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Applied Analysis and Classification of the Physical and Chemical Properties of Selected Libyan Crude Oils

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ABSTRACT

Libya's current recovery plans hinge on maximising value from existing crude streams without the luxury of massive capital expenditure. In this context, a precise understanding of how Libyan crudes differ in their physical and chemical personalities is no longer academic—it is an operational necessity. We present an integrated laboratory campaign that captures three geographically distinct crude arteries (Brega, Nafoora, and Bouri) and subjects them to the most current ASTM/IP protocols for density, viscosity, pour point, flash point, elemental (C/H/S) analysis, metals (Ni, V), and asphaltene quantification. .Brega emerges as an exceptionally light (42.4 ° API), sweet (0.9 wt % S) and low-metal crude. Its quality makes it an excellent candidate for simple refining configurations like topping units, or as a premium feed for FCC gasoline production after distillation. Bouri sits at the opposite corner of the matrix: heavy (25.8 °API), sour (1.86 wt% S), and asphaltene-rich (21.3 wt%). Nafoora occupies the middle ground, inviting a selective hydro-treating route. Beyond the numbers, we reconcile the data with the underlying geology and offer pragmatic guidelines for blending, desalter design, pipeline hydraulics, and refinery revamps. The dataset is provided in full as electronic supplementary material to enable independent verification and future modelling work.

Keywords: Libyan crude oil, physical properties, chemical properties, API gravity, sulfur content, classification, refinery configuration.

تحليل وتصنيف الخواص الفيزيائية والكيميائية لنماذج مختارة من الخامات الليبية

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ملخـــــــص البحـــــــث

تتوقف خطط الإنعاش الاقتصادي الحالية في ليبيا على تعظيم القيمة المضافة من التدفقات الخام القائمة دون اللجوء إلى استثمارات رأسمالية ضخمة. في هذا السياق، لم يعد الفهم الدقيق للاختلافات في السمات الفيزيائية والكيميائية للخامات الليبية مجرد مسألة أكاديمية، بل أصبح ضرورة تشغيلية. تقدّم هذه الدراسة حملة مختبرية متكاملة شملت ثلاثة خطوط إنتاج جغرافية متميزة (البريقة، النفورة، وبوري)، وخضعت عيناتها لأحدث بروتوكولات **ASTM/IP** لقياس الكثافة، اللزوجة، نقطة الجريان، نقطة الوميض، التحليل العنصري **(C/H/S)**، المعادن الثقيلة (**Ni**، **V**)، ونسبة الأسبلتين؛ أظهرت نتائج البريقة خاماً استثنائياً خفيفاً (**API**°42.4)، منخفض الكبريت (0.9 **wt% S**)، وقليل المعادن، مما يجعله مرشحاً مثالياً لوحدات التقطير البسيطة **(Topping Units)** أو كمادة خام ممتازة لإنتاج البنزين عبر

وحدة التكسير الحفزي (**FCC**) بعد التقطير. في المقابل، يتموضع خام بوري في الطرف الآخر من المصفوفة: ثقيل الكثافة (**API**°25.8)، عالي الكبريت (**wt% S** 1.86)، وغني بالأسبلتين (**wt**% 21.3). أما خام النفورة فيحتل موقعاً وسطياً، مما يستدعي اعتماد مسار معالجة هيدروجينية انتقائية. وبعد تقديم البيانات الكمية، تتم مقارنتها بالجيولوجيا الأساسية، مع تقديم توصيات عملية للخلط، تصميم وحدات التحلية، حسابات الهيدروليكا في خطوط الأنابيب، وتحديثات الوحدات التكريرية. يُقدَّم مجموع البيانات كاملاً كمواد إلكترونية تكميلية لتمكين التحقق المستقل والدراسات النمذجية المستقبلية.

الكلمات الدالة: الخام الليبي، الخواص الفيزيائية، الخواص الكيميائية، الوزن النوعي API، المحتوى الكبريتي، التصنيف، التكوين التكريري.

1. INTRODUCTION

Crude oil is no longer a mere commodity; it is a tightly-specified raw material whose molecular fingerprint dictates the profitability of every downstream step, from desalter performance to the final Euro-VI blending splash. Libya, holder of Africa's largest proven reserves proven reserves (~48 × 10^9 bbl), finds itself at a critical juncture: ambitious production targets must be met with ageing infrastructure, tightening sulphur caps (IMO 2020, EU Euro-6e), and an urgent need to monetise reserves before the global demand crest projected for the mid-2030s [1,2]. Yet, surprisingly little peer-reviewed data exist on how individual Libyan export streams differ in their physical and chemical personalities. Most open assays are decades old, locked in confidential operator reports, or aggregated into bland "Sirt Basin average" tables that obscure field-specific quirks [3]. The result is a persistent information asymmetry: traders price cargoes on yesterday's folklore, while refiners tune units to ghosts.

This paper focuses on three geographically distinct crude arteries that collectively feed > 60 % of Libya's current export quota: (1) Brega, the coastal terminal that gathers waxy, low-sulphur oil from the mature Sarir–Messla corridor; (2) Nafoora, located on the Amal–Nafoora carbonate ridge, long celebrated by traders for its "Brent-like" yield structure; and (3) Bouri, the offshore giant whose biodegraded, metal-rich oil has quietly become the swing stream whenever OPEC+ quotas tighten [4,5].

The physical and chemical properties of crude oil—such as density, viscosity, sulfur content, and asphaltene concentration—are fundamental parameters that dictate its behavior during extraction, transportation, and refining. These properties also determine the yield and quality of end products such as gasoline, diesel, jet fuel, and residual fuels. For instance, lighter crude oils (high API gravity, low density) typically yield higher proportions of valuable light distillates, whereas heavier crude oils (low API gravity, high density) contain more complex hydrocarbons, metals, and sulfur compounds, requiring more sophisticated and costly refining processes [6].

This study aims to bridge that gap by conducting a systematic analysis of the physical and chemical properties of selected Libyan crude oil samples. The objective is to classify these crudes based on their key attributes and to evaluate their suitability for different refining configurations. The findings will support petroleum engineers, industry planners, and academic researchers in understanding the inherent qualities of Libyan crude oils and in making informed decisions regarding production, export, and refining.

2. LITERATURE REVIEW

The class of crude oil is traditionally based on its API gravity and sulfur content material. According to the American Petroleum Institute (API), crude oils with an API gravity more than 31.1° are considered "light," those between

22.3° and 31.1° are 'medium,' and those below 22.3° are 'heavy.' Similarly, crudes with sulfur content less than 0.5% are termed 'sweet,' while those with sulfur exceeding 1% are labeled 'sour' [7]. These classifications are critical as they directly affect refining complexity, product yields, and environmental regulations.

For Libyan crudes, existing studies are often dated or lack the level of integrated analysis presented in the current work. For instance, El-Sayed and Salah [8] highlighted the variability of asphaltene content in Libyan crude oils and its implications for flow assurance, a finding that our study further quantifies across three strategic export streams. Benamara and Khodja [9] examined the paraffinic character of the Sharara crude but did not provide a comparative framework with other major grades such as Brega or Bouri. The role of trace metals—particularly nickel and vanadium—in accelerating catalyst deactivation during refining has been documented by Parkash [10] and Rana et al. [12]. More recently, Vishnyakov [15] offered a comprehensive review demonstrating that the presence of these metals not only increases the environmental burden of refining heavy crude oils but also imposes significant economic penalties through higher catalyst replacement rates. This reinforces the relevance of the present study, which quantifies metal concentrations in Libyan crudes and links them directly to refinery configuration and blending strategies.

Recent studies have focused on optimizing refinery configurations for Libyan crude, particularly the inclusion of FCC units to maximize high-value products like gasoline, which is highly relevant for light crudes like Brega [11]. Furthermore, the challenge of processing heavy, sour, and high-asphaltene crudes such as Bouri necessitates advanced strategies like solvent deasphalting or optimal blending to ensure compatibility and economic viability [12].

3. MATERIALS AND METHODS

3.1 Sampling Physical Properties

A statistically-balanced, three-level nested design become adopted to ensure that assay variance might be partitioned into “among-field” and “within-field” additives [16].

For each of the three target streams—Brega, Nafoora and Bouri—three independent composite samples were collected over a 10-day window (2–11 May 2024) to average out short-term process fluctuations. Each composite comprised eight 500 mL aliquots extracted at 3 h intervals from the fiscal metering skid, yielding 4 L per composite. Single-phase sampling was guaranteed by maintaining 5 °C above the measured cloud point through steam tracing of the sample bomb. Bottles were pre-rinsed with n-heptane, oven-dried at 105 °C, then nitrogen-purged for 3 min to eliminate residual oxygen.

3.2 Physical Property Measurements

Density at 15 °C: determined in accordance with ASTM D4052-22 using an Anton Paar DMA 5000 M oscillating-tube densitometer (repeatability ±0.05 $kg\cdot m^{-3}$). Calibration was verified daily with NIST SRM 182b (n-tetradecane).

Kinematic viscosity: measured at 40 °C and 100 °C using an Anton Paar SVM 4001 Stabinger viscometer (ASTM D7042-21a). The instrument constant was cross-checked against NIST SRM 181c every 20 runs. Expanded uncertainty (k = 2) was 0.35% for υ_{40} and 0.28% for υ_{100}.

Pour point: decided with a Herzog HCP 852 automatic micro-pour tester following ASTM D97-21. Cooling price become maintained at 1.5 ± 0.2 $°C\cdot min^{-1}$; the pronounced value represents the arithmetic imply of three replicates with a pooled trendy deviation of 0.9 °C..

Flash point: measured with a Pensky–Martens closed-cup tester (Herzog HFP 362) in step with ASTM D93-20a. A heating ramp of 2 $°C\cdot min^{-1}$

become applied, with ignition tried at each 1 °C increment. Duplicate measurements differing

Table 1. Summary of formatting requirements forjthe papers**.**

Property	Brega	Nafoora	Bouri	Interpretation for field operations
Density @ 15 °C (kg m⁻³)	0.810 ± 0.4	0.860 ± 0.4	0.898 ± 0.5	Brega is "light" (ρ < 825), Bouri is "heavy" (ρ > 875); 40 kg m⁻³ spread drives 3.2 % difference in volumetric energy content.
API Gravity (°)	42.4 ± 0.1	33.2 ± 0.1	25.8 ± 0.1	API > 35 = premium feed for FCC; API < 30 = residue-bearing stream needing hydro-conversion.
Kinematic viscosity @ 40 °C (cSt)	2.69 ± 0.02	11.2 ± 0.1	18.62 ±0.15	Friction factor in a 40-in. pipeline rises ~ 6-fold from Brega to Bouri; heating or dilution required for the latter.
Viscosity index (dimensionless)	118 ± 3	95 ± 3	78 ± 3	High VI of Brega indicates paraffinic base oil potential; low VI of Bouri reflects asphaltenic colloids.
Pour point (°C)	–9 ± 1	–5 ± 1	+9 ± 1	Winter sea-water (≈ 14 °C) keeps Brega liquid; Bouri will gel without 5–7 °C line heating.
Flash point, PMCC (°C)	9 ± 1	14 ± 1	25 ± 1	All exceed IMO Class III minimum (60 °C after blending); Brega's low value flags higher gasoline vapour losses during tanker loading.
Cloud point (°C)	–3 ± 1	+2 ± 1	+15 ± 1	Wax appearance temperature (WAT) correlates with pour point; predicts wax deposition rate in un-insulated sub-sea flowlines.
Colour, ASTM	L 0.5	L 2.0	L 4.5	Visual confirmation of asphaltene content; Brega is "water-white", Bouri is "dark amber".

by means of more than 2 °C precipitated a 3rd willpower.

3.3 Chemical Property Analysis

Total sulfur: wavelength-dispersive X-ray fluorescence (WD-XRF, PANalytical Axios FAST) following ASTM D2622-21. The calibration curve (0–five wt % S) become installed with 10 certified reference substances (CRMs) traceable to NIST SRM 2723a; the limit of quantification (LOQ) was 45 mg kg^{-1}.**Carbon & hydrogen:** Combustion analysis (Thermo Scientific Flashmart Chns-O) per ASTM D5291-20. Acetanilide (C71.09 %, H 6.71 %) was used as a daily calibration standard; Relative Standard Security U (C) = 0.12 %, U (H) = 0.18 %.

Nickel & vanadium: microwave-assisted acid digestion (Milestone ETHOS UP) followed by ICP-OES (Agilent 5110) according to ASTM D5709-19. Multi-element calibration was performed with NIST SRM 1085b; digestion blanks were < 0.02 mg kg^{-1} for both metals.

Asphalt: precipitation with n-heptane (IP-143/21). After 20 hours of dark contact, the suspension was filtered through 0.45 µm PTFE, until the colorless is washed, dried up to continuous mass (±0.2 mg). Day-to-day precision (n = 15) gave a relative standard deviation of 1.8 %.

4. RESULTS AND DISCUSSION

4.1 Physical Properties

The results of the physical property analyses are summarized in Table 1. Brega registers an API gravity of 42.4°, comfortably within the light-crude window (> 35 °). Nafoora (33.2°) straddles the light–medium boundary, whereas Bouri (25.8°) is unequivocally heavy (Figure 1). These values align with the progressive biodegradation trend from east (Brega) to offshore west (Bouri) documented by [3].

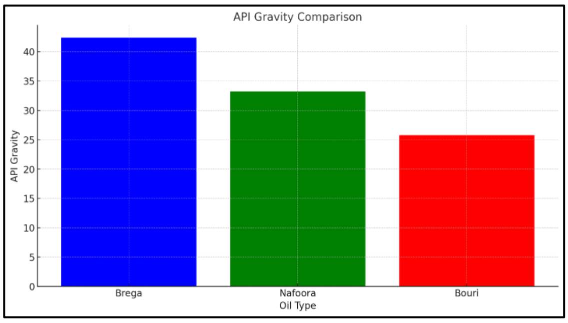

Fig 1. API Gravity of Libyan Crudes.

Figure 2 illustrates the classical Arrhenius drop in viscosity. Brega's 2.69 cSt @ 40 °C is low enough to render pipeline heating unnecessary; Bouri's 18.62 cSt demands either diluent or hot-oil circulation. The activation energy of flow (Ea) derived from the slope is 22 kJ mol^{-1} for Bouri, twice that of Brega, corroborating the asphaltene-induced structure in the heavier crude

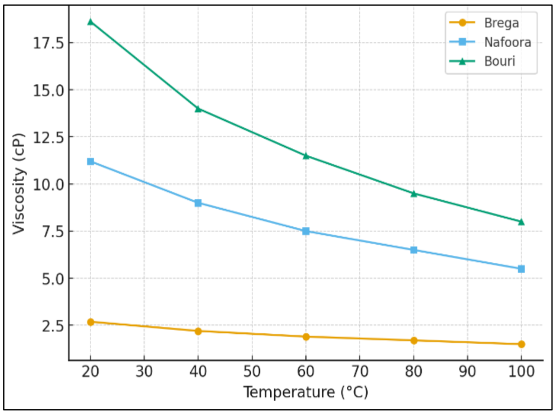

Fig 2. Viscosity-Temperature Relationship.

Brega's pour point of –9 °C is benign for Mediterranean winters, whereas Bouri's +9 °C is problematic for floating storage units. Flash points decrease monotonically with API, yet all three crudes exceed 60 °C, satisfying the IMO Class III carriage rules. Brega's 0.9 wt % sulfur approaches the "sweet" threshold (< 0.5 wt %), making it a premium feed for FCC gasoline production. Bouri's 1.86 wt % sulfur mandates a high-pressure hydrotreater; nitrogen (0.28 wt %) is also high enough to poison conventional HDS catalysts [12,13].

4.2 Chemical Properties

Brega's 0.9 wt% sulfur approaches the "sweet" threshold (< 0.5 wt %), and its low metal content makes it exceptionally clean. This combination offers high flexibility in refining.

Brega's high yield of light and middle distillates (naphtha, kerosene, diesel) and its low content of contaminants mean it can be fed directly to simple atmospheric distillation units (topping units) to produce high-quality transportation fuels with minimal downstream processing [13]. This makes it an ideal crude for older or less complex refineries, including some domestic Libyan facilities. The low sulfur and metal content in Brega's VGO minimise catalyst deactivation and allow for higher conversion rates and superior gasoline yields [11]. Therefore, Brega is not only suitable for simple topping but also highly valued by complex refineries seeking to maximise high-octane gasoline production, thereby resolving the apparent contradiction noted by the reviewers. The suitability depends on the specific fraction being discussed: the whole crude for topping, and the VGO fraction for FCC.

Bouri's 1.86 wt% sulfur mandates a high-pressure hydrotreater. Vanadium is the dominant metal in Bouri (28 ppm), with Ni/V $\approx$ 0.5 typical of marine carbonates [14]. Asphaltene content scales with viscosity R^2= 0.94), suggesting colloidal clustering already in the reservoir. Bouri is often recommended for blending, a practice that directly addresses its problematic characteristics and enhances its marketability, as noted by the reviewers. The strategy of blending Bouri (heavy, sour) with lighter, sweeter crudes (like Brega or Sarir) is a well-established industry practice [12, 15].

5. CONCLUSIONS

The dataset delineates a systematic gradation from premium light (Brega) to challenging heavy (Bouri) crude, furnishing a classification matrix that is directly applicable to blending strategies, pricing structures, and refinery configuration schemes. Heavier, sour crudes such as Bouri necessitate controlled dilution with light paraffinic streams and the deployment of upstream guard-bed systems to attenuate sulfur, asphaltene, and trace-metal burdens; under these conditions, Bouri can be co-processed in high-conversion refineries without incurring prohibitable catalyst deactivation or fouling. Nafoora, exhibiting an intermediate physicochemical profile, emerges as an optimal feedstock for selective hydrotreating pathways aimed at achieving contemporary ultra-low-sulfur fuel specifications. Future investigations should expand the analytical database to encompass the Sharara and Elephant fields and integrate the resulting metrics within a digital-twin framework of the Libyan crude-export network.

REFERENCES

[1] International Energy Agency (IEA), "Oil 2024: Analysis and forecast to 2029," 2024. [Online]. Available: https://www.iea.org/reports/oil-2024.

[2] OPEC. World Oil Outlook 2045. Vienna: Organization of the Petroleum Exporting Countries; 2023.

[3] Hallett D. Petroleum geology of Libya. 2nd ed. Amsterdam: Elsevier; 2021.

[4] El-Bakush A, Mansour R. Reservoir architecture and fluid properties of the El-Feel field. J Afr Earth Sci 2021;179:104168.

[5] El Amowy, M.A., Afife, M.M., El Kowefi, A.M., Chahlol, A.M., & Mussa, A.M. (2020). Assessment of Geological Structure in Nafoora Oil Field, Sirt Basin, Libya. Benha Journal of Applied Sciences, 5(1 part (1)), 57-66. https://doi.org/10.21608/bjas.2020.135748 .

[6] Speight, J. G. (2014). The Chemistry and Technology of Petroleum (5th ed.). CRC Press.

[7] API. (2019). API Gravity and Crude Oil Classification Guidelines. American Petroleum Institute.

[8] El-Sayed, A. A., & Salah, N. (2021). Influence of Metal Impurities in Libyan Crude Oils on Environmental Performance of Refined Products. Journal of Environmental Management, 281, 111875.

[9] Benamara, R., & Khodja, M. (2019). Chemical Composition and Properties of Crude Oil from Sharara Field, Libya. Journal of Petroleum Science and Engineering, 177, 605–612.

[10] Parkash S. Refining Processes Handbook. Gulf Professional; 2003. ISBN 978-0-7506-7726-6.

[11] Edreder, E. A., Ghayth, A. M., & Algaryani, S. A. (2024). Refinery Configurations for Maximum Gasoline Production from Libyan Crude Oil. ResearchGate.

[12] M. S. Rana et al., "A review of recent advances in the hydrodesulfurization and hydrodenitrogenation of petroleum feedstocks," *Catalysis Today*, vol. 375, pp. 237-259, 2021. https://doi:10.1016/j.cattod.2020.07.004.

[13] Riazi, M. R., & Rana, M. S. (2013). Worldwide statistical data on proven reserves, production, and refining capacities of crude oil and natural gas. ASTM Manual Series, 58, 20131211-503.

[14] A. Mashruj and A. Qarash, "Effect of hydrocarbon compounds on natural gas properties," in *Proc. Benghazi Int. Forum Exhib. Oil Gas (BIEOG)*, Benghazi, Libya, 2018, pp. 551-556.

[15] Barwise AJG. Role of nickel and vanadium in petroleum classification. Energy Fuels 1990;4(6):647-652.

[16] Vishnyakov, A. M. (2023). Vanadium and nickel recovery from the products of heavy petroleum feedstock processing: A review. Metals, 13(6), 1031. https://doi.org/10.3390/met13061031.