A Study of Preliminary Evaluation of Risks Impacting the Development of Shale Gas in Algeria Using the EEA Method

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Abstract: Algeria has firmly established itself as one of the top ten natural gas exporters in the world in recent years, largely due to its vast reserves of conventional natural gas. However, as the production potential of many of these conventional oil and gas fields approaches its peak, the country has been exploring new avenues for energy development. This has led to a strategic shift toward the exploitation of unconventional resources, with shale gas emerging as a key focus. Shale gas, which involves extracting natural gas trapped in shale rock formations, offers promising opportunities for Algeria to maintain its position as a major energy exporter. However, the extraction process is complex and poses unique challenges that require high-tech methods, advanced drilling techniques, and significant capital investment. Additionally, shale gas extraction involves various risks that must be carefully assessed to prevent environmental and operational hazards. This paper delves into the various stages of shale gas exploitation, from exploration to extraction, and examines the multitude of risks that accompany each phase. These risks can range from environmental concerns such as water contamination, seismic activity, and ecosystem disruption, to economic and operational risks that may arise due to the high costs and technological demands of shale gas development. To address these challenges, the study employs a qualitative approach by utilizing the Environmental Effects Analysis (EEA) method. The EEA method is particularly effective in systematically assessing the potential environmental impacts associated with shale gas development, allowing for a detailed classification and estimation of these impacts. The case study focuses on the Ain Salah region in Algeria, a site that holds significant shale gas potential but is also sensitive to environmental degradation. By analyzing the region's specific risks, the paper aims to provide valuable insights into the environmental, social, and economic implications of shale gas development in Algeria. Through this analysis, the paper seeks to offer actionable recommendations for mitigating the risks identified, promoting sustainable and responsible shale gas exploitation in Algeria. The goal is to ensure that the development of shale gas not only contributes to Algeria's energy security and economic growth but also minimizes adverse environmental effects, balancing energy needs with ecological preservation. In doing so, the paper hopes to contribute to the broader conversation on how to harness unconventional energy resources in a way that is both technologically feasible and environmentally sound.

Keywords: Shale Gas, Algeria, EEA Method.

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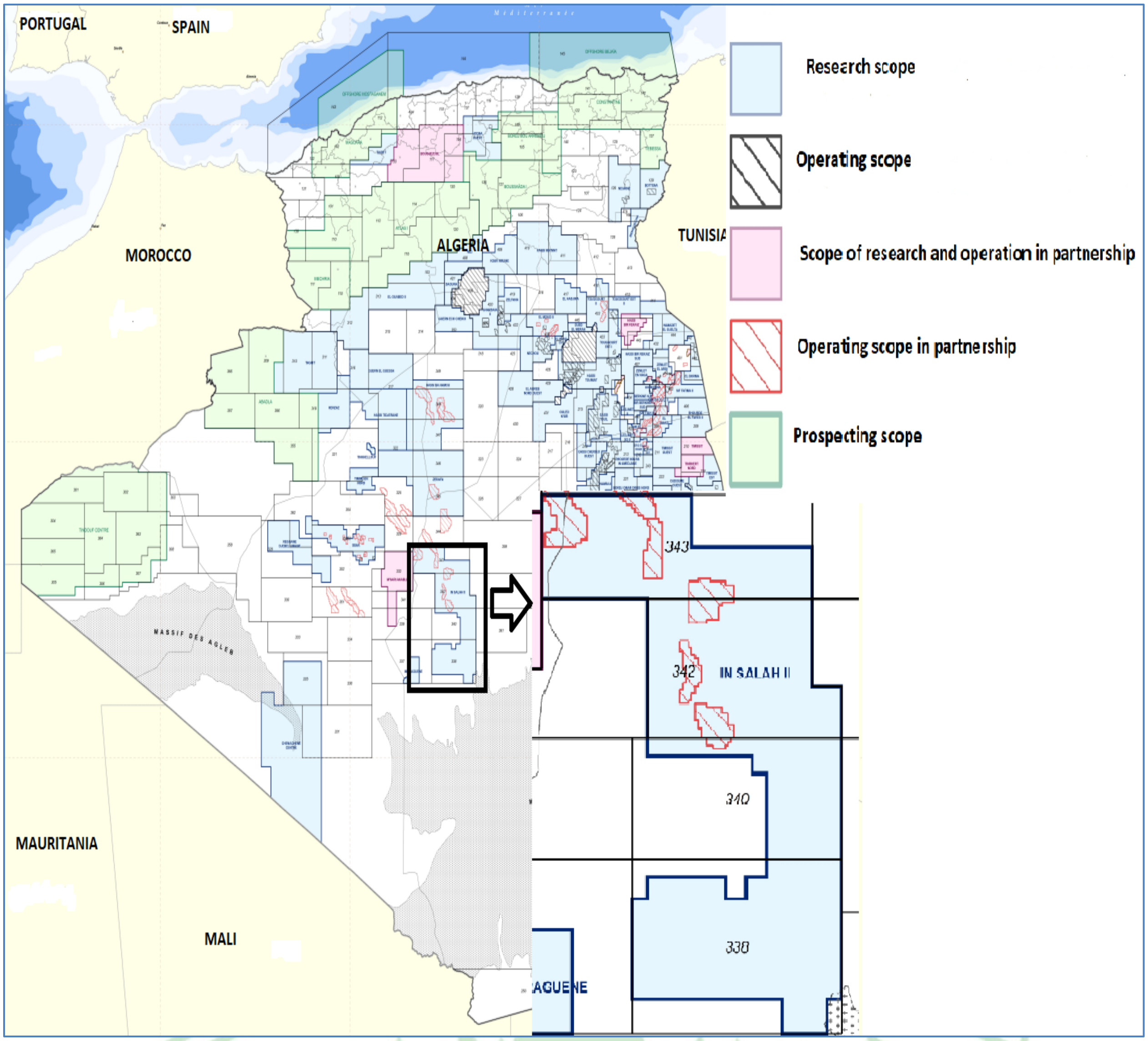
Introduction

The industry of exploiting shale gas in Algeria is facing great challenges that almost led to the hold off of this activity. Indeed, the most important of these challenges are environmental concerns and civil society pressure to stop this activity because of its serious consequences, especially on the pollution of groundwater and the vicinity of the exploitation of shale gas.

Therefore, Algeria sought to take these concerns into consideration by strengthening the laws that regulate this field and encouraging investment in this industry while simultaneously bearing in mind the concerns of the local population. This plan of action was confirmed by the latest law of hydrocarbons exploitation in Algeria (Cockayne, 2011).

However, the level of menace remains considerable, especially with the use of high-risk processes that are difficult to predict and to control for preventing hydraulic fracturing, especially that the national requirements for hydraulic fracturing have been introduced. The Minister of Energy officially announced at gas conference on October 12th, 2014 that domestic consumption would double by 2030 and triple by 2040 (Ministry of Energy & Mines, Algeria, 2014). Far exceeding current exports, the option of doubling the electricity production from gas turbines is one explanation. Therefore, there is a trend for depleting traditional gas and oil reserves by 2030, in the moment when the population may probably approach 50 million inhabitants. In fact, this is one option for achieving the energy security among several options that can be taken into account depending on the evolution of global energy changes.



The upstream hydrocarbon regions in Algeria national [agency for the development of hydrocarbon resources]

Highlights

- A preliminary approach to identify and assess the most significant risks to environmental issues
- The vital regulatory legislation for environmental protection in Algeria
- Preliminary assessment of risk levels and their impacts according to shale gas production life cycle

The current paper is divided into four sections: in the first section, the chief risks are identified and an overview of environmental impacts linked to the shale gas development life cycle in Algeria (Ain Salah) are delineated using a methodological approach based on the data available (Rahmouni, 2015).

In the second section, Algerian legislations and laws under execution in the field of shale gas exploitation are reviewed and summarized, especially that they regulate the activities that may trigger risks to the environment and human health.

The third section presents a comprehensive comparison of the Algerian model and the international models related to regulating water use for the hydraulic fracturing process, highlighting the weaknesses of these activities. in the study's context.

The fourth section summarizes and interprets the results of this study, clarify the limitations and suggest recommendations that aim to reduce risks and contribute to the development of shale gas exploitation in general.

1. A Preliminary Approach to Environmental Impact Assessment

This study uses a preliminary approach to identify and assess the most important risks to environmental issues. The study was established mainly on the experience of the USA in this field, where Coalbed methane production began in the 1980s; shale gas extraction is even more recent (EPA). In doing so, literature reviews, discussion with consultants studies, geological and university studies in Algeria and North America are synthesized. Eventually, the results are contextualized to the Algerian situation.

From this perspective, the study examines the impacts associated with the extraction of shale gas by exploring the differences between surface and subsurface events (Prpich, Coulon, & Anthony, 2016), and also by inspecting the differences between deterministic events (activities that are planned and certain to occur), and probabilistic events (accidents that are not planned and uncertain to occur).

Deterministic events include water withdrawal through the hydraulic fracturing processes such as the treatment and/or elimination of wastewater (reflux and fluids produced) and chemical products.

Probabilistic events cover a probability range that extends from the impossibility up to certainty. The probability of a risk to materialize, as it is a possible event in a future time frame although not materialized yet, is not measurable but only estimable (Hurtado. A Eguilior. F, Recreo S, 2014). This type of events make negative impacts on the environment, even though the plans, practices, and regulations are fabricated perfectly. Probabilistic events can be approached in at least two different ways. The first is through environmental impact studies which generally focus on these issues by minimizing and mitigation measures. The second is through limiting the pace and magnitude (scale) of development in general.

The qualitative assessment of these impacts is made by developing criteria (assessment grid) to gauge the severity and eventuality of the impacts that may occur.

All potential problems are studied at each stage according to the available information. It is therefore necessary to take into account that the data on the risks which are presented in this study are preliminary in nature and should be interpreted with caution.

In comparison to conventional gas, the risks and impacts of shale gas extraction are studied on the basis of the amount of energy obtained. One limitation of this study is that the data and figures on the magnitude of effects are either not available or not sufficiently robust. In particular, there is no clear exact figures to recoverable shale gas resources from shale gas wells in Algeria.

1.1 An Overview of Environmental Impacts

Based on the literature of research carried out on the environmental impacts in relation with the exploration and exploitation of shale gas (Esterhuyse, Kemp, & Redelinghuys, 2013), the present study is conducted following a preselection of the impacts common in the studies which have evaluated the shale gas development lifecycle.

1.1.1 Contamination of Groundwater

With this regard, three types of pollutants can be considered:

- Chemical additives used for hydraulic fracturing
- Bedrock hydrocarbons
- Substances present in the bedrock

Water contamination can be caused by creating a differential path during drilling operations or by incidents resulting in the leakage of liquids on the ground (motor oil, fracturing aids, effluents, etc.). The risks of contamination vary considerably from one environment to another.

1.1.2 Soil Contamination

This type of events involves spills in which a drilling substance has leaked over a surface other than water. These spills often take place in the area of drilling itself. The most common type of spilled fluid is diesel fuel. Other liquids spilled on the drilling mud include fracturing fluid and wastewater.

1.1.3 Water Consumption

Hydraulic fracturing requires large amounts of water. A consensus of all the parts operate on the quantities used from 10,000 to 20,000 m^3 (EPA) of water by drilling. This quantity equals 4 to 8 Olympic swimming pools or the annual consumption of 300 to 600 individuals.

1.1.4 Wastewater

The fracking water which rises (flow back) is stored in open-air settlings, near or on the site of drilling. These basins are double basins retention and the site itself is lined with a double waterproof membrane.

The water which rises from the boreholes is stored on site or exported off the site to be processed or simply stored.

These waters may contain "resident chemical elements" (heavy metals and / or radioactive elements naturally present in the target layers which rise with the drilling muds) United States Environmental Protection Agency (EPA). Actually, this poses problems with volatile emissions.

1.1.5 Air Pollution

There are several potential sources of air emissions from fueling operations such as hydraulic fracturing, including gas evolution of methane from forward reflux when the well is put into production, the emissions from the engines of the circulation of trucks, diesel used in drilling equipment, and dust from the use of dirt roads.

1.1.6 Noises

The sources of noise result from the movements of trucks during the phases of a well construction and development, these noises are temporary and emitted by the machinery and the pumps used.

2. Review of Algerian Regulations

The table sets out the laws and regulations applied to the protection of the environment. This review of the regulations has been used in the preliminary assessment of the related impacts of shale gas. Worth noting, this list is a summative rather than an exhaustive one.

Table.1: List of decrees applicable in Algeria with regard to the environment (Official journal of the Algerian republic)

Effects	Legislation and decrees
Groundwater contamination	Executive Decree No.18-154 of 19 Ramadhan 14399 corresponding to 04-06-2018 relating to protection perimeters of water resources.
Soil contamination	Executive Decree No. 93-161 of July 10, 1993 regulating the discharge of oils and lubricants into the natural environment.
Consumption of water resources	Executive decree No. 13-298 of 11 Chaoual 1434 corresponding to 18-08-2013 fixing the terms of granting the authorization of using water resources.

Waste	- Executive decree No. 93-160 of 10-06-1993 regulating discharges of industrial liquid effluents. - Executive decree No. 06-141 of 20 Rabie El Aouel 1427 corresponding to 19-04-2006 defining the limit values of industrial liquid effluent discharges.
Air pollution	- Executive Decree No. 93-165 of 07-10-1993 regulating atmospheric emissions of fumes, gases, dust, odors and solid particles from fixed installations. - Executive Decree No. 06-138 of 16 Rabie El Aouel 1427 corresponding to 15-04-2006 regulating the issue in the atmosphere of gases, fumes, vapors, liquid particles or solid, as well as the conditions under which their control. - Executive decree No. 07-207 of 15 Joumada Ethania 1428 corresponding to 30-06-2007 regulating the use of substances that deplete the ozone layer, their mixtures, and products that contain them.
The effects of noise	Executive Decree No. 93-184 of 27-07-1993 regulating the issue of noise.

Regarding the hydraulic fracturing operation, there is no issued regulation or decree from the Algerian state to set requirements that determine the techniques decree to be used in managing this technology (Ministry of Energy & Mines, Algeria ,2014).

Table.2: Impact assessment grid (Holt et al., 2014)

	I	II	III	IV	
	Probability				

	Outputs	**RARE**	**OCCASIONAL**	**POSSIBLE**	**FREQUENT**	**no available data**
1	MINIMUM - Minimal public safety consequences; Planned or unplanned emissions that do not result in exceedances of environmental standards - Slight.	**LOW**	**LOW**	**LOW**	**MODERATE**	**UNCLASSIFIED**
2	MINOR - Minor public security consequences -Planned or accidental fumes that could lead to exceeding environment protection guidelines in the immediate region of the point of emission, but should not result in important consequences for the environment and health - Minor	**LOW**	**MODERATE**	**MODERATE**	**HIGH**	
3	MODERATE - Localized public security consequences - Emanations or events leading to an overrun environmental risks in the region immediate from the point of emission; consequences on the people living in the area of the site because of the noise, odors or traffic.- Moderate	**MODERATE**	**HIGH**	**HIGH**	**VERY HIGH**	
4	MAJOR - Major public security consequences - Continuous emissions and exceedances of environmental standards - Major	**MODERATE**	**HIGH**	**VERY HIGH**	**VERY HIGH**	

5	CATASTROPHIC – severe security consequences catastrophic public events, i.e. events causing a pollution that can lead to damage to the health of people in the surrounding because of the contamination of drinkable water supply sources; accident resulting in loss of life or workers. - Catastrophic	**HIGH**	**VERY HIGH**	**VERY HIGH**	**VERY HIGH**
	No data allowing for evaluation	**UNCLASSIFIED**			

The probabilities have been classified according to the following index (**Holt et al., 2014**):

RARE: Never encountered or happened since the exploitation of shale gas industry began; not likely to happen in near future if the current knowledge and existing controls on shale gas exploitation are taken into account and systematically applied.

OCCASIONAL: Rarely encountered in the gas extraction industry; could be likely to occur in the foreseeable future if management and controls are less than best practices.

POSSIBLE: Encountered several times in the gas extraction industry; usually lead to short-term consequences.

FREQUENT: occur several times a year on a site or within a company; usually lead to long-term consequences.

The combination of consequences and probabilities leads to the characterization of risks (impacts).

Table.3 Risk levels as presented in Holt et al., 2014

Very high risk	
High risk	
Moderate risk	

Low risk	

3. Preliminary Assessment of the Impacts According to the Life Cycle of Shale Gas Wells Development

This section describes the assessment of environmental impacts according to the life cycle of a shale gas well; this study presents an inspection of a well in the region of Ain Salah during the well drilling activity, fracturing, and production, based on the following six steps:

(Environmental Protection Agency (EPA) Gao & You , 2018) :

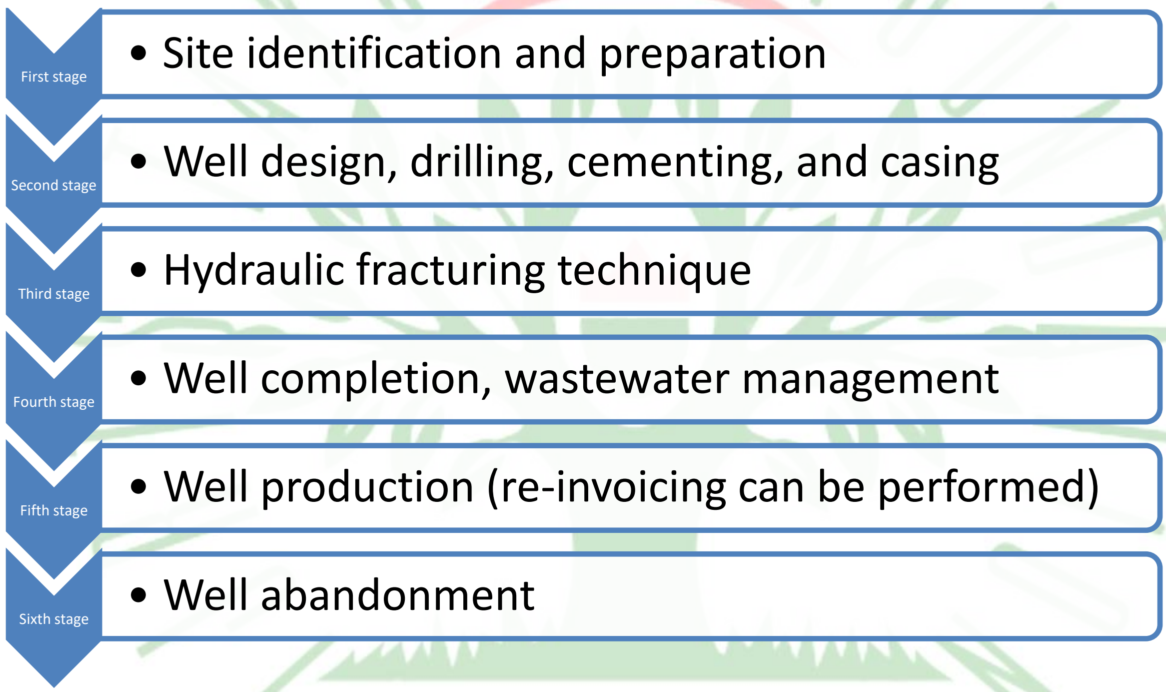


Figure.1: Shale gas production life cycle

The evaluation criteria:

- Regulatory requirements
- Backing on USA experience
- Studies carried out in this area
- Conventional drilling activities carried out in Algeria
- Judgment of domain experts

3.1 Site Identification and Preparation

Preparation activities mainly consist of clearing and leveling an area of adequate size and surface in order to support the heavy equipment movement. Site access roads must also be designed and constructed. The surface area of the well is usually up to 1 hectare with other land requirements requisite for site access roads, pipelines, and other infrastructure.

Table.4: Impacts related to site identification and preparation

N	Impacts	Causes	Probability	Gravity	risk level
1	**Groundwater contamination**	**Unclassified**			
2	**Soil contamination**	**-Solid waste -Spill of gear oils**	**Rare**	**low**	
3	**Water consumption**	**Construction works**	**Rare**	**Minimal**	
4	**Wastewater**	**Unclassified**			
5	**Air pollution**	**Gear emission**	**Rare**	**Minimal**	
6	**Noises**	**Gear movement**	**Occasional**	**Minimal**	

3.2 Well Design, Drilling, Cementing and Casing

As the bit attached to the end of the drill pipe digs a path through the rock, drilling mud is pumped into the hole that is being drilled. The mud cools the bit and exerts pressure to maintain the integrity of the hole. It also prevents the intrusion of water and gas potentially present in the rock formations traversed, and is used to extract drill cuttings.

Cementation: The aim of cementing a casing in the well is to isolate the different geological formations from the wellbore. Well cementing is accomplished by using a mixed combination of neat slurry and is carried out in two stages with blindness. Cementation is carried out at the level of the impermeable layer separating the two aquifers. After a certain period of time, drilling is continued with a reduced diameter in the lower layer to be captured. (Oriji & Dulu, 2014; Kevin et all; 2020).

Flares: During the drilling of wells, flares are safety equipment. They are used to evacuate, far from the drill, any inflow of gas ("gas show, gas kick") in order to ensure the safety of workers by burning the natural gas emitted. Later, in the production test phase, the initial flare can be replaced by an invisible flame incinerator.

Muds / cuttings: Cuttings (crushed rock) are generated during the drilling stage. They consist of small fragments of rock crushed by the drill bit. These fragments are carried to the surface by the movement of the drilling fluid. The cuttings coated with drilling fluid must be characterized and disposed in a place that complies with the regulations.

Table.5: Impacts related to well design, drilling, cementing, and casing

N	Impacts	Causes	Probability	Gravity	risk level
1	**Groundwater contamination**	**-Drill mud** **-Spill** **-Leak (migration)** **-Poor cementation** **- Bad tubing**	**Occasional**	**Low**	
2	**Soil contamination**	**-Spill** **-Wastewater** **-Solid waste (mud)**	**Occasional**	**Low**	
3	**Water consumption**	**-Drilling work**	**Frequent**	**Low**	
4	**Wastewater**	**-Rejection of drilling operations**	**Frequent**	**Low**	
5	**Air pollution**	**-Gas flared** **-Gas leak** **-Wastewater**	**Occasional**	**Low**	
6	**Noises**	**-Machines** **- Device**	**Occasional**	**Low**	

		-Traffic			

This stage generally has moderate impacts that are manageable through effective monitoring and the use of cleaner technologies.

Water consumption is classified as high following an estimate of 5905 m^3 with an estimated drilling time of 84 days.

3.3 Hydraulic Fracturing Techniques

Hydraulic fracturing refers to the process by which a fluid is injected into the high-pressure wells to open or create fractures in rock formations in order to release the gas and thus improve the productivity of these wells. Fracturing fluid is composed of 90% water, 9.5% sand and 0.5% chemical additives (Rahm, 2012).

The function of the sand is to prevent the fractures formed from closing (supporting agent in charge) under the stress exerted by the rock mass; chemical additives have multiple functions which can constitute the formulation of fracturing fluids.

Hydraulic fracturing operations are most often carried out at a depth of more than 2 kilometers, depending on the characteristics of the Algerian deposits, i.e. the well should be below the potential reserves of drinking water.

Table.6: Impacts related to hydraulic fracturing

N	Impacts	Causes	Probability	Gravity	risk level
1	**Groundwater contamination**	**-Migration through fractures**	**Occasional**	**Moderate**	
		-Migration by abandoning	**Rare**	**Moderate**	
		-Leak on casing	**Occasional**	**high**	
		-Migration of gas through old wells	**Possible**	**Very high**	
		-Accidental well	**Possible**	**Catastrophic**	

		eruption			
2	**Soil contamination**	**-Spill of chemical products**	**Occasional**	**Moderate**	
		- Wastewater discharge (retention basin / accident)	**Occasional**	**Moderate**	
		-Accidental well eruption	**Possible**	**Catastrophic**	
3	**Water consumption**	**-Mixture used for fracturing**	**Possible**	**Moderate**	
4	**Wastewater**	**-Fracking flow back**	**Occasional**	**Moderate**	
5	**Air pollution**	**-The leaks** **-Wastewater** **-Transport (too many truck)** **-The pumps**	**Occasional**	**Low**	
6	**Noises**	**-The pumps** **-Machines** **- Device**	**Occasional**	**Moderate**	

By the use of chemicals and the transport of fracturing wastewater, this step is considered critical for the environment whether in terms of deterministic or / and probabilistic events. Estimates suggest that 12,000 to 25,000 m^3 fracturing fluids can be used per well. Therefore, the development of several sites may present a greater risk to water resources in certain regions.

3.4 Well Completion and Wastewater Management

Completion is understood to mean the activities carried out following drilling and aimed at establishing the production process within the well. The operator who wants to complete a well must provide a completion program. This program describes the equipment (production casing) as well as the perforation and stimulation work that are carried out in the well.

During the first days (or weeks) after the end of the fracturing, the pressure in the well decreases and some of the fracturing fluid (called reflux), which can vary from 20 to 50% of what has been injected, rises to the surface through the well with gas and is channeled to the separator (water - gas). At the end of this step, the gas leaving the well can emit water in vapor form which must be removed during the gas treatment.

Some shale contains water which may then possibly rise with the reflux water and it is called "formation water" or "production water". This wastewater contains, in addition to the chemicals initially added, contaminants naturally present in the geological layers and released during fracturing, in particular, salts, metals, and potentially radioactive elements.

Table.7: Impacts related to well completion, wastewater management

N	Impacts	Causes	Probability	Gravity	risk level
1	**Groundwater contamination**	**- Migration through fractures -Migration by dumping - Leak on casing**	**Occasional**	**Moderate**	
2	**Soil contamination**	**-Wastewater discharge (retention basin / accident -Accidental well eruption**	**Occasional**	**Moderate**	
3	**Water consumption**	**Unclassified**			
4	**Wastewater**	**-Fracturing flow back**	**Possible**	**Moderate**	
5	**Air pollution**	**-Gas leaks -Wastewater**	**Occasional**	**Low**	

6	**Noises**	**-Transport**	**Rare**	**Low**	

Certain processes associated with well completions, in particular, are potentially significant sources of methane from unconventional gas production (O'Sullivan and Paltsev, 2012)

In this step, no water is consumed; rather, there is only wastewater.

3.5 Well Production

Site design and layout should retain or minimize loss of any valuable habitats or species whilst avoiding habitat fragmentation, particularly associated with road, rail and pipeline infrastructure. Opportunities for habitat creation and enhancement should be identified for implementation during construction, operation and decommissioning phases. (Moore and Less 2012). Detection of all risks may occur during the production and laws can be established to address these problems in order to avoid any harmful effects on the environment or on humans' health.

The flow of gas may be expected to decrease rapidly after the initial phase which is estimated at 40 years according to Algerian regulations.

Table.8: Impacts related to well production

N	Impacts	Causes	Probability	Gravity	risk level
1	**Groundwater contamination**	**- Migration through fractures** **- Leak on casing**	**Occasional**	**Moderate**	
2	**Soil contamination**	**Unclassified**			
3	**Water consumption**	**Unclassified**			
4	**Wastewater**	**- Flow back**	**Rare**	**Low**	
5	**Air pollution**	**-Gas leaks**	**Occasional**	**Low**	

		-Flared gas			
6	**Noises**	**Unclassified**			

This stage remains the most critical because of the likelihood of groundwater contamination and air pollution, but the latter can be reduced if the control system is properly implemented.

3.6 Well Abandonment

When a shale gas well reaches its production limit and becomes impractical, it must be abandoned by putting plugs on it. To abandon a shale gas well, the specialist uses a dip tube to inject cement into the annular space of the borehole, as well as into the casing string. The operation is done from the bottom up; this is what constitutes a well plug. The process of well abandonment is extremely important for rehabilitating the ocean and preserving soils and water resources because it prevents any possible leakage of polluted liquids into groundwater or onto surface and precludes any potential emission of gas from the well.

Table.9: Impacts related to well abandonment

N	**Impacts**	**Causes**	**Probability**	**Gravity**	**risk level**
1	**Groundwater contamination**	**Migration through poor plugging**			
2	**Soil contamination**	**Unclassified**			
3	**Water consumption**	**Unclassified**			
4	**Wastewater**	**Unclassified**			
5	**Air pollution**	**Unclassified**			
6	**Noises**	**Unclassified**			

In order to provide all the expected guarantees that the well is perfectly inactive, an assessment of the state of the surrounding soil, surface water and groundwater must be conducted. When necessary, decontamination is set up to ensure the return of life to what it was like before the exploitation of shale gas.

This stage requires caution because of the likelihood of groundwater pollution, but for other risks, there is no sufficient data which proves these impacts on the ground, so they are considered unclassified.

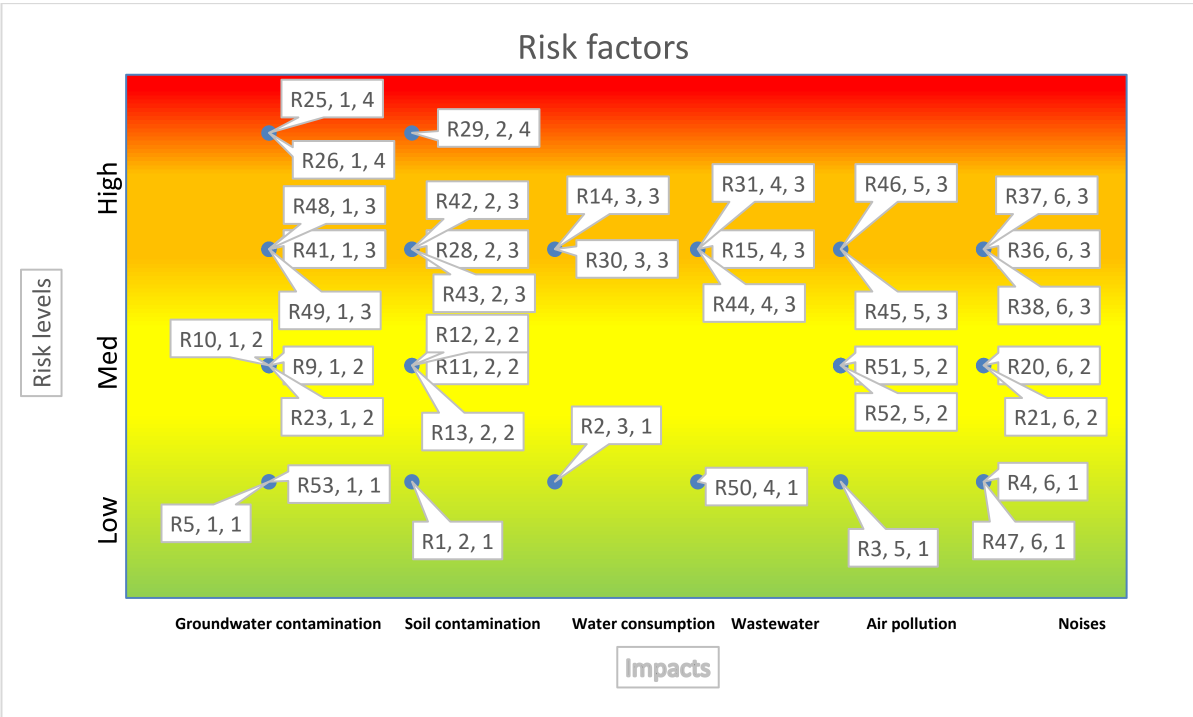
4. Summary and Interpretation of Results

Table .10: summary of risk assessment chart

Potential risks arising from the exploitation of shale gas	Risk Factors	Impacts	Risk levels
-Solid waste	R1	2	1
-Spill of gear oils	R2	3	1
Construction works	R3	5	1
Gear emission	R4	6	1
Gear movement	R5	1	1
Drill mud	R6	1	2
Spill	R7	1	2
-Leak (migration)	R8	1	2
Poor cementation	R9	1	2
Bad tubing	R10	1	2
Spill	R11	2	2
Wastewater	R12	2	2
Solid waste	R13	2	2
Drilling work	R14	3	3
Rejection of drilling operations	R15	4	3
Gas flared	R16	5	2
Gas leak	R17	5	2
Wastewater	R18	5	2
Machines	R19	6	2
Device	R20	6	2

Traffic				**R21**	**6**	**2**
Migration through fractures				**R22**	**1**	**3**
Migration by abandoning				**R23**	**1**	**2**
Leak on casing				**R24**	**1**	**3**
Migration of gas through old wells				**R25**	**1**	**4**
Accidental well eruption				**R26**	**1**	**4**
Spill of chemical products				**R27**	**2**	**3**
Wastewater discharge (retention basin / accident)				**R28**	**2**	**3**
Accidental well eruption				**R29**	**2**	**4**
Mixture used for fracturing				**R30**	**3**	**3**
Fracking flow back				**R31**	**4**	**3**
The leaks				**R32**	**5**	**2**
Wastewater				**R33**	**5**	**2**
Transport (too many truck)				**R34**	**5**	**2**
The pumps				**R35**	**5**	**2**
The pumps				**R36**	**6**	**3**
Machines				**R37**	**6**	**3**
Device				**R38**	**6**	**3**
Migration through fractures				**R39**	**1**	**3**
Migration by dumping				**R40**	**1**	**3**
Leak on casing				**R41**	**1**	**3**
Wastewater discharge (retention basin / accident				**R42**	**2**	**3**
Accidental well eruption				**R43**	**2**	**3**
Fracturing flow back				**R44**	**4**	**3**
Gas leaks				**R45**	**5**	**3**
Wastewater				**R46**	**5**	**3**
Transport				**R47**	**6**	**1**
Migration through fractures				**R48**	**1**	**3**
Leak on casing				**R49**	**1**	**3**
Flow back				**R50**	**4**	**1**
Gas leaks				**R51**	**5**	**2**

Flared gas				**R52**	**5**	**2**
Migration through poor plugging				**R53**	**1**	**1**



The preliminary impact assessment is summarized in the chart. This table also establishes an overall assessment of the impacts in all stages of shale gas development (Gao & You, 2018).

The findings of the present study are in concord with previous studies on analyzing the phases of the life cycle of shale gas development (Zaili et al., 2011). Thus, the results indicate that the hydraulic fracturing phase has extremely high impacts (consumption, contamination, wastewater treatment, etc.). This is due to several causes including the following:

- The use of larger volumes of water and chemicals compared to classic gas extraction.
- The challenge of ensuring the integrity of wells throughout development, as well as the operational and abandonment lifespans in order to avoid the risk of water contamination in the underground and / or on the surface.
- The challenge of ensuring that no chemical and wastewater spills; in addition to the possibility of rapid intervention if this occurs.

- The challenge of developing the correct mechanisms for selection of geological sites.
- Establishing a human cadre to deal with chemicals and water flowback to meet the challenge of developing more ecological options.
- The challenge of ensuring the essential requirements for the use of installations and equipment during construction and hydraulic fracturing, leading to atmospheric emissions and noise effects.
- Planning models for trucks for organization the transportation in the field of shale gas exploitation depending on the amount of water consumed.

Conclusion

The process of exploiting unconventional gas resources entails numerous risks. This paper has presented a study of the various risks from a qualitative research synthesis point of view and has attempted to contextualize the results to shale gas exploitation in Algeria by synthesizing the available data and suggesting pertinent recommendations. Nonetheless, further research is needed to improve the safety measures by collecting data from different perspectives and presenting comprehensive quantitative and qualitative accounts. In so doing, it is vital to take into account several factors such as population centers and the nature of chemical compositions used during all stages of production in order to dispel all concerns of civil society and make this industry as safe and environmentally friendly as possible.

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