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## ORGANOBENTONITDA NEFT MAHSULOTLARI ADSORBSIYASINING IZOTERMA, KINETIKA VA TERMODINAMIK QONUNIYATLARI

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### ANNOTATSIYA

*Maqolada mahalliy organobentonitda neft mahsulotlari adsorbsiyasining statik qonuniyatlari o'rganilgan. Langmuir, Freundlich va Temkin izoterma modellari, psevdobirinchi va psevdodikkinchi tartib kinetik modellar hamda termodinamik parametrlar ( $\Delta G^\circ$ ,  $\Delta H^\circ$ ,  $\Delta S^\circ$ ) aniqlandi. Langmuir modeli bo'yicha maksimal sorbsion sig'im 95 mg/g, jarayon psevdodikkinchi tartibga ( $R^2 = 0,995$ ) bo'ysunadi va endotermik ( $\Delta H^\circ = +14,2$  kJ/mol) tabiatga ega.*

**Kalit so'zlar:** adsorbsiya, izoterma, Langmuir, Freundlich, kinetika, psevdodikkinchi tartib, termodinamika, organobentonit.

### ABSTRACT

*The article studies static regularities of petroleum-product adsorption on local organobentonite. Langmuir, Freundlich and Temkin isotherm models, pseudo-first and pseudo-second order kinetic models and thermodynamic parameters ( $\Delta G^\circ$ ,  $\Delta H^\circ$ ,  $\Delta S^\circ$ ) were determined. The Langmuir maximum capacity is 95 mg/g; the process follows pseudo-second order ( $R^2 = 0.995$ ) and is endothermic ( $\Delta H^\circ = +14.2$  kJ/mol).*

**Keywords:** adsorption, isotherm, Langmuir, Freundlich, kinetics, pseudo-second order, thermodynamics, organobentonite.

### KIRISH

Adsorbentning amaliy qiymati uning muvozanat sig'imi, jarayon tezligi va harorat bog'liqligi bilan belgilanadi. Izoterma modellari sorbent yuzasining tabiatini va maksimal sig'imni, kinetik modellar tezlikni cheklovchi bosqichni, termodinamik parametrlar esa jarayonning o'z-o'zidan kechishi va issiqlik effektini tavsiflaydi [1, 2]. Mazkur ishda mahalliy organobentonitda neft mahsulotlari adsorbsiyasining statik qonuniyatlari kompleks o'rganilgan.

### Tadqiqot obyekti va usullari

Modifikatsiyalangan mahalliy bentonit (organobentonit) sorbent sifatida ishlatildi. Adsorbsion tajribalar partiyali (statik) usulda, neft mahsulotlarining modeli eritmalarida olib borildi. Muvozanat konsentratsiyasi gravimetrik va spektrofotometrik usulda o'Ichandi. Optimal statik sharoit: pH 7,0; sorbent dozasi 8 g/l; kontakt vaqti 60 daqiqqa; harorat 25 °C.

Muvozanat sig'imi va tozalash samaradorligi quyidagicha hisoblandi:

$$qe = (C_0 - C_e) \cdot V / m, \quad \eta = (C_0 - C_e) / C_0 \cdot 100\% \quad (1)$$

bu yerda  $C_0$  va  $C_e$  — boshlang'ich va muvozanat konsentratsiyalari, mg/l;  $V$  — eritma hajmi, l;  $m$  — sorbent massasi, g. Langmuir va Freundlich izoterma modellarining chiziqli shakllari:

$$C_e/q_e = 1/(q_{max} \cdot K_L) + C_e/q_{max} \quad (2)$$

$$\ln q_e = \ln KF + (1/n) \cdot \ln C_e \quad (3)$$

Kinetika psevdо-ikkinchi tartib modeli bilan tavsiflandi:

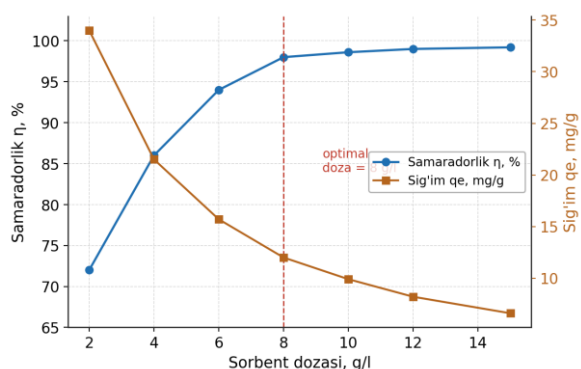
$$t/q_t = 1/(k_2 \cdot q_e^2) + t/q_e \quad (4)$$

Termodinamik parametrlar van't-Hoff tenglamasidan aniqlandi:

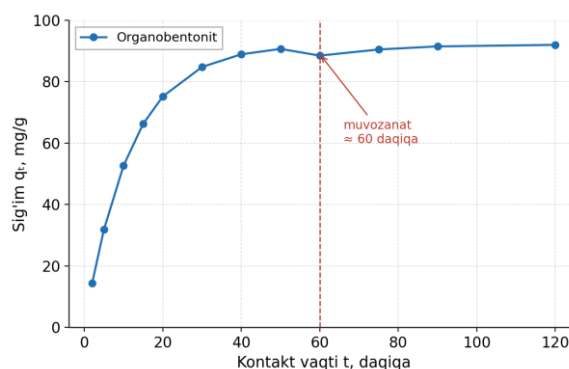
$$\ln K_c = \Delta S^\circ / R - \Delta H^\circ / (R \cdot T), \quad \Delta G^\circ = -R \cdot T \cdot \ln K_c \quad (5)$$

### Natijalar va ularning muhokamasi

Sorbent dozasi va kontakt vaqtining ta'siri 1-rasmda keltirilgan. Doza 8 g/l gacha oshganda tozalash samaradorligi keskin ortib, undan keyin sig'imi ( $q_e$ ) kamayadi; muvozanat esa taxminan 60 daqiqada qaror topadi.



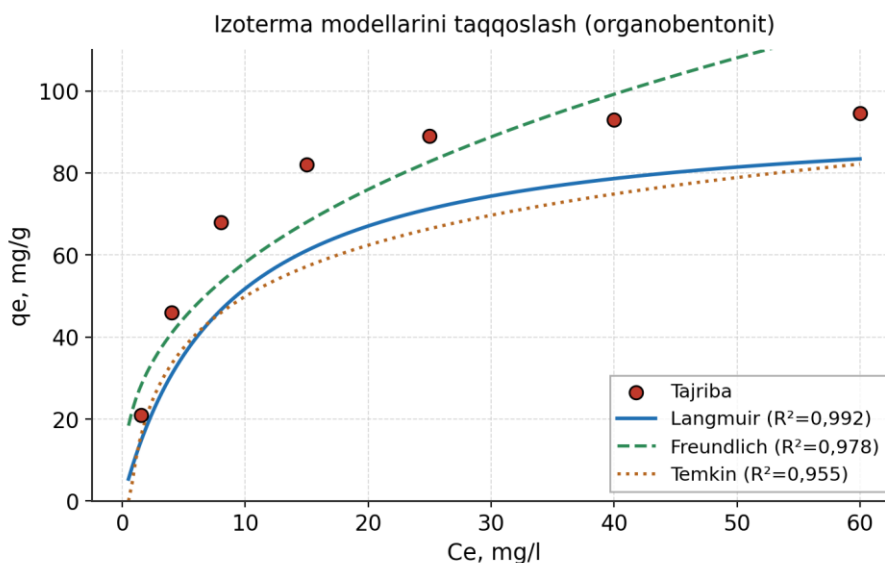
1a-rasm. Sorbent dozasining samaradorlik va sig'imga ta'siri



1b-rasm. Kontakt vaqtining sig'imga ta'siri

Izoterma modellarini taqqoslash (2-rasm) Langmuir modelining tajriba nuqtalariga eng yaxshi mos kelishini ( $R^2 = 0,992$ ) ko'rsatdi. Bu organobentonit yuzasidagi adsorbsiyaning monoqatlamli va to'yinuvchi tabiatini bildiradi. Langmuir maksimal sig'imi  $q_{max} = 95$  mg/g bo'lib, bu xom bentonitnikidan (18 mg/g) 5,3

baravar yuqori. Freundlich koefitsienti  $n = 2,6$  jarayonning qulayligini, ajralish koefitsienti  $RL = 0,077$  ( $0 < RL < 1$ ) esa izoterma qulay ekanligini tasdiqlaydi.

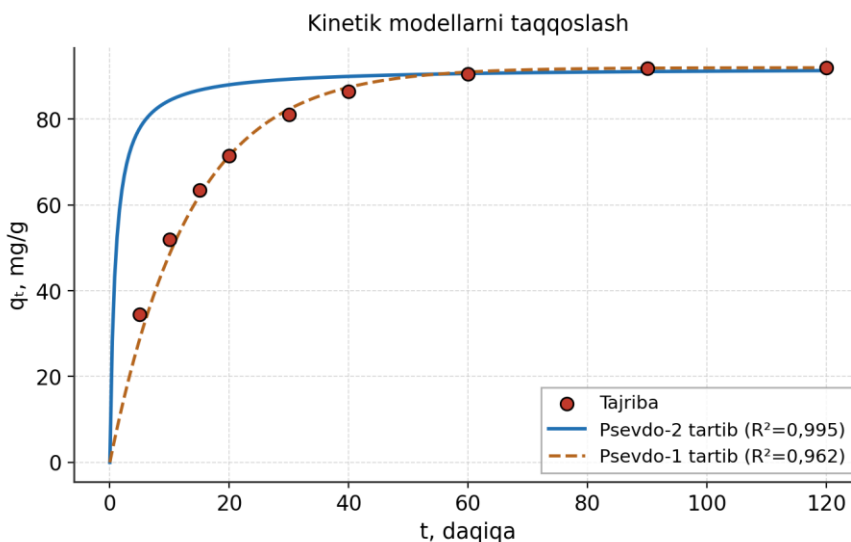


2-rasm. Izoterma modellarini (Langmuir, Freundlich, Temkin) taqqoslash

1-jadval. Izoterma modellarining parametrlari (organobentonit)

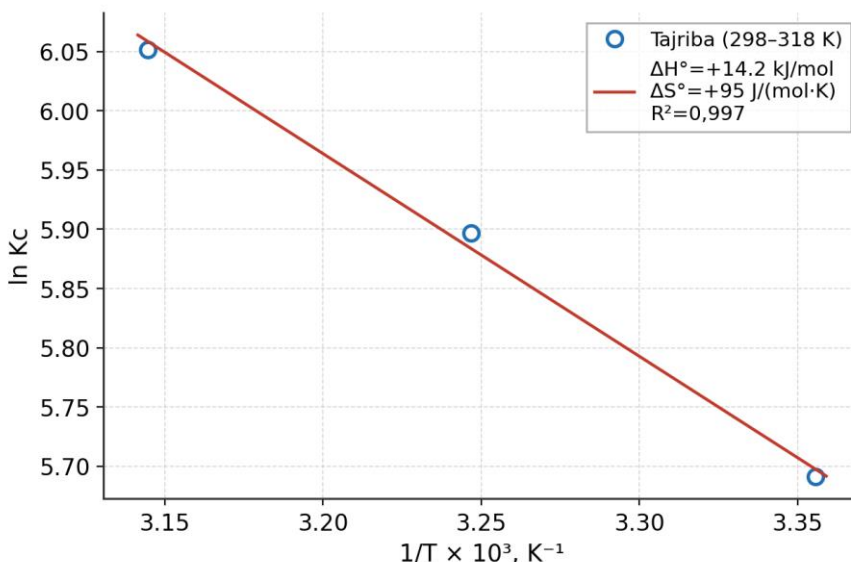
Model	Parametrlar	R <sup>2</sup>
Langmuir	$q_{max} = 95 \text{ mg/g}$ ; $KL = 0,12 \text{ l/mg}$ ; $RL = 0,077$	0,992
Freundlich	$KF \approx 24$ ; $n = 2,6$	0,978
Temkin	$B = 16,8 \text{ J/mol}$	0,955

Kinetik tahlil (3-rasm) psevdoo-ikkinchi tartib modelining ustunligini ( $R^2 = 0,995$ ;  $q_e = 92 \text{ mg/g}$ ;  $k_2 = 0,012 \text{ g/(mg}\cdot\text{daq)}$ ) ko'rsatdi. Bu adsorbsiya tezligini xemosorbsion o'zaro ta'sir cheklashini bildiradi. Veber–Morris tahlili jarayonda ichki diffuziyaning ham hissa qo'shishini, ammo u yagona tezlik cheklovchi bosqich emasligini ko'rsatdi.



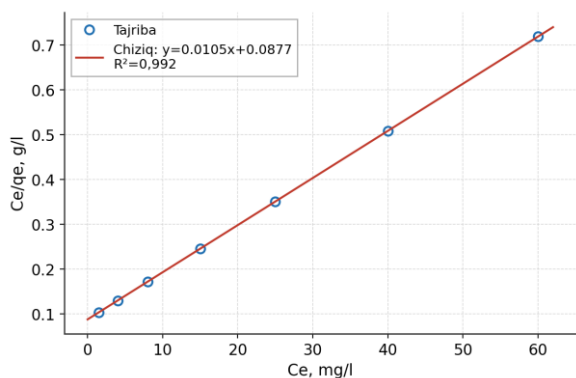
*3-rasm. Kinetik modellarni (psevdo-1 va psevdo-2 tartib) taqqoslash*

Termodinamik tahlil (4-rasm) jarayonning o‘z-o‘zidan kechishini va endotermik tabiatini tasdiqladi. Manfiy  $\Delta G^\circ$  qiymatlari (298, 308, 318 K da mos ravishda  $-14,1$ ;  $-15,1$ ;  $-16,0$  kJ/mol) jarayonning o‘z-o‘zidan kechishini, musbat  $\Delta H^\circ$  ( $+14,2$  kJ/mol) esa endotermikligini, musbat  $\Delta S^\circ$  ( $+95$  J/(mol·K)) qattiq–suyuq chegarada tartibsizlik ortishini ko‘rsatadi.

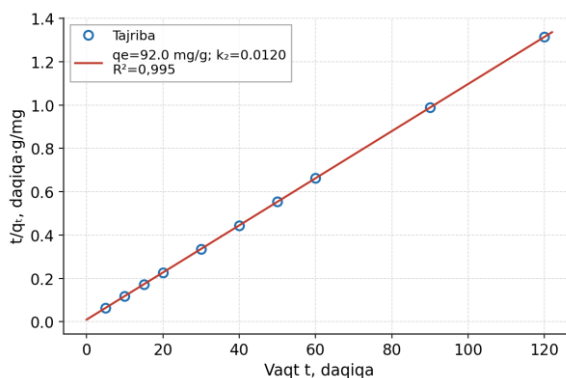


*4-rasm. Van't-Hoff bog‘liqligi ( $\ln Kc \sim 1/T$ ) bo‘yicha termodinamik parametrlar*

Langmuir izotermasining chiziqli shakli va psevdo-ikkinchi tartib modelining chiziqli shakli 5-rasmda keltirilgan.  $C_e/q_e \sim C_e$  bog‘liqligining yuqori chiziqiligi ( $R^2 = 0,992$ ) maksimal sig‘im va Langmuir konstantasini ishonchli aniqlash imkonini berdi; ajralish koeffitsienti  $RL = 0,077$  ( $0 < RL < 1$ ) adsorbsiyaning qulay ekanligini tasdiqlaydi.



*5a-rasm. Langmuir izotermasining chiziqli shakli*



*5b-rasm. Psevdo-ikkinchi tartib modelining chiziqli shakli*

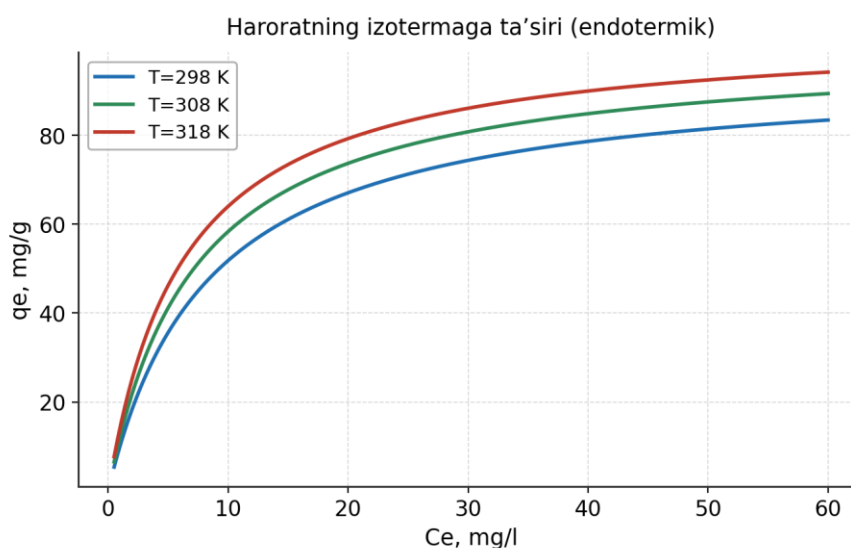
Kinetik parametrlar 2-jadvalda keltirilgan. Psevdo-ikkinchi tartib modeli butun jarayonni eng yaxshi tavsifladi ( $R^2 = 0,995$ ); hisoblangan muvozanat sig‘imi ( $q_e = 92$

mg/g) tajriba qiymatiga juda yaqin. Veber–Morris egri chizig‘ining koordinatalar boshidan o‘tmasligi adsorbsiya tezligida ham sirt reaksiyasi, ham ichki diffuziya ishtirok etishini ko‘rsatadi.

**2-jadval. Kinetik modellarning parametrlari (organobentonit)**

Model	Parametrlar	R <sup>2</sup>
Psevdo-1 tartib	$k_1 = 0,058 \text{ l/daq}$ ; $q_e = 71 \text{ mg/g}$	0,962
Psevdo-2 tartib	$k_2 = 0,012 \text{ g/(mg}\cdot\text{daq)}$ ; $q_e = 92 \text{ mg/g}$	0,995
Veber–Morris	$k_{id} = 6,4 \text{ mg/(g}\cdot\text{daq}^{0,5})$	0,948

Haroratning izotermaga ta’siri (6-rasm) jarayonning endotermik tabiatini bevosita tasdiqlaydi: harorat 298 dan 318 K gacha oshganda izoterma yuqoriga siljiydi va maksimal sig‘im ortadi. Bu termodinamik tahlildagi musbat  $\Delta H^\circ$  qiymati bilan to‘liq muvofiq bo‘lib, adsorbsiya mexanizmini quyidagicha izohlaydi: organobentonitning qatlamlararo organofil fazasi neft mahsulotlari molekularini partitsiya yo‘li bilan yutadi; psevdo-ikkinchi tartib kinetikasi va monoqatlamli Langmuir izotermasi jarayonning to‘yinuvchi va selektiv tabiatini tasdiqlaydi [8, 9].



6-rasm. Haroratning adsorbsiya izotermasiga ta’siri (298, 308, 318 K)

**XULOSA**

Mahalliy organobentonitda neft mahsulotlari adsorbsiyasi Langmuir izotermasiga ( $q_{max} = 95 \text{ mg/g}$ ;  $R^2 = 0,992$ ) va psevdo-ikkinchi tartib kinetikasiga ( $R^2 = 0,995$ ) bo‘ysunadi. Jarayon o‘z-o‘zidan kechuvchi ( $\Delta G^\circ < 0$ ) va endotermik ( $\Delta H^\circ = +14,2 \text{ kJ/mol}$ ) bo‘lib, monoqatlamli xemosorbsion mexanizmga ega. Bu natijalar organobentonitning yuqori sorbsion salohiyatini tasdiqlaydi.

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