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Importance of the Study of Environmental Aspects in the Exploitation of Unconventional Reservoirs for Risk Assessment of the Activity in Argentina

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Abstract

There is an expectation that the exploitation of unconventional hydrocarbons (UH) reservoirs will contribute to satisfy the growing demand of energy, since conventional reservoirs are on a declining stage. However, environmental consequences of the fluids used on unconventional formations are an aspect that has not been analyzed in depth in the region. Approximately 10-40% of the volume injected of fracturing fluids returns to the surface during the hydraulic fracturing process. The flowback not only includes the chemicals added, but may also contain various substances suspended from the formation. This situation demands the development of appropriate technologies for flowback treatment and the need to consider the existing legal context and the ecologic and environmental conditions. The impacts associated with UH activities that need to be analyzed in order to accomplish control and standardization, include those related to consumption of surface water or groundwater, potential contamination of regional water resources, treatment and final disposal of flowback. It is possible to achieve the sustainability of the activity, based on an environmental analysis.

The objective of this work is the analysis of the environmental aspects associated to the extraction of UH (shale and tight). A comparative analysis of the activity, in a national and international context, including legal aspects, technologies used and environmental risk is performed. Additionally, possible mitigation measures of environmental risks are evaluated. The study includes the analysis of the existing environmental legislative framework in different regions where the exploitation of UH could be made. It also includes the analysis of the actual effluent management strategy. A description of the environmental conditions, including climatic, geological, hydrological and ecological conditions is performed in areas with completion activities, in order to identify the regions with higher level of environmental risk. Possible technologies for flowback water treatment and reuse are analyzed, depending on physicochemical characteristics and volumes of water. The novelty of this work is the analysis of the factors that determine the environmental risk in the extraction of UH, especially in the hydraulic fracturing process, which includes technologies, environmental conditions at the site and the legal context in the region. This allows identify the areas of higher and lower level of environmental risk in order to proceed to the identification, implementation and development of potential mitigation measures to achieve the sustainability of the activity.

Introduction

Unconventional hydrocarbons (UH) have reached great interest all over the world and in recent times in Argentina with the elaboration of a plan to exploit Vaca Muerta reservoir with productive epicenter in Neuquén Basin (Di Sbroiavacca, 2013; Riavitz, 2015, Stinco, 2015).

Hydrocarbons play an important role, not only in the national energy matrix of which they constitute an 86%, but also in their by-products (Riavitz, 2015). The availability of energy is an essential requirement for the operation of any modern society. There is an expectation that the exploitation of UH will contribute to satisfy the growing demand of energy since conventional reservoirs are on a declining stage (Riavitz, 2015).

In recent years, many issues have been raised relating to environmental aspects of UH including fresh water source, handling and disposal of effluent, chemical safety, fresh water aquifer protection, atmosphere and landscape (RS & RAE, 2012; ANI, 2013; Taillant et al., 2013; Nakhwa et al., 2013, Hoffman et al., 2014; Sarandón, 2015). Also important are pollution, air quality problems and population disruption caused by traffic and noise (Sarandón, 2015; Estrada et al., 2016).

Environmental consequences of the fluids used on unconventional formations are an aspect that has not been analyzed in depth in the region (Sarandón, 2015) or in the rest of the world (Morgan, 2014; Souther et al., 2014). Approximately 10-40% of the volume injected of fracturing fluids returns to the surface during the hydraulic fracturing process. The flowback not only includes the chemicals added, but may also contain various substances suspended from the formation. It can contain halides, strontium, barium, radioactive materials and different organic or inorganic substances (Annevelink et al., 2016). This situation demands the development of appropriate technologies for flowback treatment and the need to improve the techniques involved in the exploitation, especially in the stimulation activity (IAPG, 2012; King, 2012). This development may also consider the existing legal context and the ecologic and environmental conditions of the region (ANI, 2013; Taillant et al., 2013; Sarandón, 2015). The impacts associated with unconventional activities that need to be analyzed in order to accomplish control and standardization, mainly include those related to consumption of surface water or groundwater, potential contamination of regional water resources, treatment and final disposal of flowback (USEPA, 2014). It is possible to achieve the sustainability of the activity, based on an environmental analysis.

This paper presents an analysis of the environmental aspects of the exploitation of unconventional reservoirs in order to evaluate the risk of the activity. To this end, existing normative framework, natural and socioeconomic conditions of the area and applicable technologies are considered.

Objectives and Scope

The objective of this work is the analysis of the consequences of the interaction between the operations performed for the exploration and exploitation of UH and the environment in which it is developed. By environment is understood the combination of factors and conditions of the natural environment (physical and biotic) and the human environment (social, economic, cultural, land use, infrastructure, territorial system, vulnerable groups). A comparative analysis of the activity, in a national and international context, including legal aspects, technologies used and contamination risk is performed. Additionally, possible mitigation measures of environmental risks are evaluated.

Methodological Strategy

With the aim of evaluating the existing environmental legislative framework in different regions where UH could be exploited, a review and comparative analysis of the general and environmental regulatory framework was performed in Argentina and in the main provinces where unconventional exploration and/ or exploitation activities are carried out: Neuquén, Santa Cruz and Salta. This analysis was completed with the review of the effluent management strategy, comparing with the criteria referenced by other countries (especially the United States of America).

In order to perform a preliminary evaluation of the site environmental risk, a structured, conceptual and qualitative analysis was carried out in specific sectors corresponding to each of the areas of exploration and exploitation of UH: Neuquén Basin (Neuquén, Vaca Muerta Formation), Golfo San Jorge Basin (Santa Cruz, Pozo D-129 Formation) and Paleozoic NW Basin (Salta, Los Monos Formation). In each of them, 10 analysis sites were located in concession areas for exploitation and/or exploration, using as reference the map of concessions of the Energy Secretariat Geographic Information System (GIS) corresponding mostly to existing oil well sites or areas with different environmental conditions (Fig. 1 to 3).

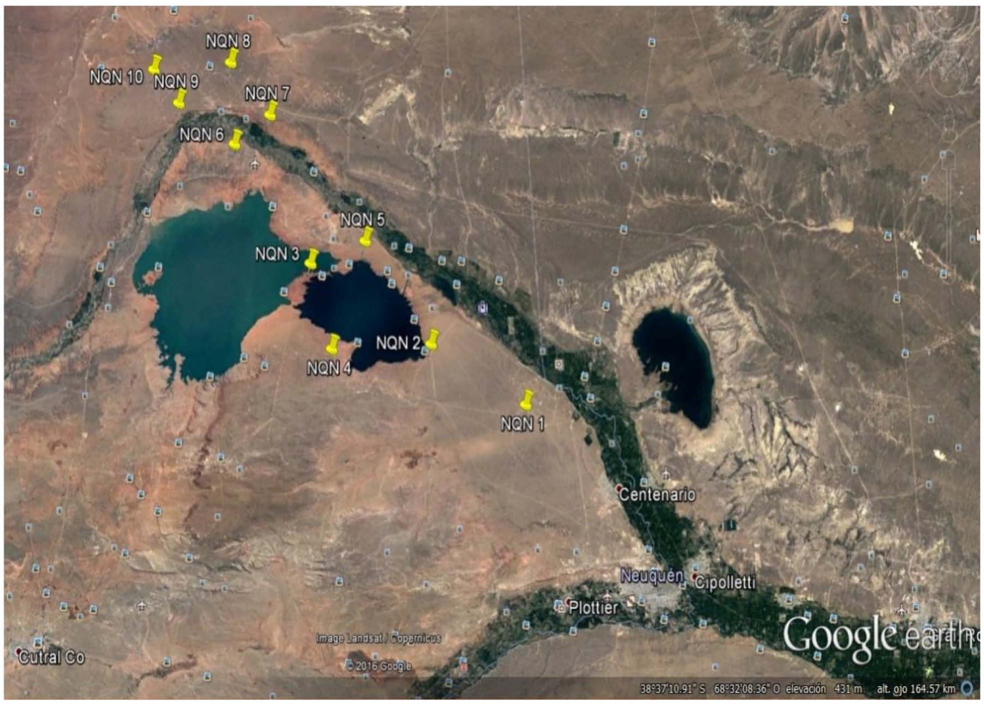

Figure 1—Location of 10 points of analysis (NQN 1 to NQN 10) on Neuquén basin (Vaca Muerta Formation). Source: Google Earth (2016).

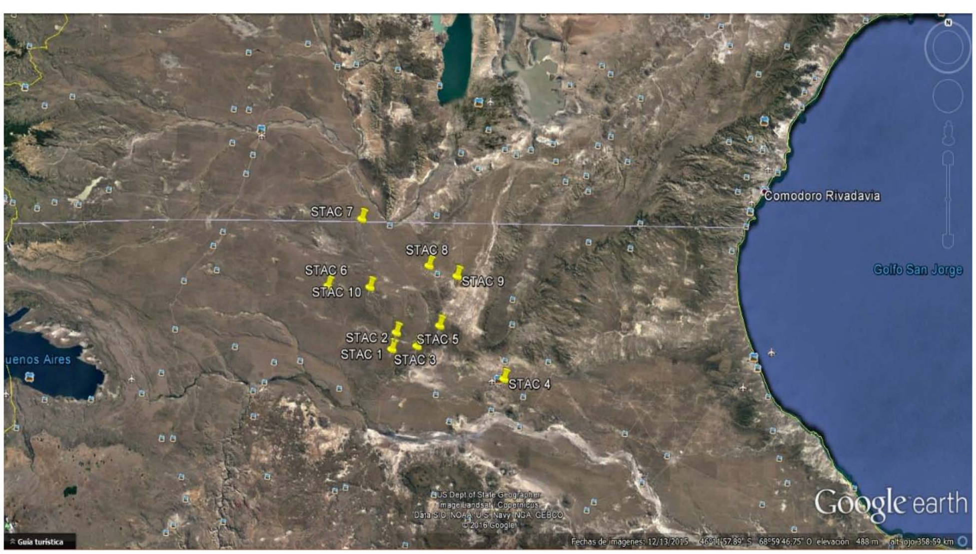

Figure 2—Location of 10 points of analysis (STAC 1 to STAC 10) on Golfo San Jorge Basin (Pozo D-129 Formation). Source: Google Earth (2016).

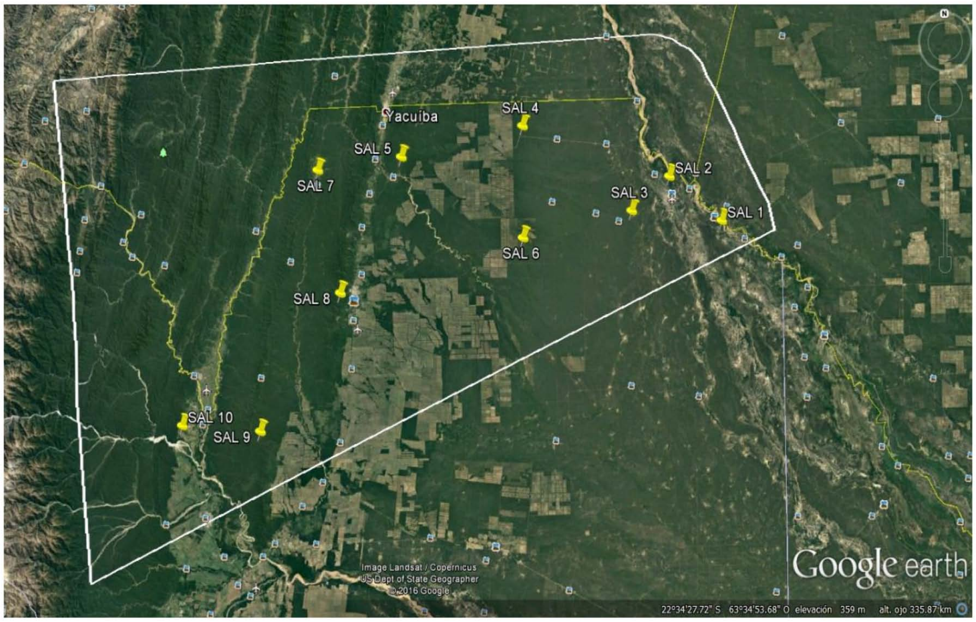

Figure 3—Location of 10 points of analysis (SAL 1 to SAL 10) on Paleozoic NW Basin (Los Monos Formation). Source: Google Earth (2016).

Depending on the information available at the regional level, and based on the visual analysis of satellite images for an area of analysis of 100 km2 (10 × 10 km), each site was characterized according to 20 parameters or indicators referred to the conditions of the natural physical, biotic or ecological and the human environment (Fig 4 to 6; Table 1).

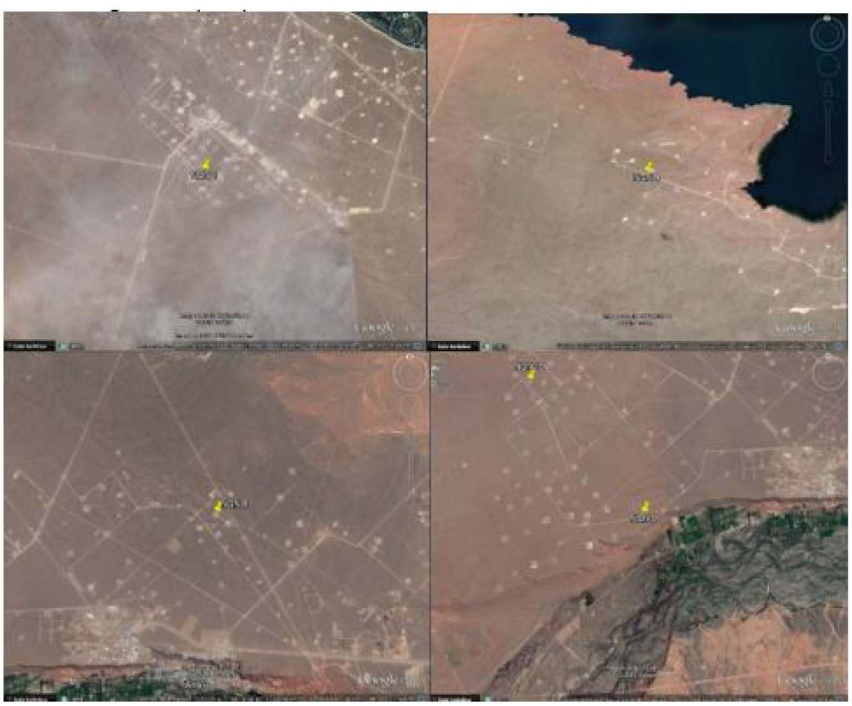

Figure 4—Image clipping for NQN 1, NQN 4, NQN 8 and NQN 9 (approximate area of 100 km2) in the Neuquén Catchment (Neuquén, Fm Vaca Muerta). Source: Google Earth (2016).

Figure 5—Image clipping of point STAC 1, STAC 4, STAC 8 and STAC 9 (approximate area of 100 km2), in the Gulf Basin of San Jorge (Santa Cruz, Fm Pozo 129). Source: Google Earth (2016).

Figure 6—Image clipping of the point SAL 2, SAL 4, SAL 5 and SAL 8 (approximate area of 100 km2) in the Northwest basin (Paleozoic, Salta, Los Monos Fm). Source: Google Earth (2016).

Table 1—Parameters of the natural physical environment (1 to 9), biotic or ecological (10 to 13) and human environment (14 a 20) used in the environmental site analysis.

N°	INDICATOR	DESCRIPTION
1	Temperature	Low temperatures determine a longer time of recovering; biochemical processes are slower. When the temperature is extreme, it results in an operational technological challenge.
2	Precipitation	High precipitation generates instability of the land, more risk of water erosion, increase of hydrogeological risk, landslides, torrential phenomenon, floods, extreme events, etc. Demand for contingency measures, more operational risks.
3	Relief	Abrupt relief increases the risk of erosion and landslide or mass removal.
4	Wind	Frequent and intense winds produce more dispersion of atmospheric pollutants, especially particulate matter (powder, gaseous emissions) and potential contamination to populated or productive areas.
5	Water depth	Lower depth of groundwater increases the risk of contamination by intentional or accidental spills, as well as contact with hazardous substances.
6	Wetlands*	The proximity to a wetland (stream, river, lake, pond) increases the risk of contamination by intentional or accidental spill.
7	Water resources*	The availability of water resources conditions the hydraulic fracturing operation.
8	Land quality	High quality of the land implies more risk to the environment when an accidental spill occurs or degradation by occupation, erosion or contamination.
9	Hydrologic regime	Increased intermittence of the watercourse increases the risk of torrential activity, erosion and flooding, increasing the risk of accidents during the operation phase.
10	Eco-region	Type of eco-region, sensitivity, vulnerability.
11	Physiognomic diversity	A higher diversity of species or life forms increases the risk of deterioration of more number of species, being an ecosystem more vulnerable and of greater biotic wealth.
12	Highland Ecosystem	High altitude ecosystems are more vulnerable to human activity.
13	Protected ecosystems*	Proximity to protected ecosystems or species with legal protection (natural monument, protected species, etc.), represent a higher risk of degradation and environmental damage.
14	Infrastructure	The lack of roads or paved roads increases the risk of accidents, leads to the need for their adaptation, increasing the environmental impacts of the entire activity
15	Services	Deficiency in public services (energy, gas, water, sewage) increases the risks and environmental impacts associated with a greater human presence and an increase in the demand for natural resources.
16	Waste management	The availability of integrated solid waste management systems and / or special or hazardous waste management systems increases the environmental risk of the activity by increasing the generation of solid, liquid or gaseous waste.
17	Populated Centers *	The proximity to populated centers increases the risk of interference with local activities, degradation of essential natural resources (water), restriction of movement of people and goods, competition for natural resources, alteration of the local economy, spontaneous immigration, etc.
18	Productive areas*	The proximity to areas of intense agricultural activity increases the risk of interference with local activities, alteration of the pattern of land use, degradation of resources, competition for inputs and local labor.
19	Territorial system	The intervention in unstructured territorial systems increases the risk of degradation of the same, alteration of the pattern of occupation and mobility. Presence of Aboriginal territories or under special management.
20	Historical areas*	Intervention in areas protected by their historical or archaeological value increases the risk of degradation or damage to local heritage.

For each of the 30 sites, each parameter or indicator was analyzed and a value was assigned on a scale of 1 to 5, corresponding to a lower (1) or greater (5) environmental risk. In the case of the indicators identified by an asterisk (*), the following risk and distance ratio was used: 5 (less than 500 m); 4 (between 500 and 1000 m); 3 (between 1000 and 3000 m); 2 (between 3000 and 5000 m) and 1 (More than 5000 m).

Finally, following the scheme proposed in Sarandón (2015), an analysis of UH exploitation activity was carried out, identifying for each stage the main activities, risks and environmental impacts and possible mitigation measures. In addition, the possible technologies applicable to the treatment of flowback water and its reuse were analyzed, depending on their physical-chemical characteristics and the volume of water to be treated.

Results and Discussions

Environmental aspects are critical to the development and future of the exploitation of UH. When undertaking an activity in a certain place, it is important to evaluate the risk associated. In this context, environmental risk includes the set of factors that can condition the activity related to environmental issues.

It is possible to recognize three components that make the environmental risk of the activity of exploration and/or exploitation of UH:

- The environmental regulatory framework determines the conditions or restrictions on the management of natural resources and waste and the requirement of certain technologies or practices. For example, it may determine the possibility to use groundwater, the requirement to manage special waste under certain standards and/or the requirement to treat the flowback before it is discharged in a receptor body. In the same way, the characteristics of the environmental impact assessment procedure and its administrative complexity also play an important role in the decision to develop the activity in a certain place. In this context, it is important to note that in some municipalities it is forbidden to develop the fracking activity.
- The conditions of the surrounding environment, including aspects of the natural environment (climate, geomorphology, ecology) as well as of the human environment (including social, economic, territorial or infrastructure aspects), establish a decisive framework for the development of the activity, because it may have vulnerable elements or impose extreme operational conditions (temperature, elevation). The activity to be developed must incorporate certain practices or precautions to avoid the occurrence of environmental damage, minimize impacts and variations on the ecosystem, adjust to extreme conditions and avoid the increase of natural or human risks (hydrogeological, diseases, etc.). This is especially important if the activity takes place within or near a protected natural area or a site of historical or patrimonial value (paleontological, geological, natural). Similarly, some aspects such as the presence of vulnerable groups, aboriginal communities and territories, productive activities (agricultural, hunting, extractive) and potentially vulnerable services (tourism, recreation, sports) must be considered to avoid conflicts and achieve the acceptance and trust of the local community, in what is known as social license.
- Finally, the third component of the environmental risk is the technology used. This component is the variable that is in hands of the industry or company and allows the local adaptation of the activity. It also can generate negative environmental impacts if it is not adapted to the conditions present in the territory and to the current regulations. However, it can generate positive environmental impacts if there are developed advanced technologies that replace and/or improve current operational practices and procedures that only tended to solve the need to "produce" and just to make available the energy present in the subsoil.

Evaluation of the Legal Framework

There are different types of environmental regulations for the exploitation of hydrocarbons: general and specific rules for the activity and sector. The Argentine National Constitution in its article 41 explicitly incorporates the right to a healthy, balanced environment, suitable for human development and so that productive activities satisfy present needs without compromising those of future generations. In different regulatory bodies are the national and provincial environmental laws that contain the principles of environmental management.

Vaca Muerta Formation, located in Neuquén and Mendoza, is the most important of Argentina and its conditions make it an unconventional goal of the shale type of excellence in the world. Pozo D-129 Formation is located in Chubut and Santa Cruz, and Los Monos Formation is located in Jujuy and Salta. Based on the areas that are being explored and/or exploited, Neuquén and Santa Cruz were selected to perform a study of the current legislation. On the other hand, Salta was also studied in order to consider the north of Argentina as a potential UH.

Table 2 shows a comparative analysis of the different environmental aspects related to the hydrocarbon activity present in the legislation of Argentina.

Table 2—Comparative analysis of the environmental aspects present in the regulations related to UH in Neuquén, Salta and Santa Cruz. (*) Specific regulations for UH.

Environmental Aspect	Neuquén	Santa Cruz	Salta
Preservation, protection, defense and restoration of the environment	X	X	X
Use of techniques to avoid the loss or damage of natural resources and the environment	X	X	X
Standards and procedures for exploration and exploitation of unconventional reservoirs (*)	X		
Rational and sustainable management of surface and groundwater resources	X	X	X
Declaration of the estimated volume and source of water to use during the drilling and completion phases of the well (*)	X		
Prohibition, during the drilling and termination stages of unconventional wells, of the use of groundwater with aptitude for population supply and irrigation (*)	X		
Treatment of the totality of flowback water for reuse and disposal (*)	X		
Procedures for treatment and final disposal of wastes from oil extraction		X	
Prohibition of discharge into public, surface or underground waters of solid, liquid or gaseous substances that may contaminate or modify its quality	X	X	
Prohibition of discharge of flowback water into surface water bodies (*)	X		
Prohibition of discharge of production water to any receiver body	X		
Presentation to the environmental authority the physical-chemical analysis of flowback water (*)	X		
Prohibition of the increase of saline concentration in the exploited aquifer	X		
Disposal of non-recyclable liquid wastes in sludge and completion fluids by confinement in permeable dry and insulated surface layers by impermeable layers, or by injection into deep sterile layers	X		
Disposal of water based fluids or biodegradable polymers in the soil, roads or land without vegetation	X		
Recycling of oil based fluids or distillates with the production oil to be processed in treatment plant	X		
Permissible maximum limits of liquid effluents discharged into water bodies	X	X	
Methods of analysis of liquid effluents	X	X	
Quality standards for water sources		X	
Presentation of an aquifer vulnerability study			X
Prohibition of generation of environmental damage during the exploration, production, transportation and industrialization of hydrocarbons, as well as with produced waters, and all substances and materials used in these operations			X

In relation to the environmental risks associated to exploration and/or exploitation of UH, the three provinces seek to achieve a sustainable management of the natural resources in order to preserve the environment. However, in relation to unconventional reservoirs, Neuquén is the only one with specific regulation of the activity (Order 1483/12) which establishes the rules and procedures for exploration and exploitation of UH. According to this regulation, the alternatives allowed for flowback treatment are: reuse in the hydrocarbon industry, reuse in irrigation associated to a productive project or environmental recomposition and final disposal in a sinkhole. Likewise, the use of groundwater for drilling and completion stages is prohibited. Neuquén and Santa Cruz establish limits of liquid effluents discharged in water and the respective methods of analysis. On the other hand, Salta and Santa Cruz have a general hydrocarbon regulation and none related to unconventional activity at this moment.

In an international context, United States of America (USA) is the most advanced country in the extraction of UH. The development of hydraulic fracturing technology caused a series of studies by the Environmental Protection Agency (EPA), focusing on the potential risk of impact on water resources of this activity (USEPA, 2004, 2011, 2012 and 2014: Sarandón, 2015). The regulations include discharges of wastewater from exploration, drilling, production, well treatment and well completion activities. The EPA has an effluent limitations guidelines and standards for unconventional oil and gas extraction. The current regulation in the USA includes effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best practicable control technology currently available, water quality standards, guidelines and standards for underground injection and restrictions for the use of hazardous wastes. The EPA establishes pretreatment standards that prevent the discharge of pollutants in wastewater from unconventional oil and gas extraction facilities to publicly owned treatment works.

From the analysis of the normative framework in a national and international context, it could be concluded that Neuquén improved the normative development related to the hydrocarbon activity; however, the national legislation does not reach the level of precision of the EPA.

Preliminary Environmental Site Assessment

For each of the 30 selected sites (3 concession areas × 10 sites), the 20 indicators defined in Table 1 were analyzed, allowing a preliminary environmental site assessment to be carried out. Table 3 shows the mean values between the 10 sites of each study area for each of the 20 indicators, as well as the ERV (Environmental Risk Value), which corresponds to the sum of the 20 indicators. The ERV has a minimum value of 20 (1 point for each indicator) and a maximum of 100 (20 indicators for a maximum value of 5 each).

Table 3—Comparative analysis of the preliminary environmental site assessment among the three study areas (Salta, Neuquén and Santa Cruz). AVG: Average. ERV: Environmental Risk Value (sum of 20 indicators).

COMP	Nº	INDICATOR	SALTA		NEUQUEN		SANTA CRUZ	
			AVG	RISK	AVG	RISK	AVG	RISK
I. Natural physical environment	1	Temperature	1	Very low	4	High	3	Medium
	2	Precipitation	4	High	2	Low	2	Low
	3	Relief	3	Medium	2	Low	2	Low
	4	Wind	1	Very low	5	Very high	5	Very high
	5	Water depth	3	Medium	1	Very low	4	High
	6	Wetlands*	3	Medium	3	Medium	2	Low
	7	Water resources*	3	Medium	2	Low	4	High
	8	Land quality	3	Medium	2	Low	1	Very low
	9	Hydrologic regime	3	Medium	1	Very low	2	Low
II. Biotic or ecological	10	Eco-región	4	High	2	Low	2	Low
	11	Physiognomic diversity	4	High	2	Low	1	Very low
	12	Highland Ecosystem	2	Low	1	Very low	1	Very low
	13	Protected ecosystems*	4	High	2	Low	1	Very low
III. Human environment	14	Infrastructure	5	Very high	4	High	5	Very high
	15	Services	5	Very high	4	High	5	Very high
	16	Waste management	4	High	3	Medium	4	High
	17	Populated Centers *	2	Low	2	Low	1	Very low
	18	Productive areas*	3	Medium	2	Low	1	Very low
	19	Territorial system	4	High	4	High	4	High
	20	Historical areas*	2	Low	1	Very low	1	Very low
	ERV	**TOTAL**	**61,40**	**0**	**48,60**	**0**	**51,00**	**0**

The results indicate that the area of Salta is the one that shows the highest medium value ERV (61.40) among the areas, with maximum values of 71.00 (in the SAL 10 site) and minimum values of 55.0 (SAL 6). The Neuquén area showed mean ERV values of 48.60 with maximums at NQN 7 (56.00) and minimums at NQN 3 (41.0). On the other hand, Santa Cruz showed mean ERV values of 51.00 with maximums in STAC 9 (60.00) and minimums in STAC 4 (47.00).

In Salta, the indicators that showed the highest value (very high risk) were 14 (lack of infrastructure), and 15 (lack of services). The indicators that showed high ERV were number 2 (high rainfall), 10 (sensitivity of the Eco-region), 11 (great physiognomic diversity of vegetation), 13 (presence of protected ecosystems), 16 (difficulty in implementing hazardous waste management systems in the area), and 19 (lack of an organized territory). In this area, the indicators with lowest ERV were 1 (high temperatures) and 4 (moderate winds).

In Neuquén, the indicator that showed the highest value was 4 (strong winds in the region), followed by 1 (low temperatures), 14 and 15 (lack of infrastructure and services in the area), and 19 (unstructured territorial structure). In this area, the indicators that showed the lowest values were 5 (depth of the water table), 9 (regulation infrastructure of the hydrological system in this sector), 12 (no activity in a high altitude), and 20 (lack of vestiges of historical heritage in this sector).

On the other hand, in Santa Cruz, the indicator that showed the highest value was 4 (strong winds), 14 and 15 (lack of infrastructure and services), followed by 5 (water depth), 7 (lack of water resources), 16 (deficiencies in the management of hazardous waste), and 19 (disorganized territorial structure). In this area, the indicators with lowest ERV were 8 (low land use ability), 11 (low physiognomic diversity of vegetation), 12 (low altitude of the region), 13 (no activity in protected areas), 17 and 18 (lack of populated centers and productive activity in the region), and 20 (low presence of historical heritage registers).

It is possible that if other sectors are sampled, higher (or lower) values occur in some of the indicators identified as very low (or very high) risk, since these values correspond to the existing reality in the area of application that corresponds to a rectangle of 10 × 10 km (100 km2). This evaluation of the site is of regional and subregional scale, can be done with published information and regional, geographic and ecological information. This analysis can be complemented (as has been the case in the present study), with information from remote sensing (aerial photographs, satellite images), being suitable to use, for example, Google Earth or similar.

Remote sensing provides sufficient information on terrain and geoforms, land cover, type of vegetation, proximity to bodies of water, land uses (agriculture, livestock, forest plantations), infrastructure (roads, electric lines), populated centers (area, extent), areas of special management (natural protected areas, aboriginal territories) or territorial structure. It also allows mapping a study area (concession area, geographic region, river basin, municipality, etc.). It can be useful to complement the analysis with a field visit to the area under study.

The environmental assessment of the site, together with the evaluation of the regulations, allows defining or adjusting the technological complexity and the environmental management system to be used (IAPG, 2012; King, 2012).

Analysis of Applicable Technologies

Technological innovation plays a very important role in the development of UH, to optimize the maximum volumes with minimum production costs, and to consider and internalize the challenge to fulfill the environmental norms and conditions in which it develops, including both natural and social aspects. In order to evaluate the influence of technology used in the exploration and/or exploitation of UH on environmental risk, and following Sarandón (2015), we analyzed the main stages of the activities, identifying the environmental impacts and mitigation measures for potential risks and impacts.

Table 4 presents a synthesis o f environmental impacts and measures for drilling, co mpletion and fracking activities. Water is a critical resource in these three stages, being the location of aquifers in relation to the depth of the reservoir, in each area evaluated, of great importance for environmental risks assessment. The aspects related to water (location of aquifers, water availability and flowback water management), are discussed below, for each area where the exploration or exploitation UH activity is or could be carried out: Neuquén Basin (province of Neuquén, Fm Vaca Muerta), Golfo San Jorge Basin (province of Santa Cruz, Fm Pozo 129) and Noroeste Basin (Paleozoica) (province of Salta, Fm Los Monos).

Table 4—Impacts and environmental measures related to drilling, completion and fracture activities, especially in relation to water (Modified from Sarandón, 2015).

Stage	Activity Description	Impacts	Measures
Drilling	Vertical and horizontal drilling.	Generation of solid waste (cuttings), semisolids (drilling muds), liquid effluents and fugitive gaseous emissions. Incidents and accidents with environmental consequences.	Handling and disposal of special solid waste (cuttings). Management and treatment of liquid effluents. Monitoring and control of fugitive emissions. Prevention and response to environmental contingencies.
Completion	Completion of the well: casing and pipe cementing. Punching.	Generation of waste (solid, liquid). Ensure proper well completion and monitoring. Environmental incidents.	Inspect and certify termination. Cleaning and integral waste management (solid, liquid). Prevention and response to environmental contingencies.
Fracking	Movement and installation of equipment and personnel. Hydraulic stimulation with water, sand and pressure additives.	Consumption, transport, collection and management of water, sand and additives (chemical substances). Management (recovery, reuse), treatment and final disposal of return water (flowback).	Precautionary handling of special substances and products. Integral management of return water. Plans for monitoring, environmental monitoring and contingency. Monitoring microseismicity.

In Neuquén, the aquifer of Loma La Lata, Aguada Pichana and Lindero Atravesado, represented by the Neuquén Group, is protected by Neuquen legislation (Decree 1483/12). In Loma La Lata is at a depth between 600 m and 900 m. In the other two sites would be located below 180 m with variable thickness, up to more than 200 m. The generating rock (Shaleoil/gas deposit) in Loma La Lata-Loma Campana is on the Fm Vaca Muerta that lies at a depth of 2500 m to 3000 m. Similar source is present in Aguada Pichana, across the Neuquén River. In Lindero Atravesado the Lajas Formation (of the Cuyo Group) will be exploited with tight gas, at a depth of 4200 m. Taking into account an average of the riskiest depth would be 2500 m for Loma La Lata and Loma Campana, where the riskiest depth for the aquifer is 900 m. In the other zones of analysis, it is between 200 m and 4200 m, reducing the risk significantly.

In Santa Cruz, at Los Perales, Estancia La Cholita and Canadon Yatel sites (Golfo San Jorge Basin, West Flank), the main aquifer of the basin (Patagonia Formation) no longer appears, being the only one very small, housed in the so-called "Patagonian rounds" from 5-10 m to 15-20 m depth, depending on position. In the El Trebol Reservoir (North Flank), however, the Patagonia Formation is found as an aquifer between 20 and 80-120 m. The generating rock (Shaleoil / gas) is the Formation Pozo D-129, in Los Perales and Estancia La Cholita at a depth between 2800 m and 4700 m, and in Canadon Yatel between 2400 m and 4500 m. In El Trebol Reservoir (in non-conventional exploitation) between 1500 m and 4000 m. An another possible formation is Pozo Anticlinal Aguada Bandera, less known and deeper (more or less below 5000 m). For this zone, the depth of the highest aquifer is at 120 m, and the depth of the generating rock that will be coincident with the one of the chosen deposits with greater risk is 1500 m.

In Salta, aquifers are very variable, depending on the location of the reservoir. Estimated depths of the order of 20 to 90 m are considered. The generating rock (Shaleoil/gas deposit), Formation Los Monos (in Anticlinal Ramos and Aguarague) is located at a depth greater than 3000 m (it is mentioned up to 5500 m). With respect to the risk assessment between aquifer and reservoir, is the area of lower risk given since aquifers could be located at an upper bound of 90 m and depths of formation up to 5500 m, take into account that it is an area where no productive activity was performed of unconventional.

Although all stages of UH activity may be relevant to environmental risk, the location of aquifers and depth of reservoirs is critical during drilling, completion and fracking. The completion of wells is the most critical stage of all, since a failure in the barrier effect would cause a contact between the hydrocarbon and the external environment (water, soil).

Other important point, is the availability of water. Drilling and fracking requires very large volume of water, approximately 20,000 m3/day of water in drilling and fracking activities (Laurenzano et al., 2106). Although the total volume may seem large, the volumes of water used in many other energy production activities are quite revealing. For example, a combined cycle power plant consumes 3,897,000 m3/year and a reservoir of Secondary Recovery 3,604,000 m3/year.

The volume of water used in the fracking is rarely 1 to 2% of the total water used in the area. However, if the region is suffering from water shortages, any water extraction might cause concern to the public. In these areas of severe water scarcity, recycling of produced water and mixing with high salinity brines, that are too saline for any agricultural use, is possible and surprisingly effective and economical, in large-scale fracturing operations. Technology should play an important role increasing the water efficiency of the activity (King, 2012, George King Consulting).

A third point to analyze is the flowback water, where the technologies for its treatment and reuse are relevant, depending on its physical-chemical characteristics and the volume of water to be treated. This point is of fundamental importance in the province of Neuquén, which has exhaustive legislation regarding reuse and disposal. For example, the management of flowback water in 2015, had the following percentages: 9.12 % reused, 68.88 % sink and 21.99 % without data (Laurenzano et al., 2016). The reuse was in the hydrocarbon activity, in irrigation associated with a productive project or environmental restoration of an intervened area. The final disposal in sinkhole, according regulation. The law is exhaustive in the sense of the prohibition of the discharge to water bodies even with treatment. For reuse, it is established that it can be used in drilling, and secondary recovery. The requirements for the discharge to sinkholes are:

- Cementation and corrosion profiles and hermeticity tests in order to minimize accidents that may lead to contamination of aquifers during drilling activity.
- Characteristics and isopach map of sink formation and seal formation, the seismic profile and depth of the aquifer levels, in order to protect the superior aquifers.
- Characteristics and origin of the fluid to be injected, the expected flow rate and pressure, physical chemical analysis including ions, conductivity, density, pH, hydrocarbon concentration, analysis of water compatibility between the injected fluid and the water of formation based on SO4 and CO3 and simulation of injection.

It is important to note that Santa Cruz establishes maximum limits of liquid effluents discharged into water and the respective methods of analysis. On the other hand, Salta and Santa Cruz have a general provincial hydrocarbon regulation and currently none related to unconventional activity.

Technology plays a fundamental role in all the stages involved in the exploitation of unconventional resources, it is important to identify those with greater risk potential in order to be able to elaborate technical and other mitigation measures by the implementing body or agencies (King, 2012).

Conclusions and Recommendations

Environmental risk assessment is a useful tool at regional and subregional levels. It can be done with background information (regional, geographic, ecological, socioeconomic), and can be complemented with information from remote sensing and possibly with a visit to the study area.

The result of the analysis of three areas with unconventional reservoirs, allows highlighting the most relevant environmental factors (natural or anthropic) at risk. Together, with the evaluation of regulations, allows the identification of technological complexity and/or management system; and the areas with highest and lowest level of environmental risk. This allows identifying, implementing and/or developing potential mitigation measures with the objective of achieving the sustainability of the activity.

From the analysis of the normative framework, it could be concluded that Neuquén improved the normative development related to the unconventional activity while Salta and Santa Cruz currently do not have a specific rule. In an international context, USA has the most advanced regulation of the activity.

The impacts associated to the principal aspects related to the unconventional activity (consumption of superficial and/or underground water, flowback treatment and disposal), were deeply analyzed. It represents the challenges for the development of new technologies.

The additional information provided by this work is the analysis of the factors that determine the environmental risk in the extraction of UH, which includes the technology in use, the ecological and environmental conditions at the site and the legal context in force in the region.

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