HSR London International Conference on Multidisciplinary Academic Research
(HSR-ICMAR) 2026
https://houghtonstreetreview.com/index.php/conference

UDC 628.316.12:622.276

ADSORPTIVE DEEP PURIFICATION OF OIL-AND-GAS WASTEWATER USING LOCAL ORGANOBENTONITE

Dustov Aziz Yusufovich[1]
Shukrullayev Doniyor Dilshodovich[2]
Tog‘ayev Hasan Abdivohid o‘g‘li[1],
[1]Iqtisodiyot va pedagogika universiteti Qarshi, O‘zbekiston
[2]Qarshi davlat texnika universiteti Qarshi, O‘zbekiston

Abstract. This paper summarizes the development of an adsorptive deep-purification technology for oil-and-gas wastewater based on local organobentonite. Navbahor bentonite was modified with a cationic surfactant, increasing the basal spacing from 1.35 to 2.05 nm. Equilibrium followed the Langmuir model (q_{max} = 95 mg/g, R^2 = 0.992) and pseudo-second-order kinetics (R^2 = 0.995); the process was endothermic ($\Delta H°$ = +14.2 kJ/mol). Fixed-bed studies gave a dynamic capacity of 57 mg/g, and the overall removal efficiency reached 98%. The local organobentonite is a low-cost alternative to imported activated carbon.

Keywords: organobentonite, adsorption, oil-and-gas wastewater, Langmuir isotherm, fixed-bed, deep purification.

1. Introduction

Wastewater from oil-and-gas production contains dissolved petroleum products and organic compounds that conventional mechanical and flotation stages cannot reduce to permissible limits [1, 2]. Adsorption is a reliable final (deep-purification) stage capable of lowering residual dissolved hydrocarbons below regulatory thresholds. Natural bentonite is hydrophilic and weakly retains non-polar hydrocarbons; modification with a cationic surfactant converts it into an organophilic sorbent with greatly enhanced affinity for petroleum products [3, 4]. This work summarizes the synthesis, characterization and adsorption performance of local organobentonite and the resulting treatment technology.

2. Materials and Methods

Local Navbahor (Navoi) bentonite (montmorillonite content 78%, cation exchange capacity 0.95 meq/g) was modified with a cationic surfactant in aqueous medium under optimized conditions (1.0 CEC, 60 °C, 3 h). Structural changes were examined by XRD, FTIR and low-temperature nitrogen adsorption (BET). Batch and fixed-bed (column) adsorption experiments were performed with petroleum-product model solutions.

Equilibrium capacity and removal efficiency were obtained from a mass balance, the Langmuir model was used for the isotherm and the Thomas model for the breakthrough curve:

$$C_e/q_e = 1/(q_{max}\cdot K_L) + C_e/q_{max} \quad (1)$$

$$\ln(C_0/C_t - 1) = (k_{Th}\cdot q_0\cdot m)/Q - k_{Th}\cdot C_0\cdot t \quad (2)$$

3. Results and Discussion

XRD and FTIR confirmed successful modification: the basal spacing d_{001} expanded from 1.35 to 2.05 nm and aliphatic C–H bands appeared at 2920 and 2850 cm^{-1}. The BET surface area decreased from 65 to 25 m^2/g, indicating that uptake proceeds by partition into the interlayer organic phase rather than by surface adsorption.

Equilibrium data were best described by the Langmuir isotherm (Fig. 1), giving a maximum capacity of 95 mg/g — 5.3 times higher than raw bentonite (18 mg/g). The separation factor R_L = 0.077 confirms favourable adsorption, and the kinetics followed the pseudo-second-order model (R^2 = 0.995, q_e = 92 mg/g). Thermodynamic analysis indicated a spontaneous ($\Delta G° < 0$) and endothermic ($\Delta H°$ = +14.2 kJ/mol) process.

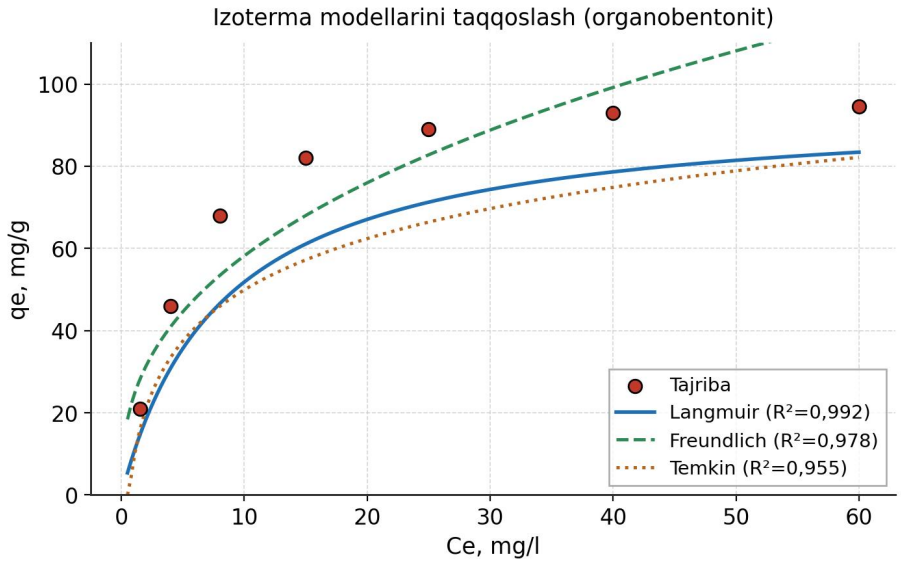


Fig. 1. Comparison of adsorption isotherm models (organobentonite)

Fixed-bed experiments (Fig. 2) were described well by the Thomas and Yoon–Nelson models ($R^2 > 0.985$), yielding a dynamic capacity of 57 mg/g (about 60% of the static maximum). The breakthrough behaviour provides the basis for adsorber design.

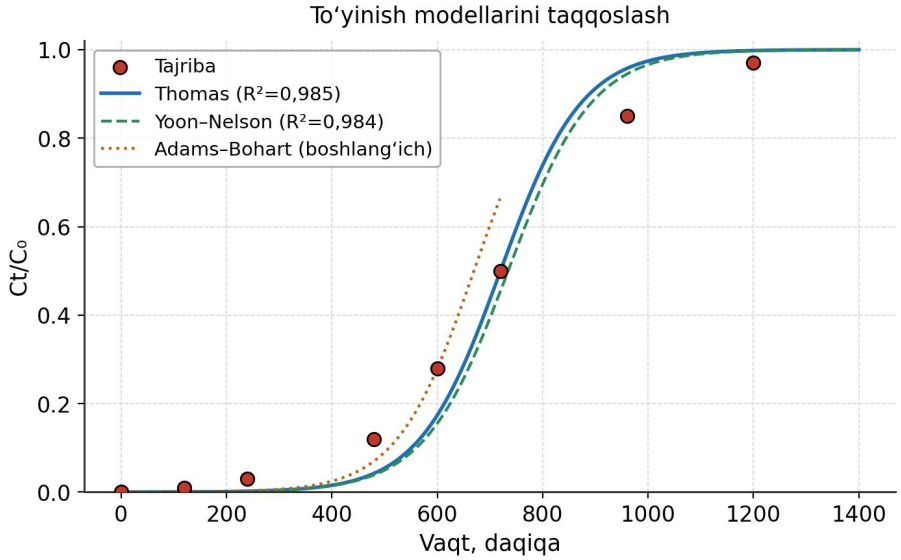


Fig. 2. Breakthrough models (Thomas, Yoon–Nelson, Adams–Bohart)

In multicomponent real wastewater (Fig. 3), the organobentonite effectively removed petroleum products (98%), suspended solids (93%), iron compounds (93%) and chemical oxygen demand (79%), reaching equilibrium within 60–90 min. The proposed technology integrates an organobentonite adsorber block (2 working + 1 standby) after the existing mechanical-flotation stage, lowering petroleum products from 100 to about 2.0 mg/l (below the 3.0 mg/l limit) at an overall efficiency of about 98%.

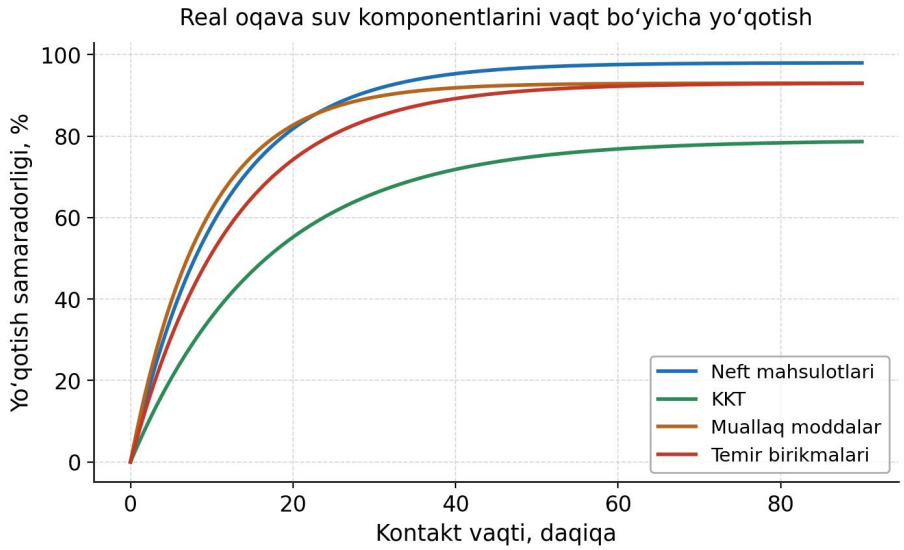


Fig. 3. Time-dependent removal of real wastewater components

Because the sorbent is produced from a local raw material and can be regenerated (82% capacity retained after six cycles), the treatment cost is 40–60% lower than with imported activated carbon, demonstrating both environmental and economic feasibility.

Compared with other sorbents tested under identical conditions, the organobentonite (q_{max} = 95 mg/g) outperformed raw bentonite (18 mg/g) and natural zeolite (35 mg/g) and approached activated carbon (180 mg/g) while remaining far cheaper and locally available. The Freundlich capacity coefficient ($K_F \approx 24$) and the favourable separation factor support its high affinity for petroleum products. Notably, the high capacity is achieved despite a low specific surface area (25 m^2/g), which confirms that uptake proceeds by partition into the interlayer organic phase rather than by surface adsorption — a feature that distinguishes organobentonite from classical porous sorbents.

The kinetic and thermodynamic behaviour was further analysed using the pseudo-second-order rate law and the van’t Hoff relation:

$$t/q_t = 1/(k_2 \cdot q_e^2) + t/q_e \quad (3)$$

$$\ln K_c = \Delta S^\circ/R - \Delta H^\circ/(R \cdot T) \quad (4)$$

The pseudo-second-order model described the entire kinetic curve with high accuracy (k_2 = 0.012 $g \cdot mg^{-1} \cdot min^{-1}$, q_e = 92 mg/g, R^2 = 0.995), indicating that chemisorption-type interactions govern the uptake rate, whereas the pseudo-first-order model fitted only the initial stage (R^2 = 0.962). The positive ΔH° (+14.2 kJ/mol) and ΔS° (+95 $J \cdot mol^{-1} \cdot K^{-1}$), together with negative ΔG° values (from −14.1 to −16.0 kJ/mol over 298–318 K), confirm a spontaneous, endothermic process accompanied by increased randomness at the solid–liquid interface.

On the basis of these results, an adsorptive deep-purification technology was designed (Fig. 4). The organobentonite adsorber block is installed after the existing mechanical-flotation stage and operates in a 2-working + 1-standby configuration, providing continuous treatment of 2700 m^3/day while one adsorber is regenerated. A namuna (design) calculation yielded an adsorber diameter of 3.8 m and a bed height of 1.67 m for an empty-bed contact time of 20 min.

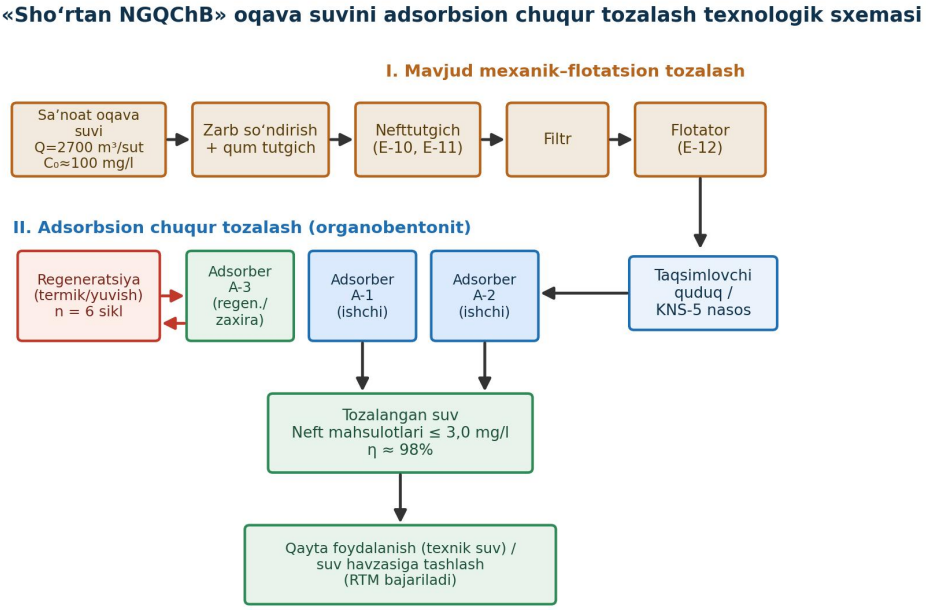


Fig. 4. Technological scheme of adsorptive deep purification of oil-and-gas wastewater

4. Conclusion

Local organobentonite is an effective and low-cost sorbent for the deep purification of oil-and-gas wastewater. It exhibits a Langmuir capacity of 95 mg/g, pseudo-second-order kinetics, an endothermic character and a dynamic capacity of 57 mg/g, providing about 98% removal of petroleum products. The technology is a viable, locally sourced alternative to imported activated carbon.

References

1. Yu F. et al. Adsorptive removal of oil from water: A review // Journal of Environmental Management. — 2020. — Vol. 268. — 110692.
2. Fakhru’l-Razi A. et al. Review of technologies for oil and gas produced water treatment // Journal of Hazardous Materials. — 2009. — Vol. 170. — P. 530–551.
3. de Paiva L.B., Morales A.R., Valenzuela Díaz F.R. Organoclays: Properties, preparation and applications // Applied Clay Science. — 2008. — Vol. 42. — P. 8–24.
4. Beall G.W. The use of organoclays in water treatment // Applied Clay Science. — 2003. — Vol. 24. — P. 11–20.
5. Langmuir I. The adsorption of gases on plane surfaces of glass, mica and platinum // J. Am. Chem. Soc. — 1918. — Vol. 40. — P. 1361–1403.
6. Ho Y.S., McKay G. Pseudo-second order model for sorption processes // Process Biochemistry. — 1999. — Vol. 34. — P. 451–465.
7. Thomas H.C. Heterogeneous ion exchange in a flowing system // J. Am. Chem. Soc. — 1944. — Vol. 66. — P. 1664–1666.