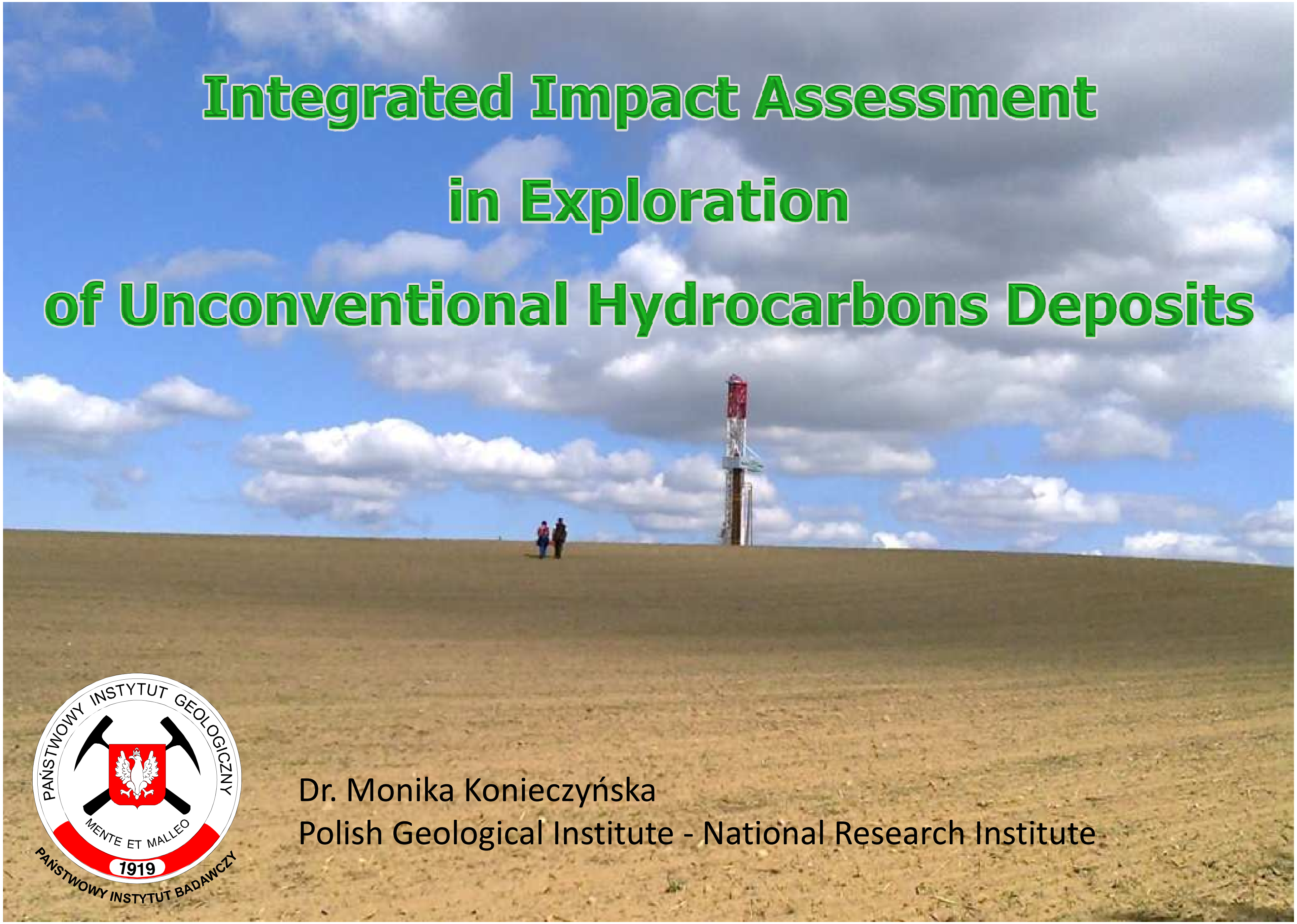
Integrated Impact Assessment in Exploration of Unconventional Hydrocarbons Deposits



Dr. Monika Konieczyńska
Polish Geological Institute - National Research Institute

TO BE PRESENTED

1. What unconventional hydrocarbons deposits are
2. How they are explored and documented
3. The scope of activities and their temporal character
4. Potential hazards and risks
5. Need for information and data
6. Findings of research in Poland

CONVENTIONAL AND UNCONVENTIONAL HYDROCARBONS DEPOSITS

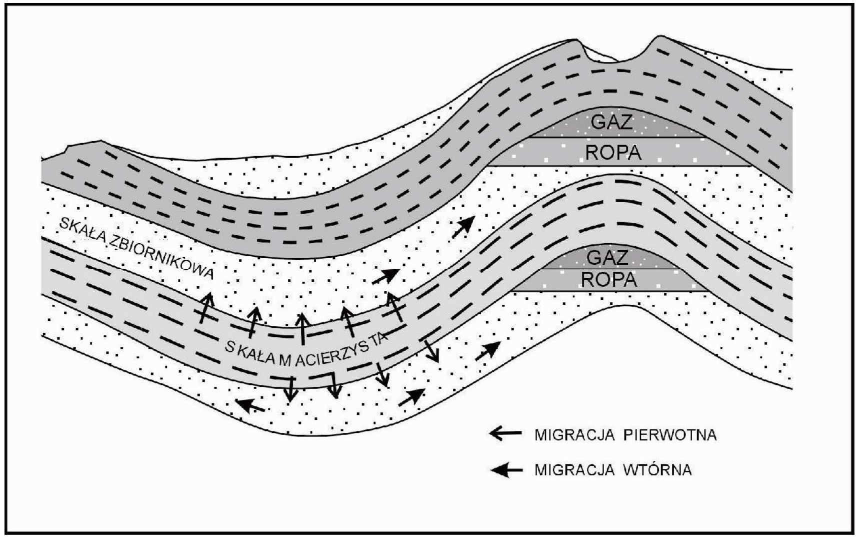
Hydrocarbons created by high temperature and pressure posed on organic matter present in fine grained material deposited in water reservoirs, buried with time deep underground

Conventional

- part of oil and gas left the original bedrock and migrated towards geological traps in reservoir rocks
- permeability and porosity of rock big enough to conduct gas, oil and water
- exploited since 18th century

Unconventional

- original bedrock still might contain significant amounts of oil and gas
- low permeability, lack of conductive porosity
- not so easy to derive products using conventional technology



Oil and natural gas the same in both types of deposits!

Unconventional are:

- fine grained reservoir with very low permeability,
- character of predominant bindings between rock and hydrocarbons,
- and some parts of technological process to be used in order to get the product up to the land surface

Source: Zawisza, 2009

TECHNOLOGY TO EXPLORE AND STIMULATE INFLOW

- Drilling preceded by detailed geological study including 2D and 3D seismic (need for data mining and acquisition)
- Exploration by vertical and horizontal (directional) drilling with high performance borehole geophysics
- Long horizontal sections up to 2.000-3.000 m
- Production stimulated by hydraulic fracturing, several fracturing stages per well
- Water and chemicals used for stimulation, need for storage capacity
- Several site reconstructions for different operations
- Need for power, common use of diesel engines
- Drilling waste and flowback production
- Gases, dust and noise emissions
- Road transport more intensive than in conventional drilling

TECHNOLOGY TO EXPLORE AND STIMULATE INFLOW

- Drilling preceded by detailed geological study including 2D and 3D seismic (need for data mining and acquisition)
- Exploration by vertical and horizontal (directional) drilling with high performance borehole geophysics
- Long horizontal sections up to 2.000-3.000 m
- Production stimulated by hydraulic fracturing, several fracturing stages per well
- Water and chemicals used for stimulation, need for storage capacity
- **Several site reconstructions for different operations**
- Need for power, common use of diesel engines
- Drilling waste and flowback production
- Gases, dust and noise emissions
- Road transport more intensive than in conventional drilling

TECHNOLOGY TO EXPLORE AND STIMULATE INFLOW

- Drilling preceded by detailed geological study including 2D and 3D seismic (need for data mining and acquisition)
- Exploration by vertical and horizontal (directional) drilling with high performance borehole geophysics
- Long horizontal sections up to 2.000-3.000 m
- **Production stimulated by hydraulic fracturing, several fracturing stages per well**
- Water and chemicals used for stimulation, need for storage capacity
- **Several site reconstructions for different operations**
- Need for power, common use of diesel engines
- Drilling waste and flowback production
- Gases, dust and noise emissions
- Road transport more intensive than in conventional drilling

TECHNOLOGY TO EXPLORE AND STIMULATE INFLOW

- Drilling preceded by detailed geological study including 2D and 3D seismic (need for data mining and acquisition)
- Exploration by vertical and horizontal (directional) drilling with high performance borehole geophysics
- Long horizontal sections up to 2.000-3.000 m
- **Production stimulated by hydraulic fracturing, several fracturing stages per well**
- Water and chemicals used for stimulation, need for storage capacity
- **Several site reconstructions for different operations**
- Need for power, common use of diesel engines
- **Drilling waste and flowback production**
- Gases, dust and noise emissions
- Road transport more intensive than in conventional drilling

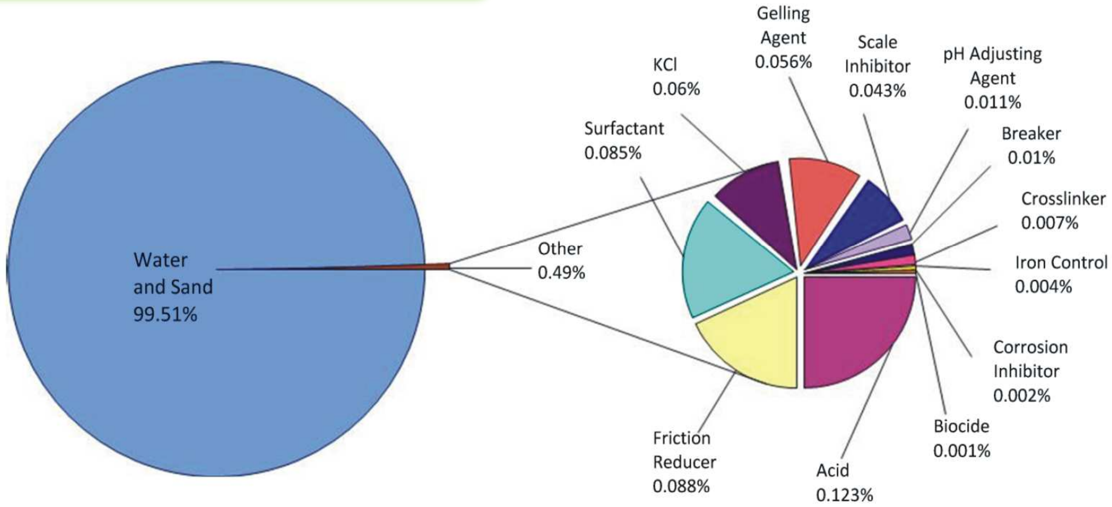






TECHNOLOGY TO EXPLORE AND STIMULATE INFLOW

Hydraulic fracturing – a mixture of water, sand and chemicals pumped under high pressure into perspective geological horizon in order to create artificial effective porosity to improve permeability and enable gas and/or oil flow towards a well



Toxicity of fracturing fluid chemicals - examples

(Source: Łebkowska, Woźnicka, 2010)

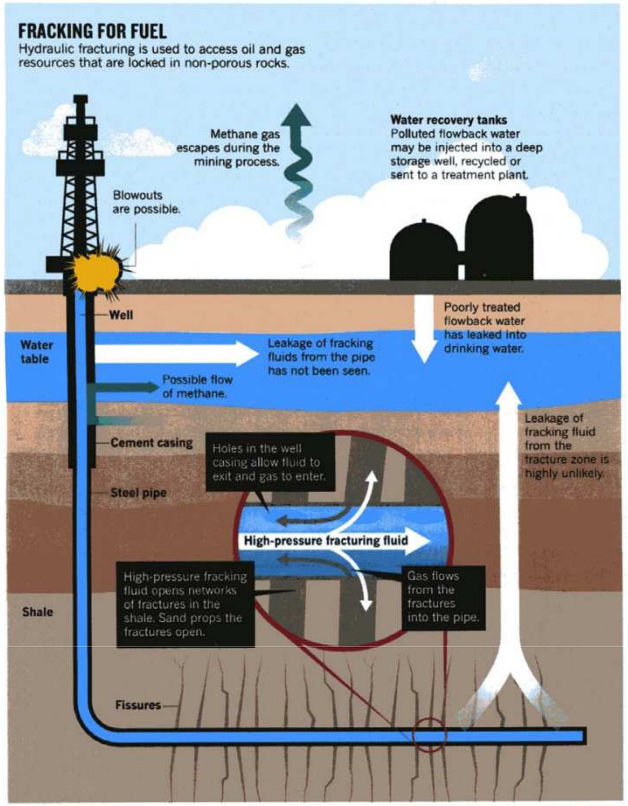
Frac fluid constituent	Test organism	LC(EC) $_{50}$ [mg/l]	TUa	Group	Toxicity	PNEC [mg/l]
Sodium chloride	*Daphnia magna*	1413.22	0.07	I	Slightly toxic	1.41
Isopropyl alcohol	*Crangon crangon*	1150.00	0.74	I	Slightly toxic	1.15
Ethylene glycol	*Oryzias latipes*	1000.00	0.43	I	Slightly toxic	1.00
Sodium carbonate	*Ceriodaphnia dubia*	199.80	0.55	I	Slightly toxic	0.20
Citric acid	*Carcinus maenas*	160.00	0.25	I	Slightly toxic	0.16
N, n-dimethylformamide	*Crangon crangon*	100.00	0.20	I	Slightly toxic	0.10
Glutaraldehyde	*Daphnia magna*	3.5	2.86	II	Toxic	0.003
Hydrochloric acid	*Netrium digitus*	25.00	50.00	III	Very Toxic	0.025
Guar gum	*Daphnia magna*	24.1	23.23	III	Very Toxic	0.024
Potassium chloride	*Lampsilis straminea claibornen*	13.5	44.40	III	Very Toxic	0.013
Boron	*Hyalella azteka*	3.04	23.02	III	Very Toxic	0.003
Crude oil distillates	*Cancer magister*	0.038	23158	IV	Extremely toxic	0.00004

LC – *lethal concentration*,
TUa – *acute toxic unit*,
PNEC – *predicted environmental no effect concentration*

HAZARDS AND RISKS OF DEPOSITS EXPLORATION

Identified main hazards of shale gas operations in the U.S.A. and Canada:

- ✓ loss of integrity of wellbore systems,
- ✓ creation of migration pathways that allow upward migration of gases and chemical substances,
- ✓ induction of low magnitude seismicity,
- ✓ incidents related to well site construction, storage and transportation,
- ✓ spills and leaks of chemical substances,
- ✓ reduction in water quality or availability,
- ✓ landscape disturbance with negatively impacts on biotopes, wildlife or local communities,
- ✓ deterioration in local or regional air quality,
- ✓ GHG emissions



Source: Howarth et al., 2011

Risk – a combination of the likelihood of an incident or hazardous event and this event actual threat understood as an adverse effect on human health, safety and/or natural environment .

In Europe – not possible to follow only American experience:

In different natural conditions risk caused by similar events may differ significantly

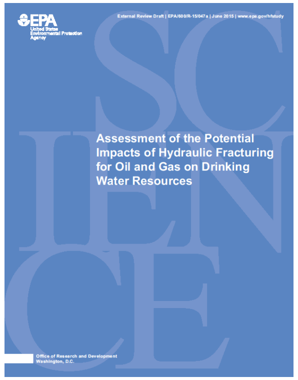
Development of oil and gas exploration and production technology also in health and environmental safety aspects

Different legal provisions and requirements on environmental protection and mining activities

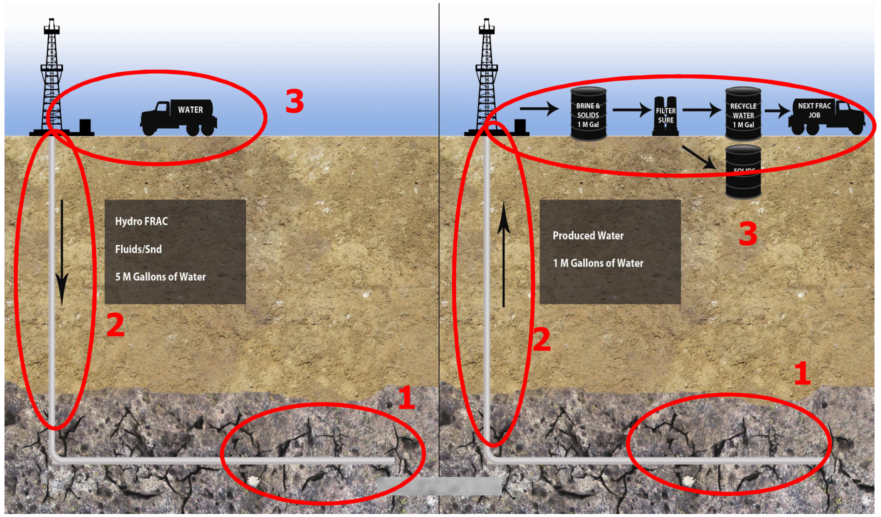
NEED FOR INFORMATION AND DATA

Need for measurements and data collection and analysis to identify hazards, assess actual impact and evaluate environmental and human health risk due to exploration and possible future production of hydrocarbons from unconventional deposits in European countries:

- baseline environmental status evaluation
- geological conditions (sealing complexes, presence of natural faults and their permeability, conflicts with other subsurface resources or activities)
- monitoring of gas, dust and noise emissions during drilling and well completion works (hydraulic fracturing and gas production tests)
- seismometric measurements of quakes and vibrations induced by hydraulic fracturing
- microseismic survey to assess the extend of fractures propagation
- water management and waste management practices evaluation in terms of amount and properties of drilling waste, including especially flowback fluids from hydraulic fracturing
- disclosure of chemical substances used for drilling and boreholes stimulation and assessment of transportation and storage procedures
- environmental assessment after completion of work and actual impact evaluation based on comparison to the results of baseline measurements



US EPA , draft , June 2015

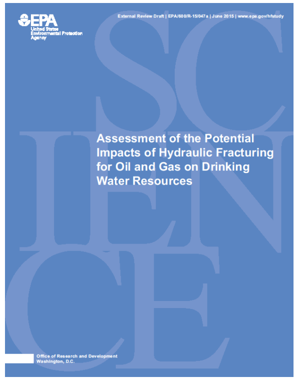


Polish Geological Institute
National Research Institute
www.pgi.gov.pl

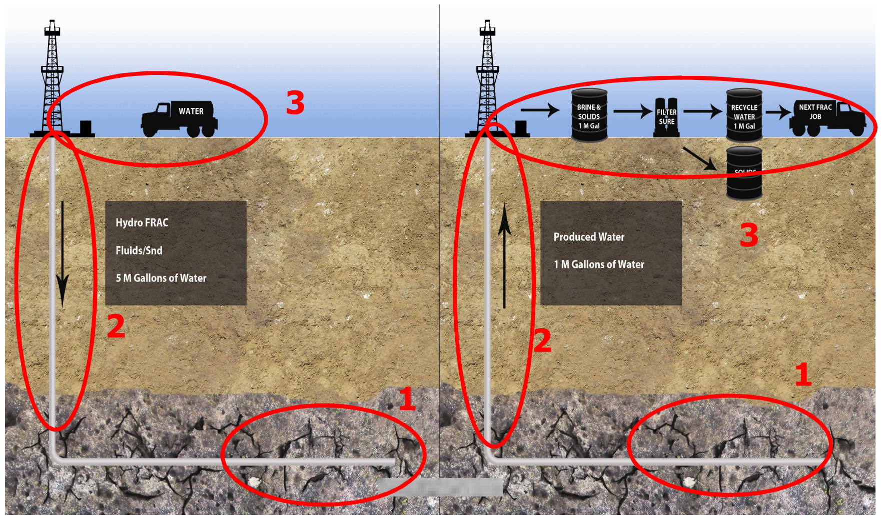
NEED FOR INFORMATION AND DATA

Need for measurements and data collection and analysis to identify hazards, assess actual impact and evaluate environmental and human health risk due to exploration and possible future production of hydrocarbons from unconventional deposits in European countries:

- baseline environmental status evaluation
- **geological conditions (sealing complexes, presence of natural faults and their permeability, conflicts with other subsurface resources or activities)**
- monitoring of gas, dust and noise emissions during drilling and well completion works (hydraulic fracturing and gas production tests)
- seismometric measurements of quakes and vibrations induced by hydraulic fracturing
- microseismic survey to assess the extend of fractures propagation
- water management and waste management practices evaluation in terms of amount and properties of drilling waste, including especially flowback fluids from hydraulic fracturing
- disclosure of chemical substances used for drilling and boreholes stimulation and assessment of transportation and storage procedures
- environmental assessment after completion of work and actual impact evaluation based on comparison to the results of baseline measurements



US EPA , draft , June 2015

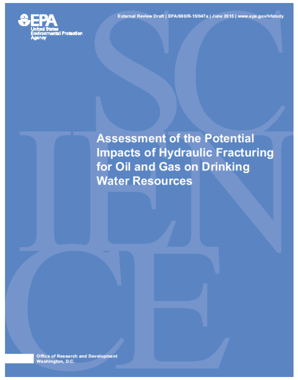


Polish Geological Institute
National Research Institute
www.pgi.gov.pl

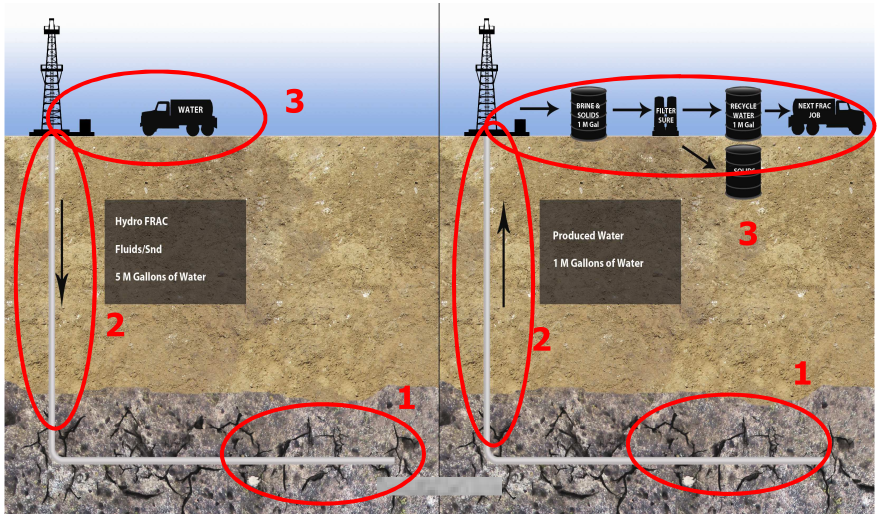
NEED FOR INFORMATION AND DATA

Need for measurements and data collection and analysis to identify hazards, assess actual impact and evaluate environmental and human health risk due to exploration and possible future production of hydrocarbons from unconventional deposits in European countries:

- baseline environmental status evaluation
- **<u>geological conditions (sealing complexes, presence of natural faults and their permeability, conflicts with other subsurface resources or activities)</u>**
- monitoring of gas, dust and noise emissions during drilling and well completion works (hydraulic fracturing and gas production tests)
- seismometric measurements of quakes and vibrations induced by hydraulic fracturing
- **<u>microseismic survey to assess the extend of fractures propagation</u>**
- water management and waste management practices evaluation in terms of amount and properties of drilling waste, including especially flowback fluids from hydraulic fracturing
- disclosure of chemical substances used for drilling and boreholes stimulation and assessment of transportation and storage procedures
- environmental assessment after completion of work and actual impact evaluation based on comparison to the results of baseline measurements



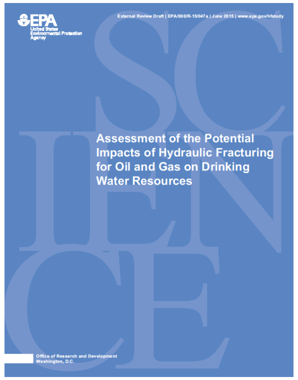
US EPA , draft , June 2015



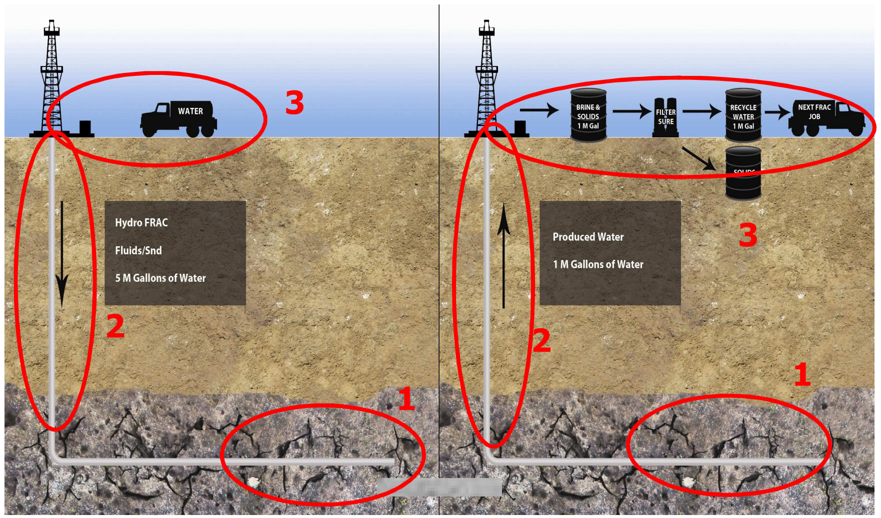
NEED FOR INFORMATION AND DATA

Need for measurements and data collection and analysis to identify hazards, assess actual impact and evaluate environmental and human health risk due to exploration and possible future production of hydrocarbons from unconventional deposits in European countries:

- baseline environmental status evaluation
- **<u>geological conditions (sealing complexes, presence of natural faults and their permeability, conflicts with other subsurface resources or activities)</u>**
- monitoring of gas, dust and noise emissions during drilling and well completion works (hydraulic fracturing and gas production tests)
- seismometric measurements of quakes and vibrations induced by hydraulic fracturing
- **<u>microseismic survey to assess the extend of fractures propagation</u>**
- **<u>water management and waste management practices evaluation in terms of amount and properties of drilling waste, including especially flowback fluids from hydraulic fracturing</u>**
- disclosure of chemical substances used for drilling and boreholes stimulation and assessment of transportation and storage procedures
- environmental assessment after completion of work and actual impact evaluation based on comparison to the results of baseline measurements



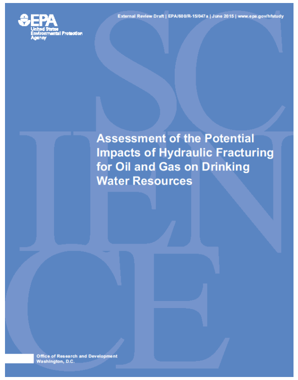
US EPA , draft , June 2015



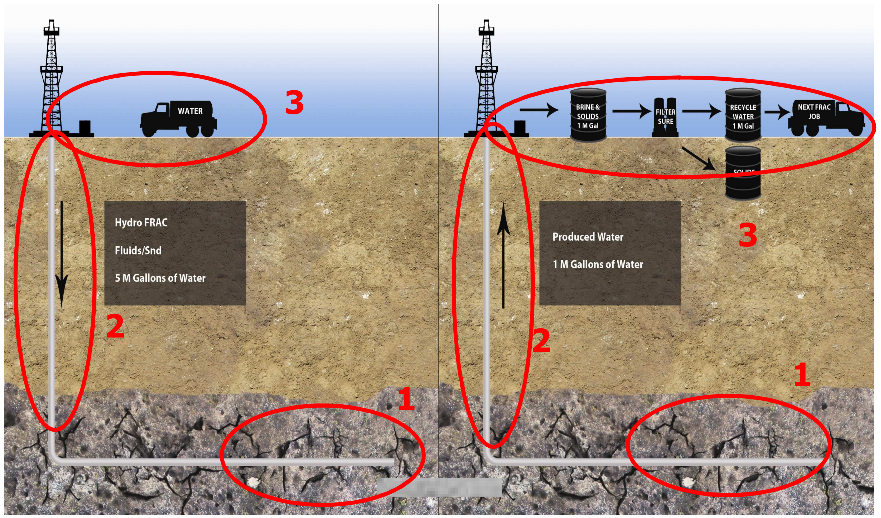
NEED FOR INFORMATION AND DATA

Need for measurements and data collection and analysis to identify hazards, assess actual impact and evaluate environmental and human health risk due to exploration and possible future production of hydrocarbons from unconventional deposits in European countries:

- baseline environmental status evaluation
- **geological conditions (sealing complexes, presence of natural faults and their permeability, conflicts with other subsurface resources or activities)**
- monitoring of gas, dust and noise emissions during drilling and well completion works (hydraulic fracturing and gas production tests)
- seismometric measurements of quakes and vibrations induced by hydraulic fracturing
- **microseismic survey to assess the extend of fractures propagation**
- **water management and waste management practices evaluation in terms of amount and properties of drilling waste, including especially flowback fluids from hydraulic fracturing**
- **disclosure of chemical substances used for drilling and boreholes stimulation and assessment of transportation and storage procedures**
- environmental assessment after completion of work and actual impact evaluation based on comparison to the results of baseline measurements



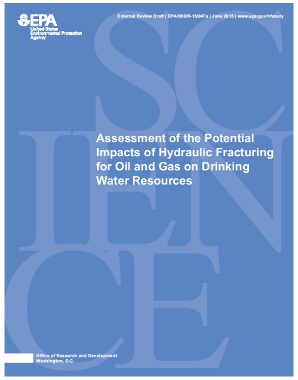
US EPA , draft , June 2015



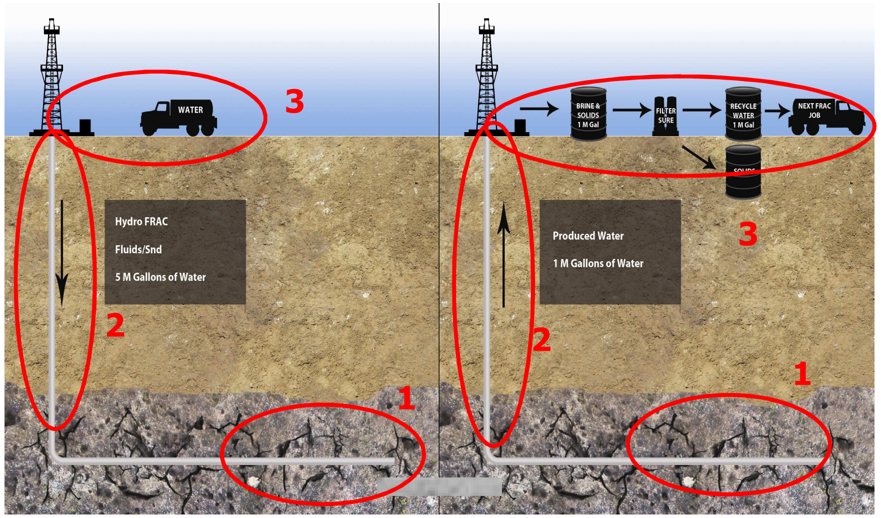
NEED FOR INFORMATION AND DATA

Need for measurements and data collection and analysis to identify hazards, assess actual impact and evaluate environmental and human health risk due to exploration and possible future production of hydrocarbons from unconventional deposits in European countries:

- baseline environmental status evaluation
- **geological conditions (sealing complexes, presence of natural faults and their permeability, conflicts with other subsurface resources or activities)**
- ***monitoring of gas, dust and noise emissions during drilling and well completion works (hydraulic fracturing and gas production tests)***
- ***seismometric measurements of quakes and vibrations induced by hydraulic fracturing***
- **microseismic survey to assess the extend of fractures propagation**
- **water management and waste management practices evaluation in terms of amount and properties of drilling waste, including especially flowback fluids from hydraulic fracturing**
- **disclosure of chemical substances used for drilling and boreholes stimulation and assessment of transportation and storage procedures**
- environmental assessment after completion of work and actual impact evaluation based on comparison to the results of baseline measurements



US EPA , draft , June 2015



Polish Geological Institute
National Research Institute
www.pgi.gov.pl

FINDINGS OF RESEARCH IN POLAND

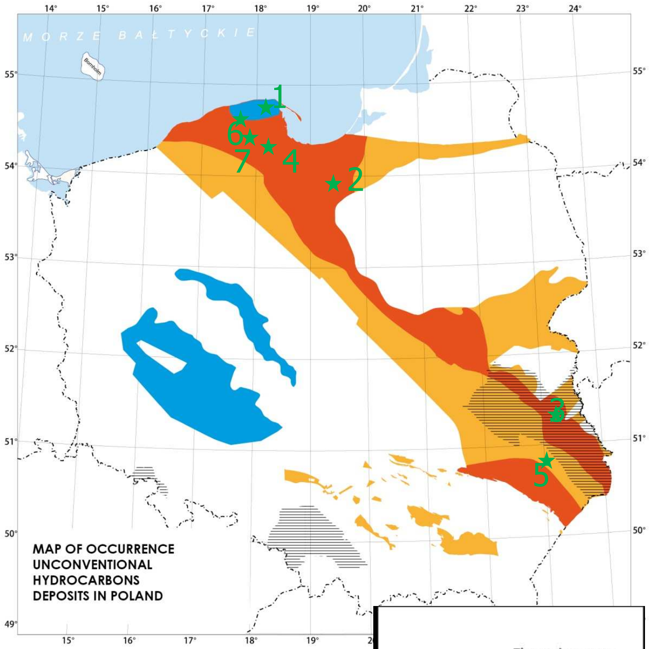
- understanding of operations
- geological and hydrogeological conditions
- environmental and process monitoring
- impact analysis

FINDINGS OF RESEARCH IN POLAND

Since summer 2011 - monitoring programs on 7 shale gas exploration sites - all wellbore exploration phases covered:

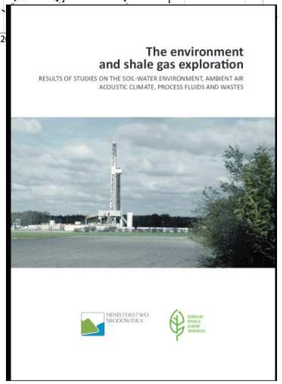
- site construction
- drilling
- well completion including hydraulic fracturing stimulation,
- well testing
- site restoration

On 4 locations - long term monitoring has been launched



<u>Inevitable:</u>

- ✓ changes to land use pattern
- ✓ temporary landscape disturbances
- ✓ increased noise level during operations
- ✓ increased heavy truck traffic during the operations



<u>Possible:</u>

- ✓ air pollution
- ✓ surface spills
- ✓ soil degradation
- ✓ fresh water resources decline
- ✓ fresh water contamination
- ✓ uncontrolled methane and norms releases
- ✓ induced seismicity
- ✓ hazards due to improper waste management

CONCLUSIONS

- Environmental impact of unconventional hydrocarbons deposits exploration (and future production) highly dependent on local geological and environmental conditions. Proper local conditions recognition and field development planning with respect to them may significantly minimize the risk of adverse environmetal impact of operations.
- No footprint on land surface measured so far and not expected providing that the whole process properly managed with respect to local conditions & legal regulations, in accordance with best professional knowledge, HSE standards and best operation practice.
- Not sufficient data on actual response to exploration work especially from subsurface. Need for observations, data collection and analysis.
- Responsible environmental impact assessment only with full disclosure of data, procedures and substances – need for cooperation between operators and assessment teams.
- In the future, ensuring safety of the environment and sufficient public perception and safety in production areas will require an adequate control of technical operations and the establishment of uniform monitoring system with site specific monitoring programs.

REFERENCES

„Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources” (draft), 2015, US EPA, http://www2.epa.gov/hfstudy

Environmental Aspects of Hydraulic Fracturing Treatment Performed on the Łebień LE-2H Well (PGI-NRI/RIEP Gdańsk, November 2011) http://www.pgi.gov.pl/en/all-events/4087-environmental-impact-hydraulic-fracturing-lebien.html

Howarth R. W., Ingraffea A. & Engelder T., 2011 – „**Natural gas: Should fracking stop?”,** Nature, vol. 477, Iss. 7364

Konieczyńska M., Adamczak-Biały T., Brodecki A., Brzezińska A., Janica R., Dziekan-Kamińska E., Fajfer J., Feldman-Olszewska A., Felter A., Frydel J., Głuszyński A., Gryczko-Gostyńska A., Jarosiński M., Joźwiak K., Kordalski Z.bigniew, Kowalewski T., Kijewska S., Lichtarski G., Lidzbarski M., Lipińska O., Mikołajków J., Nidental M., Otwinowski J., Pasierowska B., Pergół S., Podhalańska T., Roman M., Rosowiecka O., Sobień K., Starzycka A., Stec B., Śliwiński Ł., Waksmundzka M., Woźnicka M., Dzieniewicz M., Guzy P., Izydor G., Konopka E., Kotarba m., Kowalski T., Lewkiewicz-Kołysa A., Macuda J., Nagy S., Sechman H., Bernaciak M., Grzelak W., Janicki W., Korkosz A., Kozak k., Kudłak B., Męcik M., Zabiegała B., 2015 – **„The Environment and Shale Gas Exploration – results of studies on soil-water environment, ambient air, acoustic climate, process fluids and wastes”.** Generalna Dyrekcja Ochrony Środowiska, ISBN 978-83-62940-97-4, http://www.gdos.gov.pl/shale-gas-reports (with 10 partial reports in Polish)

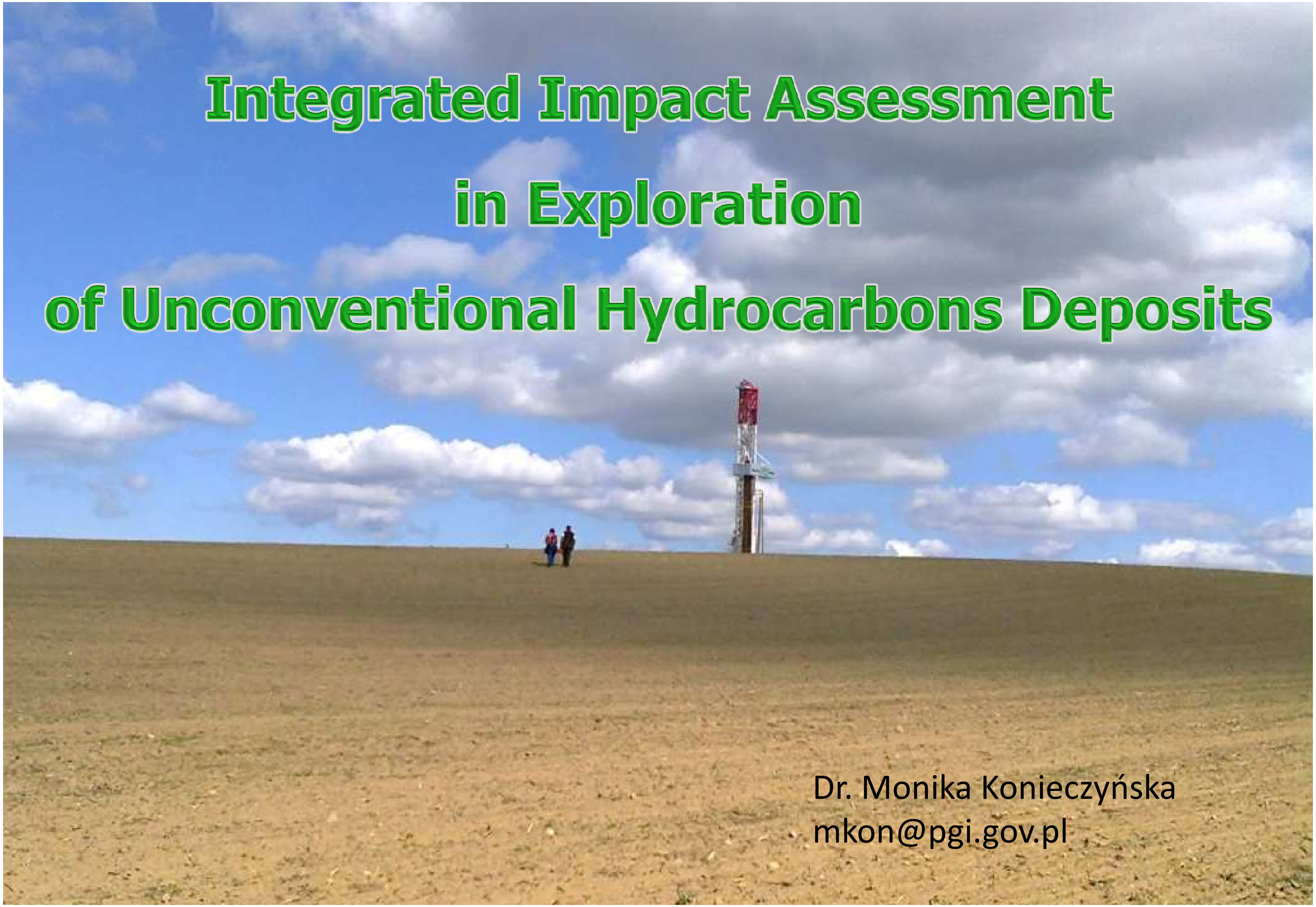
Łebkowska M., Woźnicka M., 2010 **– „Oddziaływanie na środowisko procesu szczelinowania hydraulicznego stosowanego na potrzeby poszukiwania i eksploatacji gazu łupkowego”** („*Environmental impact of hydraulic fracturing used in exploration and production of shale gas”), expertise for Polish Ministry of Environment, in Polish, unpublished.*

Macuda J., Konieczyńska M., 2015 – **„Environmental impact of exploration from unconventional gas deposits in Poland”** *(Wpływ prac poszukiwawczych na środowisko w eksploracji niekonwencjonalnych złóż gazowych w Polsce).* Ecological Chemistry and Engineering. S = Chemia i Inżynieria Ekologiczna. S (ECOL CHEM ENG S.) 2015, 22(4), ss:703-717.

ter Heege, J. and the members of the M4ShaleGas consortium, 2016 – **„Integrated review of data and best practices for shale gas operations in the USA and Canada”,** M4ShaleGas Project deliverable number: D21.1, published April 2016 by M4ShaleGas Consortium, http://www.m4shalegas.eu/reportsp5.html

Zawisza L., 2009 – „Geologia Naftowa”, AGH, Kraków, in Polish.

Integrated Impact Assessment in Exploration of Unconventional Hydrocarbons Deposits



Dr. Monika Konieczyńska
mkon@pgi.gov.pl

Polish Geological Institute
National Research Institute
www.pgi.gov.pl