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# Tracing Groundwater Pollution in the Oil Industry: Myths and Reality

H. A. Ostera, C. Torres, and M. Fasola, Centro de Tecnología Argentina de Repsol YPF



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## Abstract

During the last years, a complete set of brines, groundwaters and surficial waters surveys was carried out in oilfields in order to determine the presumed oil born contribution to the groundwater pollution. The survey included the most important basins in Argentina and a wide variety of geological and hydrogeological conditions. Although conventional hydrogeochemistry played an initial role, the isotope tool has been the key for unravelling some delicate and doubtful cases. Most brines are very well characterized by their isotope composition and high salinity, leading to an easy recognition in the case of mixing. Besides the stable isotope composition of oxygen and hydrogen, tritium and Sr isotopes helped to model the interaction of production waters, groundwaters and surficial waters. As a matter of fact, and except for some old passives, the results showed that the improvement and change in water managing practices during the last decade avoided major problems. Despite this situation, the lack of knowledge on the new practices of oil industry and a high degree of incredulity from the people, limits the appreciation of this improvement to the courts and specialists. A thoroughful campaign to clarify the results, utility, confidence and limits of a multitracer approach is necessary to face the public concern in order to demonstrate that the oil activity can be environmentally friendly and that the water resources are a common heritage that will be preserved.

## Introduction

From the beginning of oil exploitation in Argentina, several environmental accidents have been pointed out. Towards the 90`s, the rise of public concern on the environment and the possibility of litigation from landowners, NGO and government agencies caused a change in the treatment of oil industry pollution. The oil companies faced with trials, demands and discredit due bad antique environmental practices and the lack of responsability of some oilfield operators.

Since the 90`s, the improvement on spill and waste management, environmentally friendly techonologies and a focus on best practices were the norm in the oil industry. However, many passive exist even today and some of them are being object of remediation. One of the most critical matters is the existence of groundwater contamination related with infiltration ponds, secondary recovery projects and spills. Although there were many cases in the past, nowadays the strict control policies limit the possibility of casual or deliberate "production water" mixing with surficial waters or groundwaters. However, the existence of groundwater contamination due past practices has been object of debate. Many landowners from arid regions feel that the oil companies have contaminated their water resources and that they are paying the mistakes from decades ago, starting a legal battle claiming for their rights and the oil companies' liablility. As a consequence, a battery of studies was done in critical areas to constrain and evaluate the problem.

## Objectives

The aim of this contribution is to present groundwater studies from suspected contaminated sites in Argentina, showing some results in order to demonstrate that it is possible to constrain the real responsabilities, even in cases were could have been accepted and approved bad practices. Some suggestions to improve environmental perfomance and clarify related issues are also presented.

## Case studies and discussion

### Case 1: Cuyo Basin, Northern Mendoza

Water scarcity is commonly considered the major water-resources problem in arid regions. In Northern Mendoza, the oil exploitation started in 1943 and live together with an extensive irrigation area with average rainfall of 150-200 mm/a. The area is underlayed by a major Quaternary aquifer system, mainly recharged by the Mendoza and Tununyan rivers (Figure 1). From its upstream margin, the aquifer system exhibits marked layering, with three aquifer units separated by interbedded aquitards. Soil salinization is a widespread problem which affects population and production. The buildup of ordinary salinity in groundwater in this arid-region threatens the oil exploitation, because the lack of understanding on the causes of salinization and the pressumed responsibility of the oil companies. Although many studies have been conducted on the salinization problem [1 and references therein] and the origin of salts has been discussed, there is an agreement on the anthropogenic origin. These may arise mainly from industrial and domestic waste streams, fertilizers and soil amendments, overexplotation, pumping and petroleum extraction (with mixing of brines). Traditional approaches to investigate groundwater salinization have relied on water quality measurements made with “conventional” hydrogeochemistry. However, such studies are limited and frequently sparse, and they do little to identify sources of salt influx. In order to fingerprint sources of salinity, a complete set of environmental tracers were used to determine which mechanisms of groundwater salinization are most important at present. Chemical, deuterium and oxygen-18 analyses have been performed in samples collected over the whole area, folowing standard sampling criteria and notation [2,3,4,5]. $^{87}Sr/^{86}Sr$ and $^{34}S/^{32}S$ analyses were also done on selected samples. The great difference in the stable isotope ratios between the oil brines coming from the Cuyo Basin [δD-60 ‰, $\delta^{18}O$:-3.91 ‰, $^{87}Sr/^{86}Sr$: 0.71282; $Cl^-$:33370 mg/L] groundwater [$-141 \leq \delta D \leq -111$; $-18.9$ ‰ $\leq \delta^{18}O \leq -15.7$ ‰; $0.707181 \leq {}^{87}Sr/^{86}Sr \leq 0.707499$] and surficial water [δD: -138.6 ‰; $\delta^{18}O$:-18.71 ‰, $^{87}Sr/^{86}Sr$: 0.707127, Cl-: 145 mg/L] allowed us to detect eventual mixing of groundwater with production waters (figures 2 & 3). At present, in the sampled wells groundwater has no evidences of brine pollution within the analytical error. Strontium and sulfur isotope also reinforced this hypothesis. On the other hand, the simulation of the evaporative isotope fractionation with a single fractionation models led to an explanation on the causes of isotope enrichment and salinization of groundwaters. It appears to be the result of soil fractionation and concentration in irrigation waters due the wrong management of the groundwater resources, including flooding, pumping, and poorly-constructed and/or highly-corroded wells.

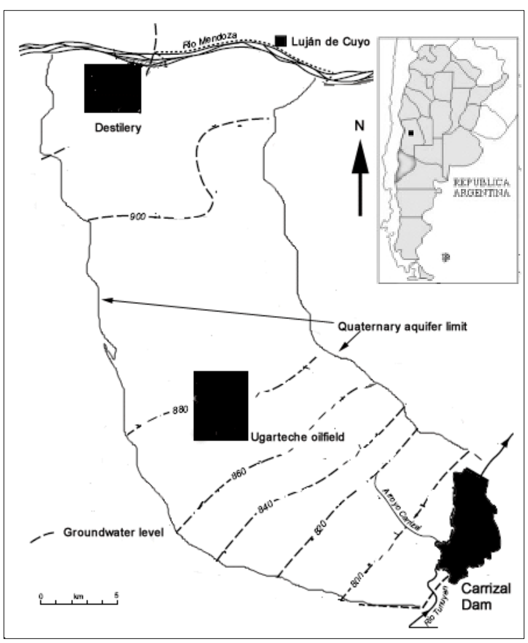


**Figure 1. Location map. Cuyo Basin Case.**

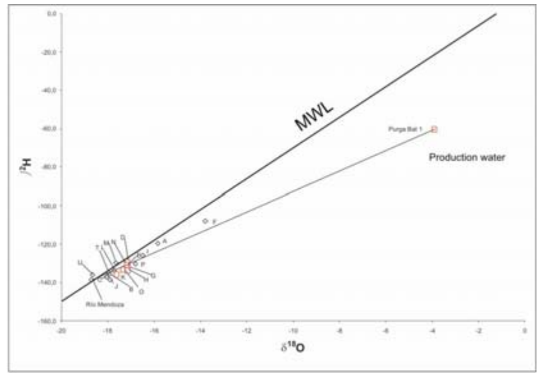


**Figure 2. Case 1. Isotope composition of groundwater wells(GW), Mendoza river(SW) and production water(PW). MWL: Meteoric water line. Hypothetical mixing line between SW and PW is shown.**

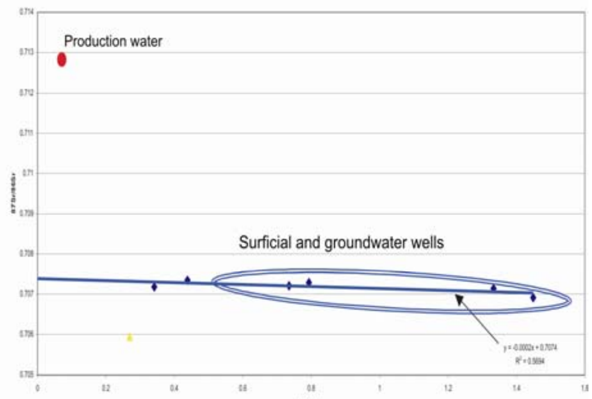


**Figure 3. Case 1. Isotope ratio vs.1/Sr diagram showing the differences between GW-SW and PW.**

## Case 2: San Jorge Gulf Basin, Chubut and Santa Cruz

This case comprises an area of around 120,000 $km^2$, with petroleum activity since 1907. More than 20, 000 oil wells have been drilled (Figure 4). The main land use is focused in cattle, although minor agricultural activity is present. It is also an arid region, with less than 300 mm/a of rainfall.The main surficial multiaquifers are located in Quaternary coarse grained continental deposits (*Rodados Patagónicos Fm.*) and Tertiary sandy-clay deposits (*Patagonia Fm.*). Usually, the groundwaters have a moderate to high degree of salinity.

Groundwaters were sampled in two main coastal and continental areas [6,7]: Northeastearn Santa Cruz and Southeastern Chubut. In this case, water stable isotopes, tritium and hydrogeochemistry were the selected tools.

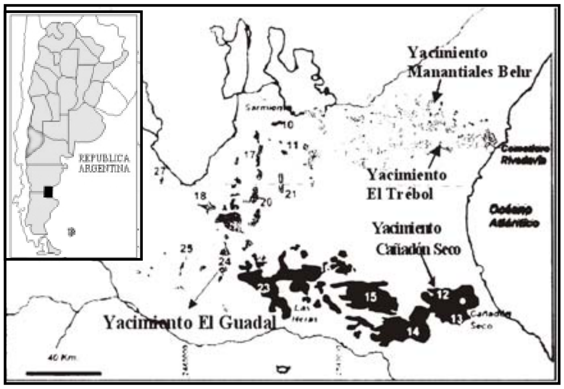


**Figure 4. Location Map, San Jorge Gulf Basin Case**

The observed $\delta D$ and $\delta^{18}O$ values of the groundwater samples showed a wide range: $-86‰ \leq \delta 2H \leq -106‰$ and $10.7‰ \leq \delta 18O \leq -12.3$ ‰ (Figures 5,6,7). Chloride concentrations varies from 32mg/L to 587 mg/L. Piston-flux was recognized in the groundwater trend, which was associated with an increasing in salinity. Groundwater $\delta D$ and $\delta^{18}O$ follow the same trend that surface and precipitation water, which suggest that aquifers receive their recharge from it. Evaporation enrichment of fresh and brackish samples compared to modern precipitation also has been detected.

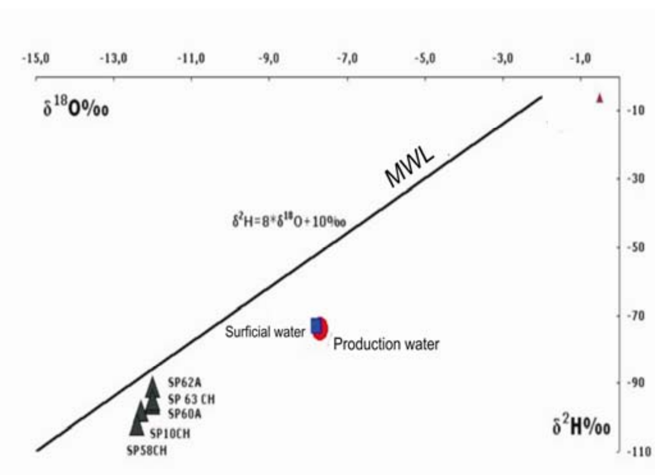


**Figure 5. Case 2. Manantiales Behr oilfield. Groundwater wells and surficial polluted waters.**

The obtained values for production water are distinctive: $-60‰ \leq \delta D \leq -74‰$ and $-5.4‰ \leq \delta^{18}O \leq -7.7‰$, $Cl^-$: 4500-12000mg/L.

The data analysis indicated that the two main processes that influence the groundwater composition in the San Jorge gulf coastal and continental area were evaporation and salt dissolution. These two processes account for the range in $\delta D$, $\delta^{18}O$ and $Cl^-$ values that was observed in the samples.

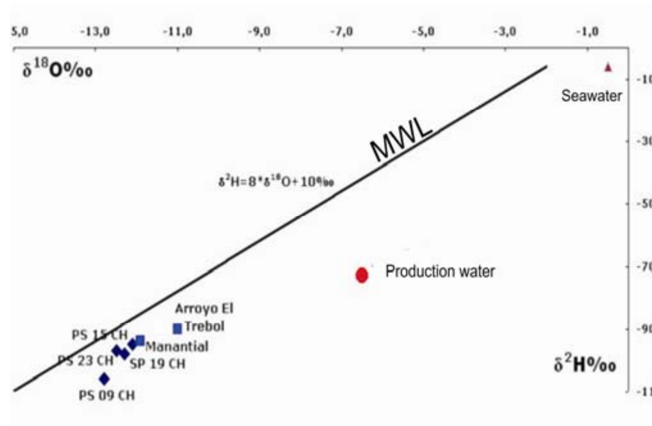


**Figura 6. Case 2. El Trebol oilfield. Groundwaters and surficial waters without evidence of mixing.**

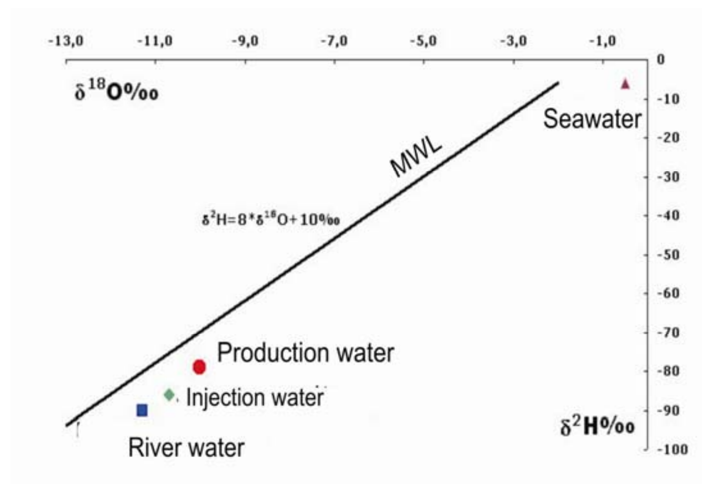


**Figure 7. Case 2. El Guadal oilfield. Injection waters show the mixing with river water.**

In most cases, the main cause of groundwater salinization could be associated with transit thorough marine sediments rather than mixing with oil production waters. Only in a few, very well constrained and authority approved cases (Figure 5) there is some evidence of mixing between formation waters and surficial waters. This also can be seen in Figure 7, where sampling of production waters shows the input of river waters associated to water injection. The data also reveals that bad practices in irrigation control led to leaks in water supply pipelines (not shown).

### Case 3: Neuquen Basin, Neuquen

The Neuquén Basin in northern Patagonia, Argentina, has long been valued for its oil and gas production. The most significant accumulations of gas (Figure 8) are located in the central region of the Neuquén Basin, where the Sierras Blancas Formation, a Late Jurassic eolian sandstone, is the main producing reservoir in the Loma de la Lata gas field. The area has been tapped for its oil and gas reserves for years. The region has a mean precipitation of 250 mm/a, with an arid climate. In this case, a production water infiltration pond has caused a major damage in the surficial aquifers. These aquifers, located in Quaternary fluvial sandstones and conglomerates are feeded by the Neuquen River. The isotope fingerprint of this river is controlled by the Andes snowfall, which is empoverished relative to local precipitation.

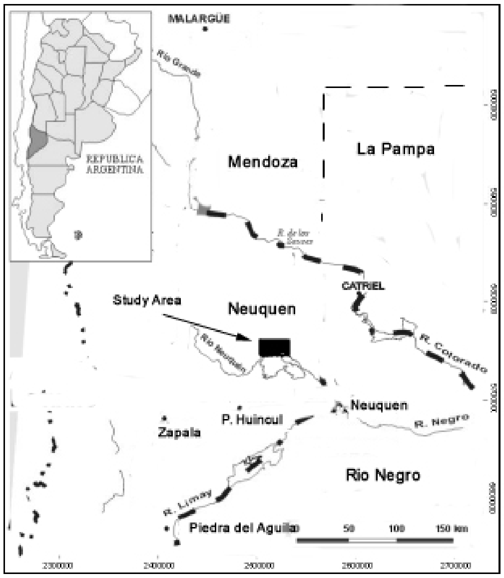


**Figure 8. Location map. Neuquen Basin Case**.

The groundwater values of δD and $\delta^{18}O$ (Figure 9) confirm that its most important source is the Neuquen River (δD:-90.7‰, $\delta^{18}O$-12‰, Cl-:49mg/L); however, evaporation trends due the high evaporation rate have been registered. The systematic sampling of remediation wells [-79 ‰≤ δD ≤ -89 ‰, -9.7‰ ≤δ18O ≤—10.7‰, 156≤ Cl-≤1224 mg/L] led to the recognition of groundwater pollution with oil connate waters [dD:-50 ‰, d18O:-6.4‰. $Cl^-$:14200 mg/L] in a restricted area, and also quantified the relative amounts of groundwater pollution.

## Discussion

All these examples show that it is possible to constrain responsabilities and determine in most cases the posibility of water pollution due the petroleum extraction activities.

The formation waters have a distinctive composition; even minor amounts (up to 1%) can be distinguished using isotope and geochemical tecniques. So, which is the reason of the permanent claim on the role of the industry in groundwater pollution?

First, the public awareness and concern on environmental matters. Second, decades of bad practices (even approved). Third, the lack of knowledge on the new environmental management techniques. Fourth, there is no confidence in the government agencies for tracking environmental issues. Fifth, the people´s vision about a profit-motivated, short-term and self-interested behaviour of the industry.

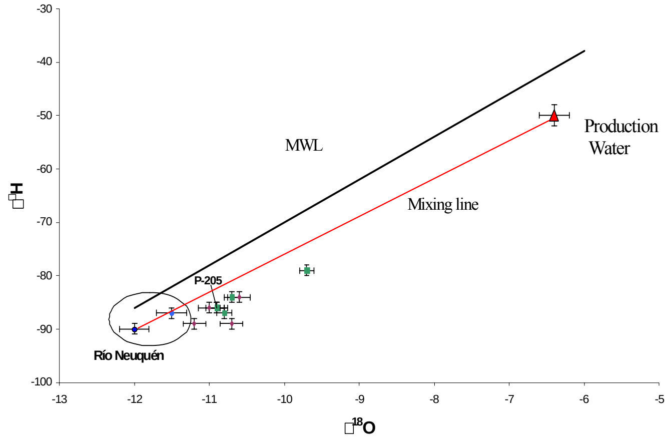


**Figure 9. Case 3. Neuquen Basin. Samples, meteoric water line and mixing line for wells**

How can the industry afford these challenges? This implies the assumption of best management practices (BMP) for groundwater management, including the implementation of environmentally friendly operating procedures for reducing and preventing pollution. Although this is a common practice, not always the control mechanisms are good enough. These BMP must be internalized by the personnel and should be known by the government agencies, NGO´S and the public itself. The personnel must face the fact that it could not be possibble o would be more dificcult to control or manage pollution after it is generated.

On the other hand, independence and transparency on basic scientific studies can minimize impacts and potentially even act as a reference frame to avoid conflicts in areas where the oil exploitation live together with agricultural/ cattle/ touristical activities of great commercial value and common interest.

An appropiate communication policy and permanent contact with governmente agencies, NGO´s and concerned people is necessary to gain trust, credibility and to prevent new urban myths about water pollution by the industry.

## Conclusions

1. The use of appropriate chemical and isotopic tools permits a clear reconossaince of groundwater interaction with brines and can discriminate between differents causes of salinization in conflictive areas.
2. The improvement in environmental management in the oil industry has minimized the possibility of negative impacts on the water resources.
3. The implementation of best management practices, personnel training and control mechanismis should be mandatory and will improve the environmental perfomance.
4. Independence and transparency on basic scientific studies is the clue in critical areas.
5. An effort on best communication strategies and close contact between the main actors (industry, government and people) is necessary in order to clarify the advances in environmental issues by the industry and avoid misinterpretations or mistakes based on prejudgment and lack of knowledge.

## References

1. Panarello, H.O. & Dapeña, C. "*Mecanismos de recarga y salinización en las cuencas de los ríos Mendoza y Tunuyán, Mendoza, República Argentina: evidenciados por isótopos ambientales*." Memorias del XII Congreso Geológico de Bolivia. Tarija, Bolivia (1996): 531-543.

2. Panarello, H.O. y Parica, C.A. "*Isótopos del oxígeno en hidrogeología e hidrología. Primeros valores en aguas de lluvia de Buenos Aires"*. (1984). Revista de la Asociación Geológica Argentina, XXXIX (1-2): 3-11.

3. Centro de Tecnologia Argentina, RepsolYPF. TRP y MA. "*Norma interna de muestreo de aguas."* (2004). Internal report, 34 pp..

4. Panarello, H., H. Ostera y R. Cordero. "*Estudio de las causas de salinización en la zona de Ugarteche, Cuenca Norte de Mendoza."* (2003). CTA Internal Report, 31 pp.

5. Ostera, H., H. Panarello, R. Cordero y M. Fasola. "*Aplicación de isótopos de Sr al estudio de las causas de la salinización de las aguas subterráneas del área de Ugarteche, Provincia de Mendoza."* (2004). CTA Internal Report, 31 pp.

6. Dapeña, C, H. Ostera y H. Panarello. "*Estudio isotópico de las aguas subterráneas y superficiales del Distrito Comodoro Rivadavia. Provincia de Chubut."* (2005). CTA Internal Report, 17 pp.

7. Dapeña, C, H. Panarello y H. Ostera. "*Estudio isotópico de las aguas subterráneas y superficiales en el área de Caleta Olivia, Provincia de Santa Cruz."* (2005). CTA Internal Report, 13 pp.

8. Centro de Tecnología Argentina – INGEIS. "*Estudio isotópico de las aguas subterráneas y superficiales en el sector del pozo LLL-32 del Yacimiento Loma de La Lata, Provincia de Neuquén."* (2005). CTA Internal report, 33 pp.