processes

MDPI

Editorial

In-Situ and Ex-Situ Processes during Production, Transportation and Refinery of Heavy Oil

Firdavs Aliev * and Danis Nurgaliev

Institute of Geology and Petroleum Technologies, Kazan Federal University, 420008 Kazan, Russia
* Correspondence: aquathermolysis@gmail.com

Heavy oil and natural bitumen are expected to be alternatives to the depleting conventional crude oil resources for the coming decades, mainly due to their sustainability, safety and huge number of reserves worldwide [1,2]. However, there are some challenges, not only with the recovery of such unconventional hydrocarbons, but also with their transportation, storage and refinery, due to their high viscosity and density, low ratio of $H/C_{at.}$ and significant content of heteroatoms, asphaltenes and heavy metals [3–6]. The latter is prone to poisoning catalysts during refinery processes, which is very cost effective [7]. Various industrially applied and successfully enhanced oil recovery techniques have been developed to produce heavy oil and natural bitumen via temporary viscosity reduction [8]. However, the rheology and quality of the recovered crude oil, and its environmental consequences, remain unsatisfactory. The industry needs hybrid techniques to combine recovery with processing in order to permanently reduce viscosity and improve the quality of the produced crude oil with less impact on the environment. Therefore, the subject of in situ and ex situ upgrading is becoming more and more relevant both from a scientific and practical point of view. The given Special Issue (SI) gathered eight selected articles which highlight the emerging scientific insights and technological advances in enhanced oil recovery methods and in the catalytic upgrading of heavy oil.

In total, fourteen manuscripts were submitted for consideration in the given Special Issue, among which eight were accepted for publication. The selected published articles are listed below:

1. Okhotnikova, E.S.; Barskaya, E.E.; Ganeeva, Y.M.; Yusupova, T.N.; Dengaev, A.V.; Vakhin, A.V. Catalytic Conversion of Oil in Model and Natural Reservoir Rocks. *Processes* **2023**, *11*, 2380. https://doi.org/10.3390/pr11082380.
2. Kholmurodov, T.; Mirzaev, O.; Affane, B.; Tajik, A.; Romanova, K.; Galyametdinov, Y.; Dengaev, A.; Vakhin, A. Thermochemical Upgrading of Heavy Crude Oil in Reservoir Conditions. *Processes* **2023**, *11*, 2156. https://doi.org/10.3390/pr11072156.
3. Wang, J.; Zhang, Z.; Wang, Q.; Lou, T.; Pan, Z.; Hu, M. Integrated a Fused Silica Capillary Cell and In Situ Raman Spectroscopy for Determining the Solubility of CO2 in n-Decane and n-Decane + n-Hexane System. *Processes* **2023**, *11*, 1137. https://doi.org/10.3390/pr11041137.
4. Sorokin, A.S.; Bolotov, A.V.; Nuriev, D.R.; Derevyanko, V.K.; Minkhanov, I.F.; Varfolomeev, M.A. Dynamic Criteria for Physical Modeling of Oil Displacement by Gas Injection. *Processes* **2022**, *10*, 2620. https://doi.org/10.3390/pr10122620.
5. Anikin, O.V.; Bolotov, A.V.; Mukhutdinova, A.R.; Varfolomeev, M.A. Evaluation of the Kinetic and Thermodynamic Behavior of Tracers for Their Applicability in SWCTT. *Processes* **2022**, *10*, 2395. https://doi.org/10.3390/pr10112395.
6. Ponomarev, A.A.; Gafurov, M.R.; Kadyrov, M.A.; Tugushev, O.A.; Drugov, D.A.; Vaganov, Y.V.; Zavatsky, M.D. Impact of Geomagnetic Fields on the Geochemical Evolution of Oil. *Processes* **2022**, *10*, 2376. https://doi.org/10.3390/pr10112376.

Citation: Aliev, F.; Nurgaliev, D. In-Situ and Ex-Situ Processes during Production, Transportation and Refinery of Heavy Oil. *Processes* **2024**, *12*, 273. https://doi.org/10.3390/pr12020273

Received: 22 January 2024
Accepted: 24 January 2024
Published: 26 January 2024

7. Aliev, F.; Mirzaev, O.; Kholmurodov, T.; Slavkina, O.; Vakhin, A. Utilization of Carbon Dioxide via Catalytic Hydrogenation Processes during Steam-Based Enhanced Oil Recovery. *Processes* **2022**, *10*, 2306. https://doi.org/10.3390/pr10112306.
8. Kholmurodov, T.; Aliev, F.; Mirzaev, O.; Dengaev, A.; Tajik, A.; Vakhin, A. Hydrothermal In-Reservoir Upgrading of Heavy Oil in the Presence of Non-Ionic Surfactants. *Processes* **2022**, *10*, 2176. https://doi.org/10.3390/pr10112176.

Contribution 1 explored the catalytic performance of metal oxides on the low-temperature and high-temperature oxidation of heavy oil reservoir rocks. The results of the experiments showed that salt additive Na_3PO_4 promotes the catalytic activity of Cr_2O_3 and Al_2O_3. The authors compared the dry and wet oxidation processes and concluded that water inhibits polymerization reactions after the cracking of hydrocarbons.

Contribution 2 proposed a novel method to process heavy oil in refineries by combining steam and non-ionic surfactants. Based on their experimental results, the authors concluded that surfactants play a dominant role in dispersing asphaltene agglomerates, thereby facilitating the decomposition process under mild hydrothermal conditions and leading to a noticeable enhancement of crude oil properties.

Contribution 3 carried out a fundamental study to understand the solubility of CO_2 in normal alkanes imitating crude oil. The study combined a fused silica capillary cell with Raman spectroscopy to develop the prediction model for the solubility of CO_2 in n-alkanes. The output of the prediction model was matched with the experimental data, and the mean relative deviation was less than 4%, which is precise enough for CO_2 EOR applications.

Contribution 4 conducted slim tube displacement experiments to calculate the minimum miscibility pressure using statistical regression and quadratic extrapolation. The estimated minimum miscibility pressure was determined to be 37.09 MPa, while the average range values for all applied methods was determined to be 36.92 MPa.

Contribution 5 is devoted to the application of a single-well chemical tracer test. In particular, the effect of the structure on the kinetic and thermodynamic components of tracers was investigated.

Contribution 6 aimed to attract scholars' focus to the issues of the geochemical evolution of oil under geomagnetic fields. The findings showed that the geochemical characteristics of oil were changed under electromagnetic exposure, while the number of paramagnetic centers remained constant.

Contribution 7 proposed a hybrid CO_2-assisted hydrothermal upgrading of heavy oil in-place. For the first time, in this Special Issue, a novel approach to reduce carbon dioxide emissions during steam-based oil recovery techniques via in situ catalytic hydrogenation processes was proposed and published. The role of the catalysts in the conversion of CO_2 into normal alkanes was demonstrated.

Contribution 8 also aimed to modify the conventional hydrothermal upgrading with the co-addition of surfactants. The experimental results showed that surfactants lead to the in-depth destructive hydrogenation of the high-molecular components of heavy oil such as resins and asphaltenes.

In general, the contributions highlighted the importance of the neglected area in both downstream and upstream processes, and the relevance of global energy transition from conventional high-energy-consuming thermal recovery and upgrading methods toward hybrid-enhanced oil recovery and upgrading techniques. We hope that this Special Issue will be helpful in solving the previously mentioned difficulties in the petroleum industry. Furthermore, the contributions have raised many questions that warrant further investigation and provide an impetus for future research.

Author Contributions: Conceptualization, D.N.; writing—original draft preparation, F.A.; supervision, D.N. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: This project received support from The Ministry of Science and Higher Education of the Russian Federation under agreement No. 075-15-2022-299 within the framework of the development program for a world-class Research Center "Efficient development of the global liquid hydrocarbon reserves".

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Martínez-Palou, R.; de Lourdes Mosqueira, M.; Zapata-Rendón, B.; Mar-Juárez, E.; Bernal-Huicochea, C.; de la Cruz Clavel-López, J.; Aburto, J. Transportation of heavy and extra-heavy crude oil by pipeline: A review. *J. Pet. Sci. Eng.* **2011**, *75*, 274–282. [CrossRef]
2. Li, Y.; Wang, Z.; Hu, Z.; Xu, B.; Li, Y.; Pu, W.; Zhao, J. A review of in situ upgrading technology for heavy crude oil. *Petroleum* **2021**, *7*, 117–122. [CrossRef]
3. Aliev, F.; Ali Akhunov, A.; Mirzaev, O.; Vakhin, A. Development of New Amphiphilic Catalytic Steam Additives for Hydrothermal Enhanced Oil Recovery Techniques. *Catalysts* **2022**, *12*, 921. [CrossRef]
4. Hashemi, R.; Nassar, N.N.; Almao, P.P. Nanoparticle technology for heavy oil in-situ upgrading and recovery enhancement: Opportunities and challenges. *Appl. Energy* **2014**, *133*, 374–387. [CrossRef]
5. Marafi, A.; Albazzaz, H.; Rana, M.S. Hydroprocessing of heavy residual oil: Opportunities and challenges. *Catal. Today* **2019**, *329*, 125–134. [CrossRef]
6. Santos, R.G.D.; Loh, W.; Bannwart, A.C.; Trevisan, O.V. An overview of heavy oil properties and its recovery and transportation methods. *Braz. J. Chem. Eng.* **2014**, *31*, 571–590. [CrossRef]
7. Carolin, C.F.; Kumar, P.S.; Saravanan, A.; Joshiba, G.J.; Naushad, M. Efficient techniques for the removal of toxic heavy metals from aquatic environment: A review. *J. Environ. Chem. Eng.* **2017**, *5*, 2782–2799. [CrossRef]
8. Thomas, S. Enhanced oil recovery—An overview. *Oil Gas Sci. Technol.-Rev. L'IFP* **2008**, *63*, 9–19. [CrossRef]