Technical Normalization of Activities in Shale Gas Exploration: The Case of Water Resources

Renata Mendes Pelicer
Institute of Energy and Environment, Universidade de São Paulo
Av. Prof. Luciano Gualberto, 1289 - Vila Universitaria, São Paulo - SP, 05508-900
Tel: +55 11 98929-9392 E-mail: cluck5@hotmail.com

Henrique Toby
Institute of Energy and Environment, Universidade de São Paulo
Av. Prof. Luciano Gualberto, 1289 - Vila Universitaria, São Paulo - SP, 05508-900
Tel: +55 12 99737-6061 E-mail: henriquetoby@yahoo.com.br

Hirdan Katarina de Medeiros Costa
Institute of Energy and Environment, Universidade de São Paulo
Av. Prof. Luciano Gualberto, 1289 - Vila Universitaria, São Paulo - SP, 05508-900
Tel: + 55 11 96373-2483 E-mail: hirdan@usp.br

Thiago Luis Felipe Brito
Institute of Energy and Environment, Universidade de São Paulo
Av. Prof. Luciano Gualberto, 1289 - Vila Universitaria, São Paulo - SP, 05508-900
Tel: + 55 11 91132-3347 E-mail: thiagobrito@usp.br

Stephanie San Martín Cañas
Institute of Energy and Environment, Universidade de São Paulo
Av. Prof. Luciano Gualberto, 1289 - Vila Universitaria, São Paulo - SP, 05508-900
Tel: + 55 11 96994-1327 E-mail: stephanie.sanmartin@usp.br

Edmilson Moutinho dos Santos
Institute of Energy and Environment, Universidade de São Paulo
Av. Prof. Luciano Gualberto, 1289 - Vila Universitaria, São Paulo - SP, 05508-900
Tel: + 55 11 99614-5989 E-mail: edsantos@iee.usp.br

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Abstract
The exploration of unconventional resources using the hydraulic fracturing technique was decisive for the significant increase in hydrocarbon production in North and South America, with the consequent reduction in their dependence on external energy. However, in Brazil, production from unconventional sources continues to be debated due to the perception, by part of civil society, that the risks related to this activity outweigh its benefits. This work aims to analyze the impact of hydraulic fracturing on the environment, in particular with regard to water resources, as well as the most relevant regulation for water management, for the definition of a proposal for the structure of a specific technical standard to be used as a standard and good practice recommendation in the development of conventional gas exploration activities through hydraulic fracturing, aiming not only at the operational aspects of such activities, but also addressing the control and minimization of potential environmental impacts associated with water resources. Thus, it is possible to establish clear, objective, and easy-to-follow rules by the specialist society to ensure their development in suitable regions, limiting the occurrence and scope of any negative events to limits compatible with the benefits generated by the activity.
Keywords: shale gas, hydraulic fracturing, regulation, unconventional resources, normalization, mitigation
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1. Introduction

Shale gas is being considered as an alternative for the reduction of the dependency of natural gas in the future, however, there is still missing the creation of technical norms that are solid regarding the topic to minimize those environmental risks and to guarantee the operational safety or integrity of the exploration process (TAIOLI, 2013). In 2014, the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) enacted the Resolution n° 21 that set the requisites that the rights-holders of Exploration and Production of Petroleum and Natural gas must comply during the execution of hydraulic fracturing techniques (fracking) in unconventional resources.

The pathways planned by the normalization in Brazil may follow different directions and have diverse results, but all have one thing in common: the way the norms are done. Thus, the purpose of this work is to analyze the concepts that involve the hydraulic fracturing activities, as well as the existing legislations with the objective of proposing technical norms that create standards, rules or that stablish optimal criteria for the acceptance of these type of services. All with the intention to provide comfort, safety, harmony and quality for the exploration and production activities of unconventional natural gas.

2. Water use on fracturing activities

Water management is an essential component of oil and gas operations. Although the global volume of fresh water used by the oil and gas industry is considerably lower than in the agriculture, power and some other sectors (AQUASTAT: FAO, 2012), the oil and gas industry can be a significant user of fresh water at the local and regional scale. Oil and gas operations may also involve the handling and management of large volumes of produced water, wastewater and rainfall run-off. So, the efficient use of water is a key aspect that must be considered as part of the water management process in the industry as a whole but even more regarding the development of unconventional resources. Tables 1 and 2 present typical water uses, quality requirements and generalized categories of water quality. Table 3 estimates the volumes for each stage of the project.

Table 1. Typical use of water (Source: IPIECA, 2013 – Good Practice Guidelines for the Development of Shale Oil and Gas)

Water Uses	
Personnel Supply	- drinking, personal hygiene, food preparation - laundry, toilet flushing and cleaning
Construction and Comissioning	- concrete batching, dust control, road surfacing - hydro-testing pipelines
Drilling and Completion	- drilling fluids, cementing, completion brines - frac fluids
Returned Water	
Wastewater	- black water sewage effluent - grey water hand basins, showers, baths, laundries and kitchens - industrial effluent and drainage
Produced Water	- water that has come from the hydrocarbon reservoir
Flowback water	- produced fluid after fracking

Table 2. Generalized categories of water and their quality (Source: IPIECA, 2013 – Good Practice Guidelines for the Development of Shale Oil and Gas)

Category	Quality, TDS (mg/L)
Fresh water	<2,000
Slightly brackish	<4,000
Brackish	<15,000

Table 3. Summary of water uses, quality and return flows for different categories of tasks in oil and gas operations (Source: IPIECA, 2013 – Good Practice Guidelines for the Development of Shale Oil and Gas)

Sector	Water use	Volume Range	Quality Requirement, TDS (mg/L)	Water Returns	Water demand changes with time
Water uses common across the oil and gas resource types.	Personnel	0.18 – 0.35 m3/person/day	<600	Grey Water Black Water	Volumes generally higher during construction when there is a larger number of personnel and lower during operation.
	Construction and commissioning	0.45 – 0.55 m3/m3 concrete 1,000 – 3,000 m3/d	<2,000 - >15,000	Concrete wash water Hydrotest water	Hydrotest volumes are dependent on the pipe lengths and diameter. Concrete volumes on the size of the facility. Quantities are generally higher during construction of a facility.
	Exploration and drilling	200 - 4.000 m3/well	<4,000	Drilling fluid recirculation pits	Volumes depend on the length of the well. Total quantities used in an operation will depend on the drilling program.
	Process and operations	100 - 500 m3/d	<2,000 - >15,000	Firefighting water Drainage water Condenser water Dehydration water	Volumes are dependent on the equipment used and facility size, but generally quantities remain constant during operation of the facility.
Shale Gas	Hydraulic Fracturing and Production	3,800 – 60,000 m3/well	<2,000 – 30,000	Flowback water Produced water	Volumes will depend on the drilling / completion programs and on the extension of the well and can be higher in the initial phase.

3. ANP regulation on water resources (hydraulic fracturing)

The ANP Resolution n° 21 was enacted on November 11th of 2014, with its publication in the Official Journal of the Union. According to the article 1°, this norm establishes the requisites to be complied by the right-holders of Exploration and Production of Petroleum and Natural Gas that may execute the hydraulic fracturing techniques in unconventional reservoirs.

By means of clarification, the Resolution n° 21/2014 of the ANP establishes in Article 3 that:

> Article 3. The Environmental Management System shall contain a detailed plan of control, treatment, and disposal of the Generated Effluents by the drilling and hydraulic fracturing activities in an Unconventional Reservoir.
>
> Sole Paragraph. The water used should be preferentially consider Generated Effluent, unsittable or poor-quality water for human and animal consumption, or water resulting from industrial and domestic effluents provided that the treatment enables it of the intended use.

In this sense, a guideline can be understood concerning the type of desired water resource to be used in the hydraulic fracturing activities to be carry out in the country, i.e., the Regulatory Agency recommends the use of effluents. The article 7 of the same Resolution stablishes that:

> Article 7. In order to approve Hydraulic Fracturing in Unconventional Reservoirs by the ANP, the operator shall ensure, by means of tests, models, analyses, and studies, that the maximum fracture length remains at a safe distance from the existent water bodies, in accordance with Good Petroleum Industry Practices.
>
> § 1º It is prohibited Hydraulic Fracturing in Unconventional Reservoirs in wells within distances smaller than 200 m from water wells for domestic, public, or industrial supply, irrigation, animal consumption, among other human water uses.

In this way, through this article's wording, it is possible to reflect on the specificities and attention given to the safety issues considering that the drilling operations may interfere with the use of water bodies, and even further, in terms of guaranteeing that such resources remain free of contaminants. Regarding Hydraulic Fracturing in Unconventional Reservoirs, there are relevant aspects of the Resolution 21/2014 of the ANP, as follows:

> (i) Mandatory preliminary studies and surveys: analysis reports for water bodies (1000 m) and prohibited fracturing in wells within distances smaller than 200 m from water resources; (ii) Well drilling pilot project: safety barriers; (iii) Fracture simulation: probability of fractures reaching prohibited intervals; (iv) Risk analysis: risk assessment and classification, and the establishment of control measures; (v) Implementation of operations ensuring structural integrity of facilities; (vi) Emergency response: procedures to eliminate or minimize the consequences of accidents identified in the risk analysis; (vii) Environmental Management System (EMS): control, effluent treatment, effluent source, annual environmental impact assessment, chemical records; (viii) Well Integrity Management System (WIMS): application of techniques, operational and organizational methods intended to prevent and mitigate unintentional fluid flow into the surface or between the underground geologic formations during the stages of the entire well lifecycle (project, construction, production, intervention, and plug and abandonment).

4. Proposal for the structure of the technical norm on hydraulic fracturing activities in unconventional reservoirs

The technical norms are rules elaborated by a group of people to stablish an acceptable pattern. The objective is to guarantee the quality of a specific product or service. The norms create patterns, rules, or stablish optimal criteria for the acceptance of products and services. All with the intention of providing comfort, safety, harmony, and quality. The normalization plays a relevant role in the technological development and promotion of innovation for different sectors. The development of mechanisms for natural resources exploitation shall be benefited from the proper development of consistent technical bases and Good Practices consolidated through consensus among specialists. Particularly, the normalization could play a key role during the process of sustainable development of unconventional natural gas, acting in the control, minimization and mitigation of potential impacts generated by its exploration and production.

Therefore, advantages of the normalization are:

> (i) Standardization: a good example is the bolt threads. Could one imagine if every manufacturer makes bolts and nuts with angles that differ from each other? It would be extremely difficult to combine different models; (ii) Technical terminology: it also includes the units of measurements. Certainly, it is easier for the technological trade and exchange, businesses and users, even in different countries. A good (bad) example is when you travel to the United States and check the weather forecast in degrees Fahrenheit (oF). We cannot tell if it is cold or hot because we are used to think in degrees Celsius (oC); (iii) Standard dimensions: from cargo containers to wheelchairs for the physically disabled, it is possible to image the difficulty. Loss of space on vessels, incompatible load with trains and trucks, and the subsequent increase of costs and decrease in quality of life; (iv) Standardized Communication: from smartphones to credit cards that provide global transactions; (v) Signaling: it is more an achievement for safety. For instance, the symbol for infectious waste is the same everywhere; (vi) Biddings: when a requested product demands technical standards and conformity assessments, therefore it facilitates comparisons and excludes those products that do not comply with the required level.

Regarding the approach to environmental aspects and potential impacts associated with the activities of Hydraulic Fracturing in Unconventional Reservoirs (related to water resources), the most relevant points are highlighted and can be considered as specific opportunities to be properly addressed by the technical normalization. The establishment of an Environmental Management System (EMS) for the Project enables the control regarding the environmental issues of the activity, as well as their lifecycle monitoring concerning environmental impacts. Also, some benefits can be associated:

(i) corporate image improvement; (ii) promotion of production processes improvement; (iii)reduction of risks and environmental accidents; (iv) promotion of elimination or minimization of the consequences related to accidents that were identified during the risk analysis; (v) improvement of the energy efficiency and materials; (vi) reduction of unnecessary raw material expenditure; (vii) control and treatment of effluents; (viii) control the chemical inventory lists; (ix) compliance of the environmental legislation; (x) promotion of the annual Environmental Impact Assessment; (xi) evaluation and classification of possible scenarios, and establishment of control measures; (xii) pursuit of sustainable development; (xiii) promotion of a balance between the environmental protection and socioeconomic needs.

From the hydraulic fracturing techniques, the use of unconventional resources may strongly contribute to maintain the exploration activities in mature basins by increasing their recovery factors. This technique consists in inducing artificial fracture propagation in rock formations using external pressures. Hence, simulation models for fracture propagation are of great importance to understand and verify the probability of fractures surpassing the permitted safety limits.

The risk analysis is important for the overall success of the final project results. To be ahead of possible eventualities and risks during a project helps professionals by providing contingency action plans to handle abnormal situations. Such analysis must include well drilling and hydraulic fracturing operations.

The environmental licensing process of the project is important and necessary because it is an instrument that provides the conditions for the establishment of developments and activities, that intends to eliminate, if possible, or minimize the environmental impacts, and at the same time, seeks to guarantee the social and economic development of the country. The purpose is to be effective at protecting the environment, a fundamental aspect for maintaining key resources that are necessary to ensure the sustainability of both ecosystems and businesses. In general, the environmental licensing process is conducted in three phases:

(i) Prior License (PL) – issued during the preliminary stage of the planning of the intended development or activity. This license approves the location and conception of the development, verifies the environmental feasibility and stablishes mandatory basic requirements and conditions that must be followed during the next stages of the implementation; (ii) Installation License (IL) – authorizes the installation of the development or activity in accordance with the technical specifications in the approved plans, programs and projects, including the environmental control measures and other conditions; (iii) Operation License (OL) – authorizes the operation of the development or activity, after verification of the effective compliance of the preceding licenses, in accordance with the environmental control measures and conditions required for the operation. Its validity period varies from 4 to 10 years, at the discretion of the competent environmental agency.

The environmental survey should be considered to facilitate the analysis of impacts that are borne by the environment. Such survey must be conducted for all project phases (operation, production and monitoring) and shall at least contain the following elements:

(i) Surface water; (ii) Ground water; (iii) Drinking water abstraction; (iv) Water resource availability (current and expected); (v) Existing underground wells and structures.

The well integrity management should be conducted to avoid groundwater contamination (e.g., fluid migration between rock formations). the fracturing fluid injection and effluents reinjection, especially, can cause seismic disturbances that in some cases compromise the well integrity which generates the impacts previously mentioned. Therefore, it is crucial that the project and operations (i.e., drilling, hydraulic fracturing, and effluents reinjection) follow the Good Practices guidelines, existing regulation and mitigation measures included in the risk analysis. Such management must include all stages of the well lifecycle (i.e., project, construction, production, intervention, and plug and abandonment).

The assistance management to EMS and WIMS as wells as the confirmation of expected reservoir parameters are essential to avoid and/or minimize possible environmental impacts. The operations management ensure the good condition of a business by monitoring the activities performance and promoting improvements. For this to be possible, a cycle of activities must be conducted: planning, organization, direction and control.

Further, the change management is also part of the operations management and has as main objective to increase the project success rates with a lower impact on people and a higher Return on Investment (ROI). The change management can be defined as the application of structured processes and a leadership toolkit to address the human factor of the change while focusing on the achievement of an expected business result.

It is a unique approach that is not frequently or properly applied in the corporate environment, a sector that often considers change management as a synonym for both project management and people management. Nevertheless, if the organization expects changes that really deliver good ROI, it cannot ignore people transition through such organizational transformations. One of the main characteristics of change management is centered on how individuals and teams are affected by a process of organizational transition. This is therefore a multi- and interdisciplinary approach where many sciences and research converge.

The continuous monitoring of the environmental conditions (EMS and WIMS) throughout the project life-cycle (exploration, production, and plugging and abandonment) to facilitate the continuous performance management and evaluation (e.g., to be conducted as part of the licensing conditions compliance) may include:

> (i) Surface water quality, (ii) Ground water quality, (iii) Drinking water collection points, (iv) Water resource availability, (v) Water volumes and sources, (vi) Chemical substances, nature, and volume of proppant material, (vii) Water flowback rate, (viii) Produced water volume and treatment solution, (ix) Occurrence of methane infiltration, (x) Volume, nature, location, and clean-up of spills.

As part of the monitoring of the main environmental conditions, the information should be used to update all models (e.g., groundwater flow, roads, microseismicity) to guarantee that the hydraulic fracturing project is running based on the most recent information. During operations, the monitoring and control of microseismicity and well integrity should be used to guarantee that hydraulic system fractures and pollutants do not extend beyond the gas-producing formations and do not result in events and/or incidents concerning seismicity and pollution.

5. Final Remarks

The study was able to preliminarily address important issues about the regulatory approach that involves the activity of hydraulic fracturing in unconventional resources, including the aspects of environmental impacts related to the water resources. It is clear that some of the risks posed by hydraulic fracturing, that is the process of extraction of unconventional natural gas that was the priority of this research, are dealt by the existing legislation in Brazil. At the same time, the existing legal framework for the exploration and production of oil and gas, without considering the particularities that directly involve the production of unconventional natural gas, offers some guideline and/or requisites that should be met to control or mitigate potential adverse impacts related to the production of unconventional natural gas.

Examples of the analyzed national and federal regulations indicate the predisposition for the use of available recommendations, including guidelines and Good Practices indicated in the technical normalization, as a way of guaranteeing a proper protection, and not necessarily acting through formal legal regulations that could inhibit the development of hydraulic fracturing activities. The building of legal provisions by consensus indicates that the public involved with the exploration and production of unconventional oil and gas should be consulted and provide constructive information to be used in the decision-making processes of regulatory agencies and governments.

In this way, the pathway for the sustainability in the exploration of unconventional natural gas is connected to the country's capacity to organize the technical debate related to the different areas of potential interest linked to the environmental impacts on water resources, as well as the Good Practices that should be adopted by the industry, looking for the interest areas equating and a robust solution for the society. Therefore, the development of a national technical normalization may hold an important position in the construction and preparation of this debate.

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