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Monitoring Heavy Fractions Production in Pre-Salt Wells from Fields with Gas Reinjection

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Abstract
Gas reinjection used in enhanced oil recovery, a process widely applied in pre-salt fields, is one of the factors that can lead to asphaltenes destabilization. Thus, the development of a methodology that allows the monitoring of asphaltenes precipitation risk in the field during production has its relevance. Through it, there could be an indication that a head loss in the production casing or a depletion in the reservoir would be associated with that flow assurance phenomenon. The identification of risks allows the proposition of more adequate control and remediation strategies. In this context, the Asphaltene Solubility Class Index (ASCI) method presents itself as a possibility to follow the impact of gas injection on the production of heavy fractions of petroleum. This work presents a study of the mixing dynamics evaluation between the injected gas and the reservoir fluid for five wells of two fields using the ASCI technique. The results for most of the set of analyzed samples suggest that there was no fractionation of asphaltenes by oil and gas contact in the period comprised by the sampling dates. Only for one well the samples showed some distinction in the ASCI index that may be related to the arrival of the injected gas. However, a statistical confirmation would be necessary, which depends on the continuity of production monitoring.

Keywords
asphaltenes; ASCI; gas reinjection

Introduction
Gas reinjection rests among the processes used to maintain reservoir pressure and increase oil recovery. This procedure is widely applied in pre-salt fields and, in addition to being associated with the optimization of oil production, it avoids gas flaring, reducing the emission of GH gases. One of the problems related to the use of this method is the fact that light ends such as natural gas and carbon dioxide can lead to asphaltenes destabilization. Among the consequences of precipitation and deposition of asphaltenes are damage to the formation, clogging of production casing and flowlines. The recognition of those risks allows for the proposition of more adequate control and remediation strategies. Thus, the development of a methodology that allows one to monitor asphaltenes precipitation in the field during production has its relevance. Through it, it would be possible to have an indication that a head loss in the production casing or a depletion in the reservoir would be associated with that phenomenon. In this context, the Asphaltene Solubility Class Index (ASCI) method, developed by Total [1], presents itself as a possibility to understand the impact of gas reinjection on the production of heavy fractions of petroleum.

Characterization by the ASCI method is based on the asphaltenes solubility behavior, being soluble in aromatic solvents, such as toluene and benzene, but insoluble in low molecular weight n-alkanes such as n-pentane and n-heptane. The determination of the index is carried out by adding a few drops of the oil sample to mixtures of known toluene and n-heptane ratio, so that the sample amount added is insignificant in relation to the solvents. This high dilution ratio minimizes the effect of non-asphaltenic components of the oil on the asphaltenes solubility. There are 21 solutions of n-heptane and toluene, numbered from 0 to 20, ranging from 0% w/w n-heptane (solution 0 and ASCI 0) to 100 % w/w n-heptane (solution 20 and ASCI 20), with additions of 5 %w/w for each mixture. If precipitation of asphaltenes is observed in the k mixture, where k is defined by the number of heptol solution, but not in the k-1 mixture, the ASCI is taken as k. From the index obtained in the analysis, the studied asphaltenes are classified comparatively. The higher the ASCI, the more soluble the asphaltenic fraction, as more precipitant, n-alkane, is needed to induce phase separation [1], [2].

If the gas injection is sufficient to promote asphaltenes precipitation with consequent deposition in the reservoir or in the production system, the fluid produced after the enhanced oil recovery (EOR) process is expected to present a change in the ASCI value in relation to the original fluid. In this scenario, this ASCI is expected to increase as production occurs, as only the most soluble asphaltenes will be present in the post-EOR produced oil. Therefore, the evolution of the asphaltenes solubility index presented in samples collected in different periods of production could contribute to the identification of a possible problem related to those compounds.

This work presents a study of the mixing dynamics evaluation between the injected gas and the reservoir fluid for two fields using the ASCI index.

Methodology

For this study, oils produced in pre-salt fields subjected to an enhanced recovery process based on gas reinjection were selected. The analyzes were carried out for five samples from two fields.

Standard mixtures of toluene and n-heptane were placed in 15 mL conical centrifuge tubes, according to Tab. 1.

Table 1. Heptol mixtures for ASCI.

ASCI	0	1	2	…	18	19	20
Toluene (%w/w)	100	95	90	…	10	5	0
n-heptane (%w/w)	0	5	10	…	90	95	100

For ASCI determination, 2 droplets of sample were added to each tube containing approximately 10 mL of heptol (mixture of n-heptane and toluene). Then, the mixtures were manually shaken and stored in an oven at 60 °C for 48 hours. After this period, it was evaluated in which heptol mixtures tube the asphaltene precipitation happened. If precipitation of asphaltenes was observed in mixture k, but not observed in mixture k-1, the ASCI was taken as k.

As the results obtained with n-heptane and toluene did not provide an adequate interpretation in some cases, alternatively, pentane was used instead of n-heptane, as the former is a more efficient precipitating agent for asphaltenes.

Results and Discussion

Table 2 presents the results obtained for the asphaltene solubility index when heptane is used as one of the solvents in the standard mixture (ASCI C7) and when pentane is one of these solvents (ASCI C5).

Table 2. ASCI results for analyzed samples.

Field	Well	Sample	Sampling Date	ASCI C7	ASCI C5
1	A	TFR-01	09/10/2009	N	18
1	A	production	29/06/2016	N	18
1	A	production	22/10/2016	N	18
1	A	production	15/02/2017	N	18
1	B	TFR-01	15/08/2012	N	18
1	B	production	22/10/2016	N	18
1	B	production	15/02/2017	N	18
1	B	production	01/11/2017	N	19
2	C	TFC-01	15/03/2014	N	20
2	C	TFC-02	15/03/2014	N	18
2	C	TFC-03	15/03/2014	19	16
2	C	production	20/07/2017	19	17
2	C	production	31/01/2018	20	17
2	C	production	06/02/2018	19	16
2	C	production	28/04/2018	19	16
2	C	production	12/03/2020	18	15
2	D	TP-01	25/06/2011	19	16
2	D	production	13/06/2016	16	15
2	D	production	12/10/2016	19	16
2	D	production	21/12/2017	18	16
2	D	production	03/06/2019	20	17
2	D	production	05/08/2019	19	16
2	D	production	15/11/2019	19	16
2	D	production	27/02/2020	19	16
2	E	TFR-01	20/11/2012	17	15
2	E	production	07/06/2016	17	15
2	E	production	10/10/2016	19	16
2	E	production	21/12/2017	19	16
2	E	production	03/06/2019	17	13

*N - not observed solids

As can be seen in Tab. 2, the original fluids (TFR-01) from wells “A” and “B” did not show precipitated solids when using the ASCI technique with heptane. This is an indication that the solubility of the asphaltenes present in these oils is high, which does not necessarily represent a high fluid stability in relation to the asphaltenes. Such behavior, in addition to depending on the type of asphaltene, depends also on other oil properties. As the result obtained through the ASCI C7 makes any further interpretation difficult for the purpose of this study, since it was not observed an evolution of the ASCI index in the samples collected post-EOR, an alternative to be used is to replace heptane with pentane. Pentane, being a more critical precipitating agent for asphaltenes, would be able to precipitate more soluble asphaltenes from the bulk in order to increase the method resolution for more stable asphaltenes. For data completeness and confirmation of the information obtained for the samples taken as reference, which are the original fluids, all samples collected after the gas injection procedure were analyzed with heptane. The answer of using the ASCI methodology with pentane was positive in the sense of allowing the solids identification in the evaluated sets. However, the index values were high, which could impair the recognition of any changes in the system during production accumulation. Anyway, the analyzes were complete. There was no change in the ASCI for the samples collected post-EOR in relation to the original ones, indicating that there was no asphaltenes fractionation due to the contact of oil with gas.

The gas injected into field “1” is the produced gas, whose methane content is around 80% molar and 1% molar in CO_2.

An increase in the GOR of the well “A” was observed from April 2016 due to the influence of the injector well “F” with detection of the F tracer as early as March 2016. Given these data, some hypotheses can be proposed to justify the results obtained: 1) the injected gas was not enough to promote asphaltenes precipitation of; 2) the amount of asphaltenes deposited in the reservoir or production systems is very small, preventing its perception in the oil produced (it is known that the

ratio between the asphaltenes that deposit and those that precipitate is very low); 3) preferential route favors gas breakthrough without much of the oil having been contacted with it; 4) pentane appears as a poorly selective solvent.
Well “B” is under the influence of the injector well “G” and the increase in GOR was observed in May 2018 with G tracer detection in February 2018. Therefore, the samples studied for this well predate this observation. Anyway, as mentioned before, the high value observed for the ASCI would make it difficult to identify changes that could occur in the system in the near future.
Figures 1 and 2 show graphs with GOR data from producers wells “A” and “B”, respectively, in addition to the methane and CO_2 contents in the produced gas and ASCI values obtained for the samples available for analysis.

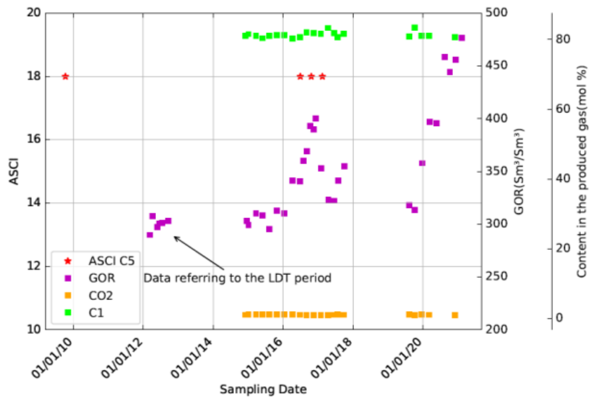

Figure 1. ASCI and well “A” production data.

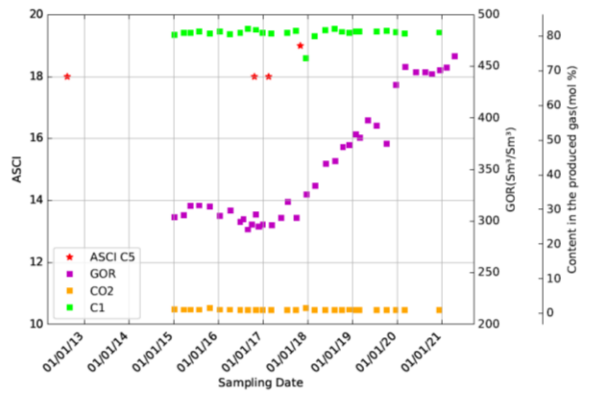

Figure 2. ASCI and well “B” production data.

Wireline Formation Test (WFT) samples were taken as a reference for well “C”. In two samples, the formation of precipitate was not observed, preventing the determination of the ASCI index, and the third sample presented a very high ASCI C7, which makes it difficult to assess the evolution of the index. The ASCI C7 of the samples collected after the beginning of the enhanced recovery phase were also high and showed similar values to the original sample in which the determination of the index was possible. ASCI C5 data for samples collected post-EOR were also similar to each other, showing a slight decrease with monitoring chronology. For the WFT samples, the ASCI C5 showed differences in values, which may be related to the different sampling depths. However, confirmation of this hypothesis depends on further analysis. The composition of the injected gas is a mixture of rich gas and poor gas in CO_2 since there is a system for removing CO_2 from the produced gas. An increase in GOR was observed in fluid from well “C” due to the gas injection in wells “H”, “I” and “J”. The well “H” injects gas since 2013, stopping from 2016 to 2018 and had a tracer detected in producer well “C” in May 2019. The wells “I” and “J” injected only for one year between 2017 and 2018 and did not have gas tracer injection. However, it is likely that the gas from these two wells also reached well “C”. The results suggest that there was no asphaltenes fractionation due to the contact of oil with gas.
Figure 3 shows a graph with GOR data, CO_2 content in the produced gas and ASCI values obtained for the analyzed samples from the producer well “C”.

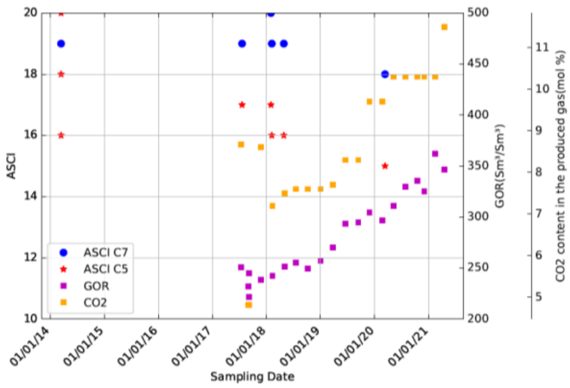

Figure 3. ASCI and well C production data.

Except for the first sample collected after gas injection, whose ASCI C7 data is difficult to understand without knowing more details about the production, all samples from well “D” showed high ASCI C7 values similar to the original sample (TP-01). The values remained equivalent to each other for the ASCI C5. The injector with the greatest influence on the well “D” is the well “K”, but that well is also influenced by the well “L”. The well “K” injected gas between November 2016 and September 2017 and between June 2018 and January 2019. The well “L” injected gas between July 2015 and March 2019 and between December 2020 and April 2021. The tracer of gas injected into the well “K” in August 2018 was detected in January 2019. The observed variation in ASCI values is at the detection limit, which seems to indicate that there has not been a significant extraction of its asphaltene fraction.
Figure 4 shows a graph with GOR data, CO_2 content in the produced gas and ASCI values obtained for the analyzed samples from producer well “D”.

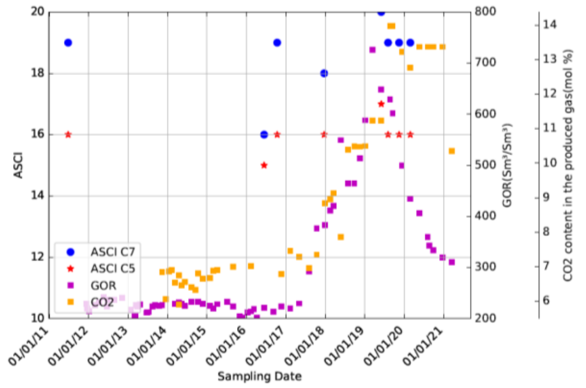

Figure 4. ASCI and well “D” production data.

For the samples from well “E”, a slight increase in ASCI C7 is observed for the samples collected in October 2016 and December 2017, which returns to the original value in the sample collected a year and a half later. Unfortunately, samples from this time interval were not available to verify whether the trend remained and could be related to some event that occurred in that period. The ASCI C5 followed the same behavior as the ASCI C7, but with a very subtle increase, which does not allow to say that the numbers are different, followed by a more significant decline. The greatest influence for well “E” is from the injector well “L”, with a much weaker influence from well “M” and even less from well “N”. The gas tracer injected into the well “L” in November 2015 was detected in July 2016. The well “L” injected gas between July 2015 and March 2019 and between December 2020 and April 2021. The well “M” injected gas between June 2013 and July 2015 and between February 2020 and November 2020. The samples that showed the highest ASCI C7 were collected after the detection of the gas tracer from well “L” and whose sampling dates coincide with the gas injection period. Even so, the disturbances observed are at the limit of the uncertainty of the method and require statistical corroboration that depends on a greater number of analyzed samples.
Figure 5 shows a graph with GOR data, CO_2 content in the produced gas and ASCI values obtained for the analyzed samples from the producer well “E”.

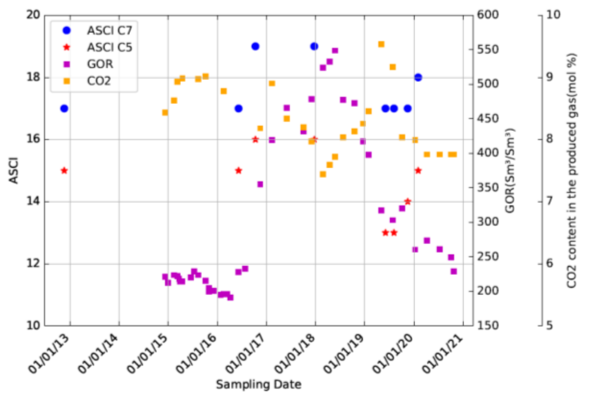

Figure 5. ASCI and well “E” production data.

Conclusions

Asphaltene precipitation was assessed using the Asphaltene Solubility Class Index (ASCI) technique for several samples of five wells from two different fields. The objective was to investigate the effect of gas reinjection on the asphaltenes destabilization from pre-salt oils subjected to this EOR method. The sets of samples evaluated for fluids from wells “A”, “B”, “C” and “D” suggest that there was no fractionation of asphaltenes by oil and gas contact in the period comprised by the sampling dates of analyzed samples. On the other hand, the samples from well “E” showed some variation in the ASCI value that may be related to the arrival of the injected gas. However, this information lacks statistical confirmation, which depends on the continuity of production monitoring.

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Responsibility Notice

The authors are the only responsible for the paper content.

References

[1] Passade-Boupat, N.; Zhou, H.; Rondon-Gonzalez, M. “Asphaltene Precipitation from Crude Oils: How to Predict It and to Anticipate Treatment?”, Middle East Oil Show, SPE 164184-MS, Manama, Bahrain, 10-13 March 2013.

[2] Passade-Boupat, N., Gingras, J., Desplobins, C., *et al*. “Could the Asphaltene Solubility Class Index Be Used as the ‘Wax Appearance Temperature’ of Asphaltenes? Illustration through the Study of the Polydispersity of PetroPhase 2017 Asphaltenes”, Energy & Fuels, v. 32, pp. 2760-2768, 2018.