BALAI BESAR PENGUJIAN MINYAK DAN GAS BUMI LEMIGAS

LEMBARAN PUBLIKASI MINYAK DAN GAS BUMI (LPMGB)

Vol. 60 No. 2, August 2026 : 103 - 112 - http://journal.lemigas.esdm.go.id

ISSN: 2089-3396 e-ISSN: 2598-0300

Evaluation of Demulsifier Y as a Replacement for Demulsifier X in Minas Field Crude Oil Based on Water Separation and Basic Sediment & Water (BS&W) Performance

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Article Info:

Manuscript received
May 12th, 2026

Revised
June 25th, 2026

Approved
August 18th, 2026

Published
August 31st, 2026

Keywords:

BS&W,
crude oil,
demulsifier,
minas field,
water separation.

ABSTRACT

This study was conducted to evaluate the suitability of replacing Demulsifier X with Demulsifier Y in Minas Field crude oil following the expiration of the supply contract for Demulsifier X. The evaluation was performed through water separation and Basic Sediment and Water (BS&W) testing. The test was conducted using the bottle test method at 79.4°C (175°F), with concentration levels of 0, 50, and 100 ppm and retention times of 0, 1, and 2 hours. Demulsifier X, Demulsifier Y, and a 1:1 mixture of both demulsifiers were evaluated to assess separation performance and compatibility during a potential transition period. The test results showed that all demulsifier treatments produced Loose Rag (LR) interface quality, while the blank sample showed Tight Rag (TR). At a concentration of 100 ppm, Demulsifier Y produced water separation of 80%, higher than Demulsifier X at 76%. The mixture of Demulsifier X and Demulsifier Y also achieved 80% water separation, indicating good compatibility between the two products. BS&W analysis showed that Demulsifier X, Demulsifier Y, and their mixture produced a final BS&W value of 0.0%, indicating effective dehydration performance. These results demonstrate that Demulsifier Y provides comparable or slightly superior performance to Demulsifier X and can be considered a suitable replacement for Minas Field crude oil applications. The compatibility of both demulsifiers also supports gradual field implementation without adversely affecting oil-water separation performance.

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INTRODUCTION

In the petroleum production process, the formation of water-in-oil emulsions is a major problem frequently encountered in the petroleum industry. These emulsions are formed due to the mixing of crude oil and formation water during production, transportation, and processing. Emulsion stability is generally caused by the presence of natural compounds such as asphaltenes, resins, and solid particles that form a protective layer at the oil-water interface, making the separation of the two phases difficult (Raya et al., 2020; Saad et al., 2019).

This condition can increase fluid viscosity, reduce production efficiency, and increase the potential of corrosion and fouling in crude oil processing production facilities (Raya et al., 2020; Alade et al., 2021).

The formation and stability of petroleum emulsions are strongly influenced by crude oil composition, droplet size distribution, interfacial film properties, and the presence of naturally occurring surfactants (Fingas & Fieldhouse 2009). Crude oil emulsion stability is influenced by crude oil composition, particularly the presence of naturally occurring surface-active compounds such as asphaltenes and resins. Crude oils containing higher concentrations of these compounds generally form more stable water-in-oil emulsions, making dehydration more challenging and increasing the importance of selecting an appropriate demulsification strategy (Abdulredha et al., 2020; Lee & Babadagli 2021)

One of the most common methods used to break emulsions is the injection of chemical demulsifiers. Demulsifiers work by disrupting the stability of the oil-water interface, allowing water droplets to coalesce and separate from the oil phase (Tang et al., 2024). The success of a demulsifier application depends heavily on characteristics of the crude oil, retention time, operating temperature, produced water composition, and the type of emulsion formed. Therefore, each oil field requires a specific evaluation before replacing or optimizing the demulsifier formulation (Tang et al., 2024; Oliveira et al., 2024).

The successful selection of a demulsifier requires consideration of crude oil characteristics, operating conditions, and emulsion behavior because a formulation that performs effectively in one production system may not necessarily provide the same performance in another. Consequently, laboratory bottle testing remains a key screening method for chemical selection and dosage optimization (Kokal 2005). Chemical demulsifiers function by disrupting the interfacial film surrounding dispersed water droplets, thereby facilitating droplet coalescence and accelerating phase separation. The effectiveness of a demulsifier depends not only on its formulation but also on the compatibility between the chemical and the characteristics of the crude oil being treated (Ezzat et al., 2020).

Minas Field is one of the largest oil fields in Indonesia that produces crude oil with certain characteristics that require effective emulsion control to maintain the performance of production facilities and product quality. In an effort to improve operational efficiency and optimize production chemical costs, an evaluation was conducted on replacing Demulsifier X with Demulsifier Y. The type change of demulsifier must be tested first through laboratory analysis that is able to describe the actual performance for the oil and water separation process.

In oilfield operations, the performance of a demulsifier is strongly influenced by the characteristics of the crude oil being treated. Although commercial demulsifiers may serve the same function, each product is formulated differently and may exhibit different separation efficiencies depending on crude oil composition, water chemistry, operating temperature, and emulsion stability. Therefore, a demulsifier that performs effectively in one field may not necessarily provide the same performance in another field. Following the expiration of the supply contract for Demulsifier X, an evaluation was required to identify a suitable replacement from another vendor and to verify its compatibility with Minas Field crude oil. This study was therefore conducted to determine whether Demulsifier Y could provide oil-water separation performance equivalent to or better than the existing demulsifier under representative laboratory conditions.

The objective of this study was not only to compare the performance of two commercial demulsifiers but also to identify a demulsifier that is most suitable for Minas Field crude oil. Since the chemical formulations of demulsifiers vary among vendors and are generally proprietary, performance -based laboratory testing remains one of the most reliable approaches for selecting an appropriate product for field application.

Water separation parameter is one of the main indicators in evaluating demulsifier performance because it shows the chemical's ability to accelerate the separation of water from oil emulsions. Furthermore, the top cut BS&W (Basic Sediment and Water) analysis is used to assess the quality of the separated oil. A low BS&W value indicates a successful dehydration process and an important requirement in the specifications of oil to be transported or further processed. The oil industry generally requires low BS&W levels to minimize corrosion problems, salt deposition, and operational disruptions at facilities (SPE PetroWiki 2025; BASF Oilfield Chemicals 2024).

Based on this background, this study aims to analyze the suitability of replacing Demulsifier X with Demulsifier Y in Minas Field crude oil through water separation and top cut BS&W testing. The study’s results are expected to provide a technical basis in determining the effectiveness of Demulsifier Y for replacing Demulsifier X while also supporting the optimization of the crude oil dehydration process in the Minas Field.

The novelty of this study lies in the systematic evaluation of an alternative demulsifier for Minas Field crude oil following the expiration of the existing supplier contract. In addition to comparing water separation and BS&W performance, this work investigates the compatibility between the existing and replacement demulsifiers to support a safe and practical transition strategy for field implementation.

METHODOLOGY

This research was conducted through an experimental method in the laboratory with the aim of evaluating the performance of Demulsifier Y to replace Demulsifier X in breaking down oil-water emulsions in crude oil originating from the Minas Field. The research stages include crude oil sampling, bottle test testing, and Sediment and Water (S&W) content analysis in the treated samples.

Crude oil sampling

Crude oil samples were collected according to procedures in accordance with ASTM D4057-22 to ensure the samples represented field fluid conditions. Before sampling, the sampling point was cleaned and allowed to flow for approximately two minutes to remove any potential contamination residue. The samples were then placed in clean, airtight Nalgene containers. The oil temperature was recorded immediately after collection to document the sample's actual condition. The samples were then transported to the laboratory, observing proper storage and transportation conditions to maintain their physical characteristics until testing.

Bottle test

The demulsifier performance evaluation was conducted using the bottle test method. The test was conducted using 100 mL Petrolite tubes that had previously been cleaned. Each tube was filled with a mixture of 70 mL of formation water and 30 mL of crude oil. The mixture was then heated in a water bath at 175°F (79.4°C) to simulate field operating conditions and produce a homogeneous emulsion. After the temperature conditions were reached, Demulsifier X, Demulsifier Y, and a mixture of Demulsifiers X and Y with a 1:1 ratio were added to each sample at concentrations of 0 ppm, 50 ppm, and 100 ppm. Next, the tubes were shaken manually 100 times so that the demulsifier could be evenly distributed in the emulsion system. Initial observations were made immediately after mixing, and then the tubes were placed back into the water bath. The volume of separated water was observed and recorded after an incubation time of 1 hour and 2 hours to determine the effectiveness of the water separation process.

In addition to measuring the percentage of water separation, interface quality was visually evaluated to assess the effectiveness of emulsion breaking. Interface quality describes the appearance of the oil-water interface and remaining emulsion layer after treatment. A sharp (SH) interface represents a clean and distinct separation between oil and water phases with little or no visible emulsion and is generally considered the best separation condition. A loose rag (LR) interface indicates a weak and unstable emulsion layer that can be readily separated, suggesting effective demulsification and water droplet coalescence. A tight rag (TR) interface refers to a stable and persistent emulsion layer between the oil and water phases, indicating incomplete separation and stronger emulsion stability.

A webby (WB) interface is characterized by the presence of string-like or web-like emulsion structures, indicating partial emulsion breakdown but poor coalescence efficiency. In some cases, the interface may be not detectable (ND), where the separation boundary cannot be clearly identified due to severe emulsion stability or excessive dispersion. Interface quality is generally ranked from best to worst as: sharp (SH), loose rag (LR), tight rag (TR), webby (WB), and not detectable (ND). A sharper and cleaner interface indicates better demulsifier performance and more efficient oil-water separation.

In addition to interface quality, the quality of the separated water phase was visually evaluated as an indicator of demulsification effectiveness. Water quality was classified into six categories ranging from clear (C) to not detectable (ND). clear (C) indicates transparent water with little or no visible oil contamination and represents the best separation condition. slightly turbid (ST) describes water that appears slightly cloudy due to the presence of a small amount of dispersed oil droplets. Moderately turbid (MT) indicates a greater concentration of dispersed oil, resulting in a noticeably cloudy appearance. Very turbid (VT) represents poor water quality with a high concentration of suspended oil droplets. Emulsified (EM) indicates that a significant portion of the oil remains dispersed in the water phase as a stable emulsion. Not detectable (ND) refers to conditions in which no distinct water phase can be identified due to severe emulsion stability and ineffective phase separation. Water quality is generally ranked from best to worst as: clear (C), slightly turbid (ST), moderately turbid (MT), very turbid (VT), emulsified (EM), and not detectable (ND). Clearer water indicates lower oil carryover and more efficient oil-water separation performance.

Basic sediment and water (BS&W) analysis (top cut)

After the bottle test is completed, an analysis of the sediment and water (S&W) content is carried out on the top oil layer (top cut), which is approximately 5% of the sample surface volume. The sample taken is then mixed with a suitable solvent and heated to a temperature of 140°F before being centrifuged. F46 is a laboratory reagent used as an analytical aid during BS&W determination and is not part of the demulsifier performance evaluation. The reagent assists in releasing residual water and emulsion entrained within the oil phase before centrifugation, thereby improving the accuracy of BS&W measurements. In this study, BS&W analyses were performed both with and without the addition of F46 to evaluate the extent of residual entrained water and emulsion remaining after demulsifier treatment.

The centrifugation stage aims to accelerate the separation between the oil, water, and suspended solids phases so that the water and sediment content can be measured more accurately. The basic sediment and water (BS&W) values obtained are then used as quality parameters for the treated oil. The data are compared between types of demulsifiers and between demulsifier concentrations to determine the most optimal formulation and evaluate the suitability of replacing demulsifier X with demulsifier Y.

RESULTS AND DISCUSSION

Effect of demulsifier concentration on water separation

The water separation results graph is presented in Figure 1. Under blank conditions, water separation only reached 1% at the start of observation and increased to 2% after 1 hour, then to 3% after 2 hours. The addition of Demulsifier X at a concentration of 50 ppm increased water separation from 68% to 74% within 1 hour and 2 hours. At 100 ppm concentration, water separation increased from 74% to 76% after 1 hour and remained constant until the end of the observation. These results indicate that Demulsifier X is effective in breaking down oil-water emulsions, thereby accelerating the process of separating water from Minas crude oil. The stability of the separation percentage after 1 hour indicates that the system has reached a separation equilibrium condition and no significant changes occur in the following hours (Tang et al., 2024).

The bottle test result, the blank sample showed a tight rag (TR) condition which indicates the emulsion is still stable and separation of oil and water is less effective. In contrast, all treatments using Demulsifier X, Demulsifier Y, or a mixture of both produced loose rag (LR) and slightly turbid (ST) water quality. The ST condition indicates that most of the water has separated from the oil, although there are still a few oil droplets that cause the water to appear slightly cloudy. The formation of LR indicates that the emulsion layer has weakened so that the coalescence of water droplets and the separation process take place faster and more effectively compared to the blank sample (Dow 2025).

The occurrence of LR in all treated samples indicates that both demulsifiers effectively destabilized the interfacial film surrounding dispersed water droplets. This condition promoted droplet coalescence and accelerated gravity separation compared with the blank sample, which remained in a TR condition and exhibited poor separation performance. The interface observations were consistent with the measured water separation percentages.

Meanwhile, when compared with Demulsifier X, Demulsifier Y showed slightly higher performance at both tested concentrations as shown in Figure 2 below. At 50 ppm concentration,

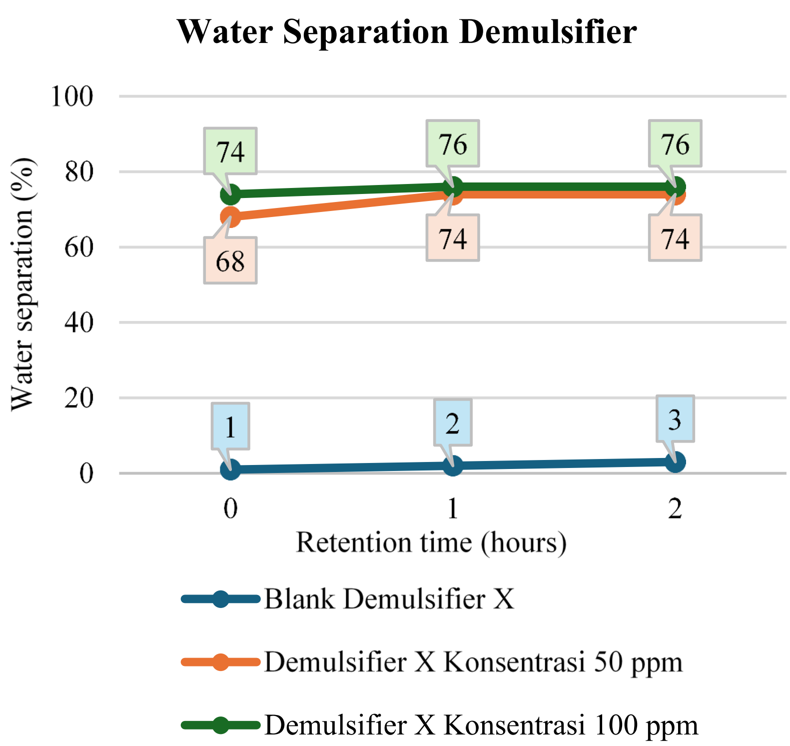

Figure 1. Concentration and retention time effect on water separation of demulsifier X

Demulsifier Y produced 76% water separation after 2 hours, while Demulsifier X only achieved 74%. More obvious difference was seen at a concentration of 100 ppm, where Demulsifier Y achieved 80% water separation, while Demulsifier X achieved 76%.

In addition to producing a higher percentage of water separation, Demulsifier Y also showed a more consistent increase during the observation period, while Demulsifier X tended to reach a stable condition after 1 hour. Although the difference between Demulsifier X and Demulsifier Y was relatively small, Demulsifier Y consistently produced slightly higher water separation percentages at both tested concentrations. At 100 ppm, Demulsifier Y achieved 80% water separation compared with 76% for Demulsifier X. These results indicate that Demulsifier Y can provide performance at least equivalent to the existing product and may offer a modest improvement in dehydration efficiency. Even relatively small improvements in water separation efficiency can provide operational benefits by reducing emulsion carryover, improving dehydration performance, and supporting more stable separator operation. Therefore, comparative bottle-test performance remains an important consideration during demulsifier selection and replacement programs (Schramm 1992).

Demulsifier Y is mixed with demulsifier X at a ratio of 1:1 at each concentration of 50 ppm and 100 ppm as a simulation of the field. If there is still demulsifier X remaining when injecting demulsifier Y, the percentage of water separation is presented in Figure 3. In this mixture at a 50 ppm concentration, water separation increased from 68% at the initial observation to 76% after 1 hour and then stabilized for up to 2 hours. Meanwhile, at 100 ppm concentration, the percentage of water separation increased from 66% to 78% after 1 hour and reached 80% at 2 hours of observation. These results indicate that mixing the two demulsifiers does not cause an antagonistic effect that can reduce the effectiveness of the demulsification process. On the contrary, the performance of the mixture is still able to achieve a water separation level comparable to the use of Demulsifier Y only, especially at 100 ppm concentration. Thus, if Demulsifier Y is mixed with the remaining Demulsifier X, the oil and water separation performance is not affected, so that the transition to the use of demulsifiers in Minas Field can be

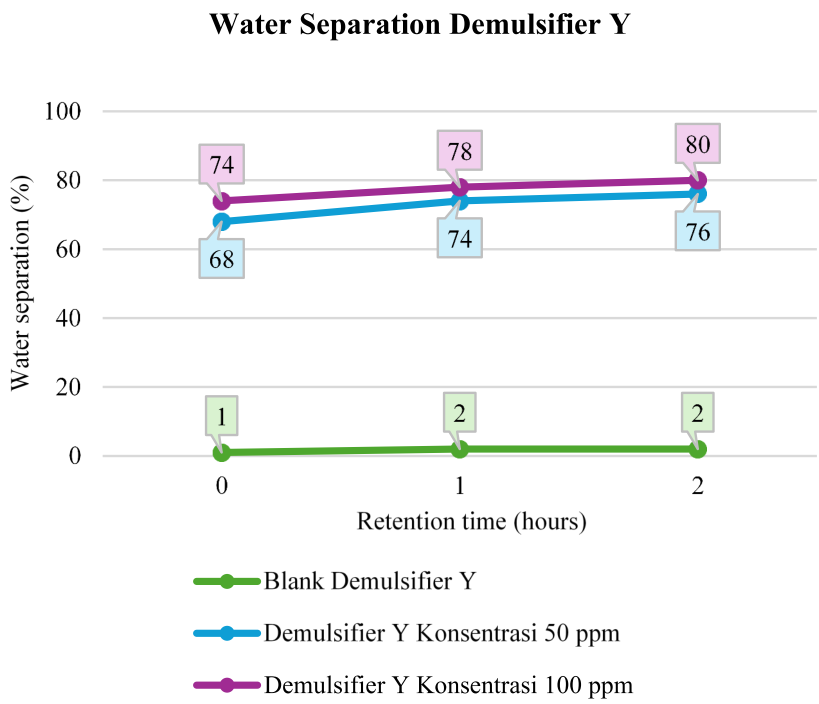

Figure 2. Effect of concentration and retention time on water separation of demulsifier Y.

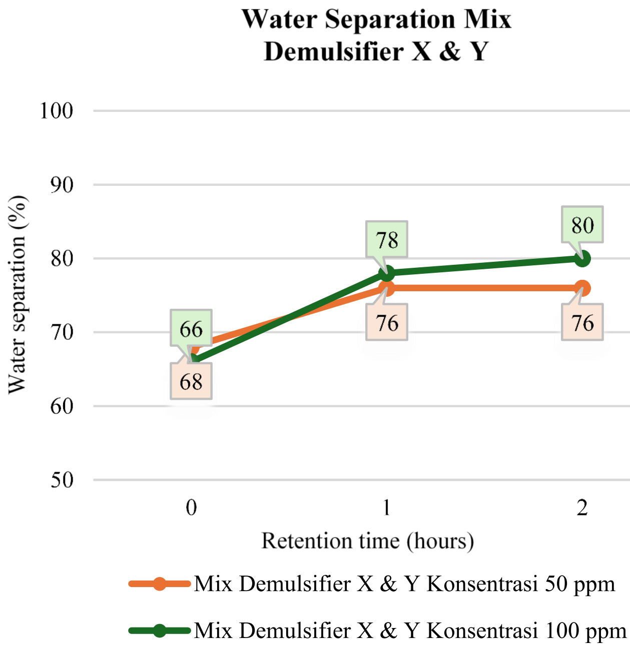

Figure 3. Effect of mixing demulsifier X and demulsifier Y on water separation.

carried out gradually without causing negative impacts on the operational process.

A gradual transition from Demulsifier X to Demulsifier Y is considered more practical than an immediate replacement. Following the expiration of the existing supplier contract, residual quantities of Demulsifier X may remain in storage tanks, injection systems, and transfer lines. The compatibility test conducted using a 1:1 mixture of Demulsifier X and Demulsifier Y demonstrated that no adverse interaction occurred between the two products. Therefore, the transition to Demulsifier Y can be carried out progressively while maintaining separation performance and minimizing operational disruption. Based on laboratory results, a dosage of 100 ppm is recommended as the initial concentration for field implementation because it consistently achieved the highest water separation performance while maintaining a final BS&W value of 0.0%. Further field optimization may be performed to determine the most economical dosage under actual operating conditions.

Basic sediment & water (BS&W)

Analysis

Top-cut analysis of Basic Sediment & Water (BS&W) results shows that the sample without the addition of demulsifier (blank) still contains relatively high amounts of water and emulsion. Since F46 was used only as an analytical reagent, the effectiveness of Demulsifiers X and Y was primarily evaluated based on bottle test performance, interface quality, and BS&W reduction. The results of the BS&W analysis conducted with and without the addition of F46 are presented in Table 1.

Under blank conditions (0 ppm demulsifier), the top-cut oil still contained significant amounts of water and emulsion, with BS&W values of 20.0% and emulsion contents ranging from 16.8% to 17.2%. These results indicate that a substantial portion of water remained entrained within the oil phase in the absence of demulsifier treatment. Following the addition of Demulsifier X, Demulsifier Y, or a mixture of both products at concentrations of 50 and 100 ppm, the BS&W value decreased to 0.2%, while the residual emulsion content was also reduced to 0.2%. This result demonstrates the effectiveness of the demulsifiers in destabilizing the oil-water emulsion and promoting water droplet coalescence.

BS&W measurements performed with the addition of F46 further reduced the measured BS&W and emulsion values to 0.0% for all treated samples. Since F46 was applied solely as an analytical reagent during BS&W determination,

Table 1. BS&W test results.

Chemical		Top Cut			
		Without F46		With F46	
Demul- sifier	Concen-tration (ppm)	BS&W (%)	Emulsion (%)	BS&W (%)	Emul-sion (%)
X	0	20.0	16.8	18.0	0.0
	50	0.2	0.2	0.0	0.0
	100	0.2	0.2	0.0	0.0
Y	0	20.0	17.2	18.0	0.0
	50	0.2	0.2	0.0	0.0
	100	0.2	0.2	0.0	0.0
Mix	50	0.2	0.2	0.0	0.0
X & Y	100	0.2	0.2	0.0	0.0

these results indicate that only trace amounts of water and emulsion remained entrained in the oil after demulsifier treatment. Therefore, the primary performance evaluation remains based on the effectiveness of Demulsifiers X and Y and their mixture in reducing BS&W before analytical assistance provided by F46.

No significant differences were observed among all treatments in terms of final oil quality. All treatments achieved low BS&W values and minimal residual emulsion, indicating effective dehydration performance. These results confirm that Demulsifier Y can provide oil quality comparable to Demulsifier X and suitable for application in Minas Field crude oil treatment.

The primary differentiation between the tested demulsifiers was observed in the bottle test water separation performance, whereas BS&W analysis demonstrated that all treatments could produce dehydrated crude oil with comparable final quality. Therefore, the selection of Demulsifier Y was primarily supported by its ability to achieve slightly higher water separation efficiency while maintaining equivalent BS&W performance.

Detailed chemical composition data for Demulsifier X and Demulsifier Y are proprietary information owned by their respective vendors and are therefore not available to the authors. However, both products are commercial oilfield demulsifiers designed for treatment of water in oil emulsions. Consequently, the present study focuses on performance-based evaluation through water separation and BS&W measurements. The results demonstrate that Demulsifier Y provides separation performance comparable to Demulsifier X under the tested conditions.

The present work was conducted as a laboratory evaluation to support the replacement of Demulsifier X following the expiration of the existing supplier contract. Although the bottle test and BS&W results indicate that Demulsifier Y is a suitable replacement, field validation is recommended as the next stage to confirm performance under actual operating conditions and establish the optimum operating dosage.

CONCLUSION

Based on bottle tests and BS&W analyses, Demulsifier Y demonstrated performance comparable to or slightly better than Demulsifier X in separating water from Minas Field crude oil. At 100 ppm concentration, Demulsifier Y achieved 80% water separation compared with 76% for Demulsifier X. A 1:1 mixture of Demulsifier X and Demulsifier Y also achieved 80% water separation, indicating compatibility during transition periods.

All treated samples produced a final BS&W value of 0.0%, demonstrating effective dehydration performance. These results support the use of Demulsifier Y as a suitable replacement for Demulsifier X following the expiration of the existing supplier contract and indicate that gradual implementation can be performed without negatively affecting oil-water separation performance.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to the Minas Laboratory of PT. Pertamina Hulu Rokan for the support, facilities, and technical assistance provided, which made research on the evaluation of the replacement of Demulsifier X with Demulsifier Y in crude oil from the Minas Field possible. Their support and cooperation significantly contributed to the completion of this research.

DECLARATIONS

Author contributions

Samsinar Sri Ningsih contributed to study conceptualization, manuscript preparation, manuscript editing, literature review, data interpretation, and overall coordination of the journal submission and publication process; Maulana Hardi contributed to research supervision, project oversight, and laboratory management; Tyas Kuswardani contributed to resource provision, laboratory support, data verification, and validation of experimental results; Erik Indra Putra contributed to technical discussions, data management, data analysis, and the interpretation of experimental findings. The authors declare that the work presented in this manuscript is original and has not been published elsewhere. The manuscript is not currently under consideration by any other journal or publication.

Funding statement

This research was supported by Minas Laboratory, PT Pertamina Hulu Rokan, through its operational and technical support program for the Gathering Station facilities in Minas Field. The study was undertaken to provide laboratory-based evaluation of a demulsifier and to support decision-making for production chemical management and crude oil treatment operations.

Competing interest

The authors declare that they have no competing financial or personal interests that could have appeared to influence the work reported in this paper.

Use of AI or AI-assisted technologies

The authors used Microsoft Copilot technology solely for language improvement and grammatical editing during manuscript preparation. All scientific analyses, interpretations, conclusions, and final manuscript content remain the responsibility of the authors.

GLOSSARY OF TERMS AND SYMBOLS

Terms & Symbol	Definition	Unit
BS&W	Basic Sediment and Water	%
BS	Basic Sediment	%
SH	Sharp interface; clear and distinct separation between oil and water phases with little or no visible emulsion	-
LR	Loose Rag; weak and unstable emulsion layer indicating effective demulsification and water separation	-
TR	Tight Rag; stable and persistent emulsion layer indicating incomplete oil-water separation	-
WB	Webby; web-like emulsion structure indicating partial emulsion breakdown and poor coalescence	-
C	Clear; transparent water with little or no visible oil contamination	-
ST	Slightly Turbid; slightly cloudy water containing a small amount of dispersed oil droplets	-
MT	Moderately Turbid; noticeably cloudy water due to a moderate concentration of dispersed oil droplets	-
VT	Very Turbid; highly cloudy water containing substantial dispersed oil droplets	-

EM	Emulsified; stable oil-water emulsion remains present in the separated water phase.	-
ND	Not Detectable; interface boundary or water phase cannot be clearly identified due to severe emulsion stability.	-
F46	Laboratory analytical reagent used during BS&W determination to improve phase separation before centrifugation.	-
ppm	Parts Per Million	ppm
°F	Degree Fahrenheit	°F
°C	Degree Celsius	°C

REFERENCES

Abdulredha, M. M., Aslina, H. S., & Luqman, C. A. (2020). Overview of Petroleum Emulsions, Formation, Influence, Influence, and Demulsification Treatment Techniques. Arabian Journal of Chemistry, 13(1), 3403-3428.https:// doi.org/10.1016/j.arabjc.2018.11.014.

Alade, O.S., Mahmoud, M., Al Shehri, D.A., & Sultan, A.S. (2021). Rapid Determination of Emulsion Stability Using Turbidity Measurement Incorporating Artificial Neural Network (ANN): Experimental Validation Using Video/Optical Microscopy and Kinetic Modeling. ACS Omega, 6(8), 5910–5920.https://doi.org/ 1.1021/acsomega.1c00017.

BASF Oilfield Chemicals. (2024). Your One-Stop-Shop to Demulsification. BASF Energy Resources.

Dow Inc. (2025). Demulsifiers: Break Emulsions for Better Oil Separation. Dow Chemical Company.

Ezzat, A. O., Atta, A. M., & Al-Lohedan, H. A. (2020). One-Step Synthesis of Amphiphilic Nonylphenol Polyethyleneimine for Demulsification of Water in Heavy Crude Oil Emulsions. ACS Omega, 5(16), 9212-9223. https://doi.org/10.1021/acsomega.0c0000.

Fingas, M., & Fieldhouse, B. (2009). Studies on Crude Oil and Petroleum Product Emulsions: Water-in-Oil Emulsions and Related Issues. Journal of Hazardous Materials, 170(1), 9-14. https://doi.or /10.1016/j.jhazmat.2009.04.061.

Kokal, S. L. (2005). Crude Oil Emulsions: A State-of-the-Art Review. SPE Production & Facilities, 20(1), 5-13. https://doi.org/10.2118 77497-PA.

Lee, J., & Babadagli, T. (2021). Comprehensive Review on Heavy-Oil Emulsions: Colloid Science and Practical Applications. Chemical Engineering Science, 246, 116995.

Oliveira, R.S., Meliande, A.S., Barreto, G.S., Ladeira, J.A., Dal'Col, C., Mendonça, P.P. (2024). Optimization of Demulsifier Formulation for Separation of Water from Crude Oil Emulsions in Deepwater Environment. SPE Brazil Flow Assurance Technology Congress.

Raya, S.A., Mohd Saaid, I., Ahmed, A.A., & Umar, A.A. (2020). A critical review of development and demulsification mechanisms of crude oil emulsion in the petroleum industry. Journal of Petroleum Exploration and Production Technology, 10(4), 1711–1728. https:// doi.org/10.1007 s13202-020-00830-7

Saad, M.A., Kamil, M., Abdurahman, N.H., Yunus, R.M., & Awad, O.I. (2019). An Overview of Recent Advances in State-of-the-Art Techniques in the Demulsification of Crude Oil Emulsions. Processes, 7(7), 470.

Schramm, L. L. (1992). Petroleum Emulsions: Basic Principles. American Chemical Society, Advances in Chemistry Series, 231, 1-49.

SPE Society of Petroleum Engineers (SPE). (2025). Oil Demulsifier Selection and Optimization. PetroWiki. https://doi.org/10.211 /PW0651.

Tang, L., Wang, T., Xu, Y., He, X., Yan, A., Zhang, Z., Li, Y., & Chen, G. (2024). Research and Application Progress of Crude Oil Demulsification Technology. Processes, 12(10), 2292. https://doi.org/10.3390/pr12102292.