Crossref
DOI: 10.31643/2027/6445.17
Earth and Planetary Sciences: Earth-Surface Processes

Innovative technologies for paraffin deposit removal in oil tubing to enhance oil recovery: a mechanical approach

[1] **Alisheva Zh.N.**, [2] **Sarsenbayev M.A.**, [3] **Sarsenbaev Zh.A.**, [4*] **Baibotaeva S. E.**

[1] *D.A. Kunayev Institute of Mining, Almaty, Kazakhstan*
[2] *LLP Scientific and Technological Park of Al-Farabi Kazakh National University, Almaty, Kazakhstan*
[3] *LLP Innovation Plus, Almaty, Kazakhstan*
[4] *M. Auezov South Kazakhstan University, Shymkent, Kazakhstan*

** Corresponding author email: sbaibotaeva@mail.ru*

Received: *April 22, 2025*
Peer-reviewed: *August 6, 2025*
Accepted: *November 18, 2025*

ABSTRACT

Asphaltene - resin - paraffin deposits (ARPD) on the inner wall of production tubing shorten service intervals, elevate operating expenditures, and frequently induce downtime at mature fields. This paper presents the design and field performance of a rod-driven in-well scraper that provides continuous tubing cleaning during routine sucker-rod operation without chemical dosing or surface interventions. The scraper sub is inserted into the rod string and is compatible with Ø73 - 89 mm tubing and Ø19 - 22 mm rods. Performance was evaluated on a before/after basis using the inter-cleaning period (ICP), downtime, and annual cleaning costs, with extrapolation to multi-well programs. Field deployments of model CP TP ST 01KZ achieved an ICP of 144 - 280 days with zero cleaning-induced downtime (0 days yr^{-1}). Annual cleaning costs were ~0.265 million KZT per well (scheduled service only), which is ≈31× lower than hot-wash budgets on the same asset. The implied per-well saving is ≈7.94 million KZT yr^{-1}; for a 50-well program, this corresponds to ≥397 million KZT yr^{-1} in avoided expenditure. Continuous in-well action of the reciprocating toothed head on each rod stroke disrupts the boundary wax layer and limits deposit regrowth between services, eliminating periodic thermal/chemical treatments and their logistics. The subassembly mass (≈30 kg) permits installation with standard handling; the pump string configuration is unchanged apart from the insertion of the scraper section. Compared with thermal, chemical, and batch mechanical methods, the technology extends service intervals, removes cleaning-related shut-ins, and compresses the cleaning budget to a predictable, low annual service cost. The results support routine use of rod-driven scraping for ARPD control in wax-prone wells and provide quantitative guidance for field-scale rollout and further optimization (wear resistance, centralization tolerances, and application in deviated completions).

Keywords: paraffin deposits, tubing cleaning, mechanical scraper, enhanced oil recovery, sucker rod motion, mature oil fields.

Information about authors:

Alisheva Zhanat Nurkuatovna — *PhD, Senior Researcher, D.A. Kunayev Institute of Mining, Abay str., 191, 050046, Almaty, Kazakhstan. Email: zhannat_86.2007@mail.ru; ORCID ID: https://orcid.org/0000-0003-0929-4984*

Sarsenbayev Mukhtar Abdikalykovich — *Director, LLP Scientific and Technological Park of Al-Farabi Kazakh National University, al-Farabi Ave., 71, 050040, Almaty, Kazakhstan. Email: mukhtar.sarsenbaev@mail.ru; ORCID ID: https://orcid.org/0009-0006-0644-4886*

Sarsenbaev Zhasulan Abdigapparovich — *Engineer, LLP Innovation Plus, Tole Bi Street str., 90, 050031, Almaty, Kazakhstan. Email: zhasstin@mail.ru; ORCID ID: https://orcid.org/0009-0003-3895-4985*

Baibotaeva Saltanat Elikbaevna — *PhD, Associate Professor, M. Auezov South Kazakhstan University, Tauke Khan Ave., 5, 160012, Shymkent, Kazakhstan. Email: sbaibotaeva@mail.ru; ORCID ID: https://orcid.org/0000-0002-9406-3322*

Introduction

Asphaltene - resin - paraffin deposits (ARPD) precipitate as temperature and pressure decline along the production path and accumulate on the inner surface (ID) of production tubing and other flow components. The resulting organic scaling increases hydraulic resistance and lifting energy demand, accelerates wear of downhole equipment, and triggers recurrent interventions and shut-ins, ultimately depressing well deliverability and field economics.

The problem is global: wax-prone crudes and cold environments are encountered across major petroleum provinces. Chemical (solvent/inhibitor), thermal (hot-wash), and batch mechanical methods are widely applied to mitigate ARPD, each with well-known advantages and trade-offs; nonetheless, these approaches are logistics-intensive, shutdown-dependent, and often transient under high-wax conditions, with additional concerns related to operating cost and HSE performance [[1], [2], [3]].

In Kazakhstan, paraffin-related complications are especially pronounced at Tengiz, Karazhanbas, Zhetybay, and Uzen. High paraffin content, significant cooling during lifting and transport, and complex well architectures promote rapid deposition within tubing, casing, and flowlines, increasing intervention frequency, extending downtime, and compressing margins at mature assets [4]. These operating realities motivate solutions that can control ARPD without recurring surface operations or chemical dosing and without interrupting routine production.

Objective, prior work, and contribution. Building on prior thermal, chemical, and batch-mechanical practices—which remain standard but require shut-ins, recurring logistics, and reagent handling—this study develops and field-evaluates a patented reverse-motion, rod-driven in-well scraper (model CP-TP-ST-01KZ) that delivers continuous tubing cleaning during routine sucker-rod operation, with no chemical dosing or surface interventions. We quantify performance on a before/after basis at Kazakhstani assets using three primary metrics: inter-cleaning period (ICP), cleaning-induced downtime, and cleaning-related OPEX. Field deployments demonstrate multi-month ICP (144 - 280 days) with zero cleaning-induced downtime, and compress annual cleaning costs to ≈ 0.265 million KZT per well, which is ~31× lower than hot-wash programs; this corresponds to ≈ 7.94 million KZT per well-year in avoided expenditure and ≥ 397 million KZT yr^{-1} for a 50-well program. The scraper sub integrates into standard strings (Ø73 - 89 mm tubing, Ø19 - 22 mm rods) and adds minimal handling mass (~30 kg). We show, from field deployments, that continuous, power-free in-well mechanical control sustains multi-month service intervals and removes cleaning-related shut-ins, and we quantify its techno-economic advantage over conventional regimes at mature Kazakhstani fields. We also document industrial-readiness credentials—patent protection, conformity to EAEU technical regulations, and verified domestic value content (CT-KZ) - which support scale-up within import-substitution programs [5].

Figure 1 illustrates the decline in well production rate during operation as a result of paraffin deposit accumulation. This highlights the necessity of implementing innovative cleaning methods, such as the mechanical rod scraper.

The economic impact of paraffin deposition in Kazakhstan includes substantial expenditures on pipeline cleaning, equipment repair, and a decline in production volumes. Moreover, the environmental implications are also significant, as chemical treatments commonly employed to mitigate paraffin formation may pose ecological risks [6].

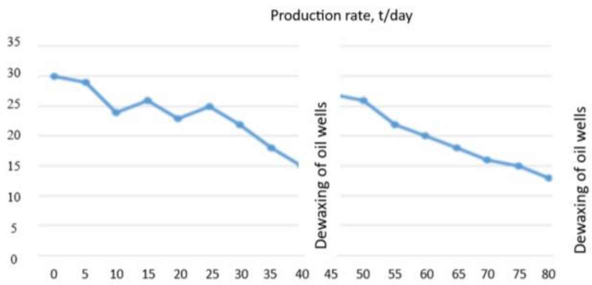

Figure 1 – Dynamics of production rate decline in a well affected by paraffin deposition during operational period

Experimental Section

Study area and materials. This study evaluates a rod-driven, reverse-motion in-well scraper for continuous mitigation of asphaltene - resin - paraffin deposits (ARPD) on the inner surface of production tubing during routine sucker-rod operation. The test envelope covered tubing strings (TBS) with nominal sizes of Ø73 - 89 mm and sucker rods Ø19 - 22 mm. Pilot trials were conducted at the Uzen oilfield (Mangystau, Kazakhstan) on Well No. 118 (GU-90), No. 2734 (GU-34), and No. 6095 (GU-15).

Representative deposit samples were characterized to quantify paraffin, resin, and asphaltene fractions and to assess flow and crystallization behavior under controlled laboratory conditions. Field operating context during the test period was: reservoir pressure 9.0 - 9.5 MPa and temperature 50 - 60 °C; the produced crude contained 12 - 15 wt.% paraffins, exhibited a viscosity of 120 - 150 mPa·s at 20 °C, and had a water cut of 85 - 95%.

1. Solvent extraction and gravimetry (resins/asphaltenes; paraffins by difference). A Soxhlet extraction system (Büchi B-811, Büchi Labortechnik AG, Switzerland) was used to fractionate deposit samples. Post-extraction masses were determined gravimetrically on an analytical balance (Mettler Toledo XS205DU, Mettler-Toledo GmbH, Switzerland; readability ±0.01 mg). Fractions were dried to constant mass and reported as wt.% of the initial sample. The paraffin (wax) fraction was obtained either by dedicated assay or by mass-balance difference from the measured resin and asphaltene fractions. Across representative

samples, the deposits were found to contain 40 - 60 wt.% wax, 10 - 15 wt.% asphaltenes, and 20 - 30 wt.% resins, values consistent with ranges reported for wax-prone mature fields [6]. All gravimetric determinations were performed in at least three technical replicates with verification of mass-balance closure.

2. Viscosity of crude oil. Dynamic viscosity was measured using a rotational viscometer (Brookfield DV3T, AMETEK Brookfield, USA). Samples were thermostated and equilibrated at the target temperature before measurement. Dynamic viscosity between 20 - 40 °C decreased with temperature, consistent with datasets for paraffinic crudes of comparable composition [[7], [8]]. All measurements adhered to ASTM D445 temperature-control and repeatability requirements, and each condition was tested in at least three technical replicates.

3. Wax solidification temperatures. Wax appearance, crystallization, and solidification behavior were determined by differential scanning calorimetry (DSC 214 Polyma, NETZSCH-Gerätebau GmbH, Germany). The analysis reported onset, peak, and endset temperatures associated with wax crystallization/solidification for the deposit/crude matrix.

4. Field operating parameters. Reservoir pressure, temperature, and water-cut values contemporaneous with sampling were taken from field operating logs and are provided above to contextualize the laboratory measurements [[7], [8], [9]].

Research Objectives. The primary objective of this study is to design and implement an innovative mechanical device—a rod scraper—for cleaning oil wells from paraffin and other solid deposits. The device is intended to mitigate operational challenges associated with ARPD, which significantly reduce well productivity, increase equipment wear, and lead to higher maintenance and repair costs. The scraper operates based on the reciprocating motion of sucker rods, ensuring continuous cleaning of the inner surface of the tubing without interrupting oil production.

As part of the study, the following tasks were accomplished:

- The design of the rod scraper was optimized to enhance the efficiency of paraffin removal from the inner surfaces of tubing and sucker rods.
- Pilot field tests of the device were conducted at wells No. 118 of GU-90, No. 2734 of GU-34, and No. 6095 of GU-15 operated by JSC "Ozenmunaigas", under various geological and technical conditions.
- A comparative analysis was performed between the proposed method and existing cleaning technologies (thermal, chemical, and other mechanical methods) in terms of efficiency, environmental safety, and economic feasibility.

Geological Characteristics of the Pilot Testing Site – Uzen Oilfield. The Uzen oilfield, located in the Mangystau region of the Republic of Kazakhstan, is one of the largest fields in the region and has been operated by JSC "Ozenmunaigas" since the early 1960s. Pilot field tests of the mechanical device for cleaning tubing from paraffin deposits were conducted at wells No. 118 (GU-90), No. 2734 (GU-34), and No. 6095 (GU-15), located within the Uzen structural zone.

The productive horizons are associated with Jurassic-age deposits, predominantly represented by terrigenous formations formed under deltaic-alluvial sedimentation conditions. Of particular interest are horizons XIII - XIV (Callovian stage), identified at depths ranging from 1,150 to 1,350 meters, as shown in the stratigraphic section along line P - P' and the structural map of the top of horizon XIII. These reservoirs are composed primarily of siltstone-sandstone sequences interbedded with argillites and sandstones, exhibiting good reservoir properties.

The upper part of the lithological-stratigraphic section consists of Albian deposits (horizons VI - VIII), while the main productive interval belongs to the Jurassic formation, beginning with horizon XIII, which is oil and gas-saturated. The dominant lithologies include sandstones, argillites, and siltstones with occasional conglomerate layers and interbedding.

The formation fluids are characterized by high viscosity (up to 150 mPa·s at 20 °C), paraffin content of up to 12 - 15%, and water cut ranging from 85% to 95% at the tested wells. Reservoir pressure varies between 9.0 and 9.5 MPa, with the formation temperature averaging around 55 °C.

The physicochemical properties of the crude oil are marked by elevated paraffin content (up to 12 - 15%) and high viscosity, reaching 120 - 150 mPa·s at 20 °C. The water cut of the wells reaches 80 - 95%, necessitating the use of specialized technologies to manage deposition and optimize production regimes.

Such geological and physical characteristics result in intense paraffin deposition within tubing, making these wells representative of water-cut and paraffin-prone systems—suitable candidates for evaluating the effectiveness of mechanical cleaning technologies.

Table 1 – Generalized Geological and Production Characteristics of the Productive Reservoirs of the Uzen Oilfield

Geological and Reservoir	
Parameter	**Value**
Reservoir type	Terrigenous (siltstone-sandstone)
Productive horizons	XIII - XIV (Callovian stage)
Depth of occurrence	1.200 – 1.350 m
Effective porosity	17 - 20%
Permeability	0.05 - 0.2 μm²
Reservoir pressure	9.0 - 9.5 MPa
Reservoir temperature	50 - 60 °C
Water cut	85 - 95%
Technological Conditions	
Crude oil pour point (max)	Up to +35 °C
Gas factor	20 - 40 m³/t
Saturation pressure	5.5 - 6.0 MPa
ARPD characteristics	Intensive deposition
Operational features	Frequent tubing cleaning, high water cut

Table 1 summarizes the principal geological, reservoir, and operational parameters of the Uzen oilfield, providing a basis for evaluating the influence of thermobaric conditions, water cut, and reservoir structure on the performance of the mechanical tubing cleaning technology for paraffin removal.

Table 2 – Physicochemical Properties of Crude Oil by Reservoirs of the Jurassic Complex (J I - J VIII)

Parameter	J I	J II	J III	J VI	J VIII
Density, g/cm³	0.849	0.849	0.851	0.863	0.822
Viscosity, cSt (at 40 °C)	15.78	8.5	12.45	15.31	3.4
Paraffin content, wt.%	27.0	23.4	22.4	16.51	–
Resin content (silica gel), wt.%	11.0	27.0	12.45	14.0	–
Asphaltene content, wt.%	–	–	–	–	5.4
Sulfur content, wt.%	0.17	0.13	0.17	0.22	–
Pour point, °C	31	30	30	30	–
Flash point, °C	-15	-15	-13	–	–

Table 2 presents a stratified characterization of crude oil from the main productive horizons of the Jurassic complex. The values of density, viscosity, and the content of paraffins, resins, and asphaltenes confirm a high tendency for ARPD formation, particularly in intervals J I - J III, which are considered the least favorable in terms of operational conditions.

Figure 2 shows geological cross-sections along lines I-I ′ and II-II ′, passing through the central part of the Uzen oilfield. The sections illustrate the structure of the productive horizons, including XIII and XIV (Callovian stage), which were the focus of the pilot field tests.

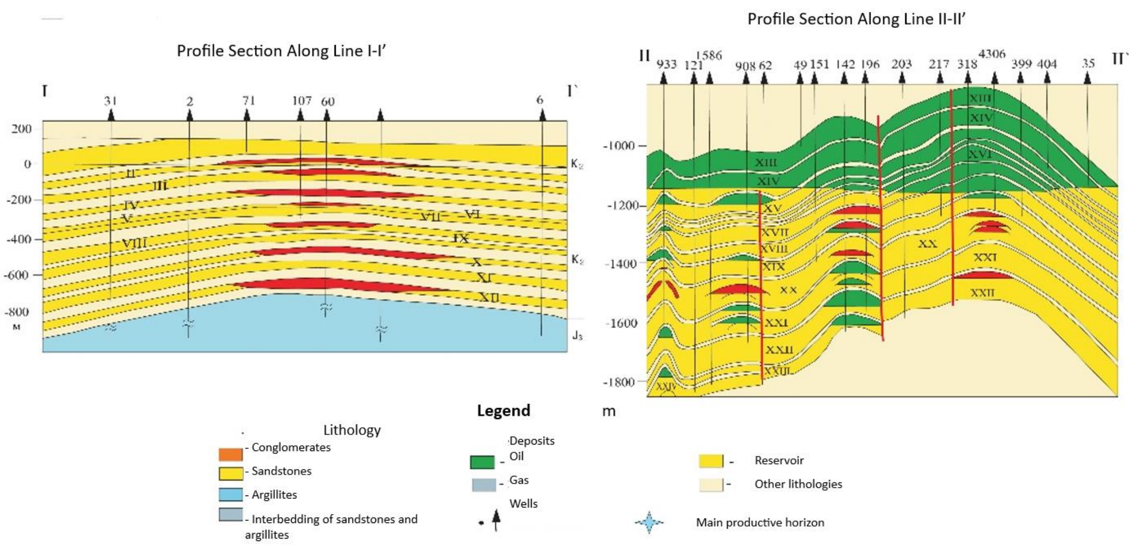

Figure 2 – Geological Cross-Sections of the Uzen Oilfield (Lines I-I’ and II-II’)

Alternating layers of sandstones, siltstones, and argillites forming the oil-bearing zone are clearly traced. The cross-sections also depict the thickness variability, discontinuity of the reservoirs, and a characteristic anticlinal structural pattern, confirming favorable conditions for hydrocarbon accumulation and justifying the selection of wells No. 118, No. 2734, and No. 6095 for the experimental trials.

Operating Principle of the Device. Full name and model. Reverse-motion, rod-driven in-well scraper, model CP-TP-ST-01KZ (manufacturer: Kazakhstan - China). Certificate No. 5104620; Chinese utility model patent CN ZL 2015 2 0892020.4 and industrial design ZL 2016 3 0164862.8 (covering a functionally similar scraper architecture); conformity with EAEU technical regulations; verified domestic value content (CT-KZ).

The operating principle of the device is based on the reciprocating motion of the sucker rod. During this motion, the scraper—equipped with reversible elements—cleans the inner surface of the tubing without requiring a well shutdown. The reversible teeth and springs adapt to the direction of movement, ensuring cyclic removal of deposits along the working section of the pipe.

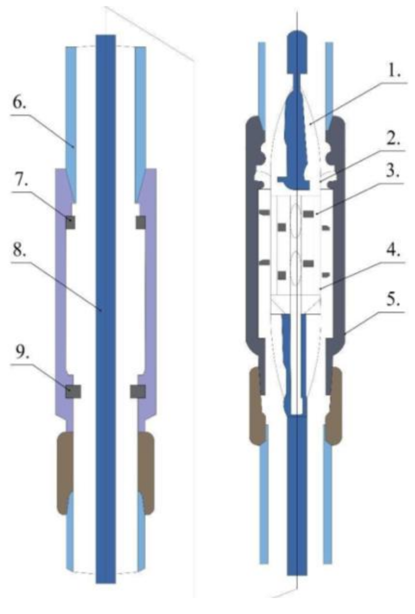

Figure 3 – Schematic Diagram of the Device

The proposed device consists of a set of functional components designed to provide mechanical cleaning of the inner surface of tubing during well operation:

1. Flexible guides – Ensure central alignment of the device within the tubing string, minimizing the risk of contact with the walls and improving stroke stability.
2. Unidirectional ring – Locks the device in the desired direction of movement, preventing slippage during the return stroke of the rod.
3. Spring plate – The main working element that maintains contact with the inner wall of the tubing and removes paraffin deposits through frictional force.
4. Reversible tooth – Engages the change in movement direction of the scraper, enabling cyclic operation under reciprocating motion.
5. Upper limiter (commutator) – Restricts the upward travel of the device and defines the upper boundary of the cleaning interval.
6. Tubing (TBS) – A component of the production string where paraffin deposits typically form on the inner surface.
7. Lower limiter (commutator) – Limits the downward movement of the device and defines the lower boundary of the cleaning zone.
8. Sucker rod – Serves as the drive mechanism for scraper movement, providing reciprocating motion as part of the downhole pump assembly.
9. Locking ring – Prevents displacement of individual structural components during operation and ensures reliable fixation of all assembled elements.

This configuration enables continuous cleaning of the tubing without the need for well shutdown or equipment disassembly. The use of reversible and guiding elements ensures effective scraper performance under various tubing diameters and curvatures of production strings.

Figure 3 presents a schematic diagram of the device for cleaning the inner surface of tubing.

Comparison with Existing Methods. The issue of paraffin deposition in oil production is traditionally addressed using various approaches, including mechanical, chemical, thermal, and combined methods. However, each of these techniques has its own advantages and limitations. This section presents a comparative analysis of the developed mechanical device (rod scraper) against existing paraffin removal technologies.

Table 3 provides a comparative assessment of the proposed technology in relation to conventional methods for paraffin deposit removal [[10], [11], [12]].

Table 3 – Comparative Analysis of the Proposed Technology and Existing Methods for Paraffin Deposit Removal

№	Criterion	Mechanical Methods	Chemical Methods	Thermal Methods	Combined Methods	Proposed Rod Scraper
1	Operating principle	Mechanical removal of paraffin using rigid scrapers	Paraffin dissolution by chemical reagents	Heating of oil and tubing to melt deposits	Combination of chemical, mechanical, and thermal techniques	Removal of deposits through reciprocating motion of sucker rods
2	Need to shut down production	Required for scraper replacement	Not required, reagents injected into the flow	Required for steam or hot oil treatment	Partially required, depending on the method combination	Not required; cleaning occurs during normal well operation
3	Energy efficiency	Moderate, requires periodic scraper retrieval	High costs due to reagent usage	High energy consumption for heating	High due to complexity of integrated treatment	High, no external power supply needed
4	Environmental safety	Moderate, removed paraffin may require disposal	Low, potential environmental contamination by chemicals	Low, due to high energy demand and possible reservoir damage	Low, combined chemical and thermal impact intensifies risks	High, no chemicals or energy-intensive processes used
5	Implementation complexity	Moderate, requires equipment replacement	Moderate, requires chemical injection systems	High, requires installation of heating systems	Very high, complex coordination of technologies required	Low, easily integrated into existing systems without modification
6	Need for continuous monitoring	High, due to wear of mechanical parts	High, constant reagent dosing required	High, temperature control required	Very high, all systems require monitoring	Low, operates via rod movement without external control
7	Durability and reliability	Moderate, requires regular maintenance	Moderate, potential buildup of by-products in tubing	Low, frequent overheating may damage reservoir	Moderate, control system complexity reduces reliability	High, minimal wear during long-term use

Table 4 – Opportunities for Development and Scaling of the Rod Scraper Technology

№	Direction	Description
1	Horizontal and deviated wells	Adaptation of the design for operation in complex well trajectories, including multilateral wells.
2	Design and material improvement	Enhancement of wear resistance and corrosion protection; optimization of reversible elements and springs to reduce drag.
3	Integration of digital solutions	Implementation of monitoring and AI-based analytics to assess cleaning efficiency and predict deposit formation.
4	Combination with other methods	Integration with chemical inhibitors and thermal flushing to enhance the overall cleaning effect.
5	Scaling and commercialization	Deployment across oilfields in Kazakhstan and export of the technology to regions facing similar challenges.

Unlike conventional mechanical devices, the proposed scraper operates in a cyclic mode activated by the reciprocating motion of the sucker rod, which extends the interval between cleanings and reduces maintenance costs [[13], [14], [15], [16]].

Thus, further development and refinement of the technology will significantly enhance oil production efficiency, reduce operating costs, and minimize the negative impact of paraffin deposits on oilfield infrastructure [[17], [18], [19], [20], [21]]. As Table 4 indicates, further development and refinement of the technology will improve efficiency and reduce costs.

Discussion of Results

A three-well pilot (No. 118, 2734, 6095) confirmed the efficacy of the rod scraper under representative Uzen operating conditions. Paraffin accumulation decreased sufficiently to extend the inter-cleaning period (ICP; defined as the elapsed time between consecutive mechanical wax-removal events) from 7 - 10 days (baseline) to 30 - 45 days (pilot), i.e., a ≈3 - 6× increase and a ≈70 - 85% reduction in intervention frequency. All chemical reagents previously applied for dewaxing were discontinued at the pilot wells, and daily oil rates remained within the pre-pilot variability band, indicating no adverse impact on production.

Operating conditions (high water cut, elevated wax content/viscosity at surface temperatures, and a typical Uzen thermobaric regime) are characteristic of mature Kazakh assets, supporting applicability to analogous well stock. Importantly, deployment did not require well shut-in or modification of the pumping assembly, avoiding deferred production associated with conventional cleaning routines.

To ensure that ICP gains reflected genuine wax-control performance rather than scheduling artifacts, effectiveness was tracked via routinely available indicators: (i) the count of mechanical cleaning events per month, (ii) torque/load trends on the rod string and drive amperage, and (iii) wellhead pressure/ΔP stabilization between cleanings. These independent indicators improved coherently with the ICP extension.

The field outcome is consistent with laboratory characterization: deposits rich in paraffin (≈40 - 60 wt.%) and DSC evidence of wax crystallization near operating temperatures, together with temperature-dependent viscosity measured on the crude, provide a mechanistic basis for the observed reduction in deposition frequency. Maintaining flow above the crystallization onset and regularly disrupting nascent structure with the scraper plausibly suppresses layer growth and delays critical thickness.

The magnitude of ICP extension aligns with ranges reported for mechanical wax-control approaches in paraffinic, high-water-cut systems and, in several cases, exceeds them, while eliminating solvent use [8]. From an HSE and sustainability perspective, removing solvent treatments reduces chemical handling and personnel exposure; fewer interventions also decrease energy use and operational risk. Limitations include the three-well scope and a finite observation window; broader deployment should include longer monitoring to capture seasonality, quantification of removed wax mass or thickness where feasible, and stratified analysis by water cut and fluid rheology. Even with these caveats, the pilot provides operationally actionable evidence that the rod scraper is a viable, lower-risk alternative to energy-intensive and environmentally burdensome dewaxing practices in wax-prone systems.

Conclusions

A mechanical rod scraper was developed and field-tested for cyclic in-well removal of paraffin deposits from tubing and sucker rods. Representative deposits contained 40-60 wt.% wax, 10-15 wt.% asphaltenes, and 20-30 wt.% resins. Differential scanning calorimetry showed a crystallization onset overlapping field operating temperatures (≈50-60 °C), indicating elevated deposition risk. The crude contained 12-15 wt.% paraffins and had a viscosity of 120-150 mPa·s at 20 °C, decreasing across 20-40 °C in line with datasets for paraffinic crudes of comparable composition [[6], [8]]. Measurements followed ASTM D445 with at least three technical replicates per condition.

In pilot operation, the inter-cleaning period (ICP) increased from 7-10 days (baseline) to 30-45 days with the scraper, a 3-6× extension corresponding to ~70-85% fewer interventions under 9.0-9.5 MPa, 50-60 °C, and 85-95% water cut. Relative to conventional mechanical/chemical/thermal routines, the device delivered ICP gains that meet or exceed typical literature ranges for mechanical wax control (≈1.5-4×) while avoiding reagent use and thermal energy input. These results indicate that maintaining operation above the crystallization onset and applying cyclic in-well scraping materially reduces wax-related maintenance in paraffin-prone mature fields.

Key operational advantages:

- Continuous operation. Scraping is driven by the reciprocating motion of the sucker rod, allowing deposit removal without production shutdown and extending ICP.
- Lower operating cost. Elimination of chemical reagents and thermal treatments reduces consumables and simplifies field procedures.
- Environmental and integrity benefits. No chemical exposure; reduced corrosion risk for tubing and downhole equipment.
- Drop-in integration. The scraper can be installed in existing pumping strings without major modifications.
- Adaptability. Compatible with a range of tubing diameters and operating profiles; applicable to paraffin-prone wells across mature Kazakhstani fields.

Recommendations

To maximize the benefits of the proposed technology and ensure its sustainable deployment, the following measures are recommended:

- Field-wide implementation at oilfields with high paraffin deposition potential (e.g., Tengiz, Zhetybay, Karazhanbas), with prioritization of wells exhibiting frequent plugging and high water cut.
- Optimization of operational parameters based on field-specific monitoring of scraper performance, allowing adjustment of stroke frequency, contact force, and cleaning interval.
- Integrated approach: In cases of severe deposition, the mechanical scraper may be combined with periodic thermal treatments to enhance cleaning efficiency without compromising equipment integrity.
- Further R&D: Investigation into material wear resistance and structural reliability under complex geological conditions, including horizontal and high-viscosity wells.
- Development of an automated monitoring system to track scraper performance in real time, enabling predictive maintenance and further improving operational safety and efficiency.

Conflict of Interest: On behalf of all authors, the corresponding author declares that there is no conflict of interest.

CRediT author statement: **Zh. Alisheva**: Conceptualization, Methodology, Supervision, Reviewing and Editing; **M. Sarsenbayev**: Data curation, Writing draft preparation; **Zh. Sarsenbaev**: Visualization, Investigation; **S. Baibotaeva**: Software.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Cite this article as: Alisheva ZhN, Sarsenbayev MA, Sarsenbaev ZhA, Baibotaeva SE. Innovative technologies for paraffin deposit removal in oil tubing to enhance oil recovery: a mechanical approach. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2027; 341(2):49-59. https://doi.org/10.31643/2027/6445.17

Мұнай өндіруді арттыру үшін мұнай құбырларын парафиндік шөгінділерден тазалаудың инновациялық технологиялары: механикалық әдіс

[1]Алишева Ж.Н., [2]Сарсенбаев М.А., [3]Сарсенбаев Ж.А., [4] Байботаева С.Е.

[1] Д.А. Қонаев атындағы Тау-кен істері институты, Алматы, Қазақстан
[2] әл-Фараби атындағы Қазақ Ұлттық Университетінің Ғылыми-технологиялық паркі ЖШС, Алматы, Қазақстан
[3] Инновациялар Плюс ЖШС, Алматы, Қазақстан
[4] М.Әуезов ат. Оңтүстік Қазақстан университеті, Шымкент, Қазақстан

ТҮЙІНДЕМЕ
Мұнай ұңғымалары құбырларының (ҰҚ) ішкі бетіндегі асфальт-шайыр-парафинді шөгінділер (АШПШ) құбырлардың қызмет көрсету мерзімін қысқартады, операциялық шығындарды арттырады және және кемелденген кен орындарының жиі тоқтап қалуына әкеледі. Жұмыста ұңғыішілік штангалы қырғыштың құрылымы және штангілі сорғының штаттық жұмысы кезінде ҰҚ-ны үздіксіз тазалау бойынша далалық сынақтардың нәтижелері ұсынылады; әдіс

химиялық дозалауды да, жер үстіндегі операцияларды да талап етпейді. Торап штангілер колоннасына енгізіледі және Ø73 - 89 мм НКҚ-мен, Ø19 - 22 мм штангілермен үйлесімді. Өнімділік енгізуге дейін/кейін салыстыру арқылы бағаланды: онда тазалаудың аралық кезеңі (ТАК), тоқтап тұру уақыты және тазалауға кететін жылдық шығын, әрі қарай көп ұңғымалы бағдарламаға таратылуы (экстраполяциялануы) ескеріліп жасалды. СР ТР ST 01KZ моделі бойынша өндіріске енгізулер ТАК 144 - 280 тәулікке жеткізілді, ал тазалауға байланысты тоқтап тұру — 0 тәул/жыл. Тазалауға жылдық шығын ~0,265 млн KZT/ұңғы (тек регламенттік қызмет), бұл сол қордағы ыстық жуу бюджетінен шамамен 31 есе төмен. Тиісінше, бір ұңғымаға үнем ≈7,94 млн KZT/жыл құрайды; 50 ұңғы көлемінде жиынтық әсер ≥397 млн KZT/жыл үнемдейді. Штангінің әр жүрісінде кері-ілгері қозғалатын тісті бастиек ҰҚ ішіндегі шекаралық парафин қабатын бұзып, қызмет көрсету арасындағы шөгінді өсуін тежейді; бұл мерзімді термиялық/химиялық өңдеулер мен оларға байланысты болатын логистика қажеттілігін жояды. Тораптың массасы шамамен 30 кг, сондықтан монтаж стандартты құралдармен орындалады; қырғыш секциясын енгізуден басқа сорғы колоннасының компоновкасы өзгермейді. Жылулық, химиялық және механикалық тәсілдермен салыстырғанда ұсынылған технология сервистік мерзім аралығын ұзартады, тазалау үшін тоқтап тұруды жояды және тазалау бюджетін төмен тұрақты жылдық қызмет көрсету шығынына дейін қысқартады. Алынған нәтижелер парафинді ұңғымаларда АШПШ-ды мониторинг жасау үшін қырғышты тұрақты пайдалану мүмкіндігін растайды және қорға масштабтауға және одан әрі оңтайландыруға (тозуға төзімділік, орталықтандыру талаптары, бағытталған ұңғымаларда пайдалану) сандық нұсқаулар береді.

Мақала келді: *22 сәуір 2025*
Сараптамадан өтті: *6 тамыз 2025*
Қабылданды: *18 қараша 2025*

Түйін сөздер: парафин шөгінділері, ҰҚ тазарту, механикалық қырғыш, мұнайберуді арттыру, штангалар қозғалысы, кемелденген кен орындары.

Авторлар туралы ақпарат:

Алишева Жанат Нуркуатовна — *PhD, жетекші ғылыми қызметкер, Д.А. Қонаев атындағы Тау-кен істері институты, Абай даңғ., 191, 050046, Алматы, Қазақстан. Email: zhannat_86.2007@mail.ru; ORCID ID: https://orcid.org/0000-0003-0929-4984*

Сәрсенбаев Мухтар Абдикалыкович — *Директор, әл-Фараби атындағы ҚазҰУ-нің Ғылыми-технологиялық паркі ЖШС, әл-Фараби даңғ., 71, 050040, Алматы, Қазақстан. Email: mukhtar.sarsenbaev@mail.ru; ORCID ID: https://orcid.org/0009-0006-0644-4886*

Сарсенбаев Жасулан Абдигаппарович — *Инженер, Инновациялар Плюс ЖШС, Төле би көш., 90, 050031, Алматы, Қазақстан. Email: zhasstin@mail.ru; ORCID ID: https://orcid.org/0009-0003-3895-4985*

Байботаева Салтанат Еликбаевна — *PhD, доцент, М.Әуезов атындағы Оңтүстік Қазақстан университеті, Тәуке-хан даңғ., 5, 160012, Шымкент, Қазақстан. Email: sbaibotaeva@mail.ru; ORCID ID: https://orcid.org/0000-0002-9406-3322*

Инновационные технологии очистки нефтяных труб от парафиновых отложений для повышения нефтеотдачи: механический подход

[1]Алишева Ж.Н., [2]Сарсенбаев М. А., [3]Сарсенбаев Ж.А., [4] Байботаева С.Е.

[1] Институт Горного дела имени Д.А. Кунаева, Алматы, Казахстан
[2]ТОО Научно-технологический парк Казахского национального университета имени Аль-Фараби, Алматы, Казахстан
[3]ТОО Инновации Плюс, Алматы, Казахстан
[4]Южно-Казахстанский университет имени М. Ауэзова, Шымкент, Казахстан

Поступила: *22 апреля 2025*
Рецензирование: *6 августа 2025*
Принята в печать: *18 ноября 2025*

АННОТАЦИЯ

Асфальтосмолопарафиновые отложения (АСПО) на внутренней поверхности насосно-компрессорных труб (НКТ) сокращают межсервисные интервалы, повышают эксплуатационные затраты и нередко вызывают простои на зрелых месторождениях. В работе представлены конструкция и результаты полевых испытаний внутрискважинного штангового скребка, обеспечивающего непрерывную очистку НКТ в процессе штатной работы штангового насоса без химических дозировок и поверхностных операций. Узел врезается в колонну штанг и совместим с НКТ Ø73 - 89 мм и штангами Ø19 - 22 мм. Эффективность оценивалась по ключевым метрикам до/после внедрения: межочистной период (МОП), простой и годовые затраты на очистку, с экстраполяцией на многоскважинные программы. По результатам внедрений скребка СР ТР ST 01KZ достигнут МОП 144 - 280 сут, при этом простой, обусловленный очисткой, равен 0 сут/год. Годовые затраты на очистку составили ~0,265 млн KZT на скважину (регламентное обслуживание), что примерно в 31 раз ниже бюджета горячих промывок на том же фонде. Соответственно, экономия на одной скважине — около 7,94 млн KZT/год; при фонде 50 скважин совокупный эффект достигает ≥ 397 млн KZT/год предотвращённых расходов. Непрерывное внутрискважинное действие возвратно-поступательной зубчатой головки при каждом ходе

	штанги разрушает граничный парафиновый слой и ограничивает нарастание отложений между обслуживаниями, устраняя необходимость периодических термических/химических воздействий и связанной с ними логистики. Масса узла порядка 30 кг позволяет выполнять монтаж штатными средствами; компоновка насосной установки не изменяется, кроме врезки секции со скребком. В сравнении с тепловыми, химическими и пакет-механическими методами технология обеспечивает более длительные межсервисные интервалы, исключает простои, связанные с очисткой, и сводит бюджет на очистку к предсказуемой, низкой годовой стоимости обслуживания. Полученные результаты подтверждают возможность регулярного применения скребка для контроля АСПО на парафинистых скважинах и предоставляют количественные ориентиры для масштабирования на фонд и дальнейшей оптимизации (износостойкость, требования к центровке, применение в наклонно-направленных стволах).
	Ключевые слова: Парафиновые отложения, очистка НКТ, механический скребок, увеличение нефтеотдачи, движение насосных штанг, зрелые месторождения.
Алишева Жанат Нуркуатовна	***Информация об авторах:*** *PhD, Ведущий научный сотрудник, Институт Горного дела имени Д.А. Кунаева, пр. Абая, 191, 050046, Алматы, Казахстан. Email: zhannat_86.2007@mail.ru; ORCID ID: https://orcid.org/0000-0003-0929-4984*
Сарсенбаев Мухтар Абдикалыкович	*Директор, ТОО Научно-технологический парк Казахского национального университета имени Аль-Фараби, пр. аль-Фараби, 71, 050040, Алматы, Казахстан. Email: mukhtar.sarsenbaev@mail.ru; ORCID ID: https://orcid.org/0009-0006-0644-4886*
Сарсенбаев Жасулан Абдигаппарович	*Инженер, ТОО Инновации Плюс, ул. Толе би, 90, 050031, Алматы, Казахстан. Email: zhasstin@mail.ru; ORCID ID: https://orcid.org/0009-0003-3895-4985*
Байботаева Салтанат Еликбаевна	*PhD, доцент, Южно-Казахстанский университет имени М. Ауэзова, Пр. Тауке-хана, 5, 160012, Шымкент, Казахстан. Email: sbaibotaeva@mail.ru; ORCID ID: https://orcid.org/0000-0002-9406-3322*

References

[1] Pat. 7700 KZ. Method for cleaning oil pumping wells from paraffin and other deposits. Sarsenbaev AA, Zhan YM, Karibai E, Altybai KA, Sarsenbaev MA, Sarsenbaev ZA. Appl. 30.12.2022, publ. 30.12.2022. https://qazpatent.kz/en/content/poleznaya-model-30122022

[2] Metaksa GP, Alisheva ZN, Metaksa AS, Fedotenko NA. Scientific and technical fundamentals of changing the properties of hydrocarbons in conditions of optimal subsoil use. Eurasian Mining. 2023; 2:75-79. https://doi.org/10.17580/em.2023.02.16

[3] Wang X, Gurbanov H, Adygezalova M, Alizade E. Investigation of Removing Asphaltene-Resin-Paraffin Deposits by Chemical Method for Azerbaijan High-Paraffin Oil Production Process. Energies. 2024; 17(15):3622. https://doi.org/10.3390/en17153622

[4] Nuruallaev V, Usubaliev B. New methods for combating asphalt-resin-paraffin deposits in oil transportation processes. Proceedings on Engineering Sciences. 2021; 3(2):193-200. https://doi.org/10.24874/PES03.02.007

[5] Korobov GYu, Parfenov DV, Nguyen VT. Mekhanizmy obrazovaniya asfal'tosmoloparafinovykh otlozheniy i faktory intensivnosti ikh formirovaniya [Mechanisms of formation of asphalt-resin-paraffin deposits and factors of the intensity of their formation]. Izvestiya Tomsk Polytechnic University. Engineering of Georesources. 2023; 334(4):103–116. https://doi.org/10.18799/24131830/2023/4/3940

[6] Tanirbergenova S, Ongarbayev Y, Tileuberdi Y, Zhambolova A, Kanzharkan E, Mansurov Z. Selection of solvents for the removal of asphaltene-resin-paraffin deposits. Processes. 2022; 10(7):1262. https://doi.org/10.3390/pr10071262.

[7] Alisheva Z, Nadirov K, Al-Dujaili AN, Bimbetova G, Nadirova Z, Zhantasov M, Tileuberdi N, Dauletuly A. Integrated strategies for controlling water cut in mature oil fields in Kazakhstan. Polymers. 2025; 17(7):829. https://doi.org/10.3390/polym17070829.

[8] Wang X, Gurbanov H, Adygezalova M, Alizade E. Investigation of removing asphaltene-resin-paraffin deposits by chemical method for Azerbaijan high-paraffin oil production process. Energies. 2024; 17(15):3622. https://doi.org/10.3390/en17153622.

[9] Khuramshina RA, Muratova VI. Studies of the use of ultrasonic equipment for the removal of asphalt-resin-paraffin deposits at oil and gas transport and storage facilities. Materials Science Forum. 2024; 1080:157-162. https://doi.org/10.4028/p-2p7s8j.

[10] Akbari A, Kazemzadeh Y, Martyushev D, Cortes F, et al. Using ultrasonic and microwave to prevent and reduce wax deposition in oil production. Petroleum, 2024; 10(4):584-593. https://doi.org/10.1016/j.petlm.2024.09.002

[11] Garcia MC. Mechanical cleaning devices for wax deposition in pipelines. Journal of Natural Gas Science and Engineering. 2020; 77:103248. https://doi.org/10.1016/j.jngse.2020.103248

[12] Ahmed S. Integrated approaches to mitigate paraffin deposition in oil production. Journal of Petroleum Exploration and Production Technology. 2021;11(2):581-593. https://doi.org/10.1007/s13202-020-01100-3

[13] Gurbanov GR, Adigozalova MB, Akhmedov SF. Research into the influence of the depressant additive Difron-4201 on the formation of paraffin deposits in laboratory conditions. Azerbaijan Oil Economy. 2020; 12:30-36. https://doi.org/10.20944/preprints202407.1242.v1

[14] Aum YK, Aum PT, da Silva DN, et al. Effective removal of paraffin deposits using oil-in-water microemulsion systems. Fuel. 2024; 358:130112. https://doi.org/10.1016/j.fuel.2023.130112

[15] Gao X, Huang Q, Yun Q, Li Q, Li W, Liang Y, Wang K, Chen C, Liu H, Paso KG. Modeling wax deposit removal during pigging with foam pigs. Geoenergy Science and Engineering. 2024. https://doi.org/10.1016/j.geoen.2024.212713

[16] Panahov EM, Abbasov SZ, Ismayilov AS, Gurbanov GR. Development of a new composition for the prevention of asphaltene-paraffin-resin deposits. Azerbaijan Oil Economy. 2023; 14:65-70. https://doi.org/10.20944/preprints202407.1242.v1

[17] Johnson M. Advances in paraffin deposition prevention in oil pipelines. Journal of Petroleum Science and Engineering. 2015; 126:208-215. https://doi.org/10.1016/j.petrol.2014.12.024

[18] Smith JA. Chemical methods for paraffin control in crude oil production. Energy & Fuels. 2017; 31(5):5056-5062. https://doi.org/10.1021/acs.energyfuels.7b00123

[19] Bell E, Santos G, Daraboina N, Sarica C. Visualization of thermal removal mechanism of paraffin deposits: Providing guidelines for minimum temperature requirements. Fuel. 2024; 356:129577. https://doi.org/10.1016/j.fuel.2023.129577

[20] Wang Y. Thermal techniques in paraffin removal from oil pipelines. Petroleum Science. 2019; 16(3):693-702. https://doi.org/10.1007/s12182-019-0323-3

[21] Wang Z, Zhang K, Sun H. Melting and removing wax deposition by thermal washing in oil well. Geoenergy Science and Engineering. 2024; 237:212808. https://doi.org/10.1016/j.geoen.2024.212808