the Carpathian Region; the impact on the soil cover of possible hydrocarbon manifestations from abandoned wells in the Carpathian Region; natural and man-made gas pollution in the Bytkiv and Pasichna settlements.

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Conflict of Interest

None.

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Екологічні наслідки видобування нафти і газу на прикладі Битків-Бабченського нафтогазового родовища

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Анотація. Більшість технологічних процесів створюють техногенне навантаження на навколишнє середовище – не винятком є нафтогазовидобувна галузь. Через нафтогазовидобування на площі Битків-Бабченського родовища спостерігається загазованість території населених пунктів Пасічна і Битків, витоки нафти на денну поверхню, проте, необхідно прагнути мінімізації негативного впливу та збереження довкілля. Метою дослідження було проведення комплексного аналізу екологічного стану атмосфери, ґрунтів, гідросфери та техногенних фізичних полів (радіаційного, шумового, вібраційного, електромагнітного) поблизу різних об'єктів нафтогазовидобування Битків-Бабченського родовища для визначення техногенного впливу процесу видобування нафти й газу. Використовувалися такі методи: спостереження, вимірювання показників довкілля, метеорологічних параметрів та параметрів фізичних полів, лабораторні методи аналізу. Використано широкий спектр сучасних приладів, який дозволяє проводити експрес-аналіз та визначати параметри фізичних полів. У лабораторних умовах проводився більш детальний аналіз проб води та ґрунтів із використанням фізико-хімічних методів аналізу. Визначені хімічні, фізико-хімічні показники якості води, вміст летких органічних сполук, поліароматичних вуглеводнів відповідали нормативним показникам. З токсичних елементів виявлено стронцій, вміст якого не перевищував гранично допустиму концентрацію. За вмістом солей вода гідрокарбонатна слабомінералізована. Ґрунти низькозасолені з нейтральним pH ґрунтового розчину. Вміст рухомих сполук заліза, фосфору, азоту, відповідно, дуже низький, низький і середній, а органічної речовини – дуже високий. Встановлено, що параметри техногенних фізичних полів не перевищують допустимих норм. Результати дослідження показали, що техногенний вплив процесу нафтогазовидобування на атмосферне повітря, водні об'єкти та ґрунти знаходиться у межах допустимих норм. Практичне значення отриманих результатів полягає у комплексному спостереженні протягом року за станом природних об'єктів, що є важливим для фахівців нафтогазової галузі під час оцінки впливу об'єктів нафтогазовидобування на довкілля та розробки природоохоронних заходів

Ключові слова: нафтогазова галузь; техногенні фізичні поля; фізико-хімічні дослідження; загазованість; атмосферне повітря; ґрунти; об'єкти гідросфери