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PETROLEUM ENGINEERING

Microorganism enhanced oil recovery (MEOR) technology application feasibility in the Pilon field reservoirs, Morichal District, Monagas State

INGENIERÍA DE PETRÓLEOS

Factibilidad de aplicación de la tecnología de recuperación mejorada de hidrocarburos con microorganismos (MEOR) en yacimientos del campo Pilón, distrito Morichal, estado Monagas

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Abstract

The present research work arises in relation to the needs of the oil industry to produce those deposits of the Morichal District, possessors of high remaining reserves, where MEOR symbolizes a biotechnological, effective and profitable alternative that uses the injection of microorganisms as an additional strategy to the conventional treatments of improved recovery of hydrocarbons. Different oil fields located in different parts of the world have implemented this process with similar approaches and expectations, however, the results have had discrepancies, since bacteria are significantly affected by variations in subsoil conditions, which is why a methodology was designed to select wells candidates to carry out this technique, which exhibits the most suitable environment for such purposes, coupled with it, certain correlations were established from statistical programs to predict both Water Cut (%) and Recovery Factor (%), which represent important aspects to compare and guarantee how feasible the MEOR process can be in this potentially important area within the oil context, noting that they yielded satisfactory estimates in the wells particularly under study belonging to the Pilon Field, since they affected on average a 38% increase in the recovery factor and an approximate decrease in the water cut of 16% projecting optimistic expectations regarding the success of this process.
Keywords: *Bioproducts, Enhanced oil recovery, MEOR, Morichal district.*

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Resumen

El presente trabajo de investigación surge en relación con las necesidades de la industria petrolera para producir aquellos yacimientos del Distrito Morichal, poseedores de altas reservas remanentes, donde MEOR simboliza una alternativa biotecnológica, efectiva y rentable que emplea la inyección de microorganismos como una estrategia adicional a los tratamientos convencionales de recuperación mejorada de hidrocarburos. Distintos campos petroleros situados en diversas partes del mundo han implementado este proceso con enfoques y expectativas similares, sin embargo, los resultados han tenido discrepancias, puesto que las bacterias se ven afectadas significativamente por las variaciones en las condiciones del subsuelo, es por ello, que se diseñó una metodología de selección de pozos candidatos para llevar a cabo esta técnica, donde se exhibe el ambiente más idóneo para tales fines, aunado a ello, se establecieron ciertas correlaciones a partir de programas estadísticos para predecir tanto el Corte de Agua (%) como el Factor de Recobro (%), que representan aspectos importantes para cotejar y garantizar que tan factible puede ser el proceso MEOR en esta área potencialmente importante dentro del contexto petrolero, acotando que las mismas arrojaron estimaciones satisfactorias en los pozos particularmente en estudio pertenecientes al Campo Pilón, pues incidieron en promedio en un incremento del 38% en el factor de recobro y un descenso aproximado en el corte de agua de 16% proyectando expectativas optimistas referente al éxito de este proceso.

Palabras claves: *Bioproductos, Distrito morichal, MEOR, Recuperación mejorada de hidrocarburos*.

1. Introduction

Because oil is the main source of energy and raw materials for the global chemical industry, exploration and extraction techniques are constantly being researched and optimized [(1)]. Light Oil reserves are depleting and needs for transportation full liquids poses new problems to refineries in order to meet the growing demand [(2)]. In general, about 10% of the initial oil in place (IOIP) is recoverable through primary production and secondary recovery can promote the production to one third of the IOIP and still two-thirds are left on place. In other words, a great volume of oil remains unrecoverable after the convention technologies reach their economic limit [(3)]. Relating a little within this context, it can be emphasized that one of those scenarios that does not escape from this reality is undoubtedly the Morichal District; added to this, an interesting aspect should be exalted, and it is precisely that as the global supply of light and medium crudes oils decreases, heavy crude oil reservoirs become more important, then it is from this problem that the need to apply enhanced oil recovery (EOR) methods arises. However, these techniques often result in high costs and complex applications. The selection of the optimal recovery method is significantly influenced by economical issues. Consequently, development of cost-effective technologies which bring maximum oil reserves to production is a main topic of interest in today's energy research. Microbial enhanced oil recovery is potentially a low-priced technique in which different microorganisms and their metabolic products are convinced to exploit the remaining trapped oil in the reservoir [(4)].

Microbial Enhanced Oil Recovery (MEOR) is an important tertiary oil recovery approach which uses microorganisms and their metabolites including biosurfactants, biopolymers, biogenic acids, enzymes, solvents, and biogases to mobilize residual oil. In addition, all the additives used in MEOR are biodegradable, which are environmentally friendly [(5)]. Once injected, the bacteria move through the interstitial water and congregate at the oil-rock and oil-water interfaces, where they metabolize very small amounts of hydrocarbons to generate chemical bioproducts that increase the mobility of oil in formation. MEOR methods offer several unique advantages over other enhanced oil recovery (EOR) processes. First, the technologies do not require large amounts of energy consumption as do thermal processes; second, microbial products are usually biodegradable and harmless; third, the implementation of microbial processes is easy to handle in the field, because it requires minimal modifications to existing facilities [6].

In order to implement the MEOR technique in the Morichal District reservoir, the characteristics were studied in detail. In the same way, it was carried out a comparison of the results of previous experiences of fields at national and international level once the improved recovery with microorganisms was applied, and this way it was proposed a methodology of application of the MEOR process in reservoirs of the Pilon field, at the same time evaluating a study of feasibility of application of technology Microorganisms Enhanced Oil Recovery in the Morichal District, Monagas state, because, to implement a new technique it is necessary to corroborate that the characteristics of the area under study are adapted to the minimum conditions required for the treatment in question.

2. Methodology

Bibliographic material was compiled, supported by reliable sources, used to study in detail the conditions of the Morichal District reservoirs, highlighting a series of parameters within which the temperature, permeability, pH of the crude, salinity of the formation, among others, are found. Next, wells belonging to the Pilon Field are shown as possible candidates for a bacterial injection process.

Together, we proceeded to deepen in detail the practices carried out at the national and international level, where the MEOR technique has been implemented, where the comparisons were established according to different parameters, pointed out in a kind of table-summary. For an effective MEOR process depends on the following parameters: temperature of the formation, viscosity of the crude oil, permeability, salinity, °API gravity of crude oil, pH, pressure, residual oil saturation, depth, porosity, bacterial content of the reservoirs [6]. Especially the oil recovery factor (%) and water cut (%), once the technique was applied, for such comparisons, it became necessary to employ a statistical method known as Paired Sample Hypothesis Testing. This statistical method began by determining the differences between what the wells produced before treatment and their production after treatment through the simple equation that consists of subtracting the Pre-MEOR to the Post-MEOR. It is necessary to statistically demonstrate that the averages of these differences are greater than zero to verify that there was an improvement once the microbial treatment was applied, therefore, certain conditions are shows in Table 1.

Table 1. *Conditions for applying Paired Sample Hypothesis Testing*

% Recovery Factor	% Water Cut
Ho $\mu d \leq 0$ Hi $\mu d > 0$ Test of a tail (right side)	Ho $\mu d \geq 0$ Hi $\mu d < 0$ Test of a tail (left side)

Ho represents the null hypothesis of the research, Hi the alternative hypothesis and μd indicates the average of the differences. It is important to mention that this last hypothesis corresponds to what we want to test. Once the hypotheses were established, the level of significance was determined (α =0.05) according to the nature of the research and the criteria of the researchers. Next, it is required the degrees of freedom (df) which represent the minimum number of independent coordinates, using the Eq.1:

$$df = n - 1 \qquad (1)$$

Where n is the number of observations (experiences that were considered for the study). Once the degrees of freedom were calculated, we proceeded to look for the statistical critical value (tα), intercepting this value with that of significance (tα). Since the sample has less than 30 elements (n<30), the population mean was estimated by the Student T Distribution (7) as shown in Figure 1. Once the test statistic (t calculated) is obtained, we proceed to comply with the decision rule as shown in Table 2 and thus make known the measures of the recovery factor and water cut.

Table 2. *Decision rule*

% Recovery Factor	% Water Cut
Rejection Ho if t calculated > tα	Rejection Ho if t calculated < tα
No rejection Ho if t calculated < tα	No rejection Ho if t calculated > tα

From this, the test statistic (t calculated) was calculated by Eq. 2:

$$T_{CAL} = \frac{\bar{d} - \mu d}{\frac{Sd}{\sqrt{n}}} \qquad (2)$$

Being $\bar{d}$ the mean of the differences, Sd the standard deviation of the differences (Eq. 3), µd the value to be tested assumed as zero, since it is desired to know whether it is greater or less than this to determine whether there was improvement in the process and the sample size.

$$Sd=\sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} \qquad (3)$$

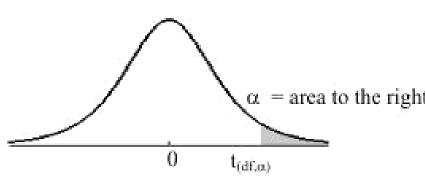
x: Is each of the differences of MEOR $\bar{x}$: The average of the differences of MEOR

Idealized to the search of correlations that allow to estimate and/or to predict so much the percentage of water cut as the oil recovery factor based on the reflected experiences, a statistical package known as SPSS Statistics was used for such aims to establish the model of multiple regression known as correlation, establishing the following criterion in Eq.4:

$$Ho:\beta_1+\beta_2+\beta_3+\beta_4+\beta_5+\beta_6=0 \qquad (4)$$

Hi: At least a $\beta_i \neq 0$

Critical Values of Student's *t*-Distribution



df	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005
	α = area to the right							
1	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.656
2	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925
3	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841
4	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604
5	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032
6	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707
7	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499
8	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355
9	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250
10	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169

Figure 1. *Table T- Student (7)*

β: Independent variables (Temperature, API, Porosity, Salinity, Viscosity, Permeability*Depth)

Implementing a significance level of $\alpha = 0.05$, a decision rule was established to determine whether at least one of the variables enters the model

$$F_{cal} > \text{Significance} \rightarrow \text{Rejection Ho}$$

$$F_{cal} < \text{Significance} \rightarrow \text{No Rejection Ho}$$

The following criterion allows us to specifically identify which variables enter the model:

$$\text{If } t < \text{Significance} \rightarrow \text{Rejection Ho}$$

$$\text{If } t > \text{Significance} \rightarrow \text{No rejection Ho}$$

3. Results and discussion

In relation to the coefficients (thrown by the statistical program) of each of the variables, the following correlation is established to predict the water cut (%) and recovery factor (%) specifically Eq.5 and Eq.6 that can occur after implementing a MEOR treatment in a well that meets the optimal conditions:

$$\%Water\ Cut = -227.591 + 0.373T + 8.087API - 0.002Sal + 6.276Ø - 1.341x10^{-6} k \times Depth \quad (5)$$

$$\%Recovery\ Factor = 246.882 - 6.576API + 0.001Sal - 4.085Ø + 1.022 \times 10^{-6} k \times Depth - 0.005\mu \quad (6)$$

At the same time, the requirements of the MEOR technology were pointed out, which served as the basis for a methodology of use, systematized in a flow chart reflecting the optimal range of applicability according to the characteristic. In order to satisfy the expectations of this work, a feasibility study of MEOR technology was carried out based on the proposed methodology of use, relating the real data with the application standards reflected in the flow chart. The previously deduced correlations were used, as observed in Eq. 5 and 6, to estimate the factors of recovery and water cuts in the wells once the bacterial treatment was applied, corroborating how prospective it is MEOR in this zone, since it allows establishing comparisons aligned to the original production and the predictions made.

Structurally, the Morichal District presents as a north-dipping monocline, being high at the south and low at the north, containing braided channel plain deposits, as well as continuous and very thick sand bodies, making them as unconsolidated sandstone lithologic extra-heavy oil reservoirs ranging from 8.4° to 30°API. This district is featured with high average porosity of 33-40%, high permeability of 100-4500 mD and high crude saturation of 80%, temperatures from 100 to 137 °F and the formation oil viscosity between 500 and 5000 cP [8,9].

The Morichal District is made up of the Heavy and Extra Heavy crude oils, with the Pilon, Jobo, Morichal and Cerro Negro fields. Of the above-mentioned fields, Pilon is the one with the lightest crude oil (11. 5º - 17º API) and is located to the east of Jobo Field with an average depth of 3250 feet. It is divided in two sectors: East and West, being a producer of the Oficina formation, where the main prospective member is the Oficina-01 reservoir, presenting high permeability due to its condition of unconsolidated formation, it is associated to a large aquifer that contributes to the effects of pressure maintenance [10].

These areas have specific characteristics that make oil extraction a complex process, due to the high viscosity of the crude oil, which generates resistance to flow through the integrated production system [9]. In order to improve the production and decrease the viscosity of the crude oil, the Gas Lift (GL) has been implemented, whose reason is emphasized to the increase of the Gas-Petroleum Ratio, it has been difficult to apply another artificial lifting system, which has generated the use of this technique for more than 5 decades. However, the corrosion conditions associated to the increase in the water cut and the

CO_2 content have caused damages in the production pipes during the last years, causing that the gas that passes through the perforations in the casing does not arrive with enough pressure to the operating valve, preventing that the oil cannot be lifted efficiently from the bottom to the surface, this leads to significant replacements in those pipes, which implies greater expenses, in order to maintain the production conditions of the wells in the Pilon field.

Next, Table 3 shows the wells belonging to the Pilon Field where the parameters of each one of them are specified, in order to choose as possible candidates for a bacterial injection process that basically depends on the demands of the MEOR technique [11].

Table 3. *Basic information on the wells of Pilon field.*

Well	PC0041	PC0158	PC0047
Surface coordinates	N: 105,455.66 / E: 246.245,54	N:10/ E:17	Not registered
Sand / Reservoir	"C"/ OFFICE-01	"A"/OFFICE-01	"B"/OFFICE-01
Total depth (feet)	6408	5110	5640
Permeability (mD)	2920	2870	2563
Flow Station	PC-1	PM-1	Not registered
Porosity / RF(%)	26/15	26/18	26/18
Temperature (°F)	137	126	137
API Gravity	14.8	13.2	13.8
pH	6.5	6.8	6.8
Salinity (ppm)	11500	10800	11120
Viscosity (cP)	3950	4480	4200
Pressure (lpca)	1330	1132	1515
Methods of Artificial Lift	GL	GL	GL

Despite the research background that addresses the issue of MEOR, many of the results of the application of Microbial Enhanced Oil Recovery (MEOR) technique implement in situ have not been properly reveal, however, accurate information was collected as shown in Table 4 of previous experiences at the national and international level [12-15].

Table 4 shows the site conditions of each of the experiences in various countries where the MEOR process was implemented, which potentially influence microbial growth, survival and metabolic activities that generate them. Parameters such as temperature that in all cases exceed 100°F and are lower than 170°F establish a useful reference for subsequent practices, considering that all microorganisms have an optimal development temperature that characterizes them. In relation to the above mentioned, emphasis is made on the Alton (Australia) and Trial (Canada) fields that have the lowest porosities (17%-18%) within the disclosed practices, which maintain similarity as regards their API gravity, viscosity, depth and pH, generating good results in the increases of the recovery factor as well as decreases in the water cut.

While the fields that indicate superior porosities (30-35%) also generate a greater yield in the production of oil that is a prospect considering that they are heavy crude oil with high flow resistance. On the other hand, the acidity of the fields-maintained values very close to the neutral point (7), thus ensuring that the injected bacteria remain active in the reservoir. In addition, appreciable differences are visualized both in the water cut and in the recovery factor, such changes are own characteristics that can be derived as a response to the implementation of the technique in question; for this reason, a statistical procedure called the Paired Samples Hypothesis Test was used as shown in Table 5 to verify if the results were technically favorable.

Table 4. *Table-Summary of experiences MEOR*

Field		**Alton (Australia)**	**Shengli (China)**	**Daqing (China)**	**Dagang (China)**	**Liaohe (China)**	**Trial (Canada)**	**Tia Juana and Bachaquero (Venezuela)**			
Well or block		Not registered	SHEN-48	FANG-6	Not registered	LENG-43	C	LL-2241	BACH-2248	BACH-2792-3	BACH-2930
Temperature (°F)		169	145	146	113	118	117	158	125	137	140
°API		21	12	13	12	14	22	19	11	13	14
Viscosity (cP)		2,980	5,000	4,600	6,000	9,620	2,600	2,400	9,300	9,000	9,000
pH		6.3	6.5	6.5	6.3	6	6.4	6.5	6.2	5.8	6
Depth (feet)		13,700	5,413	7,800	4,462	6,500	12,200	11,467	8,900	10,800	11,000
Salinity (ppm)		12,600	8,900	11,790	8,666	9,400	9,500	43,000	18,000	10,000	11,500
Porosity (%)		17.6	30	20.6	31	20.5	18.4	30	35	33.5	25
Permeability (mD)		448	800	350	833	725	310	1,500	3,000	3,000	2,000
Water Cut (%)	Pre-MEOR	92	93	88	73	33	95	55	78	69	71
	Post-MEOR	86	88	69	70.5	30	87	47	75.5	65	65
RF(%)	Pre-MEOR	18	20	22	31	21	14	39	16	10	15
	Post-MEOR	40	30	34	40	32	29	60	25	20	25

Table 5. *Paired Sample Hypothesis Testing: Recovery Factor (%)*

Significance (α)	**Degrees of freedom (df)**	**Statistical critical value (tα)**	**Average of differences (d)**	**Standard deviation(sd)**	**Mean of the differences(µd)**	**Test statistic (tcal)**
0.05	9	1.8331	12.9	4.89	0	7.91

Tcal > tα

7,91 > 1.8331 Rejection Ho

In summary, with a significance level of 0.05 the evidence indicates that the mean of the differences (μd) > 0, this implies that there was an improvement in the Recovery Factor (%) obtained after the MEOR treatment. In Table 6 the same test was applied for the case of Water Cut (%).

In conclusion, Tcal < tα because, -3.94 < -1.8331, Ho is rejected and at a significance level of 0.05 it is shown that μd< 0, therefore, is considered favorable, because there were decreases in water cuts once the microbial treatment was implemented. Figure 2 represents the substantially vital reservoir parameters for the microorganisms to be implemented in the Campo Pilon of the Morichal District. Constructed based on investigations of various sources including Institute for Reservoir Studies (IRS), United States Department of Energy (DOE) and National Petroleum Company of China (CNPC) [4].

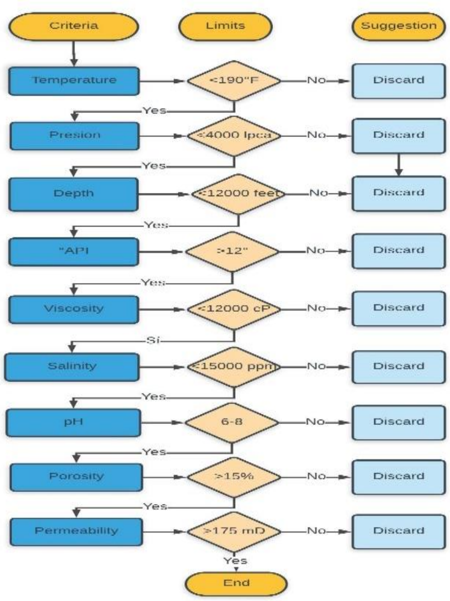


Figure 2. *Flowchart representing the criteria for applying the MEOR process in the wells of Pilon Field belonging to the Morichal District.*

In Table 7 it is evident that the temperature of the wells in the Pilon field complies with one of the most relevant criteria in the MEOR microbial treatment. The fact that these wells comply with this requirement is satisfactory, because the temperature can restrict the survival of microorganisms, growth and their metabolic products by exceeding the indicated limitations.

The pressures at which 3 of the Pilon field wells are located (PC0047, PC0158, PC0041) show that they comply with the requirement of using pressures lower than 4000 lpca; considering that exceeding this range has a contradictory effect on bacterial growth, where its impact on microbial growth is insignificant, however, the increase in pressure influences the redox potential of the gases and increases the solubility of the gas, noting that this potential indicates the oxygen relations of living microorganisms and can be used to specify the environment in which a microorganism is capable of generating energy and synthesizing new cells, influencing the selection of exogenous bacteria if necessary.

On the other hand, the depth values that the wells of the Pilon field have, which allows to compare with the limitation that emphasizes the depth for MEOR processes, is considered feasible because it is below the maximum value established so far (12000 feet). These values indicate that they are located in shallow formations, which facilitates the injection of the bacteria and nutrients whose accessibility can contribute to the success of the technique.

It becomes evident that the wells of the Pilon field meet one of the criteria (degrees °API) required by the method to achieve a satisfactory response of the field. Since they are high molecular weight hydrocarbons, as is the case of the wells indicated, the source of action of the microorganisms is such that it allows them to dissolve their metabolic products in the crude oil, generating greater mobility and ease of extraction.

Table 6. *Paired Sample Hypothesis Testing: Water cut (%)*

Significance (α)	**Degrees of freedom (df)**	**Statistical critical value (tα)**	**Average of differences (d)**	**Standard deviation (sd)**	**Mean of the differences (μd)**	**Test statistic (tcal)**
0.05	9	-1.8331	-6.4	4.87	0	-3.94

Table 7. *Variables with the theoretical range MEOR and average values of the Pilon field*

Variable	**Theoretical Range**	**Average values of the Pilon field**
Temperature	<190 °F	133 °F
Pressure	< 4,000 lpca	1,326 lpca
Depth	<12,000 feet	5,719 feet
°API	> 12°	13.9°
Viscosity	<12,000 Cp	4,210 Cp
Salinity	<15,000 ppm	11,140 ppm
pH	6-8	6.7
Porosity	>15%	26%
Permeability	>175 mD	2,784 mD

It becomes evident that the wells of the Pilon field meet one of the criteria (degrees °API) required by the method to achieve a satisfactory response of the field. Since they are high molecular weight hydrocarbons, as is the case of the wells indicated, the source of action of the microorganisms is such that it allows them to dissolve their metabolic products in the crude oil, generating greater mobility and ease of extraction.

The respective permeabilities of the wells in the Pilon field exceed 175 mD, which can affect favorable treatment responses because the area of movement of the microorganisms is sufficient to allow the bacteria to reproduce. Similarly, with porosity being greater than 15% in which there is an appropriate size for bacterial growth, these geological characteristics of the deposit favor the injection of microorganisms.

According to the viscosity values that the wells of the Pilon field have, they are considered propitious for such treatments, since the bacterial concentration and the time necessary for the microorganisms to reproduce and have an impact on the improvement of the relative mobility of oil with respect to water are not excessively high to fulfill their functions, which in economic terms is a benefit since they influence the costs that the process demands.

The salinities belonging to the field wells exhibit values lower than 15000 ppm, so, it shows that they comply with the optimum range, considering that the tolerance of the microorganisms to sodium chloride is one of the most important characteristics needed for the survival of the organisms used in MEOR.

In general, oil has a pH between 3-10 and for microbial development it should be close to 7 as indicated in Table 7, showing that the acidity of the wells in the Pilon field is close to neutral.

Based on the correlation obtained in the point to estimate both the recovery factor and the percentage of water cut (Eq. 5 and 6) and in relation to what is indicated in the flow chart that represents the criteria for the application of the microbial technique (Figure 2), it is demonstrated in Table 8 the application of these correlations with the data concerning the wells under study, they are PC0041, PC0158, PC0047.

Table 8. *Estimation of %Water Cut and %RF of the wells in the Pilon field*

Wells	Water Cut%		Recovery Factor%	
	Actual Value	**Calculated Value**	**Actual Value**	**Calculated Value**
PC0041	66	58	15	54
PC0158	70	48	18	57
PC0047	75	56	18	54

It was evidenced that at greater depths greater water cuts were obtained and in turn influenced the decrease of the recovery factor, this is attributed to the fact that, at greater pressures, water production tends to displace that of oil, being a singular characteristic of this field, because it is associated to an active aquifer.

Emphasizing the percentage of water cut usually generated by such field, which is around 65-75% and additionally, in the approximate standards of calculated water cuts (54%) it is shown that such processes of improved recovery involving microorganisms can cause a decrease in this parameter, in addition the recovery factors estimated by this technique represent a volume of crude close to 55%, which when compared to the real values that range between 15 and 18% is considered feasible as they are heavy crude oils, with high flow resistance.

In general terms, the wells selected for the study offer a favorable scenario for the development of the metabolic activities of the bacteria, demonstrating that it is a technically efficient and viable procedure to be implemented in wells of the Pilon field with the expectation of producing profitably under the dependence of biotechnology. Based on the analyses made in previous paragraphs, collaborative efforts should be made in order to analyze phenomena in MEOR, this leads to the representation of reliable interpretations before and after the process, which prepare the appropriate situation for the investment in this method in reservoirs that reasonably fit the parameters of the necessary selection criteria [(4)].

According to Saavedra [(16)], which highlighted with relevance that the characteristics of the reservoir must be widely considered in order to choose the microorganism culture that most favors the recovery of hydrocarbons. The field tests of MEOR have been carried out in the oilfields of many countries and exhibited diverse degrees of success; such countries as Canada, United States, Romania, Russia have demonstrated good results when applying the MEOR technique [(17)]. In general, however, microbial methods for heavy oil recovery have not been developed at an industrial level due to insufficient data specific to heavy oil or unconventional oil fields. With reduced availability of conventional crudes, increased energy demand, and current oil prices, microbial enhanced oil recovery (MEOR) for heavy oil is an area of research that should be further considered. Recently, China has been a leader in the microbial field, the studies and their successes in field trials may further inspire the application of this method worldwide [6].

4. Conclusion

The wells particularly under study located in the Morichal District showed average permeabilities of 2785 mD, porosities of 26%, salinities of 11140 ppm, °API around 13.9, pH near 7 and temperatures ranging from 126-137 °F. It was demonstrated through Paired Sample Tests experiences where favorable decreases in the water cut and a significant increase in the recovery factor are reflected, whose differentials are indicative of the success of the process. The predictions made through the correlations to the wells under study showed satisfactory responses, since they showed an average increase in the recovery factor of 38% and a decrease in the water cut of around 16%. It is proven that the wells PC047, PC0158, PC041 belonging to the Morichal District are a favorable scenario to implement the technology of improved recovery via microbial because it has the necessary potential that the process demands.

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