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The Prospects and Effects of Unconventional Oil and Gas Exploitation Activities

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Abstract
Unconventional hydrocarbons are hydrocarbon sources located in zones different from those typically associated with conventional hydrocarbon accumulations. This alternative energy resource, originating primarily from the United States and Russia, has begun to attract attention and development efforts in Indonesia. One of the Indonesian regions with potential for unconventional hydrocarbons especially shale gas is the North East Java Basin. However, several environmental issues must be considered in unconventional oil and gas exploitation activities. These include impacts on surface water and groundwater, air resources, as well as waste management and disposal problems. Therefore, alongside the advancement of technologies for unconventional oil and gas exploitation, it is essential to develop environmentally sustainable technologies that can address these challenges. This article discusses the role of geophysics in assessing both the potential and limitations of its application in resolving environmental problems, particularly those related to land and inland water environments.

1. Introduction

Unconventional hydrocarbons are sources of hydrocarbons that are in a zone different from the zone normally found in hydrocarbons. Unconventional oil and gas development (UOGD, sometimes referred to as “fracking” or “hydraulic fracturing”) is an industrial process to extract methane gas and/or oil deposits primarily from shale or “tight” rock [1].

The hydrocarbon resource triangle (Fig. 1) highlights the fundamental distinctions between conventional and unconventional hydrocarbons. Conventional hydrocarbon accumulations generally produce flow upon drilling, making extraction relatively straightforward. In contrast, unconventional hydrocarbons originate in fine-grained, organic carbon–rich rocks that serve as both the source and reservoir for oil and natural gas. These formations, often called "continuous-type deposits" or "tight formations," are widespread and extend across large areas.

Unconventional reservoirs may exhibit porosity similar to conventional reservoir rocks; however, their minuscule pore sizes and lack of permeability significantly hinder hydrocarbon flow. Consequently, hydrocarbons in unconventional reservoirs remain trapped within the source rock unless natural fractures or artificial stimulation, such as hydraulic fracturing, occurs. This resistance to flow underscores the challenges and technological requirements associated with extracting hydrocarbons from these formations [2].

In the past few years, the US gas market has been transformed by the large-scale development of shale gas. Large shale gas reserves, high gas prices, technological advanced and a well-developed onshore drilling industry have contributed to favourable conditions under which shale gas production is expected to be around 20% of total US production in 2011.This alternative energy resource comes from the United States and Russia is one of the renewable energies that is being implemented in Indonesia.

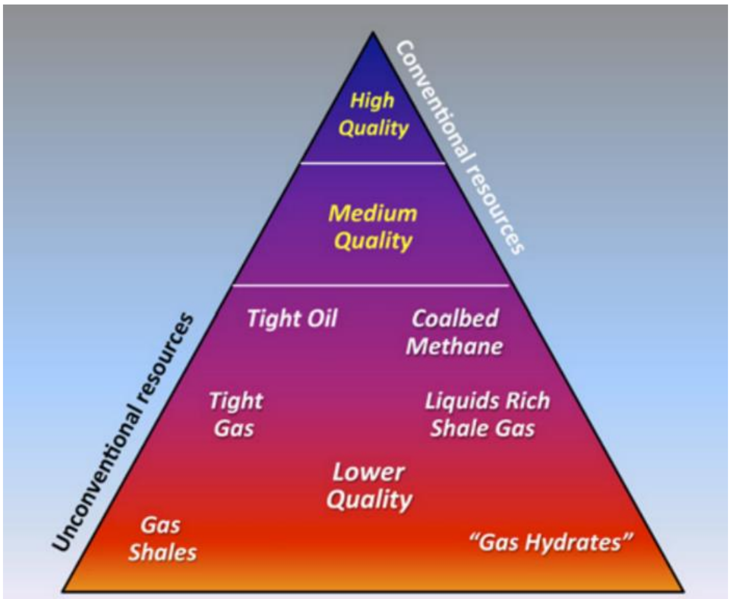


Fig 1. Hydrocarbon resource diagram summarizing conventional and unconventional reservoirs [3].

Currently the focus of oil production in Indonesia is still heavily focused on availability of conventional oil and gas. In fact, several developed countries many have started to produce oil and gas (here in after called hydrocarbons) unconventional to meet needs domestic use and export purposes [4].

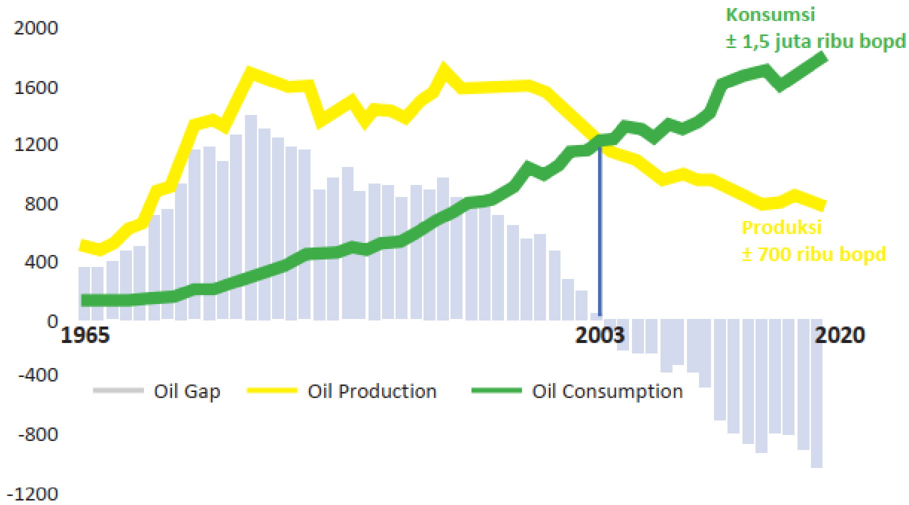
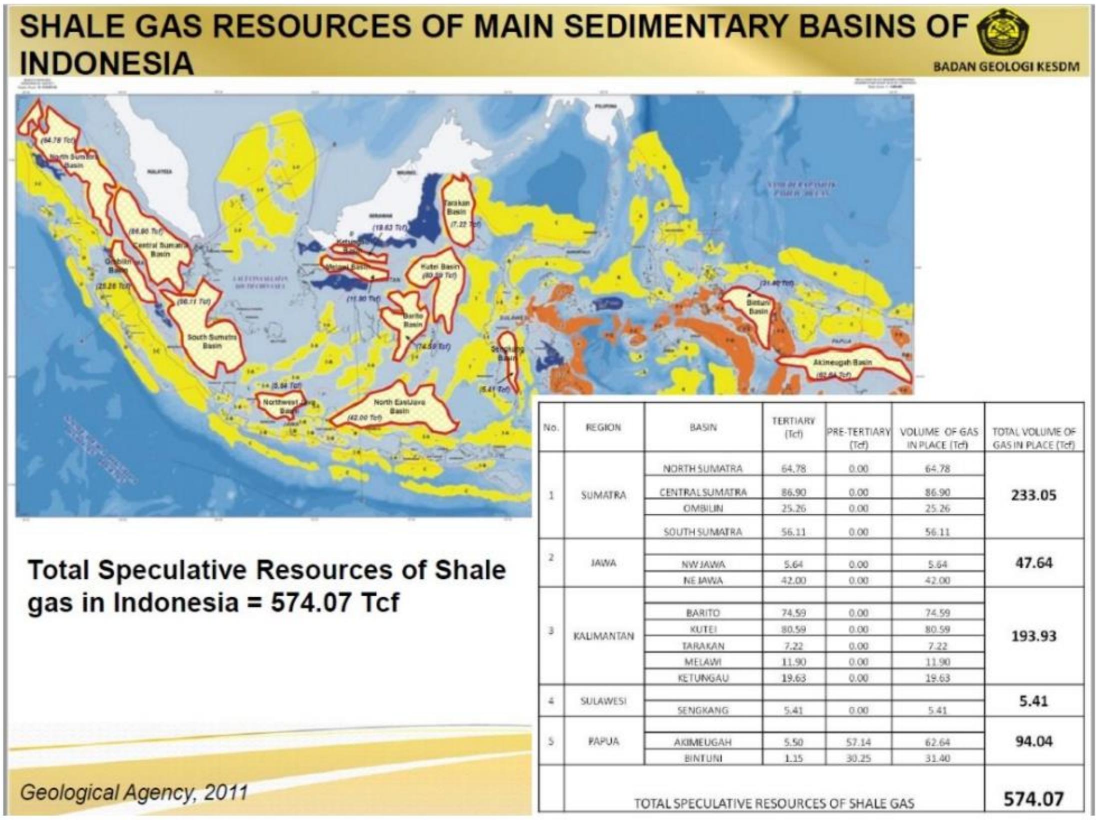


Fig 2. The graph of oil production vs consumption in Indonesia shows that there is a gap between consumption and production needs [5].

According to the [6] unconventional hydrocarbons are sources of hydrocarbons that are in a different zone from the normal zone where hydrocarbons are found in general. These hydrocarbons include shale gas (natural gas originating from formations consisting of shale), coalbed methane (gas that appears in coal seams, as well as tight oil and shale oil (crude oil originating from shale formations). Indonesia has unconventional hydrocarbon reserves reaching 1037 TCF (trillion cubic feet) which is divided into 574 TCF for shale gas, and 453 TCF is coalbed methane. A further and in-depth study process is needed regarding availability of unconventional hydrocarbon sources in Indonesia.



No.	REGION	BASIN	TERTIARY (Tcf)	PRE-TERTIARY (Tcf)	VOLUME OF GAS IN PLACE (Tcf)	TOTAL VOLUME OF GAS IN PLACE (Tcf)
1	SUMATRA	NORTH SUMATRA	64.78	0.00	64.78	233.05
		CENTRAL SUMATRA	86.90	0.00	86.90	
		OMBILIN	25.26	0.00	25.26	
		SOUTH SUMATRA	56.11	0.00	56.11	
2	JAWA	NW JAWA	5.64	0.00	5.64	47.64
		NE JAWA	42.00	0.00	42.00	
3	KALIMANTAN	BARITO	74.59	0.00	74.59	193.93
		KUTEI	80.59	0.00	80.59	
		TARAKAN	7.22	0.00	7.22	
		MELAWI	11.90	0.00	11.90	
		KETUNGAU	19.63	0.00	19.63	
4	SULAWESI	SENGKANG	5.41	0.00	5.41	5.41
5	PAPUA	AKIMEUGAH	5.50	57.14	62.64	94.04
		BINTUNI	1.15	30.25	31.40	
	TOTAL SPECULATIVE RESOURCES OF SHALE GAS					574.07

Fig 3. Map of shale gas distribution in Indonesia [7]

One of the potentials for unconventional hydrocarbons in Indonesia is in North East Java Basin (Northeast Java Basin) where it is found shale gas content is 42 TCF [8]. During this time, Basin North East Java is known as a basin rich in hydrocarbon sources, it has even been produced in several areas. This is from the presence of the system petroleum in many basin formations.

Although unconventional oil and gas (UOG) production shares several processes with conventional oil and gas extraction, it differs in key ways. Notably, it employs directional (horizontal) drilling and large-volume hydraulic fracturing to enhance the flow of natural gas or oil to the wellhead. Furthermore, compared to conventional methods, there is greater uncertainty surrounding UOG production, particularly regarding the composition of hydraulic fracturing fluids (HFF) and their potential impacts.

2. Methodology

2.1. Data Sources and Searches

The data used in this paper is raw data taken from Ministry of Energy and Mineral Resources of Indonesia. The data consists of seven wells spread across the North East Java basin. The data has been pre-processed by the author to see whether the seven wells have unconventional hydrocarbon prospects. The data distribution map is shown in Figure 4.

2.2. Data Extraction

Raw data includes data from seven wells, geochemical data, and final well report data. All data is processed using interactive petro physics software to determine unconventional hydrocarbon prospect zones. Prospect zone data has been analyzed by the author in previous research, this paper only explains prospect zones and the effects of unconventional hydrocarbon exploitation.

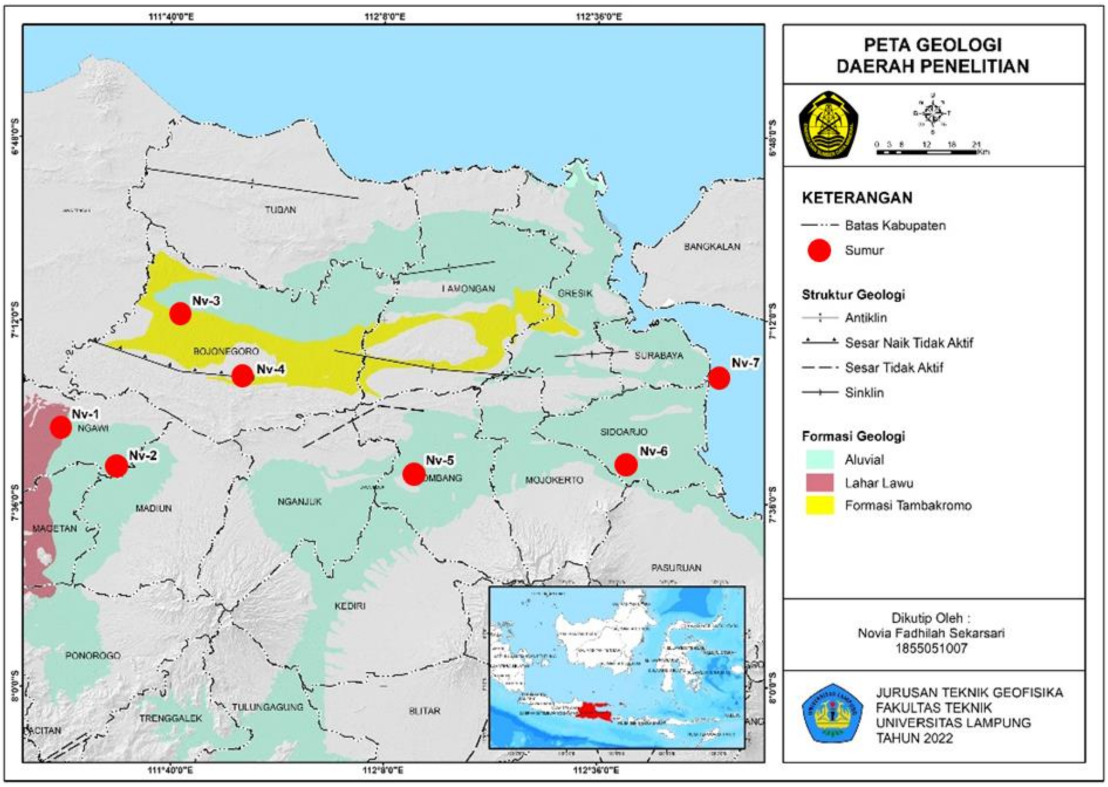


Fig 4. Geological map of the research area

3. Results and Discussions

3.1. Unconventional Hydrocarbon Prospects

The petroleum system (petroleum system) is a component that must be owned to enable the collection and accumulation of petroleum in a basin that requires an understanding of the petroleum system and processes that work in an area, which will be very influential to exploration success.

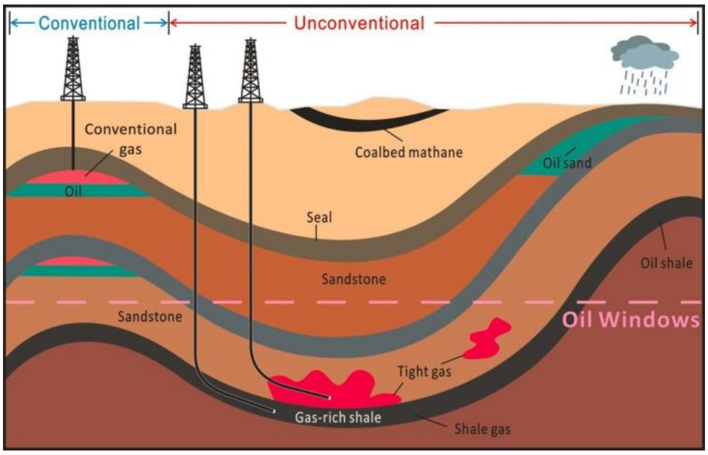


Fig 5. Scheme of conventional and unconventional petroleum systems [9].

Petro physical and geochemical analysis was carried out on the seven wells. After carrying out the analysis, it can be concluded whether there is an unconventional hydrocarbon prospect zone in each well.

Table 1. Analysis results

Well	Zone	Depth (FT)	Sw	Perm	Mobility (mD/cP)	Transmissibility (mDm/cP)	TOC (wt %)	Kerogen Quality	Unconv	Lithology
Nv-1	1	130,5-1423,5	n/a	n/a	-	-	n/a	-	-	-
	2	1423,5-1558,5	0,001	160	3200	39680	0,62	medium	-	-
	3	1558,5-1992	0,5	400,39	6903,28	559165,34	0,56	medium	-	-
	4	1992-3296	0,4	525,43	9059,14	3040337,28	0,90	medium	-	-
	5	3295-3646,5	0,3	371,34	6402,41	582939,78	0,68	medium	-	-
	6	3646,5-4845,5	0,31	332,55	6651	1872648,91	0,68	medium	-	-
	7	4845,5-6246,5	0,17	654,73	10912,17	4571543,10	0,66	medium	-	-
	8	6246,5-7176	0,2	816,2	13603,33	3418517,67	0,52	medium	-	-
Nv-2	1	32-2504	0,02	40,527	764,66	437584,55	0,26	less	-	-
	2	2504-3235	0,058	15,22	304,4	22775,21	0,10	less	-	-
	3	3235-3665	0,112	0,075	1,5	11,19	0,55	medium	v	*Claystone*
	4	3665-3826	0,046	0,08	1,74	10,43	0,73	medium	v	*Limestone*
	5	3826-4406,5	0,102	0,083	1,80	63,78	0,54	medium	v	*Limestone*
	6	4406,5-6469,5	0,08	0,07	1,52	98,91	0,50	medium	v	*Karbonat*
Nv-3	1	1455,5-1531,5	0,6	141,58	2320,98	951,60	0,74	medium	-	-
	2	1531,5-2073,5	0,56	246,4	4039,34	7876,72	0,45	less	-	-
	3	2073,5-2454	0,56	154,78	2537,38	8347,97	0,42	less	-	-
	4	2454-3766,5	0,56	174,4	2859,02	51719,61	0,43	less	-	-
	5	3766,5-4261	0,55	108,88	1784,92	18866,58	0,42	less	-	-
	6	4261-4926	0,42	125,56	2369,06	82798,53	1,07	good	-	-
	7	4926-5973	0,43	63,36	1195,47	55111,25	0,52	medium	-	-
	8	5973-7123,5	0,63	20,71	390,75	4661,70	1,43	good	-	-
Nv-4	1	118-382	n/a	n/a	-	-	n/a	-	-	-
	2	380-1120,5	n/a	n/a	-	-	n/a	-	-	-
	3	1120,5-2562	0,46	81,96	1490,18	685,48	1,2	good	-	-
	4	2562-3617	0,47	49,26	895,64	161,21	1,1	good	-	-
	5	3617-4039	0,34	0,056	1,04	11,41	1,03	good	v	*Shale*
	6	4039-4830	0,3	0,063	1,17	11,15	1,23	good	v	*Shale*
	7	4830-7133	0,17	0,068	1,26	10,02	1,3	good	v	*Limestone*
	8	7133-10.632	0,29	0,07	1,11	78,91	1,4	good	v	*Siltstone*
Nv-5	1	44,5-149,5	n/a	n/a	-	-	0,56	medium	-	-
	2	149,5-1292	0,42	493	9480,77	823689,23	0,46	less	-	-
	3	1292-2752,5	0,51	262,4	5466,67	251357,33	1,18	good	-	-
	4	2752,5-3220,5	0,57	101,6	2116,67	7747	1,28	good	-	-
	5	3220,5-3819,5	0,63	33,8	563,33	2484,3	0,87	medium	-	-
	6	3819,5-4344,5	0,71	37,75	563,43	6440,04	0,69	medium	-	-
	7	4344,5-4952	0,7	48,1	717,91	215,37	1,2	good	-	-
Nv-6	1	591-970	0,47	732,9	15268,75	513030	1,3	good	-	-
	2	970-1249,5	0,47	518,51	10370,2	278128,76	0,61	medium	-	-
	3	1249,5-1433,5	0,5	573,41	11468,2	199661,36	0,75	medium	-	-
	4	1433,5-1566	0,55	463,67	9273,4	56845,94	0,63	medium	-	-
	5	1566-1765	0,5	553,65	11073	189237,57	0,74	medium	-	-
	6	1765-2000	0,57	318,26	6365,2	120302,28	1,28	good	-	-
	7	2000-2048	0,49	521,62	10432,4	33905,3	1,27	good	-	-
	8	2048-2445,5	0,59	302,98	6059,6	140885,7	0,87	medium	-	-
	9	2445,5-2545	0,63	262,79	5255,8	7515,79	1,02	good	-	-
	10	2545-2743,5	0,72	102,13	2042,6	3411,14	0,69	medium	-	-
Nv-7	1	16,5-245	n/a	n/a	-	-	n/a	-	-	-
	2	245-742,5	0,1	15,6	273,68	284,63	0,77	medium	-	-
	3	742,5-1000	0,27	708,65	12432,46	289303,25	0,83	medium	-	-
	4	1000-1400,5	0,26	508,34	8918,25	326407,79	0,69	medium	-	-
	5	1400,5-1897	0,35	579,93	10174,21	455295,92	0,40	less	-	-
	6	1897-1988	0,001	0,09	1,58	12,32	0,77	medium	v	*Shale*
	7	1988-2201,5	0,34	250,62	3341,60	56807,2	0,4	less	-	-
	8	2201,5-3439,5	0,07	708,7	7874,44	666256,74	0,53	medium	-	-

From the results of the analysis of all wells, it shows that there are 9 zones is an unconventional reservoir zone, namely, well Nv-2 zone 3 (3235 – 3665 FT), zone 4 (3665-3826 FT), zone 5 (3826-4406.5 FT), and zone 6 (4406.5-6469.5 FT), well Nv-4 zone 5 (3617-4039 FT) zone 6 (4039-4830 FT), zone 7 (4830-7133 FT), and zone 8 (7133-10632 FT), as well as well Nv-7 zone 6 (1897-1988 FT).

3.2. The Effects of Unconventional Hydrocarbon Exploitation Activities

Hydraulic fracturing, commonly known as fracking, carries risks similar to those associated with other fossil fuel extraction methods. It can release pollutants into the air and water, potentially impacting environmental quality.

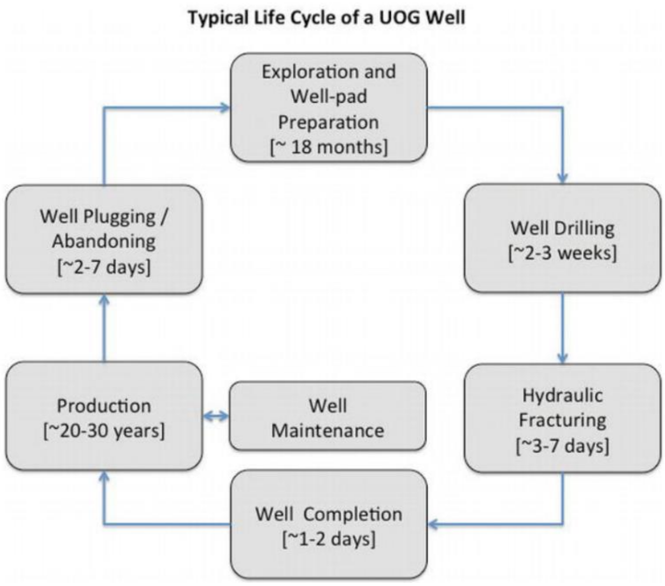


Fig 6. The typical life cycle of an unconventional oil or gas well [10].

Every phase of the life cycle contributes to emissions, effluents, and waste that can pose health risks to both workers and surrounding communities. These impacts are examined in this chapter based on their exposure pathways, such as air or water. The potential for health impacts typically depends on the severity of the chemical and nonchemical stressors involved, which act as triggers for adverse health effects.

3.3. Effects on Surfaces Water and Groundwater Resources

Most of the public attention surrounding hydraulic fracturing concerns the risks of surface and groundwater pollution, especially in the context of drinking water wells. Hydraulic fracturing, commonly known as fracking, has drawn significant public scrutiny due to concerns about potential pollution of surface and groundwater resources, particularly drinking water supplies. This process is heavily reliant on substantial quantities of water, making shale energy development a water-intensive activity. For a single shale gas well, a slick-water frack often requires millions of gallons of water. The exact volume depends on factors such as the length of the horizontal well section, also known as the lateral, and the number of fracking stages conducted [3]

Water quality can be impacted by several factors related to hydraulic fracturing and oil or gas extraction activities. These include accidental spills of chemicals used in the fracturing process, as well as the spillage or leakage of brines from flow back water. Additionally, improper disposal of wastewater poses a significant risk to drinking water sources. Leaking valves, damaged casing on wells, and uncontrolled blowouts can also lead to contamination. Other potential threats include the leakage and migration of gas up well annuli due to inadequate or faulty cementing, as well as the migration of contaminants from uncased or unplugged orphaned and abandoned oil or gas wells that lack proper protections. Surface spills of chemicals used in hydraulic fracturing do occur, primarily as the result of accidents during transport. These are potentially the highest-risk occurrences because of the volume transported (many trucks per well pad).

3.4. Effects on Air Resources

The nonstop operations of UOG production facilities expose nearby residents and communities to a persistent, though fluctuating, level of airborne pollutants. Alongside occasional acute symptoms, this prolonged exposure may lead to adverse effects from cumulative build-up over time. Activities such as drilling, hydraulic fracturing, and the functioning of UOG infrastructure including valves, pipelines, condensate tanks, and flow back or produced water tanks are key sources of emissions. Maintenance tasks, such as fluid offloading or additional fracking phases, often result in significant hydrocarbon releases, particularly at natural gas sites. Local residents frequently report unpleasant odors and a range of health issues, including headaches, nosebleeds, skin irritations, chronic exhaustion, and neurological disturbances.

3.5. Effects on Waste Management and Disposal

Wastewater is the most significant waste product generated during oil and gas production, primarily comprising produced water. This water, largely saline, is mixed with hydrocarbons and suspended solids. Produced water may also contain drilling additives, methane, petroleum condensate, heavy metals, and naturally occurring radioactive materials (NORM). Typically, flow back and produced water are temporarily held in on-site storage facilities, such as evaporation pits or tanks, before being reused, recycled, or disposed of. However, these storage methods pose environmental risks. Unlined pits can lead to groundwater contamination, while volatile compounds can escape into the air. Flooding events may cause pits to overflow, spreading hazardous substances into nearby ecosystems and water sources. Additionally, spills from damaged pipes or deteriorated pit walls can result in localized contamination of soil and water. Including problems with surface and ground water resources, air resources, waste management and disposal.

4. Conclusion

Unconventional hydrocarbons are sources of hydrocarbons that are in a zone different from the zone normally found in hydrocarbons. This alternative energy resource comes from the United States and Russia is one of the renewable energies that is being implemented in Indonesia. One of the potential basins is the North East Java basin. From the results of data processing, three wells have shale gas prospects at a certain depth. However, hydraulic fracturing has emerged as a contentious issue, sparking heated public debates and dividing communities. The practice has led to conflicts among neighbours while drawing demands from environmental groups and community health advocates for moratoriums and increased scientific examination.

The challenge of proving causality between unconventional oil and gas operations and their impacts often falls unfairly on individuals or communities, demanding a level of scientific expertise and resources beyond their reach. This underscores the need for regulators, public health officials, scientists, and the oil and gas industry to collaborate in fostering transparency, improving data collection, and conducting focused epidemiological and toxicological research. As unconventional oil and gas development continues to expand, affecting both rural and urban areas in Indonesia, it is crucial to establish a framework of coexistence rooted in trust. By prioritizing safety over profits and committing to meaningful investments in local communities, stakeholders can address health risks systematically, providing a solid foundation for informed and effective regulatory measures.

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