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Sahifalovchi:
Yuldoshev D.N.

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Raxmatov M.

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MUROJAAT UCHUN MANZIL:
Pochta manzili: 180003, Qarshi, Ko‘chabog‘,17.Qarshi davlat universiteti, Filologiya fakulteti binosi, 107-xona.
Telefon: 97-222-10-80
TelegramID: https://t.me/Qardu_Xabarlari2024
Elektron pochta:qardu_xabarlari@mail.ru
Veb-sayt: https://qarshidu.uz/oz/page/ilmiy-jurnal-NEW

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FIZIKA-MATEMATIKA

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КОЭФФИЦИЕНТ ЭЛЕКТРОМЕХАНИЧЕСКОЙ СВЯЗИ ПЬЕЗОЭЛЕКТРИЧЕСКИХ КРИСТАЛЛОВ

Асраров Шухрат Аббасович
Самаркандский филиал
ТУИТ
asrorovshuxrat867@gmail.com
ORCID 0009-0008-6585
УДК 621.534.28

Аннотация. В статье анализируются способы генерации и распространения ультразвуковых волн и упругие свойства применяемых для этой цели пьезоэлектрических материалов. В статье представлены параметры, характеризующие явления прямого и обратного пьезоэлектрических эффектов, и уравнения связи между ними. Изучены методы определения коэффициента электромеханической связи пьезоэлектрического материала, который считается важным при высокоэффективном преобразовании высокочастотных радиосигналов в ультразвуковые волны. При этом электрическая энергия, передаваемая на пьезоэлектрическую пластину превращается в энергию упругой деформации и приводит к деформации пластины, сформированной на основе обратного пьезоэлектрического эффекта. В статье поясняется метод расчета коэффициента электромеханической связи материалов через значения резонансных и антирезонансных частот. Представлены расчетные данные, коэффициенты электромеханической связи различных диэлектрических кристаллов и пьезоэлектрических керамических материалов.

Ключевые слова: пьезоэффект, звуковые волны, деформация, импеданс, радиоимпульс, пьезомодуль, кристалл, пьезопреобразователь, резонанс, антирезонанс, коэффициент электромеханической связи.

PIEZOLEKTRIK KRISTALLARNING ELEKTROMEXANIK BOG'LANISH KOEFFITSIENTI

Annotatsiya. Ushbu maqolada ultratovush to‘lqinlarini hosil qilish va tarqatish usullari va buning uchun qo‘llaniladigan pyezoelektrik materiallarning xususiyatlari tahlil qilingan. Maqolada to‘g‘ri va teskari pyezoeffekt hodisalarini xarakterlovchi parametrlar va ular orasidagi bog‘lanish tenglamalari keltirilgan. Yuqori chastotali radiosignallarni ultratovush to‘lqinlariga yuqori samarali aylantirishda muhim hisoblangan pyezoelektrik materialning elektromexanik bog‘lanish koeffitsiyentini aniqlash usullari o‘rganilgan. Bunda asosan pyezoelektrk plastinkaga uzatilgan elektr energiya teskari pyezoeffektga asosan hosil bo‘lgan plastinkaning deformatsiysini ifodalovchi elastic deformatsiya energiyasiga aylanishi hisobga olingan. Maqolada materiallarning elektromexanik bog‘lanish koeffitsiyentini rezonans va antirezonans chastotalari qiymatlari orqali hisoblash usuli yoritib berilgan. Turli xil dielektrik kristallar va pyezoelektrik keramika materiallarining hisoblangan elektromexanik bog‘lanish koeffitsiyentlari qiymatlari keltirilgan.

Kalit so‘zlar. Pyezoeffekt, tovush to‘lqinlari, deformatsiya, impedans, radioimpuls, pyezomodul, kristall, pyezoalmashtirgich, rezonans, antirezonans, elektromexanik bog‘lanish koeffitsiyenti

Введение. Пьезоэлектрические материалы являются основными источниками возбуждения обьемных ультразвуковых волн и широко используются в акустоэлектронике [1-3]. Пьезоэлектрический материал обладает несимметричной атомной решеткой. При приложении электрического поля его размеры изменяются (обратный пьезоэффект). И наоборот, если материал подвергнут деформации, то в нем возникает электрическое поле (прямой пьезоэффект).

В последнее время в связи с совершенствованием электрических-коммуникациоонных систем спрос на различные высокочастотные и широкополосные устройства на акустических волнах постоянно растет. Одним из важных параметров таких приборов является коэффициент электромеханической связи акустических волн, характеризующий эффективность преобразования мощности в пьезоматериале.

Исходя из вышеуказанного, в настоящей работе ставилась задача теоретического исследования возбуждения акустических волн и методик расчетов коэффициента электромеханических связей в пьезоэлектрических кристаллах.

Обзор литературных данных. Пьезоэффект – связь между электрической поляризацией (индукцией) или электрическим полем и механическим напряжением или деформацией, которая наблюдается у некоторых диэлектриков и полупроводников.

Пьезоэлектрик можно представить в виде активного четырехполюсника, описываемого четырьмя переменными.

$D = \varepsilon E$ – закон Максвелла (с учетом механической стороны)

$u = S\sigma$ – закон Гука (с учетом электрической стороны)

Т.о. уравнения пьезоэффекта могут быть четырех видов.

Причем первое уравнение отражает закон Гука (с учетом электрической стороны), а второе - закон Максвелла (с учетом механической стороны) [4].

$$\begin{cases} u_i = S_{ij}^E \sigma_j + \left(d_{im}\right)^t E_m \\ D_m = d_{im}\sigma_i + \varepsilon_{mn}^{\sigma} E_n \end{cases} \quad (1) \qquad \begin{cases} u_i = S_{ij}^D \sigma_j + \left(g_{im}\right)^t D_m \\ E_m = -g_{im}\sigma_i + \beta_{mn}^{\sigma} D_n \end{cases} \quad (2)$$

$$\begin{cases} \sigma_i = C_{ij}^E u_i - \left(e_{im}\right)^t E_m \\ D_m = -e_{im}u_i + \varepsilon_{mn}^{\sigma} E_n \end{cases} \quad (3) \qquad \begin{cases} \sigma_i = C_{ij}^D u_j - \left(h_{im}\right)^t D_m \\ E_m = -h_{im}u_i + \beta_{mn}^{u} D_n \end{cases} \quad (4)$$

$$i, j = 1,...,6;\ m, n = 1,...,3$$

Система уравнений (1) определяет константы S^E, d, ε^σ .

• d-**пьезомодуль,** определяет величину деформации в свободном ($\sigma = 0$) элементе при E =const; [Кл/Н] ~ 10^{-12};

Система уравнений (3) определяет константы C^E, e, ε^u .

• e-**пьезоконстанта,** определяет механические напряжения в заторможенном (u=0) элементе при E =const; [Кл/м^2] ~ 10^1.

Система уравнений (2) определяет константы S^D, g, β^σ .

• g-**пьезоконстанта давления,** характеризует напряженность электрического поля в режиме холостого хода (σ=0) при постоянных механических напряжениях σ =cons; [Вм/Н] ~ 10^{-3};

Система уравнений (4) определяет константы C^D, h, β^u .

• h-**пьезоконстанта деформации,** определяет напряженность электрического поля в режиме холостого хода (D=0) при заданных деформациях u =const; [В/м^2] ~ 10^8.

Таблица 1. Связь между константами [5]

упругие	диэлектрические	пьзоэлектрические	уравнения
$S^E - S^D = gd = dg$	-	$d = e^\sigma g$; $g = \beta^\sigma d$	(1) – (3)
$C^D - C^E = he = eh$	-	$e = \varepsilon^u h$; $h = \beta^u e$	(2) - (4)
-	$\varepsilon^\sigma - \varepsilon^u = de = ed$	$d = e S^E$; $e = d C^E$	(1) – (2)
-	$\beta^u - \beta^\sigma = hg = gh$	$g = h S^D$; $h = g C^D$	(3) – (4)

Во многих случаях работу пьезоматериала удобно оценить применительно к различным режимам работы комбинацией этих параметров.

Наиболее важным из них является коэффициент электромеханической связи, характеризующий эффективность преобразования мощности в пьезоматериале. От величины коэффициента электромеханической связи прямо зависит пьезоэффект. С помощью этого параметра сравнивают пьезоматериал с различными константами. Для каждой системы граничных условий и каждой ориентации электрического поля существует свой коэффициент.

Методология исследований. Для возбуждения ультразвуковых волн с помощью пьезоэффекта в кристаллах используют резонансные и нерезонансные методы [6,7]. В резонансном методе в качестве пьезопреобразователя используется тонкая пластинка из пьезоэлектрического кристалла. Под действием радиоимпульса, подводимого от генератора высокочастотных колебаний, в пьезопластинке, благодаря обратному пьезоэффекту, возникают упругие колебания. Максимальная эффективность преобразования получается при совпадении частоты заполнения радиоимпульса с частотой собственных колебаний пластинки (для свободной пластинки)

$$\nu_0 = \frac{V}{2a} \tag{1}$$

V - скорость возбужденной моды УВ, a – толщина пластинки. Качественно, также, понятно, что мощность генерируемой упругой волны должна зависеть от коэффициента электромеханической связи и от соотношения импедансов пьезопреобразователя $(Z_n = \rho_n \cdot V_n)$ и $(Z = \rho \cdot V)$, в котором возбуждается ультразвуковая волна. Можно принять [2], что мощность акустической волны, генерируемой пьезопреобразователем P_{ak} пропорциональна

$$P_{ak} \sim K_{ЭМ}^2 \frac{Z}{Z_n} \nu_0 U_{ЭЛ}^2 \tag{2}$$

где $U_{ЭЛ}$ – электрическое напряжение, приложенное к пьезопластинке. Из (2) следует, что для достижения максимальной эффективности преобразования необходимо иметь наибольшее значение $K_{ЭМ}^2$.

Добиться этого можно применением материалов с большими значениями пьезомодулей, а также выбором оптимального кристаллографического среза, что обусловлено сильной анизотропией $K_{ЭМ}^2$.

Возьмем тонкую пластинку толщиной a из пьезоэлектрического кристалла. Ориентацию пластинки зададим единичным вектором нормали $\vec{n}$, направленным от нижней стороны пластинки к верхней. Пусть поверхности пластинки металлизированы и пусть на пластинку действует однородное механическое напряжение σ_{ij}. Найдем деформацию пластинки и плотность зарядов на обкладках. Поскольку поверхности металлизированы, то они будут эквипотенциальными поверхностями. Очевидно, что любые плоскости, паралелльные обкладкам также будут являться эквипотенциальными поверхностями. В такой системе электрический потенциал φ зависит от одной координаты Z, отсчитываемой по нормали к пластинке. В этом случае, уравнение состояния пьезоэлектрического кристалла записывается в виде

$$D_i = -\varepsilon_0 \varepsilon_{ij} n_j \frac{d\varphi}{dZ} + d_{ilk}\sigma_{lk} \tag{3}$$

$$n_{ij} = -n_k g_{kij} \frac{d\varphi}{dZ} + S_{ijkl}\sigma_{kl} \tag{4}$$

При разомкнутых обкладках разность потенциалов

$$U = \varphi(0) - \varphi(a) = -a\frac{d\varphi}{dZ}$$

не равна нулю, т.е. внутри пластинки действует электрическое поле. С другой стороны, при разомкнутых обкладках $n_i D_i = o$.

Учитывая это, получим:

$$\frac{d\varphi}{dZ} = \frac{n_k d_{kim}\sigma_{im}}{\varepsilon_0 \varepsilon_{pq} n_p n_q} \tag{5}$$

Деформация зависит не только от упругих, но и от пьезоэлектрических свойств кристалла. Подставив (5) в (4) получаем

$$n_{ik} = -\frac{d_{rtv} n_r \sigma_{tv}}{\varepsilon_0 \varepsilon_{pq} n_p n_q} n_m d_{imk} + S_{iklm} \sigma_{lm}$$

Полученное выражение можно переписать в виде:

$$n_{ik} = \left[S_{iklm} - \frac{(n_r d_{rik})(n_t n_{tlm})}{\varepsilon_0 \varepsilon_{pq} n_p n_q} \right] \sigma_{lm} \qquad (6)$$

Выражение в скобках играет роль нового, зависящего от пьезомодулей тензора упругой податливости. Пьезоэффект уменьшает податливость кристалла, т.е. увеличивает его жесткость. Ужесточение кристалла обусловлено тем, что работа внешних сил, приложенных к поверхности пластинки, затрачивается теперь не только на создание энергии упругой деформации

$$W_{упр} = \frac{a}{2} \sigma_{ik} n_{ik} = \frac{a}{2} S_{iklm} \sigma_{ik} \sigma_{lm} - \frac{a}{2} \frac{(d_{ikm} n_i \sigma_{km})^2}{\varepsilon_0 \varepsilon_{pq} n_p n_q}$$

приходящейся на единицу площади пластинки, но и на создание электрической энергии

$$W_{ЭЛ} = \frac{UC^2}{2} = \frac{1}{2} \frac{\varepsilon_0 \varepsilon_{pq} n_p n_q}{a} \left(\frac{a (d_{ikm} n_i \sigma_{km})^2}{\varepsilon_0 \varepsilon_{pq} n_p n_q} \right) = \frac{a}{2} \frac{(d_{ikm} n_i \sigma_{km})^2}{\varepsilon_0 \varepsilon_{pq} n_p n_q}.$$

Таким образом, деформация уменьшается ровно на столько, чтобы связанное с этим уменьшение упругой энергии компенсировало появление энергии электрического поля. Отношение

$$K_{ЭМ}^2 = \frac{W_{ЭЛ}}{(W_{упр} + W_{ЭЛ})} \qquad (7)$$

показывает, какая часть механической энергии, затраченной на деформирование пластинки перешла в электрическую. Величина $K_{ЭМ}^2$ называется коэффициентом электромеханической связи, который можно представить в виде:

$$K_{ЭМ}^2 = \frac{(d_{ikm} n_i \sigma_{km})^2}{\varepsilon_0 \varepsilon_{pq} n_p n_q S_{rtlv} \sigma_{rt} \sigma_{lv}} \qquad (8)$$

или

$$K_{ЭМ}^2 = \frac{(e_{ikm} n_i \sigma_{km})^2}{\varepsilon_0 \varepsilon_{pq} n_p n_q C_{rtlv} \eta_{rt} \eta_{lv}} \qquad (9)$$

Если нормали $\vec{n}$ последовательно придавать различные ориентации, то по формулам (8) или (9) можно рассчитать указательную поверхность коэффициента электромеханической связи для заданной деформации кристалла.

Результаты и их обсуждение

Коэффициент электромеханической связи обычно определяют путем измерения частот резонанса (ν_R) и антирезонанса (ν_R) колеблющейся пьезопластинки [8,9]. Проводимость свободного пьезопластинки равна

$$\frac{1}{Z} = \frac{1}{2} \frac{i\omega a в \varepsilon_{33}}{4\pi c} \left[1 + \frac{4\pi d_{33}^2}{\varepsilon_{33} S_{11}^E} \left(\frac{tg \frac{wa}{2V}}{\frac{wa}{2V}} \right) \right], \qquad (10)$$

где a, $в$, с – длина, ширина и толщина бруска: V –скорость распространения продольных ультразвуковых волн.

Если $tg\frac{wa}{2V}\to\infty$ или $\frac{wa}{2V}=\frac{\pi}{2}(2n+1)$, $n=0,1,2,\ldots$, то $\frac{1}{Z}\to\infty$ и наступает резонанс.

Наинизшая частота резонанса равна

$$\nu_R=\frac{V}{2a}. \tag{11}$$

На антирезонансной частоте выражение в скобках в правой части (10) равна нулю

$$1+\frac{4\pi d_{33}^2}{\varepsilon_{33}S_{11}^E}\left(\frac{tg\frac{\omega_A a}{2V}}{\frac{\omega_A a}{2V}}\right)=0 \tag{12}$$

Отсюда получаем

$$\frac{\omega_A a}{2V}ctg\frac{w_A a}{2V}=-\frac{4\pi d_{33}^2}{\varepsilon_{33}S_{11}^E} \tag{13}$$

Определяя коэффициэнт электромеханической связи выражением:

$$K_{ЭМ}^2=\frac{4\pi d_{33}^2}{\varepsilon_{33}S_{11}^E} \tag{14}$$

получаем после некоторых переобразований

$$\frac{w_A a}{2V}ctg\frac{w_A a}{2V}=-\frac{K_{ЭМ}^2}{1-K_{ЭМ}^2} \tag{15}$$

Найдем теперь выражение, позволяющее определить коэффициент электромеханической связи в зависимости от резонансной и антирезонансной частот ν_R и ν_A. Разность между этими частотами обычно мала, мы можем записать:

$$\nu_A=\nu_R+\Delta\nu; \quad \omega_A=\omega_R+2\pi\Delta\nu \tag{16}$$

Подставив эти величины в (15) и заметив что:

$$ctg(\alpha+\beta)=(ctg\alpha\cdot ctg\beta-1)/(ctg\alpha+ctg\beta)$$

получаем

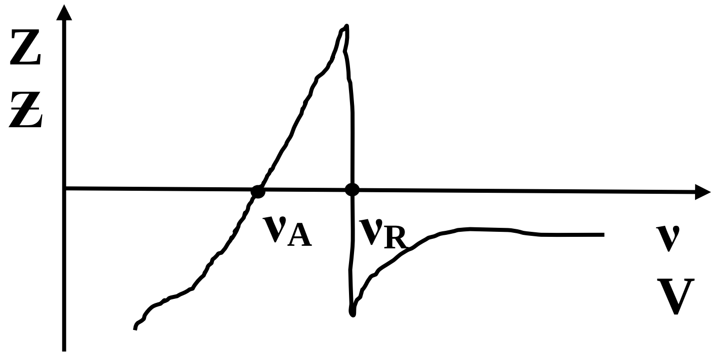
$$\frac{\pi}{2}\left(1+\frac{\Delta\nu}{\nu_R}\right)\frac{ctg\frac{\pi}{2}ctg\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}-1}{ctg\frac{\pi}{2}ctg\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}}=\frac{\frac{\pi}{2}\left(1+\frac{\Delta\nu}{\nu_R}\right)}{ctg\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}}=-\frac{K_{ЭМ}^2}{1-K_{ЭМ}^2}$$

Разлагаем выражение для $tg\left(\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}\right)$ в ряд по степеням $\frac{\pi\Delta\nu}{2\nu_R}$

$$tg\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}=\left(ctg\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}\right)^{-1}=\frac{\pi}{2}\frac{\Delta\nu}{\nu_R}+\frac{1}{3}\left(\frac{\pi}{2}\cdot\frac{\Delta\nu}{\nu_R}\right)^3+\ldots$$

Разрешая это уравнение относительно $K_{ЭМ}^2$, получаем

$$K_{ЭМ}^2=\frac{\pi^2}{4}\cdot\frac{\Delta\nu}{\nu_R}\left[1+\frac{(4-\pi^2)}{4}\cdot\frac{\Delta\nu}{\nu_R}+\left(\frac{(\pi^2-4)}{4}\right)\left(\frac{\pi^2}{4}\right)\left(\frac{\Delta\nu}{\nu_R}\right)^2+\ldots\right]$$



Обычно можно ограничиться первым членом $K_{ЭМ}^2 \approx \frac{\pi^2}{4} \cdot \frac{\nu_R - \nu_A}{\nu_R}$

Таким образом, измеряя частоты резонанса и антирезонанса (рис.1), можно определить $K_{ЭМ}^2$.

Таблица 2 Параметры пьезоэлектрических материалов [10,11]

Материал	Плотность $\rho x10^3$,кг/м^3	Скорость звука,$Vx10^3$, м/с	Коэффициент электромеханической связи, $K_{ЭМ}^2$
Кварц, (SiO_2)	2,6	5,4	0,095
Ниобат лития, ($LiNbO_3$)	4,7	7,2 $[001]_L$	0,55
Арсенид галлия, (GaAs)	5,32	1,9	0,0004
Пьезокерамика, (ЦТС-19)	7,45	3,12	0,28/0,64 (K_{31}/K_{33})
Сегнетово соль	1,77	3,9	0,67
Сульфат лития	2,05	4,7	0,37

Выводы

1.Рассмотрены вопросы использования эффективных методов теории электрических цепей.

2.Исследована методика определения коэффициента электромеханической связи.

3.Приведены расчетные данные коэффициента электромеханической связи некоторых пьезоэлектрических материалов.

Список использованной литературы:

1. Кузьминов Ю.С. Электрооптический и нелинейнооптический кристалл ниобата лития.М.: Наука, 1987.-263 с.
2. Campbell C. // Surface Acoustic Wave Devices and Their Signal Processing Aplications. Boston:Academic, 1989.475 p.
3. Campbell C. // Surface Acoustic Wave Devices for Mobile and Wireless Communications. Boston:Academic, 1998.633 p.
4. Физическая акустика / Под ред.Ж.Мезона. – М.: Мир, 1966,т.1, ч.А, гл.3.
5. Пьезокерамические преобразователи: Справочник / В.В.Гонопольский, Б.А.Касаткин, Ф.Ф.Легуша, М.И.Прудько, С.И.Пугачев. – М.: Судостроение,1984. – 256 с.
6. Дьелесан Э., Руайе Д. Упругие волны в твердых телах. Применение для обработки сигналов. – М.:Наука, 1982.-424 с.
7. Кайно Г. Акустические волны (Устройства, визуализация и аналоговая обработка сигналов. – М.: Мир, 1990. -656 с.
8. Коновалов С.И., Кузьменко А.Г. Определение частот резананса и антирезонанса пьезокерамического пластинчатого пребразователя на основании частотной характеристики его входного электрического импеданса. - Известия СПбГЭТУ «ЛЕТИ» № 2/2018, с.56-61.
9. Островский И.В., Надточий А.Б., Коротченков О.А., Никандрова М.В. Добротность

пьезоэлектрических преобразователей из ниобата лития при высоких уровнях возбуждения. - Журнал технической физики, 2003, том 73, вып.10, с.97-100.

10. Бобцов А.А., Бойков В.И., Быстров С.В., Григорьев В.В., Карев П.В. Исполнительные устройства и системы для микроперемещений. - СПб: Университет ИТМО, 2017. -134 с.

11. Акустические кристаллы // Под редакцией М.П.Шаскольской. - М.: Наука, 1982.- 632 с.

FULLERENNING DISPERS ERITMALARINI YORUG'LIKNING DINAMIK SOCHILISH USULIDA TADQIQI

Maxmanov Urol Kudratovich
O'zbekiston Respublikasi Fanlar akademiyasi
Ion-plazma va lazer texnologiyalari instituti
"Optika va spektroskopiya" laboratoriyasi mudiri
fizika-matematika fanlari doktori, katta ilmiy xodim,
urol_m@mail.ru
ORCID 0000-0002-7185-2812
Bekmurodov Zohiriddin Bekmurodovich
O'zbekiston Respublikasi Fanlar akademiyasi
Ion-plazma va lazer texnologiyalari institutikichik ilmiy xodimi
zohiriddinbekmurodov@gmail.com
ORCID 0009-0000-8461-1818
Chuliyev Tohirjon Abdulloyevich
Guliston davlat universiteti tayanch doktoranti
chuliyevtohirjon@gmail.com
ORCID 0009-0008-2938-0955
UDK: 546.26.043:535

Annotatsiya. Ushbu ishda ksilol/etanol tizimida C_{60} fulleren dispers nanoklasterlarining shakllanishi va vaqt bo'yicha o'sishi ko'rib chiqilgan. Bu jarayonlarning o'ziga xos xususiyatlari yorug'likning dinamik sochilishi (YDS) usuli bilan o'rganilgan. C_{60}/ksilol/etanol aralashmasida nanoklasterlarning hosil bo'lishi komponentlarning hajmiy tarkibiga va eritmaning saqlash vaqtiga bog'liqligi eksperimental ravishda o'rnatilgan. C_{60}/ksilol/etanol (ksilol/etanol nisbati 0.6/0.4) eritmasida sintezlangan fulleren nanoklasterlari o'rtacha o'lchami eritmani 20 soat saqlangandan so'ng ~6,87 nm dan ~14,17 nm gacha oshishi aniqlandi. C_{60}/ksilol/etanol aralashmasida erigan moddalar molekulalarining o'z-o'zidan yig'ilish barqarorligiga erishish vaqti aniqlangan. Dastlabki eritmaning 100 soat davomida saqlanishi nanoklasterlarning o'rtacha o'lchamlari ~22,6 nm gacha oshib, o'zgarishsiz qolishiga olib kelgan, ushbu davrda C_{60}/ksilol/etanol tizimidagi C_{60} nanozarralarini o'z-o'zidan yig'ilish jarayonining barqarorligiga erishilgan.

Kalit so'zlar: C_{60} fulleren, ksilol/etanol tizimi, C_{60}/ksilol/etanol eritmasi, nanoklaster, barqarorlik, YDS.

STUDY OF DISPERSED SOLUTIONS OF FULLERENE BY DYNAMIC LIGHT SCATTERING METHOD

Abstract. In this work, the formation and growth of C_{60} fullerene dispersed nanoclusters in the xylene/ethanol system was considered. Specific features of these processes were studied by the dynamic light scattering (DLS) method. It was established experimentally that the formation of nanoclusters in the C_{60}/xylene/ethanol mixture depends on the volume content of the components and the storage time of the solution. It was found that the average size of fullerene nanoclusters synthesized in C_{60}/xylene/ethanol (xylene/ethanol ratio 0.6/0.4) solution increases from ~6.87 nm to ~14.17 nm after 20 hours of solution storage. The time to self-assembly stability of solute molecules in C_{60}/xylene/ethanol mixture was determined. Keeping the initial solution for 100 hours resulted in the average size of nanoclusters increasing up to 22.6 nm and remaining unchanged; during this period, the stability of the self-assembly process of C_{60} nanoparticles in the system was achieved.

Keywords: fullerene C_{60}, xylene/ethanol system, C_{60}/xylene/ethanol solution, nanocluster, stability, DLS.

Kirish. So'nggi yillarda nanoo'lchamli zarrachalarning fizik va kimyoviy tabiatini o'rganish dunyodagi shu soha olimlarining diqqat markazida bo'lib kelmoqda [1-2]. Shu jihatdan nanoo'lchamli fulleren (diametri <1 nm) asosidagi nanomateriallarni sintez qilishning har xil usullari yaratilmoqda va mavjudlari takomillashtirib borilmoqda [3]. C_{60} fulleren molekulasidagi barcha uglerod atomlari uning kvazisferik sirtidagi uchlarida joylashgan bo‘lib, atomlar C-C va C=C ko‘rinishda kovalent bog‘langan [4]. Fulleren molekulalarining ajoyib xususiyatlaridan biri ularning vaqt o‘tishi bilan organik erituvchilarda o‘z-o‘zidan yig‘ilib turli shakl va o‘lchamdagi agregatlar hosil qilish qobilyatidir va bu jarayonda erituvchining tabiati muhim rol o‘ynaydi [5-6].

Zamonaviy nanotexnologiyada turli xil nanostrukturali materiallarni sintez qilish uchun eritmadagi nanoo‘lchamli zarrachalarning o‘z-o‘zidan hosil bo‘lish xususiyatiga asoslangan yangicha yondashuvlar rivojlanmoqda. C_{60} fulleren asosidagi nanomateriallar ajoyib elektron, optik, issiqlik xususiyatlari va kimyoviy/biologik faolligi [7-8] sababli tibbiyotda, zamonaviy elektronikada, materialshunoslikda, quyosh panellarida va boshqa ko‘plab texnologik sohalarda ishlatilish istiqboli mavjud [9-11].

Hozirga qadar turli xil erituvchilardagi C_{60} fullerenning xususiyatlari bo‘yicha juda ko‘p nazariy va eksperemental ma’lumotlar mavjud [12-14]. Turli organik erituvchilarda fulleren molekulalari o‘z-o‘zidan yig‘ilib, individual fulleren molekulalaridan sezilarli darajada farq qiladigan nanoklasterlar hosil qilishi sababli bu eritmalarni kolloid sistemalar deb hisoblash mumkin [15]. Bu holda fulleren nanoklasterlarining xususiyatlari (nur sindirish ko‘rsatkichi, optik yutilishi, issiqlik o‘tkazuvchanlik va elektrokinetik potensiali) ularning geometrik o‘lchamlariga bog‘liq bo‘ladi. Shunday bo‘lishiga qaramasdan, C_{60} fulleren molekulalarining turli komponentli erituvchilardagi holati, klasterlanishi va molekulalararo o‘zaro ta’sirlarning darajasiga doir tadqiqotlar dolzarb bo‘lib qolmoqda.

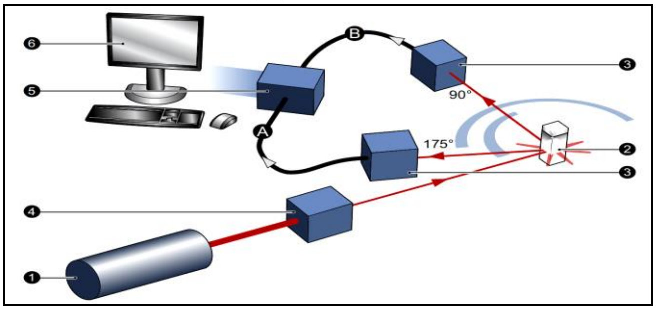
Binar organik erituvchilarda C_{60} molekulalarining o‘z-o‘zidan yig‘ilishi jarayoni foydalanilgan erituvchining fizik-kimyoviy xususiyatlari va eritma konsentratsiyasiga bog‘liq. Ushbu ishning maqsadi ksilol/etanol binar erituvchilar sistemasidagi C_{60} fulleren molekulalarining holati, nanoklasterlar gidrodinamik o‘lchamlarini YDS usuli orqali experimental o‘rganish hisoblanadi. YDS usulida ishlaydigan Zetasizer Nano ZEN3600 (Malvern Instruments Ltd.) qurilmasining afzalliklari kengroq yoritiladi.

Tadqiqot usuli va qurilmalar. Tajribada C_{60} fullerenning kristal kukuni (tozaligi >99.8%) hamda tozaligi >99% bo‘lgan erituvchilar ksilol va etanoldan foydalanildi. Barcha reagentlar Sigma Aldrich ishlab chiqaruvchisi (AQSh) tomonidan yetkazib berilgan. C_{60} molekulaning diametri ~0.714 nm, nur sindirish ko‘rsatkichi ~1.96 va dielektirik singdiruvchanligi ~3.61. Sof etanol va ksilolning dielektrik singdiruvchanligi mos holda ~24 va ~2.57 ni tashkil etadi.

Tadqiq qilinadigan C_{60} fullerenning har xil konsentratsiyali eritmalarini tayyorlash uchun dastlab elektron tarozida o‘lchab olingan C_{60} kukuni kolbaga solinib, unga ma’lum nisbatlardagi ksilol (yoki etanol) erituvchilar aralashmasi qo‘shiladi. Germetik berk kolbadagi ushbu aralashma xona temperaturasida 3-4 soat davomida 2÷2.5 Hz chastotada avtomatlashgan magnit aralashtirgich yordamida molekulyar eritma holatiga kelguncha aralashtiriladi. Keyingi barcha o‘lchashlar xona temperaturasida ($T \approx 24 \pm 1$ °C) amalga oshirildi. Tajribada tayyor eritma namunalari ma’lum sharoitlarda qorong‘i xonada saqlandi.

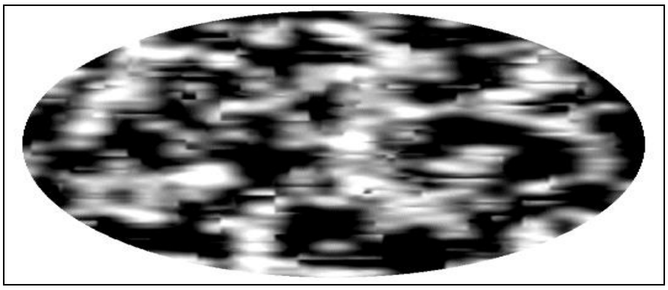
Eritmalardagi C_{60} nanoklasterlarining o‘rtacha gidrodinamik o‘lchamini va ularning eritmalarda taqsimlanishini aniqlash uchun Zetasizer Nano ZEN3600 (Malvern Instruments Ltd.) qurilmasida YDS usulidan foydalanildi. Qurilma 4 mVt quvvatga ega va to‘lqin uzunligi ~632,8 nm bo‘lgan lazer bilan jihozlangan. Ushbu qurilmada o‘lchangan nanozarrachaning o‘lchami sifatida bir xil tezlikda diffuziyalangan sferik nanozarrachaning diametri hisoblanadi. Qurilma dastlab YDS usulidan foydalanib namunadagi zarrachaning broun harakati parametrlarini o‘lchash orqali zarrachaning o‘lchamini aniqlaydi, keyin esa broun harakati nazaryasidan foydalanib zarracha o‘lchamini interpretatsiya qiladi.

Endi Zetasizer Nano ZEN3600 qurilmasining ishlash tamoyili haqida qisqacha to‘xtalib o‘tamiz. Qurilmada YDS sistemasi 6 ta asosiy qismdan iborat (1-rasm). ① lazer - namunani yorutuvchi yorug‘lik manbai, ② kveta – eritma joylashgan kvars idish, ③ detektor – eritmadan sochilgan yorug‘likning intensivligini qayd qiluvchi element. Fulleren nanozarrachasi yorug‘likni barcha yo‘nalishlarda sochganligi sababli detektorni istalgan holatda joylastirish mumkin. Odatda Zetasizer Nanoning ma’lum bir usullarida detektorni 175° yoki 90° da o‘rnatiladi. Sochilgan yorug‘likning intensivligini detektor yaxshi sezishi uchun uni ma’lum bir holatda o‘rnatish zarur. Zetasizer Nano ZEN3600 qurilmasida esa detektor namunaga tushayotgan dastlabki nur yo‘nalishiga nisbatan 175° burchak ostida sochilgan nurlarni qayd etadi. Agar detektorga o‘ta ko‘p yorug‘lik tushsa qurilma zo‘riqadi. Buni bartaraf qilish uchun ④ attenuatordan (laserning intensivligini va bu orqali sochilgan yorug‘likning intensivligini kamaytiradi) foydaliniladi. Agar juda kichik zarrachalar yoki past konsentratsiyali namunalar bo‘lsa, ular yorug‘likni ko‘p sochmaydi. Bu holda sochilgan yorug‘likning miqdorini oshirish uchun attenuator orqali laser nuri intensivligini oshiriladi. Agar katta o‘lchamli nanozarrachalar yoki yuqori konsentratsiyali fulleren eritmalari bo‘lsa, aksincha bo‘ladi, ya’ni ulardan sochilgan yorug‘likning miqdorini kamaytirish zarur. Bu holda attenuatordan lazer nuri intensivligini kamaytirishda foydalaniladi. O‘lchashlar olib borilayotganda, attenuator holatini Zetasizer avtomatik ravishda mos holatga joylashtiradi. Detektorga tushgan, sochilgan yorug‘lik intensivligi ⑤ korrelyatorga uzatiladi va bu qurilmada signal raqamli signalga aylantiriladi. Korrelyatator o‘zgarayotgan intensivlik qiymatini olish uchun ketma-ket vaqt intervalidagi sochilgan yorug‘lik intensivliklarini bir-biri bilan taqqoslaydi. Korrelyator signalni ⑥ kompyuterga uzatadi, kompyuterdagi maxsus Zetasizer dasturi ma’lumotlarni tahlil qiladi va zarracha o‘lchamini aniqlaydi.



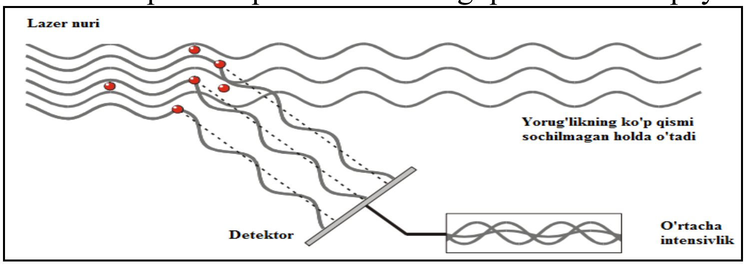
1-rasm. Zetasizer Nano tizimi blok tuzilmasi

Natijalar va ularning muhokamasi. Fulleren eritmasidagi muallaq nanozarralarning suyuqlik molekulalari ta’siridagi tartibsiz harakatiga Broun harakati deb qabul qilinadi. Suyuqlikda zarrachalarning tartibsiz harakatida ularning tezligi zarrachaning o‘lchamiga qarab aniqlanadi. Bunda kichik zarrachalarning tezroq, katta zarrachalarning esa sekinroq harakatlanishi (diffuziyalanishi) e’tiborga olinadi. Yorug‘likning dinamik sochilishi (Foton Korrelyatsiya Spektroskopiya ham deb ataladi) broun harakatini va uning zarracha o‘lchamiga bog‘liqligini aniqlaydi. Bu vazifani zarrachalarni lazer nuri ta’sirida sochilgan yorug‘likdagi intensevlik fluktatsiyasini tahlil qilish orqali amalga oshiradi. Agar kichik bir zarracha lazer nuri bilan yoritilsa, zarracha barcha yo‘nalishlarda yorug‘likni sochadi. Agar ekranni zarrachaga juda yaqin qilib joylashtirilsa, sochilgan nur ekrani yoritadi. Agar bitta zarrachani tinch turgan minglab zarrachalar bilan almashtirilsa, ekranda yonma-yon turgan yorug‘ va qorong‘i sohalardan iborat bo‘lgan tasvir hosil bo‘ldi (2-rasm).



2-rasm. Fulleren eritmasida sochilgan yorug‘likning intensivlik fluktatsiyasi

3-rasmda fulleren eritmasida nanoklasterlar tomonidan sochilgan to‘lqinning maxsus detektorda qayd etilishi tasvirlangan. Ekranda sochilgan nurlarning interferensiyasi sodir bo‘ladi, ya’ni yorug‘ soha bir xil fazadagi sochilgan to‘lqinlarning qo‘shilishidan hosil bo‘lgan, qorong‘i soha esa qarama-qarshi fazalarning qo‘shilishidan paydo bo‘lgan.



3-rasm. Fulleren eritmasida sochilgan yorug‘likning detektorda qayd etilishi.

Biz yuqoridagi misolda fulleren nanozarrachasi tinch holatda deb olgandik. Bu vaziyatda yorug‘ va qorong‘i sohalar o‘lcham jihatidan ham, joylashish jihatidan ham o‘zgarmas bo‘ladi. Aslida, suyuqlikdagi suspenziyalangan fulleren nanozarrachasi hech qachon tinch turmaydi, ular har doim suyuqlik zarrachalari bilan tartibsiz ta’sirlashib Broun harakatida bo‘ladi. YDS usulidan foydalanish uchun Broun harakatidagi katta zarrachalar sekinroq, kichik zarrachalar esa tezroq harakatlanishini hisobga olish muhim hisoblanib, nanozarrachaning olgan tezligi va uning o‘lchami orasidagi bog‘liqlik Stoks-Eynshteyn tenglamasidan aniqlanadi:

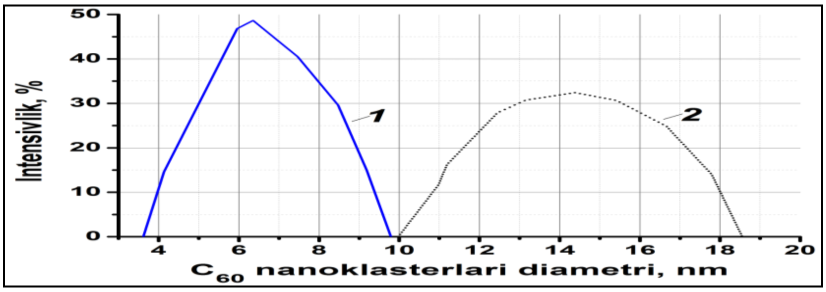
$$d_h = \frac{kT}{3\pi D_h \eta}$$

bu yerda: d_h - nanoklasterning gidrodinamik radiusi, k - Bolsman doimiysi, T- absolyut temperatura, D_h –diffuziya koeffitsiyenti va η - eritmaning dinamik qovushqoqligi.

Zarrachalar to‘xtovsiz doimo harakatlanganda yorug‘ va qorong‘i sohalar ham harakatlanib ko‘rinadi. Sochilgan yorug‘likning bir xil yoki qarama-qarshi fazalari qo‘shilish yorug‘ va qorong‘i sohalar intensivlikning oshishi yoki kamayishiga sabab bo‘ladi, yoki boshqacha qilib aytganda, ma’lum bir joyda intensivlik fluktatsiyasi yuzaga keladi. Zetasizer Nano tizimi intensivlik fluktatsiyasining qiymatini o‘lchaydi va bundan foydalanib zarrachaning o‘lchamini aniqlaydi.

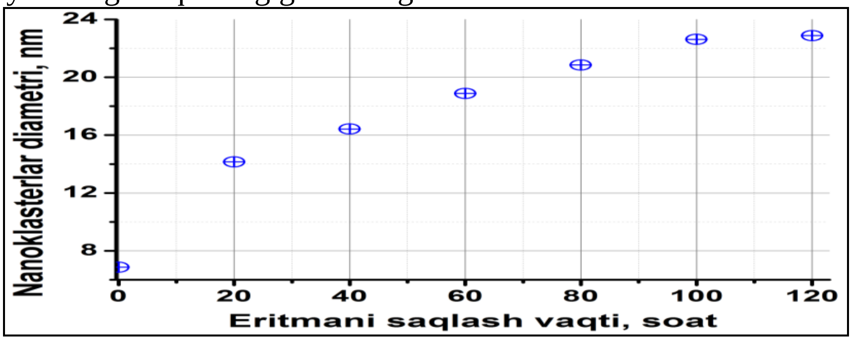
C_{60}/ksilol/etanol eritmasidagi C_{60} fulleren molekulalarining o‘z-o‘zidan yig‘ilishini baholash uchun YDS usulidan foydalanib, hosil bo‘lgan C_{60} nanoklasterlarining gidrodinamik diametri o‘lchandi. 4-rasmda C_{60}/ksilol/etanol (ksilol va etanolning hajmiy ulushlari mos ravishda 0.6:0.4 nisbatda) eritmasida sintezlangan fulleren nanoklasterlari o‘lcham taqsimotining eritma tayyorlangandan birdaniga (*1* egri chiziq) va eritmani 20 soat saqlangandan so‘ng (*2* egri chiziq) o‘zgarish evolyutsiyasi keltirilgan. Eritma tayyorlangandan birdaniga o‘lchanganda sintezlangan nanoklasterlari gidrodinamik diametri ~3,6÷9,8 nm oralig‘ida joylashgan bo‘lib, nanoklasterlarning o‘rtacha diametri ~6,87 nm ni tashkil etdi (*1* egri chiziqqa qarang). So‘ngra C_{60}/ksilol/etanol eritmani bir necha soat (20 soat) davomida qorong‘i xonada saqlagandan so‘ng o‘lchash olib borildi.

Bu holda sintezlangan nanoklasterlarning gidrodinamik diametri oshganligi ko‘rinib turibdi (*2* egri chiziqqa qarang). C_{60} nanoklasterlarning o‘rtacha gidrodinamik diametri ~14,17 nm, minimal va maksimal diametrlari esa mos holda ~9,98 nm va ~18,56 nm ga mos kelmoqda. Shuni ta’kidlash kerakki, yangi tayyorlangan C_{60}/ksilol eritma (C_{60}~0,2 mg/ml) YDS usulida o‘rganilganda, unda sintezlangan nanoklasterlar qayd etilmadi. C_{60}/ksilol eritmaga 40% hajmiy ulushda etanol qo‘shilganda yangi tayyorlangan C_{60}/ksilol/etanol eritmada nanoklasterlarning hosil bo‘lganligi qayd etildi (4-rasm, *1* egri chiziq). Ushbu effekt C_{60}-C_{60} va C_{60}-erituvchi molekulalar o‘rtasidagi o‘zaro ta’sir kuchlarining qayta taqsimlanishida erituvchilarning qutbliligi (eritmaga etanol qo‘shilishi) muhim rol o‘ynashini ko‘rsatadi. Undan tashqari ishchi eritma (C_{60}/ksilol/etanol) bir necha soatgacha qorong‘i xonada saqlanganda, C_{60}-erituvchilar molekulalari o‘rtasidagi o‘zaro ta’sir kuchlaridan C_{60}-C_{60} molekulalari o‘rtasidagi o‘zaro ta’sir kuchlari ortiq bo‘lishi yuzaga keladi. Natijada yanada kattaroq o‘lchamli nanoklasterlar hosil bo‘ladi (4-rasm, *2* egri chiziq).



4-rasm. C_{60}/ksilol/etanol (ksilol va etanolning hajmiy ulushlari mos ravishda 0.6:0.4 nisbatda) eritmasida sintezlangan fulleren nanoklasterlari o‘lcham taqsimotining vaqt bo‘yicha o‘zgarishi: *1* – eritma tayyorlangandan birdaniga, *2* – eritmani 20 soat saqlangandan so‘ng. Eritmadagi C_{60} konsentratsiyasi ~0.2 mg/ml.

C_{60}/ksilol/etanol (ksilol va etanolning hajmiy ulushlari mos ravishda 0.6:0.4 nisbatda) tizimida hosil bo‘lgan C_{60} nanoklasterlarining o‘rtacha diametrining lazer nuri intensivligi bo‘yicha taqsimotining vaqt o‘tishi bilan o‘zgarishi 5-rasmda ko‘rsatilgan. Eritmaning saqlash vaqti oshishi bilan C_{60} nanoklasterlarining gidrodinamik diametri ortishi rasmdan ko‘rinib turibdi. Dastlabki eritmada C_{60} nanoklasterlarining o‘rtacha geometrik o‘lchamlari ~6,9 nm bo‘lgan, eritmani 100 soat davomida saqlanishi nanoklasterlarning o‘rtacha o‘lchamlari ~22,6 nm gacha oshishiga mos keladi. Shuni ta’kidlash joizki, C_{60}/ksilol/etanol eritmani 100 soatdan keyingi saqlash nanoklasterlarning o‘lchamlarining o‘zgarishiga olib kelmaydi (5-rasm). Bu shuni ko‘rsatadiki, eritmani saqlashning ushbu davrida C_{60}/ksilol/etanol tizimidagi C_{60} nanozarralarini o‘z-o‘zidan yig‘ilish jarayonining barqarorligiga erishilgan.



5-rasm. C_{60}/ksilol/etanol (ksilol va etanolning hajmiy ulushlari mos ravishda 0.6:0.4 nisbatda) eritmasida sintezlangan fulleren nanoklasterlarining o‘rtacha o‘lchami taqsimotining (intensivlik bo‘yicha) vaqt davomida o‘zgarishi. Eritmadagi C_{60} konsentratsiyasi ~0.2 mg/ml.

Shunday qilib, binar erituvchilarda C_{60} fullerenning o‘z-o‘zidan yig‘ilish xususiyatlarini oʻrganishdan olingan natijalar shunga oʻxshash tabiatdagi organik nanoklasterning shakllanishini tahlil qilishda yordam beradi. C_{60} nanoklasterlarining oʻziga xos parametrlari (eritma ichida va tashqarisida barqarorlik, fotoelektrik xususiyatlar, elektronlarni tashish, energiyani saqlash va boshqa xususiyatlar) hali ham toʻliq tushunilmagan va shuning uchun kelajakdagi tadqiqotlarimiz uchun ajoyib sohadir.

Xulosa. Ikki komponentli erituvchi tizimida C_{60} fulleren molekulalarining oʻzaro ta'siri va oʻz-oʻzidan yigʻilish jarayonlarini oʻrganishning eksperimental natijalarini taqdim etildi. Yuqori aniqlikdagi YDS usulidan foydalangan holda olingan eksperimental natijalarimiz binar (ksilol/etanol) erituvchi tizimida C_{60} molekulalarining nanoklasterlari hosil boʻlishini tasdiqlaydi. C_{60}/ksilol/etanol eritmasidagi molekulalararo oʻzaro ta'sir darajasi C_{60}/ksilol/etanol eritmasini saqlash vaqtiga ham, komponentlarining hajmiy ulushlariga ham bogʻliqligi aniqlandi. YDS usuli yordamida nafaqat fulleren nanoklasterlarining oʻlchamini aniqlash, balki eritmada molekulalararo oʻzaro ta'sirlarning barqarorligini baholash imkoni borligi koʻrsatib berildi.

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Foydalanilgan adabiyotlar

1. Luyts K., Napierska D., Nemery B., Hoet P.H. (2013). How physico-chemical characteristics of nanoparticles cause their toxicity: complex and unresolved interrelations // *Environmental science: processes & impacts*, *15*(1), 23-38. https://doi.org/10.1039/C2EM30237C
2. Taylor R., Coulombe S., Otanicar T., Phelan P., Gunawan A., Tyagi H. (2013). Small particles, big impacts: A review of the diverse applications of nanofluids // *Journal of applied physics*, *113*(1). https://doi.org/10.1063/1.4754271
3. Bakhramov S.A., Makhmanov U.K., Aslonov B.A. (2023). The Synthesis of C_{70} Fullerene Nanowhiskers Using the Evaporating Drop Method // *Condensed Matter, 8 (3), 62-71*. https://doi.org/10.3390/condmat8030062
4. Meng-Chih S., Yung Hui Y. (2019). Introduction to Carbon Structures // *Carbon Nanomaterials for Bioimaging, Bioanalysis, and Therapy*, 1-14. https://doi.org/10.1002/9781119373476.ch1
5. Bao L., Xu T., Guo K., Huang W., Lu, X. (2022). Supramolecular Engineering of Crystalline Fullerene Micro-Nano-Architectures // *Advanced Materials*, *34*(52), 2200189. https://doi.org/10.1002/adma.202200189
6. Makhmanov U.K. (2022). Refractive and Electrophysical Properties of Dispersed Solutions of Fullerene C_{60} in Binary Solvents *// Journal of Engineering Physics and Thermophysics, 95 (2), 527-532.* https://doi.org/10.1007/s10891-022-02508-9
7. Ghavanloo E., Rafii-Tabar H., Kausar A., Giannopoulos G.I., Fazelzadeh, S.A. (2023). Experimental and computational physics of fullerenes and their nanocomposites: Synthesis, thermo-mechanical characteristics and nanomedicine applications // *Physics Reports*, *996*, 1-116. https://doi.org/10.1016/j.physrep.2022.10.003
8. Grätzel M. (2007). Photovoltaic and photoelectrochemical conversion of solar energy // *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *365*(1853), 993-1005. https://doi.org/10.1098/rsta.2006.1963
9. García de Arquer F.P., Talapin D.V., Klimov V.I., Arakawa Y., Bayer M., Sargent E.H. (2021). Semiconductor quantum dots: Technological progress and future challenges // *Science*, *373*(6555), eaaz8541. https://doi.org/10.1126/science.aaz8541
10. Bodunde O.P., Ikumapayi O.M., Akinlabi E.T., Oladapo B.I., Adeoye A.O., Fatoba S.O. (2021). A futuristic insight into a "nano-doctor": A clinical review on medical diagnosis and devices using nanotechnology // *Materials Today: Proceedings*, *44*, 1144-1153. https://doi.org/10.1016/j.matpr.2020.11.232
11. Ranabhat K., Patrikeev L., Revina A.A.E., Andrianov K., Lapshinsky V., Sofronova E. (2016). An introduction to solar cell technology // *Journal of Applied Engineering Science*, *14*(4). https://doi.org/10.5937/jaes14-10879
12. Schur D.V., Zaginaichenko S.Y., Veziroglu T.N. (2015). The hydrogenation process as a method of investigation of fullerene C_{60} molecule // *International journal of hydrogen energy*, *40*(6), 2742-2762. https://doi.org/10.1016/j.ijhydene.2014.12.092

13. Makhmanov U.K., . Kokhkharov A.M., Bakhramov S.A., Esanov S.A., Erts D. (2022). Self-assembly of C_{60} fullerene molecules in the hexane–xylene solvent system // *Fullerenes, nanotubes and carbon nanostructures*, *30(1), 80–84.* https://doi.org/10.1080/1536383X.2021.1992390.

14. Beheshtian J., Peyghan A.A., Bagheri Z. (2012). Theoretical investigation of C_{60} fullerene functionalization with tetrazine // *Computational and Theoretical Chemistry*, *992*, 164-167. https://doi.org/10.1016/j.comptc.2012.05.039

15. Makhmanov U.K., Kokhkharov A.M., Aslonov B.A., Esanov Sh.A., Bekmurodov Z., Musurmonov K.N., Shukurov A.X., Chuliyev T.A. (2024). Behavior of fullerene C_{60} in xylene/dimethylformamide binary solvents // *Uzbek Journal of Physics, 26 (1), 1-5*. https//doi.org/10.52304/.v26i1.490

TAJRIBA NATIJALARI VA ZAMONAVIY KVANTO-KIMYOVIY HISOBLASH USULLARI

A.A. Nekboyev
Qarshi davlat universiteti, tayanch doktorant
B.T. Qo‘yliyev
Qarshi davlat universiteti, professor
bahromq@rambler.ru
U.E. Salomov
Qarshi davlat universiteti, tayanch doktorant
D.B. Gulmuratova
Qarshi davlat universiteti, magistr
A. Xudayberdiyev
Qarshi davlat universiteti, talaba
ORCID: 0009-0005-9065-7050,
UDK. 546.11:544.18(045)

Annotatsiya: So‘nggi yillarda kvanto-kimyoviy hisoblash usullari, xususan, zichlik funksional nazariyasi (DFT) usulining rivojlanishi kvanto-kimyoviy hisoblashlar orqali elektron o‘tishlarning kattaliklarini, molekulalarning tebranma chastotalarini va o‘rtacha o‘lchamdagi molekulalar uchun modellashtirish usuli bilan olingan natijalarni tajribada olingan natijalar bilan taqqoslash imkoni tug‘ildi. Kompyuter texnologiyalarining jadal rivojlanishi mutaxassislarning ko‘plab molekulyar xususiyatlarni, xususan, nano o‘lchamli materiallarning xususiyatlarini, shuningdek, biologik tizimlarda sodir bo‘ladigan reaksiyalar va jarayonlarni tushunishi, modellashtirish va bashorat qilish uchun kvanto-kimyoviy hisoblashlardan foydalanishiga yordam berdi.

Kvanto-kimyoviy hisoblash usullari molekulalarning turli fizik-kimyoviy xossalarini, ularning elektron tuzilishi va fazoviy tuzilishini tavsiflash imkonini beradi. Hisoblash usullaridan foydalanish eksperimental tadqiqotlar uchun mavjud bo‘lmagan yoki qiyin bo‘lgan molekulyar tizimlarning xususiyatlarini o‘rganishga imkon beradi (elektron o‘tish holatlari va fazoviy tuzilmalari, elektron tuzilmalar va kuchli hamda zaif molekulalararo H-bog‘lanishga ega bo‘lgan har xil turdagi assotsiatsiyalar, komplekslar va molekulyar klasterlarning geometrik parametrlari).

Kalit so‘zlar: Vodorod bog‘lanish, tebranma spektr, zichlik funksional nazariyasi (DFT), assotsiatsiya, klaster.

EXPERIMENTAL RESULTS AND MODERN QUANTUM-CHEMICAL CALCULATION METHODS

Abstract: In recent years, the development of quantum-chemical computational methods, particularly the Density Functional Theory (DFT), has enabled the comparison of results obtained through quantum-chemical calculations–such as electronic transitions, vibrational frequencies of molecules, and modeling of medium-sized molecules—with experimental data. The rapid advancement of computer technology has allowed specialists to use quantum-chemical calculations to understand, model, and predict many molecular properties, particularly those of nanoscale materials, as well as reactions and processes occurring in biological systems.

Quantum-chemical computational methods allow for the description of various physicochemical properties of molecules, including their electronic structure and spatial arrangement. The use of these computational methods enables the study of properties of molecular systems that are difficult or impossible to investigate experimentally, such as electronic transition states and spatial structures, electronic configurations, and the geometric parameters of different types of associations, complexes, and molecular clusters that involve strong and weak intermolecular hydrogen bonding.

Key words: Hydrogen bond, vibrational spectrum, density functional theory (DFT), association, cluster.

Kirish. Kvanto-kimyoviy hisoblashlar yordamida molekulalarning geometrik parametrlarini, tebranma spektrlarini, asosiy holat energiyasini, termodinamik parametrlarni va molekulalardagi elektron zichlik taqsimotini aniqlash mumkin. Bu hisoblashlarni amalga oshirish va natijalarni eksperimental ma'lumotlar bilan solishtirish, yangi bilimlarni olish va tajriba natijalarini chuqur tahlil qilish imkonini yaratadi. Zamonaviy kvanto-kimyoviy hisoblash usullari, asosan, Shredinger tenglamasiga asoslanadi, bu tenglama barqaror holatlar uchun ishlatiladi. Odatda, bu tenglama adiabatik usulda yechiladi, ya'ni elektronlar va yadro harakatlari alohida ko'rib chiqiladi. Boshqacha qilib aytganda, elektronlar va yadroning harakatini turli alohida tenglamalar orqali yechish mumkin deb hisoblanadi. Shu yondashuv yordamida, elektron to'lqin funksiyasi uchun Shredinger tenglamasi quyidagi shaklda ifodalanadi.

$$\hat{H}\Psi = E\Psi \quad (1)$$

Bu yerda $\hat{H}$ — sistemaning Gamilton operatori bo'lib, u kinetik va potensial energiya operatorlarining yig'indisidan iborat. $\Psi = \Psi(x_1, x_1, \ldots, x_n)$ — n ta zarracha sistemasi uchun to'lqin funksiyasini ifodalaydi, bu funksiya zarrachalarning fazodagi joylashishi va spiniga bog'liq bo'ladi. E — umumiy elektron energiyasini bildiradi. Molekulaning elektronlari uchun Shredinger tenglamasini yechish orqali yadrolarning turli konfiguratsiyalariga qarab elektronlarning ichki energiyasini hisoblash mumkin [1-3], bunda elektron energiyasi yadro koordinatalariga bog'liq bo'ladi. Biroq ko'p elektronli tizimlar juda ko'p erkinlik darajalariga ega, shuning uchun bu tizimlar uchun Shredinger tenglamasini aniq yechish juda qiyin. Shunday qilib, elektronlar uchun bu tenglama faqat taxminiy yoki yaqinlashgan usullar bilan yechiladi.

Zichlik funksional nazariyasi (DFT) hozirgi kunda molekulalarning elektron tuzilishini o'rganishda juda samarali usul bo'lib xizmat qilmoqda. DFT usulidagi asosiy yutuqlardan biri, ayniqsa, 3 parametrli Becke funksionali (B3LYP) ning rivojlanishi hisoblanadi. Bu yutuqlar va kompyuter hisoblash quvvatining tez o'sishi natijasida yuqori molekulyar tizimlarni yuqori darajadagi aniqlik bilan hisoblash imkoniyati yaratildi. B3LYP funksionalini o'rta o'lchamli yadro to'plamlaridan foydalangan holda ishlatish, 100 dan ortiq atomni o'z ichiga olgan sistemalarni hisoblash imkonini beradi. Bu esa ko'plab yangi imkoniyatlarga yo'l ochadi. Mexanik gepotezalarni o'rganishda, turli o'tish holatlarini va o'zaro bog'lanishlarni aniqlash uchun ko'plab hisoblashlarni amalga oshirish zarur bo'ladi. Shu bilan birga, bu modellarda keltirilgan taxminlarning aniqligi, asosiy hisoblash usulining aniqligidan yuqori yoki unga teng bo'lishi kerak.

Tadqiqot metodologiyasi. Kvant mexanikasi ko'p elektronli sistemalarni hisoblash imkonini beradi. Biroq oddiy sistemalarni, masalan, vodorod atomi, geliy yoki vodorod molekulasini hisoblash Shredinger tenglamasining aniq yoki taxminiy yechimlari yordamida oson amalga oshiriladi. Ammo ko'p elektronli sistemalarni hisoblashda esa katta qiyinchiliklar yuzaga keladi, chunki bu sistemalarning hisoblashlari ancha murakkab va murakkabliklari Shredinger tenglamasini yechishni sezilarli darajada qiyinlashtiradi. Ushbu muammoni yechishning bir usuli — Xartri-Fok yoki o'ziga xos maydon (SCF) usuli [4]. Bu yondashuvda har bir elektronning joylashuvi, uning harakatini belgilovchi atom yadrosi maydoni va boshqa elektronlar tomonidan yaratilgan o'rtacha (effektiv) maydonni hisobga oladi.

Kvant kimyosining taraqqiyoti Tomas-Fermi va Tomas-Fermi-Dirak modellariga asoslanadi, ular elektron zichligi funksiyasidan foydalanib atomlar va molekulalarning energiyasini hisoblashning nazariy asoslarini taqdim etgan. Xartri-Fok nazariyasi esa ab initio hisoblash metodlarining dastlabki usullaridan biri bo'lib, to'g'ridan to'g'ri Shredinger tenglamasidan ishlab chiqilgan. Ushbu metod Xartri potensialini qo'llasa-da, elektronlarning almashinish oʻzaro taʼsirini hisobga oladi, bu esa elektron toʻlqin funksiyasining antisimmetrik tabiatini taʼminlaydi. Natijada atomlarning umumiy bogʻlanish energiyasi kamayadi, shu bilan birga parallel spinli elektronlar bir-biridan masofalanadi. Nazariyaning kamchiligi shundaki, u antiparallel spinlar bilan ikkita elektron orasidagi harakatdagi korrelyatsiyani hisobga olmaydi. DFT da funksional elektron zichligi boʻlib, u fazo va vaqtning funksiyasidir. Toʻgʻridan toʻgʻri koʻp atomli zarrachalarning toʻlqin funksiyasi bilan shugʻullanadigan. Xartri-Fok nazariyasidan farqli oʻlaroq, Zichlik funksional nazariyasida (DFT) elektron zichligi tizimning asosiy xususiyati sifatida qaraladi. Elektron zichligini hisoblash usuli tizimning energetik xususiyatlarini tezroq aniqlash imkonini beradi. Koʻp atomli tizimlarda elektron toʻlqin funksiyasi barcha atomlarning koordinatalarini hisobga olgan holda *3N* oʻzgaruvchiga bogʻliq boʻladi, holbuki elektron zichligi faqat uchta fazoviy oʻzgaruvchiga x, y, z. bogʻliqdir. Xoyenburg va Kon elektron zichligi hisoblashlarda muhim rol oʻynashini koʻrsatib, maxsus bir teorema ishlab chiqdilar. Ularning teoremasiga koʻra, har qanday tizimning elektron zichligi uning asosiy holatining barcha xususiyatlarini aniqlashda toʻliq va yetarli maʼlumotlarni beradi. Har bir sistemadagi elektron zichligi faqat uchta fazoviy oʻzgaruvchiga x, y, z bogʻliq boʻlgani uchun, bu yondashuv hisoblashlarni ancha soddalashtiradi va sistemaga qoʻyilgan cheklovlarni kamaytiradi. Ushbu yondashuvning asosida Tomas-Fermi nazariyasining elektron zichligi orqali tashqi maydondagi elektron xususiyatlarini ifodalash va uni umumlashtirish jarayoni yotadi. Kon-Sham nazariyasi esa, zichlik funksional nazariyasining (DFT) rivojlanishi bilan, kondensirlangan moddalarning zamonaviy elektron xususiyatlarini oʻrganishning asosiy nazariy prinsipiga aylangan.

Natijalar va muhokama. Zichlik funksional nazariyasining asosi shundaki, oʻzaro taʼsir qiluvchi zarrachalar tizimining xususiyatlarini elektron zichligi funksiyasi $n(r)$ yordamida tavsiflash mumkin. Ushbu uch oʻlchovli skalyar funksiya elektron zichligi $n(r)$ funksiyasi tizimning energetik holati va uning fazodagi taqsimotini toʻliq aniqlaydi. Kon va Hoyenberg nol haroratdagi koʻp elektronli sistemalarda bunday funksionalning mavjudligini birinchi boʻlib isbotlashgan. Ularning tadqiqotlari elektron zichlik funksiyasi sistemaning asosiy holatini toʻliq tavsiflash uchun zarur ekanligini koʻrsatdi. Keyinchalik Mermin bu teoremani kengaytirib, Kon va Hoyenberg tomonidan keltirilgan natijalarni haroratning istalgan qiymatiga ega sistemalarga ham tatbiq qilish imkoniyatini yaratdi [5]. Biroq dastlabki ishlarda elektron zichligini funksional sifatida qurish uchun aniq usullar taqdim etilmagan edi. Zichlik funksionalini amaliy tarzda yaratishning birinchi yondashuvi Kon va Sham tomonidan ishlab chiqilgan [6]. Ularning ishlari, zichlik funksiyasini hisoblashda asosiy vosita sifatida ishlatiladigan aniq yondashuvni taqdim etdi [7].

Hoyenberg-Kon teoremasining asosida Kon va Sham tomonidan ishlab chiqilgan yondashuv, zichlik funksionalining hisoblanishini imkoniyat yaratdi. Kon-Sham nazariyasi, tizimning haqiqiy asosiy holat zichligi, oʻzaro taʼsir qilmaydigan zarrachalardan iborat xayoliy tizimning asosiy holat zichligi sifatida ifodalanganini koʻrsatadi. Bu yondashuv mustaqil zarrachalar uchun yechilishi mumkin boʻlgan tenglamalar toʻplamini yaratadi, bu esa tizimning energiya funksiyasini hisoblash imkonini beradi.

Xartri-Fok usuli va uning turli modifikatsiyalari, shuningdek, Kon-Sham usulining qoʻllanilishi, zamonaviy hisoblash mexanizmlari va dasturiy taʼminotlar yordamida amalga oshiriladi. Bu metodlar molekulyar tizimlarning energetik va dinamik xususiyatlarini yuqori aniqlikda tahlil qilish imkonini beradi. Molekulyar xususiyatlarni aniqlashda ishlatiladigan dasturiy paketlar, masalan, GAUSSIAN, CADPAC, CRYSTAL, HYPERCHEM, GAMESS, ADF va SPARTAN, ilgʻor kvant-kimyoviy hisoblashlarni amalga oshirish uchun moʻljallangan boʻlib, molekulalarning energetik jihatlari, strukturaviy o‘zgarishlari va boshqa fizikaviy xususiyatlarini tahlil qiladi [8].

Tebranma spektroskopiya turli ilmiy sohalarda, ayniqsa, materiallar va molekulyar tizimlarni o‘rganishda muhim tahlil vositasi sifatida ishlatiladi. Bu usulda, yutish zonalari va molekulalardagi yoki kimyoviy guruhlardagi o‘zaro ta’sirlar tebranish spektrining shaklini va xususiyatlarini belgilovchi asosiy omil hisoblanadi. Bunga sabab, namunadagi barcha atom yadrolarining qo‘shma harakati molekulaning umumiy tebranish spektridagi chiziqlarga ta’sir ko‘rsatadi. N ta yadrolar uchun eksperimental ravishda kuzatilgan $3N-6$ dan ortiq polasalar mavjud emas. Tebranma chastotalardan kuch doimiylarini olish hal qilinmagan matematik muammodir, chunki ko‘p polosalar amalda kuzatilmaydi. Misol uchun, garmonik yaqinlashuvda farqlar, kombinatsiyalangan chiziqlar va nomuvofiqliklarning mavjudligi sababli, bu muammo hali to‘liq yechimini topmagan. Bu turdagi murakkab holatlar, tahlil qilishda turli xil xatoliklar va tafovutlarga olib kelishi mumkin. Potensial sirt energiyasini aniq hisoblash uchun samarali va optimallashtirilgan hisoblash kodlarini ishlab chiqish yoki topish bu muammoni hal qilish uchun muhim qadam bo‘lishi mumkin. Yangi va kuchli hisoblash metodlarini qo‘llash, energiya qiymatlarini yaxshilash va nomuvofiqliklarni kamaytirish orqali yanada aniqroq va ishonchli natijalarga erishish mumkin.

Ko‘p atomli molekulalarning tebranish nazariyasida eng keng tarqalgan g‘oya bu birinchi marta A.Elyashevich tomonidan taklif qilingan umumlashgan koordinatalar (q_i) sistemasidagi atomlarning tebranishidir va mustaqil ravishda Uilson (GF usuli) kiritgan. Bu nazariyada bog‘ uzunligining o‘zgarishi, bog‘ orasidagi burchakning o‘zgarishi, bog‘ uzunligi va tekisliklar orasidagi burchaklarni o‘zgartirish, juft bog‘larni hosil qiluvchi tekisliklar orasidagi digedral burchaklar va ko‘p burchakli burchaklarning o‘zgarishi molekulaning strukturasiga va uning dinamikasiga ta’sir qiladi. Tebranish masalasini hal qilish uchun molekulaning kinetik va kuch konstantalari aniq bo‘lishi kerak. Polimer zanjirining geometrik parametrlarini hisobga olish, T matritsasini ma’lum algoritmlar yordamida aniq tuzishni ta’minlaydi, ammo U matritsasining elementlarini aniqlash ancha murakkab va qiyinroq hisoblanadi [9-12].

Kimyoviy bog‘lanishning kuch konstantasi $K(i)$ bu bog‘ning uzayishi natijasida hosil bo‘lgan to‘la molekulyar energiya qi ning ikkinchi tartibli hosilasiga teng $(\partial^2E/\partial^2qi)$, bu mexanik xususiyatlarining asosiy xarakteristikasi bo‘lib ko‘rinadi.

Katta yoki murakkab tizimlar bilan ishlay oladigan kvanto-kimyoviy hisoblash usullarni ishlab chiqish kvant kimyosining muhim masalasidir. Dastlab kvant kimyogarlari katta tizimlarni o‘rganish uchun yarim empirik molekulyar orbital usulini ishlab chiqdilar. Ushbu usullar ko‘pincha ma’lum molekulalarning xususiyatlarini takrorlash orqali optimallashtirilgan ko‘plab empirik parametrlarni o‘z ichiga oladi. Odatda parametrlar parametrlangan tizimlar uchun to‘g‘ri bo‘ladi. Katta molekulaning turli konformatsiyasining nisbiy energiyalari, bog‘lanish energiyalari va vodorod bog‘lanish tizimining tuzilishi kabi ko‘plab fizikaviy xususiyatlarni hisoblashda yarim empirik metodlarning natijalari ko‘pincha ishonchsiz bo‘ladi. Bu, ayniqsa, vodorod bog‘lanishli molekulyar klasterlar uchun muammo tug‘diradi, chunki bu turdagi metodlar tizimning murakkab o‘zaro ta’sirlarini to‘liq aks ettira olmaydi. So‘nggi yillarda katta molekulyar sistemalarni o‘rganish uchun kvanto-kimyoviy hisoblash usullarining bir qator yangi variantlari ishlab chiqildi. Masalan, AM1, PM3, va MNDO kabi yarim empirik usullar hisoblashlarni oldindan tayyorlangan ma’lumotlar bilan almashtirib, hisoblash jarayonini sezilarli darajada tezlashtiradi [13]. Bu metodlar, ayniqsa, katta molekulalarni tahlil qilishda qo‘llanilib, murakkab sistemalar uchun hisoblashlarni ancha osonlashtiradi.

Xulosa. Kuch konstantalari yarim empirik yondashuvda antimateriya masalasini hal qilish orqali olingan maxsus empirik parametrlar sifatida qaraladi. Ushbu konstantalar

kvant mexanikasi hisoblashlarida, amaliy hisoblashlardagi taxminiy qiymatlar sifatida ham qo‘llanilishi mumkin. Bu esa sistemaning xususiyatlarini o‘rganishda samarali bo‘lib, natijalar empirik asosda bo‘lganligi sababli taxminiy darajada bo‘ladi.

Bu usullar, asosan, kvant mexanikasi va statistik metodlarni kombinatsiya qilib, molekular tizimlarning xususiyatlarini taqdim etadi. **Modified Differential Negligible Overlap (MNDO)** usuli, o‘z navbatida, yarim empirik yondashuvlar sirasiga kiradi va molekulalar bilan bog‘liq bir qator xususiyatlarni hisoblash uchun ishlatiladi.

MNDO usuli ko‘pincha molekulalarning energetik holatlarini aniqlash, issiqlik hosil bo‘lishini, geometrik tuzilmani, dipol momentlarini va ionlanish energiyasini takrorlashda qo‘llaniladi. Bu yerda parametrlar atomlarning turiga qarab belgilanadi, ya’ni har bir atom turi uchun o‘ziga xos parametrlar mavjud.

Noempirik yondashuv esa, kuch konstantalari elektron holatlarning energiyasining yadro koordinatalariga nisbatan ikkilamchi hosilalari sifatida qaraladi va bu kuch konstantalari kvant mexanikasi orqali hisoblanadi. Bunday yondashuv ancha chuqur va umumiy bo‘lib, tizimning noaniqligini kamaytiradi, ammo bu usulda ko‘proq hisoblash resurslari va vaqt talab qilinadi.

Bugungi kunda kvant mexanikasi va kuchli kompyuterlar yordamida noempirik yondashuvlarning rivojlanishi yanada istiqbolli bo‘lib, ko‘plab yangi yondashuvlar va metodlar ishlab chiqilmoqda. Kompyuterlar va dasturlar yanada kuchli va tezlashayotganligi sababli, bu metodlarning yanada rivojlanishi va keng qo‘llanilishi kutilmoqda.

Foydalanilgan adabiyotlar

1. Бурштейн К.Я., Шорыгин П.П. Квантово-химические расчеты в органической химии и молекулярной спектроскопии// М.: Наука, 1989.- 98 с.
2. Беленький Л.И. Развитие квантово-химических исследований гетероциклов в институте органической химии российской академии наук // Химия гетероциклических соединений, 2011.-№1.-С.7-26.
3. Sadley J. Jaworski A. Theoretical studies of vibrational spectra of imidazole and its various forms., J. Mol. Struct., 1992.-V.274.-PP.247-257.
4. Мак-Вини Р., Сатклиф Б. Квантовая механика молекул // М.: Мир, 1972.-380 с.
5. Mermin D. Thermal Properties of the Inhomogeneous Electron Gas // Phys. Rev., 1965.-V.137.-P.1441.
6. Hohnberg P., Kohn W. Inhomogeneous electron gas // Phys. Rev. 1964, A.136.-p.864.
7. Gross E. K. U., Dobson J. F. Petersilka M. Density-functional theory of time dependent phenomena / Topics in Current Chemistry, vol. 181, edited by R. Nalewajski // Springer, 1996.-PP.81-172.
8. Бутырская Е.В. Компьютерная химия: основы теории и работа с программами Gaussian, Gauss View // М.: СОЛОН-Пресс, 2011.-224 с.
9. Грибов Л.А., Дементьев В.А. Методы и алгоритмы вычислений в теории колебательных спектров молекул // М.: Наука,1981.-356 с.
10. Волькенштейн М.В., Грибов Л.А., Ельяшевич М.А., Степанов Б.И. Колебания молекул // М.: Наука,1972.-700 с.
11. Gerratt J., Mills I.M. Force constants and dipole-moment derivatives of molecules from Hartree-Fok Calculation // J.Chem. Phys., 1968.-V.49.-№4. pp. 1719-1729.
12. Mathieu D. Simonitti Ph. Harmonic IR Spectra from Empirical Force Fields and ab into Dipole-Moment Derivatives // Int. J. Quntum Chem, 1998.-V.69.-№6.-PP.707-711.
13. Дементьев В.А., Смирнов В.И., Грибов Л.А. Фортран-программы для расчета колебаний молекул // Деп. В ВИНИТИ, 1976.-№4018-76, 1976.

QOPLAMA HOSIL QILUVCHI ISHA BIR JINSLI KORROZIYA INGIBITORI ISHLAB CHIQARISHNING TEXNOLOGIK ASPEKTLARI

Ismatov Sherzod Aktam o‘g‘li, o‘qituvchi
Qarshi muhandislik-iqtisodiyot instituti
Axmedov Vohid Nizomovich, dotsent
Buxoro muhandislik-texnologiya instituti
sherzodismatov412@gmail.com
ORCID 0009-0006-7016-909X
UDK 622.2:551.3.053

Annotatsiya. Mazkur maqolada qoplama hosil qiluvchi korroziya ingibitorining olinish texnologik imkoniyatlari tadqiqi natijalari keltirilgan. Shuningdek, texnologik jarayon bosqichlari va material balans asosida jarayon rejimi muhokamasi keltirilgan.Har bir bosqichlar uchun rejimlar o‘rganilgan va asosda material balans shakllantirilgan. Material balans asosida umumiy unum chiqarilgan. Taklif etilayotgan texnologiya turli xil markali po‘latdan tayyorlangan neft va gaz sanoati qurilmalarini korrozion yemirilishga qarshi gipan, glitserin, dibutilftalat va erituvchi asosida modifikatsiyalangan ingibitor olishning texnologik sxemasini ishlab chiqish. Shu munosabat bilan sintez qilinadigan birikmalar asosida sintezlangan moddalar qoplama hosil qilishi bois ularni korroziya ingibitorlari sifatida ishlatish imkonini beradi. Taklif etilayotgan texnologiya asosida tarkib uchun kerakli reagentlar aralashmasi berilgan nisbat orqali o‘lchanib ko‘ylakli reaktorga 65 ^{0}C-85 ^{0}C harorat, 1-1,1 atm bosim, 100-150 ayl/min chastota va 45-55 daqiqa vaqt davomida tikilish reaksiyasi orqali gel mahsuloti olingan. Hosil bo‘lgan mahsulot ikkinchi reaktor gomogenizatorda polifunksiongal guruh hisobiga reaksiya 98 % unum bilan borganligi aniqlangan. Ikkinchi reaktorga sig‘im orqali organik erituvchi 65-68% ga yetguncha aralashtirilib reaktorda 45^{0}C-50^{0}C harorat, 1 atm bosim, 20-40 ayl/min chastota va 30-35 daqiqa vaqt davomiyligida qizil-pushti, qovushqoqligi yuqori quyuq massa olingan. Ushbu mahsulot filtr orqali bir jinsli qoplama hosil qiluvchi ingibitor saqlash uchun sig‘imga nasos yordamida yuborilib tayyor mahsulot olingan.

Kalit so‘zlar: ko‘ylakli reaktor, sig‘im, ISHA termobarqaror qoplama, glitserin, gipan, dibutilftalat, reaktor, xomashyo.

Abstract. This article presents the results of the study of the technological possibilities of production of coating-forming corrosion inhibitor. Also, a discussion of the process mode based on technological process stages and material balance is presented. Modes for each stage are studied and the material balance is formed on the basis. Based on the material balance, the total output was released. The proposed technology is the development of a technological scheme for obtaining a modified inhibitor based on hypan, glycerin, dibutyl phthalate and solvent against corrosion of oil and gas industry equipment made of different brands of steel. In this regard, substances synthesized on the basis of synthetic compounds form a coating, which allows them to be used as corrosion inhibitors. On the basis of the proposed technology, the required mixture of reagents for the composition is measured by the given ratio, and the reaction of staring into the jacketed reactor at a temperature of 65 0C-85 0C, a pressure of 1-1.1 atm, a frequency of 100-150 rpm and a time of 45-55 minutes gel product was obtained through It was determined that the resulting product reacted with 98% efficiency due to the polyfunctional group in the second reactor homogenizer. In the second reactor, the organic solvent was mixed until it reached 65-68%, and the temperature of 450C-500C, the pressure of 1 atm, the frequency of 20-40 rpm and the duration of 30-35 minutes were obtained in the reactor. This product is sent through a filter to the inhibitor, which forms a homogeneous coating, to the storage tank, and the finished product is obtained.

Key words: jacketed reactor, capacity, ISHA thermostable coating, glycerin, hypan, dibutyl phthalate, reactor, raw materials.

Kirish. Taklif etilayotgan texnologiya turli xil markali po‘latdan tayyorlangan neft va gaz sanoati qurilmalarini korrozion yemirilishga qarshi gipan, glitserin, dibutilftalat va erituvchi asosida modifikatsiyalangan ingibitor olishning texnologik sxemasini ishlab chiqish. Shu munosabat bilan sintez qilinadigan birikmalar asosida sintezlangan moddalar qoplama hosil qilishi sababli ularni korroziya ingibitorlari sifatida ishlatish imkoni beradi.

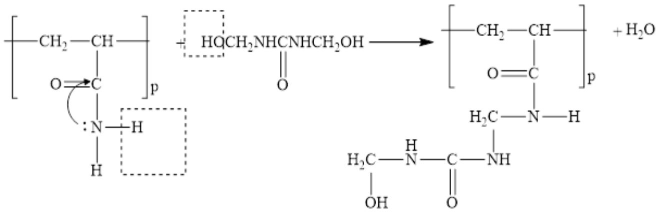
Tadqiqot metodologiyasi. Ishda qoplama hosil qiluvchi organik birikmalarni va ularning hosilalarini sintez qilish, reaksion xossalarini tadqiq qilish va texnologiyasini yaratish hamda sintez jarayoniga ta’sir qiluvchi omillar; harorat, reagentlar nisbati, vaqt va erituvchi tabiati ta’sirini o‘rganish, ishlatishi va olinish texnologiyalarini ishlab chiqishdan iborat. Shunga asosan quyidagi vazifalarni yechish zarur:

– qoplama hosil qiluvchi birikmalar sintez qilish, ularning fizik-kimyoviy xossalarni, sintez jarayoniga ta’sir etuvchi omillarni o‘rganish;

– sintez jarayoniga asosan muqobil variantlarni tanlash va u asosda optimal texnologiyasini yaratish;

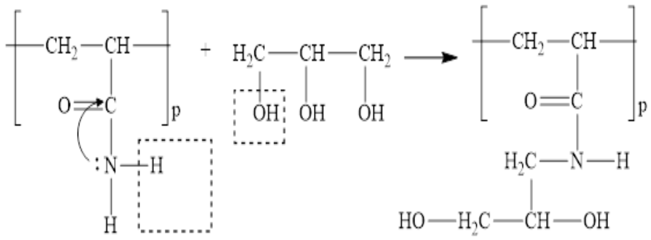
– olingan moddalarning xossalari hamda ularni samarali korroziya ingibitorlari maqsadida ishlatishdan iborat.

Sanoat chiqindisini turli xil nisbatda tikuvchi agentlar bilan tikish orqali poli (oligo)merlar olindi. Tikilish reaksiyasi umumiy holda quyidagicha ifodalandi:



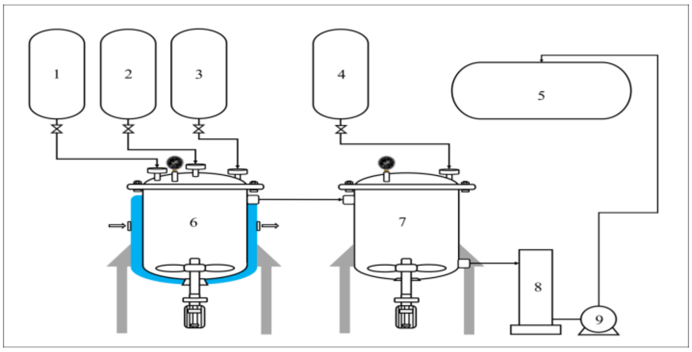
Sintez qilingan moddaning strukturasi zamonaviy tekshirish usullari orqali isbotlandi. Bunda IQ tasvirida karbonil guruhi uchun 3224 sm^{-1} da –OH bog‘ining, 1540 va 1624 sm^{-1} sohalarda karbonil (-C(O)-), 1404 sm^{-1} C-N bog‘i uchun, ikkilamchi amindagi N-H bog‘i 3343 sm^{-1} guruhlar uchun xos bo‘lgan valent tebranishlar hamda deformatsion tebranishlarni ko‘rish mumkin.

Gipanning glitserin bilan tikilish mahsuloti ham zamonaviy tekshirish usullari bilan o‘rganildi. Reaksiya tenglamasi quyidagicha:



Olingan birikmaning tarkibida 613 sm^{-1} benzol halqasida C-H bog‘ining yutilishi, 1078 sm^{-1} da 1078 sm^{-1} chuqur yutilish OH bog‘ining deformatsion, 1668 va 1648 sm^{-1} sohalarida yutilish karbonil –C(O)- guruhi uchun valent tebranish, 3324 sm^{-1} sohasidagi yutilish ikkilamchi amin (-NH-) bog‘iga xos bo‘lgan valent tebranishlarni ko‘rish mumkin.

Natija va muhokama. Taklif etilayotgan texnologiya asosida (1-rasm) tarkib uchun kerakli reagentlar (10 % li gipan (1), glitserin (2) va dibutilftalat (3)) aralashmasi berilgan nisbat orqali dozatorlar yordamida o‘lchanib ko‘ylakli reaktor(6)ga yuboriladi. Ushbu reaktor(6)da 650C-850C harorat, 1-1,1 atm bosim, 100-150 ayl/min chastota va 45-55 daqiqa vaqt davomida tikilish reaksiyasi orqali gel mahsuloti hosil bo‘ladi. Hosil bo‘lgan mahsulot ikkinchi reaktor(7) gomogenizatorga yuboriladi. (6) reaktorda polifunksiongal guruh hisobiga reaksiya 98 % unum bilan boradi. Dibutilftalat olingan ingibitorning plyonka hosil qilish qobiliyatini oshiradi. Ikkinchi reaktor(7)ga sig‘im(4) orqali organik erituvchi 65-68% ga yetguncha nisbatdagi aralashmasi jo‘natiladi. Bu reaktor(7)da 450C-500C harorat, 1 atm bosim, 20-40 ayl/min chastota va 30-35 daqiqa vaqt davomiyligida qizil-pushti, qovushqoqligi yuqori quyuq massa hosil bo‘ladi. Ushbu mahsulot filtr(8)ga jo‘natiladi. Filtrdan o‘tgan bir jinsli qoplama hosil qiluvchi ingibitor saqlash uchun sig‘imga(5) nasos(9) yordamida yuboriladi.



1-rasm. ISHA qoplama hosil qiluvchi korroziya ingibitori olishning texnologik sxemasi

1-2-3-4-5- sig‘im, 6-reaktor, 7-gomogenizator 8- filtr, 9-nasos.

1-jadval

Xomashyoning sarflari

№	Xomashyo	Mahsulotni qo‘shish nisbati
6-reaktorda		
1	10% li gipan	55
2	Glitserin	28-30
3	Dibutilftalat	17-15
7-reaktorda		
4	Erituvchi	35-32
5	Ingibitor	65-68

Xulosa. Taklif etiladigan texnologiya asosida 98 % unum bilan uzluksiz, termobarqaror ingibitor ishlab chiqarish texnologiyasi yaratiladi va jarayonni boshqarish imkoniyati mavjuddir. Ushbu texnologik ishlab chiqarish sxemasidan yaratilgan ISHA bir jinsli korroziya ingibitori chet eldan keltirilayotgan analoglardan arzonligi hamda foydali ish koeffitsiyenti yuqori bo‘ladi.

Foydalanilgan adabiyotlar:

1. Axmedov V.N., Ro‘zieva K.E., Raxmatov M.S., Panoyev N.Sh., Ro‘ziyev H.R., Murodjonov S.M. Gidrofob sement olishning ba’zi aspektlari // Fan va texnologiyalar taraqqiyoti. Ilmiy-texnikaviy jurnal, Buxoro, 2018 №1. 69-73b. (02.00.00;№14)

2. Axmedov V.N., Niyozov L.N., Panoev N.Sh., Vaxmudjonov S.M. Production and application of hudrophobizing polimer compositions // International journal of advanced research in science, Engeneering and Technology, India, Vol. 5, Issue 11, November 2018. page7340-7345.

3. Ниязов Л.Н., Паноев Н.Ш., Ахмедов В.Н., Муроджонов С.М., Хайдаров А.А. Гидрофобизация цементных и керамических изделий с использованим водорастворимых кремнеорганических соединений // Композиционный материал. - Узбекский научно-технический и производственный журнал, 2019. №1. S106-109 (02.00.00; №4)

4. N.Sh. Panoyev, V.N. Axmedov. Kremniyorganik birikmalar asosidagi teploizolyatsion qoplamalarning yangi tarkibini yaratish va xossalarini o‘rganish // Fan va texnologiyalar taraqqiyoti. Ilmiy-texnikaviy jurnal, Buxoro, 2019 №3. 64-69 b. (02.00.00; №14)

5. В.Н. Ахмедов, Л.Н. Ниязов, К.Э.Рузиева, Ф.Ф. Рахимов, Паноев Н.Ш. Гидрофобизация в строителстве. (монография).- Издателство Бухара, Дурдона, 2018. с160.

6. В.Н Ахмедов., М.С Рахматов., Н.Ш.Паноев. Технология получения композиций на основе кремниёрганических гидрофобизируюших полимеров // II international scientific conference of young researchers. Baku, 2018. s 472-474.

7. В. Собиров., В.Н Ахмедов., Н.Ш. Паноев. Влияние параметры на выход кремниорганических мономеров // Сборник трудов международной научно-технической конференции студентов, магистрантов на тему Молодеж-залог будушева великой степи. Шимкент, 2019. C 294-296.

8. В.Н. Ахмедов, Н.Ш. Паноэв, С.М. Махмуджонов. Получения гидрофобизириюших композиции полимеров и их применения в строителстве // II Всероссийская молодежная научно-практическая конференция Экологические проблемы промишленно развитых и ресурсодобиваюших регионов: пути решения 2018. 20-21 декабря.

9. Жумабоев Б.О., ва Исматов Ш.А. Свойства И технология многофункционалных органоминерал

ных покритий, устойчивых к агрессивным средам, для крупнотоннажного оборудования по сбору, хранению и транспортировке нефти и газа. Journal of multidisciplinary bulletin, 6(4), 86-92.

10. Ataqulova D., Bobomuradov O‘., Oripova L., Ismatov Sh., Kurbanov M., va Kodirov A. (2023). A New Highly Effective Inhibitor Based On 2, 7-Dimethyl-2, 7-Diciano-3, 6-Diazaoctan. Journal of Pharmaceutical Negative Results, 883-889.

11. Meliyeva K.O., Bobomurodov O‘.Z., Mavlanov Z.A. va Ismatov Sh A (2023). Study of secondary methods of oil production in the last period of operation. Innovations in Technology and Science Education, 2(8), 397-400.

12. Allanazarovich, M. Z., & Mustfoyevich, A. S. (2022). Prevention of potential metal deposition in industrial equipment.

13. Olimjonovich, J. B., Ismatov Sh. A. (2024). Protection Of Underground Gas Pipes From Corrosion Using Polymer Coatings. Scientific Impulse, 2(20), 78-81.

14. Raxmatov E. A., Abdullayev A. A., Jumaboyev B. O. Polietilen ishlab chiqarish liniyasida sovutuvchi tizim qurulmalarini takominlashtirish //O‘zbekistonda fanlararo innovatsiyalar va ilmiy tadqiqotlar jurnali. – 2022. – T. 2. – №. 14. – C. 246-250.

15. Rizayev, S. A., Jumaboyev, B. O., & Yuldashev, X. M. (2022). Atsetilen diollar sintezi va ularning xossalari. Journal of integrated education and research, 1(4), 218-223.

СРАВНЕНИЕ МОДЕЛЕЙ КОЛЕБАНИЯ ЗДАНИЙ С ПОДВИЖНЫМ ФУНДАМЕНТОМ ПРИ РЕАЛЬНЫХ СЕЙСМИЧЕСКИХ ВОЗДЕЙСТВИЯХ

Мирзаев Ибрахим,
Ташкентский государственный транспортный университет, профессор,
ibrakhim.mir@mail.ru
ORCID 0000-0002-8616-9717,
Турдиев Маликжон Сайфиддин ўғли,
Ташкентский государственный транспортный университет,
базовый докторант,
malikjon_ts@mail.ru
ORCID 0000-0002-2499-0243,
UDK 539.3, 519.633

Аннотация. В данной работе ранее полученные результаты по сдвиговой модели здания сравниваются с результатами, полученными с помощью моделей балки Тимошенко и Бернулли-Эйлера. В сдвиговой модели повороты масс не учитываются, а в балочной модели Бернулли-Эйлера учитываютя углы поворота за счет изгиба, а в модели балки Тимошенко дополнительно учитывается сдвиговая деформация. Построены матрицы метода конечных элементов и алгоритм решения задачи неявной схемой Ньюмарка, создан комплекс программ. Исследованы колебания зданий на скользящих фундаментах с сухим трением под действием реальных землетрясений. Использовались образцы четырехэтажного и девятиэтажного здания с набором двух записей землетрясений интенсивностью 8 и 9 баллов по шкале MSK-64. Полученные результаты для перерезывающих сил по этажам четырех и девятиэтажных зданий, подвергшихся воздействию двух землетрясений по их реальным записям акселерограмм, представлены в четырех таблицах. В таблицах указаны максимальные значения перезывающих сил по этажам зданий.

Ключевые слова: Здание, Сейсмические волны, Сейсмическая изоляция, Фторопласт, Сухое трение, Реальные записи землетрясения.

REAL SEYSMIK TA’SIRLAR OSTIDA HARAKATLANUVCHI POYDEVORLI BINOLARNING TEBRANISH MODELLARINI SOLISHTIRISH

Annotatsiya. Ushbu maqolada siljish modelidan ilgari olingan natijalar Timoshenko va Eyler-Bernulli modellari yordamida olingan natijalar bilan solishtiriladi. Siljish modelida massa aylanishlari hisobga olinmaydi, Eyler-Bernulli modelida esa egilish natijasidagi aylanish burchaklari, Timoshenko balka modelida esa kesish deformatsiyasi qo‘shimcha ravishda hisobga olinadi. Chekli elementlar usulining matritsalari va oshkormas Nyumark sxemasi yordamida masalani yechish algoritmi tuzilib, dasturlar to‘plami yaratildi. Haqiqiy zilzilalar ta’sirida quruq ishqalanishli sirpanuvchan poydevorlardagi binolarning tebranishlari o‘rganildi. To‘rt qavatli va to‘qqiz qavatli binolarning namunalari MSK-64 shkalasi bo‘yicha 8 va 9 intensivlikdagi zilzilalarning ikkita yozuvlari to‘plami bilan ishlatilgan. Ikkita zilzila sodir bo‘lgan to‘rt va to‘qqiz qavatli binolarning qavatlari uchun kesish kuchlari uchun ularning haqiqiy akselerogramma yozuvlaridan olingan natijalar to‘rtta jadvalda keltirilgan. Jadvallarda binolarning qavatlari bo‘yicha kesish kuchlarining maksimal qiymatlari ko‘rsatilgan.

Kalit so'zlar: Bino, Seysmik to'lqinlar, Seysmik izolyatsiya, Ftoroplastik, Quruq ishqalanish, Haqiqiy yer qimirlashi yozuvlari.

Введение. В последние десятилетия в странах мира проводятся различные меры защиты зданий и сооружений от печальных последствий сильных землетрясений. Важность защиты зданий и сооружений от воздействия очень сильных землетрясений не вызывает сомнений, так как это связано с жизнью и здоровьем людей. Для уменьшения силы воздействия землетрясений на здания и сооружения используются различные способы сейсмоизоляции, демпфирования и другие конструктивные решения [1-10].

В статье [5] предложена гибридная система пассивного управления, названная демпфированной изолированной структурной системой (система ДИСО), для конструкций атомных электростанций (АЭС) с двойной защитной оболочкой, в которой внешняя защитная оболочка неизолирована, а внутренняя защитная оболочка и оборудование изолированы соединительными демпферами, установленными между двумя защитными оболочками.

Статья [6] посвящена математическому исследованию системы с отрицательной жесткостью, которая может быть использована для сейсмоизоляции гражданских сооружений. Для расчета реального отклика системы с отрицательной жесткостью предлагается подходящая модификация итерационного численного метода Ньюмарка.

В статье [7] предлагается использование различных систем выносных опор в высотных зданиях и мостах при типичных землетрясениях и ветровом воздействии, применяется МКЭ.

В статье [8] исследуется циклическое поведение нового типа соединения балки и колонны с демпферами из стальных пластин. Проведено сравнение численных решений с экспериментальными результатами.

В статье [9] представлен краткий обзор экспериментальных динамических характеристик слайдеров с изогнутой поверхностью, полученных в результате динамических испытаний для различных типов устройств, проведенных в лаборатории фонда EUCENTRE.

В статье [10] проанализировано поведение эластомерных подшипников, принятых для сейсмической защиты зданий и мостов, реализованных в модели OpenSees HystereticPoly. Метод постоянного среднего ускорения Ньюмарка используется для численного решения нелинейных уравнений равновесия анализируемой конструкции, поскольку такой численный метод интегрирования по времени является одновременно более точным и безусловно устойчивым.

В статье [11] представлен численный анализ на основе конечных элементов для случая гибкой консольной шпунтовой стены с конструкцией на стороне засыпки и без нее. В этой статье начальные статические изгибающие моменты и горизонтальные напряжения до приложения какой-либо сейсмической нагрузки сравниваются с теорией Кулона.

В [12] приведены уравнения движения и численный метод решения задачи воздействия волны на конструкцию с распределенными и сосредоточенными параметрами.

В статье [13] приведены матрицы масс, жесткостей и демпфирования балки Тимошенко.

В работе [14] использован алгоритм вычислений при учете вертикальной компоненты сейсмической волны и дополнительной податливой связи ростверка и фундамента.

Следует отметить, что динамические задачи с сухим трением являются существенно нелинейными задачами [14, 15]. В этих статьях для оценки эффективности сейсмоизоляции турбоагрегата АЭС устройствами сухого трения предлагается численный алгоритм решения нелинейной динамической задачи [15].

В исследовании [16] предложена экспериментально – аналитическая методика определения динамического коэффициента сухого трения способом создания свободных колебаний трущихся систем в лабораторных условиях.

В данной работе сравниваются разные модели расчета зданий со скользящим фундаментом при воздействии реальных землетрясений.

Методология исследования. Пусть задано горизонтальное движение основания здания в виде сейсмограммы реального землетрясения. Примем, что нижняя часть фундамента здания движется вместе с основанием, а верхняя часть фундамента, так называемый ростверк, разделен от нижней части фундамента двухслойным фторопластом [14, 18]. В качестве модели взаимодействия двух слоев фторопласта примем модель сухого трения Кулона.

Одномерные модели здания представим в виде уравнений, приведенных в [13-15].

Все три задачи решаются методом Ньюмарка [17]. За основу воздействия возмем оцифрованные реальные записи акселерограмм землетрясений [18], по ним вычисляем сейсмограммы на заданных шагах по времени, затем производим аппроксимацию сплайн функцией Эрмита для использования значений перемещений в требуемые моменты времени. В нелинейных задачах требуется шаг по времени в методе Ньюмарка брать намного меньше шага записи землетрясения.

Результаты и обсуждение. Обсудим результаты расчетов на следующих примерах. Пусть заданы характеристики 4 и 9 этажных зданий [14], а также акселерограммы горизонтальной компоненты двух следующих землетрясений [18]:

1. Abhar – 000475 (20.06.1990 г, 8 баллов по MSK-64, максимальное ускорение – 1.93 м/с^2, максимальное перемещение – 0.0641 м, шаг оцифрования – 0.005 с, продолжительность – 36 с);
2. Duzce – 001226 (17.08.1999 г, 9 баллов по MSK-64, максимальное ускорение – 3.66 м/с^2, максимальное перемещение – 0.1065 м, шаг оцифрования – 0.005 с, продолжительность – 36 с).

Четырехэтажное здание серии 76-017СА/53 имеет следующие характеристики [14]: кирпичное здание размером в плане 389.88 м^2; сосредоточенные массы в уровнях верхней части фундамента и этажей M_0=698000 кг, M_1=495000 кг, M_2=495000 кг, M_3=495000 кг, M_4=497575 кг, при этом общий вес здания, давящий на нижнюю часть фундамента, равен P=26269635 Н; сдвиговые жесткости по этажам одинаковы $k_i=16.08•10^8$ Н/м; вязкость материала здания по этажам одинаковы $\mu_i=26.9•10^5$ Нс/м.

Девятиэтажное здание серии 76-017СП/53 имеет следующие характеристики [14]: крупнопанельное здание размером в плане 291.6 м^2; сосредоточенные массы в уровнях верхней части фундамента и этажей M_0=449000 кг, M_1=379500 кг, M_2=379500 кг, M_3=379500 кг, M_4=379500 кг, M_5=379500 кг, M_6=379500 кг, M_7=379500 кг, M_8=379500 кг, M_9=341000 кг, при этом общий вес здания, давящий на нижнюю часть фундамента, равен P=37494800 Н; сдвиговые жесткости по этажам одинаковы $k_i=32.357•10^9$ Н/м; вязкость материала здания по этажам одинаковы $\mu_i=10.58•10^6$ Нс/м.

При численном решении задач с сухим трением, не зависимо от выбора явной или неявной конечно-разностной схемы, шаг по времени необходимо подбирать для обеспечения достаточной точности. В наших примерах расчетов шаг по времени был выбран равным 0.001 с.

В таблицах 1-4 представлены результаты расчетов максимальных значений перерезывающих усилий по этажам зданий для их трех моделей без учета и с учетом скольжения в фундаменте. В них приняты обозначения Mod1 – сдвиговая модель с сосредоточенными массами на уровнях этажей, Mod2 – модель балки Тимошенко с распределенными и сосредоточенными параметрами, Mod3 – модель балки Бернулли-Эйлера с распределенными и сосредоточенными параметрами.

Таблица 1. Максимальные значения перерезывающих усилий q_{max} по этажам для четырехэтажного здания при землетрясении №1

Этажи	Без скольжения q_{max}			Со скольжением f=0.05 q_{max}		
	Mod1	Mod2	Mod3	Mod1	Mod2	Mod3
1	16400	16400	4260	2250	1960	1550
2	14800	14300	3300	2590	2170	989
3	11700	10800	2330	2520	2070	845
4	7310	6100	1370	1800	1430	1100

Таблица 2. Максимальные значения перерезывающих усилий q_{max} по этажам для четырехэтажного здания при землетрясении №2

Этажи	Без скольжения q_{max}			Со скольжением f=0.05 q_{max}		
	Mod1	Mod2	Mod3	Mod1	Mod2	Mod3
1	27900	27300	8040	2010	1890	1360
2	24200	23100	6220	2370	2040	976
3	18300	16900	4400	2370	2240	831
4	11100	9360	2580	2120	1890	564

Таблица 3. Максимальные значения перерезывающих усилий q_{max} по этажам для девятиэтажного здания при землетрясении №1

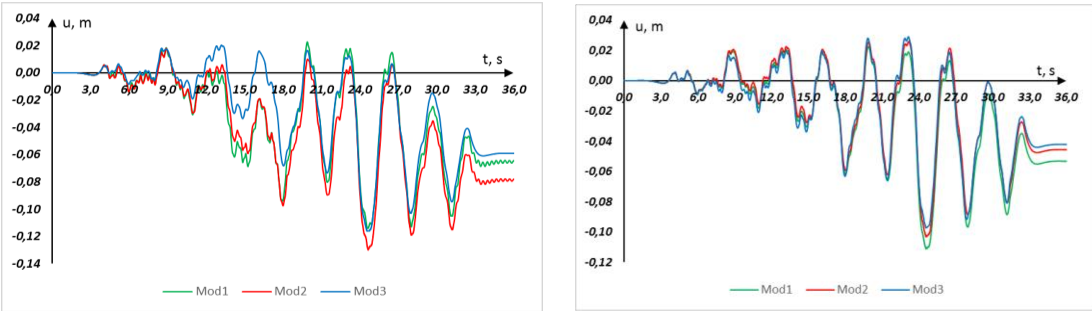
Этажи	Без скольжения q_{max}			Со скольжением f=0.05 q_{max}		
	Mod1	Mod2	Mod3	Mod1	Mod2	Mod3
1	10400	9600	7630	2350	1910	1620
2	9660	8830	6910	2680	2110	1730
3	8720	7990	6170	2910	2280	1820
4	7680	7070	5400	3000	2330	1850
5	6530	6060	4590	2900	2230	1800
6	5300	4960	3750	2650	2070	1650
7	4000	3800	2860	2310	1770	1400
8	2650	2560	1920	1710	1300	1020
9	1260	1240	928	876	672	538

Таблица 4. Максимальные значения перерезывающих усилий q_{max} по этажам для девятиэтажного здания при землетрясении №2

Этажи	Без скольжения q_{max}			с скольжения f=0.05 q_{max}		
	Mod1	Mod2	Mod3	Mod1	Mod2	Mod3
1	19400	17400	12900	2210	1730	1910
2	18100	16300	11600	2450	1940	1680
3	16500	14900	10300	2670	2050	1740
4	14600	13400	9050	2850	2070	1760
5	12500	11600	7670	2950	1990	1700
6	10200	9650	6240	2890	1840	1560
7	7770	7440	4740	2580	1610	1310
8	5150	5040	3170	1950	1230	962
9	2460	2450	1530	1000	653	502

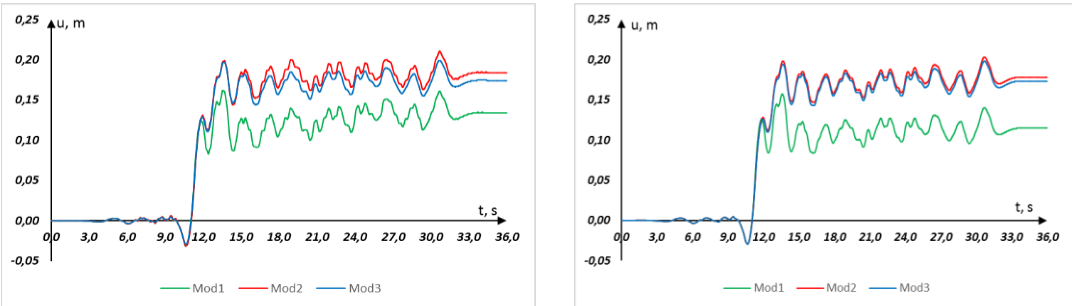
В таблицах 1-4 приведены максимальные перерезывающие усилия по этажам 4 и 9 этажных зданий по разным трем их моделям при воздействии вышеуказанных двух землетрясений. По этим таблицам видно, что наилучшую адекватность имеет модель балки Тимошенко, так как эта модель учитывает, как изгибные, так и сдвиговые колебания зданий.

На рис. 1 и 2 представлены результаты расчетов изменения перемещений по времени на уровнях крыш четырехэтажного и девятиэтажного зданий при землетрясениях №1 и №2 с учетом скользящего элемента. Из графиков видно, что перемещения по моделям 1 и 2 очень близки, а перемещения, рассчитанные по модели 3 сильно отличаются от них. В расчетах лучше использовать модель балки Тимошенко, так как в ней дополнительно можно учесть влияние податливости основания на качение.



a) b)

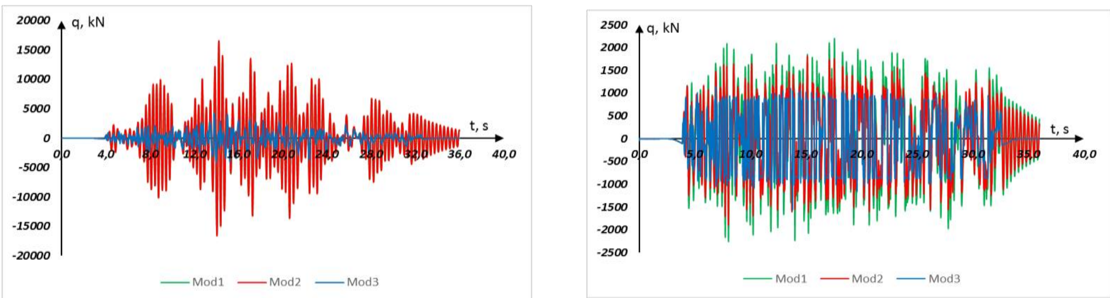
Рис. 1. Горизонтальные перемещения крыш четырехэтажного (a) и девятиэтажного (b) зданий при землетрясении №1 с учетом скользящего элемента.



a) b)

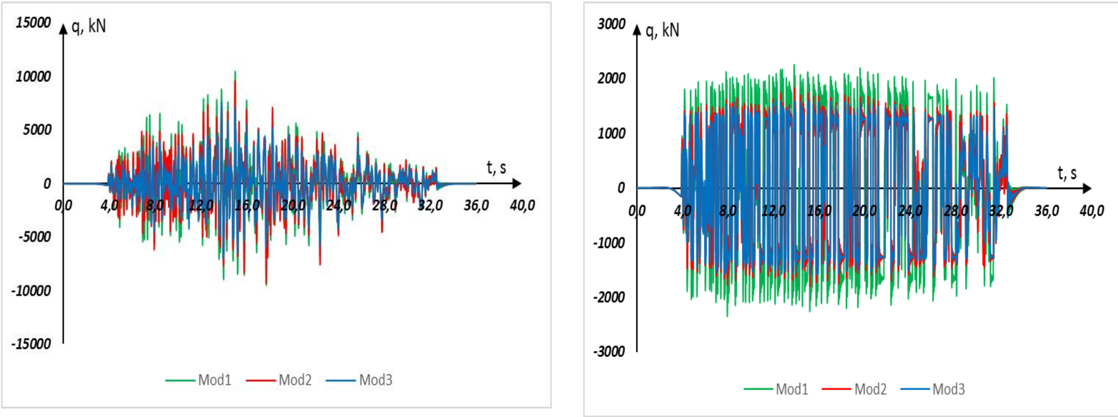
Рис. 2. Горизонтальные перемещения крыш четырехэтажного (a) и девятиэтажного (b) зданий при землетрясении №2 с учетом скользящего элемента.

На рис. 3 и 4 представлены результаты расчетов изменения перезывающих усилий по времени в уровне первого этажа четырехэтажного и девятиэтажного зданий при землетрясении №1 для случаев без учета и с учетом скользящего элемента.



a) b)

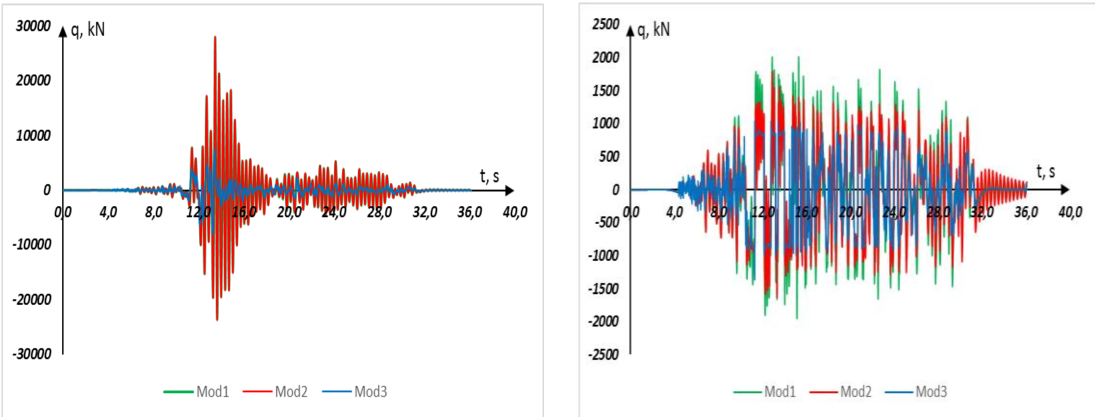
Рис. 3. Изменения перезывающих усилий по времени в уровне первого этажа четырехэтажного здания при землетрясении №1 для случаев без учета (a) и с учетом (b) скользящего элемента.



a) b)

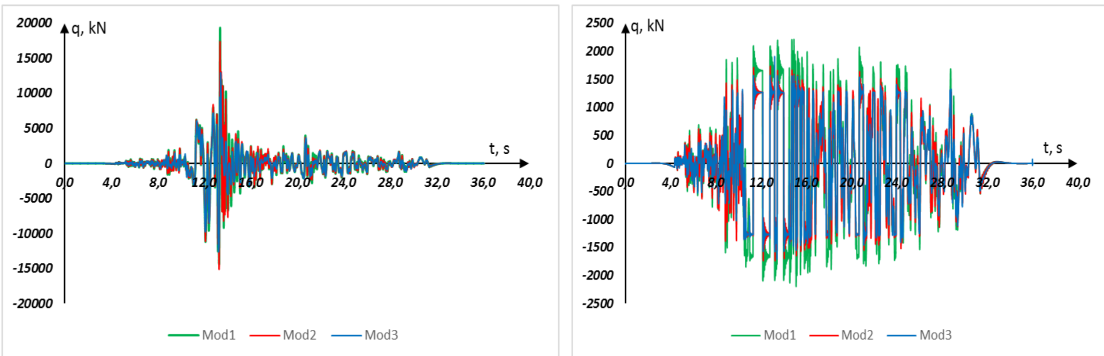
Рис. 4. Изменения перезывающих усилий по времени в уровне первого этажа девятиэтажного здания при землетрясении №1 для случаев без учета (a) и с учетом (b) скользящего элемента.

На рис. 5 и 6 представлены результаты расчетов изменения перезывающих усилий по времени в уровне первого этажа четырехэтажного и девятиэтажного зданий при землетрясении №2 для случаев без учета и с учетом скользящего элемента.



a) b)

Рис. 5. Изменения перезывающих усилий по времени в уровне первого этажа четырехэтажного здания при землетрясении №2 для случаев без учета (a) и с учетом (b) скользящего элемента.



a) b)

Рис. 6. Изменения перезывающих усилий по времени в уровне первого этажа девятиэтажного здания при землетрясении №2 для случаев без учета (a) и с учетом (b) скользящего элемента.

Из рисунков 1-6 так же можно сделать вывод о лучшей адекватности модели балки Тимошенко.

Выводы и предложения. По результатам проведенного исследования можно сделать следующее заключение:

1. При 8 и 9 балльных землетрясениях перезывающие усилия, вычисленные по моделям балки Тимошенко и балки Бернулли-Эйлера от сдвиговой модели с сосредоточенными массами зданий, отличаются до 25 – 30% и на 40%, соответственно.
2. В расчетах зданий со скользящим фундаментом рекомендуется использовать модель балки Тимошенко, так как в ней дополнительно можно учесть влияние податливости основания на качение.

Список использованной литературы:

1. Hongmei R., Qiaoqiao F., Zheng L., Shaking Table Test and Parameter Analysis on Vibration Control of a New Damping System (PDAL), Buildings 2022, 12, 896;
2. Paronesso M., Lignos D.G., Seismic design and performance of steel concentrically braced frame buildings with dissipative floor connectors, Earthquake Engineering Structural Dynamics, 2022, Pp. 1-21;
3. Losanno D., Spizzuoco M., Serino G., Optimal design of the seismic protection system for isolated bridges, Earthquakes and Structures, 2014, Vol. 7, Pp. 969-999;
4. Sreeman D., Kumar B.R., Optimization Study of Isolated Building using Shape Memory Alloy with Friction Pendulum System under Near-fault Excitations, International Journal of Engineering, Applications 2022, Vol. 35, No. 11;
5. Di Wu., Jingtian Lin., Yan Xiong., Analysis of Seismic Isolation Performance of X-Shaped Rubber Bearings (XRBs), Buildings 2022, 12, 1102;
6. Chatzikonstantinou N., Triantafyllos K.M., Athanatopoulou A., Integration Method for Response History Analysis of Single-Degree-of-Freedom Systems with Negative Stiffness, Buildings 2022, 12, 1214;
7. Nagarajaiah S., Chen L., Wang M., Adaptive Stiffness Structures with Dampers: Seismic and Wind Response Reduction Using Passive Negative Stiffness and Inerter Systems, Journal of Structural Engineering, 2022, 148(11), 04022179;
8. Yangchao Ru., Liusheng He., Huanjun Jiang., Investigation on a self-centering beam-column joint with tapered steel plate dampers, Journal of Constructional Steel Research, 2022, 197, 107479;
9. Stefano Barone B., Calvi G.M., Pavese A., Experimental dynamic response of spherical friction-based isolation devices, Journal of earthquake engineering 2017;
10. Vaiana N., Capuano R., Sessa S., Marmo F., Rosati L., Nonlinear Dynamic Analysis of Seismically Base-Isolated Structures by a Novel OpenSees Hysteretic Material Model, Appl. Sci. 2021, 11, 900;
11. Xiaoyu Guan., Gopal S. P. Madabhushi., Numerical Modelling of Structures Adjacent to Retaining Walls Subjected to Earthquake Loading, Geosciences 2020, 10, 486;
12. Mirzaev I.M., Reactions of composite structures, with concentrated and distributed parameters, to seismic action (vertical vibrations), Sov Min Sci, 1976, 12 (3), Pp. 296-300;
13. Mardonov B., Mirzaev I., Nishonov N., An E., Kosimov E., Study of the uplift of buried pipelines in liquefied soils based on the earthquake record, E3S Web of Conferences 2024, 515, 04009;
14. Mirzaev I., Turdiyev M.S., Vibrations of buildings with a sliding foundation having lateral yielding contact under real seismic impacts, AIP Conference Proceedings 2022, 2432, 030050;
15. Mirzaev I., Turdiev M., Seismic Isolation of NPP Turbine Unit Using Dry Friction Devices. Proceedings of MPCPE 2022, Lecture Notes in Civil Engineering, 2023, Vol. 335. ISBN 978-3-031-30569-6 ISBN 978-3-031-30570-2 (eBook);
16. Mirzaev I., Sagdiev Kh., Yuvmitov A., Turdiev M., Egamberdiev B., Experimental determination of dynamic coefficient of amonton-coulomb dry friction, Facta Universitatis Series Mechanical Engineering, 2024, 12 p;
17. Chopra K.A., Dynamics of structures, Fourth Edi . USA, Berkeley, Prentice Hall, One Lake Street, Upper Saddle River, 2012, NJ 07458, 980 p;
18. Ambraseys N.N., Smit P., Douglas J., Margaris B., Sigbjörnsson R., Ólafsson S., Suhadolc P., Costa G., Internet site for European strong-motion data, Bollettino di Geofisica Teorica ed Applicata, 2004, 45(3).

ВЛИЯНИЕ ЭЛЕКТРОННОЙ И ИОННОЙ БОМБАРДИРОВКИ НА МОРФОЛОГИЮ, СОСТАВ И СТРУКТУРУ ПОВЕРХНОСТИ ПЛЕНОК CaF_2/Si

Умирзаков Б.Е.
Ташкентский государственный технический университет, профессор
be.umirzakov@gmail.com
ORCID 0000-0002-9815-2111
Донаев С.Б.
Ташкентский государственный технический университет, профессор
sardor.donaev@gmail.com
ORCID 0000-0001-5656-126
Донаев Б.Д.
Каршинский инжинерно-экономический институт, профессор
sb.donaev@gmail.com
ORCID 0000-0002-9142-4671
Ширинов Г.М.
Ташкентский государственный технический университет, докторант
ganjimurod777@gmail.com
ORCID 0000-0002-7188-2560
Мирзаева Р.С.
Каршинский государственный университет, магистр
ruhsoramirzayeva7@gmail.com
УДК 533.537

Аннотация: С использованием методов оже-электронной и фотоэлектронной спектроскопии, спектроскопии упруго-отраженных медленных электронов изучено влияние электронной и ионной бомбардировки на состав и электронной структуры гетероэпитаксиальной системы $CaF_2/Si(111)$. Показано, что при бомбардировке ионами Ar^+ происходит разупорядочение приповерхностных слоев и обогащение поверхности атомами Ca. При дозах $D = 6{\cdot}10^{16}$ см$^{-2}$ поверхность CaF_2 полностью покрывается атомами Ca. Все это приводит к существенному изменению плотности состояния валентных электронов. В случае электронной бомбардировки с энергией 1-5 кэВ происходит обогащение поверхности, атомами Ca, однако, до плотности тока 500 мкА/см^2 не происходит полное испарение F с поверхностных слоев.

Ключевые слова: электронная бомбардировка, ионная бомбардировка, отжиг, наноразмерных структур, бомбардировки.

Abstract: The effect of electron and ion bombardment on the composition and electronic structure of the heteroepitaxial $CaF_2/Si(111)$ system has been studied using Auger electron and photoelectron spectroscopy, and spectroscopy of elastically reflected slow electrons. It is shown that when bombarded with Ag^+ ions, the near-surface layers are disordered and the surface is enriched with Ca atoms. At doses of $D = 6{\cdot}10^{16}$ cm^{-2}, the surface of CaF2 is completely covered with Ca atoms. All this leads to a significant change in the density of the valence electron state. In the case of electron bombardment with an energy of 1-5 keV, the surface is enriched with Ca atoms, however, up to a current density of 500 μA/cm^2, complete evaporation of F from the surface layers does not occur.

Key words: Electron bombardment, ion bombardment, annealing, nanoscale structures, bombardment.

Введение. Слоистые нанопленочные структуры на основе Si/CaF_2 имеют большие перспективы для создания новых приборов твердотельной электроники (резонансно-туннельных диодов, высокочастотных транзисторов, приборов с отрицательным дифференциальным сопротивлением и магнитооптических приборов), где используются квантово-размерные эффекты [1-6]. Наряду с такими многослойными структурами, весьма перспективными являются упорядоченные одинаковые нанокристаллические фазы одного материала на поверхности другого материала [7-9].

Нанопленочные структуры в основном выращиваются методами молекулярно-лучевой и твердофазной эпитаксии. При этом сплошные однородные пленки Si на поверхности $CoSi_2$ и CaF_2 формируются начиная с толщины $d \geq 5.0$-6.0 нм [10]. Известно [11-13], что при уменьшении размеров наноструктур до величины, соизмеримой с длиной свободного пробега электронов или де-Бройлевской длиной волны, происходит резкое изменение их физических (электрических, оптических и др.) свойств, т. е. начинают проявляться квантоворазмерные эффекты. Следовательно, современное развитие наноэлектроники во многих случаях требует получения отдельных нанокристаллических фаз и нанопленок с толщиной $d \leq 4.0$-5.0 нм. В работах [14-16] для получения подобных структур использовался метод низкоэнергетической ионной бомбардировки. Однако, при этом нанофазы состояли из атомов подложки и легирующего элемента, т. е. невозможно было получить однокомпонентных фаз и пленок. Кроме того, эти структуры не растут на поверхности, а формируется в поверхностных слоях подложки.

Влияние низкоэнергетической бомбардировки ионов активных металлов (Ba, Na) и инертных (Ar^+) газов на состав, структуру и свойства МЛЭ - пленок CaF_2 изучены в работах [3-5, 7-9]. При этом показано, что в процессе ионной бомбардировки происходит разложение CaF_2 на составляющие, и поверхность обогащается атомами Ca (при бомбардировке ионами Ar^+) и Ca + Ba (при бомбардировке ионами Ba^+). Определены оптимальные условия ионной имплантации и последующего отжига для получения наноразмерных структур типа $Ca – Me – F_2$ [17].

В данной работе впервые приводятся экспериментальные результаты по влиянию электронной бомбардировки и бомбардировки ионами Ar^+ на состав и структуру системы CaF_2/Si.

Методика эксперимента. В качестве объектов исследования использованы эпитаксиальные пленки CaF_2/Si(111) с толщиной 60.0-80.0 нм, полученных в условиях сверхвысокого вакуума (~ 10^{-8} Па) методом молекулярно-лучевой эпитаксии. Для сравнения использовались также монокристаллические образцы CaF_2(111) с размерами 10 × 10 × 0.5 мм.

Напыление Si осуществлялось со скоростью 0.1-0.2 нм/мин в условиях высокого вакуума ($P = 10^{-8}$ Па) при комнатной температуре подложки. Испарение Si проводилось электронным лучом, скорость роста задавалась микропроцессорным контроллером с кварцевыми датчиками. Элементный и химический составы поверхности исследуемых образцов определялись методом оже-электронной спектроскопии (ОЭС).

На рис.1 приведена динамика изменения спектров УОЭ ($–dR/dE_p(E_p)$) CaF_2 при бомбардировке ионами Ar^+ с E_0 = 0,5 кэВ разными дозами, полученных в области энергий E_p = 1 – 10 эВ, в основном охватывающей запрещенную зону пленки CaF_2. Известно, что верхний край валентной зоны образуется из 2p уровней электронов фтора, а дно зоны проводимости из 3d – и 4s – электронных состояний ионов Ca. В спектре нелегированного CaF_2 обнаруживаются максимумы при энергиях E_1 = 3,5 и E_2 = 7,5 эВ относительно уровня вакуума. С ростом дозы облучения от 10^{14} $см^{-2}$ до $8 \cdot 10^{14}$ $см^{-2}$ положение и форма пика E_1 заметно не меняется, а интенсивность пика E_2 увеличивается. Появляются особенности при энергиях E_3 = 2,0 эВ (вблизи E_C) и E_4 = 6 эВ. С ростом дозы облучения ионов до $2 \cdot 10^{15}$ $см^{-2}$ интенсивности пиков E_2 и E_3 и их полуширина увеличиваются. Эти изменения происходят до величины $D = 6 \cdot 10^{15}$ $см^{-2}$. При этом вместо пиков E_2 и E_3 появляется один пологий максимум в области E_p = 1 – 4 эВ, а пик E_1 смещается в сторону E_V. При дальнейшем росте дозы поверхностная область CaF_2 покрывается атомами Ca и, следовательно, установить какую-либо закономерность достаточно трудно. Возникновение пика E_2 можно связать с наличием в узлах решетки некоторого количества Ca, не связанного с фтором. При бомбардировке поверхности CaF_2 ионами Ar^+, фтор с приповерхностной области удаляется, следовательно, происходит увеличение концентрации Ca. Пики E_1 и E_3 могут быть связаны с поверхностными состояниями и дефектами, которые зависят от разупорядочения поверхности. На рис.2 приведены спектры фотоэлектронов ($h\nu$ = 21,2 эВ) для CaF_2, полученные после бомбардировки ионами Ar^+ с E_0 = 0,5 кэВ разными дозами.

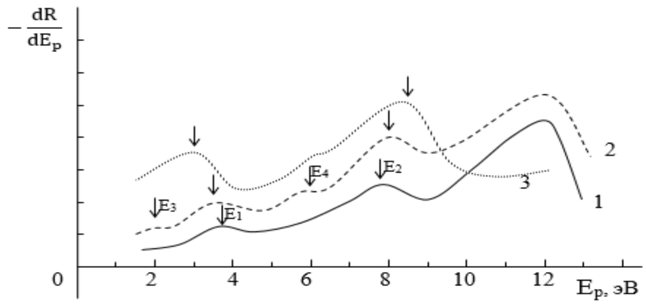


Рис.1. Зависимости $-\frac{dR}{dE_p}(E_p)$ для пленки CaF_2, полученные после бомбардировки ионами Ar^+ с E = 0,5 кэВ при дозах D, $см^{-2}$: 1 – 0; 2 – $8\cdot10^{14}$, 3 – $5\cdot10^{15}$.

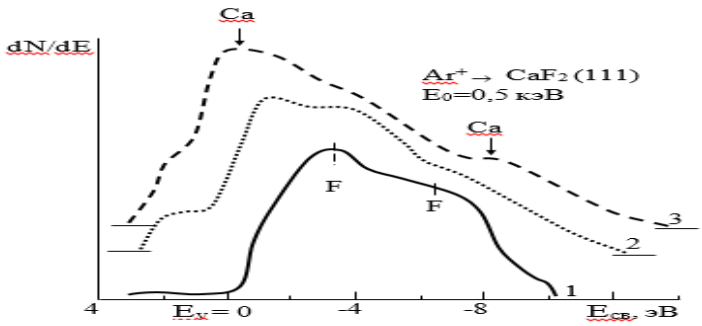


Рис.2. УФЭС CaF_2, облученного ионами Ar^+ с E_0 = 0,5 кэВ при дозах D, $см^{-2}$: 1 – 0; 2 – $6\cdot10^{15}$; 3 – $8\cdot10^{16}$.

Анализ спектров УОЭ совместно с УФЭС показывает, что увеличение концентрации атомов Ca и разупорядочение приповерхностного слоя приводят к образованию примесной зоны вблизи E_V с шириной 3,5 – 4 эВ и вблизи E_C с шириной 2 – 3 эВ. Следовательно, ширина запрещенной зоны уменьшается на 6 – 7 эВ, и условная ширина запрещенной зоны сильно легированного (D = (6 – 8)$\cdot10^{15}$ $см^{-2}$) CaF_2 составляет 4 – 5 эВ.

Прогрев пленки CaF_2/Si, облученного ионами Ar^+, приводит к кристаллизации разупорядоченных областей CaF_2 и формированию нанокристаллических фаз (при дозах D ≤ 5 · 10^{15} $см^{-2}$) и пленок (при D > 10^{16} $см^{-2}$) Ca с толщиной до h = 5 – 6 нм. В частности, пленки Ca формируются при T = 850 – 900 K.

Было проведено исследование влияния электронной бомбардировки на состав и свойства пленок CaF_2/Si (111). Энергия электронов изменялась в пределах E_e = 1 – 5 кэВ, а плотность тока – 20 - 500 мкА/$см^2$. На рис.3 приведена зависимость интенсивности оже-пика фтора ($E_{оже}$ = 646 эВ) от времени бомбардировки электронами с E_e = 5 кэВ при плотностях тока j_e = 40, 200, 500 мкА/$см^2$. Видно, что при j_e = 40 мкА/$см^2$ состав поверхности CaF_2 практически не меняется в течение 2 – 3 час. бомбардировки. Затем с ростом j_e начинает уменьшаться интенсивность пика фтора (увеличение концентрации Ca). Резкое уменьшение концентрации F наблюдается, начиная с j_e = 80 – 100 мкА/см^2. Наибольшее уменьшение C_F наблюдается при j_e = 450 – 500 мкА/см^2. Основные изменения происходят в течение 1 – 1,5 часа. Затем с ростом концентрации F и Ca практически не изменяется (C_F = 5 – 10 ат.%, C_{Ca} = 90 – 95 ат.%). При $j_e \geq 500$ мкА/см^2 наряду с фтором происходит удаление Ca с поверхностных слоев (частично CaF_2 может удаляться в виде молекулы).

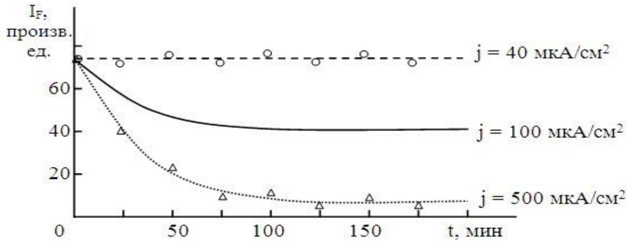


Рис.3. Зависимости интенсивности оже-пика F (E = 646 эВ) от плотности тока электронов, E_e = 5 кэВ.

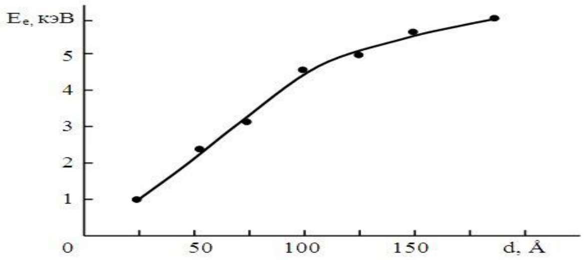


Рис.4. Зависимости толщины, обогащенной Ca пленки от энергии электронов, j_e = 500 мкА/см^2.

Из приведенных данных следует, что при электронной бомбардировке, как в случае ионной бомбардировки, происходит разложение CaF_2 на составляющие и удаление фтора с приповерхностной области. В отличие от ионной бомбардировки при электронной бомбардировке основная часть (~ 1/3 часть) облучаемой поверхности при исследуемых значениях j_e изменяется практически одинаково, т.е. не происходит образования отдельных нанокластерных фаз. Толщина пленки, обогащенной Ca, зависит от энергии электронов (рис.4).

Механизм «сухого» удаления CaF_2 до настоящего времени не совсем понятен, так как прямое радиационное выбивание атомов исключается из-за того, что слишком малы энергии электронов. Также нереально термическое испарение из-за незначительности нагрева электронным пучком. Наиболее вероятно происходит удаление ионизованного фтора из решетки электростатическими силами в процессе электронно-стимулированной десорбции. Схема электронно-стимулированной десорбции в ионной молекуле AC (A - анион; C - катион) по модели KF [18, 19]. При воздействии облучения на кристалл AC (позиция 1) происходит образование 2х зарядного возбужденного катиона C^{2+} (позиция 2) из-за ухода валентного электрона. В результате межатомного перехода образуется поверхностный анион A^+, который выталкивается из молекулы своими положительно заряженными соседями (позиция 3).

Выводы.

1. Показано, что при бомбардировке CaF_2/Si(111) ионами Ar^+ с E_0 = 1 кэВ при D = $D_H = 6 \cdot 10^{16}$ см$^{-2}$ поверхность CaF_2 полностью покрывается атомами Ca. При этом электронная структура поверхности становится характерным для металлических пленок.

2. При электронной бомбардировке также происходит разложение CaF_2 на составляющие и испарение F с поверхностных слоев в виде F_2. Однако полное испарение фтора не наблюдается вплоть до j_e = 500 мкА/см$^{-2}$. Толщина слоя, обогащенного кальцием зависит от энергии электронов.

3. В случае бомбардировки ионами Ar^+ при малых дозах ($D \leq 5 \cdot 10^{15}$ $см^{-2}$) наблюдается образование отдельных нанокластерных фаз. В случае элекиронной бомбардировки такие фазы не образуются.

Список использованной литературы:

1. Watanabe M., Iketani Y., Asada M. Epitaxial Growth and Electrical Characteristics of CaF_2/Si/CaF_2 Resonant Tunneling Diode Structures Grown on Si(111) 1°-off Substrate, Jpn. J. Appl. Phys., 2000, Vol. 39, № 10A, pp.L964-L967.
2. Donaev S.B., Umirzakov B.E. Nanoscale structures Si created by ion bombardment on the surface of CaF_2 // The International Symposium "New Tendencies of Developing Fundamental and Applied Physics: Problems, Achievements, Prospective". November 10-11, Tashkent, 2016. p. 325-326.
3. Сутурин С.М., Банщиков А.Г., Соколов Н.С., Тягинов С.Э., Векслер М.И. Статические вольтамперные характеристики туннельных МДП структур Au/CaF_2/n-Si(111). - ФТП, 2008. Том 42, Вып.11. - С.1333-1338.
4. Губин С.П. Получение, строение и свойства магнитных материалов на основе кобальт содержащих наночастиц / С.П. Губин, Ю.А. Кокшаров. - Неорганические материалы. 2002, Том 38, № 1, с.1287-1305.
5. Кричевцов Б.Б., Гастев С.В., Ильющенков Д.С., Кавеев А.К., Соколов Н.С. Магнитные свойства массивов наночастиц кобальта на поверхности CaF_2(110)/Si(001). - ФТТ, 2009, Том 51, Вып. 1. - С.109-117.
6. Isakhanov Z.A, Mukhtarov, Z.E., Umirzakov B.E., Ruzibaeva M.K. Optimum ion implantation and annealing conditions for stimulating secondary negative ion emission // Technical physics, Volume 56, Issue 4, Page 546-549.
7. Зотов А.В., Саранин А.А. Магические кластеры и другие атомные конструкции: самоорганизация упорядоченных наноструктур на поверхности кремния. - Природа. 2006, № 4. - С.11-18.
8. Chang H.H., Lai M.Y., Wei J.H., Wei C.M., Wang Y.L. Structure determination of surface magic clusters. // Phys. Rev. Lett. 2004, Vol 92, № 6, P.066103-4.
9. Jian-Long Li, Jin-Feng Jia, Xue-Jin Liang, Xi Liu, Jun-Zhong Wang, Qi-Kun Xue, Zhi-Qiang Li, John S. Tse, Zhenyu Zhang, and S. B. Zhang. Spontaneous Assembly of Perfectly Ordered Identical-Size Nanocluster Arrays. // Phys. Rev. Lett. 2002, 88, p.066101.
10. Umirzakov B.E., Ashurov R.K., Donaev S.B. The Morphology and Electronic Properties of Si Nanoscale Structures on a CaF_2 Surface. *Technical Physics*, 2019, 64(2), Page 232–235.
11. Демиховская В.Я. // Соросовский образовательный журнал. 1997. № 5. С. 80.
12. Сдобняков Н.Ю., Репчак С.В., Самсонов В.М., Базулев А.Н., Кульпин Д.А., Соколов Д.Н. - Поверхность. Рентген, синхротр. и нейтрон. исслед. 2011. № 5. - С. 109.
13. Umirzakov B.E., Pugacheva T.S., Tashatov A.T., Tashmukhamedova D.A. Electronic structure and optical properties of CaF_2 films under low energy Ba^+ ion-implantation combined with annealing // Nuclear instruments & methods in physics research section b-beam interactions with materials and atoms. Volume 166, Page 572-576.
14. Muradkabilov D.M., Tashmukhamedova D.A., Umirzakov B.E. // J. Surf. Investigat. 2013. Vol. 7. N 5. P. 967–971.
15. Donaev S.B., Djurabekova F., Tashmukhamedova D.A., Umirzakov B.E. Formation of nanodimensional structures on surfaces of GaAs and Si by means of ion implantation // Physica status solidi c: current topics in solid state physics, Volume 12, Issue 1-2, Page 89-93.
16. Рысбаев А.С., Хужаниязов Ж.Б., Рахимов А.М., Бекпулатов И.Р. // ЖТФ. 2014. Т. 84. Вып. 10. С. 107–111. [Rysbaev A.S., Khuzhaniyazov Zh.B., Rakhimov A.M., Bekpulatov I.R. // Techn. Phys. 2014. Vol. 59. N 10. P. 1526–1530.]
17. Umirzakov B.E., Tashmukhamedova D.A., Ruzibaeva M.K., Djurabekova F.G., Donaev S.B. Investigation of change of the composition in structure of the CaF_2/Si films surface at the low energy bombardment. Nuclear Instruments and Methods in Physics Research B 326 (2014), p.322-325.
18. Knotek M.L., Feibelman P.J. Stability of ionically bonded surfaces in ionizing environments. // Surf. Sci., 1979, Vol 90, № 1, p.78-90.
19. Алтухов А.А., Жирнов В.В. Исследование электронно-стимулированной десорбции фтора в эпитаксиальных слоях флюорит-кремний. - Техника средств связи, сер. ТПО, научно-техни. сб., 1989, Вып.1. - С.71-76.

SPATIAL STRUCTURES OF TETRAPEPTIDE FRAGMENTS OF ORYZATENSIN MOLECULE

N.İ. Aliyeva[1], L.N.Agayeva[1], S.R.Ahmadova[2], G.T. Imanova[3]
[1]Baku State University, ul. Z. Khalilova 23, Baku, AZ-1148, Azerbaijan
[2]Azerbaijan Technical University H.Javid Avenue 25, Baku, Azerbaijan AZ 1073
[3]Institute of Radiation Problems, Ministry of Science and Education Republic of Azerbaijan, Baku AZ-1143, Azerbaijan
Corresponding author.
gunel_imanova55@mail.ru

Abstract. The spatial structure of H-Gly1-Tyr2-Pro3-Met4-Tyr5-Pro6-Leu7-Pro8-Arg9-OH molecule was studied by theoretical conformational analysis method. The spatial structure of the molecule is studied by dividing it into fragments. In the first approach, the spatial structures of H-Gly1-Tyr2-Pro3-Met4, Met4-Tyr5-Pro6-Leu7 and Pro6-Leu7-Pro8-Arg9 tetrapeptide fragments of the molecule were studied based on the low-energy conformations of the corresponding amino acid residues forming them. The potential function of the system is chosen as the sum of non-bonded, electrostatic and torsion interactions and the energy of hydrogen bonds. As a result of the calculations, the set of low-energy conformations of each tetrapeptide fragment, the values of their dihedral rotation angles and the interaction energies that stabilize them were determined.

Keywords: exorphin, oryzatensin, opioid, structure, conformation,

ORYZATENSIN MOLEKULASINING TETRAPEPTID FRAGMENTLARINING FAZOVIY TUZILMALARI

Annotatsiya. H-Gly1-Tyr2-Pro3-Met4-Tyr5-Pro6-Leu7-Pro8-Arg9-Ohning fazoviy tuzilishi nazariy konformatsion tahlil usuli bilan, molekulaning fazoviy tuzilishi esa fragmentlarga bo‘linib o‘rganildi. Birinchi yondashuvda molekulaning H-Gly1-Tyr2-Pro3-Met4, Met4-Tyr5-Pro6-Leu7 va Pro6-Leu7-Pro8-Arg9 tetrapeptid fragmentlarining fazoviy tuzilmalari ularni tashkil etuvchi muvofiq amintutemalari kam energiyali konformatsiyalariga asoslanib o‘rganildi. Tizimning potensial funksiyasi bog‘lanmagan, elektrostatik va burilish o‘zaro ta’sirlarining va vodorod bog‘lanishlari energiyalarining yig‘indisi sifatida tanlandi. Hisoblashlar natijasida har bir tetrapeptid fragmentning kam energiyali konformatsiyalar to‘plami, ularning digidral burilish burchaklari qiymatlari va ularni barqarorlashtiruvchi o‘zaro ta’sir energiyalari aniqlandi.

Kalit so‘zlar: ekzorfing, orizatenzin, opioid, tuzilish, konformatsiya.

Introduction. Oryzatensin is a biologically active peptide molecule derived from rice protein. Its primary structure is H-Gly1-Tyr2-Pro3-Met4-Tyr5-Pro6-Leu7-Pro8-Arg9-OH. Orizatensin affects the growth of intestinal microbes, it is a molecule with anti-opioid activity that is resistant to many effects in the body. Oryzatensin molecule consists of 9 amino acid residues, 154 atoms and 42 dihedral rotation angles. The spatial structure of the molecule is studied by dividing it into fragments. In the first approach, the spatial structures of the H-Gly1-Tyr2-Pro3-Met4, Met4-Tyr5-Pro6-Leu7 and Pro6-Leu7-Pro8-Arg9 tetrapeptide fragments of the molecule were studied based on the low-energy conformations of the corresponding amino acid residues forming them [1-3].

Method. The molecule was calculated using the method of theoretical conformational analysis. The potential function of the system is chosen as the sum of non-bonded, electrostatic and torsion interactions and the energy of hydrogen bonds. Nonvalent interactions were assessed by Lennard-Jones potential. Electrostatic interactions were calculated in a monopole approximation according to the Coulomb's law using partial charges on atoms. The conformational possibilities connection with which the value of the dielectric constant was assumed to be 10. The energy of hydrogen bonds was estimated using the Morse potential. We have studied the structural and functional organizations of the opioid peptides enkephalins, endorphins, endomorphins, dynorphins, neoendorphins, adrenorphin, and are currently studying the spatial structures of opioid peptides, obtained from food. This work is a continuation of our previous studies [4-13].

When presenting the results of the calculation, we used the classification of peptide structures according to conformations, forms of the main chain, and shapes of the peptide skeleton. Conformational states are completely determined by the dihedral angles of the main and side chains of all amino acid residues included in a given molecule. The backbone forms of the fragment are formed by combinations of the R, B, L, P forms of residues in a given sequence. The forms of the main chain of the dipeptide can be divided into two classes - folded (f) and unfolded (e) forms, which are called shapes. All conformations are grouped according to the forms of the main chain, and the forms are grouped according to the shapes. To designate the conformational states of the residues, identifiers of the Xij type were used, where X determines the low-energy regions of the conformational map $\varphi-\psi$: $R(\varphi,\psi=-180°-0°)$, $B(\varphi=-180°-0°,\psi=0°-180°)$, $L(\varphi,\psi=0°-180°)$ and $P(\varphi=0°-180°,\psi=-180°-0°)$; ij…=11…,12…,13…,21… determines the position of the side chain, and index 1 corresponding to an angle value ranging from 0 to 120°, 2 - from 120° to -120°, and 3 - from -120° to 0°. The designations and readings of rotation angles correspond to the IUPAC-IUB nomenclature [14].

Results and discussion. 1. H-Gly1-Tyr2-Pro3-Met4 fragment

The spatial structure of the N-side Gly1-Tyr2-Pro3-Met4 tetrapeptide of the oryzatensin molecule is composed of methylamide-N-acetyl-glycine, methylamide-N-acetyl-L-tyrosine, methylamide-N-acetyl-L-proline and methylamide-N-acetyl- It was studied based on stable conformations of L-methionine. It is known that the R form of the amino acid residue located in front of the proline amino acid residue is highly energetic. Since the Tyr2 amino acid residue precedes proline, only the B form of its main chain was chosen as the starting variant. Therefore, in the first approximation, several hundred conformations of the eight forms of the main chain belonging to the four shapes were calculated. Then, the lowest energy conformation of each form was selected, and the share, total and relative energies of non-valent, electrostatic and torsional interaction energies are shown in table 1. The relative energies of the selected lowest energy conformations of the Gly1-Tyr2-Pro3-Met4 tetrapeptide fragment vary in the energy range of 0-2.0 kcal/mol. Table 2 shows the interaction energies between and within the amino acid residues in low-energy conformations of the N-side tetrapeptide fragment of the oryzatensin molecule, and table 3 shows the values of their dihedral rotation angles. The arrangement of atoms in those conformations is shown in figure 1.

The results of the calculations show that there was no sharp differentiation according to the energies of the shapes and the shapes of the main chain. As can be seen from Table 1, the non-valent interaction energy is in the range of (-7.0)-(-4.9) kcal/mol, the electrostatic interaction energy is in the range of (0.6)-(1.1) kcal/mol, the torsional interaction energy is (1.0)- (1.7) varies in the range of kcal/mol.

Table 1. Low-energy conformations of the N-side tetrapeptide fragment of the oryzatensin molecule, the contribution of non-valent, electrostatic, torsional interaction energies to them,total and relative energies

№	Shapes	Conformation	U_{nv}	U_{el}	U_{tors}	U_{tot}	U_{rel}
1	eee	B BBB	-4.9	0.6	1.5	-2.8	1.9
2	eee	L B BB	-6.0	0.9	1.4	-3.6	1.1
3	fee	R B BB	-5.8	0.9	1.3	-3.6	1.1
4	fee	P B BB	-5.7	0.7	1.7	-3.3	1.4
5	eef	B B R R	-6.2	0.9	1.3	-4.0	0.7
6	fef	R B R R	-6.3	0.8	1.2	-4.3	0.4
7	fef	P B R R	-6.3	0.9	1.0	-4.5	0.2
8	eef	L B R R	-7.0	1.1	1.2	-4.7	0.0

The most stable conformation of the tetrapeptide fragment is the LB_3RR_{33} conformation belonging to the eef shape. The non-valent interaction energy for the stabilization of this conformation is (-7.0) kcal/mol, the electrostatic interaction energy is (1.1) kcal/mol, and the torsional interaction energy is (1.2) kcal/mol. In this conformation, Gly1-Tyr2 (-2.9) kcal/mol, Tyr2-Pro3 (-3.8) kcal/mol, and Pro3-Met4 (-2.1) kcal/mol contribute to the stabilization of the molecule. Tyr2-Met4 contributes up to (-2.9) kcal/mol to stabilize the conformation. The second low-energy conformation of the eef shape is BB_3RR_{33}. Its relative energy is (0.7) kcal/mol. As it can be seen, this conformation differs from the previous conformation only in terms of the shape of the main chain of glycine 1. Therefore, the interaction energies that stabilize it correspond to the interaction energies in the above-mentioned conformation.

The relative energy of the LBBB conformation of the eee shape is (1.1) kcal/mol. Non-valent interaction energy (-6.0) kcal/mol, electrostatic interaction energy (0.9) kcal/mol, and torsional interaction energy (1.4) kcal/mol contribute to its stabilization. Stabilization of this conformation is contributed by Tyr2-Gly1 (- 1.0) kcal/mol, Tyr2-Pro3 (-4.0) kcal/mol, Tyr2-Met4 (-3.5) kcal/mol. The second lowest energy conformation of the eee shape is BB_1BB_1. Apparently, this conformation differs from the other one according to the shape of the main chain of glycine1. Therefore, the interaction between amino acids is different only between Gly1-Tyr2. Other interaction energies are the same as in the previous. The most stable conformation of the fee shape is RB_2BB_{33} with a relative energy of (1.1) kcal/mol. Non-valent interaction energy (-5.8) kcal/mol, electrostatic interaction energy (0.9) kcal/mol, and torsional interaction energy (1.3) kcal/mol contribute to its stabilization. Another low-energy conformation of the fee shape, PB_1BB_{22}, has a relative energy of (1.4) kcal/mol. They differ from each other only in the shape of the main chain of the first amino acid glycine. The most stable conformation of fefshape is PB_3RR_{33}. Non-valent interaction energy (-6.3) kcal/mol, electrostatic interaction energy (0.9) kcal/mol, and torsional interaction energy (1.1) kcal/mol contribute to its stabilization. Another low-energy conformation of this shape is the RB_3RR_{33} conformation, which differs from it in the shape of the glycine backbone. Its relative energy is (0.4) kcal/mol. Therefore, the interaction energies between the amino acids that stabilize the conformations are almost the sameconformation.

As a result of the study of the spatial structure of the Gly1-Tyr2-Pro3-Met4 fragment, its low-energy conformations, the interaction forces between the amino acids that stabilize them, and the values of the dihedral rotation angles of the stable conformations were determined. Since the spatial structure of the oryzatensin molecule was studied by dividing it into fragments, the obtained results will be used as starting options for calculating the spatial structures of subsequent fragments of the molecule.

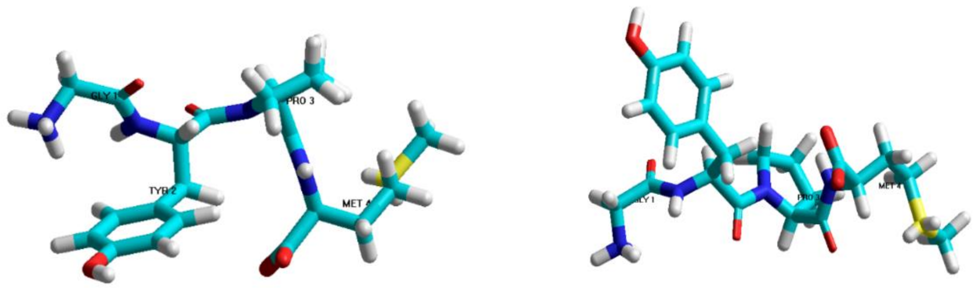
Table 2. Interaction energies within and between amino acid residues in low-energy conformations of the Gly1-Tyr2-Pro3-Met4 fragment of the oryzatensin molecule.

GLY 1	TYR 2	PRO 3	MET 4	
3.2 3.1 3.5 3.3	-2.1 -1.5 -2.7 -2.9	-0.5 -0.9 -0.6 -0.5	0.1 0.2 -0.3 -0.2	GLY 1
	0.7 0.7 1.0 0.9	-4.1 -4.8 -3.8 -3.8	-3.5 -2.8 -2.8 -2.9	TYR 2
		0.3 0.3 0.3 0.3	-0.9 -1.1 -2.1 -2.1	PRO 3
			1.8 1.9 2.1 2.0	MET 4

As a result of the study of the spatial structure of the Gly1-Tyr2-Pro3-Met4 fragment, its low-energy conformations, the interaction forces between the amino acids that stabilize them, and the values of the dihedral rotation angles of the stable conformations were determined. Since the spatial structure of the oryzatensin molecule was studied by dividing it into fragments, the obtained results will be used as starting options for calculating the spatial structures of subsequent fragments of the molecule.

Table 3. Geometric parameters of low-energy conformations of the Gly1-Tyr2-Pro3-Met4 fragment of the oryzatensin molecule

ϕ_1	70	-67	77	72
Ψ_1	83	-81	-61	75
ω_1	180	181	180	182
ϕ_2	-124	-107	-111	-112
χ_2^1	58	184	-62	-60
χ_2^2	93	79	90	-92
χ_2^3	0	0	0	0
Ψ_2	144	126	150	150
ω_2	179	178	173	172
Ψ_3	118	135	-48	-48
ω_3	176	178	177	177
ϕ_4	-150	-114	-117	-117
χ_4^1	59	-63	-62	-62
χ_4^2	179	-59	-60	-60
χ_4^3	178	178	179	178
χ_4^4	180	181	180	180
Ψ_4	161	143	-58	-57
ω_4	180	180	180	180
ΔU	**1.1**	**1.1**	**0.2**	**0**



a) LB_3RR_{33} b)PB_3RR_{33}

Figure 1. Atomic model of spatial structure of the Gly1-Tyr2-Pro3-Met4 fragment of the oryzatensin molecule a) and b) corresponded to the structures with the relative energies 0 kcal/mol and 0.2 kcal/mol, respectively.

2. Met4-Tyr5-Pro6-Leu7 fragment

The spatial structure of the Met1-Tyr2-Pro3-Leu4 tetrapeptide fragment was studied based on the low-energy conformations of the Met, Pro, Tyr and Leu amino acid residues forming it. As shown by the amino acid sequence of the fragment, the Tyr5 and Leu7 amino acid residues precede the Pro amino acid residue, and as mentioned, the R forms of their main chains are highly energetic. For this reason, conformations corresponding to the R form of the main chain were not taken into account when starting options were selected to calculate the spatial structure of the fragment. Therefore, in order to study the spatial structure of the tetrapeptide Met4-Leu7 fragment, the conformations of the main chain corresponding to its four shapes were calculated. The results of the calculations show that there is no differentiation according to the energies of the shapes and forms of the main chain, but only according to the energies of the conformations. Then, the lowest energy conformation of each form of the main chain was selected, and the contribution of non-valent, electrostatic, torsional interaction energies to the total energy, total and relative energies are shown in table 4. Interaction energies within and between amino acid residues in those conformations are shown in table 5, their geometrical parameters are shown in table 6, and the spatial arrangement of atoms in those conformations is shown in figure 2.

Table 4. Low-energy conformations of Met4-Tyr5-Pro6-Leu7 fragment of oryzatensin molecule, the contribution of non-valent, electrostatic, torsional interaction energies to them, total and relative energies

№	Shapes	Conformation	U_{nv}	U_{el}	U_{tors}	U_{tot}	U_{rel}
1	eef	B_{21} B_1 R B_{21}	-12.7	0.4	1.5	-10.9	0
2	fef	R_{21} B_3 R B_{21}	-12.5	0.6	1.2	-10.7	0.2
3	eee	B_{21} B_1 B B_{21}	-12.2	0.3	1.4	-10.5	0.4
4	fee	R_{21} B_1 B B_{22}	-9.8	0.5	0.8	-8.4	2.5

Table 5. Energy inside and between residual interactions in the conformations of Gly1-Tyr2-Pro3-Met4 fragment of the oryzatensin molecule: B_{21} B_1 R B_{21}(U_{rel}=0 kcal/mol, first line), R_{21} B_3 R B_{21} (U_{rel}=0.2 kcal/mol, second line), B_{21} B_1 B B_{21} (U_{rel}=0.4 kcal/mol, third line), R_{21} B_1 B B_{22} (U_{rel}=2.5 kkal/mol, fourth line).

Met1	Tyr2	Pro3	Leu4	
0.9 0.6 0.8 1.0	-4.3 -5.2 -4.1 -2.0	-0.8 -0.5 -0.7 -0.4	-0.2 -0.2 -1.5 -0.2	Met1
	1.8 1.1 1.6 0.8	-4.2 -3.8 -4.3 -4.5	-4.0 -2.3 -3.8 -3.9	Tyr2
		0.3 0.3 0.6 0.5	-1.7 -1.8 -0.7 -0.6	Pro3
			-0.1 -0.1 0 -0.1	Leu4

In the low-energy conformations of the Met4-Leu7 tetrapeptide fragment of the oryzatensin molecule shown in table 4, non-valent interaction energies are in the range of (-12.7)-(-9.8) kcal/mol, electrostatic interaction energies are in the range of (0.3)-(0.6) kcal/mol, torsional interaction energy varies in the interval (0.8)-(1.5) kcal/mol (table 4). The global conformation of the fragment is B_{21} B_1 R B_{21} belonging to the eef shape. The interaction of Tyr2 amino acid residue with other amino acid residues plays an important role in the stabilization of this conformation, which is located in such a way that it creates a favorable interaction with Met1, Pro3 and Leu4 at the same time. As can be seen from Table 5, the Met1-Tyr2 interaction contributes to the total energy (-4.3) kcal/mol, the Tyr2-Pro3 interaction contributes to the total energy (-4.2) kcal/mol, the Tyr2-Leu4 interaction (-4.0) kcal/mol shares up to In this conformation, the interaction between Pro3-

Leu4 contributes (-1.7) kcal/mol to the total energy (table 5).

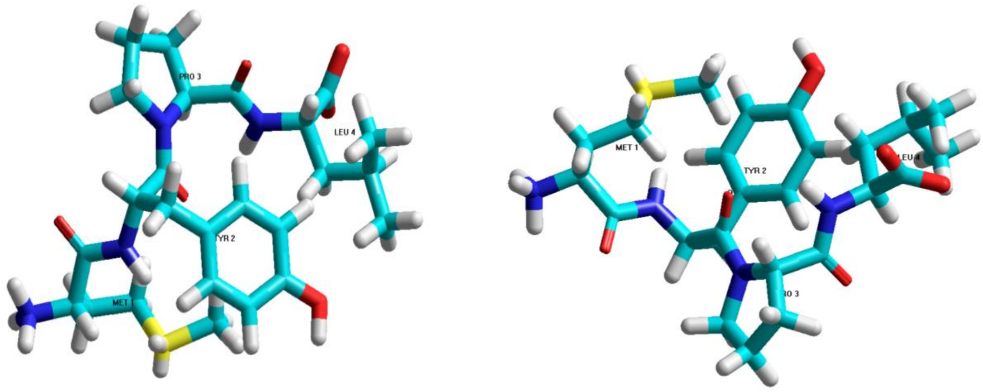
In the R_{21} B_3 R B_{21} conformation of fef, Tyr2 is in the B form of the main chain and separates the folded N- and C- sides of the fragment, its side chain Met1-Tyr2 interaction contributes to the total energy (-5.2) kcal/mol, Tyr2-Pro3 interaction effect on the total energy (-3.8) kcal/mol, Tyr2-Leu4 interaction on the total energy (-2.3) kcal/mol, Pro3-Leu4 interaction on the total energy (-1.8) kcal/mol, making it low-energy (table 5). Therefore, the relative energy of the conformation is more than 0.2 kcal/mol in the global conformation.

The relative energy of the B_{21} B_1 B B_{21} conformation of the side-opened eee shape of the main chain is 0.4 kcal/mol (table 4). As you can see, its relative energy is higher than the relative energy of the global conformation by 0.4 kcal/mol. In this conformation, the Met1 amino acid residue makes favorable interactions with Tyr2 and Leu4, which contribute (-4.1) kcal/mol and (-1.5) kcal/mol to the total energy, respectively. The interaction of the amino acid residue Tyr2 with Pro3 and Leu4 contributes (-4.3) kcal/mol and (-3.8) kcal/mol, respectively, to the total energy (Table 5).

Table 6. Geometrical parameters of the low-energy conformations of the Met4-Leu7 fragment of the oryzatensin molecule.

	B_{21} B_1 R B_{21}	R_{21} B_3 R B_{21}	B_{21} B_1 B B_{21}	R_{21} B_1 B B_{22}
ω_1	180	181	180	180
ϕ_1	-124	-92	-127	-111
χ_1^1	185	181	182	178
χ_1^2	56	62	57	58
χ_1^3	191	184	190	182
χ_1^4	181	181	184	180
Ψ_1	147	-53	144	-59
ω_2	182	182	180	181
ϕ_2	-96	-123	-91	-122
χ_2^1	56	-57	67	66
χ_2^2	79	115	87	94
χ_2^3	0	0	0	0
Ψ_2	148	150	151	150
ω_3	173	173	182	178
Ψ_3	-63	-50	100	102
ω_4	181	177	178	176
ϕ_4	-139	-104	-113	-115
χ_4^1	180	176	173	175
χ_4^2	67	62	67	66
χ_4^3	180	179	180	180
χ_4^4	176	175	181	181
Ψ_4	136	117	134	131
ω_5	179	180	178	179
ΔU	0	0.2	0.4	2.5

The most stable conformation of the fee shape is R_{21} B_1 B B_{22} with a relative energy of 2.5 kcal/mol. As it can be seen, this conformation is unable to create a favorable interaction with the following amino acid residues, which is in the R form of the first amino acid residue - the main chain of methionine, and therefore, its relative energy is 2.5 kcal/mol higher than the relative energy of the global conformation. The Tyr2-Pro3 interaction contributed up to (-4.5) kcal/mol to the total energy, and the Tyr2-Leu4 interaction energy contributed up to (-3.9) kcal/mol to the total energy, stabilizing the conformation.



a) B_{21} B_1 R B_{21} b)R_{21} B_3 R B_{21}

Figure 2. Atomic model of spatial structure of the Met4-Leu7 fragment of the oryzatensin molecule a) and b) corresponded to the structures with the relative energies 0 kcal/mol and 0.2 kcal/mol, respectively.

3. Pro6-Leu7-Pro8-Arg9-OH fragment

The spatial structure of the C-side Pro6-Leu7-Pro8-Arg9-OH fragment of the oryzatensin molecule was studied based on the low-energy conformations of the amino acids Pro, Leu and Arg that form it. As shown by the amino acid sequence of the fragment, the tetrapeptide fragment includes two proline amino acids. As mentioned above, they drastically reduce the conformational possibilities of the fragment. Therefore, the combinations of possible conformations of Leu2 and Arg4 in the four forms of the main chain belonging to the four shapes of the tetrapeptide fragment were calculated. The results of the calculations show that there is a differentiation only according to the energies of the conformations. The lowest-energy conformation of each calculated form was selected, the contribution of non-valent, electrostatic, torsional interaction energies to the total energy, total and relative energies are shown in table 7. Interaction energies within and between amino acid residues in the selected conformations are shown in table 8, their geometrical parameters are shown in table 9, and the spatial arrangement of atoms in those conformations is shown in figure 3.

Table 7. Low-energy conformations of Pro6-Leu7-Pro8-Arg9-OHfragment of oryzatensin molecule, the contribution of non-valent, electrostatic, torsional interaction energies to them, total and relative energies

№	Shapes	Conformation	U_{nv}	U_{el}	U_{tors}	U_{tot}	U_{rel}
1	fef	R B_{21} R R_{32}	-15.5	-4.3	0.7	-19.1	0
2	fee	R B_{23} B B_{33}	-16.4	-4.6	2.1	-18.9	0.2
3	eee	B B_{23} B B_{33}	-14.8	-4.9	2.2	-17.8	1.5
4	eef	B B_{21} R R_{12}	-13.9	-4.8	1.2	-17.5	1.6

Table 8. Energy inside and between residual interactions in the conformations of Pro6-Arg9 fragment of the oryzatensin molecule: R B_{21} R R_{32}(U_{rel}=0 kcal/mol, first line), R B_{23} B B_{33}(U_{rel}=0.2 kcal/mol, second line), B B_{23} B B_{33}(U_{rel}=1.5 kcal/mol, third line), B B_{21} R R_{12}(U_{rel}=1.6 kkal/mol, fourth line)

Pro1	Leu2	Pro3	Arg4	
-2.1 -2.1 -2.4 -2.4	-2.1 -2.3 -1.0 -0.9	-1.8 -1.7 -1.0 -1.2	0.1 0.3 0.1 0	Pro1
	-1.2 -0.2 -0.2 -1.2	-3.8 -5.0 -5.0 -4.0	-3.4 -5.9 -6.0 -3.2	Leu2
		0.3 0.3 0.3 0.3	-2.5 -1.8 -0.7 -2.7	Pro3
			-3.2 -2.5 -2.5 -3.4	Arg4

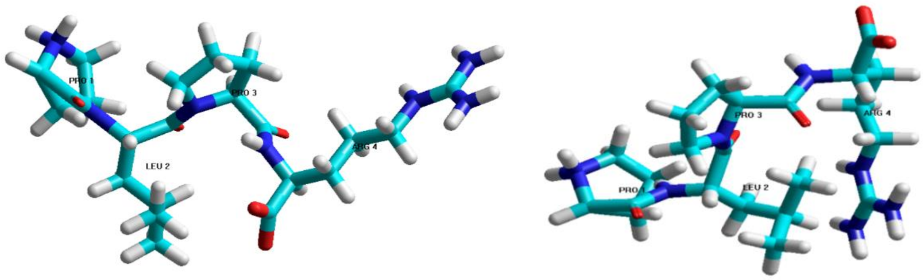
The global conformation of the Pro6-Arg9-OH fragment is R B_{31} R R_{32}belonging to the fef shape. In this conformation, the N-terminus and C-terminus of the fragment are in a coiled conformation separated by the Leu2 amino acid residue. The energy of interaction between its internal atoms of Pro1 and its atoms of Leu2 and Pro3 contributes to the total energy (-6.0) kcal/mol, the energy of interaction of amino acid residue Leu2 with other amino acid residues is up to (-8.4) kcal/mol, The Pro3-Arg4 interaction energy contributes (-2.5) kcal/mol to the total energy (Table 8).

The lowest energy conformation of the fee shape of the tetrapeptide Pro6-Arg9-OH fragment is R B_{23} B B_{33}, its relative energy is 0.2 kcal/mol. Non-valent interaction energy (-16.4) kcal/mol, electrostatic interaction energy (-4.6) kcal/mol, and torsional interaction energy (2.1) kcal/mol contribute to this conformation. As it can be seen, the conformation is the most favorable both in terms of non-valent interaction energy and electrostatic interaction energy (table 7). The contribution of Pro1 to conformation stabilization is (-6.1) kcal/mol, the contribution of Leu2 is (-11.1) kcal/mol, and the contribution of Pro3-Arg4 interaction is (-2.1) kcal/mol.

Table 9. Geometrical parameters of the low-energy conformations of the Pro6-Leu7-Pro8-Arg9-OH fragment of the oryzatensin molecule

ω_1	180	180	179	179
Ψ_1	-52	-51	131	137
ω_2	174	174	177	179
φ_2	-117	-114	-116	-123
χ_2^1	181	201	201	177
χ_2^2	68	-50	-50	62
χ_2^3	180	178	177	179
χ_2^4	175	190	190	173
Ψ_2	100	101	100	98
ω_3	177	180	180	175
Ψ_3	-54	133	134	-52
ω_4	180	181	181	179
φ_4	-136	-113	-112	-160
χ_4^1	-61	-53	-53	56
χ_4^2	181	-62	-62	183
χ_4^3	180	181	181	181
χ_4^4	180	181	181	180
Ψ_4	-58	112	112	-33
ΔU	**0**	**0.2**	**1.5**	**1.6**

The lowest energy conformation of the eee shape is (1.5) kcal/mol relative to the B B_{23} B B_{33}conformation of the fully unfolded form of the main chain. The contribution of electrostatic interaction energy to it is the largest (table 5). The interaction of the Leu2 amino acid residue with the Pro3-Arg4 dipeptide fragment following it contributes the most to the stabilization of this conformation, its value is (-11.0) kcal/mol (table 8). Conformation of eef shape is B B_{21} R R_{12}, its relative energy is (1.6) kcal/mol. The contribution of non-valent interaction energy to this conformation is (-13.9) kcal/mol, which is less than that of other low-energy conformations, as can be seen from table 5. It differs from the global conformation only in the shape of the main chain of the first proline. In the global conformation, Pro1 is in the R form of the main chain, making favorable interactions with other amino acid residues, in this conformation, it is in the unfolded B form of the main chain and cannot make effective interactions with the following amino acid residues (table 6).



a) R B_{21} R R_{32}b) R B_{23} BB_{33}

Figure 3. Atomic model of spatial structure of the Pro6-Leu7-Pro8-Arg9-OH fragment of the oryzatensin molecule a) and b) corresponded to the structures with the relative energies 0 kcal/mol and 0.2 kcal/mol, respectively.

Results. The spatial structure of H-Gly1-Tyr2-Pro3-Met4-Tyr5-Pro6-Leu7-Pro8-Arg9-OH molecule was studied by theoretical conformational analysis method. The spatial structure of the molecule is studied by dividing it into fragments. In the first approach, the spatial structures of H-Gly1-Tyr2-Pro3-Met4, Met4-Tyr5-Pro6-Leu7 and Pro6-Leu7-Pro8-Arg9 tetrapeptide fragments of the molecule were studied based on the low-energy conformations of the corresponding amino acid residues forming them. The potential function of the system is chosen as the sum of non-bonded, electrostatic and torsion interactions and the energy of hydrogen bonds. As a result of the calculations, the set of low-energy conformations of each tetrapeptide fragment, the values of their dihedral rotation angles and the interaction energies that stabilize them were determined. Since the spatial structure of the oryzatensin molecule was studied by dividing it into fragments, the obtained results will be used as starting options for calculating the spatial structures of subsequent fragments of the molecule.

References

1. Arısoy S, Çoban I, Üstün-Aytekin O. Food-Derived Opioids: Production and the effects of opioids on human health. From Conventional to Innovative Approaches for Pain Treatment,2019.https://doi.org/10.5772/intechopen.84195·

2. Garg S, Nurgali K, Mishra VK. Food Proteins as Source of Opioid Peptides-A Review.Curr Med Chem. 2016;23(9):893-910. DOI: 10.2174/0929867323666160219115226

3. E. A. Chesnokova, N. Y. Sarycheva, V. A. Dubynin, A. A. Kamensky. Food-Derived Opioid Peptides and Their Neurological Impact. Advancesin Physiological Sciences. 46 (1), p.22-46. (2015), (InRuss.).

4. Akhmedov NA, Godjaev NM, Suleymanova EV, et al. Structural organization of the [Met] encephalin and endorphins molecules. J Bioorganic Chem. 1990;16:649–667. (In Russ.).

5. Akhmedov NA, Ismailova LI, Abbasli RM, et al. Spatial Structure of Octarphin molecule IOSR. J Appl Phys (IOSR-JAP). 2016; 8:66–70.

6. Akhmedov NA, Agayeva LN, Akverdieva GA, et al. Spatial structure of the ACTH-(6-9)-PGP molecule. J Chem Soc Pak. 2021;43(5):500–504.

7. Agayeva LN, Abdinova AA, Akhmedova SR, et al. The spatial structure of the ACTH-(7–10) molecule. Biophysics. 2021;66 (4):531–534. (In Russ.).
8. Agayeva LN, Abdinova AA, Akhmedova SR, et al. The Spatial Structure of the ACTH-(7–10) molecule. Biophyics. 2021;66 (4):531–534. (In Russ.).
9. Agaeva LN, Abdinova AA, Akhmedova SR, et al. Spatial structure of Soymorphin-6 molecule. Biophyics. 2023;68 (6):1122–1127. (In Russ.).
10. Ismailova LI, Akverdieva GA, Demukhamedova SD, et al. Molecular modelling of Pro-Gly gliproline and its complexes. Mosc Univ Phys Bull. 2023;78(5):668–680. (In Russ.).
11. Akhmedov NA, Agayeva LN, Abbasli RM, et al. Spatial structure of Casoxin C Molecule. Biophyics. 2024;69(1): 1122–1127. (In Russ.).
12. Agayeva LN, Akhmedov NA and Imanova GT. Spatial Structure of the Casoxin D Molecule. Materials Research Innovations ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals Materials Research Innovations, DOI:
13 1080/14328917.2024.2342013 To link to this article: https://doi.org/10.1080/14328917.2024.2342013 Published online: 12 Apr 2024.
14. IUPAC-IUB. Quantities. Units and symbols in physical chemistry. Oxford: Blackwell Scientific.

MATRITSAVIY DIFFERENSIAL TENGLAMALAR SISTEMASI $Sp(n)$ GRUPPASINING HAQIQIY TASVIRLARI GRUPPASI TA’SIRIGA NISBATAN EKVIVALENT YECHIMLARI

Mo‘minov Qobiljon
O‘zbekiston milliy universiteti, f-m.f.d., professor
ORCID: 0000-0002-2445-749X
m.muminov@rambler.ru
G‘afforov Raxmatjon
Farg‘ona davlat universiteti, f-m.f.b.f.d (PhD),dotsent
ORCID: 0000-0002-4589-5421
gafforov.rahmatjon@mail.ru
Jo‘raboyev Saidaxbor
Farg‘ona davlat universiteti, f-m.f.b.f.d (PhD),katta o‘qituvchi
saidaxbor.juraboyev@mail.ru
ORCID: 0000-0002-2445-749X
UDK 517.98

Annotatsiya: Ushbu ishda differensial tenglamalar sistemasining yechimlari kvaternion fazoning simplektik almashtirishlarini haqiqiy tasvirlari guruhi ta’siriga nisbatan ekvivalentlikkacha aniqlikda yagona yo‘llar ko‘rinishida tavsiflangan. O‘lchami 4n ga teng haqiqiy fazolarda berilgan yo‘llarning simplektik almashtirishlarning haqiqiy tasvirlari guruhi ta’siriga nisbatan ekvivalentligi masalasi yechimi ko‘rsatilgan. Ekvivalentlik masalasini yechishda hosil bo‘lgan shartlar ba’zi guruhlar ta’sirida og‘irroq shartlarga aylanadi. Bu esa ushbu shartlarni qanoatlantiruvchi yo‘llar mavjudligiga shubha uyg‘otadi. Shu sababdan masala yechimini ifodalovchi matritsaviy invariant funksiyalar xossalari o‘rganilgan. Ushbu xossalar yordamida ekvivalentlik shartlarida hosil bo‘lgan har bir munosabatni qanoatlantiruvchi yo‘l mavjudligi va bu yo‘llar simplektik almashtirishlarning haqiqiy tasvirlari guruhi ta’siriga nisbatan ekvivalentligi ko‘rsatilgan. Olingan yo‘llar sinfi yagona aniqlanishi isbotlangan.

Isbotlash jarayonida har bir shart matritsaviy differensial tenglamalar sistemasining yechimini ifodalovchi yo‘llar sinfi mavjudligiga ta’sir qilmasligi batafsil ko‘rsatib o‘tilgan.

Kalit so‘zlar: simplektik gruppa; kvaternionlar; haqiqiy tasvirlar gruppasi.

EQUIVALENT SOLUTIONS OF THE SYSTEM OF MATRIX DIFFERENTIAL EQUATIONS WITH RESPECT TO THE ACTION OF THE GROUP REAL REPRESENTATION OF GROUP $Sp(n)$

Abstract: In this paper, solutions of a system of differential equations are described in the form of unique paths up to equivalence with respect to the action of the group of real representations of symplectic transformations of the quaternion space. The problem of equivalence of given paths in real spaces of dimensional 4n with respect to the action of the group of real representations of symplectic transformations is solved. The conditions created when solving the equivalence problem become more stringent under the actions of some groups. This raises doubts about the existence of paths that satisfy these conditions. For this reason, the properties of matrix invariant functions representing the solution to the problem were studied. Using these properties, it is shown that there exists a path satisfying each relation formed under the equivalence conditions, and that these paths are equivalent with respect to the action of the group of real representations of symplectic transformations. It is proved that the obtained class of paths is unique.

In the process of proof it is shown in detail that each condition does not affect the existence of a class of paths that represent a solution to a system of matrix differential equations.

Keywords: symplectic group; quaternion; real representation groups

Kirish. V haqiqiy sonlarning R maydoni ustida aniqlangan $4n$ o‘lchovli chiziqli fazo va $GL(V)$ to‘plam V fazoning barcha teskarilanuvchi chiziqli almashtirishlari guruhi bo‘lsin. $\mathfrak{I}$ orqali haqiqiy sonlarning R to‘plamidagi (a,b) oraliqni belgilaymiz, (bu holda, $a=\infty$ yoki $b=-\infty$ bo‘lishi mumkin).

V fazoda berilgan $\mathfrak{I}$-*yo‘l* deb, $\mathfrak{I}$ oraliqni V fazoga akslantiruvchi shunday, $\vec{x}(t)=\{x_l(t)\}_{l=1}^{4n}$ vektor funksiyaga aytiladiki, uning barcha $x_l(t):\mathfrak{I}\to R$ koordinataviy funksiyalari cheksiz marta differensiallanuvchi funksiyalarni ifodalaydi.

Aytaylik, V fazoda ikki $\vec{x}(t)=\{x_l(t)\}_{l=1}^{4n}$, $\vec{y}(t)=\{y_l(t)\}_{l=1}^{4n}$ $\mathfrak{I}$-yo‘llar va $G\subset GL(V)$ qism guruh berilgan bo‘lsin.

Agar shunday $g\in G$ element mavjud bo‘lib, barcha $t\in\mathfrak{I}$ uchun $\vec{x}(t)g=\vec{y}(t)$ tenglik o‘rinli bo‘lsa, u holda $\vec{x}(t)$ va $\vec{y}(t)$ $\mathfrak{I}$-yo‘llar $G-$*ekvivalent* deyiladi, bu yerda $\vec{x}(t)g$ ifoda $\vec{x}(t)$ satriy vektorni $g\in G$ matritsaga chapdan (odatdagi) ko‘paytmasini ifodalaydi.

$\vec{x}(t)$ va $\vec{y}(t)$ $\mathfrak{I}$-yo‘llarning ekvivalent bo‘lishini zaruriy va yetarli shartlarini topish masalasi differensial geometriyaning muhim masalalaridan biri hisoblanadi. Bunday turdagi masalalarni yechish uchun bir qancha geometrik usullar ishlab chiqilgan bo‘lsa-da, ulardan foydalanish doim ham oson bo‘lavermaydi.

Adabiyotlar tahlili. So‘nggi vaqtlarda yo‘llarning ekvivalentlik masalasini yechishda invariantlar nazariyasi metodlari faol tarzda tatbiq qilinib kelinmoqda. Bu usulda masala yechimi yo‘llarga mos $G-$invariant differensial ratsional funksiyalar differensial maydonining differensial ratsional bazislari orqali beriladi. Jumladan, [1], [2], [3] adabiyotlarda ushbu yo‘nalish bo‘yicha asosiy tushunchalar bayoni bilan bir qatorda *maxsus chiziqli*, *ortogonal, psevdoortogonal, simplektik* va boshqa klassik gruppalarga nisbatan batafsil keltirib o‘tilgan, [6-8] maqolalarda masala kvaternion fazoning simplektik almashtirishlari va ularning haqiqiy tasvirlari gruppasiga nisbatan o‘rganilgan.

Yo‘llarning $G-$ekvivalentligi masalalarini yechish uchun invariantlar nazariyasi metodlari bilan bir vaqtda turli matritsaviy tengliklardan foydalaniladi (m.n, [1], [2], [3], [4]). Shunga ko‘ra, *yechimlari $G-$ekvivalent yo‘llar sinfini tiklaydigan matritsaviy differensial tenglamalar sistemasini tavsiflash masalasi* tabiiy ravishda paydo bo‘ladi. R^n fazoning *ortogonal almashtirishlari gruppasi* va *yo‘llar* uchun bunday masala [3], [4] adabiyotda, *simplektik* va *psevdoortogonal almashtirishlar gruppalari* uchun esa mos holda, [1], [3], adabiyotlarda batafsil bayon qilingan.

Tadqiqot metodologiyasi. H^n - kvaternion sonlarning H jismi ustida aniqlangan n o‘lchovli vektor fazo bo‘lsin. $GL(H^n)$ orqali H^n fazoning barcha chiziqli almashtirishlari gruppasini belgilaymiz. $\langle x,y\rangle: H^n\times H^n\to H$ metrik funksiya sifatida

$$\langle x,y\rangle = x_1\bar{y}_1 + x_2\bar{y}_2 + \ldots + x_n\bar{y}_n \tag{1}$$

bichiziqli formani olishimiz mumkin. H^n fazoning (1) formani o‘zida invariant saqlovchi barcha chiziqli almashtirishlari gruppasi *simplektik gruppa (kompakt simplektik gruppa)* deyiladi va $Sp(n)$ ko‘rinishida belgilanadi [5], ya’ni

$$Sp(n)=\left\{\sigma\in GL\left(H^n\right):\left\langle \sigma x,\sigma y\right\rangle=\left\langle x,y\right\rangle\right\}.$$

Ma’lumki, H^n fazoni aynan $4n$ o‘lchovli V haqiqiy fazoga ayniylashtirish mumkin. Bundan kelib chiqadiki, har bir $\sigma\in GL\left(H^n\right)$ almashtirishga $\sigma'\in GL(V)$ almashtirish bir qiymatli mos keladi. Shuningdek, $\sigma\leftrightarrow\sigma'$ moslik yordamida $GL\left(H^n\right)$ gruppa $GL(V)$ gruppaning qandaydir qism gruppasiga izomorf akslanadi. Demak, $Sp(n)$ gruppa ham $GL(V)$ gruppaning ma’lum qism gruppasiga izomorf bo‘ladi. Odatda bunday qism gruppa $Sp(n)$ gruppaning *haqiqiy tasvirlari gruppasi* deyiladi. Ma’lumki, har qanday $\sigma'\in GL(V)$ chiziqli almashtirish $g\in GL(4n,R)$ matritsa orqali bir qiymatli ifodalanadi. Bu esa $Sp(n)$ gruppaning haqiqiy tasvirlari gruppasini $g\in GL(4n,R)$ matritsalar orqali ta’riflash imkonini beradi.

2-ta’rif. $Sp(n)$ gruppaning *haqiqiy tasvirlari gruppasi* deb quyidagi shartlarni qanoatlantiruvchi $g\in GL(4n,R)$ matritsalar gruppasiga aytiladi:

$$\left\{g\in GL(4n,R):gg^T=E,\ gIg^T=I,gJg^T=J,gKg^T=K,\ \det g=1\right\} \tag{2}$$

bu yerda $E-4n$-tartibli birlik matritsa,

$$I=\begin{bmatrix} I_1 & \theta & \dots & \theta \\ \theta & I_1 & \dots & \theta \\ \vdots & \vdots & \dots & \vdots \\ \theta & \theta & \dots & I_1 \end{bmatrix},\ J=\begin{bmatrix} J_1 & \theta & \dots & \theta \\ \theta & J_1 & \dots & \theta \\ \vdots & \vdots & \dots & \vdots \\ \theta & \theta & \dots & J_1 \end{bmatrix},\ K=\begin{bmatrix} K_1 & \theta & \dots & \theta \\ \theta & K_1 & \dots & \theta \\ \vdots & \vdots & \dots & \vdots \\ \theta & \theta & \dots & K_1 \end{bmatrix},$$

$\theta-$4-tartibli nol matritsa,

$$I_1=\begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \end{bmatrix},\ J_1=\begin{bmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix},\ K_1=\begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix}.$$

Bu ko‘rinishda ta’riflangan, $Sp(n)$ gruppaning haqiqiy tasvirlari gruppasini $\mathfrak{Sp}(4n)$ bilan belgilaymiz (shartli ravishda), [8].

Aytaylik, $\vec{x}(t)=\left\{x_l(t)\right\}_{l=1}^{4n}$ vektor-funksiya V fazoda berilgan $\Im$-yo‘lni ifodalasin. $\vec{x}(t)$ $\Im$-yo‘lni *r-tartibli hosilasi* deb, $\vec{x}^{(r)}(t)=\left\{x_m^{(r)}(t)\right\}_{m=1}^{4n}$ vektor funksiyaga aytiladi, bu yerda $x_m^{(r)}(t)-x_m(t)$ funksiyani *r-tartibli hosilasi*, $m=\overline{1,4n}$, $r=1,2,3,\dots$ .Ma’lumki, $\vec{x}^{(r)}(t)$ vektor-funksiya ham barcha r lar uchun $\Im$-yo‘lni ifodalaydi.

Agar ixtiyoriy $t\in(a,b)$ uchun $\vec{x}^{(1)}(t):=x'(t)\neq 0$ shart o‘rinli bo‘lsa, $\vec{x}(t)$ yo‘l *regulyar* deyiladi, [3].

Har qanday $\vec{x}(t)=\{x_m(t)\}_{m=1}^{4n}$ $\mathfrak{I}$-yo‘l uchun $M(\vec{x})(t)$ orqali $4n\times 4n$-tartibli $\left(x_l^{(s-1)}(t)\right)_{l,s=1}^{4n}$ matritsani belgilaymiz, bu erda $m-$satr $x_l^{(s-1)}(t)$ko‘rinishidagi koordinatalarga ega, bu hol uchun $x_l^{(0)}(t)=x_l(t)$. $M'(\vec{x})(t)$ orqali $\left(x_l^{(s)}(t)\right)_{l,s=1}^{4n}$ matritsani olamiz.

Agar barcha $t\in(a,b)$ uchun $detM(\vec{x})(t)\neq 0$ bo‘lsa, mos holda $\vec{x}(t)$ yo‘l *kuchli regulyar* deyiladi [3].

G gruppa $GL(4n,R)$ gruppaning ma’lum qism gruppasi bo‘lsin. Ma’lumki, ikki $\vec{x}(t)$ va $\vec{y}(t)$ $G-$ekvivalent yo‘llar uchun $\vec{y}(t)=\vec{x}(t)g$ tenglik o‘rinli. Bu holda, $\vec{y}^{(s)}(t)=\vec{x}^{(s)}(t)g$, $s=1,2,\ldots,$ va $M(\vec{y})(t)=M(\vec{x})(t)g$ tengliklar ham o‘rinli bo‘ladi. Demak, oxirgi tengliklarning o‘rinli bo‘lishidan ham $\vec{x}(t)$ va $\vec{y}(t)$ yo‘llarning $G-$ekvivalentligi kelib chiqadi.

$G=\mathfrak{Sp}(4n)$ bo‘lsin. Quyida, $\vec{x}(t)$ va $\vec{y}(t)$ regulyar yo‘llarning $\mathfrak{Sp}(4n)-$ ekvivalent bo‘lishini zaruriy va yetarli shartlarini matritsaviy funksiyalar yordamida keltirib o‘tamiz.

1-teorema. $\vec{x}(t)$ va $\vec{y}(t)$ $\mathfrak{I}$-yo‘llar $\mathfrak{Sp}(4n)-$ekvivalent bo‘lishi uchun quyidagi shartlarning bajarilishi zarur va yetarli:

1. $M'(\vec{x})(t)\left(M(\vec{x})(t)\right)^{-1}=M'(\vec{y})(t)\left(M(\vec{y})(t)\right)^{-1}$;
2. $M(\vec{x})(t)\left(M(\vec{x})(t)\right)^{T}=M(\vec{y})(t)\left(M(\vec{y})(t)\right)^{T}$;
3. $M(\vec{x})(t)I\left(M(\vec{x})(t)\right)^{T}=M(\vec{y})(t)I\left(M(\vec{y})(t)\right)^{T}$;
4. $M(\vec{x})(t)J\left(M(\vec{x})(t)\right)^{T}=M(\vec{y})(t)J\left(M(\vec{y})(t)\right)^{T}$;
5. $M(\vec{x})(t)K\left(M(\vec{x})(t)\right)^{T}=M(\vec{y})(t)K\left(M(\vec{y})(t)\right)^{T}$;
6. $detM(\vec{x})(t)=detM(\vec{y})(t)$

bu yerda $\left(M(\vec{x})(t)\right)^{T}$ matritsa $M(\vec{x})(t)$ matritsaning mos holda transponirlanganini ifodalaydi.

Ushbu teorema isboti [7] maqolada ko‘rsatib o‘tilgan.

Endi, 1-teoremada keltirilgan 1-6-tengliklarning chap qismlarini mos holda $A(t), B(t), C(t), D(t), E(t)$ matritsaviy funksiyalar va $f(t)$ sonli funksiya bilan belgilaymiz. Natijada,

$$\begin{cases} M'(\vec{x})(t)\left(M(\vec{x})(t)\right)^{-1}=A(t); \\ M(\vec{x})(t)\left(M(\vec{x})(t)\right)^{T}=B(t); \\ M(\vec{x})(t)I\left(M(\vec{x})(t)\right)^{T}=C(t); \\ M(\vec{x})(t)J\left(M(\vec{x})(t)\right)^{T}=D(t); \\ M(\vec{x})(t)K\left(M(\vec{x})(t)\right)^{T}=E(t); \\ \det\left[M(\vec{x})(t)\right]=f(t) \end{cases} \tag{3}$$

ko‘rinishidagi matritsaviy differensial tenglamalar sistemasiga ega bo‘lamiz. U holda $A(t), B(t), C(t), D(t), E(t)$ matritsaviy funksiyalar va $f(t)$ sonli funksiya uchun quyidagi xossalar o‘rinli:

1’.
$$A(t)=\begin{bmatrix} 0 & 1 & 0 & 0 & \dots & 0 \\ 0 & 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 0 & 1 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & 1 \\ a_{\tilde{n}1}(t) & a_{\tilde{n}2}(t) & a_{\tilde{n}3}(t) & a_{\tilde{n}4}(t) & \dots & a_{\tilde{n}\tilde{n}}(t) \end{bmatrix},$$

bu yerda $a_{\tilde{n}m}(t)=\dfrac{\sum_{l=1}^{\tilde{n}} x_l^{(\tilde{n})}(t)M_{ml}(\vec{x})(t)}{\det\left[M(\vec{x})(t)\right]}$, $\tilde{n}=4n$;

2’. $B(t)$ *matritsaviy funksiya xos emas, simmetrik va har qanday* $\vec{a}\in R^{4n}$ *vektorga nisbatan musbat aniqlangan, ya’ni*

$$\det B(t)\neq 0,\ \left[B(t)\right]^T=B(t),\ \vec{a}B(t)\vec{a}^T>0;$$

3’. $C(t), D(t), E(t)$ *matritsaviy funksiyalar xos emas, kososimmetrik matritsalarni ifodalaydi, ya’ni* $\det C(t)\neq 0$, $\det D(t)\neq 0$, $\det E(t)\neq 0$,

$$\left[C(t)\right]^T=-C(t),\ \left[D(t)\right]^T=-D(t),\ \left[E(t)\right]^T=-E(t);$$

4’. $B'(t)=A(t)B(t)+B(t)A^T(t)$, *bu yerda* $B'(t)-B(t)$ *matritsadan* t *o‘zgaruvchi bo‘yicha olingan birinchi tartibli hosila;*

5’. *a)* $C'(t)=A(t)C(t)+C(t)A^T(t)$; b) $C(t)\left[B(t)\right]^{-1}C(t)=-B(t)$;

6’. *a)* $D'(t)=A(t)D(t)+D(t)A^T(t)$; b) $D(t)\left[B(t)\right]^{-1}D(t)=-B(t)$;

c) $D(t)\left[C(t)\right]^{-1}D(t)=-C(t)$;

7’. *a)* $E'(t)=A(t)E(t)+E(t)$; b) $E(t)\left[B(t)\right]^{-1}E(t)=-B(t)$;

c) $E(t)\left[C(t)\right]^{-1}E(t)=-C(t)$; d) $E(t)\left[D(t)\right]^{-1}E(t)=-D(t)$

bu yerda matritsaviy funksiyalar $C(t), D(t), E(t)$ *matritsaviy funksiyalardan* t *bo‘yicha olingan birinchi tartibli hosilalar,* $\left[B(t)\right]^{-1}, \left[C(t)\right]^{-1}, \left[D(t)\right]^{-1}, \left[E(t)\right]^{-1}$ *matritsaviy funksiyalar esa mos holda,* $B(t), C(t), D(t), E(t)$ *matritsaviy funksiyalarning teskari matritsalarini ifodalaydi.*

8’. *a)* $f'(t)=a_{\tilde{n}\tilde{n}}(t)f(t)$; b) $\det B(t)=f^2(t)$.

Ushbu xossalardan foydalanib 5) sistemaning yechimi mavjud va yagonaligi haqidagi masala yechimini aniqlashimiz mumkin.

Olingan natijalar va muhokama. $X(t)=\left\{x_{l,m}(t)\right\}_{l,m=1}^{4n}$, $n\in N$ xos emas, elementlari $t\in(a,b)$ oraliqda cheksiz marta uzluksiz differensiallanuvchi funksiyalardan iborat matritsaviy funksiya va $G=\mathfrak{Sp}(4n)$ bo‘lsin.

2-teorema. Agar $A(t), B(t), C(t), D(t), E(t)$ matritsaviy funksiyalar va $f(t)$ sonli funksiya uchun 1’-8’ shartlar o‘rinli bo‘lsa, u holda quyidagi

$$\begin{cases} X'(t)=A(t)X(t), & (i) \\ X(t)X^T(t)=B(t), & (ii) \\ X(t)IX^T(t)=C(t), & (iii) \\ X(t)JX^T(t)=D(t), & (iv) \\ X(t)KX^T(t)=E(t), & (v) \\ \det X(t)=f(t), & (vi) \end{cases} \tag{4}$$

matritsaviy tenglamalar sistemasining $G-$ekvivalentlikkacha aniqlikda yechimi mavjud va yagona, bu yerda $X^T(t)$ - $X(t)$ matritsaviy funksiyaning transponirlangani,

$t\in(a,b)$.

Isbot. Mavjudligi. Dastlab, (4) sistemaning (*i*) tenglamasini o‘rganamiz. Buning uchun $A(t)$ matritsaviy funksiya o‘rniga 1’ shartda berilgan ko‘rinishini qo‘yib ma’lum hisoblashlarni bajaramiz. Natijada, $x_{1m}^{(l-1)}=x_{lm}$, ($l=\overline{1,\tilde{n}},\ m=\overline{1,\tilde{n}}$) qonuniyatga va

$$\begin{cases} x_{11}^{(\tilde{n})}-a_{\tilde{n}\tilde{n}}x_{11}^{(\tilde{n}-1)}-a_{\tilde{n}(\tilde{n}-1)}x_{11}^{(\tilde{n}-2)}-...-a_{\tilde{n}1}x_{11}=0 \\ \vdots \\ x_{1\tilde{n}}^{(\tilde{n})}-a_{\tilde{n}\tilde{n}}x_{1\tilde{n}}^{(\tilde{n}-1)}-a_{\tilde{n}(\tilde{n}-1)}x_{1\tilde{n}}^{(\tilde{n}-2)}-...-a_{\tilde{n}1}x_{1\tilde{n}}=0 \end{cases} \quad (5)$$

ko‘rinishidagi $\tilde{n}$-tartibli, chiziqli, bir jinsli oddiy differensial tenglamalar sistemasiga ega bo‘lamiz, bu yerda $\tilde{n}=4n$. Bu holda, (*i*) tenglamani har qanday $\tilde{X}(t)=\{\tilde{x}_{lm}\}_{l,m=1}^{\tilde{n}}$ yechimi va $\vec{x}(t)=\{x_{1m}\}_{m=1}^{\tilde{n}}$ vektor funksiya uchun $\tilde{x}_{lm}=\tilde{x}_{1m}^{(l-1)}$ tenglik o‘rinli bo‘lib, $\vec{x}(t)$ vektor funksyaning har bir koordinatasi

$$y^{(\tilde{n})}(t)-a_{\tilde{n}\tilde{n}}y^{(\tilde{n}-1)}(t)-a_{\tilde{n}(\tilde{n}-1)}y^{(\tilde{n}-2)}(t)-...-a_{\tilde{n}1}y(t)=0 \quad (6)$$

differensial tenglamaning yechimini ifodalaydi.

Ma’lumki [1], (6) tenglama barcha $t\in(a,b)$ qiymatlarda $\det\left[\left(\varphi_{ij}(t)\right)_{i,j=1}^{\tilde{n}}\right]\neq 0$ shartni qanoatlantiruvchi chiziqli erkli $\{\varphi_{11}(t),\varphi_{12}(t),...,\varphi_{1\tilde{n}}(t)\}$ yechimlar sistemasiga (fundamental yechimlar sistemasi) ega. U holda, $\tilde{x}_{1m}=\varphi_{1m}(t),\ \tilde{x}_{lm}=\varphi_{1m}^{(l-1)}(t),\ t\in(a,b),\ l=\overline{1,\tilde{n}},\ m=\overline{2,\tilde{n}}$ belgilashlardan foydalansak, $\tilde{X}(t)=\{\tilde{x}_{lm}\}_{l,m=1}^{\tilde{n}}$ matritsaviy funksiya (*i*) tenglamaning yechimini ifodalaydi. Demak, (*i*) tenglama har doim xosmas yechimga ega. Bu yechimni $\tilde{X}(t)$ ko‘rinishida olamiz. Shu bilan birga ixtiyoriy $g\in GL(4n,R)$ uchun $\tilde{Y}(t)=\tilde{X}(t)g$ matritsa ham (*i*) tenglamaning yechimini ifodalaydi.

Endi (*i*) tenglamani $\tilde{X}(t)$ yechimi (*ii*) tenglamani ham qanoatlantirishini ko‘rsatamiz. Buning uchun, $z(t)=\left[\tilde{X}(t)\right]^{-1}B(t)\left[\tilde{X}^T(t)\right]^{-1}$ matritsani tuzamiz. Tabiiyki, ushbu matritsa xosmas va barcha elementlari uzluksiz differensiallanuvchi funksiyalardan iborat. $z(t)$ funksiyani $t\in(a,b)$ o‘zgaruvchi bo‘yicha differensiallab, 4’ shartdan foydalanamiz, natijada

$$z'(t)=-\left[\tilde{X}(t)\right]^{-1}\left(A(t)B(t)-B'(t)+B(t)A^T(t)\right)\left[\tilde{X}^T(t)\right]^{-1}=0$$

Bu tenglikdan, $z(t)\in GL(4n,R)$ munosabatga ega bo‘lamiz. Xususiy holda, $z(t)=E$ ko‘rinishida olsak, $\tilde{X}(t)\tilde{X}^T(t)=B(t)$ tenglikka ega bo‘lamiz. Bundan, $\tilde{X}(t)$ yechim (*ii*) tenglamani ham qanoatlantirishini ko‘rsatadi. Shuningdek, $g\in GL(4n,R)$ matritsa uchun $gg^T=E$ shart o‘rinli deb olsak, $\tilde{Y}(t)=\tilde{X}(t)g$ matritsa ham (*ii*) tenglamani qanoatlantiradi. Demak, (i)-(ii) tenglamalarni bir vaqtda qanoatlantiruvchi yechim mavjud. $\tilde{X}(t)$ shunday yechimlardan biri bo‘lsin. $z_1(t)=\left[\tilde{X}(t)\right]^{-1}C(t)\left[\tilde{X}^T(t)\right]^{-1}$ matritsani tuzamiz va 5’ *a*) shartdan $z_1'(t)=0$ tenglikka ega bo‘lamiz. Bundan $z_1(t)\in GL(4n,R)$ munosabat kelib chiqadi. Endi, 5’ b) shartni e’tibrga olib $\left[z_1(t)\right]^2$

ni hisoblaymiz. Natijada,

$$\left[z_1(t)\right]^2 == -\left[\tilde{X}(t)\right]^{-1} B(t)\left[\tilde{X}^T(t)\right]^{-1} = -E$$

tenglikka ega bo‘lamiz. $z_1(t) \in GL(4n,R)$ va $\left[z_1(t)\right]^2 = -E$ munosabatlarni o‘rinli ekanligidan, xususiy holda $z_1(t) = I$ deb olishimiz mumkin. Bundan $\tilde{X}(t) I \tilde{X}^T(t) = C(t)$ tenglik kelib chiqadi, ya’ni $\tilde{X}(t)$ matritsa (*iii*) tenglamani ham qanoatlantiradi.

Agar $g \in GL(4n,R)$ matritsa uchun $gg^T = E,\ gIg^T = I$ shartlar bajarilsa, u holda $\tilde{Y}(t) = \tilde{X}(t)g$ matritsa ham (i)-(iii) tenglamalarni bir vaqtda qanoatlantiradi. Demak, (*i*)-(*iii*) tenglamalarni bir vaqtda qanoatlantiruvchi yechim mavjud. $\tilde{X}(t)$ matritsa ana shunday yechimlardan biri bo‘lsin. $z_2(t) = \left[\tilde{X}(t)\right]^{-1} D(t)\left[\tilde{X}^T(t)\right]^{-1}$ matritsani tuzamiz va 6’. *a*) va b) shartlardan foydalanamiz. Natijada, $z_2(t) \in GL(4n,R)$ va $\left[z_2(t)\right]^2 = -E$ munosabatlarga ega bo‘lamiz. 6’. c) shartni e’tiborga olib $z_2(t) I z_2(t) = I$ munosabatni olamiz. Ushbu munosabatni e’tiborga olib, xususiy holda $z_2(t) = J$ deb olishimiz mumkin, chunki $JIJ = KJ = I$. Bu holda, $\tilde{X}(t) J \tilde{X}^T(t) = D(t)$ tenglikka ega bo‘lamiz. Bu esa $\tilde{X}(t)$ matritsa (*iv*) tenglamani yechimi bo‘lishini ko‘rsatadi. Bundan tashqari, agar $g \in GL(4n,R)$ matritsa uchun $gg^T = E$, $gIg^T = I$, $gJg^T = J$ shartlar o‘rinli bo‘lsa, $\tilde{Y}(t) = \tilde{X}(t)g$ matritsa ham (*i*)-(*iv*) tenglamalarni yechimi bo‘ladi.

Aytaylik, $\tilde{X}(t)$ ana shunday yechimlardan birini ifodalasin. Avvalgi hisobashlardagidek, xosmas $z_3(t) = \left[\tilde{X}(t)\right]^{-1} E(t)\left[\tilde{X}^T(t)\right]^{-1}$ matritsani tuzamiz. Bu matritsa uchun 7’. *a*), b), c), d) shartlardan foydalanib $z_3(t) \in GL(4n,R)$, $z_3^2(t) = -E$, $z_3(t) I z_3(t) = I$, $z_3(t) J z_3(t) = J$ munosabatlarga ega bo‘lamiz. Bundan xususiy holda, $z_3(t) = K$ bo‘lishi kelib chiqadi. Bu munosabatdan esa $\tilde{X}(t) K \tilde{X}^T(t) = K$ tenglikka ega bo‘lamiz. Demak, $\tilde{X}(t)$ matritsa (*v*) tenglamaning yechimi bo‘ladi. Shuningdek, agar $g \in GL(4n,R)$ matritsa uchun $gg^T = E$, $gIg^T = I$, $gJg^T = J$, $gKg^T = K$ shartlar o‘rinli bo‘lsa, $\tilde{Y}(t) = \tilde{X}(t)g$ matritsa ham (*i*)-(*v*) tenglamalarni bir vaqtda qanoatlantiruvchi yechim bo‘ladi.

$\tilde{X}^T(t)$ shunday yechimlardan biri bo‘lsin. $u(t) = \det \tilde{X}(t)$ belgilashni kiritamiz. U holda, $\tilde{X}'(t)\left[\tilde{X}(t)\right]^{-1} = A(t)$ tenglama va 1’ shartga asosan $\frac{u'(t)}{u(t)} = a_{ññ}$ munosabatga ega bo‘lamiz. 8’ *a*) shartni e’tiborga olib, bu munosabatni $\frac{u'(t)}{u(t)} - \frac{f'(t)}{f(t)} = 0$ ko‘rinishida yozib, $u'(t) f(t) - u(t) f'(t) = 0$ tenglikka ega bo‘lamiz. $\omega(t)$ orqali $\frac{u(t)}{f(t)}$ nisbatni belgilaymiz va uni $t \in (a,b)$ o‘zgaruvchi bo‘yicha differensiallaymiz. Natijada,

$$\omega'(t)=\left[\frac{u(t)}{f(t)}\right]'=\frac{u'(t)\,f(t)-u(t)\,f'(t)}{\left[f(t)\right]^2}=0 \qquad (7)$$

munosabatga ega bo‘lamiz. Bundan, $\omega(t)=\lambda,\ \lambda-const$ yoki $u(t)=\lambda f(t)$ tenglikka ega bo‘lamiz. Ushbu tenglikda $\lambda=1$ deb deb olsak, $\det\tilde{X}(t)=f(t)$ munosabat kelib chiqadi. Bu esa $\tilde{X}(t)$ matritsani (*iv*) tenglamaning yechimi bo‘lishini ko‘rsatadi. Shuningdek, $g\in GL(4n,R)$ matritsa uchun

$$gg^T=E\,,\ gIg^T=I\,,\ gJg^T=J\,,\ gKg^T=K\,,\ \det g=1 \qquad (8)$$

shartlar o‘rinli bo‘lsa, $\tilde{Y}(t)=\tilde{X}(t)g$ matritsa ham (*i*)-(*vi*) tenglamalarning yechimini ifodalaydi. Avvalgi paragrafdan ma’lumki, (8) shartni qanoatlantiruvchi $g\in GL(4n,R)$ matritsa va $\tilde{X}(t)$, $\tilde{Y}(t)$ matritsalar uchun $\tilde{Y}(t)=\tilde{X}(t)g$ tenglik o‘rinli bo‘lsa, $\tilde{X}(t)$ va $\tilde{Y}(t)$ matritsaviy funksiyalar $G-$ekvivalent deyiladi, bu yerda G simplektik gruppaning haqiqiy tasvirlari gruppasi. Demak, (4) tenglamalar sistemasining $G-$ekvivalentlikkacha aniqlikda yechimlari mavjud.

Yagonaligi. Aytaylik, $\tilde{X}(t)$ va $\tilde{Y}(t)$ matritsalar (4) sistemaning turli xosmas yechimlarini ifodalasin. U holda, bu yechimlar uchun

$$\begin{cases}\tilde{X}'(t)\left[\tilde{X}(t)\right]^{-1}=\tilde{Y}'(t)\left[\tilde{Y}(t)\right]^{-1}\\ \tilde{X}(t)\tilde{X}^T(t)=\tilde{Y}(t)\tilde{Y}^T(t)\\ \tilde{X}(t)I\tilde{X}^T(t)=\tilde{Y}(t)I\tilde{Y}^T(t)\\ \tilde{X}(t)J\tilde{X}^T(t)=\tilde{Y}(t)J\tilde{Y}^T(t)\\ \tilde{X}(t)K\tilde{X}^T(t)=\tilde{Y}(t)K\tilde{Y}^T(t)\\ \det\tilde{X}(t)=\det\tilde{Y}(t)\end{cases}$$

sistema o‘rinli. Bu sistemadan 1-teoremaga asosan $\tilde{Y}(t)=\tilde{X}(t)g$ tenglik kelib chiqadi, bu yerda $g\in G$. Bu esa, $\tilde{X}(t)$ va $\tilde{Y}(t)$ matritsalarni $G-$ekvivalentligini anglatadi. Demak, (4) sistemaning har qanday xosmas yechimlari o‘zaro G gruppa ta’siriga nisbatan ekvivalent bo‘ladi. Boshqacha aytganda, $G-$ekvivalentlikkacha aniqlikda yagona bo‘ladi. **Teorema isbotlandi.**

Xulosa. Xulosa o‘rnida quyidagi natijani keltiramiz:

Natija. $A(t)$, $B(t)$, $C(t)$, $D(t)$, $E(t)$ matritsaviy va $f(t)$ sonli funksiyalar uchun 1’-8’ shartlar o‘rinli bo‘lsin, u holda

i) (6) sistemaning har qanday xosmas $X(t)=\{x_{lm}(t)\}_{l,m=1}^{\tilde{n}}$ yechimi uchun $\vec{x}(t)=\{x_{1m}(t)\}_{m=1}^{\tilde{n}}$ vektor funksiya kuchli regulyar $\mathfrak{I}$-yo‘lni ifodalaydi va barcha $t\in(a,b)$ qiymatlarda $X(t)=M(\vec{x})(t)$ tenglik o‘rinli bo‘ladi;

ii) (5) sistemaning yechimini ifodalovchi har qanday $M(\vec{x})(t)$ matritsa uchun $G-$ekvivalentlikgacha aniqlikda yagona, kuchli regulyar $\vec{x}(t)$ yo‘l mavjud.

Foydalanilgan adabiyotlar

1. Хаджиев Дж. Приложение теории инвариантов к дифференциальной геометрии кривых. – Ташкент, Фан, 1988.

2. Aripov R.G., Khadjiyev Dj. *The complete system of differential and integral invariants of a curve in Euclidean geometry* // Russian Mathematics –2007–Volume 11–Issue 3–pp. 1-14.

3. К. Муминов, В. Чилин. *Эквивалентность кривых в конечномерных пространствах,* LAP LAMBERT Academic Publishing, 2015.

4. Chilin V. I., Muminov K. K. *Equivalence of paths in Galilean geometry* // Journal of Mathematical Sciences–2020–Volume 245–Issue 3– pp. 297-309.
5. Iwahori N. *Some remarks on tensor invariants of O(n), U(n), Sp(n)* // Journal of the Mathematical Society of Japan–1958– Volume 10–Issue 2–pp.145-160.
6. Арипов Р.Г. Теорема о существовании и единственности системы регулярных путей для действий комплексных ортогональных групп в C^n - Узб.матем.журнал, 2001, № 2. – С. 6-12
7. Muminov, K.K., Gafforov, R.A. Systems of Matrix Differential Equations for Surfaces. Journal of Mathematical Sciences.Vol.278,No 4, 623–632 (2024).
8. Muminov K., Juraboyev S. The system of generators of d -skew field of $Sp(n)$ invariant d -rational functions // *International Journal of Applied Mathematics*. – 2022. – Т. 35. – №. 6. – pp. 903.
9. Khodyrovich M. K., Solyjonovich J. S. Equivalence of Paths under the Action of the Real Representation of Sp (n) // *Journal of Applied Mathematics and Physics*. – 2022. – Т. 10. – №. 5. – pp. 1837-1858.
10. Муминов К.К., Гаффоров Р.А. Эквивалентность путей относительно действия специальной псевдоортогональной группы. - Узбекский математический журнал, 2011, № 4. - С.135-141.
11. Муминов К.К., Гаффоров Р.А. Эквивалентность конечных систем путей относительно действия специальной псевдоортогональной группы. - Ученые записки Таврического национального университета им. В. И. Вернадского. Серия “Физико – математические науки”. Том 24 (63) № 1 (2011). - С. 90-100.
12. Муминов К.К., Гаффоров Р.А. Эквивалентность решений систем матричных уравнений относительно специальной псевдоортогональной группы. - Вестник НУУз 2014 й, 2/1.
13. Муминов К. К. и Журабоев С.С. Эквивалентность путей относительно действия специальный унитарной группы. - Вестник НУУз 2/1, (2017). С.146-150.
14. Muminov K. K., Jurabayev S. EQUIVALENCE OF PATHES WITH RESPECT TO ACTION GROUP OF MOTION OF A HYPERBOLIC PLANE //Scientific and Technical Journal of Namangan Institute of Engineering and Technology. – 2020. – Т. 2. – №. 9. – pp. 14-20..
15. Мўминов Қ. Қ, Жўрабоев С. С. *Кватернион сонларнинг ҳақиқий тасвирлари группаси таъсирига нисбатан йўлларнинг эквивалентлик масаласи* // НамДУ илмий ахборотномаси 9, (2021), б.14-21.
16. Q. Q. Mo‘minov, S. S. Jo‘raboyev. *Ikki o‘lchovli kvaternion fazolarda berilgan yo‘llarning simplektik gruppa ta’siriga nisbatan ekvivalentlik masalasi* // Ilmiy axborotnoma 1, (2022), b.37-50.
17. Juraboyev S.S. *The problem of describing the generators of a differential field of invariant differential rational functions with respect to the action of the group of real representations of symplectic transformations in a quaternion space* // Bull. Inst. Math 5(3), (2022), pp.151-165.

REFLECTION OF *SV* WAVES IN THE ELASTIC HALF-SPACE. FIELD EQUATIONS FOR ANGLES OF INCIDENCE LESS THAN THE CRITICAL ONE

Xolmurodov Abdulxamid
Qarshi davlat universiteti, professor
ORCID 0000-0003-1309-5582
Matanov Muhammad
Qarshi davlat universiteti, doktorant
ORCID 0009-0008-8858-5010
Quzratov Muxriddin
Qarshi davlat universiteti, doktorant
quzratovm95@gmail.com,
ORCID 0009-0009-9469-1853
UDK: 519.957

Annotatsiya. Ushbu maqolada Reyleigh tipidagi va *sh, p, sv* seysmik to‘lqinlarning to‘liq umumiy tushish burchagi tufayli yuzaga keladigan elastik yarim fazoning harakatini o‘rganish imkonini beruvchi munosabatlar o‘rnatiladi va to‘lqinlarning yer bo‘ylab tarqalishi bilan bog‘liq hodisalar, ikki o‘lchovli masalalarda har bir hodisa to‘lqinining xususiyatlarini tahlil qilish o‘rganiladi. Bundan tashqari, ularning o‘ziga xos xususiyatlari, turli to‘lqinlar tomonidan hosil bo‘lgan maydonlarning xususiyatlarini aniqlash, ularning tarqalishini boshqaradigan ifodalari va to‘liq umumiy tushish burchaklariga umumlashtirish ko‘rib chiqiladi. Elastik modul E va Puasson nisbati bilan aniqlangan bir xil mexanik xususiyatlarga ega yarim fazolar uchun matematik model yaratish, ushbu matematik modellar tomonidan berilgan qiymatlar asosida to‘lqin amplitudalarining kerakli qiymatlariga erishish va ularning o‘sishi va kamayishi amplitudalarining o‘zgarish grafigini olish haqida yozilgan.

Kalit so'zlar: qaytarilgan to'lqinlar, sv to'lqin, yarim fazo, tarqalish, siljish, siljish maydoni, p to'lqin, vektorlar.

Abstract. In this article relations that allow to study the movement of the elastic half-space caused by the full total angle of incidence of Rayleigh-type and *sh, p, sv* seismic waves are established and the phenomena related to the propagation of waves across the terrain, analyzing the properties of each event wave in two-dimensional problems is studied. Besides, their specific properties, determining the properties of the fields formed by different waves, their expressions governing scattering and generalization to fully general angles of incidence are discussed. Creating a mathematical model for half-spaces with the same mechanical properties determined by the elastic modulus E and Poisson's ratio, reaching the required values of the wave amplitudes based on the values given by these mathematical models, and the amplitude of their increase and decrease - all it tells us about getting a graph of change.

Key words: reflected waves, *sv* wave, half-space, propagation, displacement, displacement field, *p* wave, vectors.

Introduction. *sh*, *p*, *sv* and Rayleigh waves that reach the surface with a completely generic angle of incidence are investigated below.

The following section establishes general considerations regarding the phenomena associated with the propagation of waves through the terrain. Once the initial data has been established, the following sections analyze the characteristics of each type of incident wave in the case of two-dimensional problems, placing special emphasis on their specific characteristics. Once the characteristics of the fields produced by the different waves have been defined, the expressions that govern their propagation are generalized in the following section to completely generic angles of incidence. Finally, what happens in the particular case in which there is a plane of geometric symmetry is addressed in order to reduce the number of degrees of freedom of the models in which the expressions developed in this article are used.

In this section, the characteristics of the displacement and tension field will be studied when the incident wave is of type *sv* [1].

The incidence of an *sv wave* in the half-space generates, after its reflection, the appearance of a reflected *sv wave* and a *p* wave. Figure 1. presents the parameters of interest for the problem under analysis.

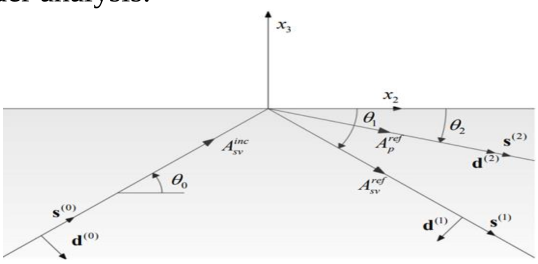


Figure 1. Angles of interest in the plane x_2x_3 for an incident sv wave.

Research methodology. Under the above assumptions, the vectors s and d are as follows:

$$s^{(0)} = \left[0,\, s_2^{(0)},\, s_3^{(0)}\right] = [0, \cos(\theta_0), \sin(\theta_0)] \quad \mathrm{d}^{(0)} = \left[0,\, d_2^{(0)},\, d_3^{(0)}\right] = [0, \sin(\theta_0), -\cos(\theta_0)]$$
$$s^{(1)} = \left[0,\, s_2^{(1)},\, s_3^{(1)}\right] = [0, \cos(\theta_1), -\sin(\theta_1)] \quad \mathrm{d}^{(1)} = \left[0,\, d_2^{(1)},\, d_3^{(1)}\right] = [0, -\sin(\theta_1), -\cos(\theta_1)]$$
$$s^{(2)} = \left[0,\, s_2^{(2)},\, s_3^{(2)}\right] = [0, \cos(\theta_2), -\sin(\theta_2)] \quad \mathrm{d}^{(2)} = \left[0,\, d_2^{(2)},\, d_3^{(2)}\right] = [0, \cos(\theta_2), -\sin(\theta_2)] \tag{1}$$

The analytical expression of the displacement field, based on the previous vectors, is the following:

$$u_1 = 0, \quad u_2 = d_2^{(0)} A_{sv}^{inc} e^{-ik_s(s^{(0)}\cdot r)} + d_2^{(1)} A_{sv}^{ref} e^{-ik_s(s^{(1)}\cdot r)} + d_2^{(2)} A_p^{ref} e^{-ik_p(s^{(2)}\cdot r)}$$
$$u_3 = d_3^{(0)} A_{sv}^{inc} e^{-ik_s(s^{(0)}\cdot r)} + d_3^{(1)} A_{sv}^{ref} e^{-ik_s(s^{(1)}\cdot r)} + d_3^{(2)} A_p^{ref} e^{-ik_p(s^{(2)}\cdot r)} \tag{2}$$

To guarantee the independence of the expressions with respect to the axis, x_2 it must be verified that:

$$k_s s_2^{(0)} = k_s s_2^{(1)} = k_p s_2^{(2)} \;\rightarrow\; \frac{\cos(\theta_0)}{c_s} = \frac{\cos(\theta_1)}{c_s} = \frac{\cos(\theta_2)}{c_p} \rightarrow \theta_0 = \theta_1 \tag{3}$$

So the angles θ_0 and θ_1 they are, also on this occasion, equal. Knowing this equality, we can verify that:

$$s_2^{(1)} = s_2^{(0)} = \cos(\theta_0),\ s_3^{(1)} = -s_3^{(0)} = -\sin(\theta_0),\ d_2^{(1)} = -d_2^{(0)} = -\sin(\theta_0),\ d_3^{(1)} = d_3^{(0)} = -\cos(\theta_0) \tag{4}$$

Similarly, from the third equality of equation (3) the relationship between the angle of the incident wave (θ_0) and that of the reflected *p* wave is obtained (θ_2) [2]. Indeed:

$$\frac{\cos(\theta_0)}{c_s} = \frac{\cos(\theta_2)}{c_p} \ \rightarrow\ \cos(\theta_2) = \frac{c_p}{c_s}\cos(\theta_0) \tag{5}$$

Differently from what happened when the incident wave was a P-type wave, the relationship that exists on this occasion between the angle of incidence of the *sv wave* and that of the reflected *p* wave is proportional to the quotient between the speed c_p and c_s, that is, to $1/\kappa$. In other words:

$$\frac{c_p}{c_s} = \sqrt{\frac{2(1-\nu)}{1-2\nu}} = \frac{1}{\kappa} > 1 \tag{6}$$

Expression (5) allows us to relate the propagation and displacement vectors of the reflected *p* wave with those of the incident *sv wave*, in a similar way to that carried out previously. So that:

$$s_2^{(2)} = \frac{1}{\kappa}s_2^{(0)},\ s_3^{(2)} = -\sqrt{1-\left[s_2^{(2)}\right]^2},\ d_2^{(2)} = s_2^{(2)} = \frac{1}{\kappa}s_2^{(0)},\ d_3^{(2)} = s_3^{(2)} = -\sqrt{1-\left[s_2^{(2)}\right]^2} \tag{7}$$

There is a particularity for this type of incident waves that can be observed by analyzing equation (5). Thus, take an angle of incidence θ_0 such that the angle of the reflected *p* wave cancels out. In these circumstances $cos\left(\theta_0\right) = \kappa$, call the angle that produces this effect θ_{cr}. Next, assume that the angle of incidence is greater than that critical angle θ_{cr} (supercritical angle). That way, the cosine of the angle of incidence will be less than κ and, therefore, the cosine of the reflected angle will be $cos\left(\theta_2\right)=1/\kappa cos\left(\theta_0\right)<1$ [3-4].

Now, imagine that the angle of incidence turns out to be less than the aforementioned critical angle (subcritical angle). Under such an assumption, $cos\left(\theta_0\right) > \kappa$ so that the cosine of the reflected angle will be $cos\left(\theta_2\right)=1/\kappa cos\left(\theta_0\right)>1.$ This is, therefore, a singularity that implies that $\sin(\theta_2) \in \mathbb{C}.$ Due to this, a modification of the formulation is necessary to take into account the fact described.

As said previously, it is necessary to modify the formulation proposed so far to take into account the phenomenon associated with the critical angle. To do this, start from the already known expressions of the displacement field and analyze its components due to the contribution of the reflected *p* wave.

$$\begin{bmatrix} u_2 \\ u_3 \end{bmatrix}^p = \begin{bmatrix} d_2^{(2)} \\ d_3^{(2)} \end{bmatrix} A_p^{ref} e^{-ik_p[\cos(\theta_2)x_2 - \sin(\theta_2)x_3]} = \begin{bmatrix} \cos(\theta_2) \\ -\sin(\theta_2) \end{bmatrix} A_p^{ref} e^{-ik_p[\cos(\theta_2)x_2 - \sin(\theta_2)x_3]}$$
$$\cos\left(\theta_2\right) = \frac{1}{\kappa}\cos\left(\theta_0\right) \qquad \sin\left(\theta_2\right) = \pm i(-1)\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0) - 1} \tag{8}$$

It is not possible to establish, a priori, the sign of the imaginary unity. In any case, the expression of the displacements can be expressed as follows:

$$\begin{bmatrix} u_2 \\ u_3 \end{bmatrix}^p = \begin{bmatrix} \frac{1}{\kappa}\cos(\theta_0) \\ \pm i(-1)\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \end{bmatrix} A_p^{ref} e^{-ik_p\left[\frac{1}{\kappa}\cos(\theta_0)x_2 - \pm ix_3\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1}\right]} \tag{9}$$

Hence, analyzing the exponential function, the appropriate solution will be the one that serves to maintain its structure. On this occasion, the structure is maintained if $-i$ is taken. In this way you have:

$$\begin{bmatrix} u_2 \\ u_3 \end{bmatrix}^p = \begin{bmatrix} \frac{1}{\kappa}\cos(\theta_0) \\ i\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \end{bmatrix} A_p^{ref} e^{-ik_p\left[\frac{1}{\kappa}\cos(\theta_0)x_2 + ix_3\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1}\right]} = \begin{bmatrix} \frac{1}{\kappa}\cos(\theta_0) \\ i\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \end{bmatrix} \cdot$$

$$\cdot A_p^{ref} e^{k_p x_3\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1}} e^{-ik_p\left[\frac{1}{\kappa}\cos(\theta_0)\right]x_2} = \begin{bmatrix} \frac{1}{\kappa}\cos(\theta_0) \\ i\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \end{bmatrix} A_p^{ref} e^{\xi x_3} e^{-ik_s\cos(\theta_0)x_2} \tag{10}$$

The dependent exponential x_3 is a term that modulates the amplitude of the wave, decreasing with depth. The value of the real constant that accompanies the variable x_3 is:

$$\xi = k_p\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \tag{11}$$

In this way, it is a wave that propagates in the direction x_2 (grazing), with displacements in x_2 and x_3, both out of phase 90^o, with a still undetermined amplitude A_p^{ref} that, in addition, decreases with depth (x_3 negative) according to ξ. This class of waves has more than notable similarities with a typology of waves known as Rayleigh waves, a type of surface wave whose wave number is $k_r = k_s\cos(\theta_0)$ and that produces movements in x_2 and x_3 out of phase with each other 90^o [5-6].

At the implementation level, y can be considered to $s^{(2)}$ be $d^{(2)}$ the following complex expressions:

$$s^{(2)} = d^{(2)} = \begin{bmatrix} 0 \\ \cos(\theta_2) \\ -\sin(\theta_2) \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{1}{\kappa}\cos(\theta_0) \\ i\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \end{bmatrix} \tag{12}$$

Thus, the previous expressions allow a relatively simple implementation of an angle of incidence lower than the critical one. However, it is instructive to obtain the displacement field equations for the case in which $\theta_0 = \theta_{cr}$. In this case, the propagation and displacement vectors of the reflected *p* wave are the following:

$$s_2^{(2)} = d_2^{(2)} = 1 \qquad s_3^{(2)} = d_3^{(2)} = 1 \tag{13}$$

the displacement field being the following:

$$\begin{gathered} u_1 = 0, \quad u_2 = d_2^{(0)} A_{sv}^{inc} e^{-ik_s(s^{(0)}\cdot r)} + d_2^{(1)} A_{sv}^{ref} e^{-ik_s(s^{(1)}\cdot r)} + A_p^{ref} e^{-ik_p x_2} \\ u_3 = d_3^{(0)} A_{sv}^{inc} e^{-ik_s(s^{(0)}\cdot r)} + d_3^{(1)} A_{sv}^{ref} e^{-ik_s(s^{(1)}\cdot r)} \end{gathered} \tag{14}$$

where it can be seen that the displacements in the y directions x_2 are x_3 the sum of the contributions of the incident and reflected *s waves* and, in the case of the displacements in x_2, also of the contribution of the reflected *p* wave which, in this case, is a grazing *p* wave [7-8].

If the incident wave is of type *sv*, it can be easily observed that the following components of the strain tensor cancel out:

$$\varepsilon_{11}=u_{1,1}=0 \qquad \varepsilon_{21}=\varepsilon_{12}=\frac{1}{2}\left(u_{1,2}+u_{2,1}\right)=0 \qquad \varepsilon_{31}=\varepsilon_{13}=\frac{1}{2}\left(u_{1,3}+u_{3,1}\right)=0 \tag{15}$$

Thus, the strain tensor of any point in the half-space has the following structure:

$$\varepsilon=\begin{pmatrix}0 & 0 & 0\\ 0 & \varepsilon_{22} & \varepsilon_{23}\\ 0 & \varepsilon_{32} & \varepsilon_{33}\end{pmatrix} \tag{16}$$

Therefore, the components of the strain tensor are obtained as follows:

$$\begin{aligned}\varepsilon_{22}=u_{2,2}&=-d_2^{(0)}s_2^{(0)}A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-d_2^{(1)}s_2^{(1)}A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}-\\&-d_2^{(2)}s_2^{(2)}A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\\ \varepsilon_{33}=u_{3,3}&=-d_3^{(0)}s_3^{(0)}A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-d_3^{(1)}s_3^{(1)}A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}-\\&-d_3^{(2)}s_3^{(2)}A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\\ \varepsilon_{23}=\varepsilon_{32}=\frac{1}{2}u_{2,3}&=\frac{1}{2}[-(d_2^{(0)}s_3^{(0)}+d_3^{(0)}s_2^{(0)})A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-\\&-(d_2^{(1)}s_3^{(1)}+d_3^{(1)}s_2^{(1)})A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}-(d_2^{(2)}s_3^{(2)}+d_3^{(2)}s_2^{(2)})A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}]\end{aligned} \tag{17}$$

As occurred in the case of the incident *p* wave, it is also worth determining on this occasion the sum of the elements of the main diagonal of the strain tensor. You have:

$$\begin{aligned}\varepsilon_{kk}=\varepsilon_{11}+\varepsilon_{22}+\varepsilon_{33}&=-(d_2^{(0)}s_2^{(0)}+d_3^{(0)}s_3^{(0)})A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-\\&-(d_2^{(1)}s_2^{(1)}+d_3^{(1)}s_3^{(1)})A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}-(d_2^{(2)}s_2^{(2)}+d_3^{(2)}s_3^{(2)})A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\end{aligned} \tag{18}$$

Regarding the stress tensor, the null components are, on this occasion, the following:

$$\sigma_{12}=\sigma_{21}=2\mu\varepsilon_{12}=0 \qquad \sigma_{13}=\sigma_{31}=2\mu\varepsilon_{13}=0 \tag{19}$$

where the stress tensor of any point in the half-space looks like the following:

$$\sigma=\begin{pmatrix}\sigma_{11} & 0 & 0\\ 0 & \sigma_{22} & \sigma_{23}\\ 0 & \sigma_{32} & \sigma_{33}\end{pmatrix} \tag{20}$$

And the non-zero components are:

$$\begin{aligned}\sigma_{11}=\lambda\varepsilon_{kk}&=-\lambda(d_2^{(0)}s_2^{(0)}+d_3^{(0)}s_3^{(0)})A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-\lambda(d_2^{(1)}s_2^{(1)}+d_3^{(1)}s_3^{(1)})A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}\\&-\lambda(d_2^{(2)}s_2^{(2)}+d_3^{(2)}s_3^{(2)})A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\\ \sigma_{22}&=-[(\lambda+2v)d_2^{(0)}s_2^{(0)}+\lambda d_3^{(0)}s_3^{(0)}]A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-[(\lambda+2v)d_2^{(1)}s_2^{(1)}+\lambda d_3^{(1)}s_3^{(1)}]A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}\\&-[(\lambda+2v)d_2^{(2)}s_2^{(2)}+\lambda d_3^{(2)}s_3^{(2)}]A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\\ \sigma_{33}&=-[\lambda d_2^{(0)}s_2^{(0)}+(\lambda+2v)d_3^{(0)}s_3^{(0)}]A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-[\lambda d_2^{(1)}s_2^{(1)}+(\lambda+2v)d_3^{(1)}s_3^{(1)}]A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}\\&-[\lambda d_2^{(2)}s_2^{(2)}+(\lambda+2v)d_3^{(2)}s_3^{(2)}]A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\\ \sigma_{23}=\sigma_{32}=2\mu\varepsilon_{23}&=-\mu(d_2^{(0)}s_3^{(0)}+d_3^{(0)}s_2^{(0)})A_{sv}^{inc}(ik_s)e^{-ik_s(s^{(0)}\cdot r)}-\\&-\mu(d_2^{(1)}s_3^{(1)}+d_3^{(1)}s_2^{(1)})A_{sv}^{ref}(ik_s)e^{-ik_s(s^{(1)}\cdot r)}-\mu(d_2^{(2)}s_3^{(2)}+d_3^{(2)}s_2^{(2)})A_p^{ref}(ik_p)e^{-ik_p(s^{(2)}\cdot r)}\end{aligned} \tag{21}$$

Results and discussions. The free surface conditions are, on this occasion, the same as in the case of the incident *p* wave, that is:

$$\text{in } x_3 = 0 \;\rightarrow\; \begin{cases} \sigma_{23} = 0 \\ \sigma_{33} = 0 \end{cases} \tag{22}$$

The component x_2 of the vectors s and d as a function of θ_0 is the following:

$$\begin{array}{lll} s_2^{(0)} = \cos(\theta_0) & s_2^{(1)} = \cos(\theta_0) & s_2^{(2)} = \dfrac{1}{\kappa}\cos(\theta_0) \\ d_2^{(0)} = \sin(\theta_0) & d_2^{(1)} = -\sin(\theta_0) & d_2^{(2)} = \dfrac{1}{\kappa}\cos(\theta_0) \end{array} \tag{23}$$

While the component x_3 is:

$$\begin{array}{lll} s_3^{(0)} = \sin(\theta_0) & s_3^{(1)} = -\sin(\theta_0) & s_3^{(2)} = -\sqrt{1-\dfrac{1}{\kappa^2}\cos^2(\theta_0)} \\ d_3^{(0)} = -\cos(\theta_0) & d_3^{(1)} = -\cos(\theta_0) & d_3^{(2)} = -\sqrt{1-\dfrac{1}{\kappa^2}\cos^2(\theta_0)} \end{array} \tag{24}$$

From the application of the first boundary condition we obtain:

$$\begin{aligned} 0 = -\mu[\sin^2(\theta_0) - \cos^2(\theta_0)]A_{sv}^{inc}(ik_s) - \mu[\sin^2(\theta_0) - \cos^2(\theta_0)]A_{sv}^{ref}(ik_s) - \\ -\mu[-\sin(\theta_2)\cos(\theta_2) - \sin(\theta_2)\cos(\theta_2)]A_p^{ref}(ik_p) \end{aligned} \tag{25}$$

From where, remembering the properties of double angles and dividing by μk_s, we finally have:

$$\cos(2\theta_0)A_{sv}^{ref} + \sin(2\theta_2)\kappa A_p^{ref} = -\cos(2\theta_0)A_{sv}^{inc} \tag{26}$$

On the other hand, from the second of the equalities ($\sigma_{33} = 0$), after performing some simple operations we have:

$$\begin{aligned} &-2\mu\cos(\theta_0)\sin(\theta_0)(ik_s)A_{sv}^{inc} - 2\mu\cos(\theta_0)\sin(\theta_0)(ik_s)A_{sv}^{ref} - \\ &-[\lambda\cos^2(\theta_2) + (\lambda+2\mu)\sin^2(\theta_2)](ik_p)A_p^{inc} = 0 \end{aligned} \tag{27}$$

Where from: $\mu\sin(2\theta_0)A_{sv}^{inc} - \mu\sin(2\theta_0)A_{sv}^{ref} - [\lambda + 2\mu\sin^2(\theta_2)]\kappa A_p^{ref} = 0$

(28)

and, after slightly modifying the expression, we finally arrive at:

$$\sin(2\theta_0)A_{sv}^{ref} - \frac{1}{\kappa}[1-2\kappa^2\cos^2(\theta_2)]A_p^{ref} = \sin(2\theta_0)]A_{sv}^{inc} \tag{29}$$

Expressions (27), (28) and (29) form a system of two equations with three unknowns. Giving a unit value to the amplitude of the incident *sv wave* we have the following system of equations [9-10]:

$$\left.\begin{aligned} \cos(2\theta_0)A_{sv}^{ref} + \sin(2\theta_2)\kappa A_p^{ref} = -\cos(2\theta_0) \\ \sin(2\theta_0)A_{sv}^{ref} + \frac{1}{\kappa}[1-2\kappa^2\cos(2\theta_2)]A_p^{ref} = \sin(2\theta_0) \end{aligned}\right\} \tag{30}$$

From whose resolution the following values are obtained for the amplitudes of the reflected waves:

$$A_{sv}^{ref} = \frac{\kappa^2\sin(2\theta_0)\sin(2\theta_2) - \cos^2(2\theta_0)}{\kappa^2\sin(2\theta_0)\sin(2\theta_2) + \cos^2(2\theta_0)} \tag{31}$$

For the *sv* wave and

$$A_p^{ref} = \frac{\kappa\sin(4\theta_0)}{\kappa^2\sin(2\theta_0)\sin(2\theta_2) + \cos^2(2\theta_0)} \tag{32}$$

for the *p* wave.

The expressions obtained are of general validity whatever the θincident angle 0. However, it is interesting to study certain situations in order to see how the amplitudes of the reflected waves behave depending on the incident angle. When $\theta_0 = \theta_{cr}$ you have:

$$\cos(\theta_2) = \frac{1}{\kappa}\cos(\theta_0) \quad \rightarrow \quad \cos(\theta_2) = 1 \quad \rightarrow \quad \sin(\theta_2) = 0 \tag{33}$$

Therefore, under these circumstances, the amplitudes take the following values:

$$A_{sv}^{ref} = -\frac{\cos(2\theta_2)}{\cos(2\theta_2)} = -1 \tag{34}$$

For the reflected *sv wave* y:

$$A_p^{ref} = -\frac{\kappa\sin(4\theta_0)}{\cos^2(2\theta_0)} = -\frac{4\kappa^2\sqrt{1-\kappa^2}(2\kappa^2-1)}{(2\kappa^2-1)^2} = -\frac{4\kappa^2\sqrt{1-\kappa^2}}{2\kappa^2-1} \tag{35}$$

for the reflected P.

Thus, when a wave strikes at an angle equal to the critical angle, the amplitude of the reflected *sv wave* takes a value equal to -1 and the amplitude of the reflected *p* wave depends on the Poisson's ratio of the medium.

On the other hand, it is possible to express the amplitude of the reflected *p* wave as follows:

$$A_p^{ref} = \frac{R}{a-bi} = \frac{R(a+bi)}{a^2+b^2} = Me^{i\alpha} \tag{36}$$

where M and $tg\left(\alpha\right)$ are:

$$M = \frac{R}{a^2+b^2}\sqrt{a^2+b^2} \qquad tg(\alpha) = \frac{b}{a} \tag{37}$$

So ref A_p^{ref} can be written:

$$A_p^{ref} = \frac{R}{\sqrt{a^2+b^2}}e^{i\alpha} \tag{38}$$

Substituting these values into the displacement components due to the contribution of the reflected *p* wave, we obtain:

$$\begin{bmatrix} u_2 \\ u_3 \end{bmatrix}^p = \begin{bmatrix} d_2^{(2)} \\ d_3^{(2)} \end{bmatrix} \frac{R}{\sqrt{a^2+b^2}} e^{i\alpha} e^{\xi x_3} e^{-ik_p x_2} = \begin{bmatrix} d_2^{(2)} \\ d_3^{(2)} \end{bmatrix} S e^{\xi x_3} e^{-ik_p x_2 + i\alpha} \tag{39}$$

where *s* and α are expressions analogous to those obtained by Achenbach, that is:

$$S = \frac{\kappa\sin(4\theta_0)}{\sqrt{4[\cos^2(\theta_0)-\kappa^2]\sin^2(2\theta_0)\cos^2(\theta_0)+\cos^4(2\theta_0)}}$$
$$\alpha = \frac{2\sin(2\theta_0)\cos(\theta_0)\sqrt{\cos^2(\theta_0)-\kappa^2}}{\cos^2(2\theta_0)} \tag{40}$$

On the other hand, another case of interest is the one that occurs when the angle of incidence is less than the critical one. As mentioned above, when the angle is subcritical, the sine of the angle θ_2 takes a complex value. So:

$$\cos(\theta_0) > \kappa \rightarrow \cos(\theta_2) = \frac{1}{\kappa}\cos(\kappa_0) > 1 \rightarrow \sin(\theta_2) = \sqrt{1-\frac{1}{\kappa^2}\cos^2(\theta_0)} \in \mathbb{C} \tag{41}$$

What can be put:

$$\sin(\theta_2) = -i\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1} \tag{42}$$

And substituting this value into the expressions of the amplitudes of the reflected waves we obtain:

$$A_{sv}^{ref} = \frac{-\cos^2(2\theta_0) - 2i\kappa^2\sin(2\theta_0)\frac{1}{\kappa}\cos(\theta_0)\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1}}{\cos^2(2\theta_0) - 2i\kappa^2\sin(2\theta_0)\frac{1}{\kappa}\cos(\theta_0)\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1}} \tag{43}$$

It is interesting to visualize a property of that breadth. So by calling $a = \cos^2(2\theta_0)$

and $b = 2\kappa\sin(2\theta_0)\cos(\theta_0)\sqrt{\frac{1}{\kappa^2}\cos^2(\theta_0)-1}$ you can write:

$$\left|A_{sv}^{ref}\right| = \frac{\left(b^2-a^2\right)^2+4a^2b^2}{\left(a^2+b^2\right)^2} = \frac{a^4+2a^2b^2+b^4}{\left(a^2+b^2\right)^2} = \frac{\left(a^2+b^2\right)^2}{\left(a^2+b^2\right)^2} = 1 \qquad (44)$$

Regarding the amplitude of the p wave we have:

$$A_p^{ref} = -\frac{\kappa\sin(4\theta_0)}{\cos^2(2\theta_0)-2i\sin(2\theta_0)\cos(\theta_0)\sqrt{\cos^2(\theta_0)-\kappa^2}} \qquad (45)$$

Also when the incident wave is of type *sv*, there is at least one angle of incidence that causes the amplitude of the reflected *sv wave* to be cancelled. Thus, for each value of the Poisson's ratio there is at least one angle of incidence for which only one p wave is reflected. For this case, the expression is:

$$\kappa^2\sin(2\theta_0)\sin(2\theta_2)-\cos^2(2\theta_0)=0 \qquad (46)$$

Which, based solely on the angle of incidence, can be written:

$$4\kappa\cos^2(\theta_0)\sqrt{1-\cos^2(\theta_0)}\sqrt{1-\frac{1}{\kappa^2}\cos^2(\theta_0)}-4\cos^4(\theta_0)+4\cos^2(\theta_0)-1=0 \qquad (47)$$

We take the following results from the expression (44) and create its graph (Figure 2).

Poisson's ratio	A_{sv}^{ref}	0	10	20	30	40	50	60	70	80	90
v=0.1	*Re_A*	-1,0	-0,6	0,1	0,7	0,9	1,0	0,8	0,0	-0,8	-0,9
	Im_A	0,0	-0,7	-0,9	-0,6	-0,2	0,0	0,0	0,0	0,0	0,0
v=0.2	*Re_A*	-1,0	-0,5	0,2	0,7	0,9	1,0	0,6	-0,1	-0,8	-0,9
	Im_A	0,0	-0,8	-0,9	-0,6	-0,2	0,0	0,0	0,0	0,0	0,0
v=0.3	*Re_A*	-1,0	-0,5	0,2	0,7	0,9	1,0	0,7	-0,4	-0,8	-0,9
	Im_A	0,0	-0,8	-0,9	-0,6	-0,2	0,0	-0,6	0,0	0,0	0,0
v=0.4	*Re_A*	-1,0	-0,4	0,3	0,8	0,9	1,0	0,9	-0,7	-0,9	-0,9
	Im_A	0,0	-0,8	-0,9	-0,5	-0,1	0,0	-0,3	-0,7	0,0	0,0

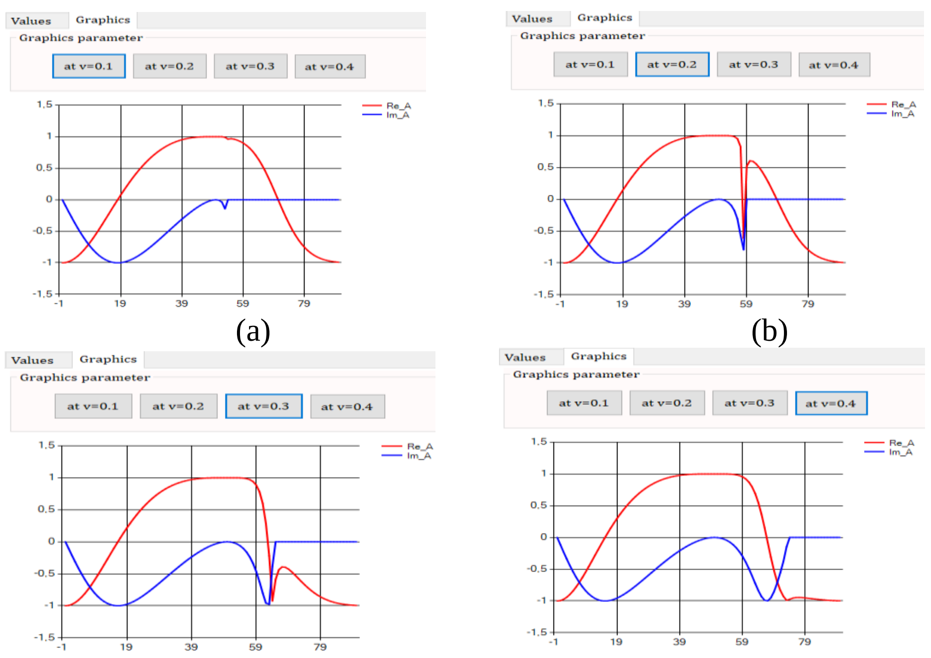


Figure 2. Variation of the amplitude of the reflected sv wave with the angle of incidence. (a), (b), (c), (d) – graphics.

Conclusion/recommendations. Therefore, there is an imaginary component other than zero in the amplitudes of the reflected *sv waves* when the angle of incidence is subcritical, a component that is canceled when the critical angle is exceeded, the moment from which the amplitude of the wave takes on real values. In a similar way to what occurred when the incident wave was of type *p*, the mode change phenomenon only takes place for terrain Poisson's coefficients lower than 0.263. For lower values, there are two mode change angles. The first of them is very close to the corresponding critical angle, the second occurring for a value of the angle of incidence greater than the critical in all cases. Figure 2 represents the variation of the real and imaginary parts of the amplitude of the reflected *sv* wave with the angle θ_0 of incidence for some values of the terrain.

References

1. Leontovich M. A. Introduction to thermodynamics. Static physics: Textbook. Village - M.: Science. 1983.-416-p.
2. Landau L.D., Lifshits E.M. Hydrodynamics.–M: Nauka, 1988.-736-p.
3. Patterman S. Hydrodynamics of superfluid fluid. M.: Mir, 1977, 520-p.
4. Dorovsky V.N. Continuum theory of filtration // Geology and Geophysics. - 1989. - No. 7. - P. 39-45.
5. Dorovsky V.N. Equations of continuum theory of filtration. Novosibirsk, 1987, 9 p. (Prepr / IGiG SB USSR Academy of Sciences, No. 9)
6. Khalatnikov I.M. Theory of superfluidity. - M.: Nauka, 1971.– 320 p.
7. Leontovich M.A. Introduction to thermodynamics. Static physics: Textbook. village –M.: Science. 1983.-416 p.
8. Kholmurodov A.E., Imomnazarov Kh.Kh. Direct and inverse dynamic problems for the equation of SH waves in a porous medium//Bulletin of NUUz, series mechanics-mathematics, 2006, No.2, pp. 86-91. (01.00.00, No.8)
9. Kholmuradov A.E., Imomnazarov Kh.Kh. Direct and inverse dynamic problems for SH-waves in porous media//Mathematical and Computer Modelling, V.45, Issues 3-4, 2007, pp. 270-280. (№1.Web of Science. IF=1.602)
10. Matanov M. (2024) Formation of wave equations in elastic and porous elastic media by the boundary element method. News of KarSU 2024 (1) 52-61.

SUN'IY IMMUN TIZIMLARI ALGORITMLARINING KASALLIKLARNI ANIQLASH VA TASNIFLASH MASALALARIDA QO'LLANILISHI

Djabbarov O.R.,
Qarshi davlat universiteti Amaliy matematika kafedrasi mudiri,
dotsent,oybekjabborov1987@mail.ru
ORCID 0000-0002-5644-1513
Eshboyev E.A.,
Qarshi davlat universiteti, dotsent,
eea1974@mail.ru
ORCID 0000-0002-7160-2733
Klicheva F.G.,
Qarshi davlat universiteti, o'qituvchi, vip.qilicheva@mail.ru
ORCID 0009-0000-7254-0813

UDK 004.622

Annotatsiya. Mazkur maqolada sun'iy intellekt usullaridan biri – sun'iy immun tizimlarining ahamiyati va tibbiyot sohasida qo'llanilishi haqida bir qator ma'lumotlar keltirilgan. Shuningdek, AIS algoritmining bir qator modellari – klonal tanlash, salbiy tanlash, immun tarmoq, dendrit hujayra algoritmlari va sun'iy immunitetni aniqlash tizimi haqida batafsil bayon etilgan. Yuqorida keltirilgan algoritmlarning tibbiyotda uchraydigan kasalliklarni tashxis qilish, genetik ifodalanishni tahlil qilish, dori vositalarini yaratish, tibbiy tasvirlarni tahlil qilish, xavfsizlik va ma'lumotlar himoyasi, davolash samaradorligini baholash kabi masalalarga tatbiq etish mumkinligi ko'rsatilgan. Maqolada keltirilgan ma'lumotlar asosida AIS algoritmlaridan foydalanib ishlovchi dasturiy vosita uchun algoritm qurish masalasini hal etish mumkin.

Ishda keltirilgan algoritmlar asosida tuziladigan dasturiy vositani aniq kasalliklar turini farqlash, tashxis aniqligini oshirish maqsadlariga yo'naltirish ishlarini amalga oshirish xulosa sifatida keltirilgan.

Kalit so‘zlar: immun tizim, algoritm, klonal tanlov, salbiy tanlov, dendrit hujayra, antigen, antitela, anomaliya, populyatsiya, genetik ifodalanish, immun xotira, immun javob, affinitet.

Abstract: This article provides various information on the importance and application of artificial immune systems (AIS) in the field of medicine. Additionally, detailed descriptions of several AIS algorithms, such as the clonal selection, negative selection, immune network, dendritic cell algorithms and artificial immune recognition system are presented. It is demonstrated that these algorithms can be applied to issues such as diagnosing diseases encountered in medicine, analyzing genetic expression, developing drugs, analyzing medical images, security and data protection and evaluating treatment efficacy. Based on the information provided in the article, it is possible to solve the problem of constructing an algorithm for a software tool using AIS algorithms.

As a conclusion, it is mentioned that the software tool based on the algorithms presented in the work can be directed towards differentiating specific types of diseases and improving diagnostic accuracy.

Key words: Immune system, algorithm, clonal selection, negative selection, dendritic cell, antigen, antibody, anomaly, population, genetic expression, immune memory, immune response, affinity.

Kirish. Sun’iy immun tizimlari (Artificial immune systems - AIS) umurtqali hayvonlarning immun tizimining tamoyillari va jarayonlariga asoslangan avtomatlashtirilgan hisoblash tizimlari sinfiga kiradi. AIS algoritmlari berilgan masalalarni hal qilish uchun immun tizimining xotirasi va o‘rganish qobiliyatidan foydalanadi [1].

AIS – amaliyotda uchraydigan muammolarni hal qilish uchun qo‘llaniladigan nazariy immunologiyada tasvirlangan modellar, tamoyillar, mexanizmlar va funksiyalardan foydalanadigan adaptiv hisoblash tizimidir [2].

Bugungi kunda tabiiy immun tizimlari to‘liq o‘rganilmagan bo‘lsa-da, immunitet tizimining ishlashini tushuntiradigan va uning elementlarining o‘zaro ta’sirini tavsiflovchi uchta asosiy nazariya mavjud. Ular quyidagilar:

- salbiy tanlov nazariyasi;
- klonal tanlov nazariyasi;
- immunitet tarmog‘i nazariyasi;

Bular AIS ning to‘rt turdagi (klonal tanlash algoritmi, salbiy tanlash algoritmi, immun tarmoq algoritmi, dendritik algoritm) algoritmlarini yaratish uchun asos bo‘ldi.

Tadqiqot metodologiyasi. Immunitet ishini kompyuterda talqin qilish uchun uning mexanizmlarini algoritmlar va raqamlar tiliga o‘tkazish kerak. Bunda antigenlarning analogi g‘ayrioddiy holatlarni tavsiflovchi ma’lumotlar bo‘ladi [3]. Ular fanda **anomaliyalar** deb ataladi.

Sun’iy antikorlarning vazifasi anomaliyalarni topishdir. Agar kompyuterda barcha tashkil etuvchilar to‘g‘ri sozlangan bo‘lsa, kompyuter simulyatsiyasi ularning deyarli har birini aniqlay oladi: masalan, tasvir bo‘laklari, ma’lumotlar paketlari, samolyotning parvoz yo‘lidagi og‘ishlari yoki dvigatel shovqini kabilarni.

AISning bir nechta tashkil etuvchilari va jarayonlari mavjud:

- Antigenler. AISda antigenler muammoli holatlar yoki tahlil qilinadigan ma’lumotlarni ifodalaydi. Ular sonli qiymatlar, qonuniyatlar yoki ma’lumotlarning boshqa ixtiyoriy shakli sifatida ifodalanishi mumkin.
- Antikorlar: Antikorlar AISda asosiy anglash va javob berish agentlaridir. Ular antigenlarni aniqlash va bog‘lash uchun javobgardir. Antikorlar tasodifiy yoki klonal tanlov jarayoni orqali yaratilishi mumkin, bunda eng samarali antikorlar tanlanadi va ko‘paytiriladi.
- Immun xotirasi: AIS immunologik xotira tushunchasini o‘z ichiga oladi, bu tizimga antigenlarni xotirada saqlab qolish imkonini beradi. Ushbu xotira tizimning kelajakda shunga o‘xshash antigenlarga yanada samarali javob berishiga yordam berishini ta’minlaydi.
- Immun javob va immun o‘rganish. Antigen aniqlanganda, AIS yangi antikorlarni ishlab chiqarish yoki mavjudlarini o‘zgartirishni o‘z ichiga olishi mumkin bo‘lgan immun

javoblarini ishlab chiqadi. Bu jarayon tizimga vaqt o‘tishi bilan o‘z ish faoliyatini moslashtirish va yaxshilash imkonini beradi.

- Begonani farqlash: AIS immunitet tizimi tananing o‘z hujayralari va begona moddalar o‘rtasidagi farqiga o‘xshash o‘ziga tegishli va o‘ziga tegishli bo‘lmagan antigenlarni ajratadi. Ushbu ajratish tizimga anomaliyalarni yoki odatdagi xatti-harakatlardan og‘ishlarni aniqlash va ularga javob berishga e’tibor qaratish imkoniyatini beradi.
- Immun bosim: AIS shuningdek, immunitet bosimi tushunchasiga ega bo‘lib, u tizimning zararsiz antigenlarga haddan tashqari ta’sir qilishini yoki juda ko‘p antigenlar bilan ortiqcha yuklanishining oldini oladi. Immunitet bosimi muvozanatli immunitet reaksiyasini va samaradorligini saqlashga yordam beradi.

AIS turli sohalarda, jumladan, optimallashtirish masalalari, qonuniyatlarni aniqlash, ma’lumotlarni qidirish va anomaliyalarni aniqlashda muvaffaqiyatli qo‘llanilmoqda [4]. AIS algoritmlari ishonchlilik, moslashuvchanlik va tajribadan o‘rganish qobiliyatini ta’minlaydi, bu ularni amaliy masalalarni hal qilish uchun moslashtiradi [5-6].

O‘tgan vaqt mobaynida bir necha turdagi sun’iy immun tizimlari metodlari ishlab chiqildi. Har bir AIS algoritmi turli jihatlarga e’tibor qaratadi yoki muayyan masalalarni hal qilish uchun turli usullardan foydalanadi. Maqolada AIS algoritmlarini qo‘llash sohalarini ko‘rib chiqish va ular qanday qilib samarali yechimlar yaratishga yordam berishi batafsil tushuntiriladi. Quyida AIS ning keng tarqalgan metodlarini keltiramiz:

Klonal tanlash algoritmi. Ushbu turdagi AIS immun tizimining klonal tanlash nazariyasiga asoslanadi. Bu turli xil antikorlar to‘plamini yaratish va klonal ko‘payish hamda mutatsiya jarayoni orqali eng samaralilarini tanlashni o‘z ichiga oladi. Bu algoritm ko‘pincha optimallashtirish va qonuniyatlarni aniqlash masalalarini hal qilish uchun ishlatiladi.

Salbiy tanlash algoritmi: Bu algoritm immun tizimidagi o‘ziga tegishli va tegishli bo‘lmaganlarni ajratish tushunchasiga asoslanadi. U o‘zi taniydigan antikorlar to‘plamini yaratishni va ularni anomaliyalar yoki og‘ishlarni aniqlash uchun boshqa antigenlar to‘plami bilan taqqoslashni o‘z ichiga oladi. Salbiy tanlash algoritmi odatda bosimlarni va kompyuter tarmoqlaridagi anomaliyalarni aniqlash uchun ishlatiladi.

Immun tarmoq algoritmi: Bu algoritm immun tizimining immun hujayralari o‘rtasidagi o‘zaro ta’sirga asoslangan. U o‘zaro ta’sirlarni tarmoq sifatida modellashtiradi va optimallashtirish hamda qonuniyatlarni aniqlash masalalarini hal qilish uchun immun tarmoq dinamikasi va immun tarmoqni optimallashtirish kabi tarmoq mexanizmlaridan foydalanadi.

Dendrit hujayra algoritmi: Bu algoritm immun tizimining dendrit hujayralarining xatti-harakatlariga asoslangan bo‘lib, ular antigen taqdimoti va immun javobida muhim rol o‘ynaydi. U tegishli javoblarni yaratish uchun antigenlardan ma’lumot to‘plash va qayta ishlashni o‘z ichiga oladi. Shuningdek, u turli masalalarni, jumladan, klasterlash va ma’lumotlarni tasniflashni hal qilish uchun ishlatilgan.

Sun’iy immunitetni aniqlash tizimi: Bu tizim - salbiy tanlov, klonal tanlov va immun xotira kabi immunitet tizimining bir nechta tarkibiy qismlarini birlashtirgan umumiy tuzilma hisoblanadi.

Yuqorida keltirilgan klonal tanlash, salbiy tanlash, immun tarmoq, dendrit hujayra va sun’iy immunitetni aniqlash kabi AIS metodlari maqolani ilmiy jihatdan asoslab, AISning keng qo‘llanish sohalarini yoritishda yordam beradi.

Natijalar va muhokama. Deyarli barcha immunitetni immitatsiya qiluvchilar salbiy va klonal tanlash algoritmlariga asoslangan. Antigenlar bit satrlariga o‘xshash - nollar va birlar ketma-ketligi hisoblanadi. AIS ma’lumotlar oqimidagi anomaliyalarni tezda taniy oladigan antikor detektorlarini yaratishi kerak.

Klonal tanlash algoritmi AIS modellaridan biri bo‘lib, biologik immun tizimining klonal seleksiya jarayoniga asoslangan. Bu algoritm asosan optimallashtirish va mashinali o‘rganish masalalarida qo‘llaniladi. Biologik immun tizimi antigenlarga (tashqi ta’sirlar) qarshi kurashish uchun o‘zidagi xos hujayralarini (antitelalarni) tanlab ko‘paytiradi [7]. Ya’ni klonal tanlash bu jarayonni o‘zida aks ettiradi. Ushbu algoritm quyidagi tushunchalarga asoslanadi:

- Antigenlar: Tashqi ta’sirlar yoki yechilishi kerak bo‘lgan masala.
- Antitelalar: Antigenlarga qarshi kurashuvchi immun tizimining hujayralari, algoritmda bu yechimlar yoki yechimning nomzodlari sifatida qaraladi.
- Afinitet: Antigenga mos keluvchi antitelaning darajasi bo‘lib, yechimning sifatini baholovchi funksiya hisoblanadi.

Klonal tanlash algoritmi quyidagi qadamlardan iborat:

1. Initsializatsiya: dastlabki populyatsiyani (antitelalarni) yaratish.
2. Baholash: har bir antitelaga mos afinitetni baholash.
3. Tanlash: yaxshi afinitetga ega bo‘lgan antitelalarni tanlash.
4. Klonlash: tanlangan antitelalarni ko‘paytirish (klonlash).
5. Giper-mutatsiya: ko‘paytirilgan klonlarga kichik o‘zgarishlar (mutatsiya) kiritish.
6. Yangilash: yangi antitelalarni populyatsiyaga kiritish va ularni baholash.
7. Takrorlash: ehtimoliy yechimlar yetarli darajada yaxshilanmagunicha yoki ma’lum bir to‘xtash mezoniga erishilgunga qadar yuqoridagi bosqichlarni takrorlash.

Klonal tanlash algoritmi bir qator sohalarda, xususan, tibbiyot sohasida uchraydigan amaliy masalalarni yechishda samarali qo‘llanilishi mumkin, masalan:

1. Kasalliklarni tashxis qilish. Klonal tanlash algoritmi kasallik belgilarini aniqlashda ishlatilishi mumkin. Bunda antigenlar kasallik alomatlarini yoki biomarkerlarni ifodalaydi, antitelalar esa kasallikni aniqlash bo‘yicha ehtimoliy tashxis qilish yechimlaridir.
2. Genetik ifodalanishni tahlil qilish. Bu algoritm gennetik ifodalanish ma’lumotlarini tahlil qilishga yordam beradi, chunki klonal tanlash algoritmi katta hajmli ma’lumotlar to‘plamini optimallashtirishda samarali hisoblanadi.
3. Dori vositalarini yaratish. Klonal tanlash algoritmi yangi dori vositalarini yaratishda ham qo‘llanilishi mumkin. Bu algoritm yangi molekulalarni yaratish va ularning kasallikka qarshi samaradorligini baholashda yordam beradi.
4. Tibbiy tasvirlarni tahlil qilish. Tibbiy tasvirlarni (masalan, rentgen, MRT, MSKT, EKG) segmentatsiya va tasniflash qilishda klonal tanlash algoritmi ishlatiladi. Bu algoritm tasvirlardagi anomaliyalarni aniqlashda va tasvirlarni avtomatik tahlil qilishda yordam beradi.

Salbiy tanlash algoritmi (Negative Selection Algorithm, NSA) AIS modellaridan biri bo‘lib, biologik immun tizimining o‘z-o‘zidan bo‘lmagan (self-nonself) farqlash jarayoniga asoslangan. Bu algoritm, asosan, anomaliyalarni aniqlash, ma’lumotlar xavfsizligi va hujumlarni aniqlash kabi masalalarini hal etishda qo‘llaniladi.

Biologik immun tizimi o‘z hujayralarini begona hujayralardan farqlash va ularga qarshi immun javobini shakllantirish orqali organizmni himoya qiladi [7,8]. Bu jarayon salbiy tanlash mexanizmi orqali amalga oshiriladi: immun tizimi o‘z hujayralariga qarshi reaktiv bo‘lgan limfotsitlarni yo‘q qiladi, natijada faqat begona hujayralarga qarshi reaktiv bo‘lgan limfotsitlar qoladi.

Salbiy tanlash algoritmi quyidagi qadamlardan iborat:

1. Initsializatsiya: Yechimlar maydoni (self-space) yaratish va uni o‘z-o‘zidan bo‘lgan namunalar (self-samples) bilan to‘ldirish.
2. Generator: Tasodifiy tarzda potensial detektorlarni (candidate detectors) yaratish.

3. Tanlash: Detektorlarni o‘z-o‘zidan bo‘lgan namunalar bilan taqqoslash va mos keluvchi detektorlarni yo‘q qilish.

4. Tasdiqlash: Mos kelmaydigan detektorlarni saqlash va ularning to‘plamini hosil qilish.

5. Anomaliyalarni aniqlash: Yangi ma’lumotlarni detektorlar to‘plami bilan taqqoslash va anomaliyalarni aniqlash.

Salbiy tanlash algoritmi tibbiyot sohasida bir qator masalalarni yechishda qo‘llanilishi mumkin:

1. Kasalliklarni tashxis qilish. NSA kasallik belgilarini aniqlashda qo‘llaniladi. Bu algoritm yordamida kasallik alomatlarini aniqlash va tahlil qilish mumkin.
2. Biomarkerlar tahlili. NSA yordamida biomarkerlarni tahlil qilish va kasalliklarni erta bosqichda aniqlash mumkin. Biomarkerlar detektorlar sifatida ishlatiladi va yangi namunalar bilan solishtiriladi.
3. Tibbiy tasvirlarni tahlil qilish. NSA tibbiy tasvirlarni segmentatsiya qilishda va anomaliyalarni aniqlashda qo‘llaniladi. Tasvirlar detektorlar to‘plami bilan taqqoslanadi va anomaliyalar aniqlanadi.
4. Xavfsizlik va ma’lumotlar himoyasi. NSA ma’lumotlar xavfsizligi va tarmoq hujumlarini aniqlashda samarali hisoblanadi. Bu algoritm yordamida tibbiy ma’lumotlar va tizimlar himoyalanadi.

Immun tarmoq algoritmi (Immune Network Algorithm, INA) AIS modellaridan biri bo‘lib, immun tizimining murakkab tarmoqlari va ularning o‘zaro ta’sirlariga asoslangan algoritmdir. Bu algoritm ko‘pincha ma’lumotlarni klasterlash, anomaliyalarni aniqlash va optimallashtirish vazifalarida qo‘llaniladi. Biologik immun tizimi antigenlar va antitelalar o‘rtasidagi o‘zaro ta’sirlarni tarmoq sifatida tashkil qiladi, bu esa tizimning yanada samarali ishlashini ta’minlaydi.

Biologik immun tizimi antigenlarni aniqlash va ularga qarshi kurashish uchun turli antitelalarni yaratadi. Bu antitelalar antigenlar bilan bog‘lanadi va tarmoq hosil qiladi. Tarmoqdagi har bir elementning faolligi boshqa elementlar bilan bo‘lgan o‘zaro ta’sirlarga bog‘liq bo‘lib, bu tizimning moslashuvchanligini ta’minlaydi. Immun tarmoq algoritmi ana shu biologik jarayonlarga asoslanadi.

Immun tarmoq algoritmi quyidagi qadamlardan iborat:

1. Initsializatsiya: dastlabki antitelalar populyatsiyasini yaratish.
2. Baholash: har bir antitelaning afinitetini baholash (antigenlar bilan bog‘lanish darajasi).
3. Tarmoqni yangilash: antitelalar o‘rtasidagi o‘zaro ta’sirlarni yangilash va tarmoqni optimallashtirish.
4. Mutatsiya va klonlash: antitelalarni ko‘paytirish va mutatsiya qilish orqali yangi antitelalarni yaratish.
5. Yangilanish va tanlash: eng yaxshi antitelalarni tanlash va yangi antitelalarni populyatsiyaga kiritish.
6. Takrorlash: ehtimoliy yechimlar yetarli darajada yaxshilanmagunicha yoki ma’lum bir to‘xtash mezoniga erishilgunga qadar yuqoridagi bosqichlarni takrorlash.

Immun tarmoq algoritmi tibbiyotda bir qator masalalarni yechishda qo‘llanilishi mumkin:

1. Kasalliklarni tashxis qilish: INA kasalliklarni aniqlash va tashxis qilishda ishlatilishi mumkin. Bu algoritm kasallik alomatlarini aniqlash va ularning murakkab tarmoqlarini tahlil qilishga yordam beradi.
2. Genetik tahlil: gen ma’lumotlarini klasterlash va tahlil qilishda ham INA qo‘llanilishi mumkin. Bu algoritm yordamida genlardagi o‘xshashliklar va farqlarni aniqlash mumkin.
3. Biomarkerlarni aniqlash: INA biomarkerlarni aniqlash va tahlil qilishda samarali hisoblanadi. Biomarkerlar kasalliklarning erta bosqichida aniqlanishiga yordam beradi.

4. Tibbiy tasvirlarni tahlil qilish: tibbiy tasvirlarni (MRT, rentgen) segmentatsiya qilish va anomaliyalarni aniqlashda INA ishlatiladi. Bu usul tasvirlardagi anomaliyalarni aniqlashga va tasvirlarni avtomatik tahlil qilishga yordam beradi.
5. Davolash samaradorligini baholash: INA yordamida turli davolash usullarining samaradorligini baholash mumkin. Bu algoritm davolashning bir qator turlarini tahlil qilish va samaradorligini aniqlashga yordam beradi.

Dendrit hujayra algoritmi (Dendritic Cell Algorithm, DCA) - bu sun'iy immun tizimi sohasida ishlab chiqilgan algoritmlardan biridir. U biologik immun himoyaga asoslangan hisoblash modellari orqali tibbiy va boshqa kompleks masalalarni hal qilish uchun ishlatiladi. Bu algoritm biologik dendritik hujayralar faoliyatiga asoslanadi.

Dendrit hujayralar biologik immun tizimining muhim qismidir. Ular antigenlarni tanish va immun javobni qaytarishda muhim rol o'ynaydi. Bu hujayralar quyidagi vazifalarni bajaradi:

- **Antigenni taqdim etish:** dendrit hujayralar antigenlarni tanib, ularni T hujayralarga taqdim eta.
- **Ogohlantirish:** ular immun tizimning boshqa hujayralariga xavf tug'ilganligi haqida xabar berishadi.
- **Faollik darajasi:** hujayralar atrof-muhitdagi ta'sirlar asosida faollik darajasini o'zgartiradi.

Dendrit hujayra algoritmi uchta asosiy qadamdan iborat:

1. Signalni qabul qilish va qayta ishlash**:** algoritm turli xil signallarni qabul qiladi, masalan, xavf signallari va antigen signallari, har bir signal turli vaziyatlarda paydo bo'ladi va ularga turli darajada e'tibor qaratiladi [9].
2. Hujayra faolligining aniqlanishi**:** Signallarga javoban hujayra faolligi aniqlanadi. Dendrit hujayralar biologik modellari asosida faollik darajasi o'rnatiladi.
3. Antigenlarni taqdim etish va sinflarga ajratish**:** Algoritm antigenlarni to'playdi va ularni sinflarga ajratadi. Immun javob qaytarish uchun ma'lumotlar boshqa algoritmlarga taqdim etiladi.

Dendrit hujayra algoritmi tibbiy masalalarni yechishda keng qo'llanilishi mumkin, xususan:

1. Kasaliklarni aniqlash va tashxis qilish:

   DCA biologik signallarni qayta ishlash orqali turli kasalliklarni aniqlashda ishlatilishi mumkin.

   Tibbiy qurilmalar tomonidan yig'ilgan ma'lumotlar algoritmga kiritiladi va natijada kasallik belgilari aniqlanadi.

2. Avtomatik monitoring va tahlil:

   Tibbiy monitoring tizimlarida DCA qo'llanilib, bemorlarning holatini avtomatik tahlil qilish va zarur chora-tadbirlarni qo'llash uchun foydalaniladi.

Sun'iy immunitetni aniqlash tizimi (Artificial Immune Recognition System - AIRS) sun'iy immun tizimining bir turi bo'lib, u tabiiy immun tizimining muayyan jihatlariga asoslangan. AIRS asosan ma'lumotlarni tasniflash va aniqlash vazifalarida qo'llaniladi. Bu tizim biologik immun tizimidagi antigen-antitela o'zaro ta'sirini modellashtiradi va ma'lumotlarni tasniflash uchun samarali vosita hisoblanadi [10].

AIRS tabiiy immun tizimidagi quyidagi mexanizmlarga asoslanadi:

- Antigenlar: tashqi ta’sirlar yoki yechilishi kerak bo‘lgan masala.
- Antitelalar: antigenlarga qarshi kurashuvchi immun tizimining hujayralari, algoritmda bu yechimlar yoki yechimning nomzodlari sifatida qaraladi.
- Afinitet: antigenga mos keluvchi antitelaning darajasi, ya’ni yechimning sifatini baholovchi funksiyadir.
- Hujayra (Retseptor) tahriri: antitelalarning o‘zgarishi va yangi antigenlarga moslashishi jarayoni.

Sun’iy immunitetni aniqlash tizimi quyidagi asosiy qadamlardan iborat:

1. Initsializatsiya: dastlabki populyatsiyani (antitelalarni) yaratish va ularning afinitetini baholash.
2. Retseptor tahriri: yangi antigenlarga moslashish uchun antitelalarni o‘zgartirish.
3. Hujayra tanlash: eng yaxshi afinitetga ega bo‘lgan antitelalarni tanlash va ularni klonlash.
4. Klonlarni yangilash: tanlangan klonlarni yangilash va ularni diversifikatsiya qilish.
5. Yangi hujayralarni yaratish: tizimni diversifikatsiya qilish uchun yangi antitelalarni yaratish va populyatsiyaga qo‘shish.
6. Takrorlash: ehtimoliy yechimlar yetarli darajada yaxshilanmagunicha yoki ma’lum bir to‘xtash mezoniga erishilmagunicha yuqoridagi bosqichlarni takrorlash.

Sun’iy immunitetni aniqlash tizimi tibbiyotda bir qator masalalarni yechishda qo‘llanilishi mumkin:

1. Kasalliklarni tashxis qilish: AIRS kasalliklarni aniqlash va tashxis qilish tizimlarini yaratishda ishlatilishi mumkin. Bu tizim antigen-antitela o‘zaro ta’sirini modellashtiradi va tashxis ma’lumotlarini tasniflaydi.
2. Genetik ifodalanishni tahlil qilish: AIRS genetik ifodalanish ma’lumotlarini tahlil qilishda yordam beradi. Bu tizim katta hajmli ma’lumotlar to‘plamini tasniflash va tahlil qilishda samarali hisoblanadi.
3. Dori vositalarini yaratish: AIRS yangi dori vositalarini yaratishda ham qo‘llanilishi mumkin. Bu tizim yangi molekulalarni yaratish va ularning kasallikka qarshi samaradorligini baholashda yordam beradi.
4. Tibbiy tasvirlarni tahlil qilish: Tibbiy tasvirlarni (masalan, rentgen, MRI) segmentatsiya va tasniflashda AIRS ishlatiladi. Bu tizim tasvirlardagi anomaliyalarni aniqlashda va tasvirlarni avtomatik tahlil qilishda yordam beradi.
5. Xavfsizlik va ma’lumotlar himoyasi: AIRS ma’lumotlar xavfsizligi va tarmoq hujumlarini aniqlashda samarali. Bu tizim yordamida tibbiy ma’lumotlar va tizimlar himoyalanadi.

Yuqoridagi ma’lumotlardan ko‘rinadiki, CSA va AIRS algoritmlari bir-biriga juda o‘xshash prinsipda ishlaydi.

Umumiy holda AIS turli xil patologik sharoitlar va kasalliklarni aniqlash hamda tasniflash masalalarida qo‘llanilishi mumkin. Quyida ularni qo‘llashga doir ba’zi misollarni keltiramiz:

1. Saratonni aniqlash: AIS saraton hujayralari va o‘smalarini aniqlash uchun ishlatilishi mumkin. Ular o‘zgargan hujayralarni tanib olish va ularga javob berishning immunitet mexanizmlarini modellashtirishni amalga oshiradi. Saratonga qarshi immunitet reaksiyasidan olingan ma’lumotlardan foydalangan holda, AIS saraton kasalligini aniqlashga yordam beradi.
2. Yuqumli kasalliklarni tashxislash: AIS virusli yoki bakterial infeksiyalar kabi turli yuqumli kasalliklarni aniqlash va tasniflash uchun qo‘llaniladi. Ular immunitet reaksiyasini tahlil qilishi va turli patogenlar o‘rtasidagi differentsial tashxislashga yordam bera oladi.

3. Avtoimmun kasalliklar: AIS revmatoid artrit kabi avtoimmun kasalliklarni tashxislash va tasniflashda samarali qo‘llanilishi mumkin. Ular ushbu kasalliklar bilan bog‘liq immunitet belgilari va qonuniyatlarini tahlil qilishi va tashxis qo‘yishni aniqlash va tegishli muolajani tanlashda yordam berishi mumkin.
4. Allergik reaktsiyalar tashxisi: AIS ni turli allergenlarga allergik reaksiyalarni aniqlash va tasniflash uchun qo‘llash mumkin. Ular allergiya bilan bog‘liq immunitet belgilarini tahlil qilishi va reaksiyaga sabab bo‘lgan allergenni aniqlashda va tegishli davolanishni tanlashda yordam bera oladi.
5. Yaxshi o‘rganilmagan kasalliklarni tashxislash: AIS an’anaviy tashxislash usullari yetarli darajada samara bera olmaydigan noyob kasalliklarni tashxislash uchun foydalanilishi mumkin. Ular bunday kasalliklar bilan bog‘liq g‘ayrioddiy immunitet belgilari va qonuniyatlarni tahlil qilishi va to‘g‘ri tashxisni topishga yordam berishi mumkin.

Xulosa. Mazkur ilmiy maqolada sun’iy immun tizimlari algoritmlarining tibbiyot sohasida qo‘llanilishi, xususan, kasalliklarni aniqlash va tasniflash masalalarida qo‘llanilishi batafsil yoritib berilgan. Klonal tanlash, salbiy tanlash, immun tarmoq, dendrit hujayra algoritmlari va sun’iy immunitetni aniqlash tizimlari kabi turli AIS algoritmlarining o‘ziga xos jihatlari va ularning afzalliklari tahlil qilingan. Ushbu algoritmlar kasalliklarni erta aniqlash, genetik ifodalanishni tahlil qilish, dori vositalarini yaratish, tibbiy tasvirlarni tahlil qilish va davolash samaradorligini baholash kabi turli tibbiy sohalarda samarali qo‘llanilishi mumkin.

Shu bilan birga, maqolada keltirilgan algoritmlardan foydalangan holda, aniq kasalliklar turini farqlash va tashxis aniqligini oshirish maqsadlariga yo‘naltirilgan dasturiy vositalarni yaratish bo‘yicha tavsiyalar berilgan. Ushbu tadqiqot sun’iy immun tizimlari algoritmlarining tibbiyotda keng qo‘llanilishi va kelajakda ularning rivojlanishi uchun yangi imkoniyatlar ochishini ta’kidlab, tibbiyot sohasida innovatsion yondashuvlarni qo‘llashga turtki bo‘ladi.

Foydalanilgan adabiyotlar

1. Dasgupta, D (1998b). An overview of artificial immune systems. Artificial Immune Systems and Their Applications. pp. 3–19. Springer, Berlin, Heidelberg, New York
2. S.Hofmeyr, S.Forrest. (2000). Architecture for an Artificial Immune System. Evolutionary computation. 8. 443-73. 10.1162/106365600568257.
3. Клычева, Ф. (2024). Применение интеллектуальных технологий в диагностике сердечно-сосудистых заболеваний. - Scientific Collection «InterConf», (187). – С. 356–359.
4. Клычева, Ф., Мухаммедиева, Д., & Эшбоев, Э. (2024). Применение искусственных иммунных систем в задачах медицинской диагностики. - Научный сборник «ИнтерКонф», (196). – С.380-384.
5. Клычева, Ф. Г., Эшбоев, Э. А., & Равшанов, Д. Г. (2022). Реализация прогнозирования сердечно-сосудистых заболеваний с использованием признаков и линейной регрессии. Universum: технические науки, (8-1 (101)). – С.14-17.
6. Klicheva F.G., Eshboyev E.A. (2023) Creation of an intelligent system to support medical diagnosis. Innovative technologica -methodical research journal. Volume 4, Issue 5 May 2023, 82-87.
7. Klicheva F. 2023. Chumoli algoritmini yurak-qon tomir kasalliklariga tashxis qo‘yishga tatbiq etish. DIGITAL TRANSFORMATION AND ARTIFICIAL INTELLIGENCE. 1, 4 (Dec. 2023), 156–159.
8. Eshboyev E., Klicheva F. (2022) Yuqori qon bosimiga ega bo‘lgan shaxslarning intellektual tahlilini amalga oshirish. // “Fan va jamiyat” jurnali. Ajiniyoz nomidagi NDPI. – 2022. – №. 3. – C. 122-123.
9. Klicheva, F. and Eshboyev, E. 2024. Tibbiy tashxis qilish masalalari uchun chumoli algoritmini qo‘llash modeli: Tibbiy tashxis qilish masalalari uchun chumoli algoritmini qo‘llash modeli. MODERN PROBLEMS AND PROSPECTS OF APPLIED MATHEMATICS. 1, 01 (Jun. 2024).
10. Klicheva, F. G., & Eshboyev, E. A. (2024). Joint use of AI methods in the diagnosis of cardiovascular diseases. In Artificial Intelligence and Information Technologies (pp. 251-256). CRC Press.

BIR O‘LCHOVLI G‘OVAK-ELASTIKLIK TENGLAMASI UCHUN BIRINCHI DARBU MASALASI

Yangiboyev Zoyir
Qarshi davlat universiteti, dotsent
Ruzimurodova Ra’no
Qarshi davlat universiteti, magistr
Umarov Ibrohim
Shahrisabz davlat pedagogika instituti, o‘qituvchi
zoyiry@mail.ru
0000-0002-5970-6468
UDK 517.95

Annotasiya. Xotirali ikkinchi tartibli giperbolik tenglamalar uchun birinchi Darbu masalasi o‘rganilib, bu masalani yechish imkoniyati ko‘rib chiqiladi. Ushbu masalaning global yechimlari mavjudligi haqidagi masala parametrning chiziqli bo‘lmagan hadi oldidagi belgisiga va uning nochiziqlilik darajasiga qarab ko‘rib chiqiladi. Ushbu masalaning yechimi uchun apriori baholar olinadi. Masalaning yechilishini nochiziqli 2-tur Volterra integral tenglamasiga ekvivalent reduksiyasi olingan. Darbu masalasining kuchli umumlashgan funksiyalar sinfida yechish mumkinligi shartlari olindi. Qo‘yilgan masala chiziqli operatorli tenglamaga keltirilib, funksional analiz usullari yordamida yechimga ega ekanligi va bu yechim kuchli umumlashgan funksiyalar sinfiga tegishliligi isbotlandi.

Kalit so‘zlar. Darbu masalasi, nochiziqli, aprior baho, global yechim, Volterra tenglamasi, giperbolik tenglama, umumlashgan yechim.

Abstract. The first Darboux problem for second-order hyperbolic integro-differential equations with power-law nonlinearity is studied. The question of the existence of global solutions to this problem is considered depending on the sign of the parameter in front of the nonlinear term and the degree of its nonlinearity. A priori estimates for the solution of this problem are obtained. An equivalent reduction of the solution to the problem to the nonlinear integral Volterra equation of the 2nd kind is obtained. Conditions for the solvability of the Darboux problem in the class of strongly generalized functions are obtained. It is proven that this problem has a solution using functional analysis methods and this solution belongs to the class of highly generalized functions.

Key words. Darbou's problem, nonlinearity, a priori estimate, global solution, Volterra equation, hyperbolic equation, generalized solution.

Kirish. 1. Masalaning qo‘yilishi. O‘zaro bog‘liq bo‘lmagan x va t o‘zgaruvchilar tekisligida xotirali chiziqli giperbolik

$$Lu := u_{tt} - u_{xx} + (\ln\sigma)'(x)u_x - b(x,t)\frac{\rho_l(x)}{\rho_s(x)}u -$$
$$-b^2(x,t)\frac{\rho_l(x)}{\rho_s(x)}\int_0^t e^{-\int_s^t b(x,y)dy} b(x,s)u(x,s)ds = f(x,t). \qquad (1)$$

tenglamani qaraylik.

Bunda u funksiya $\rho_s(x)$ porsial zichlikli g‘ovak-elastikli jismning zarrachalar bo‘lagining aralashish tezlik vektorining qidirilayotgan komponentasi, $\sigma(x) = \sqrt{\mu(x)\rho_s(x)}$ $\mu(x)$, $b(x,t)$- musbat funksiyalar, $f(x,t)$ -berilgan funksiya. $\rho_l(x)$ porsial zichlikli suyuqlik tezligining υ kompanentasi u funksiya bilan

$$\upsilon(x,t) = \int_0^t e^{-\int_s^t b(x,y)dy} b(x,s)u(x,s)ds.$$

munosabat orqali bog‘langan.

(1) tenglama g‘ovak-elastiklik nazariyasida paydo bo‘ladi. [8].

$\Gamma_{1,T} : x = t, 0 \le t \le T$ xarakteristik kesma bilan, shuningdek, $\Gamma_{2,T} : x = 0, 0 \le t \le T$ va $\Gamma_{3,T} : x = T, 0 \le t \le T$ kesmalar bilan chegaralangan uchburchakli sohani

$$D_T := \{(x,t): 0 < x < t, 0 < t < T\},\ T \le \infty$$

deb belgilaymiz.

(1) tenglama uchun D_T sohada bu integro-differensial tenglamani

$$u\big|_{\Gamma_{i,T}} = 0,\ i = 1,2 \qquad (2)$$

chegaraviy shart bo‘yicha $u(x,t)$ yechimini aniqlash haqidagi Darbuning birinchi masalasini qaraymiz (qarang., masalan, [8]).

Tadqiqot metodologiyasi. Ikkinchi tartibli xotirali giperbolik tenglama uchun Darbuning birinchi masalasi tekshiriladi. Qo‘yilgan masalaning yechilishi haqidagi savol muhokama qilinadi. Masalani yechishda differensial tenglamalarni yechish hamda funksional analiz usullaridan foydalanib qo‘yilgan masalaning yechilishi haqidagi savollarga javob olindi.

Ta’rif 1. Aytaylik, $[0,T]$ segmentda $\rho_s(x)$, $\mu(x)$ funksiyalar bir marta uzluksiz differensiallanuvchi funksiya, $\rho_l(z)$ uzluksiz funksiya, $b(x,t) \in C(\bar{D}_T)$, $f(x,t) \in C(\bar{D}_T)$ bo‘lsin. Agar $u \in C(\bar{D}_T)$ va shunday $u_n \in \tilde{C}^2(\bar{D}_T, S_T)$ funksiyalar ketma-ketligi topiladiki, $n \to \infty$ da $C(\bar{D}_T)$ fazoda $u_n \to u$ va $Lu_n \to f$ bo‘lsa, bunda

$$\tilde{C}^2(\bar{D}_T, S_T) := \{u \in C^2(D_T): u\big|_{S_T} = 0\},\ S_T := \Gamma_{1,T} \cup \Gamma_{2,T}$$

$u(x,t)$ funksiya (1), (2) masalaning D_T sohada C sinfdagi kuchli umumlashgan yechimi deyiladi.

2. G‘ovak-elastiklik tenglamasi uchun Darbu masalasining ikkinchi tur Volterra integral tenglamasiga ekvivalentlik reduksiyasi

Aytaylik, $P := P(x,t)$ nuqta D_T sohadagi ixtiyoriy nuqta bo‘lsin. $D_{x,t}$ orqali uchlari $O := O(0,0)$, P nuqtada, shuningdek, mos ravishda berilgan $\Gamma_{2,T}$ va $\Gamma_{1,T}$ to‘g‘ri chiziqlarning tashuvchisida yotuvchi P_1 va P_3 nuqtalarda bo‘lgan to‘rtburchakni belgilaymiz, bunda

$$P_1 := P_1(0, t-x),\quad P_3 := P_3((x+t)/2, (x+t)/2).$$

Ma’lumki, $D_{x,t}$ soha $D_{1x,t} := PP_1P_2P_3$ xarakteristik to‘g‘ri to‘rtburchak va $D_{2x,t} := OP_1P_2$ uchburchakdan tuzilgan, bunda $P_2 := P_2((t-x)/2, (t-x)/2)$.

Faraz qilaylik, $[0,T]$ segmentda $\rho_s(z)$, $\mu(x)$ funksiyalar uch marta uzluksiz differensiallanuvchi, $\rho_l(x)$ funksiya bir marta uzluksiz differensiallanuvchi va $b(x,t) \in C^1(\bar{D}_T)$ bo‘lsin.

Eslatma. Ma’lumki, (1), (2) masalaning koeffitsiyentlari uchun yuqoridagi shartlar bajarilganda $G(x',t';x,t)$ Grin-Adamar funksiyasi korrekt aniqlanadi. Bu funksiyaning ikkinchi tartibli xususiy hosilasi chegaralangan va bo‘lakli-uzluksiz hamda $t' + x' - t + x = 0$ maxsus ko‘pxillik orqali o‘tishda birinchi tur uzilishga ega bo‘ladi. (qarang., masalan, [8], [9]).

(1), (2) masalaning $C^2(\bar{D}_T)$ sinfdagi $u(x,t)$ klassik yechimi uchun integral

$$u(x,t) - \int\limits_{D_{x,t}} G(x',t';x,t) b^2(x',t') \frac{\rho_l(x')}{\rho_s(x')} \int\limits_0^{t'} e^{-\int_s^{t'} b(x',y)dy} b(x',s) u(x',s) ds dx' dt' =$$

$$= \int\limits_{D_{x,t}} G(x',t';x,t) f(x',t') dx' dt',\quad (x,t) \in \bar{D}_T. \qquad (3)$$

tenglik o‘rinli.

Aytaylik, $u\in C(\bar{D}_T)$ funksiya (3) ikkinchi tur Volterra integral tenglamaning yechimi bo‘lsin. f funksiya $\bar{D}_T$ to‘plamda uzluksiz bo‘lganligidan, $C^2(\bar{D}_T)$ fazo $C(\bar{D}_T)$ fazoda zichligidan, shunday $f_n\in C^2(\bar{D}_T)$ funksiyalar ketma-ketligi mavjudki, $C(\bar{D}_T)$ fazoda $n\to\infty$ da $f_n\to f$ bo‘ladi. Xuddi shunga o‘xshash, $u\in C(\bar{D}_T)$ uchun $\tilde{u}_n\in C^2(\bar{D}_T)$ funksiyalar ketma-ketligi mavjudki, $C(\bar{D}_T)$ fazoda $n\to\infty$ da $\tilde{u}_n\to u$ bo‘ladi.

u_n funksiyani quyidagi

$$u_n := M_1\tilde{u}_n + M_2 f_n,\ \ n=1,2,... \qquad (4)$$

ko‘rinishda yozib olamiz.

Bu yerda M_1 va M_2-ushbu

$$M_1 u := \int\limits_{D_{x,t}} G(x',t';x,t)b^2(x',t')\frac{\rho_l(x')}{\rho_s(x')}\int\limits_0^{t'} e^{-\int_s^{t'} b(x',y)dy} b(x',s)u(x',s)ds dx'dt',$$

$$M_2 u := \int\limits_{D_{x,t}} G(x',t';x,t)b^2(x',t')u(x',t')dx'dt', \qquad (x,t)\in D_T.$$

formulalar bilan aniqlanadigan chiziqli operator.

$\tilde{u}_n\in \tilde{C}^2(\bar{D}_T,S_T)$ ekanligini osongina ko‘rish mumkin, M_1, M_2 operatorlar $C(\bar{D}_T)$ fazoda aniqlangan chiziqli uzluksiz operatorlar, ular uchun

$$\lim_{n\to\infty}\|\tilde{u}_n-u\|_{C(\bar{D}_T)}=0,\ \ \lim_{n\to\infty}\|f_n-f\|_{C(\bar{D}_T)}=0,$$

va $C(\bar{D}_T)$ fazoda $n\to\infty$ da

$$u_n\to M_1 u + M_2 f,$$

munosabat o‘rinli. (4) tenglikdan $M_1u+M_2f=u$ bo‘lishi kelib chiqadi. Shunday qilib quyidagi lemma isbotlandi.

Natijalar va muhokama. Qo‘yilgan masalani o‘rganish jaroyonida quyidagi natijalarga kelindi.

Lemma 1. $u\in C(\bar{D}_T)$ funksiya (1), (2) masalaning D_T sohadagi C sinfdagi kuchli umumlashgan yechimi bo‘lishi uchun u (3) nochiziqli integral tenglamaning uzluksiz yechimi bo‘lishi zarur va yetarli.

(3) tenglamaning chiziqli va volterrali ekanligiga ko‘ra quyidagi lemmani isbotlash mumkin [9].

Lemma 2. (1), (2) masalaning D_T sohada C sinfdagi kuchli umumlashgan yechimi uchun

$$\|u\|_{C(\bar{D}_T)}\le c\|f\|_{C(\bar{D}_T)} \qquad (5)$$

aprior baho o‘rinli, bu yerda $c(T,\rho_l,\rho_s,\mu,b)$ koeffitsiyent u va f funksiyalarga bog‘liq bo‘lmagan musbat o‘zgarmas.

Isboti. Faraz qilaylik $u-$(1), (2) masalaning D_T sohadagi C sinfga tegishli kuchli umumlashgan yechimi bo‘lsin. U holda ta’rif 1ga ko‘ra shunday $u_n\in\tilde{C}^2(\bar{D}_T,S_T),$ funksiyalar ketma-ketligi mavjudki,

$$\lim_{n\to\infty}\|u_n-u\|_{C(\bar{D}_T)}=0,\quad \lim_{n\to\infty}\|Lu_n-f\|_{C(\bar{D}_T)}=0. \quad (6)$$

munosabatlar o‘rinli. (1) tenglikning ikkala tomoniga $u=u_n$ uchun u_{nt} ni ko‘paytirib

$$D_\tau := \{(x,t)\in D_T : 0<t<\tau,\ 0<\tau\le T\},$$

soha bo‘yicha integrallaymiz. Natijada

$$\frac{1}{2}\int_{D_T}\frac{\partial}{\partial t}\left(\frac{\partial u_n}{\partial t}\right)^2 dxdt-\int_{D_T}\frac{\partial^2 u_n}{\partial x^2}\frac{\partial u_n}{\partial t}dxdt=$$
$$=\int_{D_T}\Bigg(f-(\ln\sigma)'u_{nx}+b\frac{\rho_l}{\rho_s}u_{nt}-b^2\frac{\rho_l}{\rho_s}u_n+$$
$$+b^2\frac{\rho_l}{\rho_s}\int_0^t e^{\int_s^t b(x,y)dy}b(x,s)u_n(x,s)ds\Bigg)\times\frac{\partial u_n}{\partial t}dxdt.$$

tenglikka ega bo‘lamiz.

Faraz qilaylik

$$I_\tau := \bar{D}_\infty \cap t=\tau,\ 0<\tau\le T.$$

bo‘lsin.

U holda $u_n\big|_{S_T}=0$ ekanligini hisobga olgan holda oxirgi tenglikning chap tomonini bo‘laklab integrallab

$$\int_{D_T}\Bigg(f-(\ln\sigma)'u_{nx}+b\frac{\rho_l}{\rho_s}u_{nt}-b^2\frac{\rho_l}{\rho_s}u_n+$$
$$+b^2\frac{\rho_l}{\rho_s}\int_0^t e^{\int_s^t b(x,y)dy}b(x,s)u_n(x,s)ds\Bigg)\times\frac{\partial u_n}{\partial t}dxdt=$$
$$=\int_{\Gamma_{1,T}}\frac{1}{2\nu_t}\left(\left(\frac{\partial u_n}{\partial x}\nu_t-\frac{\partial u_n}{\partial t}\nu_x\right)^2+\left(\frac{\partial u_n}{\partial t}\right)^2(\nu_t^2-\nu_x^2)\right)ds+$$
$$+\frac{1}{2}\int_{I_\tau}\left(\left(\frac{\partial u_n}{\partial t}\right)^2+\left(\frac{\partial u_n}{\partial x}\right)^2\right)dt, \quad (7)$$

tenglikka ega bo‘lamiz. Bu yerda $\nu:=(\nu_x,\nu_t)-\partial D$ ga ichki normalning birlik vektori va $\Gamma_\tau:=\Gamma_T\cap t\le\tau.$ Ushbu

$$\nu_t\frac{\partial}{\partial x}-\nu_x\frac{\partial}{\partial t}$$

operator $\Gamma_{1,T}$ da ichki differensial operator ekanligini hisobga olsak, $u_n\big|_{S_T}=0$ ga ko‘ra

$$\left(\frac{\partial u_n}{\partial x}\nu_t-\frac{\partial u_n}{\partial t}\nu_x\right)\Bigg|_{\Gamma_{1,T}}=0. \quad (8)$$

ega bo‘lamiz.

$\left(\nu_t^2-\nu_x^2\right)\Big|_{\Gamma_{1,T}}=0$ ekanligini qo‘llab, [9], (8) va (7) dan

$$w_n(\tau):=\int_{I_\tau}\left(\left(\frac{\partial u_n}{\partial t}\right)^2+\left(\frac{\partial u_n}{\partial x}\right)^2\right)dx\le$$
$$\le 2\int_{D_T}(f-(\ln\sigma)'u_{nx}+b\frac{\rho_l}{\rho_s}u_{nt}-b^2\frac{\rho_l}{\rho_s}u_n+$$
$$+b^2\frac{\rho_l}{\rho_s}\int_0^t e^{-\int_s^t b(x,y)dy}b(x,s)u_n(x,s)ds)\frac{\partial u_n}{\partial t}dxdt. \quad (9)$$

ega bo‘lamiz.

Bunga ushbu $\varepsilon-$tengsizlikni qo‘llab

$$2fu_{nt}\le\varepsilon(u_{nt})^2+\frac{1}{\varepsilon}f^2,$$

quyidagi

$$w_n(\tau):\leq \varepsilon\int_{D_\tau}\left(\frac{\partial u}{\partial t}\right)^2 dxdt+\|f\|_{D_\tau}^2-2\int_{D_\tau}((\ln\sigma)'u_{nx}-b\frac{\rho_l}{\rho_s}u_{nt}+b^2\frac{\rho_l}{\rho_s}u_n-$$
$$-b^2\frac{\rho_l}{\rho_s}\int_0^t e^{-\int_s^t b(x,y)dy}b(x,s)u_n(x,s)ds)\frac{\partial u_n}{\partial t}dxdt. \quad (10)$$

tengsizlikka ega bo‘lamiz.

Belgilash kiritamiz:

$$A:=\max\left\{\sup_{(x,t)\in\bar{D}_T}|(\ln\sigma)'|,\ \sup_{(x,t)\in\bar{D}_T}\left|b\frac{\rho_l}{\rho_s}\right|,\ \sup_{(x,t)\in\bar{D}_T}\left|b^2\frac{\rho_l}{\rho_s}\right|,\ \sup_{(x,t)\in\bar{D}_T}\left|b^3\frac{\rho_l}{\rho_s}\right|\right\}.$$

Koshi tengsizligiga ko‘ra

$$-2\int_{D_\tau}((\ln\sigma)'u_{nx}-b\frac{\rho_l}{\rho_s}u_{nt}+b^2\frac{\rho_l}{\rho_s}u_n-$$
$$-b^2\frac{\rho_l}{\rho_s}\int_0^t e^{-\int_s^t b(x,y)dy}b(x,s)u_n(x,s)ds)\frac{\partial u_n}{\partial t}dxdt\leq$$
$$\leq A\left[4\int_{D_T}\left(\frac{\partial u_n}{\partial t}\right)^2 dxdt+\int_{D_T}\left(\frac{\partial u_n}{\partial x}\right)^2 dxdt+\int_{D_T}u_n^2dxdt\right]. \quad (11)$$

tengsizlikka kelamiz.

Keyin

$$u_n(x,t)=\int_x^t(\partial u_n(x,\tau)/\partial t)d\tau,\ (x,t)\in\bar{D}_T$$

tenglikda oddiy almashtirishlardan so‘ng

$$\int_{D_\tau}u_n^2dxdt\leq\int_{D_\tau}\left(\frac{\partial u_n}{\partial t}\right)^2 dxdt.$$

bahoga ega bo‘lamiz.

Bundan (9) va (10) ni hisobga olgan holda

$$w_n(\tau):\leq(\varepsilon+\mathrm{A}(\tau^2+4)\int_0^\tau w_n(z)dz+\frac{1}{\varepsilon}\|f\|_{L_2(D_\tau)}^2,\ 0<\tau\leq T.$$

baho kelib chiqadi. Bu tengsizlikdan Gronulla lemmasini hisobga olgan holda

$$w_n(\tau):\leq\frac{1}{\varepsilon}\|f\|_{L_2(D_\tau)}^2\exp[\tau(\varepsilon+\mathrm{A}(\tau^2+4))].$$

baho kelib chiqadi. Bunda $\varepsilon=\tau^{-1}$ deb tanlab

$$w_n(\tau):\leq\tau\|f\|_{L_2(D_\tau)}^2\exp[\tau(\mathrm{A}\tau(\tau^2+4)+1)]. \quad (12)$$

bahoga ega bo‘lamiz.

Agar $(x,t)\in\bar{D}_T$, bo‘lsa, $u_n|_{S_T}=0$ ga ko‘ra quyidagi tenglik

$$u_n(x,t)=u_n(x,t)-u_n(0,t)=\int_0^x\frac{\partial u_n(z,t)}{\partial z}dz,$$

o‘rinli, bundan (12) ga ko‘ra

$$|u_n(x,t)|^2\leq\int_0^x dz\int_0^x\left[\frac{u_n(z,t)}{x}\right]^2dz\leq x\int_{I_t}\left[\frac{u_n(z,t)}{x}\right]^2dz\leq xw_n(t)\leq tw_n(t)\leq$$
$$\leq t^2\|f\|_{L_2(D_t)}^2\exp[(At(t^2+4)+1)]\leq t^2\|f\|_{C(\bar{D}_t)}^2\,\mathrm{mes}D_t\exp[(At(t^2+4)+1)]\leq$$
$$\leq 2^{-1}t^4\|f\|_{C(\bar{D}_t)}^2\exp[(At(t^2+4)+1)],\quad(x,t)\in\bar{D}_t. \quad (13)$$

bahoga ega bo‘lamiz. (13) munosabatdan

$$\|u_n\|_{C(\bar{D}_T)}\leq\sqrt{2^{-1}}T^2\|f\|_{C(\bar{D}_t)}\exp[2^{-1}(AT(T^2+4)+1)],\quad(x,t)\in\bar{D}_T. \quad (14)$$

bo‘lishi kelib chiqadi.

(6) ga ko‘ra, oxirgi tengsizlikdan $n\to\infty$ da limitga o‘tib

$$\|u\|_{C(\bar{D}_T)} \le \sqrt{2^{-1}T^2}\,\|f\|_{C(\bar{D}_t)}\exp[2^{-1}(AT(T^2+4)+1)],\quad (x,t)\in \bar{D}_T. \quad (15)$$

baholashga ega bo‘lamiz.

(15) baholashdan (5) baho kelib chiqadi.

Quyidagi ta’rifni kiritamiz.

Ta’rif 2. Aytaylik, $[0,T]$ segmentda $\rho_s(x)$, $\mu(x)$ koeffitsiyentlar bir marta uzluksiz differensiallanuvchi, $\rho_l(x)$ uzluksiz funksiya va $b(x,t)\in C^1(\bar{D}_T)$ bo‘lsin. Agar ixtiyoriy chekli $T>0$ uchun (1), (2) masala D_T sohada uzluksiz funksiyalar sinfi C da kuchli umumlashgan yechimga ega bo‘lsa, (1), (2) masala uzluksiz funksiyalar sinfi C da global yechiladi, deyiladi.

Xulosa va takliflar.

(4) tenglamani ushbu $u = Au := M(u+f)$ operator ko‘rinishida yozib olamiz. Bunda $A: C(\bar{D}_T)\to C(\bar{D}_T)$ operator uzluksiz va kompakt, chunki $Mu := M_1u + M_2 f$ formula bilan aniqlanadigan $M: C(\bar{D}_T)\to C(\bar{D}_T)$ chiziqli operator chegaralangan va uzluksiz, $M: C(\bar{D}_T)\to C(\bar{D}_T)$ chiziqli operator kompakt hisoblanadi. Shu bilan birga lemma 1 va 2 ga ko‘ra, ixtiyoriy $s\in[0,1]$ parametr va $u = sAu$ operatorli tenglamaning ixtiyoriy $u\in C(\bar{D}_T)$ yechimi uchun

$$\|u\|_{C(\bar{D}_T)} \le c\|f\|_{C(\bar{D}_T)}$$

aprior baho o‘rinli, bunda c - u, f va s larga bog‘liq bo‘lmagan musbat o‘zgarmas son. Shuning uchun Lere-Shauder teoremasiga ko‘ra (4) tenglama lemma 2. ning shartiga ko‘ra hech bo‘lmaganda bitta $u\in C(\bar{D}_T)$ yechimga ega. Shunday qilib lemma 1 dan quyidagi teorema isbotlanadi.

Teorema. (1), (2) masala ta’rif 1. ma’nosida uzluksiz funksiyalar sinfi C da global yechiladi, ya’ni agar $f\in C(\bar{D}_T)$ bo‘lsa, u holda ixtiyoriy $T>0$ uchun (1), (2) masala D_T sohada uzluksiz funksiyalar sinfi C da kuchli umumlashgan yechimga ega bo‘lsa.

O‘rganilgan masalani bir jinsli bo‘lmagan bir o‘lchovli g‘ovak-elastiklik tenglamasi uchun ham keltirish mumkin.

Foydalanilgan adabiyotlar

1. Blokhin A.M., Dorovsky V.N. Mathematical Modelling in the Theory of Multivelocity Continuum. New York: Nova Science Publishers, Inc., 1995.
2. Imomnazarov Kh.Kh. Estimates of conditional stability of some combined inverse problems for Maxwell's equations and equations of porous media //Comp. Appl. Math. 2001. Vol. 20. P.20-34.
3. Имомназаров Х.Х. Численное моделирование некоторых задач теории фильтрации пористых сред. - Сибирский журнал индустриальной математики. 2001.Том. IV, № 2(8). С. 154-165.
4. Имомназаров Х.Х., Холмуродов А.Э. Прямые и обратные задачи динамики для SH-волн в пористых средах. - Вестник Национального университета Узбекистана. Серия механика, математика. 2006. № 2. С. 86-91.
5. Imomnazarov Kh.Kh., Kholmurodov A.E. Direct and inverse dynamic problems for SH-waves in porous media // Mathematical and Computer Modelling.
2007. Vol. 45, No. 3-4. P. 270-280.
6. Жабборов Н.М., Имомназаров Х.Х. Некоторые начально-краевые задачи механики двухскоростных сред.- Издательство Национального университета Узбекистана имени Улугбека, 2012 г.
7. Имомназаров Х.Х., Имомназаров Ш.Х., Рахмонов Т.Т., Янгибаев З.Ш. Регуляризация в обратных динамических задачах для уравнения волн ВГ в пористой среде. - Владикавк. матем. Дж. 2013. Том. 15, № 2. С. 46-58.
8. Джохадзе О.М., Харибегашвили С.С. Первая задача Дарбу для нелинейных гиперболических уравнений второго порядка - Матем. Заметка. 2008. Том. 84, № 5. С. 693-712.

9. Lerner M.E. About qualitative properties of the Riemann function // Differ.Equations. 1991. Vol. 27, Iss. 12. P. 2106-2120.

10. Смирнов М.М. Уравнения смешанного типа. М.: Наука, 1970.

11. Треногин В.А. Функциональный анализ. – Москва, Наука, 1980.

12 Imomnazarov Kh.Kh., Khujaev L.Kh., Yangiboev Z.Sh. On one inverse dynamic problem of poroelasticity for a porous medium. // Математические заметки СВФУ Апрель-июнь, Том 29, № 2, 2022. c.19-30.

13. Imomnazarov Kh.Kh., Khujaev L.Kh., Yangiboev Z.Sh. The inverse problem for a system of poroelasticity equations: the case of an unknown coefficient with a lower term depending on time. // Bulletin of the Institute of Mathematics. Vol. 5, №3, 2022, pp.143-150.

14. Imomnazarov Kh.Kh., Khujaev L.Kh., Yangiboev Z.Sh. The inverse problem for a system of poroelasticity equations: the case with an unknown Darcy time-dependent coefficient. // European Journal of Research 5(7), 2020, pp. 3-17.

IDEAL SUYUQLIKLAR FAZOSIDA QALIN SFERIK QOBIQDAN NOSTATSIONAR TO‘LQIN TARQALISHI

Shukurov A.M.
Qarshi davlat universiteti, профессор
Shukurovamon@yandex.ru
ORCID: 0000-0002-5555-9149
Jabborov A.U.
Qarshi davlat universiteti, докторант
abdullajabborov1709@gmail.com
ORCID: 0009-0005-6197-1366,
UDK: 519.63+539.3

Annotatsiya: Maqolada ideal suyuqliklar fazosida qalin sferik qobiqdan nostatsionar bo‘ylama to‘lqin tarqalishi haqidagi masala o‘rganilgan. Masalaning yechish algoritmi o‘lchovsiz vaqt bo‘yicha Laplas integral almashirishlari va o‘zgaruvchilarni to‘liq bo‘lmagan ajratish usuli yordamida ishlab chiqilgan. Tasvirlar fazosida masala ikki matritsali tenglamalar sistemasini yechishga keltirilgan bo‘lib, bu sistemaning yechimi eksponentalar bo‘yicha cheksiz qatorlar shaklida izlanadi. Qatorlar koeffitsiyentlariga nisbatan rekurrent munosabatlar hamda ular uchun boshlang‘ich shartlar topilgan. Vaqt bo‘yicha Laplas integral almashtirishlarining tasvirlar fazosida qalin sferik qobiq nuqtalarida ko‘chish vektori va kuchlanish tenzori komponentalari hamda ideal suyuqliklarning gidrodinamik xarakteristikalari uchun formulalar olingan. Tasvirdan originalga o‘tish qoldiqlar nazariyasi yordamida amalga oshirilgan. Sonli eksperimentlar o‘tkazilgan. Olingan natijalarni suvosti inshootlarinng mustahkamligini o‘rganish va ularni loyihalashtirishda foydalanish mumkin.

Kalit so‘zlar: nostatsionar to‘lqinlar, sferik qobiq, ideal suyuqlik, Laplas integral almashtirishlari, cheksiz sistema, cheksiz qator, ko‘chish vektori, kuchlanish tenzori.

PROPAGATION OF UNSTATIONARY WAVES FROM A THICK-WALLED SPHERICAL SHELL IN THE SPACE OF AN IDEAL FLUID

Abstract: The article considers the problem of propagation of non-stationary longitudinal waves from a thick-walled spherical shell in the space of ideal fluids. The algorithm for solving the problem is developed using integral Laplace transforms with respect to dimensionless time and the method of incomplete separation of variables. In the image space, the problem is reduced to solving a system of two-matrix equations, the solution of which is sought in the form of infinite series in exponentials. Recurrence relations for the coefficients of the series and initial conditions for them are found. Formulas are obtained for the components of the displacement vector and the stress tensor at points of a thick-walled spherical shell, as well as for the hydrodynamic characteristics of ideal fluids in the image space of integral Laplace transforms with respect to time. The transition from the image to the original was carried out using the theory of residues. Numerical experiments were carried out. The results can be used to study the stability of underwater structures and their design.

Key words: Non-stationary waves, spherical shell, ideal fluid, integral Laplace transform, infinite system, infinite series, displacement vector, stress tensor.

Kirish. Tutash muhitlarda, jumladan, ideal suyuqliklar fazosida nostatsionar to‘lqin tarqalishi va difraksiyasi jarayonlarini matematik modellashtirish va ularning tadqiqoti muhim va ahamiyatli bo‘lib, ular nazariy va amaliy jihatdan to‘lqinlar dinamikasining dolzarb muammolaridan biri hisoblanadi. Muammoning dolzarbligi ularning turli sohalarda dinamik kuchlanishlar ta’sirida ishlovchi yangi konstruksiyalarni yaratish hamda kemasozlik, samolyotsozlik va suvosti inshootlarni loyihalashtirishdagi amaliy masalalarini yechish bilan aniqlanadi.

Hozirgi vaqtda elastik muhitlar va ideal suyuqliklar fazosida nostatsionar to‘lqin tarqalishi va difraksiyasi jarayonlarini o‘rganishga bag‘ishlangan ko‘plab ilmiy tadqiqot ishlari mavjud bo‘lib, masalan, ulardan [1, 3, 5-7] ilmiy maqolalarni keltirish mumkin. Maqola [1] akustik yarimfazo joylashgan sferik bo‘shliqdan nostatsionar tarqalishiga bag‘ishlangan bo‘lib, unda masala yechilishi Laplas almashtirishlarining tasvirlar fazosida cheksiz chiziqli algebraik tenglamalar sistemasini yechishga keltirilgan hamda akustik muhit xarakteristikalari uchun formulalar olingan. Sonli tajribalarning natijalari grafiklar ko‘rinishida berilgan. Cheksiz ideal siqiluvchan suyuqlikda joylashgan va boshqa akustik muhit bilan to‘ldirilgan yupqa silindrik qobiqni undagi tebranuvchi sferik jism bilan o‘zaro ta’siri haqidagi masala [3] ilmiy tadqiqot ishida o‘rganilgan. Sfera markazi silindr o‘qida joylashgan. Chegaraviy shartlarni qanoatlantirgandan so‘ng, masala cheksiz algebraik tenglamalari sistemasini yechishga keltirtilgan. Silindrik hajmni to‘ldiruvchi va uni o‘rab turuvchi suyuqliklar uchun gidrodinamik xarakteristikalar uchun ifodalar topilgan. Sferik jism va siqilmaydigan suyuqlik bilan to‘ldirilgan cheksiz silindrning (qattiq jism va yupqa elastik silindrik qobiq) o‘zaro ta’siri haqidagi ichki masalaga [5] maqola bag‘ishlangan va sonli natijalar keltirilgan. [6] ishda siqiluvchan suyuqlikni o‘z ichiga oluvchi qattiq silindrda sferaning tebranishi haqidagi masala qaralgan, [7] maqolada esa yupqa elastik silindrik qobiqni to‘ldiruvchi siqiluvchi suyuqlikda berilgan qonun bo‘yicha sferik jism harakatni aniqlovchi potensialni qurish haqidagi masala o‘rganilgan. Har bir masala uchun alohida yechimlar olingan. Bularda tashqi muhitning mavjudligi e’tiborga olinmagan.

Tadqiqot metodologiyasi. Maqola ideal suyuqliklar fazosida qalin sferik qobiqdan nostatsionar bo‘ylama to‘lqin tarqalishi haqidagi masalani o‘rganishga bag‘ishlangan. Ishning maqsadi ideal suyuqliklar fazosida sferik qobiqdan nostatsionar bo‘ylama to‘lqin tarqalishi jarayonini matematik modellashtirish, yechish algoritmini ishlab chiqish va nostatsionar bo‘ylama to‘lqin tarqalishi jarayonini sonli eksperimentlar asosida tadqiq etishdan iboratdir.

Aytaylik, ideal suyuqliklar fazosida mos ravishda ichki va tashqi radiuslari r_1 va r_2, ($r_1 < r_2$) bo‘lgan qalin sferik qobiq joylashgan bo‘lsin. Qobiq va ideal suyuqliklar harakati boshlang‘ich nuqtasi sferik qobiq markazida bo‘lgan (r, θ, ϑ) sferik koordinatalar sistemasida qaraladi.

Vaqtning $\tau = 0$ boshlang‘ich momentidan boshlab qalin sferik qobiqning ichki sirtiga o‘qsimmetrik normal tekis $p_1(\tau,\theta)$ sirt kuchi ta’sir etadi.

$$\sigma_{rr}\big|_{r=r_1} = p_1(\tau,\theta)\,. \tag{1}$$

Qobiq va ideal suyuqlik o‘rtasidagi kontakt shartlar esa

$$\sigma_{rr}\big|_{r=r_2} = -\eta_0 p_0\big|_{r=r_2}\,, \qquad \left.\frac{\partial w}{\partial \tau}\right|_{r=r_2} = V_0\big|_{r=r_2} \tag{2}$$

ko‘rinishga ega bo‘ladi.

Masalaning o‘qsimmetrikligini e’tiborga olib, qalin sferik qobiq va ideal suyuqliklar muhitining harakati φ_l potensiallarga nisbatan to‘lqin tenglamalari orqali tasvirlanadi ($l = 0,1$; “0” indeks bilan atrof-muhit, “1” indeks bilan esa qobiq belgilangan):

$$\gamma_l^2 \frac{\partial^2 \varphi_l}{\partial \tau^2} = \Delta \varphi_l\,, \tag{3}$$

bu yerda Δ - (r, θ, ϑ) sferik koordinatalar sistemasida Laplas operatori.

Vaqtning $\tau = 0$ boshlang‘ich momentida qobiq va muhit tinch holatda bo‘ladi, ya’ni boshlang‘ich shartlar bir jinslidir

$$\varphi_l\big|_{\tau=0} = \left.\frac{\partial \varphi_l}{\partial \tau}\right|_{\tau=0} = 0\,. \tag{4}$$

Cheksizlikda to‘lqin so‘nadi

$$\lim_{r\to\infty}\varphi_0 = 0 \cdot$$

(5)

Bu holatda Guk qonuni [10]

$$\sigma_{rr} = \frac{\partial w}{\partial r} + 2\kappa\frac{w}{r},\ \sigma_{\theta\theta} = \kappa\sigma_{rr} + (1-\kappa)(1+2\kappa)\frac{w}{r}$$

(6)

ko‘rinishda bo‘ladi. Tezlik φ_0 potensiali tashqi muhitning xarakteristikalari hamda φ_1 potensialning ko‘chish vektori bilan bog‘lanishi

$$p_0 = -\gamma_0^2\frac{\partial\varphi_0}{\partial\tau}, \qquad V_0 = \frac{\partial\varphi_0}{\partial r}, \qquad w = \frac{\partial\varphi_1}{\partial r}$$

(7)

ko‘rinishga ega.

Ideal suyuqliklar fazosida qalin sferik qobiqdan nostatsionar bo‘ylama to‘lqin tarqalishi jarayoniga mos (1) - (5) boshlang‘ich – chegaraviy masalani yechishda o‘zgaruvchilarni to‘liq bo‘lmagan ajratish va vaqt bo‘yicha Laplas integral almashtirishlari foydalaniladi. Tasvirlar fazosida φ_l^L potensiallarni, ko‘chish vektorining w^L komponentasini va kuchlanish tenzorining σ_{rr}^L komponentasini hamda berilgan $p_1(\tau,\theta)$ funksiyani Lejandr $P_n(\cos\theta)$ ko‘phadlari [2, 8] bo‘yicha cheksiz qatorlar ko‘rinishida tasvirlab, ularni (1) - (5) boshlang‘ich – chegaraviy masalaga qo‘ygandan so‘ng qatorlar koeffitsiyentlariga nisbatan

$$\gamma_l^2 s^2\varphi_{l,n}^L = \Delta_n\varphi_{l,n}^L,\ \Delta_n = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) - \frac{n(n+1)}{r^2},$$

(8)

$$\sigma_{rrn}^L\Big|_{r=r_1} = p_{1n}^L(s),$$

(9)

$$\sigma_{rrn}^L\Big|_{r=r_2} = -\eta_0 p_{0n}^L\Big|_{r=r_2},\ sw_n^L\Big|_{r=r_2} = V_{0n}^L\Big|_{r=r_2}, \qquad (10)$$

$$\lim_{r\to\infty}\varphi_{0n}^L = 0 \cdot$$

(11)

masalaning qo‘yilishi kelib chiqadi.

(8) tenglamada $l = 1$ bo‘lganda uning yechimini

$$\varphi_{1n}^L(r,s) = \frac{1}{r^{n+1}(\gamma_1 s)^n}\left[R_{n0}(r\gamma_1 s)A_n^L(s)e^{-r\gamma_1 s} + (-1)^n G_{n0}(r\gamma_1 s)B_n^L(s)\right]$$

(12)

ko‘rinishda izlaymiz, bu yerda $A_n^L(s)$ va $B_n^L(s)$ - Laplas almashtirishlari s parametrining noma’lum funksiyalari.

(7) dagi φ_1 potensialning ko‘chish vektori bilan bog‘lanishiga ko‘ra $w_n^L(r,s)$ koeffitsiyent uchun

$$w_n^L(r,s) = -\frac{1}{r^{n+2}(\gamma_1 s)^n}[R_{n1}(r\gamma_1 s)A_n^L(s)e^{-r\gamma_1 s} + (-1)^n G_{n1}(r\gamma_1 s)B_n^L(s)]$$

(13)

ifoda kelib chiqadi.

(6) Guk qonuni va (13) ifodadan $\sigma_{rrn}^L(r,s)$ koeffitsiyent uchun esa

$$\sigma_{rrn}^L(r,s) = \frac{1}{r^{n+3}(\gamma_1 s)^n}[Q_{n1}(r\gamma_1 s)A_n^L(s)e^{-r\gamma_1 s} + (-1)^n J_{n1}(r\gamma_1 s)B_n^L(s)] \quad (14)$$

ifodani olamiz. Bu yerda

$$G_{ni}(s)=R_{ni}(-s)e^{s}-R_{ni}(s)e^{-s},\ (i=1;2),\ R_{n0}(s)=\sum_{k=0}^{n}\alpha_{nk}s^{n-k},$$

$$J_{n1}(s)=Q_{n1}(-s)e^{s}-Q_{n1}(s)e^{-s},\ Q_{n1}(s)=R_{n2}(s)-2\kappa R_{n1}(s),$$

$$R_{n1}(s)=\sum_{k=0}^{n+1}\beta_{nk}s^{n+1-k},\ \alpha_{nk}=(n+k)!/(n-k)!/2^{k},\ \alpha_{nk}=0,\ k<0,\ k>n,$$

$$R_{n2}(s)=\sum_{k=0}^{n+2}\xi_{nk}s^{n+2-k},\ \beta_{nk}=\alpha_{nk}+k\alpha_{n,k-1},\ \xi_{nk}=\beta_{nk}+k\beta_{n,k-1}.$$

(14) ifodani (1) chegaraviy shartga qo‘yib, tasvirlar fazosida $A_n^L(s)$ va $B_n^L(s)$ noma’lum funksiyalarga nisbatan cheksiz algebraik tenglamalar sistemasini olamiz va uni matritsali tenglama shaklida yozamiz:

$$\mathbf{MA}y^2+\mathbf{F}_1\mathbf{B}-\mathbf{F}_2\mathbf{B}y^2=\mathbf{p}y,\ y=e^{-r_1\gamma_1 s},$$

(15)

$$\mathbf{A}(s)=\left\|A_0^L(s),A_1^L(s),...\right\|^T,\ \mathbf{B}(s)=\left\|B_0^L(s),B_1^L(s),...\right\|^T.$$

(8) tenglamada $l=1$ bo‘lganda esa uning yechimini (5) shartga ko‘ra

$$\varphi_{0n}^L(r,s)=\frac{1}{r^{n+1}(\gamma_0 s)^n}R_{n0}(r\gamma_0 s)C_n^L(s)e^{-r\gamma_0 s},$$

(16)

ko‘rinishda izlaymiz, bu yerda $C_n^L(s)$- Laplas almashtirishlari s parametrining noma’lum funksiyalari [4].

(7) dagi tezlik φ_0 potensialining tashqi muhitning xarakteristikalari bilan bog‘lanishidan $p_{0n}^L(r,s)$ va $V_{0n}^L(r,s)$ koeffitsiyentlari uchun

$$p_{0n}^L(r,s)=-\frac{\gamma_0^2 s}{r^{n+1}(\gamma_0 s)^n}R_{n0}(r\gamma_0 s)C_n^L(s)e^{-r\gamma_0 s},$$

(17)

$$V_{0n}^L(r,s)=-\frac{1}{r^{n+2}(\gamma_0 s)^n}R_{n1}(r\gamma_0 s)C_n^L(s)e^{-r\gamma_0 s}.$$

(18)

ifodalar kelib chiqadi.

Keyin (13) (14), (17) va (18) ifodalarni (2) chegaraviy shartlarga qo‘yib, hosil bo‘lgan tengliklardan $C_n^L(s)$ noma’lumni yo‘qotgandan so‘ng, $A_n^L(s)$, $B_n^L(s)$ noma’lum funksiyalarga nisbatan tashqi muhitning xarakteristikalari uchun

$$p_{0n}^L(r,s)=-\frac{R_{n0}(r\gamma_0 s)e^{-r\gamma_0 s}e^{R_2\gamma_0 s}}{r^{n+1}(\gamma_1 s)^n R_2^2 R_{n0}(R_2\gamma_0 s)}\Big[R_{n1}(r_2\gamma_1 s)A_n^L(s)+$$
$$+(-1)^n G_{n1}(r_2\gamma_1 s)B_n^L(s)\Big], \qquad (19)$$

$$V_{0n}^L(r,s)=-\frac{R_{n1}(r\gamma_0 s)e^{-r\gamma_0 s}e^{R_2\gamma_0 s}}{r^{n+2}(\gamma_1 s)^n R_{n1}(R_2\gamma_0 s)}\Big[Q_{n1}(r_2\gamma_1 s)A_n^L(s)+$$
$$+(-1)^n J_{n1}(r_2\gamma_1 s)B_n^L(s)\Big], \qquad (20)$$

ifodalar kelib chiqadi hamda tasvirlar fazosida $A_n^L(s)$ va $B_n^L(s)$ noma’lum funksiyalarga nisbatan ikkinchi cheksiz algebraik tenglamalar sistemasini olamiz va uni matritsali tenglama shaklida yozamiz:

$$\mathbf{NA}x^2+\mathbf{T}_1\mathbf{B}-\mathbf{T}_2\mathbf{B}x^2=0, \qquad x=e^{-R_2\gamma_1 s}$$

(21)

Hosil bo‘lgan (15) va (21) matritsali tenglamalarning yechimini eksponentalar bo‘yicha cheksiz qatorlar ko‘rinishida

$$\mathbf{A}=\sum_{ij=0}^{\infty}\mathbf{a}_{ij}(s)x^{i}y^{-j-1},\qquad \mathbf{B}=\sum_{ij=0}^{\infty}\mathbf{b}_{ij}(s)x^{i}y^{-j-1}$$

(22)

izlaymiz.

Bu cheksiz qatorlarning koeffitsiyentlari quyidagi rekurrent munosabatlardan

$$a_{i,j}^{(n)}(s)=\frac{F_{2n}(s)}{M_n(s)}b_{i,j}^{(n)}(s)-\frac{F_{1n}(s)}{M_n(s)}b_{i,j-2}^{(n)}(s),\ i\ge 0,\ j\ge 2;$$

$$b_{i,j}^{(n)}(s)=\frac{T_{2n}(s)}{T_{1n}(s)}b_{i-2,j}^{(n)}(s)-\frac{N_n(s)}{T_{1n}(s)}a_{i-2,j}^{(n)}(s),\ i\ge 2,\ j\ge 0;$$

$$a_{i,0}^{(n)}(s)=\frac{F_{2n}(s)}{M_n(s)}b_{i,0}^{(n)}(s),\ i\ge 1;\ a_{i,1}^{(n)}(s)=\frac{F_{2n}(s)}{M_n(s)}b_{i,1}^{(n)}(s),\ i\ge 0;$$

$$a_{0,0}^{(n)}(s)=\frac{p_n(s)}{M_n(s)},\ a_{0j}^{(n)}(s)=0,\ j\ge 1;\ b_{0j}^{(n)}(s)=0,\ b_{1j}^{(n)}(s)=0,\ j\ge 0;\ n\ge 0$$

aniqlanadi. Bu rekurrent munosabatlar

(13) (14), (17) va (18) ifodalarga (22) qatorlarni qo'yib, tasvirlar fazosida elastik qobiq kuchlanish deformatsiya holati xarakteristikalari hamda ideal suyuqliklar muhitdagi bosim qatorlarining koeffitsiyentlari uchun

$$w_n^L(r,s)=-\frac{1}{r^{n+2}(\gamma_1 s)^n}D_{n1}(r\gamma_1 s),\ \sigma_{rrn}^L(r,s)=\frac{1}{r^{n+3}(\gamma_1 s)^n}W_{n1}(r\gamma_1 s),$$

$$p_{0n}^L(r,s)=-\frac{R_{n0}(r\gamma_0 s)e^{-r\gamma_0 s}e^{R_2\gamma_0 s}}{r^{n+1}(\gamma_1 s)^n R_2^2 R_{n0}(R_2\gamma_0 s)}D_{n1}(R_2\gamma_1 s),$$

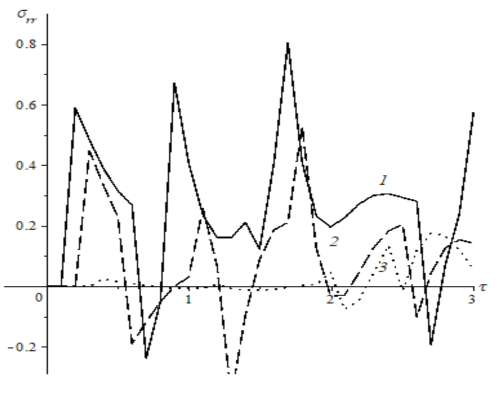
$$V_{0n}^L(r,s)=-\frac{R_{n1}(r\gamma_0 s)e^{-r\gamma_0 s}e^{R_2\gamma_0 s}}{r^{n+2}(\gamma_1 s)^n R_{n1}(R_2\gamma_0 s)}W_{n1}(R_2\gamma_1 s),$$

$$D_{n1}(t)=\sum_{ij=0}^{\infty}\left[R_{n1}(t)a_{ij}^{(n)}(s)e^{-t}+(-1)^n G_{n1}(t)b_{ij}^{(n)}(s)\right]x^i y^{-j-1},$$

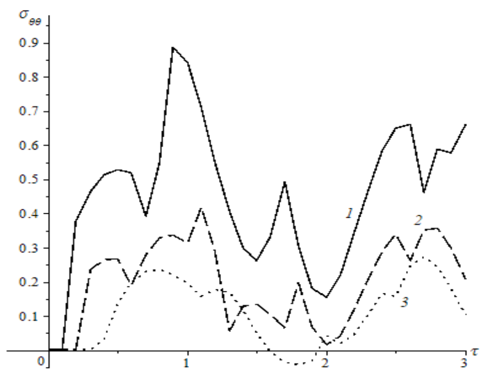
$$W_{n1}(t)=\sum_{ij=0}^{\infty}\left[Q_{n1}(t)a_{ij}^{(n)}(s)e^{-t}+(-1)^n J_{n1}(t)b_{ij}^{(n)}(s)\right]x^i y^{-j-1}$$

formulalarni olamiz. Ularning originallari qoldiqlar nazariyasi yordamida aniqlanadi [4, 9].

Natijalar va muhokama. Sonli eksperimentlar grafik shaklda keltirilgan. Sferik qobiqda va atrof-muhitda nostatsionar to'lqin jarayonlarini tadqiq etish uchun suv ($c_0=1500\,m/s$, $\rho_0=1000\,kg/m^3$) fazosida ichki va tashqi radiuslari mos ravishda $r_1=1$, $r_2=2.5$ bo'lgan sferik po'lat ($E_1=20.104\cdot 10^4$ MPa, $\nu_1=0.3$, $\rho_1=7800\,\mathrm{kg/m^3}$) qobiqni nostatsionar tebranishi natijasida to'lqin tarqalishi qaralgan. Bunga $\gamma_0=1$, $\gamma_1=0.255$, $\eta_0=0.01164$, $\kappa=0.43$ qiymatli o'lchovsiz parametrlar mos keladi. Sferik qobiq ichki sirtiga ta'sir etuvchi tekis taqsimlangan sirt kuch sifatida θ burchakka bog'liq bo'lmagan $p_1(\tau,\Theta)=p_0H(\tau)$, $p_0=1$ Xevisayd birlik funksiyasi olingan.



1-rasm.

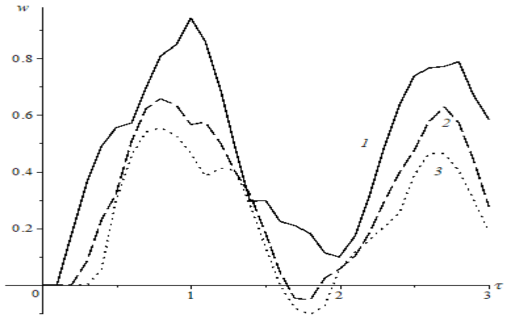


2-rasm.

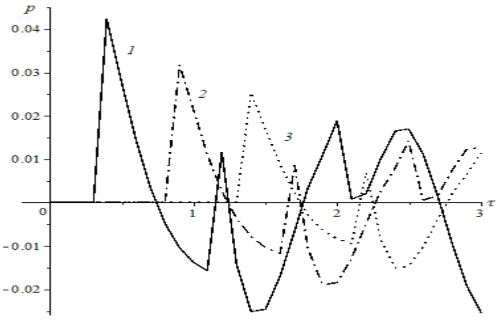
Demak, sonli eksperiment natijalari θ burchakka bog‘liq bo‘lmaydi.

Sonli natijalarda Lejandr ko‘phadlari [11] bo‘yicha yetti hadning yig‘indisi olingan bo‘lib, ular qobiqda kuchlanish tenzori σ_{rr}, $\sigma_{\theta\theta}$ va ko‘chish vektori w komponentalari hamda suvdagi bosimning τ vaqt bo‘yicha o‘zgarishining grafiklari 1-4 rasmlarda berilgan.

Bunda qobiqning kuchlanish-deformatsiya holati xarakteristikalarining 1-3 rasmlardagi 1, 2 va 3 raqamli grafiklari mos ravishda r ning 1.5, 2.0, 2.5 qiymatlarida olingan. 4-rasmdagi bosim o‘zgarishi egri chiziqlari esa r ning mos ravishda 2.5, 3.0, 3.5 qiymatlari uchun qurilgan. Sonli eksperiment grafiklari ko‘rsatadiki, to‘lqin va qaytuvchi to‘lqin kelishi bilan sakrashlar paydo bo‘ladi va r masofaning oshishi bilan ularning pasayishi kuzatiladi.



3-rasm.



4-rasm.

Xulosa. Ideal suyuqliklar fazosida qalin sferik qobiqdan nostatsionar to‘lqin tarqalishi masalasining yechim uchun samarali yechish algoritmi ishlab chiqilgan. Laplas integral almashtirishlarining tasvirlar fazosida masala cheksiz algebraik matritsali tenglamalar sistemasini yechishga keltirilib, uning yechimi cheksiz qatorlar shaklida izlanishi rekurrent munosabatlar va ular uchun boshlang‘ich shartlarga olib keladi. Bosim va kuchlanish komponentalarining vaqt bo‘yicha o‘zgarishining sonli eksperiment natijalari ko‘rsatadiki, suyuqlik bilan qalin sferik qobiq chegarasidan qaytuvchi to‘lqinlar atrof-muhitning gidrodinamik va qobiqning kuchlanish deformatsiya holatiga ta’sir etadi. Olingan natijalardan dinamik kuchlanishlar ta’sirida ishlovchi yangi konstruksiyalarni yaratishda va suvosti inshootlarni loyihalashtirishda foydalanish mumkin.

Foydalanilgan adabiyotlar

1. Gorshkov A.G., Tarlakovskiy D.V., Shukurov A.M. Rasprostraneniye voln ot sfericheskoy polosti v akusticheskom poluprostranstve // Prikladnaya matematika i mexanika. - 1991. T. 55. (1. –S. 172-174.

2. Gradshteyn I.S., Rijik I.M. Tablitsi integralov, summ, ryadov i proizvedeniy. – M.: Fiz.-matgiz, 1962. – 1108 s.

3. Дзюба В.В., Кубенко В.Д. Внутренняя осесимметричная задача о взаимодействии тонкой упругой цилиндрической оболочки, заполненной сжимаемой жидкостю и погруженной в безграничную сжимаемую жидкост, с оссиллируюшей сферой//Акустический вестник, 2002. Том 5, Н 2. С. 33 – 42.

4. Деч Г. Руководство к практическому применению преобразования Лапласа и З – преобразования. – М.: Наука, 1971. – 288 с.

5. Кубенко В. Д., Крук Л. А. Обтекание сферического тела пульсируюшим потоком жидкости в бесконечном цилиндре // Прикладная механика.– 1999.– 35, Н 6.–С. 27–31.

6. Кубенко В. Д., Дзюба В. В. Акустическое поле в жестком цилиндрическом сосуде при возбуждении колеблюшейся по заданному закону сферой // Прикладная механика.– 2000.– 36, Н 6.– С. 88–98.

7. Кубенко В. Д., Дзюба В. В. Взаимодействие тонкой упругой цилиндрической оболочки с колеблюшейся сферой. Внутренняя осесимметричная задача // Прикладная механика.– 2001.– 37, Н 2.– С. 87–95.

8. Кузнетсов Д.С. Спетсиалние функсии. – М.: Висшая школа, 1985. – 423 с.

9. Лаврентев М.А., Шабат Б.В. Методи теории функсии комплексного переменного. – М.: Наука, 1987. – 688 с.

10. Седов Л.И. Механика сплошной среди: В 2-х т. – Изд. 4-ое, испр. и доп. – М.: Наука, 1984.

11. Справочник по спетсиалним функциям с формулами, графиками и таблицами // Под ред. М.Абрамовитса, И.Стиган. – М.: Наука, 1979. – 832 с.

CHALA MAYDONLAR VA FROBENIUS GRUPPALARI

Saidov Sardor Soxib oʻgli
Qarshi davlat universiteti, oʻqituvchi
saidovsardor4199@gmail.com
ORCID 0009-0009-9452-7711,
Raufov Humoyun
Toshkent davlat transport unversiteti, oʻqituvchi
ORCID 0009-0002-1682-0858.
UDK 512.747

Annotatsiya. Ushbu maqolada zamonaviy algebraik sistemalardan birining hosil qilinishi va uning ikki karra tranzitiv Frobenius gruppalari bilan strukturaviy bogʻliqligi oʻrganiladi. Frobenius gruppasi, oʻz navbatida, chekli gruppalarning tuzilishini tushunishda, ayniqsa, ularni hosil qiluvchi normal qism gruppalari shakllanishi xatti-harakati kontekstida asosiy rol oʻynaydi. Frobenius guruhining deyarli Galua halqalari bilan oʻzaro taʼsir qilish usullari oʻrganilib, ularning munosabatlar strukturasi va turli matematik masalalarda qoʻllanilishi ochib beriladi. Zamonaviy algebraik sistemalarni taʼriflash va ularning xossalarini oʻrganish XX asrning ikkinchi yarmida axborot texnologiyalarining rivojlanishi bilan chambarchas bogʻliq. Bunga asosiy sabab qilib axborot texnologiyalarini algoritmik tuzilishida va kodlash ishlarida (kibernetikada) bu algebraik sistemalarning juda katta amaliy tatbiqlari mavjudligini koʻrsatish mumkin. Maqolada hujjatlarni oʻrganish metodidan foydalanilgan boʻlib unda A.V. Vasilyev, D.V. Churikov, I. Ponomarenko va boshqa bir qator hozirgi kunda ancha foal yevropalik olimlarning ishlaridan foydalanilgan. Biz chekli chala maydonning additiv va multiplikativ gruppasining yarim togʻri koʻpaytmasi ikki karra tranzitiv Frobenius gruppasini hosil qilishini isbotlaymiz va bu xulosa maqoladagi asosiy erishilgan natijalardan biri boʻladi.

Kalit soʻzlar: chala halqa, chala maydon, tranzitivlik, Frobenius gruppalari, Dikson algoritmi, Frobenius avtomorfizmi, yarim toʻgʻri koʻpaytma, gruppaning yadrosi, oʻrin almashtirishlar gruppasi.

NEAR-FIELDS AND FROBENIUS GROUPS

Abstract. In this article, we will study the formation of one of the modern algebraic systems and its structural connection with the doubly transitive Frobenius groups plays a key role. Methods of interaction of Frobenius groups with Galois near-rings are studied, the structure of their relations and their application to various mathematical problems revealed. The description of modern algebraic systems and the study of their properties closely related to the development of information technologies in the second half of the 20th century. The main reason for this is that there are very large practical applications of these algebraic systems in the algorithmic structure of information technologies and coding works (cybernetics). The article uses the method of studying documents, in which the works of A. V. Vasilyev, D. V. Churikov, I. Ponomarenko and a number of other European scientists, who are quite active today, are used. We prove that the semirectangular product of the additive and multiplicative group of a finite incomplete field forms a doubly transitive Frobenius group, and this conclusion is one of the main results of the article.

Key words: near-ring, near-field, transitivity, Frobenius groups, Dickson's algorithm, Frobenius automorphism, semi-direct multiplication, kernel of a group, permutations group.

Kirish. Zamonaviy algebraik sistemalardan chala maydon tushunchasi birinchi bor Leonard Dikson tomonidan 1905-yilda taqdim etilgan. Dikson chala maydonlarni chekli maydondan qanday metod yordamida hosil qilishni koʻrsatgan. Keyinchalik bu metod Dikson algoritmi deb ataladi. Chala maydon hosil qilishdan avval biz birinchi navbatda chala halqa tushunchasi bilan tanishib olishimiz lozim.

1-taʼrif. Algebraik sistema $\mathbb{K} = \langle K, +, \circ \rangle$ (oʻng) chala halqa deb nomalanadi, agarda

1. $\mathbb{K}^+ = \langle K, + \rangle -$ gruppa (neytral elementi 0);
2. $\langle K, \circ \rangle -$yarim gruppa;
3. $(x + y) \circ z = x \circ z + y \circ z$ barcha $x, y, z \in \mathbb{K}$.

Chala halqaning asosiy xossalarini (1) va (2) adabiyotlarda koʻrishingiz mumkin. Chala halqaga yorqin misolni quyidagicha keltirishimiz mumkin.

Misol. $G -$ additiv gruppa, lekin Abel gruppasi boʻlishi shart emas va $M(G) = \{f | f: G \to G\} -$ barcha G ni G ga akslantiruvchi funksiyalar toʻplami. $M(G)$ da qoʻshish amali nuqtaviy aniqlangan, yaʼni $f, g \in M(G)$ funksiyalar berilgan boʻlsa, u holda $f+g$ akslantirish uchun $(f+g)(x)=f(x)+g(x)$ ko'rinishda bo'ladi ixtiyoriy$x\in G$. Ko'rinib turibdiki, $\langle M(G),+\rangle-$ gruppa hosil qiladi, u Abel gruppasi bo'ladi, faqat qachonki G Abel gruppasi bo'lsa. Akslantirishlar kompozitsiyasini $M(G)$ da ko'paytirish sifatida olib yuqoridagi chala halqa shartlarini qanoatlantiruvchi algebraik sistemani hosil qilamiz. Haqiqatdan ham 0 - akslantirish G gruppaning ixtiyoriy elementini G gruppaning neytral elementiga akslantiruvchi akslantirishni qabul qilamiz. Additiv gruppasining f elementiga qarama-qarshi elementi sifatida $-f$ akslantirishni olsak, quyidagi tenglik $(-f)(x)=-(f(x))$ ga ko'ra additiv gruppa bo'ladi. $\langle M(G),\circ\rangle-$yarim gruppa ekanligi quyidagi tengliklar yordamida isbotlanadi.

$$((f+g)\circ h)(x)=(f+g)\big(h(x)\big)=f\big(h(x)\big)+g\big(h(x)\big)=$$
$$=(f\circ h)(x)+(g\circ h)(x)$$

Barcha $f,g,h\in M(G)$ akslantirishlar uchun o'rinli.

$M(G)$ to'plamning ko'pgina qism to'plamlari qiziqarli va foydali chala halqalar hosil qiladi. Misol uchun

$f(0)=0$ bo'lgan holatdagi akslantirishlarda.

O'zgarmas akslantirishda, ya'ni guruhning har bir elementini bitta fiksirlangan elementga akslantiradi.

Gruppaning endomorfizmlaridan qo'shish va inkor qilish amallari orqali hosil qilingan akslantirishlar to'plami uchun (endomorfizmlar to'plamining "qo'shimcha yopig'i"). Agar G Abel gruppasi bo'lsa, u holda endomorfizmlar to'plami allaqachon qo'shma yopiq, shuning uchun qo'shma yopiqlik faqat G ning endomorfizmlari to'plamidir va u shunchaki chala halqa emas, balki halqa hosil qiladi.

Agar gruppa boshqa ko'rinishdagi tuzilishga ega bo'lsa, u holda boshqa tuzilishdagi sistemalar paydo bo'ladi, masalan:

- Topologik gruppalar ustidagi uzluksiz akslantirishlar.
- Interpretatsiya amallariga nisbatan birlik elementga ega halqa ustida berilgan ko'phadlar to'plami qo'shish.
- Vektor fazo ustidagi affin akslantirishlarda.

Ixtiyoriy chala halqa yuqoridagi $M(G)$ chala halqaning qism chala halqasiga izomorf bo'ladi. $M(G)$ bu yerda qandaydir G gruppa ustidagi akslantirishlar to'plami.

Mazkur maqolada chala halqa yordamida hosil qilingan yana bir sinf chala maydonlarning ba'zi xossalarini ham sanab o'tamiz. Ammo bir izohni alohida aytib o'tishimiz lozimki, u quyidagicha chala halqa u halqa ham emas, chala maydon ham emas. Eng yaxshi ma'lum bo'lgan planar chala halqalar yordamida muvozanatli to'liq bo'lmagan blok dizaynlari (9). Bular gruppalarning belgilangan nuqtasiz avtomorfizm gruppasi orbitalaridan foydalangan holda farqli oilalarni olishning bir usuli. Jeyms R. Kley va boshqalar tomonidan bu g'oyalar umumiyroq geometrik konstruksiyalarda kengroq holatda yoritib berilgan.(10)

Tadqiqot metodologiyasi. Maqolada yangi algebraik sistemalardan biri bo'lmish Dikson chala maydonining tuzilishi va uning Frobenius gruppalari bilan ustma-ust tushishi isbotlangan.

2-ta'rif. $\mathbb{K}=\langle K,+,\circ\rangle$ chala halqa (o'ng) chala maydon deb ataladi, agarda quyidagi shartlar o'rinli bo'lsa

1. $\mathbb{K}^{\times}=\langle K\backslash\{0\},\circ\rangle-$multiplikativ gruppa bo'lsa;
2. $x\cdot 0=0$ ixtiyoriy $x\in K$.

Chala maydonlarning umumiy nazariyasini (2) va (3) adabiyotlarda topishingiz mumkin.

1936- yida Zassenhaus chekli sondagi istisnolardan tashqari (Zassenhaus chala maydonlari) ixtiyoriy chekli chala maydonni chekli maydondan uning qism maydonidan ma'lum algoritm yordamida (Dikson algoritmi) olish mumkinligini ko'rsatdi.

1-teorema(Zassenhaus). Ixtiyoriy chekli chala maydon quyidagi ikki sinfdan birida yotadi:

1. Dikson chala maydonlari.
2. Zassenhaus chala maydonlari(7 ta istisno chala maydonlar).

Eslatib oʻtamiz, $\mathbb{K}$ chala maydonning eng katta qism chala maydoni uning $Z(\mathbb{K})$ markazi boʻladi.

3-ta'rif.$\mathbb{K}$ chala maydon Dikson chala maydoni deb ataladi, agarda

1. $\mathbb{F}_0$ $q_0 = p^d$ tartibli maydon mavjud boʻlib va uning $m-$chi darajali kengaytmasi $\mathbb{F}$ uchun $\mathbb{F}^+ = \mathbb{K}^+$ va $Z(\mathbb{K}) = \mathbb{F}_0$ shartlar oʻrinli boʻlsa ;
2. Shunday $\sigma: \mathbb{F} \to Aut(\mathbb{F}/\mathbb{F}_0), x \mapsto \sigma_{x,}$ akslantirish mavjud boʻlib $\mathbb{K}$ dagi koʻpaytirish quyidagicha aniqlansa: $y \circ x = y^{\sigma_x} \cdot_{\mathbb{F}} x$, bu yerda $x, y \in \mathbb{K}$ va $\cdot_{\mathbb{F}}$ $-$ $\mathbb{F}$ maydondagi koʻpaytirish amali.

Bunday vaziyatda $\mathbb{K}$ Dikson chala maydoni $\mathbb{F} = F_{p^{dm}}$ maydonga (uning $\mathbb{F}_0 = F_{p^d}$ qism maydoni boʻyicha) bogʻlangan deyiladi.

2-teorema(Xoll-Zassenhaus(3)). p^{dm} tartibli , bu yerda p- tub son, va $q_0 = p^d$ uning sentr boʻlgan Dikson chala maydoni mavjud boʻladi, agar q_0 va m natural sonlar uchun quyidagi shartlar oʻrinli boʻlsa:

1) m sonining barcha tub boʻluvchilari $q_0 - 1$ ning ham boʻluvchisi boʻlsa;

2) Agar 4 soni m ning boʻluvchisi boʻlsa, u holda 4 soni $q_0 - 1$ ning ham boʻluvchisi.

Endi Dikson algoritmi qanday tartibda ishlashini koʻrib olsak. $\alpha -$ $\mathbb{F}$ maydonning tayin birinchi tartibli ildizi boʻlsin. Agar $= \alpha^{km+j} \in \mathbb{F}^\times$, bu yerda $k, m, j -$ butun sonlar. $j -$ daraja koʻrsatkichini m ga boʻlgandagi qoldiq, ya'ni

$$q_0^i \equiv 1 + j(q_0 - 1) \ \ (mod\ m(q_0 - 1)) \qquad (1)$$

i ga nisbatan quyidagicha yechimga ega boʻlamiz (m modul boʻyicha yagona yechimga) faqat va faqat, qachonki (q_0, m) sonlar juftligi 2-teorema shartlarini qanoatlantirsa. Bunday sonlar juftligi Dikson jufligi deb ataladi. $\mathbb{K}$ Dikson chala maydonidagi koʻpaytirish amali quyidagicha:

$$y \circ x = y^{q_0^i} \cdot x \qquad (2)$$

Shu usulda barcha $\mathbb{K}$ Dikson chala maydonlari $\mathbb{F}_{p^{dm}}$ Galua maydonlari va ularning $\mathbb{F}_{p^d}$ qism maydonlaridan kelib chiqqan.

Misol. $\mathbb{F}_\mathbf{0} = F_3 = \{0,1,-1,\}$ va $\mathbb{F}$ $-$uning 2 darajali kengaytmasi:

$\mathbb{F} = F_3[t]/(t^2 + 1) = \{0,1,-1,t,t+1,t-1,-t,-t+1,-t-1\}$.

$\alpha = t + 1$ va $\sigma: \mathbb{F} \to Aut(\mathbb{F}/\mathbb{F}_0)$, $y^\sigma = y^3$ koʻrinishida deb olsak. U holda $\sigma_{\alpha^i} = \sigma$, agarda i toq son boʻlsa, $\sigma_{\alpha^i} = \varepsilon$ $-$ayniy akslantirish koʻrinishida boʻladi agar i juft son boʻlsa.

Yuqoridagilarga koʻra $\alpha \circ \alpha = \alpha^3 \cdot \alpha = -1$ ya'ni $|\alpha| = 4$ va $\alpha^{(-1)} = \alpha^5 = -\alpha$. $\beta = \alpha^2$ deb tanlasak. U holda $\beta \circ \beta = \beta \cdot \beta = -1$ ya'ni $|\beta| = 4$. Keyinchalik esa $\alpha \circ \beta = \alpha \cdot \beta = \alpha^3 = \beta^3 \cdot \alpha^5 = \beta \circ \alpha^{(-1)}$ kabi tengliklarga ega boʻlamiz. Bu tengliklar esa oʻz navbatida $\mathbb{K}^\times$ ni Q_8 ga, ya'ni kvaternionlar gruppasiga izomorf ekanligini koʻrsatadi.

Yuqoridagi misoldan koʻrinib turibdiki, chala maydonning strukturasi birinchi tartibli ildiz α ning tanlanishiga bogʻliq boʻladi, ammo multiplikativ gruppalari bir xil tartibli va sentrlarining ham tartibi bir xil boʻlgan Dikson chala maydonlari oʻzaro izomorf boʻladi.

Natija va muhokama. Avvalo, oʻrin almashtirish gruppalari haqidagi ba'zi bir muhim faktlarni eslab olsak. $G \leq Sym(V) - V$ toʻplam ustidagi oʻrin almashtirishlar gruppasi. Gruppa G m karra tranzitiv deyiladi, agarda ixtiyoriy V^mdan olingan ikkita tartiblangan $u_i \neq u_j$,$v_i \neq v_j$va $i \neq j$ shartlar ostida $(u_1, \dots, u_m)$ va $(v_1, \dots, v_m)$ m-liklar uchun, shunday $g \in G$element topilsaki u ushbu $u_i^g = v_i$ shartni barcha $i = 1, \dots, m$ lar uchun qanoatlantirsin.

V to'plam ustidagi o'rin almashtirshlar gruppa G Frobenius gruppasi deb ataladi agarda:

- G gruppa tranzitiv (1-karra);
- Ixtiyoriy $v \in V$ element uchun G_v stablizatori trivial emas;
- Ixtiyoriy $u, v \in V$ turli elementlar juftligi uchun G_{uv} stablizator faqat birlik elementdan iborat. Boshqacha qilib aytganda, Frobenius gruppasini $G = N \rtimes H$ −uning normal qism gruppasi bo'lgan N va qism gruppa H ma'lum bir elementining stablizatorining yarim to'g'ri ko'paytmasidan iborat. Bu yerda normal qism gruppa N G gruppaning birlik elementlari va V to'plamning birorta elementini o'z o'rnida qoldirmaydigan elementlardan tuzilgan. N qism gruppa Frobenius yadrosi deb ataladi, H esa Frobenius to'ldiruvchisi deyiladi.

Chekli chala maydonlar tushunchasi va o'rin almashtirishlar gruppasi orasidagi bog'liqlikni quyidagi natijalar orqali ko'rsatamiz.

3-teorema. Agar $\mathbb{K}$ −chala maydon bo'lsa, u holda $\mathbb{K}$ to'plam ustidagi o'rin almashtirishlar gruppasi

$$G = \mathbb{K}^+ \rtimes \mathbb{K}^\times = \{x \mapsto x \circ a + b, x \in \mathbb{K} | a \in \mathbb{K}^\times, b \in \mathbb{K}^+\}$$

$\mathbb{K}^+$ yadroga va $\mathbb{K}^\times$ to'ldiruvchiga ega ikki karra tranzitiv Frobenius gruppasi bo'ladi. Va aksincha, agar gruppa $G = N \rtimes H \leq Sym(V)$ −ikki karra tranzitiv Frobenius gruppasi bo'lsa, u holda V maydon ustida $\mathbb{K}$ chala maydon strukturasi yuzaga keladi, bu yerda $\mathbb{K}^+$ gruppa yadrosi N bilan, $\mathbb{K}^\times$ esa gruppa to'ldiruvchisi H bilan ustma-ust tushadi.

Natija. Agar $\mathbb{K}$ −chala maydon va $H \leq \mathbb{K}^\times$ bo'lsa, u holda $G = \mathbb{K}^+ \times H$ −gruppa $\mathbb{K}$ to'plam ustidagi Frobenius gruppasi bo'ladi.

Xulosa. Joriy ishda zamonaviy algebraik sistemalardan biri bo'lmish chala maydonlar tushunchasi haqida ma'lumotlar berilgan. Shuningdek, chekli chala maydonning sinflari qanday strukturaviy tuzilishga ega ekanligi haqida ham aytib o'tilgan. Maqolaning ikkinchi "Chala maydonlar va Frobenius gruppalari" qismida esa chekli chala maydonlarning klassik algebraik sistemalardan bo'lmish Frobenius grupplariga, yana ham aniqroq aytadigan bo'lsak, ikki karra tranzitiv Frobenius gruppalari bilan ustma-ust tushishi ko'rsatilgan. Bunday sistemalarni va ularning xossalarini o'rganishdan asosiy maqsad shuki, ular texnologiyada, moliyaviy jarayonlarni modellashtirishda, axborot xavfsizligi va atrofda sodir bo'layotgan yana bir qator jarayonlarni yanada chuqurroq o'rganishda yordam beradi.

Foydalanilgan adabiyotlar.

1. Pilz G.// Near-Rings: What They Are and What They Are Good For, in Contemp. Math., 9, pp. 9.119. Amer. Math. Soc., Providence, R.I., 1981.https://books.google.com/books?id=b3Plqiy5ZNwC&dq=%22Near-rings%2C+the+Theory+and+its+Applications%22&pg=PP1
2. Lockhart R.// The Theory of Near-Rings. Springer Nature Switzerland AG, 2021. https://books.google.co.uz/books/about/The_Theory_of_Near_Rings.html?id=a3hOEAAAQBAJ&redir_esc=y
3. Krull W.// Algebraische Theorie der zerlegbaren Ringe (Algebraische Theorie der Ringe III), Mathematische Annalen, Vol. 92 (1924), pp. 183-213.https://link.springer.com/article/10.1007/BF01448006
4. J. Bagherian, I. Ponomarenko, A. Rahnamai Barghi.// On cyclotomic schemes over finite near-fields, J. Algebraic Combin., vol. 27 (2008), 171-185. https://arxiv.org/abs/math/0611495v1
5. Чуриков Д.В., Васильев А.В. // Automorphism groups of cyclotomic schemes over finite near-fields, Сиб.элк. мат. изв. Том-13 (2016), 1271-1282.https://www.mathnet.ru/php/archive.phtml?wshow=paper&jrnid=semr&paperid=749&option_lang=rus
6. J. D. Dixon and B. Mortimer //Permutation Groups, Graduate Texts in Mathematics, vol. 163, Springer (1996).https://link.springer.com/book/10.1007/978-1-4612-0731-3
7. M. Hall, Jr. //The theory of groups. The Macmillan Company, New York, N.Y. 1959.https://books.google.co.uz/books/about/The_Theory_of_Groups.html?id=oyxnWF9ssI8C&redir_esc=y

8. H. Zassenhaus // Uber endliche Fastkorper, Abh. Math. Sem. Hamburg, 11 (1936), 18-220.https://www.semanticscholar.org/paper/%C3%9Cber-endliche-Fastk%C3%B6rper-Zassenhaus/68e0721125228cb71e144f5dc7120c83ba8ad618

9. Pilz G. // Nearrings, The theory and it's applications, Amsterdam (1983).https://www.sciencedirect.com/bookseries/north-holland-mathematics-studies/vol/23/suppl/C

10. Clay J. // Nearrings:Genesis and aplications, Oxford(1992).https://books.google.co.uz/books/about/Nearrings.html?id=IqxY_TzTbI8C&redir_esc=y

TABIIY TILNI QAYTA ISHLASHDA O‘ZBEK TILI MATNLARINI IMLO TAHRIRLASH ALGORITMLARI VA DASTURI

Eshqarayeva Narxol G‘uzarovna
Qarshi davlat universiteti dotsent
1970narxol@gmail.com
ORCID 0009-0002-0830-0406
Boymurodov Farrux Farxod o‘g‘li
Qarshi davlat universiteti doktorant
farruxboymurodov96@gmail.com
ORCID 0009-0000-9453-5273
Xujamurotova Mashxura G‘ayrat qizi
TATU Qarshi filiali, asisstent o‘qituvchi
mashxuraxujamurotova@gmail.com
UDK 681.142.33(045)

Annotatsiya: Globalizatsiya va raqamli axborotlashtirish jarayonida o‘zbek tilining rivojida axborot texnologiyalari o‘ta muhim o‘ringa ega. Kompyuter lingvistikasining tabiiy tilni qayta ishlash (Natural Language Processing – NLP) jarayoni va tabiiy tilning kompyuter tushunadigan til (formal) shakli yaratilishi natijasida tilga oid masalalar (tahrir, tahlil, tarjima, elektron matnni ovozlashtirish, og‘zaki nutqni elektron matnga aylantirish, robot bilan muloqot qilish, yirik matnni ixcham matnga aylantirish kabi) bo‘yicha kompyuter dasturlari yaratilmoqda. Ushbu maqolada kompyuter lingvistikasining asosiy yo‘nalishlaridan biri hisoblangan tabiiy tilni qayta ishlash (NLP)da matnlarni Python dasturlash tilida yozilgan UZMORF dasturi va vositalari ko‘rib chiqiladi. Bu dastur o‘zbek tilidagi so‘zlar va ularning imloviy hamda grammatik tahrirlash va qayta ishlash jarayonlarini avtomatlashtirish maqsadida yaratilgan. Tizim matnlar ustida ishlaydi va so‘zlar ustida sintaktik va morfologik tahlillarni amalga oshiradi. Tizim ushbu tahlillar natijasida so‘zlar va ularning grammatik yechimlarini aniqlaydi va xato bo‘lgan joylarni belgilaydi.

Kalit so‘zlar: NLP, imlo tahrir, grammatik tahrir, uzmorf.

ALGORITHMS AND SOFTWARE FOR SPELLING CORRECTION OF UZBEK TEXTS IN NATURAL LANGUAGE PROCESSING

Abstract: In the process of globalization and digital informatization, information technologies play a very important role in the development of the Uzbek language. As a result of the Natural Language Processing (NLP) process of computer linguistics and the creation of a (formal) form of natural language that can be understood by a computer, language-related issues (editing, analysis, translation, voicing electronic text, converting spoken speech into electronic text, communicating with a robot , such as converting large text into compact text) are being created. This article reviews the UZMORF program and tools written in the Python programming language for natural language processing (NLP), which is one of the main areas of computational linguistics. This program was created to automate the editing and processing of Uzbek words and their spelling and grammar. The system works on texts and performs syntactic and morphological analysis on words. As a result of these analyses, the system determines the words and their grammatical solutions and marks the places where there are errors.

Key words: NLP, orthographic correction, grammatical correction, uzmorf.

Kirish. Tabiiy til matni yuqori sifatga ega bo‘lishi uchun matnni qayta ishlashda to‘liq tahlil qilish jarayonlarini amalga oshirish kerak. Biroq bunday tahlilni yaratishda yuzaga keladigan qiyinchiliklar shundan iboratki, amalda hozirgacha ishlab chiqilgan barcha nazariy qoidalar hali amalga oshirilmagan. Bu yerda asosiy muammolar — matnni tahlil qilishning murakkabligi va dunyo tillarining to‘liq modelini amalga oshiradigan tizimni yaratishning murakkabligidir. Matnni tahlil qilish tizimi foydalanuvchi tomonidan kiritilgan matnni sintaksis (jumla tuzilishi), semantika (matnda ishlatiladigan tushunchalar) va pragmatik (tushunchalardan to‘g‘ri foydalanish) nuqtayi nazaridan tahlil qila olishi kerak [2]. Bizning tizim foydalanuvchi tomonidan kiritilgan matnni imloviy xatolarini aniqlash va to‘g‘irlash imkoniyatlariga ega. Bunda tizim natijani xulosa qilishi uchun mos bo‘lgan ichki tasavvurida yaratishi va tabiiy tilda javobini sintez qilishi kerak. Umuman olganda, ushbu maqolada matn tahlilini qo‘llab-quvvatlaydigan tizim, ya’ni UZMORF dasturi “Imlo tahlil” va “Grammatik tahrir” modullarini o‘z ichiga oladi.

UZMORF dasturi o‘zbek tili bo‘yicha matnlarni avtomatik ravishda qayta ishlash uchun yaratilgan dastur hisoblanadi. Bu dastur o‘zbek tilidagi so‘zlar va ularning morfologik tuzilishini tahlil qiladi va uni kompyuterlar ustida qayta ishlash uchun tayyorlash uchun yordam beradi. UZMORF dasturining ishlash prinsiplari quyidagicha:

So‘zlar va ularning morfologik tuzilishi: UZMORF o‘zbek tilidagi har bir so‘zning morfologik tuzilishini aniqlaydi. Bu tuzilish ma’lumotlari so‘zning qaysi qismi, qaysi jinsga tegishli, ularning shakli bilan bog‘liq ma’lumotlarni o‘z ichiga oladi.

Morfologik tahlil: Dastur o‘zbek tili morfologiyasi bo‘yicha tayyorlangan til qoidalari va xususiyatlarga asoslanadi. So‘zlar tahlil qilinishi va ularning morfologik ma’lumotlari aniqlanishi uchun morfologik analiz usullaridan foydalanadi.

Yordamchi dasturlar va modullar: UZMORF dasturi Python dasturlash tilida yozilgan bo‘lib, matnlarni o‘zbek tilidagi so‘z va ularning tuzilishi bo‘yicha tahlil qilish uchun modullardan foydalanadi. Bu modullar matnlar bilan ishlashda va ulardagi morfologik ma’lumotlarni aniqlashda yordam beradi.

O‘zbek tilidagi tajribali ma’lumotlar bazasi: UZMORF dasturi tahlil qilayotgan matnlarni ustida amal qilishi uchun o‘zbek tilidagi so‘zlar va ularning morfologik ma’lumotlarini o‘z ichiga olgan ma’lumotlar bazasidan foydalanadi.

Texnik taraqqiyotlar: UZMORF dasturi texnik taraqqiyotlarni ham ko‘rib chiqib, yangi o‘zbek tilidagi so‘zlar va ularning morfologik tuzilishi bo‘yicha yangi ma’lumotlarni qo‘llab-quvvatlash uchun yangilanadi.

UZMORF dasturidan o‘zbek tilidagi matnlarni avtomatik ravishda qayta ishlash va ularning morfologik tuzilishini tahlil qilish uchun foydalaniladi. Bu dastur o‘zbek tilidagi matnlarni tahrir qilish, avtomatik tarjima qilish, tilni o‘rgatish va boshqa texnik vositalarda ham foydalanilishi mumkin.

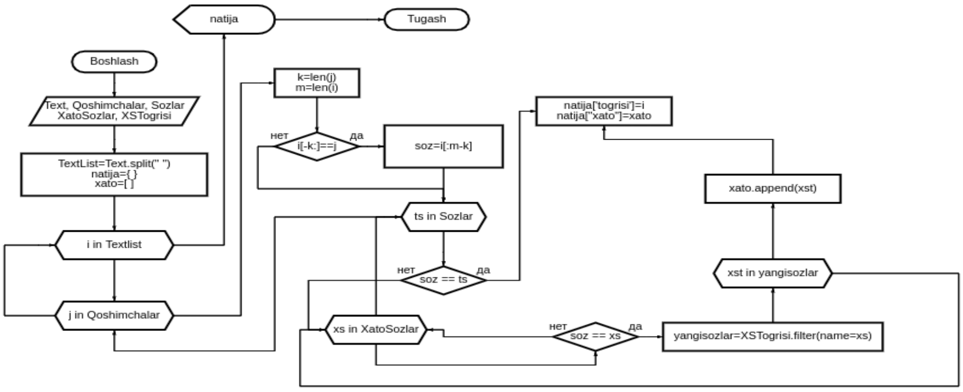
O‘zbek tili so‘zlarini grammatik tahrirlash uchun bir nechta usullar mavjud:

Orfografiya: So‘zlar tahrirlanayotgan paytda o‘zbek tilining orfografiya qoidalari hisobga olinishi kerak. Bu harflarni to‘g‘ri joylashish, qo‘shimcha belgilar va unlilar to‘g‘ri qo‘llanilishi, so‘zlarning bosh harflari katta yoki kichik yozilishi va boshqalar kabi qoidalarni o‘z ichiga oladi.

Morfologiya: Morfologiya so‘z shakli va tushunchalari bo‘yicha tahrirlashni ta’minlaydi. Bu, so‘zning shakli bo‘yicha tahrirlashni o‘z ichiga oladi.

Leksikologiya: Tahrirlash jarayonida leksikologiya ham muhim o‘rin egallaydi. Bu so‘zlar va ularning ma’nolari, ularning mazmuni va so‘z yoki iboralarning amaliy va estetik to‘g‘riligi bo‘yicha tahrirlashni ta’minlaydi.

Tadqiqot metodologiyasi. Tizim bazasiga o‘zbek tilining lotin yozuvidagi 86000 ga yaqin so‘zlar kiritilgan. Ushbu har bir so‘zga tegishli bo‘lgan imloviy xato so‘zlar biriktirib chiqilgan, ya’ni har bir so‘zning xato yozilishi ehtimoli kamida undagi harflar soniga teng deb olinib barcha variantlari kiritib chiqilgan. Foydalanuvchi tomonidan kiritilgan matndagi imloviy xato so‘zning imloviy to‘g‘ri shakli bir qancha bo‘lishi mumkin. Foydalanuvchi matniga mos bo‘lgan so‘zni aniqlash imkoniyatiga ega.



1-rasm.UZMORF dasturi matnni tahrirlash algoritmlarining blok sxemasi.

Foydalanuvchi tekshirilishi kerak bo‘lgan matnini kiritadi va tizim quyidagi etaplar bo‘yicha matnni tahrir qiladi:

- kiritilgan matnni so‘zlarga ajratib chiqiladi va so‘zdan qo‘shimchalar ajratib olinadi;
- har bir so‘zni bazada mavjud so‘z o‘zaklari ro‘yxatida mavjudliligi tekshiriladi. Mavjud bo‘lsa, ushbu so‘z o‘z holicha qoldiriladi aks holda har bir so‘zga mos bo‘lgan imloviy xato so‘zlar ro‘yxatidan tekshirib ko‘riladi va moslari aniqlanib imloviy xato yozilgan so‘zlarning to‘g‘ri variantlari foydalanuvchiga ro‘yxat ko‘rinishida taqdim etiladi;
- so‘ngra foydalanuvchiga imloviy xato yozilgan so‘zlar ajratib beriladi va foydalanuvchi xatoligi mavjud bo‘lgan so‘zlarni to‘g‘irlaydi, ya’ni kiritilgan matnga mos bo‘lgan so‘zlarni tanlab o‘zgartirib chiqishi talab etiladi.

So‘zlar bazasida mavjud bo‘lmagan yoki endi ishlatilayotgan so‘zlarning xatosini aniqlash uchun dasturda sun’iy intellekt algoritmi *"Spell Checker"* (matnni tekshiruvchi) algoritmlaridan foydalanilgan. Ushbu algoritmlar, matnlardagi so‘z xatolarini aniqlab chiqarish va ularni tahrirlashda yordam beradi. Ya’ni har bir so‘zni mavjud lug‘atlar va grammatik qoidalariga muvofiq tekshiradi. Agar kiritilgan so‘z mavjud lug‘atlarda topilmagan yoki uni tahrirlash uchun alternativlar mavjud bo‘lsa, so‘zni tekshiruvchi algoritmi bu alternativlarni taklif qiladi. Ushbu holatlarni bartaraf etish uchun sun’iy intellekt algoritmi quyidagi ko‘rinishda shakllantirilgan:

```
import re
from collections import Counter
def words(text):
    return re.findall(r'\w+', text.lower())
def train(features):
    model = Counter()
    for word in features:
        model[word] += 1
    return model
def edits1(word):
    letters    = 'abcdefghijklmnopqrstuvwxyz'
    splits     = [(word[:i], word[i:])    for i in range(len(word) + 1)]
    deletes    = [L + R[1:]               for L, R in splits if R]
    transposes = [L + R[1] + R[0] + R[2:] for L, R in splits if len(R)>1]
    replaces   = [L + c + R[1:]           for L, R in splits if R for c in letters]
    inserts    = [L + c + R               for L, R in splits for c in letters]
    return set(deletes + transposes + replaces + inserts)
def known(words, model):
    return set(w for w in words if w in model)
def known_edits2(word, model):
```

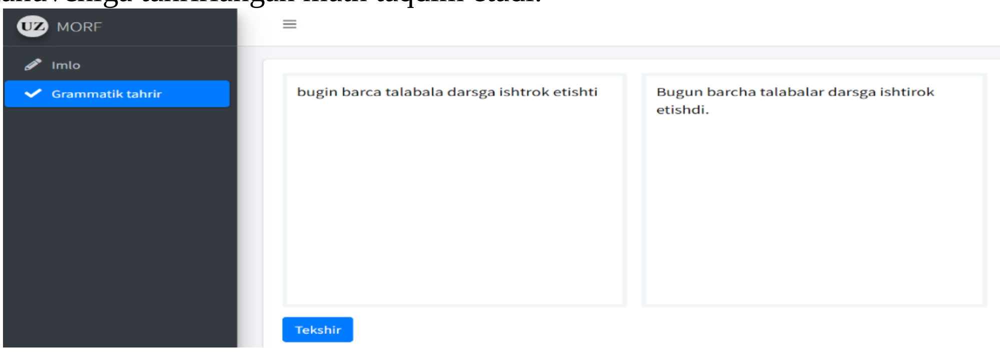
```
        return set(e2 for e1 in edits1(word) for e2 in edits1(e1) if e2 in model)
    def known_words(words, model):
        return known(words, model) or known(edits1(word), model) or known_edits2(word, model) or [word]
    def correction(word, model):
        return max(known_words([word], model), key=model.get)
    def spell_check(text, model):
        return [correction(word, model) for word in words(text)]
    # Example usage
    text = "Thes is a smple text with an errer."
    WORDS = train(words(open('sozlar.xlsx').read()))
    corrected_text = spell_check(text, WORDS)
    print(corrected_text)
```

Bu misolda, **‘spellchecker’** Python paketini ishlatamiz. U matnlardan foydalanish uchun yopiq mavjud so‘zlar va xato so‘zlar ro‘yxatini topadi va ularga to‘g‘ri qilingan variantlarni taklif qiladi. Natijada to‘g‘ri so‘zlar bilan to‘ldirilgan matn qaytariladi. Ya’ni, *'sozlar.xlsx'* nomli fayl bilan so‘zlar bazasi kiritiladi. Bu faylda odatiy matnlardan olingan so‘zlar ro‘yxati bo‘ladi. 'WORDS' nomli lug‘atga so‘zlar va ularning muqobillari tanlab olinadi. **‘correction’** funksiyasi kiritilgan so‘z uchun eng muqobil variantni topadi. **‘spell_check’** funksiyasi esa matndagi har bir so‘zni tekshiradi va to‘g‘ri yozuvlar ro‘yxatini qaytaradi.

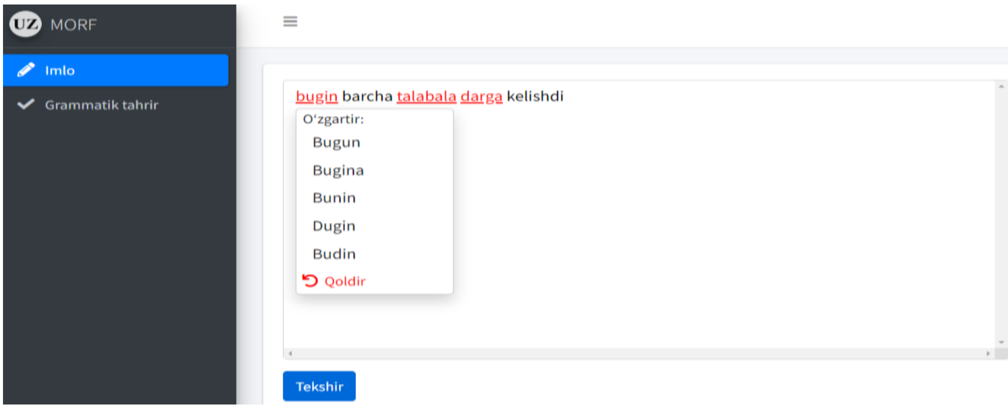
Natijalar va muhokama. Avtomatik tahrir va tahlil qilish kompyuter lingvistikasining asosiy yo‘nalishlarining biri bo‘lib u kompyuterdagi matn muharriri (Microsoft word) rivojlanishi bilan bog‘liq holda yuzaga kelgan. Avtomatik tahrir va tahlil jarayonida kompyuterga kiritilayotgan matnning imloviy xatolari avtomatik tarzda to‘g‘irlanishi va xato ekanligi haqida foydalanuvchiga taklif etilishi nazarda tutilgan. Matnni avftomatik tahrir qilish jarayonida uning mukammal va yuqori sifatli tizimli bo‘lishi uchun unga kiritilgan matnlarni orfografik, stilistik va grammatik tarafdan unda sintaktik, semantik va paradigmatik tahrir qilish imkonini yaratish ko‘zda tutilgan.

Grammatik tahrirni avtomatik to‘g‘irlash jarayoni quyidagi algoritmlar bo‘yicha amalga oshiriladi:

- kiritilgan matnni so‘zlarga ajratib chiqiladi va so‘zdan qo‘shimchalar ajratib olinadi. Qo‘shimchalar ma’lum bir ketma-ketlikda so‘zning o‘zagiga biriktirilgan;
- har bir so‘zni bazada mavjud so‘z o‘zaklari ro‘yxatida mavjudliligi tekshiriladi. Mavjud bo‘lsa ushbu so‘z o‘z holicha qoldiriladi, aks holda har bir so‘zga mos bo‘lgan grammatik xato so‘zlar ro‘yxatidan tekshirib ko‘riladi va moslari aniqlanib grammatik xato yozilgan so‘zlarning to‘g‘ri variantlari o‘zgartirib tahrirlab chiqiladi;
- so‘ngra foydalanuvchiga grammatik xato yozilgan so‘zlar ajratib beriladi va tizim foydalanuvchiga tahrirlangan matn taqdim etadi.



2-rasm.UZMORF dasturining grammatik tahrir qilish jarayoni oynasi



3-rasm.UZMORF dasturining imlo tahrir qilish jarayoni oynasi.

Xulosa va takliflar. Ushbu maqolada o‘zbek tili so‘zlarini avtomatik imloviy tahrirlash uchun ishlab chiqilgan algoritmlarning ahamiyati, imkoniyatlari va qiyinchiliklari tahlil qilindi. Ma’lum bo‘lishicha, o‘zbek tilidagi o‘zgacha grammatik tuzilma va so‘z yasash qoidalari imloviy tahrirlash dasturiy vositalarini yaratishda o‘ziga xos yondashuvni talab qiladi. Olib borilgan izlanishlar natijasida yangi algoritm yoki mavjud algoritmlarga asoslangan dasturiy ta’minot ishlab chiqishning samarali yo‘llari aniqlangan va ular o‘zbek tilida keng qo‘llashga moslashtirilgan.

O‘zbek tilida imloviy va grammatik xatolarni samarali aniqlash uchun dasturiy ta’minot va algoritmlarni yanada rivojlantirish va ommaviy ma’lumotlar bilan sinovdan o‘tkazish lozim. Yaratilgan algoritmlar o‘zbek tilining barcha dialektlari va o‘zgacha yozilish shakllarini inobatga olishi uchun kengroq lug‘at va til qoidalari bazasi yaratish zarur. Mazkur dasturiy ta’minotni elektron pochta, matn muharrirlari va ijtimoiy tarmoqlar kabi platformalar bilan integratsiya qilish orqali kengroq foydalanuvchilarga yetkazish zarur hisoblanadi.

Foydalanilgan adabiyotlar

1. Эшкараева Н, Боймуродов Ф. Разработка программы словоформ узбекского языка с использованием алгоритма портера //International Scientific and Practical Conference on Algorithms and Current Problems of Programming. – 2023. – Т. 1. – №. 01.

2. Большакова Е.И., Клышинский Э.С., Ландэ Д.В., Носков А.А., Пескова О.В., Ягунова Е.В. Автоматическая обработка текстов на естественном языке и компьютерная лингвистика : учеб. Пособие. - М.: МИЭМ, 2011

3. Эшкараева Н. Г., Боймуродов Ф. Ф. Разработка и реализация алгоритма стемматизации и генерации словоформ для глаголов узбекского языка. - ҚарДУ ХАБ. – С. 4. – ЖУРНАЛ РАҚАМИ ЙИЛИ ЙУК

4. Nazirova E, Uzakova M, Boymurodov F Turkiy tillar oilasiga mansub o ‘zbek va qirg ‘iz tillarida elektron tarjimaning lingvo-matematik modelini ishlab chiqish: Turkiy tillar oilasiga mansub o ‘zbek va qirg ‘iz tillarida elektron tarjimaning lingvo-matematik modelini ishlab chiqish //MODERN PROBLEMS AND PROSPECTS OF APPLIED MATHEMATICS. – 2024. – Т. 1. – №. 01.

5. Nazirova E, Boymurodov F, Uzakova M O ‘zbek tili so ‘zlarni imloviy tahrirlash va qayta ishlash algoritmi: O ‘zbek tili so ‘zlarni imloviy tahrirlash va qayta ishlash algoritmi //MODERN PROBLEMS AND PROSPECTS OF APPLIED MATHEMATICS. – 2024. – Т. 1. – №. 01.

6. Boymurodov F.F. O‘zbek tili so ‘zlarni hosil qilish va avtomatik qayta ishlash tizimlari tahlili: https://doi. org/10.5281/zenodo. 11198320 //PEDAGOGICAL REFORMS AND THEIR SOLUTIONS. – 2024. – Т. 1. – №. 1. – С. 495-498.

7. Boymurodov.F.F Development of an algorithm for generating word forms for the uzbek language: https://doi. org/10.5281/zenodo. 11198320 //PEDAGOGICAL REFORMS AND THEIR SOLUTIONS. – 2024. – Т. 1. – №. 1. – С. 493-495.Боймуродов Ф. Ф. Разработка морфологического анализатора узбекского языка. – 2023.

8. Boymurodov F. Algorithm development and implementation stemmatization and generation of word forms of uzbek language for automatic processing systems texts //Конференции. – 2020.

9. Anas S. M. et al. Dynamic Response Analysis of Slab Subjected to Central Contact Blast: Exploring Effects of Blast Placement on Compression and Tension Faces //E3S Web of Conferences. – EDP Sciences, 2024. – Т. 563. – С. 02021.

10. Kayumova I. D., Eshkarayeva N., Rakhmatullaev Y. Research and practise in the training of students for server software integration: a case study in uzbekistan //Journal of Modern Technology and Engineering. – 2024. – Т. 9. – №. 1. – С. 62-67.

USING ARTIFICIAL INTELLIGENCE METHODS AND TOOLS IN EDUCATION

Ayupov Ravshan Hamdamovich[1]
Uzbek State World Languages University, professor
Kurbonov Zafar Mamanazarovich[1]
Karshi State University, associate professor
ayupovr1x1@gmail.com
kurbonov.zm@qarshidu.uz,
ORCID 0000-0002-0690-3206)
UDK 681.142.37

Abstract: Artificial intelligence (AI) has been increasingly applied in learning different subjects and teaching. AI can be used to produce mathematical modelling, computer code, images, or other media in response to users' queries. In education, AI has been implemented in automated assessment, speech recognition, adaptive and personalized provision of educational resources, and more. For example, ChatGPT, as an AI language model, can be used in various ways in education. In this article illustrated some possible use cases of this. Also, ChatGPT can be a useful tool for research assistance in education. Some ways that ChatGPT can be used in this context highlighted in this paper. As a final conclusion, we can say, that the integration of artificial intelligence and specifically, ChatGPT, can serve as a valuable tool in contemporary education.

Key words: Digital technology, mathematic modelling, language learning, artificial intelligence, ChatGPT, VR, AR, AI, integration, software, language model.

Annotatsiya: Sun’iy intellektdan (SI) turli fanlarni o‘qitishda, matematik modellashtirishda va til o‘rganishda tobora ko‘proq foydalanilmoqda. SI foydalanuvchi so‘rovlariga javoban tabiiy til, kompyuter kodi, tasvirlar yoki boshqa ommaviy axborot vositalarini yaratish uchun ishlatilishi mumkin. Ta’limda SI avtomatlashtirilgan baholash, nutqni aniqlash, ta’lim resurslarini moslashtirilgan va moslashtirilgan yetkazib berish va boshqalar uchun qo‘llaniladi. Masalan, ChatGPT sun'iy intellekt tili modeli sifatida ta’limda turli usullarda qo‘llanilishi mumkin. Ushbu maqolada buning ba’zi mumkin bo‘lgan foydalanish usullari tasvirlangan. Bundan tashqari, ChatGPT ta’lim tadqiqotlari yordami uchun foydali vosita bo‘lishi mumkin. Ushbu maqolada ChatGPT-dan foydalanishning ba’zi usullari tasvirlangan. Yakuniy xulosa sifatida shuni aytishimiz mumkinki, ta’limda sun’iy intellekt va, xususan, ChatGPT integratsiyasi qimmatli vosita bo‘lib xizmat qilishi mumkin.

Kalit so‘zlar: Raqamli texnologiyalar, matematik modellashtirish, til o‘rganish, sun’iy intellekt, ChatGPT, VR, AR, AI, integratsiya, dasturiy ta’minot, til modeli.

Introduction. Digital technology has become an essential factor in learning process, and there are various tools and techniques that teachers can use to incorporate technology into their teaching practice. The use of digital technology can enhance learners' motivation and engagement, as well as provide access to authentic materials and real-world language use. However, it is important to ensure that the use of technology is purposeful and appropriate for the learning objectives and needs of the learners. The web search results provide more information about the use of digital technology in language learning. For example, in following article [1] discusses some of the apps and programs that can be used to incorporate technology into teaching. Using technology has always been an important part of teaching, even in the pre-digital age. However, some technology (like VR – virtual reality) is still quite challenging to use successfully. The next publication [2,5] offers insights from leading experts in the use of technology in language learning and teaching through the Teachers Talk Tech podcast.

Research methodology. Artificial intelligence (AI) has been increasingly applied in learning different subjects and teaching. For example, using (AI) in mathematical modelling offers a ground-breaking approach to solving complex problems, predicting outcomes, and understanding intricate systems. Here are some of the ways AI is being integrated into mathematical modelling [2-4]:

Data Processing and Analysis - AI can rapidly analyse vast amounts of data, identifying patterns, anomalies, and relationships which can be incorporated into a mathematical model. Machine learning algorithms can be trained to predict outcomes based on historical data.

Optimization of mathematical models - AI can help optimize mathematical models, fine-tuning parameters to ensure the most accurate results. Algorithms like neural networks can optimize themselves over time, enhancing the model's predictive power.

Dynamic Model Adjustment - traditional mathematical models are static; once they're built, they don't change unless manually adjusted. With AI, models can adapt in real-time based on new data or outcomes.

Complex System Analysis - systems with many variables, like those found in biology or meteorology, can be difficult to model mathematically. AI can process these multifaceted systems more efficiently, offering insights that might be missed with traditional methods.

Predictive Analysis - With enough data, AI algorithms can predict future events or trends. This is invaluable in fields like finance, where predicting market movements can be highly profitable.

Simulation and Testing - AI can run numerous simulations in a fraction of the time it would take using other methods, allowing for extensive testing and refinement of a mathematical model.

Feature Extraction and Dimensionality Reduction - In datasets with many variables, not all of them are equally valuable for modelling. AI can identify the most significant features and reduce the dimensionality of the data, simplifying the modelling process.

Enhancing Traditional Methods - AI doesn't necessarily replace traditional mathematical modelling but enhances it. For instance, combining differential equations with machine learning techniques can help in better understanding and predicting complex biological systems.

The integration of AI in mathematical modelling enhances the capability to handle complex systems, making predictions more accurate, and offering insights that might not be apparent with traditional methods alone. As technology and methodologies continue to evolve, the symbiotic relationship between AI and mathematical modelling will only strengthen, paving the way for breakthroughs in numerous fields. The potential of AI to support mathematic modelling, language learning and teaching is significant, and some contemporary AI instruments are being developed to learn the rules and patterns of human languages on their own, providing explanations of grammatical functions such as tense, case, and gender [5]. The use of AI can help personalize the learning experience, provide immediate feedback, and enhance the learning process in a variety of ways. However, it is important to keep in mind that AI should be used to complement and support human teaching, not to replace it.

Results and discussions. Distinguishing the using of new language model app from traditional education models. For example, ChatGPT, as an AI language model, can be used in various ways in education. Here are some possible use cases:

1. *Research assistance*: ChatGPT can assist students and educators in finding and evaluating relevant research materials, such as academic papers, books, and online resources.

2. *Learning support*: ChatGPT can serve as a virtual tutor, answering questions and providing explanations on various topics. It can also provide personalized recommendations for further learning based on the user's interests and abilities.

3. *Language learning:* ChatGPT can be used as a language learning tool, allowing students to practice their writing and conversation skills with a native speaker-like partner.

4. *Writing support:* ChatGPT can help students improve their writing skills by providing feedback on grammar, syntax, and style. It can also generate writing prompts and provide suggestions for essay topics.

5. *Course design*: ChatGPT can assist educators in designing and developing educational courses, such as by suggesting course topics, creating lesson plans, and developing quizzes and assignments.

To use ChatGPT in education, educators can integrate it into various educational technologies, such as learning management systems, chatbots, or virtual assistants. Alternatively, students can access ChatGPT directly through web-based chat interfaces or messaging platforms. It is important to note that while ChatGPT can provide useful assistance, it should not be seen as a replacement for human educators, but rather as a complement to their teaching efforts.

ChatGPT can be a useful tool for research assistance in education. Here are some ways that ChatGPT can be used in this context:

1. *Summarizing and paraphrasing sources*: ChatGPT can help students summarize and paraphrase information from sources, which can be useful when incorporating research into papers. According to the Center for Innovation in Teaching and Learning at the University of Illinois, ChatGPT can help students "summarize and paraphrase information from your sources" [6].

2. *Generating bibliographies and citations*: ChatGPT can also help students generate bibliographies and citations in the format required by their university or professor. This can save time and ensure that students are accurately citing their sources. The University of Illinois also notes that ChatGPT can help students "generate bibliography and citation in the format required by your university or professor" [7].

3. *Answering test questions and writing essays:* According to the American Psychological Association, ChatGPT can answer test questions and write essays [8]. However, it's important to note that using ChatGPT in this way could raise ethical concerns, as it may be seen as a form of academic dishonesty. It's important for educators to set clear guidelines around the use of ChatGPT in their classrooms and ensure that students are using the tool in an appropriate and ethical way.

4. *Generating Ideas*: ChatGPT can help generate ideas for research papers or creative writing projects. Students can use this feature to brainstorm ideas and expand on them.

5. *Starting Point*: Teachers can use ChatGPT as a starting point for classroom discussions or activities. Students can generate answers on GPT and then work from there. GPT-generated essays can also be used as a reference for students to improve their writing skills.

Overall, ChatGPT can be used as a learning support tool in various ways to improve students' academic performance and help them develop critical thinking skills. According to the web search results, ChatGPT can be utilized as a language learning tool in education. One example of using ChatGPT for language learning is demonstrated in a video by Tom Gally, a professor at the University of Tokyo, where he showcases how ChatGPT can be used to assist people in learning and teaching second languages. ChatGPT can respond to user-generated prompts using natural language processing techniques, making it an effective tool for practicing speaking and writing in a new language. It can also be used to generate prompts for language learners to respond to, aiding in their development of reading and listening comprehension. Overall, ChatGPT has the potential to be an effective language learning tool in education, assisting both students and educators in language acquisition and practice.

ChatGPT can be used as a writing support tool in education in various ways. One way is to use ChatGPT as an ideation tool, for organization of thoughts, and for iterating on a concept. This can be done by providing ChatGPT with a prompt related to the writing task and seeing how it generates ideas and outlines [2]. Teachers can also have students run their own writing assignments through ChatGPT to see how it does and structure the assignments accordingly. This can help students see how ChatGPT generates responses and what they can learn from its methods. ChatGPT can also be used as a heuristic engine that helps the student think through refining questions. By providing a prompt or a question, ChatGPT can help students generate ideas and refine their thoughts. For writing assignments, ChatGPT can be used to help students with the research process. Students can use ChatGPT to find information on specific topics and incorporate it into their writing [9]. It is important to note that while ChatGPT can be a useful tool for writing support in education, it may also have some limitations. For instance, ChatGPT was trained using a massive dataset of text written by humans, which was pulled from the internet, and as such, the responses generated may reflect the biases of the humans who wrote the text used in the training dataset. Additionally, there are concerns that the use of AI writing tools like ChatGPT could lead to issues related to academic integrity. Therefore, it is important to use ChatGPT responsibly and alongside other writing support tools and resources.

ChatGPT can be used as a course design tool in various ways. One approach is to run course assignments through ChatGPT to see how it performs and then structure assignments accordingly. Another approach is to use ChatGPT as an ideation tool to help students organize their thoughts and iterate on concepts. Additionally, educators can use ChatGPT as a heuristic engine that helps students refine their questions and develop a deeper understanding of knowledge and skills [10]. It is important to note that ChatGPT was trained using text written by humans, so it may reflect human biases. Therefore, educators should encourage students to think critically and use ChatGPT as a tool to supplement their own knowledge and skills rather than as a replacement for them.

Conclusions and recommendations. In conclusion, the integration of artificial intelligence (AI) and specifically, ChatGPT, can serve as a valuable tool in contemporary education. ChatGPT can be utilized to assist with mathematic modelling, academic writing, help students develop research questions, organize thoughts and iterate on concepts, and provide heuristic engines to guide students in their thinking and question refinement. Furthermore, AI chatbots such as ChatGPT have the ability to produce flawless academic essays, making it a useful tool for students and educators alike. However, it is important to keep in mind that AI writing tools are constantly evolving, and the enforcement of a ChatGPT ban could result in the injustice of false positives, given that AI writing tools are always one step ahead of the tools used to detect them. Overall, the implementation of AI and ChatGPT in education has the potential to revolutionize the way students learn and educators teach.

Artificial intelligence (AI) and chatbots such as ChatGPT have become increasingly popular in contemporary education. These technologies have been used in a variety of ways to enhance and support student learning, including providing personalized feedback and guidance, assisting with mathematic modelling, academic writing, and even teaching coding skills. One of the most promising applications of AI and chatbots in education is their ability to provide personalized support and feedback to students. By analysing student data, these technologies can identify areas where students are struggling and provide targeted assistance to help them improve. This can be particularly useful for students who may be falling behind or struggling with a particular subject. Another important use of AI and chatbots in education is their ability to assist with academic writing. ChatGPT, for example, can help students with developing research questions, outlining papers, and even writing essays. These tools can help students become more confident writers and improve the quality of their work. While there are concerns that the use of chatbots in education may lead to increased plagiarism and other academic integrity issues, experts argue that these technologies can be used to complement traditional teaching methods rather than replace them. As with any new technology, there are potential risks and challenges associated with the use of AI and chatbots in education, but with careful planning and implementation, they have the potential to be a valuable tool for improving student learning outcomes. In conclusion, AI and chatbots such as ChatGPT have the potential to revolutionize education by providing personalized support and feedback to students, assisting with mathematic modelling, academic writing, and complementing traditional teaching methods. While there are challenges associated with the use of these technologies, they offer exciting possibilities for enhancing student learning outcomes in the contemporary education system.

References

1. Ayupov R.H., Tursunov S.Q. Raqamli texnologiyalar. O‘quv qo‘llanma. Toshkent: “Lesson Press” nashriyoti, 2023 yil. 464 bet.
2. Sabirjonov R.A. va boshqalar. Zamonaviy raqamli texnologiyalarning rivojlanish istiqbollari. Monografiya. – Toshkent: “Hilol Media” nashriyoti, 2022 yil. 202 bet.
3. Pete Sharma. Using Technology In Language Teaching. Cambridge English. Topic: Technology and digital. 29.10.2021
4. Hayo Reinders. Using technology to support learning. Cambridge University Press & Assessment. 28.07.2022.
5. Senad Bećirović, Amna Brdarević-Čeljo, Haris Delić. The use of digital technology in foreign language learning | SpringerLink. 27.09.2021.
6. https://citl.illinois.edu/citl-101/instructional-spaces-technologies/teaching-with-technology/chatgpt
7. https://www.scientificamerican.com/article/how-chatgpt-can-improve-education-not-threaten-it/
8. https://www.edweek.org/teaching-learning/opinion-19-ways-to-use-chatgpt-in-your classroom/2023/01
9. https://www.niu.edu/citl/resources/guides/chatgpt-and-education.shtml
10 https://annmichaelsen.com/2022/12/29/using-chatgpt-for-language-learning/

В СФЕРИЧЕСКИХ КООРДИНАТАХ ЗАДАЧА ДИРИХЛЕ ДЛЯ УРАВНЕНИЯ ЛАПЛАСА.

Сафаров Расул Чориёр ўғли
Қарши давлат университети, ўқитувчи
Тошқулова Дилшода Адҳам қизи
Қарши давлат университети, ўқитувчи
Шодиев Сардор Зокир ўғли
Қарши давлат университети, талаба
r.safarov1@g.nsu.ru
ORCID 0009-0008-6247-1373

UDK 517.95

Аннотация. В статье рассматривалась комплексная функция с двумя переменными, разложенная на вещественную и абстрактную части, приводилось определение комплексных функций, являющихся аналитическими, а также гармонической функции, приводилось уравнение Лапласа в декартовой системе координат с использованием аналитической функции с двумя переменными, а также условия Коши-Римана. Уравнение Лапласа рассматривалось в $n=3$-мерном пространстве, т. е. в сфере, и первая граничная задача была поставлена на уравнение Лапласа, т. е. задача Дирихле, была перенесена из декартовой системы координат в сферическую систему координат для уравнения Лапласа и задачи Дирихле, и было найдено более простое уравнение Лапласа и первая краевая задача. В данной работе мы ищем частное решение уравнения Лапласа в виде однородного многогранника k-порядка. А также мы приведем условия, необходимые для того, чтобы уравнение Лапласа было сферической функцией k-порядка. Решение сферической функции k-го порядка мы искали в виде произведения двух функций с помощью частного решения уравнения Лапласа, а некоторые неизвестные решения мы находили с помощью заданной задачи Дирихле, а общее решение записывали с помощью многочленов Лежандра.

Ключевые слова: уравнение Лапласа, задача Дирихле, сферическая система координат, многочлен Лежандра

Anotatsiya. Maqolada kompleks ikki o'zgaruvchili funiksiya haqiqiy va mavhum qisimlariga ajralgan holatida qaraldi, analitik bo'lgan kompleks funiksiyalarning hamda garmonik funiksiyaning ta'rifi keltirildi, ikki o'zgaruvchili analitik bo'lgan komplekis funiksiya hamda Koshi-Riman shartidan foydalanib

dekart koordinatalar sistemasida Laplas tenglamasi keltirilib chiqarildi.
Laplas tenglamasi $n=3$ o'lchamli fazoda ya'ni sharda qaraldi va Laplas tenglamasiga birinchi chegaraviy masala ya'ni Dirixle masalasi qo'yildi, Laplas tenglamasi va Dirixle masalasi uchun dekart koordinatalar sistemasidan sferik koordinatalar sistemasiga o'tildi va soddaroq ko'rinishdagi Laplas tenglamasi va Dirixle masalasi topildi. Sferik koordinatalar sistemasidagi Laplas tenglamasi uchun xususiy yechim k-tartilbli bir jinsli ko'phad ko'rinishida qidiril hamda Laplas tenglamasi k-tartilbli sferik funiksiya bo'lishi uchun zaruriy bo'lgan shartlar keltirildi. k-tartilbli sferik funiksiyaning yechimi Laplas tenglamasining xususiy yechimidan foydalanib ikki funiksiyaning ko'paytmasi ko'rinishida izlandi va berilgan Dirixle masalasidan foydalanib ba'zi noma'lumlar topildi va umumiy yechim Lejandr ko'phadlari yordamida yozildi.

Kalit so'zlar: Laplas tenglamasi, Dirixle masalasi, sferik koordinatalar sistemasi, Lejandr ko'phadi.

Введение. В статье мы рассмотрим задачу Дирихле, подставленную в уравнение Лапласа в $n=3$-мерном пространстве, примеры этой задачи приведены в большинстве узбекских литератур[13] но информация об общем решении не приводится в случае $n=3$, а только в случае $n=2$ [13]. Об уравнении Лапласа написано в большинстве литератур [2]-[13], даже по уравнению p-лапласова были получены некоторые результаты[1]. Многие результаты также были получены для задачи Дирихле или задачи Дирихле, помещенной в уравнение Лапласа[1]-[13]. Уравнение Лапласа относится к классу дифференциальных уравнений эллиптического типа с частными производными математическая физика считается одним из основных уравнений в науке об уравнениях, в уравнение Лапласа можно поместить задачи Дирихле, Неймана и третью граничную задачу, из этой статьи показано решение задачи Дирихле, которое ставится именно в уравнение Лапласа,в нашей статье уравнение Лапласа поставленная задача Дирихле отличается от задач Дирихле, поставленных в другое уравнение Лапласа. Решаем задачу Дирихле для сферы, уже получены многие результаты по задаче Дирихле, подставляемой в уравнение Лапласа в кольце и круге.

Методология исследования. Для решения задачи, поставленной в статье, в основном использовался метод Фурье, то есть поиск решения в виде. Мы использовали метод Фурье для решения задачи Дирихле, поставленной на уравнение Лапласа в статье, было бы трудно или вообще невозможно получить результат, если бы мы использовали другие методы. Метод Фурье-это метод поиска неизвестной функции в виде произведения двух одномерных функций, и мы переходим к системе уравнений, используя теорию, согласно которой производная от мультипликативной функции вычисляется по математическим законам и правилам, и что функции с двумя разными переменными равны только тогда, когда они инвариантны, решая систему уравнений по математическим законам и правилам, мы получаем записав решение в виде произведения найденных функций но это общее решение не крыло задачи Дирихле, мы ставим условие Дирихле для функций, которые искали в виде произведения, чтобы крыло задачи Дирихле, и мы получаем искомый результат, помещая задачу Дирихле в общее решение.

Результаты и обсуждения. Рассмотпим задачу Дирихле для уравнения Лапласа в шаре $(n=3)$:

$$\Delta u=\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}=0, \tag{1}$$

$$u\big|_{\partial B_R}=f(x,y,z). \tag{2}$$

Нас интересцет решение уравнение (1), с граничным условием (2).

После замены переменных

$$\begin{cases} x=\rho\sin\psi\cos\varphi, & 0\le\varphi\le 2\pi \\ y=\rho\sin\varphi\cos\psi, & -\frac{\pi}{2}<\psi<\frac{\pi}{2} \\ z=\rho\cos\varphi, & 0<\rho<\infty, \end{cases} \tag{3}$$

уравнение (1) будет иметь следующий вид:

$$\Delta u=\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial u}{\partial\theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 u}{\partial\varphi^2}=0$$

и

$u(R,\theta,\varphi)=f(\theta,\varphi)$.

Обычно (3) называют переходом от декартовой системы координат к сферической системы координат.

Определение. Если функция $f(z)=u(x,y)+iv(x,y)$, дифференцируема в точке z_0 и во всех точках вокруг нее, эта функция называется аналитической в этой точке.

Определение. Функция $f(z)$, которая является аналитической во всех точках области D, называется аналитической в области D.

Если функция $f(z)=u(x,y)+iv(x,y)$ аналитическая в поле D, то для этой функции виполняется следующее условие Коши-Римана:

$$\frac{\partial u}{\partial x}=\frac{\partial v}{\partial y},\quad \frac{\partial u}{\partial y}=-\frac{\partial v}{\partial x}\cdot \tag{4}$$

Дифференцируя первое условие (4) по x, а второе по y, и используя тот факт, что

$$\frac{\partial^2 v}{\partial x\partial y}=\frac{\partial^2 v}{\partial y\partial x},$$

мы получаем равенство

$$\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}=0\cdot \tag{5}$$

Для функции $u(x,y)$ уравнение вида (5) называется уравнением Лапласа и является одним из самых важных уравнений эллиптического типа.

Определение. Предположим, что пространства $V\subset R^3$ ограниченная поверхностью *S*. Функция $u(x,y,z)$ называется гармонической в области V, если выполняется следующами условиям:

а) функция $u(x,y,z)$ непрерывна вместе с первыми производными в области V;

б) имеет непрерывные вторые производные внутри области *V;*

с) удовлетворяет уравнению Лапласа:

$$\Delta u(x,y,z)=\frac{\partial^2 u(x,y,z)}{\partial x^2}+\frac{\partial^2 u(x,y,z)}{\partial y^2}+\frac{\partial^2 u(x,y,z)}{\partial z^2}=0 \text{ для } \forall(x,y,z)\in V.$$

Найти не известную функцию $u=u(r,\theta,\varphi)$ внутри шара, удовлетворяющую следующее уравнение:

$$\Delta u=\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial u}{\partial\theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 u}{\partial\varphi^2}=0 \tag{6}$$

и в точке $r=R$ заданные значения:

$$u(R,\theta,\varphi)=f(\theta,\varphi). \tag{7}$$

Разлагаем функцию $f(\theta,\varphi)$ в ряд по сферическим функциям $Y_k(\theta,\varphi)$:

$$f(\theta,\varphi)=\sum_{k=0}^{\infty}Y_k(\theta,\varphi)\cdot$$

Теорема. Пусть задана функция $f(x,y,z)$, непрерывная на поверхности сферы $D\subset R^3$, тогда уравнение (1), (2) будет иметь решение и решение имеет следующий вид:

$$u(r,\theta,\varphi)=\sum_{k=0}^{\infty}\left(\frac{r}{R}\right)^{k}Y_k(\theta,\varphi).$$

Доказательство: Мы знаем частные решения (6) ищется в следующем видам:

$u_k(r,\theta,\varphi)=r^kY(\theta,\varphi),$

виде, если мы поставим часты решения в (6), тогда мы получим следующая уравнения

$$\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial Y}{\partial\theta}\right)+\frac{1}{\sin^2\theta}\frac{\partial^2Y}{\partial\varphi^2}+k(k+1)Y=0, \qquad (8)$$

Ищем решение уравнения (8) следующим видам:

$Y_k(\theta,\varphi)=P(\cos\theta)\Phi(\varphi).$

Учитывая, что $Y_k(\theta,\varphi+2\pi)=Y(\theta,\varphi),$ получим

$$\begin{cases}\dfrac{d^2\Phi}{d\varphi^2}+\lambda\Phi(\varphi)=0\\ \Phi(\varphi+2\pi)=\Phi(\varphi),\end{cases} \qquad (9)$$

Откуда мы получим $\lambda=n^2, n=0,1,2,...$ и решения задачи (9):

$\Phi_n(\varphi)=A_n\cos n\varphi+B_n\sin n\varphi.$

Функция $P(\cos\theta)$ найдется из следующего уравнения:

$$\frac{1}{\sin\theta}\frac{d}{d\theta}\left[\sin\theta\frac{dP(\cos\theta)}{d\theta}\right]+\left[k(k+1)-\frac{\lambda}{\sin^2\theta}\right]P(\cos\theta)=0, \qquad (10)$$

и, следовательно, задача нахождения сферических функций на единичной сфере сводится к отысканию решений уравнения (9) при $\lambda=n^2, n=0,1,2,...$.

Полагая в (10) $t=\cos\theta,$ для функции $P(\cos\theta), 0\le\theta\le\pi,$ получаем уравнение:

$$-\left[(1-t^2)P'(t)\right]'+\frac{n^2}{1-t^2}P(t)=k(k+1)P(t). \qquad (11)$$

Ограниченными решениями уравнения (11) являются *присоединенные многочлены Лежандра*[см-2]:

$$P_{k,n}(t)=(1-t^2)^{\frac{n}{2}}\frac{d^nP_k(t)}{dt^n},$$

где

$$P_k(t)=\frac{1}{2^kk!}\frac{d^k}{dt^k}\left[(t^2-1)^k\right] \text{ —}$$

многочлены Лежандра, $k=0,1,2,...$

Теперь мы находим частные решения уравнения (10)

$$P_{k,n}(\cos\theta)=\sin^n\theta\frac{d^n}{d\cos\theta^n}\left[P_k(\cos\theta)\right],$$

где $P_{k,0}(\cos\theta)=P_k(\cos\theta), P_{k,n}(\cos\theta)=0$ при $n>k$.

После этого получим частная решения уравнения (8),

$P_{k,n}(\cos\theta)\cos n\varphi, \quad P_{k,n}(\cos\theta)\sin n\varphi.$

А общее решение будет следующим:

$$Y_k(\theta,\varphi)=\sum_{n=0}^{k}(a_{k,n}\cos n\varphi+b_{k,n}\sin n\varphi)P_{k,n}(\cos\theta), \qquad (12)$$

также являются частными решениями уравнения (8), а частные решения уравнения (6) даются формулами:

$u(r,\theta,\varphi)=r^k Y_k(\theta,\varphi).$

Решение внутренней задачи Дирихле в шаре (и других внутренних задач) находится в виде ряда по сферическим функциям $X_k(\theta,\varphi)$

$$u(r,\theta,\varphi)=\sum_{k=0}^{\infty}\left(\frac{r}{R}\right)^k X_k(\theta,\varphi).$$

И используя граничное условие (7), мы находим $X_k(\theta,\varphi)=Y_k(\theta,\varphi),$ таким образом, решение задачи Дирихле для уравнения Лапласа в шаре $r<R$ имеет вид

$$u(r,\theta,\varphi)=\sum_{k=0}^{\infty}\left(\frac{r}{R}\right)^k Y_k(\theta,\varphi).$$

Пример. Найти функцию $u=u(r,\theta,\varphi),$ которая удовлетворяет условиям определения 3, и на границе шара условию

$$u(1,\theta,\varphi)=\sin\theta(\cos\varphi+\sin\theta)+\frac{1}{3}.$$

Решение. Имеем следующую цепочку равенств:

$$f(\theta,\varphi)=\sin\theta\cos\varphi+\sin^2\theta+\frac{1}{3}=\cos\varphi\sin\theta+1-\cos^2\theta+\frac{1}{3}$$

$$=\cos\varphi\sin\theta-\frac{1}{3}(3\cos^2\theta-1)+1.$$

Из формулы(12) следует, что при

$a_{0,0}=1,\ \ 1=y_0(\theta,\varphi);$ при $a_{1,0}=b_{1,1}=0,\ \ a_{1,1}=1,\ \ \cos\varphi\sin\theta=y_1(\theta,\varphi)$ при $a_{2,0}=-\frac{1}{3},\ a_{2,1}=b_{2,1}=a_{2,2}=b_{2,2}=0$.

Следовательно $-\frac{1}{3}(3\cos^2\theta-1)=y_2(\theta,\varphi)$. Отсюда следует, что

$$u(r,\theta,\varphi)=1+r\cos\varphi\sin\theta-\frac{r^2}{3}(3\cos^2\theta-1).$$

Заключение и предложение. В статье было показано, что решение задачи Дирихле, проставленное в уравнение Лапласа, можно записать в сферической системе координат через полиномы Лежандра. Этот результат можно использовать для решения примеров и задач. Подводя итог, можно сказать, что, хотя уравнение Лапласа трудно решить в декартовой системе координат, его легче решить в другой системе координат. Вторую, третью граничные задачи, подставляемые в уравнение Лапласа, рекомендуется решать в случае $n=3$.

Использованная литература

1. Терсенов А.С. О достаточных условиях существования радиально-симметричного решения уравнения p-Лапласа // Нелинейный анализ. 2014. В. 95. П. 362-373.
2. Корпусов М. О. Нелинейные эллиптические и параболическиеуравнения математической физики. Москва: Физический факультет МГУ, 2016. – 188 с.
3. Крылов Н.В. Нелинейные эллиптические и параболические уравнения второго порядка. М.: Наука, 1985. - 376 с.
4. Крылов Н. В. Лекции по эллиптическим и параболическим уравнениям в пространствах Гельдера. Новосибирск: Научная книга, 1998. - 178 с.
5. Соболев С.Л. Некоторые применения функцианального анализа в математической физике. М.: Наука, 1988. -336 с.
6. Эванс Л. К. Уравнения с частными производными. / Пер. с англ. — Новосибирск:Тамара Рожковская, 2003. - 562 с.

7. Ландис Е.М. Уравнения второго порядка эллиптического и параболического типов. М.: Наука, 1971. - 288 с.
8. Гилбарг Д., Трудингер М. Эллиптические дифференциальные уравнения с частными производными второго порядка. – М.: Наука, 1989. – 464 с.
9. Олексий О.А. Лекции об уравнениях с частными производными. М.: БИНОМ. Лаборатория знаний, 2005. – 236 с.
10. Михайлов В.П. Дифференциалные уравнения в частных производных. М.: Наука, 1983. -424 с.
11. Алхутов Ю.А., Жиков В.В. О гельдеровости решений вырождающихся эллиптических уравнений//Доклады РАН, 2001, 378(5), 583-588.
12. Дилмурадов Н. О регулярности граничных точек для одного класса неравномерно вырождающихся эллиптических уравнений второго порядка // Докл. АН УзССР, 1984. N3.
13. М.С.Салохиддинов Б.И.Исломов Математика физика тенгламаларидан мисол ва масалалар тўплами 146-180 с.

RADIOACTIVE CONTAMINATION OF THE ENVIRONMENT DURING TECHNOGENIC-ECOLOGICAL ACCIDENTS

Nazende U. Aliyeva
Azerbaijan State University of Oil and Industry,
Azadliq Avenue, 20, AZ1010, Baku, Azerbaijan
nazendeeliyeva13@gmail.com
UDK: 539.163

Abstract. Techno genic environmental disasters cause extensive and long-term radioactive contamination of the environment. This article examines the impacts of radioactive substances released into the environment during nuclear accidents, their management approaches, and the restoration efforts. The consequences of nuclear disasters such as Chernobyl (1986) and Fukushima (2011) demonstrate that radioactive contamination not only threatens local ecosystems but also poses significant risks to human health and the economy on regional and global scales. The paper discusses modern technologies and international standards for combating radioactive contamination, as well as potential strategies for environmental restoration and radiation level reduction. The aim of this article is to present effective mechanisms for managing radioactive contamination during technogenic accidents and assess their alignment with international regulations.

Keywords: IAEA – (International Atomic Energy Agency), Radiological Protection Instruments – (RPI) NPP – (Nuclear Power Plant), Curie (Ci) – (unit of radioactivity), SNAP 9A – (U.S. radioisotope thermoelectric generator).

TEXNOGEN-EKOLOGIK AVARIYALAR DAVOMIDA ATROF-MUHITNING RADIOAKTIV IFLOSLANISHI

Annotatsiya. Texnogen ekologik falokatlar atrof-muhitning keng ko'lamli va uzoq muddatli radioaktiv ifloslanishiga sabab bo'ladi. Ushbu maqolada yadro avariyalari paytida atrof-muhitga chiqarilgan radioaktiv moddalarning ta'siri, ularni boshqarish yondashuvlari va tiklash harakatlari o'rganiladi. Chernobil (1986) va Fukusima (2011) kabi yadro falokatlarining oqibatlari radioaktiv ifloslanish nafaqat mahalliy ekotizimlarni tahlikaga solishi, balki inson salomatligi va iqtisodiyotiga ham mintaqaviy va global miqyosda jiddiy xavf tug'dirishini namoyish etadi. Maqolada radioaktiv ifloslanish bilan kurashda zamonaviy texnologiyalar va xalqaro standartlar, shuningdek, atrof-muhitni tiklash va radiatsiya darajasini kamaytirish bo'yicha potensial strategiyalar muhokama qilinadi. Ushbu maqolaning maqsadi texnogen avariyalar paytida radioaktiv ifloslanishni boshqarish bo'yicha samarali mexanizmlarni taqdim etish va ularning xalqaro me'yorlarga muvofiqligini baholashdir.

Kalit so'zlar: IAEA – (Xalqaro Atom Energetikasi Agentligi), Radiologik Himoya Asboblari – (RPI), Yadro Elektr Stansiyasi – (NPP), Kiuri (Ci) – (radioaktivlik birligi), SNAP 9A – (AQSh radioizotop termoelektrik generatori).

Introduction. How far-reaching can the impact of a nuclear accident be on the environment? How long do radioactive substances continue to affect living ecosystems and human health? Global nuclear disasters such as Chernobyl (1986) and Fukushima (2011) have demonstrated that radioactive contamination affects not only local areas but also has regional and global consequences. The ecological and socio-economic impacts of these disasters remain relevant today. How effective are modern radioactive contamination management technologies in such situations, and do they comply with international standards [1].

This research analyzes the effects of radioactive substances released into the environment during techno genic-ecological accidents and examines methods for managing them, evaluating the efficiency of existing technologies and considering safer solutions for the future. Albert Einstein once said about the risks of nuclear energy: “The danger that circles around us after splitting the atom became more powerful than our morality." This quote emphasizes the critical importance of human responsibility in the management of nuclear technologies. Techno genic accident (Industrial disaster) – These are large-scale accidents occurring at techno genic objects created by humans, resulting in numerous human casualties and causing long-term irreversible changes in ecosystems. Radioactive contamination, also referred to as radiological contamination, is the deposition or presence of radioactive substances on surfaces or within solids, liquids, or gases (including the human body), where their presence is unexpected or undesirable (according to the International Atomic Energy Agency, IAEA) [2]. SNAP 9A (Systems for Nuclear Auxiliary Power 9A) was an energy generator developed by the United States in 1964. This generator was used for the satellite Transit 5BN- The satellite failed to achieve orbit and disintegrated in the atmosphere, releasing 17,000 curies of plutonium-238, a radioactive substance. As a result, radioactive material was dispersed globally, particularly found in the Southern Hemisphere. This incident influenced the design and safety protocols of similar energy systems in the future. In 1986, as a result of the accident at the Chernobyl NPP, more than 200,000 square kilometers, primarily in Belarus, Russia, and Ukraine, were contaminated with Cs-137 at levels exceeding 37 kBq/m^2 (1 Ci/km^2). More than 600,000 people participated in the cleanup operations between 1986 and 1991, and 340,000 people were evacuated. The effectiveness of early evacuation was confirmed by the absence of acute radiation syndrome among the population. For a case-control study on thyroid cancer, thyroid doses were estimated for 607 individuals within a cohort of 150,813 male Ukrainian cleanup workers exposed to radiation from the 1986 Chernobyl nuclear power plant accident [3].

Among the medical consequences of the accident, 134 cases of radiation syndrome were identified. Of the cleanup workers, 28 people died within the first four months, and 19 more died by 2006. Leukemia developed among those exposed to radiation (with an attributable risk value of 45-60%). An 18% increase in the incidence of all types of cancer was observed in those exposed to doses exceeding 150 mSv. There was also a statistically significant increase in thyroid cancer cases among children and adolescents.The implementati on of long-term protective measures, the decay of radionuclides, and the natural remediation of contaminated areas have resulted in a significant reduction in radiation exposure for the population. As of 2015, in some settlements of the Bryansk region, the average annual effective dose for residents remains above 1 mSv. The current primary objective is to normalize the radiological situation and change the legal status of the contaminated areas, thereby enabling the population to return to normal living conditions [4].

The radioactive contaminants released as a result of the venting and hydrogen explosions at the Fukushima Daiichi nuclear reactors from March 12-15, 2011, were transported northwest and deposited onto the soil and plants via precipitation. Samples of surface soil and plant leaves were collected from 64 different locations within Fukushima Prefecture. The highest concentrations of the radionuclides (134)Cs (84.4 kBq/kg) and (137)Cs (82.0 kBq/kg) in surface soils were observed in Iitate Village, located 32 km northwest of the Fukushima Daiichi nuclear power plant. Additionally, other radionuclides such as (131)I, (129)Te, (129m)Te, (110m)Ag, and (140)La were detected in these samples. Plant leaves from areas in Tsushima and Minami-Tsushima in Namie Town, including bamboo and cabbage, were found to be highly contaminated. The concentration of radionuclides in mugwort leaves grown after the contamination event was relatively low; however, the plant-to-soil radio cesium ratio was measured at 0.023 ± 0.006. It is also expected that the decomposition of fallen leaves will contribute to the recycling of radionuclides in the environment [5-10].

Materials and methods. This research integrates two primary approaches for assessing radioactive contamination of the environment during techno genic-ecological accidents: quantitative and qualitative analysis. Quantitative analysis relies on statistical data and radiation monitoring systems to measure levels of radioactive materials. This approach involves analyzing data collected through radiation detection instruments using statistical models. Qualitative analysis, on the other hand, focuses on studying the experiences of local communities through interviews, surveys, and focus groups. This methodology aims to evaluate the long-term impacts of radiation contamination and examine the effectiveness of contemporary intervention strategies [11].

Results and discussion. Radioactive waste refers to radioactive material that is no longer intended for use but still contains or is contaminated with radionuclides. Radioactive waste can exist in gas, liquid, or solid forms (IAEA, 2018). Its radioactivity can last from a few hours to hundreds of thousands of years. For regulatory purposes, radioactive waste is defined as material with an activity concentration above clearance levels set by the regulatory body (IAEA, 2018) [12]. Most nuclear waste remains radioactive for several decades and is regularly disposed of at near- surface disposal facilities. Approximately 3% of the total volume of radioactive waste is long- lived and highly radioactive, requiring isolation from the environment for many millennia (World Nuclear Association, 2017) (Table 3.1).

Table 3.1

Compares the impacts of technogenic ecological accidents on radioactive contamination and the environment

Name of the disaster	Date	Released radioactive substances	Impact on the area	Effects on the environment and human health	Waste management strategies
Chernob yl, Ukraine	April 26, 1986	Cesium-137, Iodine-131, Strontium-90	30 km zone in Eastern Europe and the Northern Hemisphere	Increase in cancer cases, soil and water contamination, decline in biodiversity	Restricted zone, safe storage facilities, decontamination programs
				Harm to ocean life, evacuation among the population, and radiation hazard.	
Fukushima, Japan	March 11, 2011	Cesium-137, Iodine- 131	Pacific Ocean, Japanese shores	Harm to ocean life, evacuation among the population, and radiation hazard.	Water treatment systems, area isolation, and waste storage strategies.
Mayak, Russia	September 29, 1957	Strontium- 90, cesium- 137	20,000 km² area, mainly Chelyabin sk Oblast	Long-term contamination in soil and water systems, increased cancer risk.	Area isolation, waste management, long-term ecological monitoring.
Tomioka, Japan	2011	Cesium- 137, Cesium-134	Nearby area of Fukushima	Population evacuation, contamination of agricultural lands.	Radiation monitoring, restoration of agricultural lands, and waste storage.

Exposure (to radioactive waste) can lead to nausea, vomiting, hair loss, diarrhea, hemorrhaging, damage to the intestinal mucosa, central nervous system injury, and potentially death. It can also cause DNA damage, increasing the risk of cancer, especially in young children and fetuses. Radioactivity exceeding certain thresholds can disrupt the functioning of tissues or organs, resulting in acute effects such as skin erythema, hair loss, radiation burns, and acute radiation syndrome. These effects are more severe at higher doses and higher dose rates. For instance, the threshold dose for acute radiation syndrome is approximately 1 Sv (1000 mSv). Currently, no methods are known for the safe disposal of radioactive waste (Rosenfeld and Feng, 2011); however, long-term isolation in the geological environment is recommended. Low Linear Energy Transfer (LET) photon radiation results in the uniform deposition of energy throughout the tissue volume. In contrast, high LET radiation creates a rapid Bragg peak, which produces lower entrance doses while increasing the penetration depth of radiation energy into the tissue. The consequences include mutations, apoptosis, cancer development, and cell death. Contaminated areas are typically monitored on a regular basis.

Radiological protection instruments (RPI) play a crucial role in the monitoring and detection of any potential contamination spread, often involving portable research tools such as air particle monitors and area gamma monitors, as well as permanently installed area monitors. The detection and measurement of surface contamination on workers and facilities are usually carried out using Geiger counters, scintillation counters, or proportional counters. Proportional counters and dual-phosphor scintillation counters can differentiate between alpha and beta contamination, whereas Geiger counters cannot. Scintillation detectors generally prevail for handheld monitoring instruments, designed with a large detection window to expedite monitoring of extensive areas. Geiger detectors, on the other hand, have smaller windows that are more suitable for detecting localized contamination. Surface contamination is typically expressed in terms of radioactivity units per area unit for alpha or beta emitters. For the International System of Units (SI), this is measured in becquerels per square meter (Bq/m^2). Other units can also be used, such as picoCuries for 100 cm^2 or disintegrations per minute per square centimeter (1 dpm/cm^2 = 167 Bq/m^2).

Radioactive materials enter the human body either through external exposure or via airborne particles and the food chain. For example, iodine-131 can accumulate in the thyroid gland during its beta decay process, leading to mutations and the death of surrounding cells and tissues. The most dangerous type of radiation for humans is gamma radiation, which alters the structure of lipids, proteins, and DNA. An increase in radiation background can result in reduced life expectancy, the development of oncological diseases, immune deficiency, and hormonal imbalances.

Chromosomal abnormalities and morphological changes have been observed in dandelion plants growing in areas contaminated with strontium. Internal radiation exposure in animals along the food chain results in a decline in their populations. Low-intensity radiation alters the populations of fungi and bacteria. Soil contamination not only affects the infection of animals and plants but also complicates its use for agricultural purposes.

When working with radioactive materials, the primary task is to prevent leaks. Various methods are used to filter, isolate, and dispose of waste. The complete set of measures for combating environmental pollution includes the following:

Sealing production processes associated with the formation of contaminated aerosols;

İmplementing a closed-loop water supply cycle in production to minimize waste generation;

Neutralizing, centralizing, collecting, and storing radioactive waste;

Organizing sanitary protection zones, observation zones, and radiation monitoring. Observation stations (zones) are established around radiation facilities.

Continuous monitoring of radiation levels is conducted in these areas. Sanitary dosimetric control groups inspect environmental objects, conduct briefings, and oversee accident response activities in accordance with current regulations [13].

Radiocaesium-bearing microparticles (CsMPs) are glass-like particles formed from molten material, containing high concentrations of radiocaesium along with elements such as silicon (Si), oxygen (O), iron (Fe), and zinc (Zn). These particles differ significantly from the “hot particles” observed after the Chernobyl incident in terms of both their level of specific radioactivity and elemental composition.

Currently, CsMPs are classified into two primary types: Type-A and Type-B. These two types vary in terms of specific radioactivity, the ^134Cs/^137Cs ratio, size, morphology, and geographic distribution around F1NPP [14].

Dose Limit: A measure that indicates the effect of radioactive radiation on the human body and ecosystems. This measure is typically expressed in sieverts (Sv) or millisieverts (mSv). In a study on thyroid cancer involving a cohort of 150,813 Ukrainian cleanup worker exposed to radiation due to the 1986 Chernobyl Nuclear Power Plant accident, thyroid doses were calculated for 607 subjects.

Objective: To ensure that radiation levels during techno genic accidents do not exceed a specified limit. These limits are based on international standards and aim to protect individuals from long-term radiation effects. The standards established by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) are taken as a reference.

Annual Dose Limit: 1 mSv for the public, and 20 mSv for workers.

Emergency Limits: During accidents, the limit may be temporarily increased to 50 mSv.

The following methods are used to assess the amount of radioactive materials released during techno genic accidents:

Dosimeters: Devices used to measure personal radiation exposure, determining the levels of exposure for humans and animals.

Calculation of Radiation Dose:

$$D = A \times t/d2$$

D-Radiation dose (Gy)

A-Activity of the radioactive source (Bq) t-Time (seconds)

d-Distance from the source Calculation of the Isotope's Half-Life:

$$(t) = N0$$•e-^лt

N(t) represents the quantity of remaining nuclei over time, where N is the initial number of nuclei, λ is the decay constant, and t is the time.

Research and Analysis: The half-life is used to calculate how the activity of isotopes changes over time. For instance, it is possible to predict how radioactive isotopes will diminish over time during the release in a nuclear event. This information is crucial for assessing future impacts.

Radiation Risk Assessment:

$$E$$

$$R = D \bullet H$$

R-radiation risk D-radiation dose E-exposure factor

H-base factor for risk calculation

Geiger Counter: A device that detects radioactive particles and measures their quantity, widely used to measure radiation levels in various areas.

Conclusion. Measuring dose limits is considered a crucial factor in mitigating the impact of radioactive contamination in the environment during technological ecological accidents. Monitoring dose limits in accordance with international standards is of great significance for ensuring the safety of humans, living organisms, and ecosystems. Accurate measurement and proper management of radiation levels are essential steps in minimizing the effects of technological disasters. For these reasons, calculating the half-life of isotopes is a significant process for the protection of radioactive materials, assessing their impact, and developing safety protocols. The loss of almost all AC and DC power at the facility severely limited the ability to monitor essential thermodynamic parameters in reactors, containments, and spent fuel pools, as well as to operate crucial valves and equipment, significantly reducing the available options for managing the accident. As a result, Units 1, 2, and 3 became effectively cut off from their ultimate heat sink—the Pacific Ocean—for a period that far exceeded the suppression pools' heat capacity and the plant's coping time for a station blackout. Additionally, the response was complicated by multiunit interactions, as operators of different units had to compete for physical resources and the attention of the onsite emergency response center staff.

References

1. Becker, K. (2021). Long-term health effects of radiation exposure in Chernobyl and Fukushima. Cham: Springer.
2. Igarashi Y, Kogure T, Kurihara Y, Miura H, Okumura T, Satou Y, Takahashi Y, Yamaguchi N. A review of Cs-bearing microparticles in the environment emitted by the Fukushima Dai-ichi Nuclear Power Plant accident. J Environ Radioact. 2019 Sep;205-206:101-118. Doi: 10.1016/j.jenvrad.2019.04.011. Epub 2019 May 21. PMID: 31125755.
3. Drozdovitch, V., Kryuchkov, V., Bakhanova, E., et al. (2020). Estimation of radiation doses for a case-control study of thyroid cancer among Ukrainian Chernobyl cleanup workers. Health Physics, 118(1), pp. 18-35. DOI: 10.1097/HP.0000000000001120.
4. Gleick, P. H. (2023). Water, climate, and nuclear disasters: The lessons from Fukushima. Washington, D.C.: Island Press.

5. Hasegawa, T. (2021). Fukushima: The real story behind the nuclear disaster. Tokyo: Tuttle Publishing.
6. IAEA (2018). IAEA Safety Glossary: Terminology used in nuclear safety and radiation protection, 2018 edition. International Atomic Energy Agency.
7. IAEA (2021). The Fukushima Daiichi accident: Report by the Director General. Vienna: International Atomic Energy Agency.
8. International Atomic Energy Agency (IAEA). Radiasiya mühafizəsi üzrə resurslar: IAEA Radiation Protection.
9. Kushner, T. (2021). Nuclear Safety in Light of the Fukushima Disaster: Lessons Learned. London: Routledge.
10. Lyman, E. (2020). Fukushima: The Story of a Nuclear Disaster. New York: The New Press.
11. Medicina (Kaunas). 2024 Apr; 60(4): 653. Health Effects of Ionizing Radiation on the Human Body. DOI: 10.3390/medicina60040653.
12. Miller, A. (2022). The Radiological Accident in Goiânia: A Study of Contamination and Recovery. CRC Press.
13. Tazoe, H., Hosoda, M., Sorimachi, A., et al. (2012). Radioactive pollution from Fukushima Daiichi nuclear power plant in the terrestrial environment. Radiat Prot Dosimetry, 152(1-3): 198-203. DOI: 10.1093/rpd/ncs222.
14. Estimation of Radiation Doses for a Case-control Study of Thyroid Cancer Among Ukrainian Chernobyl Cleanup Workers Drozdovitch, Vladimir; Kryuchkov, Victor; Bakhanova, Elena; Golovanov, Ivan; Bazyka, Dimitry; Gudzenko, Natalia; Trotsyuk, Natalia; Hatch, Maureen; Cahoon, Elizabeth K.; Mabuchi, Kiyohiko; Bouville, André; Chumak, Vadim Author Information Health Physics 118(1):p 18-35,

THE STRUCTURE, PROPERTIES, AND APPLICATIONS OF NANO-ZrO_2 IN NUCLEAR ENERGY

Aysel M. Alakbarli
Azerbaijan State University of Oil and Industry,
Azadliq Avenue, 20, AZ1010, Baku, Azerbaijan
alekberli_18@mail.ru
UDK: 541.15

Abstract. Interest in nano-materials and technologies based on them in various directions has been steadily increasing recently. Nano with the further reduction of the dimensions of the materials, it has been possible to reach levels comparable to the free escape distances of non-equilibrium charge carriers and electronic excitations in solid materials. This shows that with the help of charge and energy carriers created in the volume of nano-particles under the influence of any factors, it is possible to achieve their use on the surface levels and from there according to the purpose. It is that nano-materials, due to their properties, are used in all fields of science and technology, especially nuclear technologies, nuclear is of great importance in the fields of physics and chemistry. The purpose of the article is that nano-zirconium and similar oxide dielectrics are of great interest due to their resistance to radiation, temperature and ambient pressure in nuclear physics and chemistry.

Keywords: Nano-ZrO2, radiolysis, nanoparticle, radiation, adsorption, gamma radiation.

NANO-ZrO_2 TUZILISHI, XUSUSIYATLARI VA YADRO ENERGIYASIDAGI QO‘LLANISHI

Annotatsiya: So'nggi vaqtlarda turli yo'nalishlarda nano-materiallar va ularning asosidagi texnologiyalarga bo'lgan qiziqish barqaror o'sib bormoqda. Nano-materiallarning o'lchamlarini yanada kichraytirish orqali ular qattiq materiallarda notenglik zaryad tashuvchilarining va elektron eksitatsiyalarining erkin chiqish masofalariga teng bo'lish darajasiga yetdi. Bu shuni ko'rsatadiki, nano-zarrachalar hajmida har qanday omillar ta'sirida yaratilgan zaryad va energiya tashuvchilaridan sirt darajalarda foydalanish va ulardan maqsadga muvofiq foydalanish mumkin. Nano-materiallar o'z xususiyatlari tufayli, ilm-fan va texnologiyaning barcha sohalarida, xususan yadro texnologiyalari, yadro fizika va kimyosida katta ahamiyatga ega. Maqolaning maqsadi nano-tsirko'niy va shunga o'xshash oksid dielektriklarning nurlanishga, haroratga va atrof-muhit bosimiga chidamliligi tufayli yadro fizika va kimyosida katta qiziqish uyg'otishini ko'rsatishdir.

Kalit so'zlar: Nano-ZrO2, radioliz, nanopartikula, radiatsiya, adsorbsiya, gamma nurlanishi.

Introduction. The core premise of atomic-hydrogen energy lies in converting the heat and radiation energy released during nuclear fission processes into more beneficial forms using hydrogen as a universal energy carrier. An analysis of the current nuclear spectrum reveals that high-power nuclear reactors primarily produce electricity based solely on thermal energy[1-2]. Research reactors are primarily utilized as neutron sources. Thus, at first glance, only the thermal potential of power-generating nuclear reactors may be harnessed. However, approximately 90% of existing nuclear reactors are water-cooled, with maximum core temperature limits typically not exceeding $T \leq 673$ K [3-4]. During the early stages of atomic-hydrogen energy development, specialized reactors were designed to support processes based on both energy and ionizing radiation sources. In this approach, low-cost electricity generated by nuclear power plants is intended to drive electrochemical and plasma-chemical processes, efficiently producing molecular hydrogen from water. It is known that the direct thermal decomposition of water occurs within a thermodynamically feasible regime at temperatures of $T \geq 1400–1600$ K [5].

Materials and Methods. The methodology and execution of the experiments were conducted in a vacuum-adsorption setup, focusing on the radiation and radiation-thermal processes involved in converting hydrogen and hydrogen-containing gases under static conditions across various irradiation durations. The apparatus schematic is provided in Figure 3.1. Sample irradiation was carried out using a gamma 60Co isotope source [6]. Experimental studies were conducted in static conditions within specially designed quartz ampoules with a volume of $V = 1$ cm^3. To prevent contamination from oils and lubricants, the vacuum-adsorption apparatus includes three cold traps cooled with liquid nitrogen. Thermo-vacuum processing of samples was conducted with a zeolite pump at $T = 300$K and $p = 10^{-3}$ Pa for a duration of 2 hours.

Results and discussion. Nuclear energy is considered a primary source of both electricity and thermal energy, playing a critical role in ensuring each country's energy reserves and security.

Nuclear energy encompasses the processing and enrichment of nuclear fuel, the production of heat-generating elements and structural materials for nuclear reactor cores, fuel combustion in reactor cores, and the disposal of radioactive waste [7-10]. A significant challenge in nuclear energy and the nuclear industry is the modernization of fuel and structural materials for the reactor cores. Materials used in nuclear reactor construction include types of steel such as austenitic, ferritic, and ferritic-martensitic steels, as well as carbon graphite materials, zirconium alloys, and various ceramics. Additionally, the storage of spent nuclear fuel and radioactive waste remains a critical issue. During such research, key priorities include the development of new fuel and structural materials, as well as the discovery of new methods for material analysis and monitoring [11].

In recent years, nanotechnology has found practical applications across nearly all fields of science and engineering. In the current era, advancements and research findings regarding the use of structural and functional nanostructured materials in nuclear energy and technology are of significant importance. Interest in nanotechnology, nanomaterials, and nanostructured materials is driven by several critical issues: nanotechnology enables the creation of fundamentally new quantum devices and materials and bridges knowledge across physics, chemistry, materials science, medicine, and computer technology. The term "nanotechnology" encompasses a set of methods and techniques that allow for the creation and modification of objects containing components with dimensions in the range of 1–100 nm. "Nanostructure" and "nanocomposite" refer to materials composed of specific-sized and composition nano-particles, as well as materials that acquire new properties when nanoparticles are embedded within a matrix. Nanostructures include macroscopic materials containing nano-objects and nanoscale elements.

The initial formation of atoms with dimensions of $0.1 \div 1$ nm is observed in nanoclusters. The term "nanoparticle" typically refers to small molecular nanoclusters, intermediate structures formed by atoms or molecules, with characteristic sizes of <100 nm [12-13]. The physical and physicochemical properties of clusters depend on the number of atoms they contain. When a cluster's properties are no longer influenced by the number of atoms, it can be considered a small-volume macroscopic material. Examples of nanosystems with dimensions under 100 nm include clusters containing 10 to 104 atoms. Two-dimensional objects with a single dimension under 100 nm, such as graphene and carbon nanotubes, are also examples. Thus, quantum mechanical phenomena in nano-objects can manifest in one, two, or three dimensions depending on the object's size [14].

Before the classification of nanostructures and nanomaterials, various ultrafine and nanoparticulate materials were already in existence. These include ultra-fine metallic powders, alloys, oxides, semiconductors, and micron-sized substances, all of which are now widely used. Nanostructured materials differ significantly in all physical properties compared to microscopic and macroscopic objects. The main manifestations of size effects include:

The primary reason for nanosystems' differing properties from macroscopic ones is the size of their structural elements;

Reduced timescales for various processes to occur;

The tunneling effect plays a central role in defining the properties of nanostructures.

The obtained results indicate that nanostructured materials play a significant role as both structural and functional materials in nearly all stages of the nuclear fuel cycle within atomic energy. The formation of new phases with a few nanometer periodicity after irradiation is particularly important. The observed effects of radiation on materials science may serve as a starting point for the development of construction materials that exhibit a "positive" response to radiation.

The prospects of applying nanotechnology in nuclear energy are directly linked to the creation of high-strength, corrosion-resistant, and radiation-resistant construction elements for nuclear power plants (NPPs) and nanostructured materials. This path represents a global trend toward developing high-dispersity, non-metallic particulate construction materials for the active zones of advanced nuclear reactors. Other applications of nanotechnology in energy include solar batteries, chemical energy converters, new energy storage sources, and hydrogen fillers (such as nanotubes). The transition to nanostructured materials enables the creation of qualitatively new materials for nuclear energy. Therefore, enhancing efforts in the field of nanotechnology and nanomaterials is one of the pressing issues for ensuring innovative and economic stability within the industry.

Radiation-catalytic processes can occur in all systems subjected to the influence of high-energy particles and gamma radiation, and they hold significant scientific and practical importance. The initial stage of all radiation-catalytic processes involves the interaction between components that constitute the high-energy particle and radiation systems, leading to energy loss and the formation of defect states. This phase is typically referred to as the "physical phase," and the data for this phase is often derived from calculations based on theoretical models.

Models have been developed to study the physical processes occurring under the influence of gamma quanta and high-energy electrons ($E \leq 400$ keV) in various materials and systems derived from them. Based on existing theoretical information regarding the interaction of ionizing radiation with solid materials, the interactions of gamma quanta and secondary δ-electrons with oxidized solid materials have been presented. This is exemplified in studies investigating the cascade of elementary processes occurring in the electronic structure of solid bodies at their surfaces [15]. The processes outlined result in the energy from ionizing radiation being converted into non-equilibrium charge carriers, excited states, emitted secondary electron cascades, and other structural defects within solid materials.

The components of the systems in which radiation-catalytic processes occur typically differ in terms of mass and electron density, structural characteristics, electrophysical properties, and chemical properties. Therefore, the interphase interactions in any form significantly influence the direction and parameters of the processes occurring within the individual components.

In the nano-ZrO_2 + H_2O system, radiation-heterogeneous processes lead to the formation of defect states at the surface in contact with water, similar to those found in oxides. A comparison of the hydrogen production rates in radiation-thermal and thermal processes within the nano-ZrO_2 + H_2O system indicates that their composition values are compatible. This suggests that some of the products from the radiation-heterogeneous processes involved in the decomposition of water participate in the oxidation of the surface.

Thus, the results obtained from the thermal and radiation-thermal decomposition of water on the surface of nano-ZrO_2 can be recommended for applications in radiation materials science, nuclear safety issues, and the resolution of ecological problems.

Phase transitions in nanoparticulate ZrO_2 have been investigated using X-ray diffraction methods, as illustrated in Figure 1. Here, the X-ray diffraction spectrum of the nano-ZrO_2 compound obtained at room temperature and under normal conditions is presented. Analysis of the X-ray diffraction spectrum using the Rietveld method revealed that the crystal structure of the nano-ZrO_2 compound conforms to monoclinic symmetry with the space group P121/c1. The lattice parameters obtained are as follows: a = 5.1481 Å, b = 5.1962 Å, c = 5.3132 Å, β = 99.25°, Z = 4, which correspond to values obtained in previous structural studies. The X-ray phase method confirmed that the samples used exhibit a monoclinic center-symmetric crystalline structure [16].

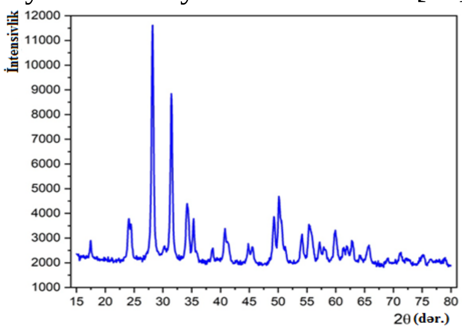


Figure 1. X-ray diffraction spectrum of the nano-ZrO_2 compound obtained at room temperature and under normal conditions

To investigate the precise dimensions of the samples, a scanning electron microscope (SEM) was employed. The microphotograph of the morphology of the nanoparticulate powder is presented in Figure 2.

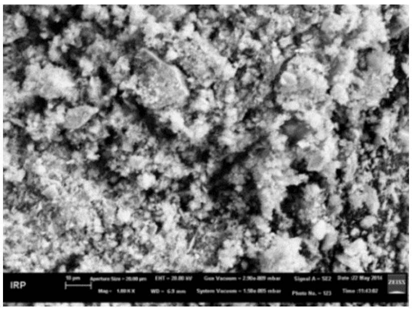


Figure 2. Microphotograph of the surface of nanoscale ZrO_2 particles

The image clearly shows that the research object is indeed on the nanoscale (nm). The size of the nanoparticles is primarily in the range of d≈25- 30 nm, which corresponds to the dimensions noted on the sample. It has been established that the ZrO_2 compound can form particles of several nanometers in size in powder form.

Conclusion. In the radiation-heterogeneous processes for hydrogen production, the characteristic feature lies in the conversion of thermal and ionizing radiation energy into a more effective form within solid materials, ultimately facilitating the transfer to the surface level. This process culminates in the generation of hydrogen, which serves as the primary energy carrier during the physical-chemical stages. As evident, the main physical processes playing a crucial role in radiation-heterogeneous processes are energy absorption, conversion, and transport. This monograph is dedicated to the study of the electophysical, spectral, and other physical-chemical properties of nano-Me, including nano-MeO systems, based on the research conducted in this field. Additionally, the results of studies discussing the effects of gamma radiation on the properties of nanoxides are presented in this monograph.

References

1. Imanova G.T. Kinetics of radiation-heterogeneous and catalytic processes of water in the presence of zirconia nanoparticles. Advanced Physical Research, 2020, vol. 2, no. 2, pp. 94–101.

2. Imanova G.T. Gamma rays mediated hydrogen generation by water decomposition on nano-ZrO2 surface. Modern Approaches on Material Science, 2021, vol. 4, no. 3, pp. 508–514. https://doi.org/10.32474/MAMS.2021.04.000186

3. Garibov A.A., Agayev T.N., Imanova G.T. Nanostructured materials based on nano-ZrO2 in the nuclear-power engineering. Journal of Radiation Researches, 2014, vol. 1, no. 1, pp. 50–56.

4. Agayev T.N., Huseynov V.I., Eyubov K.T. Research of high-temperature oxidation of zirconium by the thermo gravimetric method, Journal of Radiation Researches, 2017, vol. 4, no. 1, pp. 37–42.

5. Imanova G.T., Agayev T.N., Jabarov S.H. Investigation of structural and optical properties of zirconia dioxide nanoparticles by radiation and thermal methods. Modern Physics Letters B, 2021, vol. 35, no. 2, pp. 2150050. https://doi.org/10.1142/s0217984921500500

6. Ali I., Imanova G.T., Garibov A.A., Agayev T.N., Jabarov S.H., Almalki A.SA., Alsubaie A. Gamma rays mediated water splitting on nano-ZrO2 surface: Kinetics of molecular hydrogen formation. Radiation Physics and Chemistry, 2021, vol. 183, pp. 109431. https://doi.org/10.1016/j.radphyschem.2021.109431

7. Agayev T.N., Musayeva Sh.Z., Imanova G.T. Kinetics of formation of molecular hydrogen during the radiolysis of hexane and a mixture of C6H14–H2O on a surface of ZrO2 Nanoparticles. Russian Journal of Physical Chemistry A, 2021, vol. 95, no. 2, pp. 270–272. https://doi.org/10.1134/s0036024421020023

8. Imanova G.T., Agaev T.N., Garibov A.A., Melikova S.Z., Jabarov S.H., Akhundzada H.V. Radiation-thermocatalytic and thermocatalytic properties of n-ZrO2-n-SiO2 systems in the process of obtaining hydrogen from water at different temperatures. Journal of Molecular Structure, 2021, vol. 1241, pp. 130651. https://doi.org/10.1016/j.molstruc.2021.130651

9. Ali I., Imanova G.T., Mbianda X.Y., Alharbi O.M.L. Role of the radiations in water splitting for hydrogen generation. Sustainable Energy Technologies and Assessments, 2022, vol. 51, pp. 101926. https://doi.org/10.1016/j.seta.2021.101926

10. Ali I., Imanova G.T., Albishri H.M., Alshitari W.H., Locatelli M., Siddiqui M.N., Hameed A.M. An ionic-liquid-imprinted nanocomposite adsorbent: Simulation, kinetics and thermodynamic studies of triclosan endocrine disturbing water contaminant removal. Molecules, 2022, vol. 27, no. 17, pp. 5358. https://doi.org/10.3390/molecules27175358

11. Tursunmetova Z.A., Imanova G., Bekpulatov I. Method for low-temperature vacuum-thermal cleaning of surface single crystals Si and GaAs. Journal of Polytechnic, 2022, vol. 25, no. 2, pp. 921–927. https://doi.org/10.2339/politeknik.1119884

12. Ali I., Imanova G., Agayev T., Aliyev A., Alharbi O.M.L., Alsubaie A., Almalki A.S.A. A comparison of hydrogen production by water splitting on the surface of α-, δ- and γ-Al2O3. ChemistrySelect, 2022, vol. 7, no. 34, pp. e202202618. https://doi.org/10.1002/slct.202202618

13. Ali I., Imanova G., Agayev T., Aliyev A., Jabarov S., Albishri H.M., Alshitari W.H., Hameed A.M., Alharbi A. Seawater splitting for hydrogen generation using zirconium and its niobium alloy under gamma radiation. Molecules, 2022, vol. 27, no. 19, pp. 6325. https://doi.org/10.3390/molecules27196325

14. Imran A., Imanova G.Sorbtion: A universal technology for water purification. Advanced Physical Research, 2022, vol. 4, no. 1, pp. 5–9.

15. Agayev T., Imanova G., Aliyev A. Influence of gamma radiation on current density and volt–ampere characteristics of metallic zirconium. International Journal of Modern Physics B, 2022, vol. 36, no. 19, pp. 2250115. https://doi.org/10.1142/s0217979222501156

16. Ali I., Mahmudov H., Imanova G., Suleymanov T., Hameed A.M., Alharbi A. Hydrogen production on nano Al2O3 surface by water splitting using gamma radiation. Journal of Chemical Technology & Biotechnology, 2023, vol. 98. no. 2, pp. 1186–1191. https://doi.org/10.1002/jctb.7322

FRIDRIXS MODELINING SPEKTRI VA REZOLVENTASINI KRAMER USULI YORDAMIDA O‘RGANISH

Husenova Jasmina To‘lqinovna
Buxoro davlat universiteti talabasi
j.t.husenova@buxdu.uz
ORCID 0009-0003-3365-7922
UDK 517.984

Annotatsiya. Ushbu maqolada dastlab Fridrixs modelining spektral xossalari o‘rganilgan ishlar tahlili bayon qilingan. So‘ngra uch no‘malumli parametrli tenglamalar sistemasini yechishning Kramer usuli hamda yechimning ko‘rinishi (mavjud bo‘lgan holda) keltirilgan. $L_2[-\pi;\pi]$ Hilbert fazosida uch o‘lchamli qo‘zg‘alishga ega va Fridrixs modeli deb ataluvchi chiziqli, chegaralangan va o‘z-o‘ziga qo‘shma operator qaralgan. Veyl teoremasidan foydalanib uning muhim spektri aniqlangan. Integral tenglamalar nazaryasi usullari yordamida Fridrixs modeliga mos Fredgolm determinanti qurilgan hamda uning diskret spektri topilgan. O‘rganilayotgan Fridrixs modeli muhim spektrdan chapda joylashgan ko‘pi bilan uchta xos qiymatga ega bo‘lishi, o‘ngda joylashgan xos qiymatlarga ega bo‘lmasligi ko‘rsatilgan. Fridrixs modeliga mos rezolventa operatorini qurishda Kramer usulidan foydalanilgan. Maqolada olingan natijalar panjaradagi uchta zarrachali sistema Hamiltonianiga mos model operator muhim spektrini aniqlashda, uni tashkil qiluvchi kesmalar sonini topishda muhimdir.

Kalit so‘zlar: parametr, tenglamalar sistemasi, Fridrixs modeli, qo‘zg‘alish operatori, muhim va diskret spektrlar, Kramer qoidasi, rezolventa operatori.

INVESTIGATION OF THE SPECTRUM AND RESOLVENT OF THE FRIEDRICHS MODEL USING KRAMER’S METHOD

Annotation. In this article, firstly the analysis of the studies on the spectral properties of the Friedrichs model is presented. Then the Kramer method of solving the system of parametric equations with three unknowns and the view of the solution (if available) are given. In the Hilbert space $L_2[-\pi;\pi]$ a linear, bounded, and self-adjoint operator called the Friedrichs model with three-dimensional perturbation is considered. Its essential spectrum is determined using Weyl's theorem. Using the methods of the theory of integral equations, the Fredholm determinant corresponding to the Friedrichs model is constructed and its discrete spectrum is found. It is shown that the studied Friedrichs model has at most three eigenvalues to the left of the essential spectrum, and has no eigenvalues to the right. Cramer's method is used to construct the resolvent operator corresponding to the Friedrichs model. The results obtained in this paper are important in determining the essential spectrum of the model operator corresponding to the Hamiltonian of the three-particle system on the lattice, and in finding the number of sections that make it up.

Key words: parameter, system of equations, Friedrichs model, perturbation operator,essential and discrete spectrum, Cramer’s method, resolvent operator.

Kirish. Kvant mexanikasi, statistik mexanika va gidrodinamikaning ko‘plab dolzarb masalalari Fridrixs modeli deb ataluvchi operatorlarning spektral xossalalarini, xususan, spektri va rezolventasini o‘rganish masalasiga keltiriladi. Fridrixs modelining spektral xossalari ko‘plab ishlarda tahlil qilingan. Ulardan ba’zilariga to‘xtalamiz. [1] maqolada muhim spektri bo‘shliqga ega Fridrixs modeli qaralgan va muhim spektrdan tashqarida yotuvchi ixtiyoriy intervalda joylashgan xos qiymatlar soni uchun formula topilgan. [2] maqolada ikki o‘lchamli qo‘zg’alishga ega Fridrixs modeli xos qiymatlarining mavjudlik shartlari topilgan hamda uch zarrachali sistemaga mos Hamiltonianning muhim va nuqtali spektrlarini tavsiflashda foydalanilgan. [3] maqolada bir o‘lchamli qo‘zg’alishga ega Friedrichs modellari oilasi yagona xos qiymatga ega bo‘lishi ko‘rsatilgan hamda Fridrixs modeli nol energiyali rezonansga ega yoki nol soni xos qiymat bo‘lsa mos Fredgolm determinanti uchun asimptotik yoyilma olingan. [4] maqolada dispersiya funksiyasi maxsus ko‘rinishga ega va bir nechta nuqtada aynimagan minimumga ega bo‘ladigan hol qaralgan hamda Fridrixs modeli nol energiyali rezonansga yoki nol soni xos qiymat bo‘lishining zaruriy va yetarli shartlari topilgan. [5] maqolada ikki o‘lchamli qo‘zg'alishga ega Fridrixs modelining spektri va sonli tasviri ustma-ust tushishi uchun zaruriy va yetarli shartlar topilgan.

Ushbu maqolada $L_2[-\pi;\pi]$ Hilbert fazosida chiziqli, chegaralangan va o‘z-o‘ziga qo‘shma bo‘lgan hamda uch o‘lchamli qo‘zg‘alishga ega Fridrixs modelining muhim va diskret spektrlari topilgan. Chiziqli integral tenglamalarni yechish usulidan hamda tenglamalar sistemasini yechishning Kramer usulidan foydalanib Fridrixs modeliga mos Fredgolm determinanti va rezolventa operatori qurilgan. Ta'kidlash joizki, tadqiq qilingan Fridrixs modelini panjaradagi ikki zarrachali sistemaga mos Hamiltonian sifatida ham qarash mumkin.

II. Kramer usuli. Ushbu

$$\begin{cases} a_{11}x + a_{12}y + a_{13}z = b_1 \\ a_{21}x + a_{22}y + a_{23}z = b_2 \\ a_{31}x + a_{32}y + a_{33}z = b_3 \end{cases} \qquad (1)$$

uch noma'lumli tenglamalar sistemasini qaraymiz. Bu yerda x, y va z noma'lum sonlar bo'lib, $a_{ij},\ i,j = 1,2,3$ sonlari sistemaning koeffitsientlari hamda b_1, b_2 va b_3 sonlari ozod sonlardir. Agar (1) sistemada barcha ozod sonlar nolga teng bo'lsa, u holda (1) sistemaga bir jinsli sistema deyiladi [6].

Noma'lumlar oldidagi koeffitsientlardan tuzilgan ushbu

$$\Delta := \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}$$

uchinchi tartibli determinantga (1) sistemaning asosiy determinanti deb ataladi.

Quyidagi yordamchi determinantlarni qaraymiz:

$$\Delta_x := \begin{vmatrix} b_1 & a_{12} & a_{13} \\ b_2 & a_{22} & a_{23} \\ b_3 & a_{32} & a_{33} \end{vmatrix};\ \Delta_y := \begin{vmatrix} a_{11} & b_1 & a_{13} \\ a_{21} & b_2 & a_{23} \\ a_{31} & b_3 & a_{33} \end{vmatrix};\ \Delta_z := \begin{vmatrix} a_{11} & a_{12} & b_1 \\ a_{21} & a_{22} & b_2 \\ a_{31} & a_{32} & b_3 \end{vmatrix}$$

Yuqoridagi $\Delta_x, \Delta_y, \Delta_z$ va Δ determinantlarning aniqlanishidan

$$\Delta \cdot x = \Delta_x,\ \ \Delta \cdot y = \Delta_y,\ \Delta \cdot z = \Delta_z \qquad (2)$$

tengliklarni hosil qilamiz.

1-teorema. Faraz qilaylik, (1) sistemada $b_1 = b_2 = b_3 = 0$, ya'ni bir jinsli bo'lsin. Bu sistema noldan farqli yechimga ega bo'lishi uchun uning asosiy determinanti nolga teng, ya'ni $\Delta = 0$ bo'lishi zarur va yetarlidir.

Haqiqatan ham, bir jinsli sistema noldan farqli yechimlarga ega, masalan $x \neq 0$ bo'lsin. U holda (2) tengliklarning birinchi tenglamasi $\Delta \cdot x = 0$ dan $\Delta = 0$ kelib chiqadi.

Teskarisi, ya'ni sistemaning asosiy determinanti $\Delta = 0$ bo'lganda sistema noldan farqli yechimga ega bo'lishini ko'rsatish ham mumkin [6].

III. Fridrixs modeli va uning spektri. $L_2[-\pi;\pi]$ Hilbert fazosida

$$H = H_0 - V_1 - V_2 - V_3 \qquad (3)$$

ko'rinishdagi Fridrixs modeli deb ataluvchi operatorni qaraymiz. Bu yerda H_0 operator $u(\cdot)$ funksiyaga ko'paytirish operatori bo'lib, quyidagi ko'rinishda aniqlanadi:

$$(H_0 f)(x) = u(x)f(x), \quad f \in L_2[-\pi;\pi],$$

V_α operatorlar esa qo'zg'alish operatorlari (integral operatorlar) bo'lib,

$$(V_\alpha f)(x) = v_\alpha(x)\int_{-\pi}^{\pi} v_\alpha(t)f(t)dt,\ \ \alpha = 1,2,3, \qquad f \in L_2[-\pi;\pi]$$

ko'rinishda aniqlangan. Operatorning parameter funksiyalari $u(\cdot)$, $v_1(\cdot)$, $v_2(\cdot)$ hamda $v_3(\cdot)$ funksiyalar $[-\pi;\pi]$ kesmada aniqlangan haqiqiy qiymatli uzluksiz funksiyalar.

Parametr funksiyalarga qo'yilgan bunday shartlarda (3) tenglik bilan aniqlangan H operator $L_2[-\pi;\pi]$ Hilbert fazosidagi chiziqli, chegaralangan va o'z-o'ziga qo'shma operator bo'ladi.

Maqola matnida Hilbert fazosidagi chiziqli, chegaralangan va o'z-o'ziga qo'shma operatorning spektri $\sigma(\cdot)$ kabi, muhim spektri $\sigma_{\text{ess}}(\cdot)$ kabi, diskret spektri esa $\sigma_{\text{disc}}(\cdot)$ kabi belgilangan. Bunda operatorning barcha chekli karrali yakkalangan xos qiymatlari to'plamiga uning diskret spektri deyiladi. Diskret spektrning spektrgacha bo'lgan to'ldiruvchisiga uning muhim spektri deyiladi.

Chekli o'lchamli qo'zg'alishlarda muhim spektrning o'zgarmasligi haqidagi Veyl teoremasiga ko'ra H operatorning muhim spektri H_0 operatorning muhim spektri bilan ustma-ust tushadi [7]. H_0 operator $u(\cdot)$ uzluksiz funksiyaga ko'paytirish operatori bo'lganligi bois, faqat sof muhim spektrga ega. Shunday qilib, quyidagi tengliklar o‘rinlidir:

$$\sigma_{\text{ess}}(H) = \sigma(H_0) = \sigma_{\text{ess}}(H_0) = [m; M].$$

Bu yerda m va M sonlari

$$m := \min_{x\in[-\pi;\pi]} u(x), \qquad M := \min_{x\in[-\pi;\pi]} u(x)$$

tengliklar yordamida aniqlanadi.

H operatorning diskret spekri va rezolventasini aniqlash maqsadida $\mathbb{C}\backslash[m, M]$ sohada regulyar bo‘lgan

$$I_{\alpha\beta}(z) = \int_{-\pi}^{\pi} \frac{v_\alpha(t)\, v_\beta(t)}{u(t) - z} dt, \quad \alpha, \beta = 1,2,3$$

funksiyani hamda har bir $g \in L_2[-\pi; \pi]$ funksiya uchun

$$K_\alpha(g; z) = \int_{-\pi}^{\pi} \frac{v_\alpha(t)\, g(t)}{u(t) - z} dt, \quad \alpha = 1,2,3$$

funksiyani kiritamiz.

H operator uchun xos qiymatga nisbatan tenglamani, ya’ni $Hf = zf$ tenglamani qaraymiz. Oxirgi tenglamani unga ekvivalent bo‘lgan

$$u(x)f(x) - v_1(x)\int_{-\pi}^{\pi} v_1(t)f(t)dt - v_2(x)\int_{-\pi}^{\pi} v_2(t)f(t)dt$$

$$-v_3(x)\int_{-\pi}^{\pi} v_3(t)f(t)dt = zf(x) \qquad (4)$$

ko‘rinishda yozib olamiz.

$z \notin [m; M]$ ekanligidan barcha $x \in [-\pi; \pi]$ nuqtalarda $u(x) - z \neq 0$ bo‘lishi kelib chiqadi. Shu sababli (4) tenglamadan $f(\cdot)$ funksiya uchun quyidagi

$$f(x) = \frac{k_1\, v_1(x) + k_2\, v_2(x) + k_3\, v_3(x)}{u(x) - z} \qquad (5)$$

ifodani topamiz, bu yerda k_1, k_2, k_3 sonlari

$$k_1 = \int_{-\pi}^{\pi} v_1(t)f(t)dt; \quad k_2 = \int_{-\pi}^{\pi} v_2(t)f(t)dt; \quad k_3 = \int_{-\pi}^{\pi} v_3(t)f(t)dt \qquad (6)$$

tengliklar yordamida aniqlanadi.

$f(\cdot)$ uchun topilgan (5) ifodani (6) belgilashlarga qo‘yamiz hamda quyidagilarga ega bo‘lamiz:

$$k_1 = \int_{-\pi}^{\pi} v_1(t)\frac{k_1\, v_1(t) + k_2\, v_2(t) + k_3\, v_3(x)}{u(t) - z} dt = k_1 I_{11}(z) + k_2 I_{12}(z) + k_3 I_{13}(z);$$

$$k_2 = \int_{-\pi}^{\pi} v_2(t)\frac{k_1\, v_1(t) + k_2\, v_2(t) + k_3\, v_3(x)}{u(t) - z} dt = k_1 I_{21}(z) + k_2 I_{22}(z) + k_3 I_{23}(z);$$

$$k_3 = \int_{-\pi}^{\pi} v_3(t)\frac{k_1\, v_1(t) + k_2\, v_2(t) + k_3\, v_3(x)}{u(t) - z} dt = k_1 I_{31}(z) + k_2 I_{32}(z) + k_3 I_{33}(z);$$

yoki

$$\begin{cases} k_1(1 - I_{11}(z)) - k_2 I_{12}(z) - k_3 I_{13}(z) = 0; \\ -k_1 I_{21}(z) + k_2\big(1 - I_{22}(z)\big) - k_3 I_{23}(z) = 0; \\ -k_1 I_{31}(z) - k_2 I_{32}(z) - k_3\big(1 - I_{33}(z)\big) = 0. \end{cases} \qquad (7)$$

Shunday qilib, $z \in \mathbb{C}\backslash[m; M]$ soni H operatorning xos qiymati bo‘lishi uchun (7) tenglamalar sistemasi nolmas yechimga ega bo‘lishi zarur va yetarlidir.

O‘z navbatida (7) tenglamalar sistemasi nolmas yechimga ega bo‘lishi uchun

$$\Delta(z) := \begin{vmatrix} 1 - I_{11}(z) & -I_{12}(z) & -I_{13}(z) \\ -I_{21}(z) & 1 - I_{22}(z) & -I_{23}(z) \\ -I_{31}(z) & -I_{32}(z) & 1 - I_{33}(z) \end{vmatrix} = 0$$

bo‘lishi zarur va yetarlidir.

Shu sababli H operatorning diskret spektri uchun

$$\sigma_{\mathrm{disc}}(H) = \{ z \in \mathbb{C}\backslash[m, M] : \Delta(z) = 0\}$$

tenglik o‘rinli bo‘ladi.

Shunday qilib, quyidagi teoremani hosil qilamiz.

2-teorema. H operatorning spektri uchun

$$\sigma(H) = [m; M] \cup \{ z \in \mathbb{C}\backslash[m, M] : \Delta(z) = 0\}$$

tenglik o‘rinlidir.

Quyidagi lemma H operator xos qiymatlarining soni va joylashuv o‘rnini tavsiflaydi.

1-lemma. H operator m dan chapda joylashgan ko‘pi bilan 3 ta xos qiymatlarga ega. H operator M dan o‘ngda joylashgan xos qiymatlarga ega emas.

Isbot. $\mathcal{N}_H(z)$ orqali H operatorning $z, z \leq \min\sigma_{\mathrm{ess}}(H)$ dan chapda joylashgan xos qiymatlar soning (karraligi bila qo‘shib hisoblaganda) belgilaymiz. Ma’lumki, $\mathrm{rank}(V_1 + V_2 + V_3) = 3.$ Shu sababli, [9] ishdagi 9.3.3-teoremaga ko‘ra

$$\mathcal{N}_{\mathrm{m}}(H_0) - 3 \leq \mathcal{N}_{\mathrm{m}}(H) \leq \mathcal{N}_{\mathrm{m}}(H_0) + 3$$

qo‘sh tengsizlik o‘rinli. Aniqlanishiga ko‘ra $\mathcal{N}_{\mathrm{m}}(H_0) = 0.$ Demak, $\mathcal{N}_{\mathrm{m}}(H) \leq 3,$ ya’ni H operator m dan chapda yotuvchi ko‘pi bilan 3 ta (karraligi bilan hisoblaganda) xos qiymatlarga ega bo‘ladi.

Endi $V_1 + V_2 + V_3$ operatorning musbat aniqlangan ekanligini isbotlaymiz. Haqiqatdan ham, istalgan $f \epsilon L_2[-\pi; \pi]$ element uchun

$$((V_1 + V_2 + V_3)f, f) =$$

$$= \int_{-\pi}^{\pi} \left(v_1(x) \int_{-\pi}^{\pi} v_1(t) f(t) dt + v_2(x) \int_{-\pi}^{\pi} v_2(t) f(t) dt \right.$$

$$\left. + v_3(x) \int_{-\pi}^{\pi} v_3(t) f(t) dt \right) \overline{f(x)} dx$$

$$= \left| \int_{-\pi}^{\pi} v_1(x) f(x) dx \right|^2 + \left| \int_{-\pi}^{\pi} v_2(x) f(x) dx \right|^2 + \left| \int_{-\pi}^{\pi} v_3(x) f(x) dx \right|^2 \geq 0$$

munosabatlar o‘rinlidir. Bundan esa istalgan $z \geq M$ soni va $f \epsilon L_2[-\pi; \pi]$ element uchun

$$\big((H - z)f, f\big) = \big((H_0 - z)f, f\big) - ((V_1 + V_2 + V_3)f, f) < 0$$

munosabatlar o‘rinli ekanligi kelib chiqadi. Oxirgi mulohazadan H operator M dan o‘ngda joylashgan xos qiymatlarga ega emasligini hosil qilamiz.

IV. *H* operatorning rezolventa operatori. Ushbu bo‘limda o‘rganilayotgan H operatorga mos rezolventa operatorini qurish uchun [8] fiksirlangan $z \in \mathbb{C}\backslash\sigma(H)$ soni uchun $f, g \in L_2[-\pi; \pi]$ funksiyalarga nisbatan

$$u(x)f(x) - v_1(x) \int_{-\pi}^{\pi} v_1(t) f(t) dt - v_2(x) \int_{-\pi}^{\pi} v_2(t) f(t) dt$$

$$-v_3(x) \int_{-\pi}^{\pi} v_3(t) f(t) dt - z f(x) = g(x) \qquad (8)$$

tenglamani qaraymiz.

$z \notin [m; M]$ ekanligidan barcha $x \in [-\pi; \pi]$ nuqtalarda $u(x) - z \neq 0$ munosabat bajariladi. Shu sababli (8) tenglamadan $f(\cdot)$ funksiya uchun quyidagi ifodani topamiz:

$$f(x)=\frac{k_1\, v_1(x)+\ k_2\, v_2(x)+k_3\, v_3(x)+g(x)}{u(x)-z}. \qquad (9)$$

Bu yerda k_1, k_2 va k_3 sonlari (6) tengliklar yordamida aniqlangan. $f(\cdot)$ uchun topilgan (9) ifodani (6) belgilashlarga qo‘yamiz hamda

$$k_1=\int_{-\pi}^{\pi} v_1(t)\frac{k_1\, v_1(t)+\ k_2\, v_2(t)+k_3\, v_3(x)+g(t)}{u(t)-z}dt=$$
$$=k_1 I_{11}(z)+\ k_2 I_{12}(z)+k_3 I_{13}(z)+K_1(g;z);$$
$$k_2=\int_{-\pi}^{\pi} v_2(t)\frac{k_1\, v_1(t)+\ k_2\, v_2(t)+k_3\, v_3(x)+g(t)}{u(t)-z}dt$$
$$=\ k_1 I_{21}(z)+\ k_2 I_{22}(z)+k_3 I_{23}(z)+K_2(g;z)$$
$$k_3=\int_{-\pi}^{\pi} v_3(t)\frac{k_1\, v_1(t)+\ k_2\, v_2(t)+k_3\, v_3(x)+g(t)}{u(t)-z}dt$$
$$=\ k_1 I_{31}(z)+\ k_2 I_{32}(z)+k_3 I_{33}(z)+K_3(g;z)$$

yoki

$$\begin{cases}(1-\ I_{11}(z))k_1-I_{12}(z)k_2-I_{13}(z)k_3=K_1(g;z)\\ (1-\ I_{22}(z))k_2-\ I_{21}(z)k_1-I_{23}(z)k_3=K_2(g;z)\\ (1-\ I_{33}(z))k_3-\ I_{31}(z)k_1-I_{32}(z)k_2=K_3(g;z)\end{cases} \qquad (10)$$

tenglamalar sistemasini hosil qilamiz. (10) tenglamalar sistemasidan foydalanib, quyidagi determinantlarni tuzamiz:

$$\Delta_{k_1}(g;z):=\begin{vmatrix}K_1(g;z) & -I_{12}(z) & -I_{13}(z)\\ K_2(g;z) & 1-\ I_{22}(z) & -I_{23}(z)\\ K_3(g;z) & -I_{32}(z) & 1-\ I_{33}(z)\end{vmatrix};$$
$$\Delta_{k_2}(g;z):=\begin{vmatrix}1-\ I_{11}(z) & K_1(g;z) & -I_{13}(z)\\ -\ I_{21}(z) & K_2(g;z) & -I_{23}(z)\\ -\ I_{31}(z) & K_3(g;z) & 1-\ I_{33}(z)\end{vmatrix};$$
$$\Delta_{k_3}(g;z):=\begin{vmatrix}1-\ I_{11}(z) & -I_{12}(z) & K_1(g;z)\\ -\ I_{21}(z) & 1-\ I_{22}(z) & K_2(g;z)\\ -\ I_{31}(z) & -I_{32}(z) & K_3(g;z)\end{vmatrix}$$

Yuqoridagi belgilashlardan va Kramer usulidan foydalanib quyidagi

$$\begin{cases}\Delta(z)\cdot k_1=\Delta_{k_1}(g;z);\\ \Delta(z)\cdot k_2=\Delta_{k_2}(g;z);\\ \Delta(z)\cdot k_3=\Delta_{k_3}(g;z)\end{cases}$$

tenglamalar sistemasiga ega bo‘lamiz. Bu tenglamalar sistemasidan $\Delta(z)\neq 0$ ekanligidan foydalanib, k_1, k_2 va k_3 yechimlarni

$$\begin{cases}k_1=\dfrac{\Delta_{k_1}(g;z)}{\Delta(z)};\\ k_2=\dfrac{\Delta_{k_2}(g;z)}{\Delta(z)};\\ k_3=\dfrac{\Delta_{k_3}(g;z)}{\Delta(z)}\end{cases}$$

tenglik orqali aniqlaymiz.

k_1, k_2 va k_3 uchun topilgan ifodani $f(x)$ uchun topilgan (9) ifodaga qo‘yamiz. Bundan hosil bo‘lgan $f=R_z(H)g$ tenglikning o‘ng tomonida joylashgan ifoda H operatorga mos $R_z(H)$ rezolventa operatorining ta’sir formulasini bildiradi.

Xulosa. Ushbu maqolada uch noma’lumli parametrli chiziqli tenglamalar sistemasini yechishning Kramer usuli bayon qilingan. Panjaradagi ikki zarrachali sistema Hamiltonianiga mos Fridrixs modelining muhim va diskret spektrlari topilgan. Fridrixs modeli uch o‘lchamli qo‘zg’alishga ega bo‘lib, uning Fredgolm determinanti integral tenglamalar nazariyasidan foydalanib, rezolventa operatori esa Kramer usuli yordamida qurilgan. Maqolada olingan natijalar panjaradagi uchta zarrachali sistema Hamiltonianiga mos model operator muhim spektrini aniqlashda, uni tashkil qiluvchi kesmalar sonini topishda [10,11] muhim ahamiyatga ega.

Foydalanilgan adabiyotlar

1. М.Э.Муминов. О выражении числа собственных значений модели Фридрихса. Матем. заметки. 82:1 (2007), С. 75-83.
2. Б.И.Бахронов, Т.Х.Расулов, М.Рехман. Условия существования собственных значений трехчастичного решетчатого модельного гамильтониана. Известия вузов. Математика. 7 (2023), С. 3-12.
3. S.Albeverio, S.N.Lakaev, Z.I.Muminov. The threshold effects for a family of Friedrichs models under rank one perturbations. J. Math. Anal. Appl., 330 (2007), P. 1151-1168.
4. Т.Х.Расулов. Асимптотика дискретного спектра одного модельного оператора, ассоциированного с системой трех частиц на решетке. Теоретическая и математическая физика. 163:1 (2010), С. 34-44.
5. B.I.Bahronov, T.H.Rasulov. On the numerical range of a Friedrichs model with rank two perturbation: threshold analysis technique. AIP Conf. Proc. 2764 (2024), 030007-1 - 030007-10.
6. А.Г.Курош. Олий алгебра курси. Тошкент, Ўқитувчи, 1976.
7. М.Рид, Б. Саймон, Методы современной математической физики. Т. 4. Анализ операторов, Москва: Мир, 1982.
8. J.I.Abdullayev, R.N.G‘anixo‘jayev, M.H.Shermatov, O.I.Egamberdiyev. Funksional analiz va integral tenglamalar. Darslik, Toshkent, ELPRESS, 2013.
9. М.Ш. Бирман, М.З. Саломяк. Спектральная теория самосопряженных операторов в гильбертовом пространстве. Ленинград, Изд. Ленинградского университета. (1980), 264 с.
10. Т.Х. Расулов, З.Д. Расулова. Спектр одного трехчастичного модельного оператора на решетке с нелокальными потенциалами. Сиб. электрон. матем. изв., 12 (2015), С. 168-184.
11. T.H. Rasulov, Z.D. Rasulova. Essential and discrete spectrum of a three-particle lattice Hamiltonian with non-local potentials. Nanosystems: physics, chemistry, mathematics. 5:3 (2014), pp. 327-342.

YANGI USUL BILAN SINTEZ QILINGAN MELAMIN TAHLILI

Muminov Baxriddin Saidumarovich,
Toshkent kimyo-texnologiya ilmiy tadqiqot instituti, doktorant
baxriddin-muminov@mail.ru
ORCID- 0000-0002-1632-6860
Karimov Mas'ud Ubaydulla o'g'li,
Toshkent kimyo-texnologiya ilmiy tadqiqot instituti, t.f.d, professor
masudkarimov27@gmail.com
ORCID 0000-0001-5063-0914
Djalilov Abdulahat Turapovich
Toshkent kimyo-texnologiya ilmiy tadqiqot instituti,
O'zRFA akademigi, k.f.d., professor
gup_tniixt@mail.ru
ORCID 0000-0002-1949-5790
UDK: 661.579

Annotatsiya: Melamin plastmassa, bo'yoq, mebel, chinni idishlar ishlab chiqarishda eng muhim xomashyodir. Bu sanoat mahsulotlari ko'p sohalarda qo'llanilishi va turli xil tuzilishga egaligi bilan boshqa sanoat mahsulotlaridan farq qiladi. Melamin ko'p sohalarda foydalanishga ega bo'lgan asosiy organik kimyoviy oraliq mahsulotdir. Melaminning asl dekorativ xususiyatlariga ega ekanligi materiallarni bardoshli va chidamli qiladi. Melaminning bunday xususiyatlarga egaligi va keng qo'llanilishi unga bo'lgan talabning o'sishiga olib keladi. Bugungi kunda melamin sintezi baland temperatura va yuqori bosimlarda yoki katalizatorlar ishtirokida amalga oshiriladi. Bu esa texnologiyani murakkablashtiradi. Bu maqolada melamin olish texnologiyasi elektroliz usulidan foydalanib o'rganilgan. Tajriba qurilmasining xarakteristikalari va sxematik tuzulishi keltirilgan. Tajribada olingan moddani YaMR-spektroskopiya va IQ-spektral usulda o'rganish natijalari tahlil qilingan. Elektrolizatorda sintez qilingan melaminning elektrodlar orasidagi tok zichligiga va vaqtga bog'liqligi o'rganilgan.

Kalit so'zlar: elektroliz, elektrolit vanna, karbamid, melamin, ammoniy xlorid, elektr tok manbayi, YaMR-spektr, IQ-spektr.

ANALYSIS OF MELAMINE SYNTHESIZED BY A NEW METHOD

Abstract: Melamine is the most important raw material in the production of plastic, paint, furniture, and porcelain. These industrial products differ from other industrial products in that they are used in many fields and have different structures. Melamine is a key organic chemical intermediate with many industrial uses. The fact that melamine has original decorative properties makes the material durable and resistant. The fact that melamine has such properties and its wide use leads to an increase in its demand. Today, melamine synthesis is carried out at high temperatures and high pressures or in the presence of catalysts. This complicates the technology. In this article, the technology of obtaining melamine using the electrolysis method is studied. The characteristics and schematic structure of the experimental device are presented. The results of NMR-spectroscopy and IR-spectral methods of studying the substance obtained in the experiment were analyzed. The dependence of the melamine synthesized in the electrolyzer on the current density and time between the electrodes was studied.

Key words: electrolysis, electrolyte bath, urea, melamine, ammonium chloride, electric current source, NMR spectrum, IR spectrum.

Kirish. Melamin azotli geterosiklik organik birikmadir. U muhim azotli geterosiklik organik kimyoviy xomashyo hisoblanadi. Melamin ko'p sohalarda foydalanishga ega bo'lgan asosiy organik kimyoviy oraliq mahsulotdir [1,2]. Melamin deyarli barcha sohalarda ishlatiladi. Uning asl dekorativ xususiyatlariga ega ekanligi materiallarni bardoshli va chidamli qiladi [3]. Melaminning bunday xususiyatlarga egaligi va keng qo'llanilishi unga bo'lgan talabning o'sishiga olib keladi.

1-rasm. Melamin va melamin asosida ishlab chiqarilgan mahsulotlar.

Melaminni tajribada birinchi marta Li Bishi 1834-yilda disiyandiamid usuli bilan sintez qilgan edi. Shundan beri ikki asr davomida melamin laboratoriya va sanoatda bir qancha usullar yordamida sintez qilindi [4,5]. Bu usullarning ba’zilari yuqori bosimda, ba’zilari katalizator ishtirokida, ba’zilari esa atrof-muhitga zararli bo‘lgan usullarda sintez qilindi. Melamin sintezining ikkita mashhur usuli - disiyandiamid usuli va karbamid usulidir.

Disiyandiamid usuli: disiyandiamid usulida disiyandiamid yuqori haroratlarda (taxminan 150-200°C), odatda natriy gidroksid ishtirokida formaldegid bilan reaksiyaga kirishadi. Reaksiya bir necha kondensatsiya bosqichlari orqali o‘tadi va melamin hosil bo‘lishiga olib keladi [6,7].

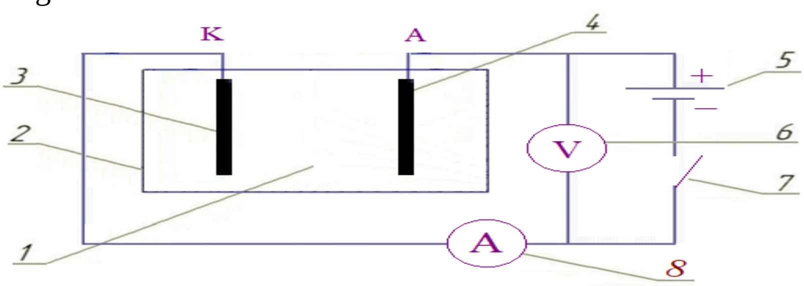
Karbamid usuli: karbamid usulida karbamid disiyandiamid usuliga o‘xshash sharoitlarda formaldegid bilan reaksiyaga kirishadi.

Melamin hosil bo‘lish mexanizmi disiyandiamid yoki karbamidning amin guruhlari va formaldegid molekulalari o‘rtasidagi kondensatsiya reaksiyalarini o‘z ichiga oladi. Ushbu kondensatsiya reaksiyalari triazin halqalarining shakllanishiga olib keladi, ular keyinchalik melamin molekulasini hosil qilish uchun bir-biriga bog‘lanadi [8]. Ishqoriy katalizatorning mavjudligi kondensatsiya reaksiyalarini osonlashtirishga yordam beradi va yuqori haroratlarda melamin hosil bo‘lishiga yordam beradi. Ammo organik sintezning rivojlanishi hisobiga yangi usullar paydo bo‘lmoqda. Bu usullardan biri elektrolizdir.

Elektroliz turli xil kimyoviy sintez jarayonlarida, shu jumladan, melamin va uning hosilalari sintezida qo‘llash mumkin bo‘lgan usuldir. Elektrokimyoviy usullar an’anaviy reagentlarga asoslangan reaksiyalarga nisbatan afzalliklarni taklif qiladi, masalan, yuqori funksional guruhga chidamlilik, yumshoq sharoitlar va barqarorlik. Ushbu usullar, ayniqsa, murakkab molekula sintezi uchun foydalidir va samarali ravishda kengaytirilishi mumkin.

Tadqiqot metodologiyasi. Organik sintezda elektroliz usuli organik birikmalarni sintez qiladigan yoki parchalaydigan kimyoviy reaksiyalarni amalga oshirish uchun elektr energiyasidan foydalanishni o‘z ichiga oladi [9,10]. Bizga elektrolizator, o‘zgarmas elektr toki, elektrodlar, ampermetr va voltimetr kerak bo‘ladi.

Elektroliz usulidan foydalanib melamin olish texnologiyasining sxematik tuzilishi 2-rasmda keltirilgan.



2-rasm. Qurilmaning tuzilishi:

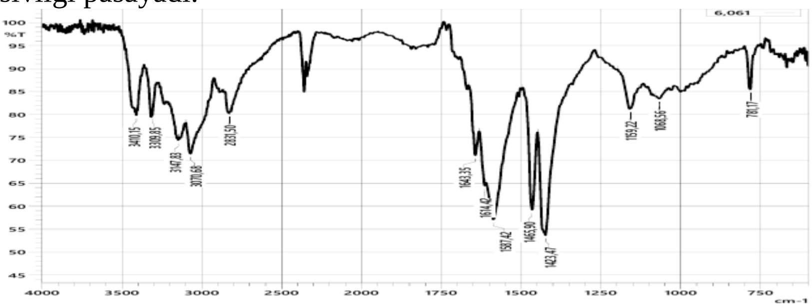
1- eritma (reaksiya boradigan hudud); 2– elektrolit vanna; 3-katod; 4-anod; 5-tok manbayi; 6- voltmetr; 7- elektr zanjir kaliti; 8- ampermetr.

Elektroliz o‘zgarmas elektr tokida ishlagani uchun biz avvalo o‘zgaruvchan elektr tokini o‘zgarmas elektr tokiga aylantiramiz. Anod elektrodni tok manbayining musbat qutbga, katodni manfiy qutbga metall simlar orqali ulaymiz.

Katod va anod sifatida grafit elektroddan foydalandik. Grafit elektr oʻtkazuvchanligi yaxshi va ishlov berish oson boʻlgan materialdir. Karbamid va ammoniy xloridni suv bilan aralashtirib elektrolizator (elektrolitik vanna)ga quyiladi. Elektr zanjir kaliti ulanganda elektrolitdan tok oʻta boshlaydi. Turli tok zichliklarida modda hosil boʻlish jarayoni oʻrganildi. Ampermetr va voltimetr bilan tok kuchi va kuchlanish oʻlchanib borildi.

Natijalar va muhokama. Elektroliz usuli yordamida sintez qilingan moddaning Infraqizil -Spektroskopiya va Yadro Magnit Rezonans analizlari olindi.

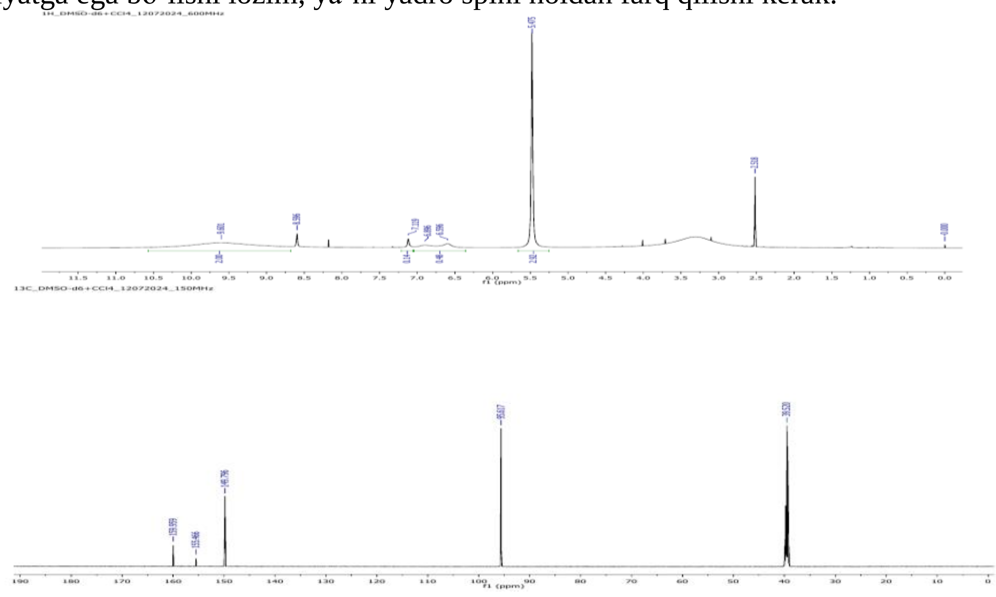
IQ-spektroskopik tahlil. Reaksiya natijasida olingan moddaning IQ-spektroskopik tahlili Shimadzu IR Tracer-100 (Yaponiyada ishlab chiqarilgan) asbobida olib borildi. Modda tarkibidagi turli funksional guruhlarning mavjudligini 400-4000 sm^{-1} chastota oraligʻida oʻrganildi [11]. Bu usul yordamida oʻrganilayotgan modda tarkibidagi funksional guruhlar mavjudligini aniqlashda keng foydalaniladi. Bu guruhlarning miqdori kamayishi bilan ularning intensivligi pasayadi.



3-rasm. Sintez qilingan melaminning IQ spektri.

3-rasmda sintez qilingan moddaning IQ-spektri keltirilgan. IQ-spektrning 3410 sm^{-1} va 3309 sm^{-1} sohasida melaminning N-H birlamchi amin guruhlarining valent tebranishlarini koʻrishimiz mumkin. Shu oraliqda joylashgan NH bogʻlarining valent tebranishlari mustaqil holatda intensiv va tor polosoga ega boʻladi. 1,3,5 triazin halqasining tebranishlari C-N, C=N esa 1423, 1465, 1587 va 1614 sm^{-1} sohada koʻrinmoqda. Bu tahlil natijalari melaminning hosil boʻlganini tasdiqlaydi.

Yadro Magnit Rezonans – spektroskopiya usuli. Bu usul moddaning radiochastotali nurlanish bilan oʻzaro taʼsirini oʻrganuvchi radiospektroskopik usullarga tegishli boʻlib, magnit-rezonans hodisasiga, tashqi magnitdagi atom yadrolarining magnit energiya darajalari orasidagi rezonansli oʻtishlar hodisasiga asoslanadi [12,13]. YMR usuli bilan tadqiq qilinadigan modda diamagnit xususiyatga ega boʻlishi va atomlarining yadrosi magnit xususiyatga ega boʻlishi lozim, yaʼni yadro spini noldan farq qilishi kerak.



4-rasm. Elektroliz usuli bilan sintez qilingan melaminning YaMR spektri

YaMR spektrlari JNM-ECZ600R spektrometrida (Yaponiya) qayd etilgan. ^{1}H

uchun DMSO-d6+CCl_4 eritmalarida 600 MHz chastotada va ^{13}C uchun DMSO-d6+CCl_4 150 MHz chastotada aniqlangan. ^1H YMR spektrlarida standart sifatida TMC (0 ppm) ishlatilgan. ^1H NMR va ^{13}C NMR spektral tahlili organik birikmalarning tuzilishini oʻrganish uchun ishlatiladigan ikkita muhim analitik usuldir. Melamin choʻqqisi 5,47, 3.4 va 2.5 ppm da koʻrindi, chunki NH2 guruhlarida hal qiluvchi proton bilan tez proton almashinuvi sodir boʻladi. ^{13}C NMR spektrida 149.8 va 159.9 ppm da yuqori signallar melaminning triazin qismiga tegishli boʻlishi mumkin.

Olingan spektr tahlil natijalari sintez qilingan melaminning tuzilishini tasdiqlaydi.

Xulosa va takliflar. Organik moddalarni olish uchun elektroliz usullari xilma-xildir. Melamin sintez qilishda an’anaviy usuldan farqli, elektroliz usulidan foydalanganimizda bir qancha afzalliklarga ega boʻldik. Bunda bizga yuqori temperatura yoki yuqori bosim kerak boʻlmaydi. Bir necha bosqichli murakkab laboratoriya texnologiyasi ham ishlatmaymiz. Shuning uchun elektroliz usuli bilan boshqa organik moddalar sintez qilishda, shu jumladan, melamin sintezida foydalanish bizga iqtisodiy samara beradi.

Foydalanilgan adabiyotlar

1. Правдин А.И. Синтез меламина. основные способы аппаратурного оформления производства. Успехи в химии и химической технологии. Том XXII. 2018. N2 (82). С. 28-31.
2. Дамаскин Б.Б. Электрохимия: учебное пособие/ Б.Б. Дамаскин, О.А. Петрий, Г.А. Цирлина. – 2-е изд., испр. и перераб. СПб.: Лань, 2015. 672 с.
3. Derek Pletcher, Robert A. Green, and Richard C. D. Brown. Flow Electrolysis Cells for the Synthetic Organic Chemistry Laboratory. Chemical Reviews. American Chemical Society. 2018, 118, 4573−459p. DOI: 10.1021/acs.chemrev.7b00360
4. Muminov B.S., Karimov M.U., Djalilov A.T., Turaev Kh.Kh., Umbarov I.A., Toshtemirov A. E., Uralov N. Production of melamine using the electrolysis method. International Scientific Research Forum in honor of 90th anniversary of Al-Farabi Kazakh National University 26-28 September, 2024. 29-34 p.
5. Пучкова Л.Н., Шаяхметова А.И. Разработка технологии производства полиаминов по бесхлорному методу. Булатовские чтения. Сбор. статей – 2018. – 259 с.
6. Муминов Б.С., Каримов М.У., Джалилов А.Т. Использование метода электролиза при синтезе органических веществ (на примере синтеза этилендиамина). Universum: Технические науки. Выпуск: 8(125). Август 2024. Часть 3. Москва 2024. 40-44с. Doi:10.32743/UniTech.2024.125.8.18037.
7. Каримов М.У., Джалилов А.Т., Муминов Б.С., Тураев Х.Х., Умбаров И.А., Тоштемиров А.Е., Уралов Н. Преимущества метода электролиза при синтезе меламина. International Scientific Research Forum in honor of 90th anniversary of Al-Farabi Kazakh National University 26-28 September, 2024. 135-136 p.
8. Muminov B.S., Karimov M.U., Djalilov A.T. Advantage of melamine synthesis by electrolysis method. International conference on interdisciplinary science. universalconference.us Volume 01, Issue 06, AQSH. Sanfransisko.2024y. 244-245s.
9. Ismoilov. F.S., Karimov M.U., Djalilov A.T., Ismailova X.Dj., // Влияние полученного на основе конденсасионных продуктов меламин-сулфонат-формалдегида суперпластификатора на физико-механические свойства сементных композиции. // Универсум технические науки 4 (109), 2023г.
10. Etilendiamin sintezida elektrolizdan foydalanish. Muminov B.S., Karimov M.U., Djalilov A.T. Journal of universal science research (JUSR). ISSN (E): 2181-4570. ResearchBib Impact Factor: 6,4 /23.09.2023. 317-323s.
11. N. Kanagathara, N. Sivakumar, K. Gayathri, P. Krishnan, N. G. Renganathan, S. Gunasekaran, G. Anbalagan. Growth and Characterization of 2, 4, 6 Triamino-1, 3, 5 Triazine – An Organic Single Crystal. Proc Indian Natn Sci Acad 79 No. 3 September 2013 pp. 467-472.
12. Muminov B.S., Karimov M.U., Djalilov A.T., Ismoilov F.S. Elektroliz usulidan foydalanib etilendiamin olish. “Oʻzmu xabarlari” tabiiy fanlar yoʻnalishi. ISSN 2181-7324. –Toshkent, 2024. 3/2 son. 406-409-b.
13. Muminov B.S., Karimov M.U., Djalilov A.T. Use of the electrolysis method in the synthesis of organic substances. “Tabiiy birikmalar kimyosining hozirgi muammolari” maszusidagi xalqaro ilmiy-amaliy konferensiya. OʻMKI. –Toshkent, 2024 -yil, 19-20 sentyabr.

2-IZOPROPIL-5-METILFENIL 2-XLORATSETAT SINTEZI
SYNTHESIS OF THE 2-ISOPROPYL-5-METHYLPHENYL 2-CHLORACETATE

Normurodov Ilyos O‘rolovich
Toshkent kimyo-texnologiya instituti Shahrisabz filiali o‘qituvchisi
ilyosnormurodov50@gmail.com,
Choriyev Azimjon Uralovich
Qarshi davlat universiteti “Organik kimyo” kafedrasi dotsenti,
azimjon-organik@mail.ru,
ORCID 0000-0002-7050-8665
Abdushukurov Anvar Kabirovich
Mirzo Ulug‘bek nomidagi O‘zbekiston Milliy universiteti
“Organik kimyo” kafedrasi professori,
abdushukurov-ximik@mail.ru,
ORCID 0000-0003-0879-9614;
Ro‘zimurodova Manzura Rustam qizi
Qarshi davlat universiteti talabasi,
azimjon-organik@mail.ru,
UDK: 547.297

Annotatsiya. Maqolada 2-izopropil-5-metilfenil 2-xloratsetatni hosil qilish imkoniyatlari tahliliy va eksperimental bayon etildi. Unda reaksiyaning borish sharoitiga urg‘u berildi. Adabiyotlar tahlili natijasida timolning kimyoviy xossalari va u asosida olib boriladigan reaksiyalarning xususiyatlari o‘rganilgan. Tadqiqotning maqsadi O-xloratsetiltimol sintez qilishning qulay usulini ishlab chiqish va O-xloratsetillash reaksiyasining mexanizmini taklif qilishdan iborat. Timolni xloratsetillash reaksiyasi katalizatorsiz dixloretan eritmasida olib borilganda faqat O-atsillash reaksiyasi borib, 2-izopropil-5-metilfenil 2-xloratsetat 95% unum bilan hosil bo‘ladi. Sintez qilingan moddalarning tarkibi va tuzilishi spektroskopik asoslandi. Yuqoridagi reaksiya dixloretanda va katalizator ishtirokisiz borganligi uchun atsil kationi (ion juftlardagi) hosil bo‘lmaydi. Shuning uchun bu reaksiya xloratsetilxlorid molekulasi karbonil guruhida nukleofil almashinish tarzida boradi va murakkab efir mahsuloti hosil bo‘ladi. Nukleofil reagent vazifasini esa timol molekulalaridagi kislorod atomi bajaradi. Xloratsetillash reaksiya mahsulotining yupqa qatlam xromatografiyasi o‘rganildi va ularning tarkibi guvoh moddalar yordamida tasdiqlandi. 2-Izopropil-5-metilfenil 2-xloratsetatning fizikaviy doimiyliklari aniqlandi, tarkibi va tuzilishi yupqa qatlam xromatografiya, IQ- va YaMR - spektrlari yordamida tasdiqlandi.

Tayanch so‘zlar: timol, xloratsetilxlorid, xloratsetillash, 2-izopropil-5-metilfenil 2-xloratsetat, nukleofil almashinish, dixloretan, xromatografiya, spektroskopiya.

Abstract. The article describes analytically and experimentally the possibilities of creating 2-isopropyl-5-methylphenyl 2-chloroacetate. It emphasized the conditions of the reaction. As a result of the literature analysis, the chemical properties of thymol and the characteristics of the reactions carried out on its basis were studied. The purpose of the study is to develop a convenient method for the synthesis of O-chloroacetylthymol and to propose the mechanism of the O-chloroacetylation reaction. When the thymol chloroacetylation reaction is carried out in a dichloroethane solution without a catalyst, only the O-acylation reaction occurs, and 2-isopropyl-5-methylphenyl 2-chloroacetate is formed with a yield of 95%. The composition and structure of the synthesized substances were confirmed spectroscopically. Since the above reaction takes place in dichloroethane and without the participation of a catalyst, acyl cations (in ion pairs) are not formed. Therefore, this reaction takes place in the form of nucleophilic exchange in the carbonyl group of the chloroacetyl chloride molecule, and a complex ether product is formed. The oxygen atom in thymol molecules acts as a nucleophilic reagent. Thin layer chromatography of the chloroacetylation reaction products was studied and their composition was confirmed with the help of reference substances. The physical constants of 2-Isopropyl-5-methylphenyl 2-chloroacetate were determined, the composition and structure were confirmed using thin layer chromatography, IR and NMR spectra.

Keywords: tymole, chloroacetylchloride, chloroacetylation,2-isopropyl-5-methylphenyl 2-chloroacetate, nucleophilic substitution, dichloroethane, chromatography, spectroscopy.

Kirish. Aromatik birikmalarni atsillash reaksiyalari bo‘yicha olib borilayotgan ilmiy tadqiqotlar hozirgi davrda ham organik kimyoning jadal sur’atlar bilan rivojlanib borayotgan muhim yo‘nalishlaridan biri hisoblanadi. Aromatik halqa tutgan turli funksional guruhlarning va atsillovchi agentlarning kimyoviy tuzilishiga hamda katalizator tabiatiga bog‘liqli holda reaksiya jarayonlarining turli yo‘nalish bo‘yicha borishi xloratsetillash reaksiyalarida ham ko‘rinadi va bu reaksiyalarni sistematik tarzda o‘rganishning nazariy va amaliy tomondan o‘ta muhim va dolzarb ekanligini ko‘rsatadi [1-4].

Tadqiqot metodologiyasi. Reaksiya mahsulotining yupqa qavatli xromatografiyasi quyidagi sharoitda, kolonka uzunligi 25 sm silufol plastinkada o‘tkazildi. Elyuent sifatida izooktan- etilatsetat 9:1 nisbatli eritmasi ishlatildi. Moddalarning tarkibini hisoblash aniq usul [5] bo‘yicha olib borildi. Moddalarni tahlil qilish avval sintez qilingan aniq moddalarni ta’sir ettirish bilan aniqlandi.

2-Izopropil-5-metilfenil 2-xloratsetatning IQ- spektri yupqa qatlamda vazelin moyida 400-4000 sm^{-1} sohalarda olindi. YaMR-spektr JEOL-400 MGs (erituvchi CCl_4, CD_3Cl) uskunasida TMS ichki standartlaridan foydalanib olingan. Spektr ma’lumotlari 1-, 2- va 3- rasmlarda keltirilgan.

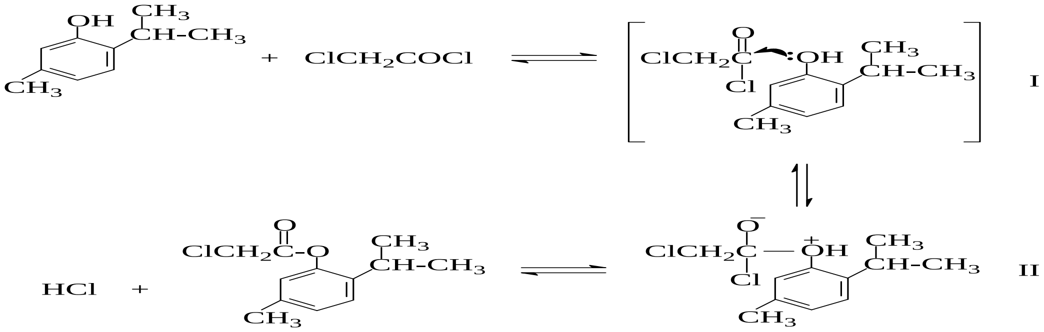
Tajriba qismi. Timolni xloratsetillash. Qaytarma sovitkichga vodorod xlorid chiqishi uchun moslashgan naycha o‘rnatilgan tubi dumaloq kolbada 0,01 mol timol, 30 ml dixloretanda eritildi, ustiga 0,01 mol xloratsetilxlorid solindi va 20 soat qaynatildi. Vodorod xlorid chiqishi to‘xtagandan so‘ng, aralashma ishqorli suvda yuvilib, dixloretanda ekstraksiya qilindi, $CaCl_2$ bilan quritildi. Dixloretan oddiy sharoitda, modda esa vakuumda 136^0C / 30 mm. sim. ust. da haydaldi. Mahsulot unumi 95%.

Reaksiya mahsulotlarining yupqa qatlam xromatografiyasi Silufol-254 plastinkasida (xloroform-metanol 20:1 sistema, UB - ochiltirgich) o‘tkazildi. Sintez qilingan moddalarning tuzilishini o‘rganish maqsadida ularni SF-26 spektrometrida YaMR-spektri, Specord IR-71 spektrometrida kyuvetaning qalinligi 10 mm bo‘lgan moslamada KBr tabletkasi ko‘rinishida 400-4000 sm-1 sohada IQ-spektri olindi.

Sintez jarayonida hosil bo‘lgan moddalarning, haqiqatdan ham hosil bo‘lganligiga ishonch hosil qilish uchun fizik-kimyoviy usullarga murojaat qilingan. Dastlabki tekshirish ishlarida yupqa qatlamli xromatografiyasi o‘rganildi. Moddalarni tozalash, ularni bir-biridan ajratish va aniqlash usullaridan biri xromatografik analiz usuli hisoblanadi. YQX silufolda turli erituvchilarda tekshirib ko‘rildi. Erituvchilar xuddi organik moddalar kabi molekulalarning qanchalik qutbli bo‘lishiga qarab, shunchalik kuchli adsorbsiyalanadi [6]. Ko‘pincha ikkita yoki uchta turli qutbli erituvchi sistemalari yaxshi ajralishni ta’minlaydi. Erituvchi tanlash uchun mikrosirkulyar usuldan foydalanildi. Mikrosirkulyar uslubda xromatografiya plastinkasiga odatdagidek, 4 sm masofada aralashmaning bir necha namunalari qo‘yiladi. So‘ngra ingichka kapilyar bilan modda aralashmasi qo‘yilgan har bir nuqtaning markaziga diametri 2 sm nam halqa hosil qilish uchun yetarli miqdorda tekshirilayotgan erituvchi yoki erituvchi sistemasi qo‘yiladi [7]. Plastinka quritildi va yod yordamida ochildi. Bunda aralashmaning ayrim komponentlari umumiy markazga ega bo‘lgan halqalar ko‘rinishida aniqlandi. Moddalar ajralishi yaxshi bo‘lgan sistemalar tanlab olindi. Bunda quyidagi erituvchi sistemalari tekshirildi: geksan va atseton (2:1; 5:2; 4:1; 7:3; 9:1), xloroform va efir (5:2), tetraxlormetan va efir (3:2), geptan va efir (1:4), xloroform va metanol (50:4), geptan va atseton (98:2), etanol va suv (1:1), geksan va sirka kislota (20:3; 49:10,5), geksan va efir (1:1; 4:1). Erituvchi sistemalari tayyorlangandan so‘ng silufolda boshlanish va tugash chiziqlari chizildi. Boshlanish chizig‘iga reaksiyaga kirishgan ikki boshlang‘ich moddalar va ular reaksiyasi natijasida hosil bo‘lgan yangi modda kapilyar yordamida tomizildi. So‘ngra kolonkaga joylashtirilib, erituvchi sistemasi tugash chizig‘igacha shimilishi kutildi. Yodli kolonkada ochiltirildi va Rf qiymatlari aniqlandi.

Natijalar va muhokama. Timolni xloratsetillash reaksiyasi katalizatorsiz dixloretan eritmasida olib borilganda faqat O-atsillash reaksiyasi borib, 2-izopropil-5-metilfenil 2-

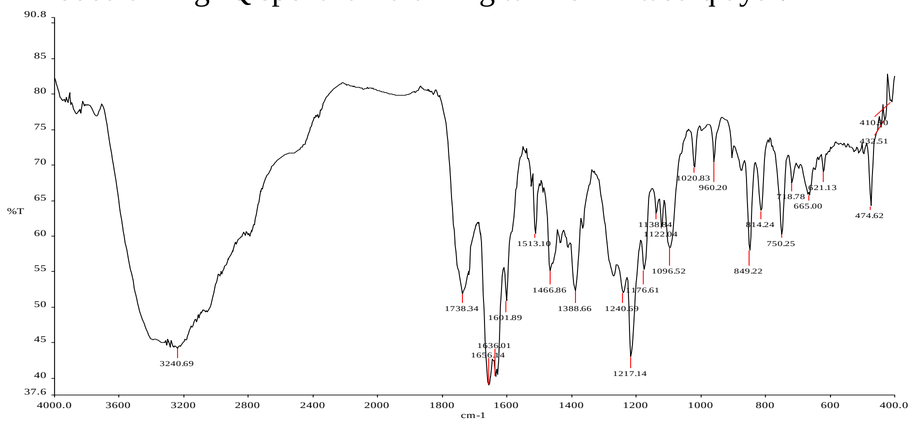
xloratsetat 95% unum bilan hosil bo‘ladi. 2-Izopropil-5-metilfenil 2-xloratsetat hosil bo‘lish mexanizmini quyidagicha tasvirlash mumkin:



Timol va xloratsetilxloridning reaksiyasi vaqtida xloratsetilxlorid molekulasida elektron zichlik elektromanfiy kislorod tomon siljigan bo‘ladi va kislorod qisman manfiy zaryadga ega bo‘ladi. Elektromanfiy xlor va kislorod atomlarining ta’siri natijasida uglerod atomi esa qisman musbat zaryadga ega bo‘ladi va timol molekulasidagi gidroksil guruhning juft elektronlari bilan ta’sirlashib, I kompleksni hosil qiladi. Reaksiya davomida kislorod va uglerod o‘rtasida valent bog‘i hosil bo‘lib, II kompleks hosil bo‘ladi va undan vodorod xlorid bilan reaksiya mahsuloti ajralib chiqadi [8].

Ma’lumki, aromatik birikmalarni aproton katalizatorlar ishtirokida galoid alkillar yoki atsilgalogenidlar bilan alkillash va atsillash reaksiyalari ionli mexanizmda boradigan reaksiyalar bo‘lib, bu reaksiyalar qutbli erituvchilarda yaxshi boradi. Yuqoridagi reaksiya dixloretanda va katalizator ishtirokisiz borganligi uchun atsil kationi (ion juftlardagi) hosil bo‘lmaydi. Shuning uchun bu reaksiya xloratsetilxlorid molekulasi karbonil guruhida nukleofil almashinish tarzida boradi va murakkab efir mahsuloti hosil bo‘ladi. Nukleofil reagent vazifasini esa timol molekulalaridagi kislorod atomi bajaradi [9].

IQ- spektr tahlili. Timolni xloratsetillash mahsuloti va xloratsetil mahsulot asosida sintez qilingan moddalarning IQ spektrlari ularning tuzilishini tasdiqlaydi.

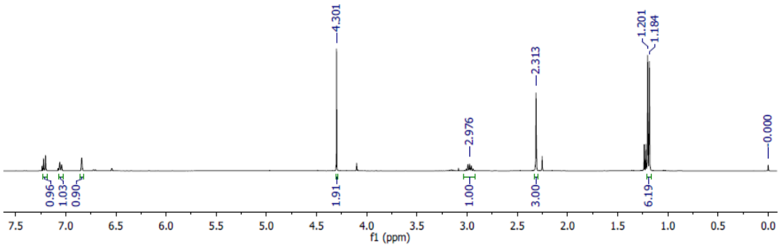


1-Rasm. 2-Izopropil-5-metilfenil 2-xloratsetatning IQ - spektri

1-rasmda keltirilgan 2-izopropil-5-metilfenil 2-xloratsetatning IQ spektrida bu birikmada aromatik halqa, karbonil guruhi, C-Cl, C-O-C, -CH_2CO- bog‘larning, halqadagi almashinishi tiplarini ko‘rsatuvchi yutilish sohalarini ko‘rsatadi. 1217-1096 sm^{-1} sohada C-O-C atsetoksi guruhining valent tebranishi, 3240 sm^{-1} sohada aromatik birikmadagi CH guruhining valent tebranishi kuzatildi. Spektr para-almashgan benzol halqasiga mos keladi. 1636-1466 sm^{-1} sohada para-almashgan benzol halqasining valent tebranishi, 1096 va 960 sm^{-1} da benzol halqasining CH guruhining yassi deformatsion tebranishi, 849 sm^{-1} da para-almashgan benzol halqasining yassi bo‘lmagan deformatsion tebranishi namoyon bo‘ldi. 1738 sm^{-1} da atsetoksi guruhidagi C = O bog‘ining valent tebranishi, 1636-1513 sm^{-1} o‘tish sohasida esa aromatik halqa skeletining tebranishida yutilish chiziqlari paydo bo‘ldi. Metilen guruhidagi C-H bog‘ining deformatsion tebranishi (δC-H) 1388 sm^{-1} intensiv sohada nur yutilishi kuzatildi. Monoxloralmashgan alkil- va arilgalogenidlarda C-

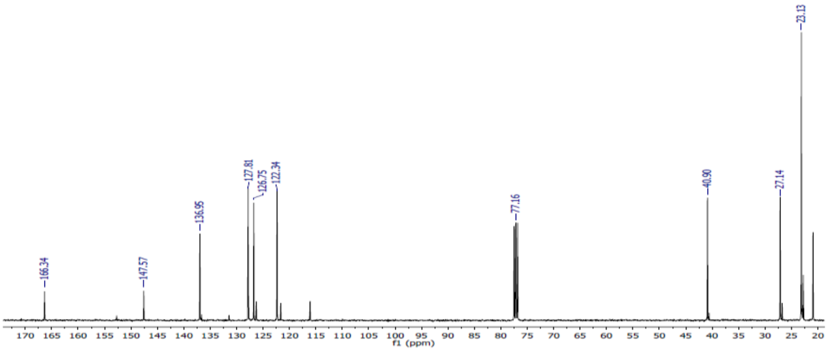
CI bog‘ining valent tebranishlari 750-665 sm^{-1} sohada intensivligi o‘rtacha yutilish chizig‘i hosil qildi.

YMR spektr tahlili. 2-Izopropil-5-metilfenil 2-xloratsetatning ^{1}H-YaMR – spektrida metil guruhi 1.2 m.u. da, metilen guruhidagi vodorod protonlari 4.3 m.u. da singlet kimyoviy siljish, aromatik halqadagi vodorod protonlari esa 7.1 m.u. da kimyoviy siljish namoyon qiladi. Chunki benzol halqasida va metilen guruhida joylashgan vodorod protonlarining kimyoviy siljishi bir-biridan farq qiladi [10].



2-rasm. 2-Izopropil-5-metilfenil 2-xloratsetatning ^{1}H-YMR - spektri

3-Rasmda keltirilgan 2-izopropil-5-metilfenil 2-xloratsetatning C-H guruh ^{13}C-YMR- spektrida dublet signali hosil qiladi, uning konstantasi JCH-127 Gs ga teng. CH_3-metil guruhlaridan 23 m.h gacha, CH_2-metilen guruhidan 27 m.h. gacha, CH-metin guruhidan 40 m.h. chegarasida signallar kuzatildi. Benzol halqasiga o‘rinbosarlarning kiritilishi uglerod kimyoviy siljishini 122-147 m.h. gacha o‘zgartiradi. Monokarbon kislotalar uchun karborsil guruhining uglerod atomi aldegid va ketonlarga nisbatan yanada ko‘proq ekranlanadi, ya’ni 166 m.h.



3-rasm. 2-Izopropil-5-metilfenil 2-xloratsetatning ^{13}C-YaMR – spektri

Xulosa va takliflar. 2-izopropil 5 metilfenil 2 xloratsetatning fizikaviy doimiyliklari aniqlandi, tarkibi va tuzilishi yupqa qatlam xromatografiya, IQ- va YMR - spektrlari yordamida tasdiqlandi.

Foydalanilgan adabiyotlar

1. Choriyev A.U., Abdushukurov A.K., Jurayev R.S., Jurayeva M.K. Di (2-izopropil-5-metilfenilkarboksimetilen) oksalat sintezi [Synthesis of the di(2-izopropyl-5-methylphenylkarboksimethylen) oxalate]. Chemistry and Chemical Engineering, 2023, 1, 33-38.

2. Smith M.B., March J. Advanced Organic Chemistry: Reactions, Mechanisms and Structure. New-York, Wiley, 2013. 1200 p.

3. Чориев А.У., Абдушукуров А.К., Хасанова З.Қ., Давронова Г.Т., Жураева М.Н. 2-изопропил-5-метилфенилкарбоксиметилен роданид синтези. //Фан ва технологиялар тараққиёти, №4/2022, 63-68 б.

4. Clayden J., Greeves N., Warren S. Organic Chemistry, 4 thedn, Oxford University Press, New York, 2012.

5. Akhmedov K.N., Yuldashev X.Y. Organik kimyo usullari [Methods of Organic chemistry]. Tashkent: Universitet Publ., 2003. 232.

6. Sumina E.G., Shtikov S.N., Sorokina O.N. i dr. Tonkosloynaya khromatografiya flavonoidov na silikagele v modifitsirovannykh mitsellyarnykh podvizhnykh fazakh na osnove dodetsilsulfata natriya [Thin layer chromatography of flavonoids on silica gel in modified micellar mobile phases based on sodium dodecyl sulfate]. Sorbtsionnyye i khromatogr. Protsessy, 2014, 14(1), 52-64.

7. Кирхнер Ю. Тонкослойная хроматография / Ю. Кирхнер - М.: Мир, 1981. -616с.

8. Li J.J. Name Reactions. A Collection of Detailed Mechanisms and Synthetic Applications. Berlin-

Heidelberg, 2009. 704 p.
9. Reichardt C. Solvents and Solvent Effects in Organic Chemistry, 2nd ed., VCH, NY, 1988. 534 p.
10. Field L.D., Sternhell S., Kalman J.R. Organic Structures from Spectra, 3rd edn, Wiley, 2003. 630 p.

UGLEROD NUQTALARI BILAN BEZATILGAN UCH O‘LCHAMLI TARTIBLANGAN TITAN DIOKSID MAKROG‘OVAKLARINING FOTOKATALITIK XOSSALARI

Xojiyeva Gulmira,
O‘zbekiston Milliy Universiteti tayanch doktoranti
Bahronova Nodira,
O‘zbekiston Milliy Universiteti talabasi
Xojiyev Shokir,
Ilg‘or texnologiyalar markazi ilmiy xodimi PhD
Researcher Wuhan University of Technology
Xoliqov Abduvali,
O‘zbekiston Milliy Universiteti professori, kimyo fanlari doktori
Akbarov Hamdam,
O‘zbekiston Milliy Universiteti professori, kimyo fanlari doktori
Umumiy va noorganik kimyo instituti “Kolloid kimyo va sanoat ekologiyasi” laboratoriyasi mudiri Eshmetov I.D taqrizi asosida
ORCID 0000-0003-0001-3939
kh.gulmira88@gmail.com
UDK 541.145+539.22

Annotatsiya. Uch o‘lchovli tartiblangan makrog‘ovak (3DOM) materiallar noyob tuzilish tufayli keng tarqalgan. Foto-hosil qilingan tashuvchilarning tez rekombinatsiyasi va cheklangan fotoreaksiyalar sababli TiO_2 asosidagi fotokatalizatorlarning rivojlanishiga katta to‘sqinlik qiladi. Ushbu ishda, uglerod nuqtalari bilan bezatilgan uch o‘lchamli tartiblangan titan dioksid makrog‘ovak CDs/3DOM-TiO_2 fotokatalizatorining fotokatalitik samaradorligi o‘rganildi. Ko‘rinadigan yorug‘lik nurlanishi ostida (λ> 420 nm) CDs/3DOM-TiO_2 fotokatalitik vodorod hosil bo‘lish tezligi (1,91 mmol h^{-1} g^{-1}) ni tashkil qilib bu 3DOM-TiO_2 nisbatan 7.72 barobar yaxshilangan faollikni ko‘rsatdi. Qulay elektron yig‘ish va o‘tkazuvchanlik xususiyatlariga ega bo‘lgan uglerod nuqtalari 3DOM-TiO_2 ga kiritilgandan keyin fotogeneratsiyalangan elektronlarning ajratish va tashishni keskin oshirishi aniqlandi. Ushbu ish yuqori sifatli va arzon fotokatalizatorlarda tashuvchilarni uzatish yo‘llarini optimallashtirish uchun yangi dizayn strategiyasini taqdim etadi.
Kalit so‘zlar: Uglerod nuqtasi, 3DOM-TiO_2, samarali elektron-teshik ajralishi, fotokataliz, vodorod hosil qilish.

PHOTOCATALYTIC PROPERTIES OF THREE-DIMENSIONAL ORDERED TITANIUM DIOXIDE MACROPOROUS DECORATED WITH CARBON DOTS

Abstract. Three-dimensional ordered macroporous (3DOM) materials have been widely concerned due to the unique structure. Fast recombination of photo-generated carriers and limited photo-response have greatly hindered the development of TiO_2-based photocatalysts. Herein, The photocatalytic efficiency of three-dimensional ordered titanium dioxide macroporous CDs/3DOM-TiO_2 photocatalyst decorated with carbon dots was studied. Under visible light irradiation (λ> 420 nm), the CDs/3DOM-TiO_2 photocatalytic hydrogen production rate was (1.91 mmol h^{-1} g^{-1}), which showed a 7.72 times improved activity compared to 3DOM-TiO_2. It was found that carbon dots with favourable electron collection and conduction properties dramatically increase the separation and transport of photogenerated electrons after incorporation into 3DOM-TiO_2. This work provides a new design strategy for the optimization of carrier’s transmission pathway in high-quality and low-cost photocatalysts.
Keywords: Carbon dots, 3DOM-TiO_2, effective electron-hole separation, photocatalysis, hydrogen production.

Kirish. Fotokatalitik texnologiya toza, yashil va samarali usul sifatida quyosh energiyasidan foydalanish uchun uzoq vaqtdan beri sanoat miqyosida fotokatalitik vodorod ishlab chiqarish bilan bog‘liq jiddiy muammolarni hal qilishning eng muhim vositalaridan biri sifatida ko‘rib chiqilayotgan texnologiyalardan biridir[1]. Turli fotokatalizatorlar orasida titan dioksidi (TiO_2) yuqori kimyoviy barqarorligi, toksik bo‘lmaganligi va arzonligi tufayli qo‘llanilishi mumkin bo‘lgan modda sifatida topilgan. Biroq nisbatan katta taqiqlangan zona energiyasi (masalan = 3,2 eV) va fotogeneratsiyalangan tashuvchilarning tez rekombinatsiyasi tufayli ko‘rinadigan infraqizil nurlarning zaif ta’siri uning keng miqyosli fotokatalizda qo‘llash uchun fotokatalitik xususiyatlarini jiddiy ravishda cheklaydi [2]. Shu sababli, fotogeneratsiyalangan tashuvchilarni ajratishni tezlashtirish va yorug‘lik ta’siri oralig‘ini toksik bo‘lmagan va arzon narxlarda kengaytirish uchun TiO_2 tuzilishi va yuzasini oqilona o‘zgartirish, struktura va funksiya munosabatlarini tushuntirish bilan birga, qiyin vaziyatni bartaraf etishning asosiy qadamlari hisoblanadi. Ma’lumki, uch o‘lchovli tartiblangan makrog‘ovak (3DOM) g‘ovak hajmining bir xil taqsimlanishi, yuqori g‘ovakligi va katta o‘ziga xos sirt maydoniga ega bo‘lgan struktura yetarli faol joylarni va samarali massa o‘tkazmasini ta’minlaydi [3]. Ayniqsa, 3DOM strukturasidagi yorug‘likning ko‘p tarqalishi va sekin foton effekti yorug‘likni yig‘ishni kuchaytiradi va fotokatalitik samaradorlikni oshiradi [4]. So‘nggi paytlarda arzon va toksik bo‘lmagan uglerod nanomaterialining yangi sinfi sifatida uglerod nuqtalari (CDs) o‘zining ajoyib elektron uzatish va yig‘ish xususiyatlari tufayli ko‘proq e’tiborni tortmoqda [5].

Tadqiqot metodologiyasi. Uch o‘lchamli makrog‘ovak strukturali 3DOM-TiO2 fotokatalizatorini sintez qilish uchun zol-gel va shablon usullaridan foydalanilgan. Prekursor sifatida etanol, titan (IV)-izopropoksid, xlorid kislota va suvdan iborat aralashmadan foydalanib 3DOM-TiO2 strukturali fotokatalizatori 420 mn li PS shabloni yordamida zol-gel va shablon usullaridan foydalanib tayyorlandi. Qizil rang tarqatuvchi uglerod nuqtalari solvotermik usul yordamida limon kislotasi va karbamiddan foydalanib sintezi qilindi. Dimetilformamid va sirka kislotasi ushbu solvotermik jarayonda erituvchi sifatida qo‘llanildi, chunki ushbu erituvchilar adabiyotlardan ma’lumki yuqori fluoressent uglerod nuqtalarini sintezlashda ishlatiladi [10]. Uglerod nuqtasi saqlagan uch o‘lchamli tartiblangan CDs/3DOM-TiO2 kompoziti suv hammomida doimiy aralashtirish yo‘li orqali tayyorlandi.

1. Tajriba qism

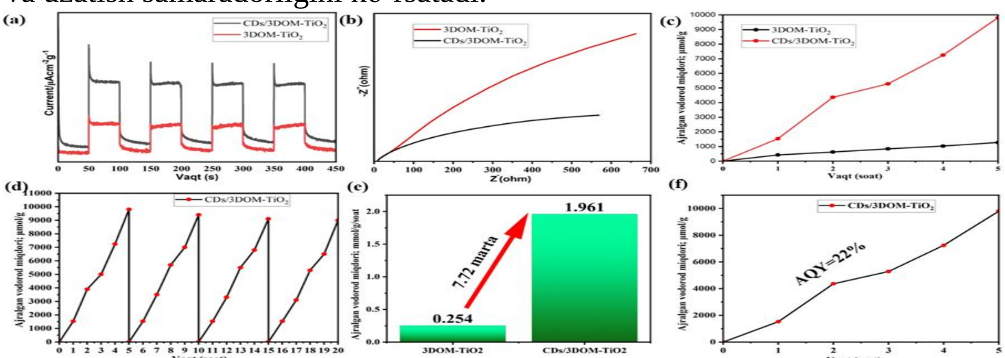
2.1 Fotoelektrokimyoviy o‘lchashlar

Fotoelektrokimyoviy o‘lchovlar standart uch elektrodli sistema bilan jihozlangan potensiostat/galvanostat CHI-660D qurilmasi yordamida 100 kHz dan 10 mGts gacha chastota diapazonida o‘lchandi. Ishchi elektrodlar sifatida tayyorlangan fotokatalizator bilan qoplangan FTO shishasi, qarama-qarshi elektrod sifatida platina elektrodi va reference elektrod sifatida Ag/AgCl (KCl bilan to‘yingan) elektrodlaridan foydalanildi. Elektrolit erimasi sifatida 0,5 mol/L Na_2SO_4 eritmasidan (100 mL) foydalanildi. Fotooqimning sinov kuchlanishi 0,5 V, yorug‘likni yoqish/o‘chirish vaqt oralig‘i 50 sekundda o‘lchandi. Simulyatsiya qilingan ko‘rinadigan yorug‘lik ostida, EIS (electrochemical impedance spectra) va vaqtinchalik fototok (photocurrent) xossalari o‘lchandi. Yorug‘lik manbai sifatida ko‘rinadigan yorug‘lik intensivligi 158 mVt/sm^2 bo‘lgan PLS-SXE-300C chiroq ishlatilgan (kesish filtri $\lambda \geq 420$ nm bilan) (PLS-SXE-300C, Beijing Perfectlight) tanlangan va yorug‘likni yetkazish uchun namuna va yorug‘lik manbayi orasidagi masofa 15 sm.

2.2. Fotokatalitik vodorod hosil qilish

Fotokatalitik vodorod hosil qilish jarayonlari yopiq sirkulyatsiya tizimida (Beijing Perfect-light Science & Technology Co., Ltd.) 158 mVt/sm^2 ko‘rinadigan yorug‘lik chiqaradigan PLS-SXE-300C lampasi yordamida amalga oshirildi. Odatda, fotokataliz orqali vodorod ishlab chiqarish bo‘yicha tajribalar suvli metanol (100 ml, 25% v/v) eritmasida olib boriladi. 20 mg fotokatalizator nanunasi vodorod reaktoriga solinadi va ustidan 100 mL suv metanol aralashmasi solinib reaktor sistemaga ulanadi. 40 minut doimiy aralashtirish orqali sistemaning gazsizlanish jarayoni amalga oshiriladi. Gazsizlanish jarayoni tugaganidan keyin idishga 420 nm kesuvchi filtr yordamida ko‘rinadigan yorug‘lik ta’sir qilindi. Yoritish manbasi bilan eritma orasi 10 sm bo‘ladi. Gaz mahsulotlarini muntazam tahlil qilish uchun (TCD) detektori bilan jihozlangan gaz xromatografiyasidan (GC) foydalanildi.

Natijalar muhokama. Hozirgi kunda fotokatalitik vodorod hosil qilish uchun yangi yuqori samarali fotokatalizatorlar yaratish va ularning fizik-kimyoviy xossalarini o‘rganish muhum ahamiyat kasb etadi [6]. Uglerod nuqtalari kiritilgan uch o‘lchamli tartiblangan titan dioksidi fotokatalizatorini yaratish va ularning fotokatalitik vodorod hosil qilish xossalari hamda fizik-kimyoviy parametrlarini o‘rganish maqsadga muvofiqdir. CDs/3DOM-TiO_2 fotokatalizatorining sintezlanish jarayoni zol-gel, shablon va solvotermik usullaridan foydalanilgan holda sintezi amalga oshirilgan va ularning strukturaviy optik va elektronik xossalari oldingi ishlarimizda e’lon qilingan [7]. Sintezlangan fotokatalizatorlarning fotokatalitik faolligini yanada tushuntirish uchun fotoelektrokimyoviy o‘lchovlar standart uch elektrodli sistema bilan jihozlangan potensiostat/galvanostat CHI-660D qurilmasi yordamida 100 kHz dan 10 mGts gacha chastota diapazonida o‘lchandi. Ishchi elektrodlar sifatida tayyorlangan fotokatalizator bilan qoplangan FTO shishasi, qarama-qarshi elektrod sifatida platina elektrodi va reference elektrod sifatida Ag/AgCl (KCl bilan to‘yingan) elektrodlaridan foydalanildi. 1-rasm. (a) vaqtinchalik fototok jarayoni (photocurrent response) ko‘rinadigan yorug‘lik ostida (λ > 420 nm) 3DOM-TiO_2 va CDs/3DOM-TiO_2 uchun bajarilgan. CDs/3DOM-TiO_2 ning fototok intensivligi 3DOM-TiO_2 ga qaraganda bir necha barobar yuqori ekanligi spektr natijalaridan ko‘rinib turibdi. 3DOM strukturasi yorug‘lik nurlanishida fotogeneratsiyalangan elektronlarning ajratish samaradorligini oshirishini va kuchliroq yorug‘lik yig‘ish qobiliyatiga ega ekanligini (slow photon effect) isbotlaydi [8]. CDs/3DOM-TiO_2 ning fototok intensivligi 3DOM-TiO_2 dan sezilarli darajada yuqoriligi, 3DOM-TiO_2 tarkibida uglerod nuqtasi mavjudligi uchun fotogeneratsiyalangan elektronlar va teshiklarni ajratish samaradorligining oshganligini ko‘rsatadi. Odatda elektrokimyoviy impedens spektrida (EIS) yarim doira bu – zaryad uzatish (ya’ni energiya ta’sirida qo‘zg‘algan elektronlarning o‘tkazuvchi zonaga o‘tishi) empedensini ifodalaydi [9]. Yarim doira diametri qanchalik kichik bo‘lsa, fotogeneratsiyalangan elektronlar va teshiklarning ajratish samaradorligi shunchalik yuqori bo‘ladi [10]. 1-rasm (b) CDs/3DOM-TiO_2 fotokatalizatorining yarim doira diametri minimal ekanligini ko‘rsatadi, bu esa PL va vaqtinchalik fototok natijalariga mos kelib tashuvchilarning eng yuqori ajratish va uzatish samaradorligini ko‘rsatadi.

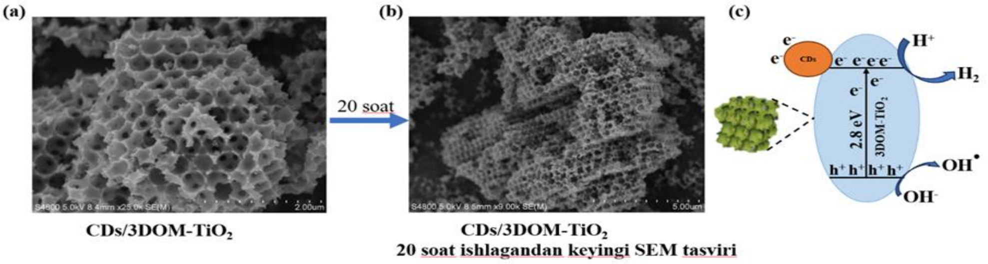


1-Rasm. (a) 3DOM-TiO_2 va CDs/3DOM-TiO_2 vaqtinchalik fototok jarayoni; (b) 3DOM-TiO_2 va CDs/3DOM-TiO_2 elektrokimyoviy impedanse spektri (Nyquist plot); (c) 3DOM-TiO_2 va CDs/3DOM-TiO_2 fotokatalizatorlaring ko‘rinuvchi nur ostidagi (λ > 420 nm) fotokatalitik vodorod hosil qilish grafigi; (d) CDs/3DOM-TiO_2 fotokatalizatorining uzoq muddatli qayta ishlash sinovi; (e) fotokatalizatorlarning vodorod hosil qilish darajasini solishtirish; (f) ko‘rinuvchi nur ostidagi (λ > 420 nm) CDs/3DOM-TiO_2 kvant rentabilligi.

Fotokatalitik reaksiyalar Beijing Perfectlight Science & Technology Co., LTD tomonidan taqdim etilgan yopiq aylanish tizimida oʻtkazildi. Reaksiyalarda ultrabinafsha (UV) yorugʻlik intensivligi kvadrat santimetr uchun 34 millivatt (mVt/sm^2) va koʻrinadigan yorugʻlik intensivligi 158 mVt/sm^2 boʻlgan PLS-SXE-300C lampasi ishlatilgan. Gaz mahsulotlari muntazam ravishda issiqlik oʻtkazuvchanlik detektori (TCD) va tashuvchi gaz sifatida Ar bilan jihozlangan gaz xromatografi (GC) yordamida tahlil qilindi. Gaz xromatograf har soat davomi avtomatik ravishda chiqayotgan gazlarni tahlil qildi. Namunalarning fotokatalitik vodorod hosil qilish xossasi koʻrinadigan yorugʻlik nurlanishida (λ> 420 nm) tekshirildi.

3DOM-TiO_2 va CDs/3DOM-TiO_2 vodorod (H_2) hosil qilish tadqiqoti 3:1 nisbatda suv va metanol aralashmasida 5 soat davomida yopiq sirkulyatsiya tizimida oʻrganilgan. 1-rasm (c) CDs/3DOM-TiO_2 ning fotokatalitik vodorod hosil qilish darajasi 3DOM-TiO_2 qaraganda ancha yuqori ekanligi kuzatildi. Fotokatalitik yoʻl bilan hosil boʻlayotgan vodorod miqdori chiziqli tartibda boʻlib, deyarli bir xil miqdorlarda oʻsishini koʻrsatdi. Bu natijalar fotokatalizatorlarning ishlash samaradorligi yaxshi ekanligini bildiradi [11]. CDs/3DOM-TiO_2 fotokatalizatorining barqaror ishlashi 20 soat davomida oʻrganildi. Har 5 soatda jarayon toʻxtatilib eritmadan katalizator chiqarib olindi va yana qayta eritmaga solinib fotokatalitik vodorod hosil qilishi tekshirildi. Bu jarayon jami 20 soat davomida 4 marta takrorlandi va 1-rasm (d) CDs/3DOM-TiO_2 fotokatalitik jarayonda ancha barqaror ekanligini namoyon qildi. 1-rasm (e) 3DOM-TiO_2 va CDs/3DOM-TiO_2 fotokatalitik vodorod hosil qilish darajalari solishtirilganda CDs/3DOM-TiO_2 fotokatalitik vodorod hosil qilish tezligi 3DOM-TiO_2 nikidan 7.72 marta yuqori ekanligi aniqlandi. 1-rasm (f) CDs/3DOM-TiO_2 fotokatalizatorining kvant rentabilligi 22% ekanligi keltirilgan (Apparent quantum yield (AQY)). Kvant rentabilligi bu fotokatalizator yuzasiga tushayotgan umumiy fotonning necha foizi elektronlarni qoʻzgʻatishga sarflanganligini (yaʼni 100 ta fotondan nechtasi katalizator yuzasiga absorbsiya boʻlib elektron hosil qilganligini) koʻrsatadi.

$$AQY = \frac{2 \times 1.961 \times 10^{-3} \times 5 \times 6.02 * 10^{23}}{36.5 \times 10^{-3} \times 38.5 \times 5 \times 3600 \times 420 \times 10^{-9} / (6.626 \times 10^{-34} \times 3 \times 10^{8})} \times 100\% = 22\%$$



2-Rasm. (a) CDs/3DOM-TiO_2 SEM tasviri; (b) CDs/3DOM-TiO_2 20 soat ishlagandan keyingi SEM tasviri; (c) fotokatalizatorning ishlash mexanizmi.

2-rasm (b) CDs/3DOM-TiO_2 katalizatorining 20 soat davomida qayta-qayta ishlatilganidan keyin olingan SEM tasvirida asosiy 3DOM strukturalaring buzilmaganligi va bu struktura fotokatalitik jarayonlarda ancha barqaror ekanligini koʻrsatadi.

Fotokatalitik jarayonning mexanizmini 2-rasm (c) quyidagicha tushuntirilishi mumkin. Bir tomondan, uglerod nuqtalari 3DOM-TiO_2 dan elektronlarni ushlab turishi va toʻplashi (reserver kabi), zaxiralashi va oʻtkazish qobiliyati bilan elektronlarni sirtga oʻtkazishi mumkin, bu esa elektron teshik juftlarini ajratishga va fazalararo elektron harakatchanligiga katta hissa qoʻshadi. Shundan soʻng, CDs/3DOM-TiO_2 ning oʻtkazuvchi zonasidagi toʻplangan fotogeneratsiyalangan elektronlar toʻgʻridan toʻgʻri vodorodni qaytarish reaksiyasida ishtirok etadi.

Boshqa tomondan, “sekin foton effekti” bilan CDs/3DOM-TiO_2 ning 3DOM tuzilishi massa oʻtkazuvchanligini oshirishi va yorugʻlikning yutilishini kuchaytirishi mumkin. Shu bilan birga, uglerod nuqtalarining up-conversion PL xususiyatlari uzunroq to‘lqin uzunligida nurlanish energiyasidan foydalanishga imkon beradi. Energiyasi kam to‘lqin uzunligi katta bo‘lgan nurlarning energiyasi yuqori to‘lqin uzunligi kichik bo‘lgan nurga aylantirish xususiyati tufayli ko‘rinuvchi nurni UB nuriga aylantiradi. Natijada fotokatalitik jarayon tezlashib ketadi. Shu sababli, CDs/3DOM-TiO_2 yetarli energiyani o‘zlashtirishi va yuqori samaradorlikka erishish uchun qo‘shimcha elektronlar va teshiklarni ishlab chiqarishi mumkin.

Xulosa. Uglerod nuqtalari kiritilgan uch o‘lchamli tartiblangan titan dioksid makrog‘ovak CDs/3DOM-TiO_2 fotokatalizatori muvaffatqiyatli sintezlandi. Ularning yuza morfologiyasi, kristal fazalari va optik xossalari oldingi ishlarimizda o‘rganilgan. Ushbu ishda ko‘rinadigan yorug‘lik nurlanishi ostida (λ> 420 nm) CDs/3DOM-TiO_2 fotokatalitik vodorod hosil bo‘lish tezligi (1,91 mmol h^{-1} g^{-1}) ni tashkil qilib, bu 3DOM-TiO_2 nisbatan 7.72 barobar yaxshilangan faollikni ko‘rsatdi. Ajoyib fotokatalitik xususiyatning tavsiya etilgan sabablarini asosan quyidagilar bilan bog‘lash mumkin: (1) qulay elektron yig‘ish va o‘tkazuvchanlik xususiyatlariga ega bo‘lgan uglerod nuqtalari fotogeneratsiyalangan elektronlarni ajratish va tashishni keskin oshiradi; (2) uglerod nuqtasi 3DOM-TiO_2 ga kiritilgandan keyin saqlanib qolgan noyob 3DOM tuzilishi mo‘l-ko‘l faol yuza maydonlarni va tez elektron uzatishni ta’minlashi va sekin foton effekti tufayli yorug‘likni yig‘ishni osonlashtirishi mumkin; (3) uglerod nuqtalarining noyob up-conversion fotolyuminesens xususiyati uzoq to‘lqin uzunligida yorug‘likdan foydalanish tezligini oshirishi mumkin. Shunday qilib, bunday kompozit fotokatalizatorlar energiya va atrof-muhit bilan bog‘liq sohalarda istiqbolli katalizatorlar bo‘lib xizmat qilishi mumkin va bu ishda ishlab chiqilgan oqilona taktika va oson sintetik usul turli xil yo‘nalishlarga yo‘naltirilgan yuqori samarali ko‘p komponentli fotokatalizatorlarni loyihalash va ishlab chiqarishga keng yo‘l ochadi.

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Foydalanilgan adabiyotlar

1. D. Zheng, H. Zhao, S. Wang, J. Hu, Z. Chen, NiO-TiO_2 p-n heterojunction for solar hydrogen generation, Catalysts 11 (2021). https://doi.org/10.3390/catal11121427.
2. Y. Zhu, Y. Tian, L. Li, J. Hou, Y. Huo, T. Sun, J. Li, 3DOM N/TiO_2 composite modified by CdS QDs with Z-scheme: enhanced photocatalytic degradation and hydrogen evolution, J. Nanoparticle Res. 24 (2022). https://doi.org/10.1007/s11051-022-05550-z.
3. W. Liu, Y. Wang, K. Qi, F. Wen, J. Wang, Broad Spectral Response Z-Scheme Three-Dimensional Ordered Macroporous Carbon Quantum Dots/TiO_2/g-C_3N_4 Composite for Boosting Photocatalysis, Langmuir 38 (2022) 4839–4847. https://doi.org/10.1021/acs.langmuir.1c03483.
4. J. Liu, H. Zhao, M. Wu, B. Van der Schueren, Y. Li, O. Deparis, J. Ye, G.A. Ozin, T. Hasan, B.L. Su, Slow Photons for Photocatalysis and Photovoltaics, Adv. Mater. 29 (2017) 1–21. https://doi.org/10.1002/adma.201605349.
5. C.T. Thanh Thuy, G. Shin, L. Jieun, H. Do Kim, G. Koyyada, J.H. Kim, Self-Doped Carbon Dots Decorated TiO2 Nanorods: A Novel Synthesis Route for Enhanced Photoelectrochemical Water Splitting, Catalysts 12 (2022). https://doi.org/10.3390/catal12101281.
6. H. Zhao, M. Wu, J. Liu, Z. Deng, Y. Li, B.L. Su, Synergistic promotion of solar-driven H_2 generation bythree-dimensionally ordered macroporous structured TiO_2-Au-CdS ternary photocatalyst, Appl. Catal. B Environ. 184 (2016) 182–190. https://doi.org/10.1016/j.apcatb.2015.11.018.
7. G. Xojiyeva, N. Bahronova, Sh. Xojiyev, A. Xoliqov, H. Akbarov, Uglerod nuqtalari bilan bezatilgan uch o‘lchamli titan dioksidining sintezi va optik xossalari, O‘zMU Xabarlari, 2024, 3/1/1, 458-462. http://journals.nuu.uz
8. F.-Y. Bai, J.-R. Han, J. Chen, Y. Yuan, K. Wei, Y.-S. Shen, Y.-F. Huang, H. Zhao, J. Liu, Z.-Y. Hu, Y.

Li, B.-L. Su, The three-dimensionally ordered microporous $CaTiO_3$ coupling $Zn_{0.3}Cd_{0.7}S$ quantum dots for simultaneously enhanced photocatalytic H_2 production and glucose conversion, J. Colloid Interface Sci. 638 (2023) 173–183. https://doi.org/10.1016/j.jcis.2023.01.123.

9. H. Zhao, J. Liu, C.F. Li, X. Zhang, Y. Li, Z.Y. Hu, B. Li, Z. Chen, J. Hu, B.L. Su, Meso-Microporous Nanosheet-Constructed 3DOM Perovskites for Remarkable Photocatalytic Hydrogen Production, Adv. Funct. Mater. 32 (2022). https://doi.org/10.1002/adfm.202112831.

10. G. Li, K. Fang, Y. Ou, W. Yuan, H. Yang, Z. Zhang, Y. Wang, Surface study of the reconstructed anatase TiO_2 (001) surface, Prog. Nat. Sci. Mater. Int. (2020). https://doi.org/10.1016/j.pnsc.2020.11.002.

11. S.H. Yeom, Temperature-Dependent Tunable Photoluminescence Properties of Carbon Nanodots Derived From Polyethylene Glycol, Thesis - Univ. Kentucky UKnowledge (2014).

POLIKARBOKSILATLI SUPERPLASTIFIKATOR SINTEZ QILISH VA UNING SAMARADORLIGI

Ismoilov Feruz Sobirovich
katta ilmiy xodim t.f.n (PhD)
Toshkent Kimyo texnologiya ilmiy-tadqiqot instituti,
ismoilovferuz54@gmail.com
Karimov Mas'ud Ubaydulla o'g'li
Toshkent Kimyo texnologiya ilmiy-tadqiqot instituti,t.f.d.prof
Djalilov Abdulaxat Turapovich.
k.f.d.prof. O'zR FA akademigi.
Toshkent Kimyo texnologiya ilmiy-tadqiqot instituti direktori
Muminov Baxriddin Saidumarovich
Toshkent Kimyo-texnologiya ilmiy tadqiqot instituti, doktorant
ORCID 0009-0002-4166-7541
UDK:691.32

Annotatsiya. Polikarboksilatli superplastifikatorlar suvda erkin radikal sopolimerizatsiyasi orqali sintez qilindi. Polikarboksilatli superplastifikatorini sintez qilishdan asosiy maqsad boshqariladigan molekulyar og'irligi, tartibga solinadigan gidrofilik-lipofil guruhlari, uzun zanjirli alkil guruhlari, bo'lgan yangi makromonomerlarni ishlab chiqarishdir. Sopolimerizatsiya paytida oziqlanish rejimi va monomerlar nisbati, nisbiy reaktivlik kabi shartlar oxirgi mahsulotda turli xil monomer ketma-ketligini keltirib chiqarishi mumkin. Polikarboksilat superplastifikatorining molekulyar shkalasi bo'yicha strukturaviy o'zgarishlar dispersiya va suvni ushlab turish xususiyatlarining o'zgarishiga, shuningdek, portland sementining mosligini yaxshilashga va beton qorishmasining mustahkamligining oshishiga olib kelishi mumkin. Laboratoriya sharoitida polikarboksilat superplastifikatori ishlab chiqarishda dastlabki qadam sifatida makromonomerlar uchun sintetik usullardagi so'nggi ishlanmalarni va polikarboksilatlarning tuzilishi va xususiyatlari o'rtasidagi munosabatlarni ko'rib chiqadi.Ushbu tadqiqotda akril kislota va makromonomer polioksietilen metallil efirdan (HPEG) sintez qilingan PCE polimerlaridagi monomer ketma-ketligi YaMR spektroskopiya bilan tavsiflangan. Optimal dispersiya samaradorligi bilan PCE yuqori HPEG makromonomer tarkibida, molekulyar og'irligi (Mw) 26,000 Da atrofida va tor molekulyar og'irlik taqsimotiga erishildi.

Kalit so'zlar: Polikarboksilat, sement, YaMR, HPEG, akril kislota, suv.

Abstract. Polycarboxylate superplasticisers were synthesised by free-radical copolymerisation in water. The main objective of the synthesis of polycarboxylate superplasticiser was to obtain new macromonomers with controlled molecular weight, adjustable hydrophilic-lipophilic groups, long-chain alkyl groups. Conditions such as feed mode and monomer ratio, relative reactivity during copolymerisation can lead to different monomer sequences in the final product. Structural changes at the molecular level of polycarboxylate superplasticiser can lead to changes in dispersion and water retention properties, as well as improve Portland cement compatibility and concrete mix strength. A review of recent developments in synthetic methods for the preparation of macromonomers and the relationship between structure and properties of polycarboxylates as a first step in the production of polycarboxylate superplasticisers in vitro. In this work, the monomeric sequence of PCE polymers synthesised from acrylic acid and polyoxyethylene methyl ether (HPEG) macromonomer was characterised by NMR spectroscopy. PCE with optimum dispersion efficiency was achieved with a high HPEG macromonomer content, a molecular weight (Mw) of about 26,000 Da and a narrow molecular weight distribution.

Key words: Polycarboxylate, cement, NMR, HPEG, Acrylic acid, Water.

Kirish. Hozirgi kunda qurilish sanoati juda tez sur'atlar bilan rivojlanmoqda. Bunday rivojlanish jarayonida xomashyo va energiya resurslaridan oqilona va samarali foydalanishga qo‘yiladigan talablar ham o‘zgarib bormoqda. Ushbu rivojlanishda mustahkamligi, ishonchliligi va chidamliligi yuqori bo‘lgan beton va temir-beton konstruksiyalarni ishlab chiqarish alohida o‘rin egallaydi. Ushbu muammoni samarali hal qilish maxsus kimyoviy qo‘shimchalardan keng foydalanishni talab qiladi. Beton xususiyatini o‘zgartirish uchun ishlatiladigan qo‘shimchalar uch guruhga bo‘linadi:

Birinchi guruhga beton va sement aralashmalarining plastiklashtiruvchi, barqarorlashtiruvchi, harakatchanligini oshiruvchi qo‘shimchalar kiradi. Beton qorishmalari ko‘pincha bir nechta kimyoviy qo‘shimchalarni o‘z ichiga oladi, ularning har biri sementning turli komponentlari bilan o‘zaro ta’sir qilishi va sementning gidratatsiya reaksiyalariga ta’sir qilishi mumkin. Qo‘shimchalar va sement o‘rtasidagi o‘zaro ta’sir aslida ikkita murakkab kimyoviy tizimlar o‘rtasidagi reaksiya sifatida ko‘rib chiqilishi mumkin. Amaldagi sement GOST standarti 31108-2016 bo‘yicha Namangan sement 450 markali oddiy portland sement edi. Klinkerning mineralogik tarkibi 1-jadvalda keltirilgan. Sementning asosiy kimyoviy tarkibi 2 jadvalda keltirilgan. Sementni tanlash C_3A ning past miqdori va uning granulometrik tarkibi bilan belgilanadi. Past C_3A tarkibi betonning issiqlik hosil bo‘lishini kamaytirishga yordam beradi. Bundan tashqari, superplastifikatorlarning ta’siri past alyuminiyli Portland sementida namoyon bo‘ladi. Tanlangan portland sementining granulometrik tarkibi zarrachalar hajmining bir xil taqsimlanishiga yordam beradi, bu esa kukun qo‘shganda zarrachalarning zich qadoqlanishi bilan aralash bog‘lovchi tuzilmani olish imkonini beradi.

1-jadval:

Klinkerning mineralogik tarkibi

C_3S	C_2S	C_3A	C_4AF
62.40%	17.56%	5.49%	14.55%

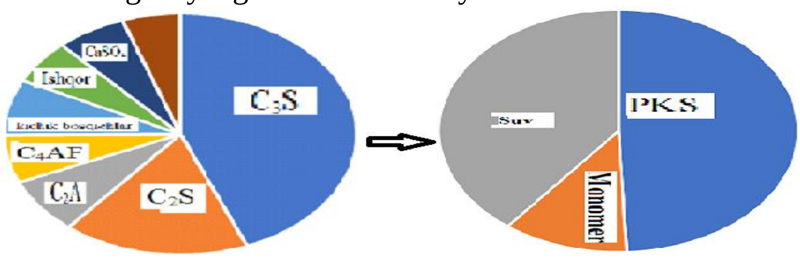
Portland sementlari ko‘p komponentli, ko‘p fazali noorganik materiallar, jumladan, asosiy komponentlar (C_3S, C_2S C_3A, C_4AF) va kichik fazalar (CaO, $CaSO_4$* H_2O, Na, K_2SO_4 va boshqalar);

2-jadval:

Klinkerning kimyoviy tarkibi:

SiO_2	AL_2O_3	Fe_2O_3	CaO	SO_3	MgO	K_2O	Na_2O	R_2O
21.65%	4.73%	4.36%	66.45%	0.41%	1.25%	0.82%	0.25%	0.70%

Aralash sementlarga yordamchi materiallar shlak, kul, mikrosilikat va ohaktosh, tosh uni va boshqalar kabi qo‘shimcha komponentlar kiradi. Xuddi shunday, superplastifikatorlar ko‘pincha qo‘shimchaning tabiatiga xos bo‘lgan yoki ularni ishlab chiqarish jarayonining natijasi bo‘lgan bir nechta komponentlarni o‘z ichiga oladi. Masalan, lignosulfonatli suv reduktorlari ligninning kimyoviy parchalanishi natijasida hosil bo‘lgan kimyoviy birikmalarning o‘ziga xos murakkab aralashmalaridir.Yuqori sifatli suv reduktorlari kabi sintetik qo‘shimchalar ko‘pincha keng molekulyar og‘irlik taqsimotiga ega bo‘lgan moddalarni, reaksiyaning yon mahsulotini yoki ma’lum bir maqsad uchun qo‘shilgan boshqa kimyoviy moddalarni o‘z ichiga oladi. Shu sababli, qo‘shimchalar-sement o‘zaro ta’sirini ushbu materiallardan optimal foydalanish uchun zarur bo‘lgan darajada tushunishga erishish uchun ham eksperimental kuzatishlar ham fizik-kimyoviy tushunchalarga tayangan holda tizimli yondashuv talab etiladi.



Sement Plastifikator eritmasi.

1- rasm. Sement va plastifikator o‘rtasidagi o‘zaro ta’sirning sxematik tasviri.

Ushbu maqola hozirgi vaqtda sement gidratatsiyasi va kimyoviy qo‘shimchalarning sement gidratatsiyasi jarayonlariga ta’siri bilan bog‘liq bo‘lgan fizik-kimyoviy tushunchalarning sharhi asosida tayyorlangan.

Ikkinchi guruh beton va sementlarning qotishi, kuchini oshirish, po‘lat armaturaga va tashqi muhitga nisbatan himoya xususiyatlarini oshiruvchi qo‘shimchalar bilan ifodalanadi:

Uchinchi guruhga beton va sement aralashmalarning muzlashdan himoyalanish, yuqori namlikka qarshiligini oshiruvchi maxsus xususiyatlar beradigan qo‘shimchalar kiradi [1].

So‘nggi paytlarda polikarboksilat tipidagi superplastifikatorlarga bo‘lgan talab tobora ommalashib bormoqda. Ushbu turdagi superplastifikatorning o‘ziga xos xususiyati shundaki, uning kimyoviy tuzilishi o‘zgartirilishi mumkin, chunki u bir nechta komponentlardan iborat polimerdir [2].

Polikarboksilat superplastifikatori suvni singdirish va past dozalarda cho‘kishni uzoq muddatli ushlab turadi. Polikarboksilatning kimyoviy tuzilishi beton mahsulotlarida uning asosiy mexanizmi samaradorligini belgilaydi [3]. Superplastifikatorlar sement zarralarining sirt zaryadlarini o‘zgartiradigan, ularni kichikroq aglomeratlarga tarqatadigan sirt faol moddalardir. Portland sementni suv bilan dastlabki aralashtirishda bunday sement klasterlarining paydo bo‘lishi 5 dan 7 nanometr (nm) gacha bo‘lgan zarrachalar orasidagi masofada harakat qiluvchi Van der -Waals kuchlari tufayli sodir bo‘ladi.Plastifikatorlar sirt-suyuqlik interfeysida kuchli itaruvchi kuchni qo‘llash orqali bu kuchni yengib o‘tishlari mumkin, bu esa tutilgan suvning chiqib ketishiga imkon beradi. Keyinchalik bu suv gidratatsiya jarayonida ishlatiladi, aks holda qo‘shilishi kerak bo‘lgan suv miqdori kamayadi [4].

Uchikava va boshqa olimlar tomonidan ta’kidlanganidek, polikarboksilat superplastifikatorlari hozirda beton mahsulotlarini sifatini va ishlash qobiliyatini yaxshilash uchun qurilish sanoatida keng foydalanib kelinmoqda. Ular sement zarralariga adsorbsiyalanadi, dispersant sifatida elektrostatik va sterik itarilish effektlari ishlaydi [5].

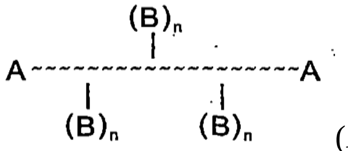
Polikarboksilatli superplastifikator to‘yinmagan karbosiklik kislota monomerlari, uzun zanjirli alkan makromonomerlari va boshqalar asosida sintezlanadi. Bu betonda ajoyib natijalar ko‘rsatgan sement dispersant edi [6]. Superplastifikator qo‘shilgan beton qorishmalarning ishlashi turli parametrlarga bog‘liq. Bir tomondan, reologiyaga qo‘shimchasining turi, kimyoviy tarkibi va molekulyar tuzilishi ta’sir qiladi [7].

Kimyoviy sintez qilib erishilgan barcha natijalarga qaramay, polikarboksilat asosidagi qo‘shimchalar uchun ularning sifatli qumlarga muvofiqligi bo‘yicha hali ham yaxshilanishlar mavjud. Ma’lumki, oz miqdorda (<0,5%) ma’lum turdagi loylarni o‘z ichiga olgan qumlar polikarboksilat superplastifikatorlarining ishlashiga to‘sqinlik qiladi [8]. Bu loylar smektit-montmorillonit loylari kabi shishish xususiyatiga ega bo‘lgan loylarni o‘z ichiga oladi va ular polikarboksilat qo‘shimchalarining tarqalish qobiliyatini butunlay bostirishga qodir [9-10].

Reaktiv guruhlar polikarboksilat magistrallaridagi –COOH guruhi bilan reaksiyaga kirishishi mumkin va –C=C- qo‘sh bog‘lari bo‘lgan yon zanjirlar ham radikal polimerlanish yo‘li bilan magistralga qo‘shilishi mumkin.Shu tarzda polikarboksilatning tuzilishi va xossalarini o‘zgartirish mumkin [11].

Tadqiqot metodologiyasi. Biz polikarboksilat superplastifkatorini 70℃ suvli eritma sharoitida erkin radikal polimerizatsiya reaksiyasi orqali makromonomer sifatida polioksietilen izobutil spirti efir (HPEG) va akril kislota (AA), metilmetakrilat (MAA), inisiatordan foydalanib, sopolimer sintez qildik. Makromonomerlarning molekulyar og‘irligi, polimerizatsiya faolligi kabi xususiyatlar polikarboksilat sifati va ishlashiga ta’sir qiluvchi omillardir. Ularni tayyorlash usullari quyidagicha ko‘rsatilgan. HPEG, AA ning radikal kopolimerizatsiyasi zanjir uzatish agenti merkaptan kislota yordamida 70°C haroratda boshlandi. Tajriba quyidagicha amalga oshiriladi: 500 ml uch bo‘yinli dumaloq tubi kolbaga MAA (2,1809 g,), HPEG (50,0112 g,), AA (6,3866 g,) va zanjir uzatuvchi

(0,86g,) qo‘shib aralashtiriladi. Tomdirgich yordamida aralashmaga inisiator (0,97 ml,) kiritildi. Keyin kolba 80°C haroratda termostatlangan moy hammomiga botirildi va reaksiyani 4 soat olib borildi. Polikarboksilat superplastfikatorning yakuniy mahsuloti sifatida 35 % li och sarg‘ish rangli suvli eritma bo‘lib, pH~8 ga keltirildi. Polikarboksilat superplastifikatorini sintez qilishda mutaxassislar polikarboksilat sopolimerlarida makromonomerning molyar nisbatlari yakuniy mahsulotda mavjud bo‘lgan haqiqiy molyar nisbatlarini aks ettirishi shart emasligini tan oladilar. Aslida, metakril kislota va akril kislota kabi yuqori reaktiv monomerlar makromonomerlar bilan birlashganda, geterogen tarkibli sopolimerlar hosil bo‘ladi.Suvli radikal sopolimerizatsiya jarayonida monomerlar payvand yoki blok zanjirlariga joylashtirilishi mumkin. Mos ravishda ikkita A va B monomerlaridan tashkil topgan tizim uchun mavjud bo‘lgan turli xil imkoniyatlarning umumiy ko‘rinishi 1-rasmda ko‘rsatilgan.



(A)

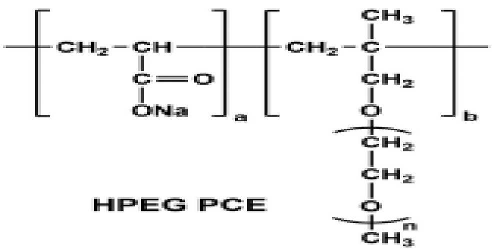
A-A-A-A-A-B-B-B-B-A-A-A-A-

-B-B-B-B-B-A-A-A-A-A-B-B-B-B- (B)

2-rasm. Monomerlar payvand (A)va blok(B) zanjirlariga joylashtirilishi.

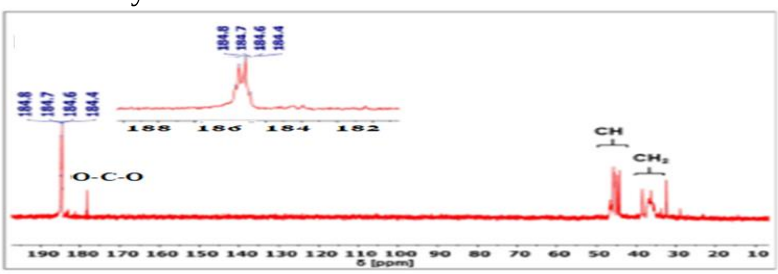
HPEG asosidagi PCE uchun ikkita tijorat mahsuloti ishlatilgan: tayyor va prefabrik turdagi anion zaryad zichligi.

PCE ning umumiy kimyoviy tuzilmalari 3-rasmda ko‘rsatilgan.



3- rasm. PCE ning umumiy kimyoviy tuzilmalari

Natijalar va muhokama. YaMR spektrlari JNM-EC3600P spektrometrida 400 MHz chastotada aniqlangan.^{1}H YaMR spektrlarida satndart sifatida TMS (0ppm) ishlatilgan. ^{1}H YaMR spektrlarida standart sifatida erituvchining kimyoviy siljishi hisobga olingan. Somopolimer rezonans cho‘qqilarining kuzatilgan nisbiy intensivligi kuzatilgan qiymatlarga yaxshi mos keldi, bu polimer va sopolimer spektrlarini qayd qilish uchun qo‘llaniladigan shartlar miqdoriy YaMR spektroskopiya ma’lumotlarini olish uchun yetarli bo‘lishini ta’minlaydi.



4-rasm. Polikarboksilatning pH ga bog‘liq YaMR spektroskopiya; pH 8 da.

4-rasmda HPEG, akrilat kopolimerining YaMR spektroskopiyasi ko‘rsatilgan. Olingan natijalar tahliliga ko‘ra, sopolimer spektrida karbonil, metin va a-metil uglerod atomlarining rezonanslari gomopolimerlardagi kabi mintaqalarda kuzatiladi, lekin gomopolimer spektrlarida ifodalanmaydigan signallar ham mavjud. Ushbu signallar monomer birliklarining sopolimer zanjiri boʻylab qanday joylashishi haqida ma'lumot beradi. Akril kislotasi miqdori ortib borayotgan AA signalining past maydon siljishini hisobga olgan holda (HPEG1.0 da d = 182 ppm dan 188 ppm gacha, polimerda mavjud boʻlgan yuqori molekulyar ogʻirlikdagi qismlarni polikarboksilat deb taxmin qilish mumkin, qolganlari ham asosiy birlik sifatida AA boʻlgan polikarboksilat sopolimeridir. Shuning uchun, Polikarboksilat uchun HPEG: AA ning taxminiy oʻrtacha tarkibi asosiy fraksiya uchun taxminiy 8:2 nisbatni tashkil qiladi. Yuqoridagi tahlilga asoslanib, sintez qilingan namuna funksional guruhga ega va shuning uchun AA va makromonomer oʻrtasida nisbatan toʻliq sopolimerizatsiya, shu jumladan, Polikarboksilat uchun monomer sifatida namoyon boʻldi. Sement pastasining suyuqligi GB / T8077-2012 "Beton qoʻshimchalari uchun sinov usuli" ga muvofiq sinovdan oʻtkazildi [12], unda biz sintez qilgan polikarboksilat superplastifikatorining 23% suvli eritmasida 0.9 % miqdorda suv sement nisbati 0.26 ga tejashga erishildi.

Xulosa va takliflar. Maqolada YaMR spektroskopiya yordamida AA va HPEG ning molyar nisbatlarida 8:2 dan 4,5 gacha boʻlgan akril kislotadan va qisqa zanjirli HPEG makromonomeridan sintez qilingan PCE sopolimerlarining mikro tuzilishi oʻrganildi. Ushbu usul ushbu PCE kopolimerlarida yuzaga keladigan mikro tuzilmani ketma-ketligini) aniqlash uchun yarim miqdoriy usul ekanligi aniqlandi. Ushbu yondashuvga rioya qilish orqali nazariy jihatdan butunlay boshqacha boʻlishi mumkin boʻlgan haqiqiy polimer tarkibining nisbatan real konsep siyasini olish mumkin. Sementdagi dispersiya tahlil natijalari bilan birlashtirish dispersiya samaradorligi qaysi mikrostrukturaviy tuzilma eng samarali ekanligini va sintez qilishda qaysi biri asosiysi boʻlishi kerakligini bilib olishga yordam beradi. Kelgusi tadqiqotlarda yon zanjir uzunligi, sopolimerizatsiya paytida PCE polimerlarining mikrostrukturaviy tuzilishiga ishlatiladigan zanjir uzatuvchi agenti va inisiator kabi parametrlarning ta'sirini ham hisobga olgan holda sintez jarayonini amalga oshirish kerak.

Foydalanilgan adabiyotlar roʻyxati

1. Исмоилов Ф.С., Каримов М.У., Джалилов А.Т// Исследование процесса синтеза суперпластификатора и его икспектра. - "Фан ва технологиялар тараққиёти" Илмий–техникавий журнал №5/2022. bet.115-119.

2.V.M. Malhotra (Ed.), 5th International Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Rome, SP173, ACI, 19972.

3. S. Sha, M. Wang, C. Shi, and Y. Xiao, "Influence of the structures of polycarboxylate superplasticizer on its performance in cement-based materials-A review," Constr. Build. Mater., vol. 233, p. 117257, 2020, doi: 10.1016/j.conbuildmat.2019.117257.

4.J. Cheung, A. Jeknavorian, L. Roberts, and D. Silva, "Impact of admixtures on the hydration kinetics of Portland cement," Cem. Concr. Res., vol. 41, no. 12, pp. 1289–1309, 2011, doi: 10.1016/j.cemconres.2011.03.005

5. H. Uchikawa, S. Hanehara, D. Sawaki, Therole of steric repulsive force in the dispersion of cement particles in fresh paste prepared with organic admixture, Cem Concr Res 27 (1) (1997) 37-50.

6. Shuncheng Xiang, Yingli Gao and Caijun Shi. // Progresses in Synthesis of Polycarboxylate Superplasticizer. // Advances in Civil EngineeringVolume 2020, Article ID 8810443, 14 pageshttps://doi.org/10.1155/2020/881044.

7.Johann Plank, HuiqunLia, ManuelIlga, Julia Pickelmann, Wolfgang Eisenreich,Yan Yaod, ZimingWang. //A microstructural analysis of isoprenol ether-based polycarboxylates andthe impact of structural motifs on the dispersing effectiveness. // Cement and Concrete Research 84 (2016) 20–29.

8. D. Atarashi, Interaction between superplasticizers and clay minerals, Jpn. Cem.Assoc. (2005) 287–292.

9. D. Atarashi, K. Yamada, A. Ito, M. Miyauchi, E. Sakai, Interaction betweenmontmorillonite and chemical admixture, J. Adv. Concr. Technol. 13 (2015)325–331.

10. L. Xoing, G. Zheng, Y. Bi, C. Fu, Effect of typical clay upon the dispersionperformance of polycarboxylate superplasticizer, in: Proceedings InternationalConference on Materials, Environmental and Biological Engineering, 2015, pp.226–229.

11. T. Yang, X. Yao, Z. Zhang, and H. Wang, "Mechanical property and structure of alkali-activated fly

ash and slagblends," Journal of Sustainable Cement-Based Materials, vol.1, no 4, pp. 167–178, 2012.

12. KZJ New Materials Group Co., Ltd. Xiamen 361101, Fujian, China // Study on Preparation of Low Hydration Thermal Polycarboxylate Superplasticizer by Low Temperature Esterification. // IOP Conf. Series: Materials Science and Engineering 392 (2018) 052001 doi:10.1088/1757-899X/392/5/052001.1-6 page.

THE ROLE OF DYNAMIC SIMULATION MODELS IN CHEMISTRY EDUCATION

Davronova F.L
Karshi international university
senior teacher of the department of
exact scienses
firuzadavronova612@gmail.com
ORCID 0009-0006-1899-7568
UDK: 54-1; 541.10(0.45)

Abstract. This paper focuses on the integration of dynamic simulation models and chemistry lessons and its importance in education. The advantages of integrated lessons over traditional lessons, the results achieved when organizing integrated lessons. An overview of dynamic simulation models are presented, identifying their important aspects and significance in practice, ways of using dynamic simulation models and solving problems arising in chemical education using simulation models. In addition, the advantages of dynamic simulation models and the types of applications are clarified. The paper presents how simulation models are used in the topic "Exothermic and endothermic reactions", the sequence of choosing simulation models, applications and why they are needed, preliminary control tests and results.

Key words: dynamic models, exothermic, endothermic, integrated learning

KIMYO TA'LIMIDA DINAMIK IMITATSION MODELLARINING O'RNI

Annotatsiya. Ushbu maqola dinamik imitatsion modellari va kimyo fanidan mashg'ulotlar integratsiyasi va uning ta'limdagi ahamiyatiga qaratilgan. Dinamik imitatsion modellarning umumiy ko'rinishi, ularning muhim jihatlari va amaliyotdagi ahamiyati, dinamik imitatsion modellardan foydalanish usullari va imitatsion modellar yordamida kimyoviy ta'limda yuzaga keladigan muammolarni hal qilish mumkinligini ko'rish mumkin. Bundan tashqari, dinamik simulyatsiya modellarining afzalliklari va qo'llanilish turlari ham taqdim etilgan. Maqolada "Ekzotermik va endotermik reaksiyalar" mavzusida imitatsion modellardan qanday foydalanilishi, imitatsion modellarni tanlash ketma-ketligi, va ular nima uchun kerakligi, dastlabki nazorat sinovlari va natijalari keltirilgan.

Kalit so'zlar: dinamik modellar, ekzotermik, endotermik, integratsiyalashgan ta'lim.

Introduction. In modern education the use of information and communication technologies is actively developing, the integration of lesson processes with simulation models is increasing. They allow us to access different forms of information presentation and actively interact with them. Stimulation of the visual apparatus and hearing, activation of various channels of perception and processing of information makes the educational process more intensive, easy, effective, colorful and subjective.

In this regard, the use of virtual reality skills in education, which creates ample opportunities for the introduction of multimedia technologies in the educational process, allows achieving promising results. Freely available electronic resources are actively used with laboratory materials, work on various subjects and topics, fill traditional forms and are integrated into the learning process. Simulation modeling allows you to simulate the behavior of a system over time. Computer simulation helps to develop and expand professional knowledge, strengthen students' professional thinking and reasoning abilities, and realize new ideas. [1].

Simulation models can take many forms. For example, "dynamic simulation models" are modeling systems used to simulate how variables and their interactions change over time. The main features of dynamic simulation modeling are as follows:

1.Dynamic models act as a critical time variable and show how the results change over time. This helps in predicting the future state of the system.

2.These models identify the relationships and effects between elements within a system. For example, it shows how one change in economic, environmental, biological, chemical or social systems can affect other elements.

3. Dynamic simulation can show how a system adapts to changing conditions.

Literature review. Molecular dynamics models are a promising class of computational models with broad applications in science education. Molecular dynamics models use classical mechanics and the atomic force approximation to calculate the motion of sets of atoms and molecules in two or three dimensions. An animation may be run simply as a video clip, or it may consist of several video clips selected to match some input signal. For example, a popular atomic-scale animation shows different pieces of atoms moving at speeds depending on temperature settings. As a result, students can experiment with the system and create accurate models endlessly. However, much can be learned from studies using animated atomic-scale models [2].

The word animation means a planned or scripted presentation of a series of images, the simplest example being video. Viewers cannot change the animation. As a result, all students see the same animation. [3]. In most scientific and engineering fields, there are two main types of computer models: data models and process models. Computer modeling becomes “dynamic” not only when the feedback processes between system components are fixed in time, but also when model development is based on the dynamic exchange of data and information between a group of modelers and a group of users [4]. Today, science educators have access to sophisticated multimedia models that allow students to view and interact with models of phenomena and processes. These simulations can provide students with visual representations of dynamic theoretical entities that are difficult to visualize in the static environment of a science textbook, but are important for understanding why materials behave the way they do [5].

In the early 1990s, behaviorist approaches were still evident, and digital learning technologies were mainly used to provide teaching aids and “learn and practice” environments. However, later on, new approaches such as "computer-assisted learning" emerged. [6]. Since the invention of molecular graphics, a subject focused on visualizing molecules using three-dimensional computer graphics, chemists have used molecular visualization tools that allow them to quickly display molecular structures and view them from different perspectives. Several free tools have been developed to display molecules on web pages [3]. Chemical concepts related to fluid equilibrium mechanics are often explained with static diagrams in many textbooks, but in most cases it is an effective way to describe phenomena involving moving molecules. [7]. Molecular dynamics simulations using forward potentials from electronic structure theory have recently been shown to open new reaction pathways in complex chemistry and allow the investigation of high-temperature and high-pressure conditions where fine-grained mechanisms are difficult to resolve experimentally. Combined with these methods for finding new reactions, our statistical systems will eventually lead to building comprehensive Monte Carlo kinetic models for complex chemistry. [8]. Numerous studies have focused on the use of simulations as a means of preparing students for laboratory activities. A more recent study compared the capabilities of 3D virtual laboratories (VL) and real laboratories (RL) as tools to familiarize students with the spatial structure of the laboratory and the devices and equipment it contains. After the VL group explored the simulation and the RL group toured the actual laboratory, all students were tested on their memory of the laboratory layout and familiarity with the equipment. The researchers concluded that virtual laboratories are an effective tool for familiarizing students with the laboratory environment [9]. The use of computer technology to facilitate learning typically takes the form of programmed instruction. Computer simulations are computer programs that create animated, interactive, game-like environments that focus on connecting real-world phenomena with basic science. Through this process, the visual and conceptual models developed by experts and scientists are made simple and easy for students to understand. [10].

Methodology. For the research design, I chose the topic “Exothermic and Endothermic Reactions” and chose 2 different teaching methods to cover this topic. 2 groups (30 students in each group) agreed to participate in the study. I named the groups A and B. Group A’s lesson traditionally began with a presentation and ended with writing on the board. To Group B, the topic of energy absorption and release in reactions was explained using dynamic simulation models. Initially a kinetic model was used to correctly determine the period of the reaction process. As a result, it can be seen that an increase in internal temperature may be required to allow energy movement as long as the change is detected during the reaction. The next step is the selection of thermodynamic models. Because it has been shown that endothermic reactions require an increase in temperature and exothermic reactions require a decrease in temperature. Then in order to study random angles we chose Monte Carlo models. Using this model facilitates to study the dynamics of reactions. Next step is choosing Computational Fluid Dynamics (CFD) model explains how gases or liquids change during the reaction. In a reaction, temperature is the change in pressure and different masses.

Analyzing of Data. The graph created by the analysis is customized into 2 groups. Trends of increasing, decreasing or staying put are analyzed in detail. Investigation is assessed by comparing two different explanations of a topic. The test results show that out of 30 students in group A, 11 students got a satisfactory grade, 5 students got a good grade and 14 students got an unsatisfactory grade. Out of 30 students in group B, 12 students were rated as excellent, 15 students were rated as good and 3 students were rated as satisfactory. Prior to this study, a research application was submitted and permission was obtained to study the integration of chemistry through simulation models.

Findings/Results. Initial implementation ideas were explored for both groups at the beginning of the study. The study assesses students’ initial skills in developing simulations and integrating chemistry. The students said that they face difficulties in subjects unrelated to their major, such as chemistry. But they noted that integrated education increases their interest and develops their analytical skills. After additional questions about how to identify the development stages of integrated education, it became clear that they had incorrect information. Students stated that it would be difficult to learn the topic orally. It is very helpful to present the material sequentially to increase student interest in all aspects of science. For example, when teaching the topic “Law of Conservation of Mass” instead of providing the concept only through the area of science, connecting it to mathematical thinking skills such as analysis and inference using dynamic modeling, the rate of learning was higher. The development of lessons in chemistry classes based on simulation models and the results of comparison of students’ knowledge, skills and abilities with traditional lessons are presented in Figure 1.

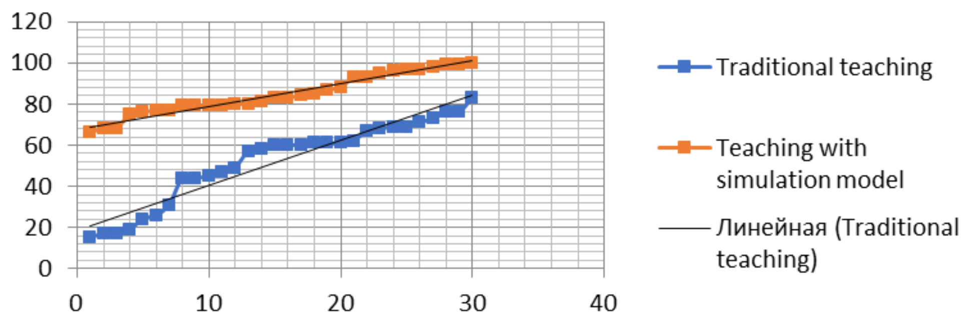


Figure 1.

Red lines represent lessons organized with simulations. Accordingly, the blue lines show the results of conventional chemistry teaching.

Group A	Traditional teaching			
	Student number	Result (out of 100 points)	Student number	Result (out of 100 points)
	1	15	16	60
	2	17	17	60
	3	17	18	61
	4	19	19	61
	5	24	20	61
	6	26	21	62
	7	31	22	67
	8	44	23	68
	9	44	24	69
	10	45	25	69
	11	47	26	71
	12	49	27	73
	13	57	28	76
	14	58	29	76
	15	60	30	83

Figure 2

Group B	Teaching with simulation model			
	Student number	Result (out of 100 points)	Student number	Result (out of 100 points)
	1	66	16	83
	2	68	17	84
	3	68	18	85
	4	75	19	87
	5	76	20	88
	6	77	21	93
	7	77	22	93
	8	79	23	95
	9	79	24	96
	10	79	25	97
	11	79	26	97
	12	80	27	98
	13	80	28	99
	14	81	29	99
	15	83	30	100

Figure 3

Discussion. When implementing integrated learning using simulation models in chemistry education, students often encounter various problems in the teaching practice of college, school. The problem is that teachers fail to develop integrated learning, and it affects students' grasp of concepts. Students become more active if the teacher achieves integration with simulation models in the college-school teaching process. First, integrated learning allows for more in-depth study and analysis of subject-specific problems in chemistry classes. This method also helps students make decisions and identify alternative strategies when they encounter difficulties in understanding. Based on the observation of the use of the assessment system, students can discuss the problems encountered in the training sessions organized with dynamic simulation models in a team and analyze them based on the results achieved. Thus, students emphasized that the sessions integrated with dynamic simulation models for skill building are unforgettable and very interesting. Teaching with this method allows students to work independently and develop self-regulation skills. At the end of the session, students were motivated and convinced that the simulations had helped them develop their understanding of simple concepts to complex ones.

Conclusion. In conclusion, simulation-based learning is important for further developing students' understanding, especially for self-assessment and analysis of knowledge gained. This study fills a gap in traditional teaching. Because the analysis and teaching of self-knowledge is activated by students having the opportunity to solve real-life problems through lessons organized in the framework of integrated science education.

Recommendations. More research is needed to implement community-based learning with groups of students studying common subjects. To get more information and compare them, integrated activities can be realized based on simulation models of the same subject in other universities. Based on the simulation models, teachers of integrated learning should consider providing teaching materials appropriate to the students' environment so that they link educational theory and practice in real-life settings.

References

1. Nsabayezu, E., Iyamuremye, A., Mukiza, J. et al. Impact of computer-based simulations on students' learning of organic chemistry in the selected secondary schools of Gicumbi District in Rwanda. Educ Inf Technol 28, 3537–3555 (2022). https://doi.org/10.1007/s10639-022-11344-6

2. Pallant, A., Tinker, R.F. Reasoning with Atomic-Scale Molecular Dynamic Models. Journal of Science Education and Technology 13, 51-66 (2004). https://doi.org/10.1023/B:JOST.0000019638.01800.d0

3.Xie, C., Pallant, A. (2011). The Molecular Workbench Software: An Innovative Dynamic Modeling Tool for Nanoscience Education. Models and Modeling in Science Education, vol 6. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0449-7_6

4. Bruce Hannon, Matthias Ruth (2000) 2nd edition Dynamic Modeling

5. Jan L. Plass, Catherine Milne, Bruce D. Homer, Ruth N. Schwartz, Elizabeth O. Hayward, Trace Jordan, Jay Verkuilen, Florrie Ng, Yan Wang and Juan Barrientos Investigating the Effectiveness of Computer Simulations for Chemistry Learning JOURNAL OF RESEARCH IN SCIENCE TEACHING vol. 49, no. 3, pp. 394–419 (2012)

6. Bellou, I., Papachristos, N.M., Mikropoulos, T.A. (2018). Digital Learning Technologies in Chemistry Education: A review. Digital Technologies: Sustainable Innovations for Improving Teaching and Learning. pp 57-80 https://doi.org/10.1007/978-3-319-73417-0_4

7. Alexandra Velazquez-Morcano Vickie M. Williamson, Guy Ashkenazi, Roy Tasker and Kenneth C. Williamson, The Use of Video Demonstrations and Particulate Animation in General Chemistry Journal of Science Education and Technology, pp 315-323 Vol. 13, No. 3, September 2004

8. Qian Yang, Carlos A.Sing_Long and Evan J. Reed (2017) Learning reduced kinetic MonteCarlo models of complex chemistry from molecular dynamics. Royal Society of Chemistry, Chem sci. 2017, 8, pp 5781-5796 https://doi.org/10.1039/C7SC01052D

9. Nico Rutten, Wouter R. van Joolingen, Jan T. Van der Veen (2012) The learning effects of computer simulations in science education. Computers & Education pp 136-153 DOI:1016/j.comp.edu.2011.07.017 https://doi.org/10.1016/j.compedu.2011.07.017

10. Adekunle I. Oladejo, Victor Olu Akinola and Nwabuno C. Nwaboku (2021) Teaching chemistry with computer simulation: Would senior school students perform better? Crawford journal of multidisciplinary research (cjmr) Vol.2 no.2, september, pp. 16-32

RESEARCH OF THE PROCESS OF OBTAINING ALCOHOLS BASED ON BY-PRODUCTS OBTAINED IN FISCHER-TROPSCH SYNTHESIS

Rakhimov Ganisher Bakhtiyorovich
Karshi Institute of Engineering and Economics, associate professor, Ph.D.
ganisher.raximov@inbox.ru
ORCID 0009-0004-1970-1541
Sayfiyev Elbek Xalmaxmat o'g'li
Lead Engineer, Uzbekistan GTL LLC
UDC 665./.7: 66-9

Abstract: Today, in the world and in our country, the need for fuel for liquid internal combustion engines used in the transport sector is met by fuels produced in an alternative form (liquefied synthetic fuels) in addition to natural liquid hydrocarbon sources. Fischer-Tropish synthesis is one of the main processes in the production technology of liquid synthetic fuel. In the Fischer-Tropsch synthesis, alkanes, alkenes, water of reaction and alcohols are formed. In this article, the factors affecting the efficiency of the Fischer-Tropsch synthesis reaction in the production of liquefied synthetic fuel and the results of the analysis of the chemical composition of the main and by-products formed in this process are studied. Also, the results of research on the extraction of technical alcohols and solvents by fractionation of additional organic products formed in the Fischer-Tropsch synthesis into fractions by the rectification method are presented.

Key words: reactor, liquefied synthetic fuel, synthesis gas, alkane, alkene, alcohol, reaction water.

FISCHER-TROPSCH SINTEZIDA HOSIL BO‘LADIGAN QO‘SHIMCHA MAHSULOTLAR ASOSIDA SPIRTLAR OLISH JARAYONINI TADQIQ QILISH

Annotatsiya: Bugungi kunda dunyoda va mamlakatimizda transport sohasida qo‘llaniladigan suyuq ichki yonuv dvigatellari yonilg‘isini ehtiyoji tabiiy suyuq uglevodorod manbalaridan tashqari alternativ shaklda (suyultirilgan sintetik yoqilg‘ilar) ishlab chiqariladigan yoqilg‘ilar orqali qondirilmoqda. Bunda suyuq sintetik yoqilg‘i ishlab chiqarish texnologiyasida Fisher-Tropish sintezi asosiy jarayonlardan biri hisoblanadi. Fisher-Tropsh sintezida alkanlar, alkenlar, reaksiya suvlari va spirtlar hosil bo‘ladi. Ushbu maqolada suyultirilgan sintetik yoqilg‘i ishlab chiqarish jarayonda Fisher-Tropsh sintezi reaksiyasi samaradorligiga ta’sir etuvchi omillar hamda ushbu jarayonda hosil bo‘ladigan asosiy va qo‘shimcha mahsulotlarni kimyoviy tarkibi tahlili natijalari o‘rganilgan. Hamda Fisher-Tropsh sintezida hosil bo‘lgan qo‘shimcha organik mahsulotlarni rektifikatsiya usulida fraksiyalarga ajiratish orqali texnik spirtlar va erituvchilar ajiratib olish bo‘yicha olingan tadqiqot natijalari keltirilgan.

Kalit so‘zlar: reaktor, suyultirilgan sintetik yoqilg‘i, sintez gazi, alkan, alken, spirt, reaksiya suvlari.

Introduction: The main share of the fuel-energy complex is made up of liquid hydrocarbon fuels of internal combustion engines. Currently, internal combustion engines make up the main part of existing transport systems. As the number of people increases, so does the number of vehicles that serve them. This, in turn, causes an increase in the need for internal combustion engine fuel. Our republic does not have enough oil reserves to fully cover this need with the help of liquid hydrocarbon fuel produced using natural oil raw materials. Therefore, this need is partially covered by the production of synthetic liquid fuel using alternative methods. The emergence of synthetic liquid fuel production technology dates back to the 40s of the XX th century. This period corresponds to the period of the Second World War, and it is important for the need for fuel in the war. The main raw materials for the production of synthetic liquid fuel are coal and natural gas.

Literature analysis: Currently, there are the following enterprises in the world producing synthetic liquid fuel based on natural gas and hard coal [1]:

1. The Sasol company in South Africa produces coal-based light olefins and gasoline.
2. Gasoline and diesel fuel based on methane from the Mossgascompany in South Africa.
3. The Malaysian “Shell” corporation produces paraffins, chemical reagents and diesel fuel based on methane raw materials.
4. Sasol Conoco Phillips in Qatar
5. Sasol Chevron Company of Nigeria
6. “Uzbekistan GTL LLC” in Uzbekistan produces methane aviation kerosene and diesel fuel.

The production process of synthetic liquid fuel is carried out mainly on the basis of raw materials of methane, and this process consists of the following technologies[1].

1. Preparation of methane raw materials: (natural gas preparation, drying, cleaning, fractionation).
2. Methods of obtaining synthesis gas from methane:

I. $CH_4 + O_2 \rightarrow 2CO + 4H_2$ partial oxidation.

II. $CH_4 + H_2O \rightarrow CO + 3H_2$ water vapor conversion.

III. $CH_4 + CO_2 \rightarrow 2CO + 2H_2$ carbonic anhydride conversion.

Synthesis gas is mainly produced in industry using partial oxidation and water vapor conversion methods.

Fisher Tropish Synthesis. In this process, the process of synthetic extraction from synthesis gas is considered, in which CO and H_2react in the reactor to produce the main product synthetic oil (Wax) and intermediate products (aldehyde, ketone, alcohol, water, etc.). The following reactions take place in the process[2].

The main reactions:

I. $nCO + (2n+1)H_2 \rightarrow C_nH_{2n+2} + nH_2O$ alkanes

II. $nCO + 2nH_2 \rightarrow C_nH_{2n} + nH_2O$ alkenes

III. $CO + H_2O \leftrightarrow CO_2 + H_2$ reaction waters

Side reactions:

I. $nCO + 2nH_2 \rightarrow H(-CH_2-)_nOH + (n+1)H_2O$ alcohols

Boudouard reactions.

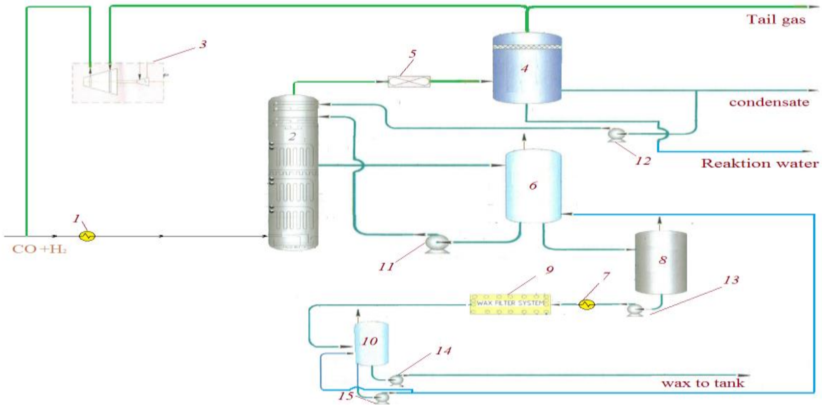
I. $2CO \rightarrow C + CO_2$

4. Refinement and fractionation of artificial oil obtained as a result of Fischer-Tropish synthesis.

Fisher-Tropish synthesis is one of the main processes in the technology of liquefied synthetic fuel. The scheme of Fischer-Tropish synthesis technology is presented in fig. 1. In this, the syngas and hydrogen mixture purified by the separator and the recycle gas in the circulation are added, heated to 112 ºC using the heat exchange equipment 1 and fed to the cube of the reactor 2 (225-230 ℃). Raw gas flows through the wax catalyst mixture loaded into the reactor, H_2 and CO components in the raw gas react with the presence of the catalyst, and wax, condensate (HC) and reaction water are formed. Condensate and reaction water formed as a result of the reaction boil at the existing temperature of the reactor, together with the components that did not participate in the reaction, the condensate and wax mixture fed to the upper part of the reactor are washed from the wax residues with the help of plates, and the exit temperature from the top of the reactor reaches 185 ºC. We cool the temperature of the effluent gas coming out of the top of the reactor to 70 ºC through the air cooling equipment 5, that is, the goal: Separator 4 is to separate condensate and reaction water from the effluent gas composition. The tail gas coming out of the separator is sent to compressor 3 for circulation. The wax formed as a result of the reaction in the reactor is added to the wax layer. Keeping the wax layer in the reactor at the intended level is carried out through the existing filters in the reactor [3].

The level of the wax layer in the reactor is controlled by changing the mode of operation of the filters in the reactor. The wax in the reactor passes through the filter and is sent from the reactor to the separator. The function of the wax drum is to clean the wax coming from the reactor from the gases contained in it. A part of the degassed wax in the drum is pumped to the separator 8, and the remaining part is pumped to the reactor through pumps. The wax poured into the separator from the separators in two trains is separated again and the gases contained in the wax are cleaned. Through the wax A/B pumps in the separator, the heat exchangers are cooled to 120 ºC by the BFW 7 and pumped to the Wax Filter System 9. In the Wax Filter System, the wax is filtered from the catalyst particles. The purified wax is sent to the separator 10 and is separated from the following gases and sent to the processing of the reaction water through the pumps 15[1,4].

Figure 1. Technological scheme of the Fischer-Tropsch process.



1-heat exchange equipment; 2-Fisher-Tropish fusion reactor; 3-compressor; 4-separator; 5-air cooling equipment; 7-heat exchange equipment; 8-separator; 9-filter; 10-separator; 11, 12, 13, 14, 15 – pumps;

Research methodology. The main product in Fischer-Tropsch synthesis is synthetic oil, and the rate of production of synthetic oil as a result of the reaction in the reactor depends on the following conditions[5]:

It depends on the composition and activity of the catalyst. An aluminum-based cobalt catalyst is used in Fischer-Tropsch synthesis technology.

Syn gas composition (amount of harmful gas, percentage of H_2/CO).

If Syn Gas contains harmful gases, it will damage the catalyst in the reactor, which will reduce the yield of the main reaction.

The main parameters in the reactor (temperature 225-230℃, pressure 3-4 MPa) affect the productivity of the main reaction.

The ratio of reacting raw materials (H_2/CO) affects the yield of the main reaction. The effect of H_2/COratios on the reaction product is presented in Table 1.

Table 1

In Fischer-Tropsch synthesis technology, the yield of the reaction depends on the ratio of raw materials (H_2/CO).

	Reaction products	Reactions	$ratio of H_2/CO$
	Methane	$CO + 3H_2 \rightarrow CH_4 + H_2O$	3
	Ethan	$2CO + 5H_2 \rightarrow C_2H_6 + 2H_2O$	2,5
	Alkanes	$nCO + (2n+1)H_2 \rightarrow C_nH_{2n+2} + nH_2O$	$(2n+1)/n$
	Alkenes	$nCO + 2nH_2 \rightarrow C_nH_{2n} + nH_2O$	2
	Alcohols	$nCO + 2nH_2 \rightarrow C_nH_{2n+1}OH + (n-1)H_2O$	2

In Fischer-Tropsch synthesis technology, the level of production of synthetic oil in the reactor depends on the conditions mentioned above, and by ensuring catalyst activity, optimal mode parameters and the required ratio of raw materials in the process, high productivity of alkanes in the reaction is achieved [6].

Analysis and results. In Fischer-Tropish technology, reaction waters and organic compounds (alcohols, ketones, aldehydes, ethers) are formed as by-products. This organic product has a high alcohol content. By rectification of the reaction waters, the additional products formed in the process of Fischer-Tropsch synthesis were divided into fractions. (Fig. 2.). 100 ml of mixture was taken. The starting boiling point is 75.5^{0}C. During the driving process, 100 ml of the mixture was introduced into 2 driving flasks and heated to 75-95℃. The vapor phase was cooled by a condenser 6 and collected in a collection flask 8. The process was carried out for 7 minutes, leaving the heavy phase as a residual product at 95℃ [7].

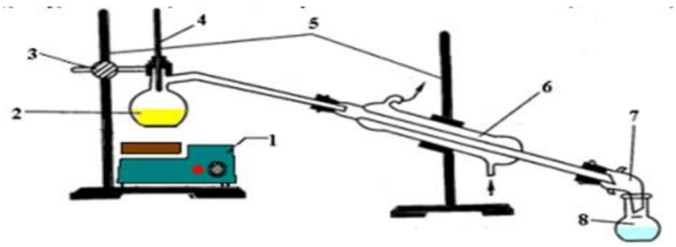


Figure 2. An instrument used for simple driving of liquids.

1) Plate, 2) driving flask (Wurtz flask), 3) clamp with asbestos paper,
2) 4) thermometer, 5) tripods, 6) Libix cooler, 7) extension, 8) collecting flask

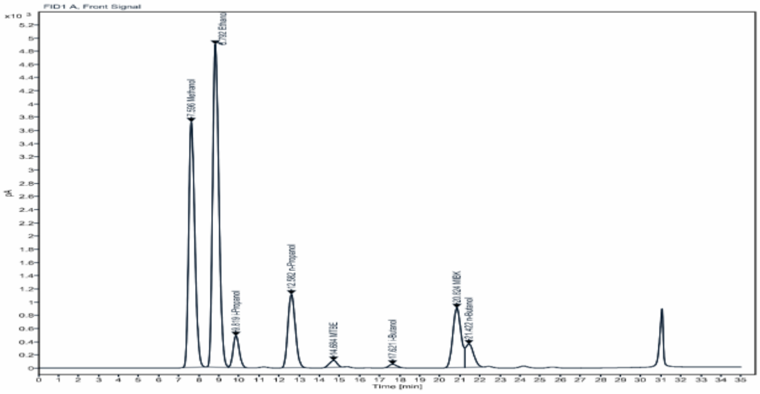
2-jadval

Results obtained by driving reaction waters and organic compounds

Fraction	Boiling temperature range, ^{0}C	Volume, ml.	Volume %
1	75,5 – 95	72	72
2	Above 95 balance	23	23
Losses		5	5

The composition of the light phase obtained from the driving process (dissolved at a temperature of 75.5-90 ℃) was analyzed using the chromatographic method (fig. 3) [7,8].

Figure 2. Reaction waters are the composition of organic products obtained as a result of purification.



Short Report (ISTD)

Name	RT [min}	RF	Oxyegen
Methanol	7.596	2.40306	18.28
Ethanol	8.792	1.62158	11.52
i-Propanol	9.819	1.37977	0.72
n-Propanol	12.582	1.18608	1.72
MTBE	14.684	0.60353	0.06
i-Butanol	17.621	3.63719	0.22
MIBK	20.824	1.00	0.00
n-Butanol	21.422	1.49949	0.62

Conclusions: According to the results of the analysis, alcohols are the main composition of the separated organic liquid. Technical alcohols or organic solvents can be produced from this mixture. The results of this analysis show that methanol and ethanol, which make up the main part of the organic liquid formed during the separation of reaction waters, can be fractionated by the method of rectification. In this case, the boiling point of methanol (64.7 ^{o}C) and ethanol (78^{o}C) is light compared to other components.

References

1. Uzbeksitan GTL MCH texnologik reglamenti.
2. For reviews of Diels-Alder reactions, see: (a) Nicolaou, K. C.; Snyder, S. A.; Montagnon, T.; Vassilikogiannakis, G. Angew. Chem., Int. Ed. 2002, 41, 1668. (b) Hayashi, Y. Cycloaddit. React. Org. Synth. 2002, 5. (c) Whiting, A. Adv. Asymmetric Synth. 1996, 126. (d) Oppolzer, W. Intermolecular Diels-Alder Reactions. In Comprehensive Organic Synthesis; Trost, B. M., Ed.; Pergamon Press, Oxford, UK, 1991; Vol. 5, Chapter 4.1, pp 315-99.
3. (a) Jung, M.E.; Ho, D.; Chu, H.V. Org. Lett. 2005, 7, 1649. (b) Jung, M.E.; Ho, D. Org. Lett. 2007, 9, 375.
4. (a) Marx, A.; Yamamoto, H. Angew. Chem., Int. Ed. 2000, 39, 178. (b) Boxer, M.B.; Yamamoto, H. Org. Lett. 2005, 7, 3127.
5. Б.С.Рачевский Сжиженные углеводородные газы. – М.: Изд-во «Нефть и газ». 2009. 640 с.

6. Rakhimov, G. B. (2023). Development of anti-detonation additive. *Экономика и социум*, (12 (115)-1), 604-607.
7. Murtazaev, F. I., & Raximov, G. B. (2023). Synthesis of sorbents used in the separation of halogens. *Sanoatda raqamli texnologiyalar*, *1*(01).
8. Rakhimov, G., Kuybokarov, O., & Karshiyev, M. (2024). Research of the catalytic properties of a catalyst selected for the production of high-molecular weight liquid synthetic hydrocarbons from synthesis gas. In *E3S Web of Conferences* (Vol. 498, p. 01008). EDP Sciences.

XLOROSULFONATLANGAN POLIETILEN ASOSIDAGI INTERPOLIMERLARNING ELEKTRON MIKROSKOPIK TAHLILI

Turasunnat Shomansurxon Karomatxo‘ja o‘g‘li.
Toshkent kimyo-texnologiya ilmiy-tadqiqot instituti tadqiqotchisi
Qiyomov Sharifjon Nozimovich.
Toshkent kimyo-texnologiya ilmiy-tadqiqot instituti katta ilmiy xodim
Nurqulov Fayzulla Nurmuminovich.
Toshkent kimyo-texnologiya ilmiy-tadqiqot instituti t.f.n.proff
Djalilov Abdulaxat Turobovich
Toshkent kimyo-texnologiya ilmiy-tadqiqot instituti.k.f.n.akad
shomansurturasunnat@gmail.com
0009-0006-7027-8587
UDK 667.6

Annotatsiya. Ushbu maqolada melamin (MM-5), melamin-formaldegid karbamid (MFK-2), melamin karbamid karbamid (MUK-4) va melamin karbamid (MU-3) amin bog‘lovchilari asosida interpolimerlarning skanerlash elektron mikroskopi (SEM) tahlil qilinadi.) va polimerning sirt strukturasidagi o‘zgarishlar o‘rganildi. Natijada, MM-5, MUK-4 va MU-3 amin bog‘lovchilari asosidagi xlorosulfonatlangan polietilen (XSPE) va epoksi qatroni ED-20 interpolimerlari mexanik kuchlanishga chidamli ekanligi aniqlandi. Polivinilxlorid (PVX), Polivinilspirt (PVS), Polietilen (PE), Xlorsulfatlangan polietien (XSPE) polimer birikmalarni boshqa tarkibli polimerlar. XSPE benzol, benzil spirti, dekalin, dioktil ftalat, ksilen, metil etil keton, n-butilamin, nitrobenzol, piridin, uglerod disulfidi, tetraxloretilen, tetralin, toluol, xlorotilxlorid, furol, xloroformin, benzol, tionil, siklogeksanol kabi erituvchilarda yaxshi eriydi.

Kalit so‘zlar. xlorsulfonatlangan polietilen, epoksid smola, interpolimer, polimer qoplama, metall konstruksiya.

ELECTRON MICROSCOPIC ANALYSIS OF INTERPOLYMERS BASED ON CHLOROSULFONATED POLYETHYLENE

Abstract. In this article, scanning electron microscopy (SEM) analysis of interpolymers based on amine binders of melamine (MM-5), melamine-formaldehyde urea (MFK-2), melamine urea urea (MUK-4) and melamine urea (MU-3) will be done.) and changes in the surface structure of the polymer were studied. As a result, it was found that interpolymers of chlorosulfonated polyethylene (XSPE) and epoxy resin ED-20 based on amine binders MM-5, MUK-4 and MU-3 are resistant to mechanical stress. Polyvinyl chloride (PVC), polyvinyl alcohol (PVA), polyethylene (PE), chlorsulfated polyethylene (XSPE) polymer compounds with other polymers. XSPE is soluble in solvents such as benzene, benzyl alcohol, decalin, dioctyl phthalate, xylene, methyl ethyl ketone, n-butylamine, nitrobenzene, pyridine, carbon disulfide, tetrachloroethylene, tetralin, toluene, chloroethylene, benzil, furan, chlorolol, chlorolol, benzene.

Key words: chlorosulfonated polyethylene, epoxy resin, interpolymer, polymer coating, metal structure.

Kirish. Bugungi kunda Respublikamizda metall konstruksiyalarni qurilish sanoatida, avtomobilsozlik, neft-gaz va kimyo sanoatida keng qo‘llash orqali zamonaviy bino va inshootlar, texnologik uskunalar va boshqa qurilish materiallarining yangi turlarni ishlab chiqishda metall konstruksiyalardan foydalanish katta iqtisodiy va ekologik samaradorlikka olib kelmoqda. Metall konstruksiyalarni qo‘llash davomiyligini oshirish va boshqa xususiyatlarni yaxshilashda ushbu metallarni yuza qismini maxsus polimer qoplamalar bilan qoplash korroziya, kimyoviy moddalar ta’siri va tashqi ta’sirlardan himoyalashi ularni qo‘llanish sohalarni kengaytirilishiga olib keladi.[1].

Adabiyotlar tahlili. Metall konstrukstiyalarni korroziyadan himoyalashda zamonaviy polimer qoplamalardan biri bu interpolimer xususiyatli qoplamalar bo‘lib ularni asosan Polivinilxlorid (PVX), Polivinilspirt (PVS), Polietilen (PE), Xlorsulfatlangan polietien (XSPE) polimer birikmalarni boshqa tarkibli polimerlar bilan interpolimerlarini olish va qo‘llash bugungi kunda katta qiziqishlarga sabab bo‘lmoqda.[2]. Masalan, epoksid smolalari asosidagi interpolimerlarni olish ushbu polimerlarni elastiklik xossalarga ijobiy ta’sir etib metall konstrukstiyalarga qo‘llanilganda metallarning egilishi, cho‘zilishi va tebranishlarga barqarorligi oshib borishi ilmiy tadqiqotlarda o‘rganilgan.[3]. Shuning uchun interpolimer materiallarni tuzilishi mexanik xossalari qo‘llanish jarayonida talab etiladigan turli xossalariga moslashtirish, ya’ni o‘zgartirish imkonini beradi.[4]. Xlorsulfinirlangan polietilen kompozit materiallar [5], kauchuk, turli bo‘yoqlar va himoya qoplamalar [6] ishlab chiqarish uchun keng qo‘llaniladi. Shu bilan birga, XSPE asosidagi qoplamalarning ultrabinafsha nurlanishiga yetarli darajada qarshilik ko‘rsatmasligi, tarkibining o‘zgarishiga va uning mustahkamligi va yopishqoqlik xususiyatlarining yomonlashishiga olib keladi va eritmalarning yuqori yopishqoqligi ushbu materialdan foydalanish sohalarini cheklaydi. Bundan tashqari, XSPE asosidagi kauchuklarni vulkanizatsiya qilish va bir qator himoya qoplamalarini yuqori haroratni talab qiladi [7]. XSPE erituvchisi sifatida toluol, vinil aromatik monomerlardan ham foydalanish mumkin. qattiqlashtiruvchi sifatida peroksid initsiatori, uchlamchi aromatik aminlar va fosforni o‘z ichiga olgan dimetakrilatdan iborat moddalar qo‘llaniladi [8].

Xlorsulfinirlangan polietilen 1-20 sm to‘lin uzunligi diapazoniga ega bo‘lgan elektromagnit energiya uchun radio yutuvchi qoplamalar olishda ishlatiladi [9].

Tadqiqot metadologiyasi. Interpolimerlarni mexanik xossalarga barqarorligi va kuch ta’sirida interpolimer strukturasidagi o‘zgarishlarni baholash uchun skanerlash elektron mikroskop usullaridan foydalangan holda fizik-kimyoviy tadqiqotlar o‘tkazish orqali ushbu polimerlarning tarkibi o‘zgarishlarni fazaviy mikrotuzilishining mikrodeformastiyalarini elektron mikroskopik o‘rganish va qo‘llash sohalarni aniqlash imkonini beradi. [10].

Xlorsulfolangan polietilen (XSPE) asosidagi interpolimer materiallar va ularni fizik-kimyoviy va mexanik xossalari haqidagi ma’lumotlar bilan tanishib chiqdik, sababi XSPE asosidagi kauchuk xususiyatli polimer materiallarn uchun polietilen, suyuq xlor va oltingugurt xomashyo resurslari yetarli bo‘lib asosan Respublikamizda “O‘zbekneftgaz” AJ tizimidagi tashkilot va korxonalari – “Sho‘rtan gaz-kimyo majmuasi” va “Ustyurt gaz-kimyo majmuasi” tomonidan bugungi kunda 500 ming tonnadan ortiq polietilen granulalari, 40,0 ming tonnadan ortiq oltingugurt va “O‘zkimyosanoat” AJ tizimidagi tashkilot va korxonalari “Navoiyazot” AJ tomonidan suyuq xlor ishlab chiqarilishi, taklif etilayotgan interpolimer materiallarni olish va qo‘llash ekologik hamda iqtisodiy jihatdan samarador texnologiyalarni yaratish imkonini beradi.

XSPE asosidagi interpolimer materiallar organik erituvchilarda yaxshi eriydi, bu qurilish materiallari sohasida lok-bo‘yoq ishlab chiqarishda foydalanish uchun zarur bo‘lgan kompozitsiyaning yopishqoqligini (adgeziya) yaxshilash, yuqori mustahkamlik, yopishish (adgeziya), ozonga, kislotali va ishqoriy muhitlarga hamda ob-havo sharoitlariga bardoshliligini yaxshilash imkonini beradi. Ushbu polimerlar birqancha xlorli kauchuk asosidagi qoplamalar bilan raqobatbardosh bo‘lib qoplama hosil qilishi, erituvchilarda yaxshi erishi, boshqa polimerlar bilan hosil qilgan interpolimerlarining moslashuvchanligi, ya’ni “o‘zaro bog‘langan” tuzilishga ega bo‘lish hamda interpolimer qoplamani qisqa vaqt ichida qurish vaqti boshqa shu turdagi polimerlardan ustunligini ko‘rsatadi.

Xlorsulfolangan interpolimerlar asosan suyuq moddalar, gazsimon xususiyatli aktivligi (agressiv yuqori bo‘lgan muhitlar, yuqori haroratga barqarorligi, fizik-mexanik ta’sirlar va tashqi omillar ta’sir etadigan temir beton, metall konstruksiyalar, matolarni qoplashda ishlatiladi. Ushbu interpolimer qoplamalar bir vaqtning o‘zida yuqoridagi omillarning bir nechtasidan himoyalash imkonini beradi. Interpolimer qoplamalarni kimyoviy moddalarga va ob-havoga chidamliligi, yaxshi fizik-mexanik xossalari, past gaz o‘tkazuvchanligi, dekorativ xususiyatlarni yaxshi saqlanishi uchun ushbu interpolimerlar metall, beton va boshqa materiallarga yaxshi yopishishi (adgeziya) kerak. Shuning uchun interpolimerlar asosidagi qoplamalarni SEM analizi orqali aralashma tarkibidagi moddalarni joylashishi va strukturadagi o‘zgarishlarni aniqlash muhim hisoblanadi.

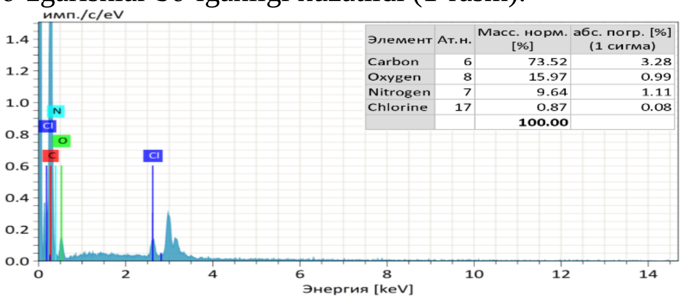
Tahlillar va natijalar. Xlorsulfolangan polietilen va epoksid smolasi asosidagi interpolimerlarni SEM analizini o‘rganishda ushbu materiallarni fizik-mexanik xossalari aniqlangan. So‘ngra ularning tarkibi va material yuzasidagi o‘zgarishlarni tahlil qilish maqsadida sinov tajribalar amalga oshirildi. Strukturadagi turli darajadagi o‘zgarishlarni yuqori aniqlikdagi maxsus skanerli elektron mikroskop usulida makro-, mezo-, mikro- va qisman nano razmerdagi o‘lchamlari o‘rganildi. Ushbu olingan MM-5, MFK-2, MUK-4 va MU-3 markali bog‘lovchi agentlarni ikki xil turdagi polimerlar yuzasiga tarqalishi alohida ko‘rib chiqildi. MM-5 markali bog‘lovchi agent XSPE va ED-20 polimerlar aralashmasi bilan yaxshi bog‘langanligi va ularning yuzasi, morfologik strukturasi SEM tahlillardan foydalanib o‘rganildi va MFK-2, MUK-4 va MU-3 markali bog‘lovchi agentlarga nisbatan 500 marta kattalashtirib ko‘rish orqali yaxshi struktura hosil qilganligi tahlillar orqali aniqlandi. MFK-2, MUK-4 va MU-3 markali bog‘lovchi agentlar asosida hosil qilingan interpolimerlar mexanik ta’sirlar natijasida polimer yuzasida siniqlar hosil bo‘lishi aniqlandi.

Tahlillar shuni ko‘rsatdiki, XSPE va ED-20 asosida olingan interpolimerlar mexanik ta’sirlar natijasida polimer matritsasi yuzasida joylashgan strukturalarga deformatsiyalanish katta ta’sir etmagan, ya’ni polimer yuzasidagi mikro zarrachalarning qisman yoki to‘liq parchalanishi hosil bo‘lmaganligini kuzatish mumkin.

Shunday qilib, interpolimer strukturaning deformatsiyaga barqarorligi bo‘yicha olib borilgan tajriba sinov ishlari natijasida polimer strukturasidagi o‘zgarishlar SEM analizi yordamida tahlil qilindi. Interpolimerlarni mexanik xususiyatlari boshlang‘ich polimer materiallarga nisbatan yaxshi natijalar olindi, ya’ni elastiklik xususiyati yuqori ekanligi aniqlandi.

MM-5, MUK-4 va MU-3 markali aminli bog‘lovchi agentlarga asoslangan XSPE va ED-20 asosida interpolimerlar mexanik ta’sirlar natijasida polimer yuzasida o‘zgarishlar analoglar bilan taqqoslanganda yuqori ekanligi aniqlandi;

MFK-2 markali aminli bog‘lovchi agent asosidagi XSPE va ED-20 interpolimerlarni mexanik xossalari o‘rganilganda polimer yuzasida parchalanishlar hosil bo‘lganligi natijada strukturada qisman o‘zgarishlar bo‘lganligi kuzatildi (1-rasm).



1-rasm. MM-5 markali aminli bog‘lovchi agentlar asosida olingan interpolimerlarni element analiz tahlili.

Natijalarga ko‘ra, tadqiqot uchun olingan xlorsulfolangan interpolimer namunaning uchta joyi o‘rganilganda elementlar teng taqsimlanganligi aniqlandi. Shuningdek, namuna tarkibida uglerod 73,5%, kislorod – 16%, azot – 10% va xlor – 1% ni tashkil etmoqda.

XSPE va ED-20 asosida olingan interpolimerlarni gomogen sistema hosil qilib qisman kimyoviy bog‘lar bilan bog‘lanishiga MM-5 markali aminli bog‘lovchi agentlarning ta’siri va ularni SEM va element analizi tahlillari shuni ko‘rsatdiki, interpolimerlarning strukturasi mexanik ta’sirlarga barqaror va tarkibidagi kimyoviy moddalar miqdori adabiyotlar bilan taqqoslanganda mos kelishi ilmiy asoslandi. Element tahlilida XSPE tarkibini tashkil etuvchi uglerod, xlor va kislorod mavjudligi aniqlandi, ammo oltingugurt miqdori 0,1% dan kam bo'lganligi uchun element analizda ko'rinmadi. ED-20 tarkibiga tegishli bo'lgan uglerod va kislorod tahlillarda aralash holda ko'ringanligi aniqlandi. MM-5 markali aminli bog'lovchi agentlar va qotiruvchi PEPA asosida olingan interpolimerlar tarkibida kimyoviy bog'lar hosil qilib bog'langan tarkiblarni element analiz tahlili o'rganilganda asosan strukturada aminlarga xos bo'lgan azot elementlarning mavjudligi aniqlandi.

Xulosalar. Taklif etilayotgan yangi MM-5, MFK-2, MUK-4 va MU-3 markali aminli bog'lovchi agentlarga asoslangan interpolimerlarni SEM analizida polimer strukturasining yuzasidagi o'zgarishlar tahlil qilingan bo'lib, olingan natijalarga asosan interpolimer tarkibidagi molekulalar bir xilda tarqalganini ko'rish mumkin. Ushbu olingan natijalardan kelib chiqib yangi turdagi interpolimerlar metall konstruksiyalarni korroziyadan va kimyoviy moddalar ta'siridan himolashda katta samara berishi aniqlandi.

Foydalanilgan adabiyotlar

1. Гумаров, А.Х. Модификация покрытий на основе хлорсульфированного полиэтилена нефтеполимерными смолами [Текст] /А.Х.Гумаров, Р.М.Гарипов, О.В.Стоянов. - Вестник Казанского технологического университета, 2011, № 9. - С.71-73.
2. Гумаров, А.Х. Модификация покрытий на основе хлорсульфированного полиэтилена эпоксидными олигомерами [Текст] /А.Х.Гумаров, Р.М.Гарипов, О.В.Стоянов. - Вестник Казанского технологического университета, 2011. - № 14. - С.138-140.
3. Гумаров, А.Х. Влияние типа отвердителей на процесс формирования покрытий на основе ХСПЭ [Текст] / А.Х.Гумаров,Р.М.Гарипов, М.В.Колпакова, О.В.Стоянов. - Вестник Казанского технологического университета, 2011. - №18. - С. 81-85
4. Нуркулов Ф.Н., Бекназаров Х.С., Нуралиев У.М., Джалилов А.Т. Синтез и свойства полисульфидного каучука. - Ташкент, «Химия и химическая технология», №3, 2012. –С. 49-51.
5. Kornev V. A. i dr. Polimernoye pokritiye na osnove xlorsulfirovannogo polietilena sistemi IN CLAD //Nauka, texnika i obrazovaniye. – 2015. – №. 8 (14). – S. 19-22.
6. Melnikov, I.A. Lakokrasochniye materiali / I.A. Melnikov. – LitRes, 2011. – 46s.
7. Shatalova YE. A., Kalinina N. K. xlorsulfirovanniy polietilen kak osnova smesey dlya rezin //Uspexi v ximii i ximicheskoy texnologii. – 2020. – T. 34. – №. 7 (230). – S. 120-122.
8. Pat. RF 2171269, MPK S09D123/00, S09D123/34. Композиция на основе хлорсулфированного полиэтилена и способ получения покритий на ее основе / М.А. Ваниев, А.М. Огрел, А.Б. Кочнов; патентообладател Волгоградский государственний технический университет. - № 99114483/04; zayavl. 07.07.1999; opubl. 27.07.2001 - 14 s.
9. Pat. RF 2412968. MPK7. Radiopogloshayusheye pokritiye / Metelyov A. I. (RU), Samoylenko A. F. (RU); Federalnoye gosudarstvennoye uni¬tarnoye predpriyatiye "Federalniy sentr dvoynix texnologiy "So¬yuz" (FGUP "FSDT "Soyuz"); - № 2009124092/05,; Zayavl. 25.06.2009; Opubl. 27.02.2011.
10. Нуркулов Ф.Н. Изучение стойкости синтезированного хлорсульфированного полиэтилена (ХСПЭ) к химическим веществам // Узбекский химический журнал, Ташкент, №5, 2012. -С.21-24.

GILAM VA GILAM MAHSULOTLARINI ISHLAB CHIQARUVCHI KORXONALARNING TOLALI CHIQINDILARINI KOMPLEKS QAYTA ISHLASHGA TAYYORLASH – FRAKSIYALARGA AJRATISH TEXNIKASI

Elmurodov Alisher Azamat o'g'li
Iqtisodiyot va pedagogika universiteti
stajyor-o'qituvchi
elmurodov2021@bk.ru
ORCID 0009-0001-4008-200X

UDK 677.026

Annotatsiya. Ushbu maqola gilam va gilam mahsulotlarini ishlab chiqaruvchi korxonalarning tolali chiqindilarini kompleks qayta ishlashga tayyorlash – fraksiyalarga ajratish texnikasi xususida bo'lib, unda O'zbekiston Respublikasi Prezidentining "2022–2026-yillarga mo'ljallangan Yangi O'zbekistonning taraqqiyot strategiyasi to'g'risida"gi 60-sonli Farmoniga muvofiq olib borilayotgan tadbirlar, jumladan, gilam va gilam mahsulotlarini ishlab chiqaruvchi korxonalarning tolali chiqindilarini kompleks qayta ishlashga tayyorlash – fraksiyalarga ajratish tadqiqoti bosqichlari, olov, qizil, yashil va oq rangli tolali chiqindilarni fraksiyaga ajratilgan IQ-spektori hamda ularning tahlili xususida fikr-mulohazalar bayon etilgan. Dastlab chiqindilarni fraksiyalarga ajratish bosqichi amalga oshirildi. Ular qayta ishlangandan so'ng, mahsulot turiga qarab rangli bo'lgan fraksiyalarni o'z rangi bilan uyg'unlashtirilgan holda ajratildi va ularning tolalari tarkibi IQ-spektorlari olindi – tahlil etildi.

Kalit so‘zlar. gilam, tolali chiqindi, fraksiya, IQ-spektori, sun’iy va sintetik kompozitsion tarkib, innovatsion usul.

PREPARATION OF FIBRE WASTE FROM CARPET AND CARPET PRODUCT MANUFACTURING ENTERPRISES FOR COMPREHENSIVE RECYCLING – TECHNIQUE OF SEPARATION INTO FRACTIONS

Abstract. This article is about “Preparation of fiber waste from carpet and rug manufacturing enterprises for complex processing - fractionation techniques”, which describes the activities carried out in accordance with the Decree of the President of the Republic of Uzbekistan No. 60 “On the Development Strategy of New Uzbekistan for 2022-2026”, including the stages of the study of preparation of fiber waste from carpet and rug manufacturing enterprises for complex processing - fractionation, the IR spectrum of fractionated fiber waste of fire, red, green and white colors and their analysis. Initially, the stage of fractionation of waste was carried out. After they were processed, colored fractions were separated according to their color, and IR spectra of their fiber composition were obtained and analyzed.

Key words. carpet, fibrous waste, fraction, IR spectrum, artificial and synthetic composite composition, innovative method.

Kirish. Bugungi kunda sanoatning turli mahsulotlarini qayta ishlash jarayonida ularning fraksiyalarga hamda har bir turdagi oraliq xomashyo uchun qayta ishlash bo‘yicha yoriqnomalarni ishlab chiqish dolzarb vazifalardan biri hisoblanadi. Chiqindi va oraliq mahsulotlarni qayta ishlash sanoat korxonalari uchun sifatli xomashyo bazasini yaratishda yordam beradi. Gilam va gilam mahsulotlarini qayta ishlash ishlab chiqarishi ko‘p, funksional ishlab chiqarish jarayoniga ega bo‘lgan sanoat korxonalaridan biridir. Ular ishlab chiqarishning dastlabki bosqichidan to tayyor mahsulot ko‘rinishiga yetgunga qadar turli tolali chiqindilar hosil qiladi. Ularni qayta ishlash orqali organik mahsulotlar va turli xildagi kompozit materiallar olish mumkin.

Gilam mahsulotlarini ishlab chiqarish orqali ulardan chiqqan tolali chiqindilarni kompleks qayta ishlash mumkin. Masalan, fasad devor gulqog‘ozlarini olish texnologiyasi innovatsion muhitni yaratadi. Jahon tajribalarida gilam va gilam mahsulotlaridan fasad devor gulqog‘ozlari olish hali to‘liq o‘zlashtirilmagan.

S.T. Maxlinaning fikriga ko‘ra, devor qog‘ozlari – bu devorlarni qoplash uchun ishlatiladigan naqshli qog‘oz yoki maxsus materiallardir. Qog‘ozlar bilan devorlarni qoplash Yevropada XV asrning oxirida paydo bo‘lgan. XIX asr boshlariga kelib, devor gulqog‘ozlari keng qo‘llanila boshlangan. Rossiyada devor gulqog‘oz XIX asrning birinchi yarmida keng tarqalgan, ammo birinchi devor qog‘ozi klassitsizmning tug‘ilishi davrida paydo bo‘lgan. XVIII asrning oxiriga kelib, devor qog‘ozi butun Rossiya bo‘ylab ichki interyerda ishlatilgan. XIX asr boshlarida devor qog‘ozi modadan chiqib ketgan, faqat chekka qishloqlarda foydalanishgan. XIX asrda Rossiyadagi devor qog‘ozi mahsulotlari Yevropa darajasiga yetadi. XX asrning o‘rtalariga kelib, namlikka chidamli yuviladigan, tovushni yutuvchi devor qog‘ozlari paydo bo‘lgan. Bugungi kunda devor qog‘oz eng keng tarqalgan interyerlarni bezagi bo‘lib qolayotganligi ta’kidlab o‘tilgan [1].

Tadqiqot metodologiyasi. Devor gulqog‘ozlari bezaklarining asosiy usuli sifatida o‘rganishning tarixiy jihati uni to‘qimachilik, grafika va interyer san’atining maxsus sintezi sifatida ko‘rib chiqishga imkon beradi. Devor bezaklari har doim ichki me’moriy makon qiyofasini shakllantirishda uslub yaratuvchi rol o‘ynagan. Devor gulqog‘ozlari san’atining rivojlanish bosqichlari interyer uslublarining evolyutsiyasi bilan belgilanadi, bu esa ASG Investment Group of Companies tarixiy obyektlarining interyerlarini tiklashda ulardan foydalanish imkoniyatlarini belgilaydi [2].

Ushbu ilmiy tadqiqot ishida kimyoviy qayta ishlash uchun sellyuloza ishlab chiqarishda biotexnologik usullardan foydalanishning asosiy yo‘nalishlari haqida umumiy ma’lumot berilgan. Biologik pishirish, pishirishdan oldin oq chiriyotgan shtammlari va fermentlari bilan yog‘och chiplarini qayta ishlash tijorat sellyuloza tarkibidagi sellyuloza bo'lmagan tarkibiy qismlarni kamaytirishga imkon bergan. Ksilanazalar va mananazlar gemitsellyuloza aralashmalarini olib tashlash uchun, sellyuloza eritmalarining yopishqoqligini pasaytirish va kimyoviy ishlov berish jarayonida uning reaktivligini oshirish uchun ishlatilishi mumkin [3].

Juda yuqori darajadagi almashtirish (DSCM = 2.1) bo'lgan karboksimetil kraxmal (CMS) namunalari eterlashtiruvchi vosita sifatida metanol suvda natriy gidroksid va monoxloroasetik kislota bilan geterogen reaksiya sharoitida ko'p bosqichli karboksimetilatsiya orqali sintez qilingan. Umumiy DSCM qiymatining bosqichma-bosqich o'sishi boshlang'ich polimerning DSCM qiymatining oshishi bilan asta-sekin kamaydi. Zanjir degradatsiyasidan so'ng 1H-NMR spektroskopiyasi orqali CMSning funksionalizatsiya naqshini aniqlash 2-O-almashtirish uchun yuqori afzalliklarni ko'rsatdi. Karboksimetil funksiyalarining taqsimlanishi O-2 ≫ O-6 > O-3 tartibida edi. Delimerizatsiyalangan namunani yuqori samarali suyuqlik xromatografiyasi va kapillyar elektroforez yordamida batafsil tahlil qilish Spurlinning statistik modeliga juda mos keladigan monomer tarkibini aniqladi [4].

Hisong Qi va boshqalar ishida sellyulozaning ishqoriy sellyuloza erituvchisi, konsentratsiyasi 7% li NaOH/12% karbamid suvli eritmasida karboksimetillanishi o'rganilgan. Karboksimetil sellyuloza (KMC) namunalari FT-IR, NMR, HPLC va yopishqoqlik xususiyati tavsiflangan. DS=0,20-0,62 bo'lgan suvda eruvchan KMC Avicel sellyuloza va paxta lintlaridan tayyorlangan. Shunday qilib, NaOH/karbamidda sellyulozaning karboksimetilyatsiyasi ma'lum bo'lgan KMC ning suvda eruvchanligi (0,20) uchun eng past DS qiymatiga ega bo'lgan polimerga olib keladi. KMC ning umumiy DS ni reagentlar va NaOH ning AGU ga molyar nisbati va reaksiya haroratini o'zgartirish orqali nazorat qilish mumkinligini isbotlaganlar. To'liq depolimerizatsiyadan so'ng HPLC yordamida strukturani tahlil qilish natijasida turli xil karboksimetillangan takrorlanuvchi birliklarning mol fraksiyalari, shuningdek, o'zgartirilmagan glyukoza oddiy statistik tuzilishga amal qilishini o'rganishgan. Karboksimetil guruhlarining AGU darajasida O-6>O-2>O-3 tartibida taqsimlanishi aniqlangan [5].

Mualliflar tomonidan turli xil usullar yordamida bir yillik o'simliklardan yarimtayyor sellyuloza, qog'oz va karton olish texnologiyasi keltirilgan hamda xomashyo turlari, ularni tayyorlash, pishirish, massani maydalash, yuvish, saralash, sellyuloza, qog'oz va karton olish usullari atroflicha yoritilgan [6].

Tolali chiqindilar asosida fasad suyuq devor gulqog'ozlarini hamda qog'oz va qog'oz mahsulotlarining kompozit turlarini olish tadqiqot natijalari sohadagi hozirgi kunning muhim nazariy hamda amaliy ahamiyatiga ega.

Natijalar va muhokama. O'rganilgan adabiyotlar tarkibida sellyuloza saqlovchi xomashyoni qayta ishlash va fraksiyalarga ajratish usullari yoritilib, asosan, gilam ishlab chiqarish chiqindilari tarkibini o'rganish maqsad qilib olindi. Gilam chiqindilaridan fasad suyuq devor qog'ozi ishlab chiqarishda fraksiyalash, chiqindilarni turli xil tolalar va materiallarga ajratish va saralash hamda chiqindilar tarkibi va tuzilishini aniqlash uchun IQ-spektr tahlili usulidan foydalanildi.

Fraksiyalangan mahsulotlardan turli tolalarni ajratib, ularni qayta ishlash texnologiyalariga yo'naltirish asosida sifatli xomashyo bazasini yaratish hamda qurilish sohasi uchun foydali xomashyo ishlab chiqariladi. Fasad suyuq devor gulqog'ozi texnologiyasini o'zlashtirish qurilish sohasida raqobatbardosh mahsulotlarni ishlab chiqarish va zamonaviy yechimlarni qo'llashga imkon beradi.

Bu jarayonda turli xil tolalar va materiallarga ajratilib, materiallar bo'yicha guruhlandi. Har bir bosqichda, qayta ishlangan mahsulotlar, mahsulot turiga qarab rangli fraksiyalarga ajratildi. Ya’ni, o‘xshash rangdagi tolalar bir-biridan ajratildi. Uch rangli fraksiyalarning o‘z rangi bilan uyg‘unlashtirilgan holda ajratilishi, keyingi bosqichda sifatli mahsulot ishlab chiqarishni ta’minlashga yordam beradi.

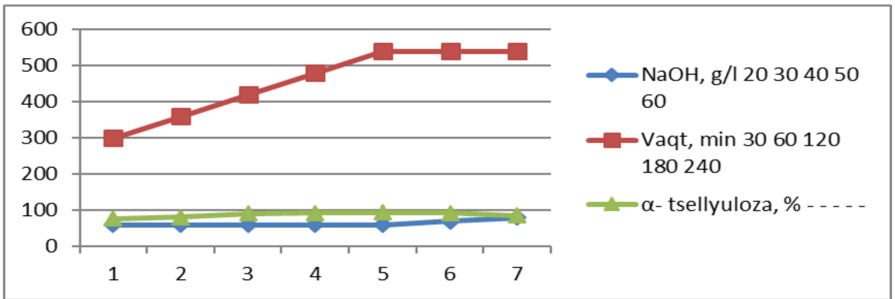
Oxirgi bosqichda esa har bir rangli fraksiya uchun tolalarning tarkibi IQ-spektorlar yordamida tahlil qilindi. Bu tolalarning tarkibini aniqlash qayta ishlash jarayonida tashkil qilishda yordam beradi.

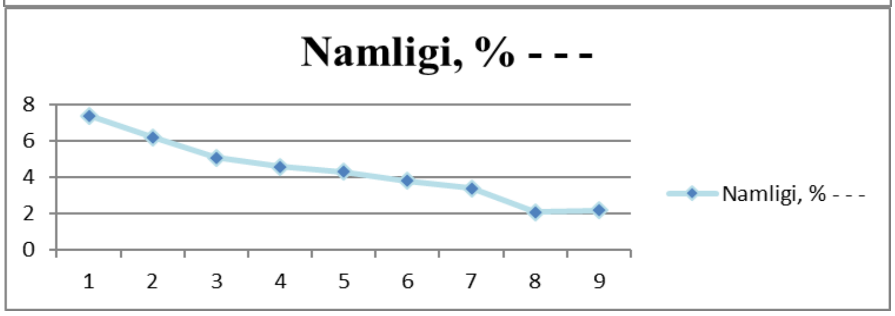
Mahalliy xomashyo asosida kimyoviy qayta ishlash uchun mos bo‘lgan sellyuloza sintezi jarayonida turli parametrlarning ta’siri, ya’ni gilam ishlab chiqarish chiqindilarini ishqoriy pishirish haroratida olingan sellyuloza sifat ko‘rsatkichlariga ta’siri o‘rganildi. Shunga ko‘ra, ishqoriy pishirish haroratining oshishi bilan a-sellyuloza samaradorligining o‘sishi bilan bog‘liq, chunki haroratning oshishi va boshqa omillarning faollashishi sellyuloza tarkibini va polimerizatsiya darajasini sezilarli darajada kamaytirishi mumkin. Jarayonda ishqoriy pishirishning harorat parametrlarini o‘rganishda optimal rejim 60°C tanlangan. Alfa-sellyuloza 93,6%, polimerlanish darajasi 780, kuli 4,5ga, namligi 3,4 ga teng. 1-jadvalda sellyulozaning ba’zi sifat ko‘rsatkichlariga (terak o‘simligini) pishirishda ishqor konsentratsiyasining ta’siri ko‘rsatilgan.

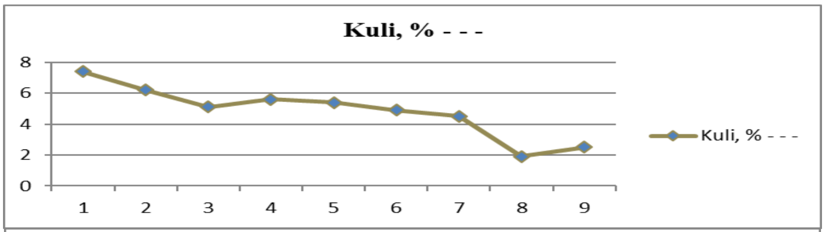
1-jadval

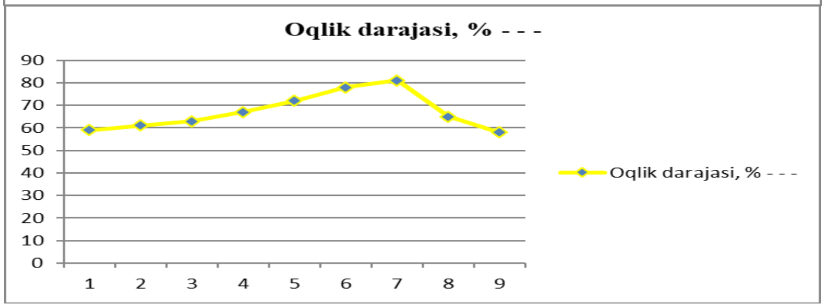
Ishqoriy pishirish vaqtining olingan sellyulozaning sifat ko‘rsatkichlariga ta’siri

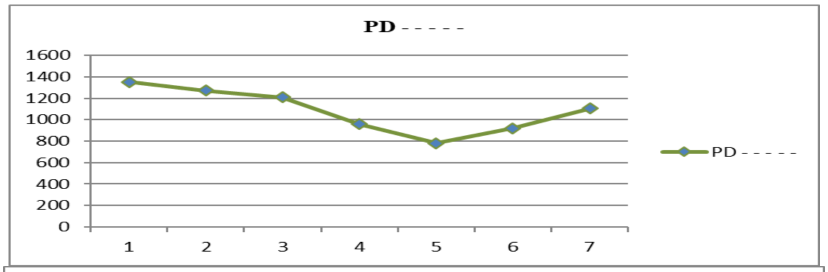
№	NaOH, g/l	Vaqt, min	α-sellyuloza, %	PD	Oqlik darajasi, %	Kuli, %	Namligi, %
1	20	30	-	-	-	-	-
2	30	60	-	-	-	-	-
3	40	120	-	-	-	-	-
4	50	180	-	-	59	7,4	7,4
5	60	240	-	-	61	6,2	6,2
6	60	300	76,7	1350	63	5,1	5,1
7	60	360	81,1	1270	67	5,6	4,6
8	60	420	91,2	1210	72	5,4	4,3
9	60	480	92,9	960	78	4,9	3,8
10	60	540	93,6	780	81	4,5	3,4
10	70	540	91,6	920	65	1,9	2,1
10	80	540	85,3	1106	58	2,5	2,2

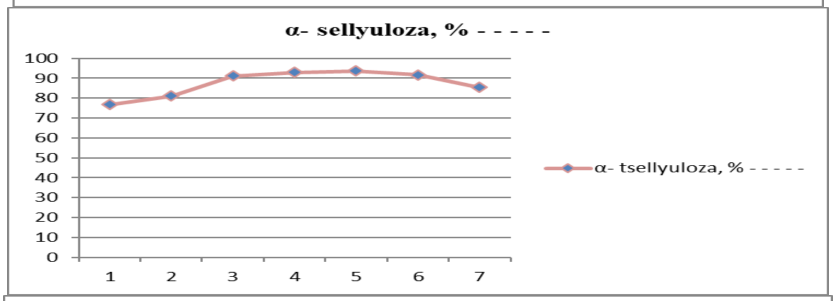


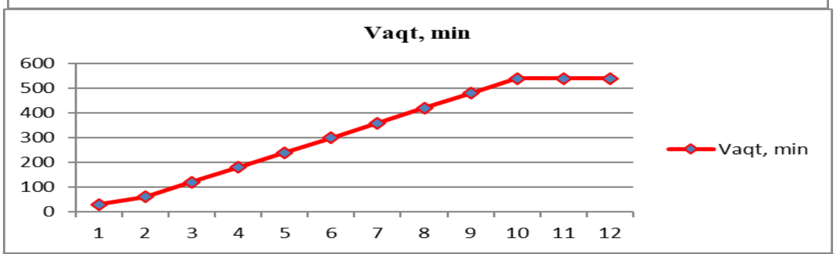


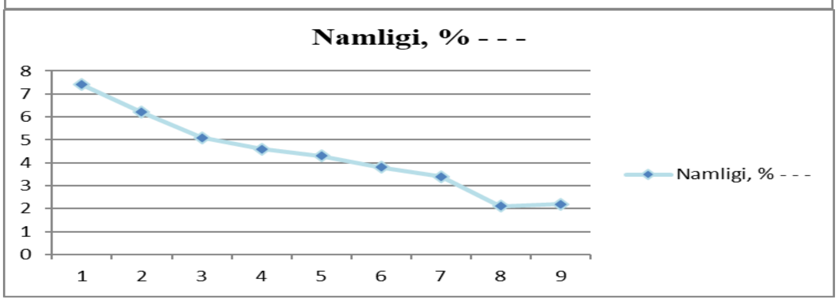












Xulosa va takliflar. Ilk bor gilam va gilam mahsulotlarini ishlab chiqaruvchi korxonalarning tolali chiqindilarini kompleks qayta ishlashga tayyorlash – fraksiyalarga ajratish tadqiqoti bosqichlari o‘zlashtirilib, fraksiyalarga ajratib olingan tolali chiqindilardan fasad suyuq devor gulqog‘ozlarini olish tadqiqotlari va tahlil natijalari amalga oshirildi.

Kompleks qayta ishlangan tolali chiqindilar asosida qog‘oz va qog‘oz mahsulotlarining kompozit turlari olindi. Olingan fasad suyuq devor gulqog‘ozlarini hamda qog‘oz turlarining sifat ko‘rsatkichlari aniqlandi va fizik-kimyoviy, mexanik-strukturaviy xossalari o‘rganildi. Burg‘ilash qorishmalari uchun tolali chiqindilar asosida stabillovchi reagent texnik pats ishlab chiqarish texnologiyasi o‘zlashtirildi. Ilk bor gilam va gilam mahsulotlarini ishlab chiqaruvchi korxonalarning tolali chiqindilari asosida fasad suyuq devor gulqog‘ozlarini olish texnologiyasi o‘zlashtirildi va ishlab chiqarishga tavsiya etildi.

Foydalanilgan adabiyotlar

1. Махлина С.Т. Обои в жилом интерьере. - Вестник СПбГИК, 2012, №1. - С.126-129.URL: https://cyberleninka.ru/article/n/oboi-v-zhilom-interiere (дата обращения: 19.10.2024).

2. Шакирова Г., Хайруллина Ф. Искусство обоев в стилевом решении интерьера: от текстиля к графике. - Мир искусств: Вестник Международного института антиквариата, 2015, №1 (09). - С.68-80. URL: https://cyberleninka.ru/article/n/iskusstvo-oboev-v-stilevom-reshenii-interiera-ot-tekstilya-k-grafike (дата обращения: 19.10.2024).

3. Новожилов Е.В., Пошина Д.Н. Биотехнологии в производстве целлюлозы для химической переработки (обзор).-Химия растительного сырья, 2011, №3.-С.15-32. URL: https://cyberleninka.ru/article/n/biotehnologii-v-proizvodstve-sellyulozy-dlya-himicheskoy-pererabotki-obzor (дата обращения: 19.10.2024).

4. Lazik W., Heinze T., Pfeiffer K. Starch derivatives of a high degree of functionalization. VI. Multistep carboxymethylation //Journal of Applied Polimer Science. 2002. 86(3):743 – 752. DOI:10.1002/app.10983

5. Hisong Qi, Tim Libert, Frank Meister, Thomas Heinze. Homogenous carboxymethylation of cellulose in the NaOH/urea aqueous solution // October 2009. Reactive and Functional Polymers 69(10):779-784. DOI:10.1016/j.reactfunctpolym.2009.06.007

6. Primkulov M.T., Raxmanberdiyev G., Murodov M.M., Miratayev A.A. Tarkibida sellyuloza saqlovchi xomashyoni qayta ishlash texnologiyasi // darslik.— Toshkent. O‘zbekiston faylasuflari milliy jamiyati nashriyoti, 2014. — 192 b.

7. Olimboyev E., Davirov Sh., O‘zbekiston to‘qimachilik sanoati mahsulotlari va ularni ishlab chiqarish texnologiyasi, To‘qimachilik sanoati, 2002.

8. E.Sh. Alimboyev va boshq., Gazlamalarning tuzilishi va tahlili, T., 2003.

ALLOKSAN DIABET SHAROITIDA JIGAR MITOXONDRIYASINING MEGAKANALIGA VA LIPIDLARNING PEREKISLI OKSIDLANISHIGA AYRIM POLIFENOL BIRIKMALARNING TA’SIRI

Sattorova Iroda Yangiboyevna
Qarshi davlat universiteti doktoranti
Pozilov Ma’murjon Komiljonovich
M.Ulug‘bek nomidagi O‘zbekiston Milliy universiteti prof v,b.
Gafurov Maxmudjon Bakiyevich
O‘zbekiston Respublikasi Fanlarakademiyasi Bioorganik kimyo instituti professori
iroda8724@gmail.com
ORCID 0009-0007-2825-4837
UDK 616.379-008.64(045)

Annotatsiya. Alloksan diabetda jigar mitoxondriyasining megakanaliga va lipidlarning perekisli oksidlanish jarayonlariga polifenol birikmalarning ta’siri o‘rganildi. Alloksan diabetda YaN-2 polifenol birikmalari jigar mPTP o‘tkazuvchanligi ortishini ingibirlab blokator sifatida ta’sir etdi. Alloksan diabet sharoitida kalamush jigar mitoxondriyasining Fe2+/sitrat bilan chaqirilgan LPOga YaN-2 polifenol birikmalari tormozlovchi ta’sir etdi. Alloksan diabet sharoitida mPTP ochilishiga eng asosiy sabablar stressning rivojlanishi, proooksidantlar, LPO induksiyasi, mRTR kompleksida tiol guruhlarini oksidlanishi keltiriladi. Alloksan diabet bilan bog‘liq mitoxondrial disfunksiyalarni biologik faol birikmalar yordamida korreksiyalash mumkin. Mana shunday biologik faol moddalardan biri polifenol birikmalar bo‘lib, hozirda in vitro va in vivo tajribalarda mitoxondriya membranasi o‘tkazuvchanligiga ta’siri katta qiziqish bilan o‘rganib kelinmoqda. Hujayralar strukturasi va funksiyalarini diabet sharoitda buzilish mexanizmlarini o‘rganish hamda ularni farmakologik agentlar yordamida korreksiya qilish zamonaviy fiziologiya va endokrinologiyaning ustuvor vazifalaridan biri hisoblanadi.

Kalit so‘zlar. Megakanal jigar, mitoxondriya, polifenol birikmalar

EFFECTS OF SOME POLYPHENOLIC COMPOUNDS ON THE MEGACHANNEL OF LIVER MITOCHONDRIA AND LIPID PEROXIDE OXIDATION IN ALLOXAN DIABETES

Abstract. In alloxan diabetes,the effect of polyphenolic compounds on the megachannel of liver mitochondria and the processes of lipid peroxide oxidation was studied.Alloxan acted as an inhibitory blocker of YaN-2 polyphenolic compounds increasing hepatic mPTP permeability in diabetes. YaN-2 polyphenolic compounds increasing hepatic mPTP permeability in diabetes.YaN-2 polyphenol compounds had an inhibitory effect on Fe2+/citrate-induced LPO of rat liver mitochondria under alloxan diabetes conditions .the main reasons for the opening of mPTP in conditions of alloxan diabetes are the development of stress,pro-oxidants,induction of LPO,oxidation of thiol groups in the mRTRcomplex.Mitochondrial dysfunctions associated with alloxan diabetes can be corrected using biologically active compounds.One of these biologically active substances is polyphenoliccompounds,the influence of which on mitochondrial membrane permeability is being studied with great interest in in vitro and in vivo experiments.One of the priority tasks of modern physiology and endocrinology is to study the mechanisms of cell structure and function disorders in diabetes and to correct them with the help of pharmacological agents.

Key words. Megachannel,liver,mitochondria,polyphenol compounds.

Kirish. Mitoxondriyada ichki va tashqi membranalaridagi mitochondrial permeability transition pore (mPTP) odam va hayvon hujayralarining faoliyatida, moddalar almashinuvining boshqarilishida hamda turli patologik holatlarning rivojlanishida asosiy rol o‘ynaydi .[1]. Birinchi marta SsA sezgir pora (mPTP) 1970 yillarda R.A. Haworth va D.R. Hunter tomonidan izolyatsiyalangan mitoxondriyalarda o‘rganilgan [2].

Hozirda mPTPning ochiq konformatsion holatiga, ya’ni permeabilizatsiyasiga olib keluvchi omillarning katta qismi ma’lum: matriks pH o‘zgarishi, $\Delta\psi$m ning kamayishi, Ca^{2+} ionlarining yuqori konsentratsiyasi, prooksidantlar, lipidlarning perekisli oksidlanishi (LPO) induksiyasi, mPTP kompleksida tiol guruhlarining oksidlanishi, noorganik fosfatlar, adenin nukleotid translokaza (adenine nucleotide translocase -ANT), ingibitorlari atraktilat va karboksiatraktilat, atsetil-CoA va erkin yog‘ kislotalari, mezo, lizofosfolipidlar, og‘ir metallar, tireoid gormonlar va boshqalar [3]. Biroq mPTP ning holatini yopilishiga ya’ni, o‘tkazuvchanlikning kamayishiga olib keluvchi ta’sirlar va moddalar ancha kamroq: adeninnukleotidlar ATF va ADF, Mg2+ ionlari, yuqori $\Delta\psi m$, pH ko‘rsatkichining pasayishi, antioksidandlar, bongkrekik kislota va ЦсA mavjudligida mPTP berk holatga o‘tadi [4]. MPTP sust o‘tkazuvchan holatida sitozoldagi Ca2+ ionlari gomeostazida, yuqori o‘tkazuvchanlik holatida esa hujayralar nobud bo‘lishida ishtirok etadi.

MPTP turli xil farmakologik agentlar uchun “nishon” sifatida o‘rin tutishi mumkin, jumladan, bunda agentlar poraning tarkibiy qismlari bilan bevosita bog‘ hosil qilishi yoki ROS, Ca2+ ionlari va pH qiymati kabi mPTP induktorlarining ta’sirini susaytirishi orqali ta’sir ko‘rsatishi mumkin [5]. MPTP ning ochiq holatga o‘tganda membrana protonlar uchun o‘tkazuvchan xossaga ega bo‘ladi va hujayra ichki qismida mavjud bo‘lgan ATF zaxirasi tezda tugab qoladi. Hujayrada ion va moddalar almashinuvi gomeostazi izdan chiqadi, fosfolipaza, nukleaza va proteaza kabi ferment tizimlari faollashishi ta’sirida hujayralarda nekroz bilan tugallanuvchi qaytmas tavsifga ega mexanizmlar kuchayadi [6].

Hozirda qandli diabet kasalligini davolovchi preparatlar xilma-xil bo‘lishiga qaramay, ularning yangi turlarini izlash va “terapevtik nishon” organlarga ta’sir mexanizmlarini o‘rganishga bo‘lgan talab ortib bormoqda. Hujayradagi mana shunday “nishon”lardan biri mitoxondriya bo‘lib, patologik sharoitlarda ularning ikki qavat membranasi va matriksda joylashgan strukturalari birinchi navbatda nafas zanjiri va mPTP disfunksiyaga uchraydi. Turli xil patologiyalarning rivojlanishida, ayniqsa, diabet sharoitida mPTP roli alohida muhokama qilinmoqda [7].

Alloksan diabet bilan bog‘liq mitoxondrial disfunksiyalarni biologik faol moddalar bilan korreksiyalash mumkin. Mana shunday biologik faol moddalardan biri polifenol birikmalar bo‘lib, hozirgi kunda in vitro va in vivo tajribalarda mitoxondriya membranasi o‘tkazuvchanligiga ta’siri o‘rganib kelinmoqda. Ammo YaN-2 (6:1 nisbat) va YaN-2 (4:1 nisbat) polifenollarning alloksan diabet sharoitida kalamush jigar mitoxondriyasi disfunksiyasiga ta’siri o‘rganilmagan.

Shu nuqtayi nazardan ushbu ishimizda alloksan bilan chaqirilgan diabet sharoitida kalamush jigar mitoxondriyasi bo‘kishiga va LPO jarayoniga ayrim polifenol birikmalarning ta’sirini o‘rganish maqsad qilib olindi.

Tadqiqot metodologiyasi. Tajribalar zotsiz vazni 180-200 gr bo‘lgan oq erkak kalamushlarda o‘tkazildi. Laboratoriya hayvonlarini oziqlantirish vivariy sharoitda hamda standart ratsional sharoitda olib borildi. Tadqiqot hayvonlarida diabet chaqirish uchun alloksandan foydalanildi. Tajriba uchun ajratilgan kalamushlar guruhlarga ajratildi: I guruh – nazorat (n=5), II guruh – tajriba (alloksan diabet, n=5), III guruh - tajriba (alloksan diabet+YaN-2 6:1 nisbat), n=6) va IV guruh tajriba (alloksan diabet+YaN-2 4:1 nisbat), n=6) hamda V guruhga (alloksan diabet+kversetin). Tajribaning II, III IVva V tajriba guruhi hayvonlarida diabet chaqirish uchun bir kunlik ochlikdan so‘ng bir marta alloksan 150 mg/kg (5% 0,2 ml dis. suv) eritmasi [8] qorin bo‘shlig‘i teriosti sohasiga yuborildi. Alloksan diabet chaqirilgan kalamushlardan har 3 kunda qon olinib, glyukoza miqdori aniqlab borildi. Kalamushlarga alloksan inyeksiya qilingandan keyin 12 kun o‘tib, qonda glyukoza miqdori 11 mmol/l dan oshgandan so‘ng, sutkasiga bir marta II guruh hayvonlariga 0,2 ml 0,9% li NaCl eritmasidan, tajribaning III va IV guruhlarga esa tadqiqot moddasidan sutkasiga bir marta 10 kun mobaynida peroral usulda yuborildi. Qonda glyukoza miqdori 11 mmol/l dan kamaygandan keyin tadqiqotlar o‘tkazildi.

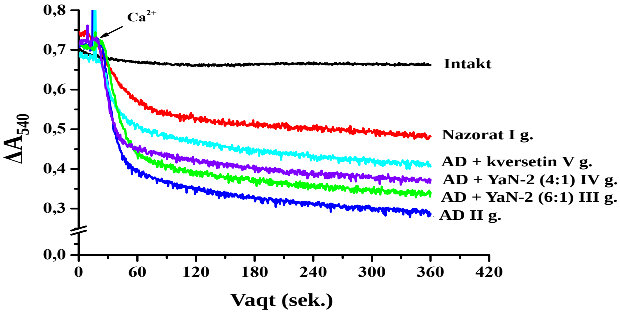
Mitoxondriyaning bo‘kish (shishish) kinetikasini (0,3-0,4 mg/ml) mitoxondriya suspenziyasining 26°C da doimo aralashtirib turgan holda optik zichligini 540 nm da ochiq yacheykada (hajmi 3 ml) o‘zgarishi bo‘yicha aniqlandi [9].

Shuningdek, mitoxondriya membranasida LPO jarayonini o‘rganish uchun Fe2+/sitrat tizimidan foydalanildi. Ushbu tizim membrana LPO natijasida mitoxondriyani bo‘kishiga va hajm o‘zgarishiga asoslanadi. Ushbu hajm o‘zgarishi fotometrik usulda aniqlandi [10].

Kalamush jigar mitoxondriyasi differensial sentrifugalash W.C.Schneider [11] usuli yordamida ajratib olindi.

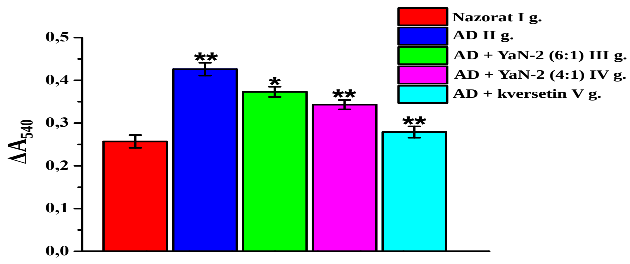
Olingan natijalarni statistik qayta ishlash va rasmlarni chizish Origin 8.6 (AQSH) kompyuter dasturi yordamida amalga oshirildi. Tajribalarda mitoxondriyaning bo‘kish kinetikasi maksimalga nisbatan foiz hisobida, 5 ta turli tajribalarning o‘rtacha arifmetik qiymatini hisoblash tarzida amalga oshirildi.

Natijalar va muhokama. Tajribada mitoxondriyaning bo‘kishi (IM da Ca2+-EGTA bufer mavjud sharoitda) mPTP ochiq holatga o‘tishini ifodalaydi. Olingan natijalarga ko‘ra, sog‘lom kalamush jigaridan ajratilgan mitoxondriyaning bo‘kish tezligi (I guruh) 0,26ΔA540/6min va alloksan diabet chaqirilgan II guruh hayvonlarning jigar mitoxondriyasi bo‘kish tezligi esa 0,42ΔA540/6min tashkil etishi aniqlandi (1-rasm).



1-rasm. Alloksan diabet sharoiti kalamush jigar mitoxondriyasi mPTP o‘tkazuvchanligiga polifenol birikmalarni ta’siri. Original rasm. (AD-alloksan diabet).

Bu esa alloksan diabetda jigar mitoxondriyasi bo‘kishi nazoratga nisbatan 63,8% ga ortganligini ko‘rsatadi. Olingan natijalardan ko‘rinadiki, alloksan diabetda kalamush jigar mitoxondriyasi bo‘kish tezligining ortishi mPTPning ochiq holatga o‘tishidan dalolat beradi. Alloksan diabet chaqirilgan III guruh hayvonlarni YaN-2 (4:1 nisbat) polifenol bilan sutkasiga bir marta 40 mg/kg miqdorda 10 kun per os usulda yuborildi va qondagi glyukoza miqdori normaga yaqinlashdi. Polifenol yuborilgan III guruh kalamushlarni jigar mitoxondriyasi ajratildi va uning bo‘kishi 0,37ΔA540/6min tashkil etib, II guruh ko‘rsatkichlariga nisbatan 12,4% ga ingibirlanganligi aniqlandi. Alloksan diabet chaqirilgan IV guruh hayvonlarga YaN-2 (4:1 nisbat) polifenoldan (40 mg/kg) va V guruhga esa mavjud gipoglikemik birikma kversetindan (40 mg/kg) yuborildi. IV va V guruh kalamush jigaridan ajratilgan mitoxondriyalarning bo‘kishi mos ravishda 0,34ΔA540/6 min va 0,28ΔA540/6 tashkil etdi. Bu esa YaN-2 (4:1 nisbat) yuborilgan IV guruh hamda kversetin yuborilgan V guruh hayvonlarning jigar mitoxondriyasi bo‘kishi alloksan diabetga nisbatan mos ravishda 19.5% va 34,3% ga ingibirlashini ko‘rsatdi (2-rasm).



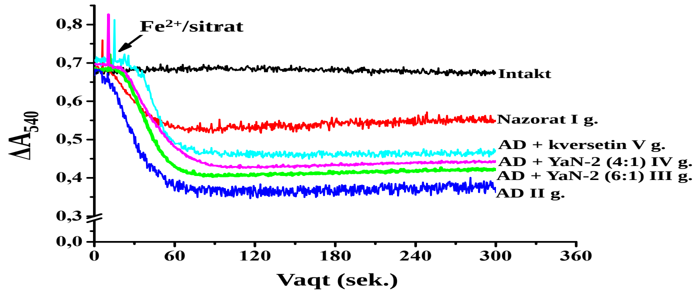
2-rasm. Alloksan diabet sharoiti kalamush jigar mitoxondriyasi mPTP o‘tkazuvchanligiga polifenol birikmalarni ta’siri. (AD-alloksan diabet).(*P<0,05; **P<0,01; n=5).

Shunday qilib, alloksan diabetda mitoxondriya disfunksiyasi rivojlanishi natijasida PTP ochiq holatga o‘tishi kuzatildi. Alloksan diabet hayvonlarni polifenol birikmalari bilan davolaganimizda, ularning mPTP holatiga samarali ta’sir etib mitoxondriya buzilishini korreksiya qilishi birinchi bo‘lib aniqlandi. Alloksan diabetda jigar mitoxondriyasining bo‘kishi uning PTP konformatsiyasining ochilishi bilan izohlanadi.

Alloksan diabet sharoitida jigar mPTP konformatsiyasining ochiq holatga kelishi membrana lipidlarini peroksidatsiya jarayoni bilan bog‘liq bo‘lishi mumkin. Ushbu taxminni aniqlash maqsadida navbatdagi tajribamizda alloksan diabet sharoitida kalamush jigar mitoxondriyasining Fe2+/sitrat yordamida chaqirilgan LPO jarayoniga polifenollarning ta’siri o‘rganildi. Bizga ma’lumki, mitoxondrial lipidlar mitoxondriya membranasi yaxlitligini va funksiyasini saqlash uchun ajralmas hisoblanadi. Temir va temir komplekslari LPOni rag‘batlantiradi [12].

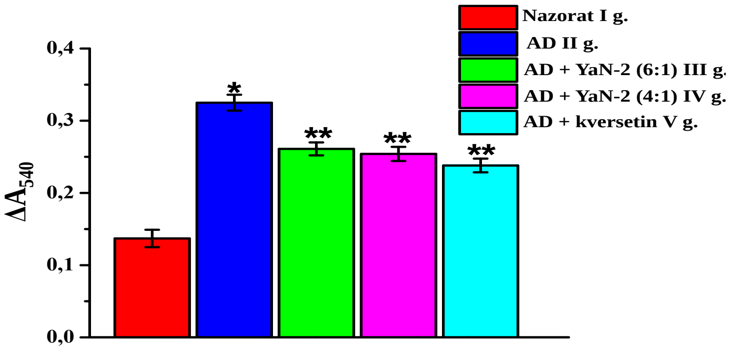
Alloksan diabet sharoitida jigar mitoxondriyasining bo‘kishi o‘z navbatida ichki va tashqi membranada joylashgan lipidlarni gidrolizga uchratishi mumkin. Tajribamizda mitoxondriya membranasida lipoperoksidatsiya jarayonini amalga oshirish uchun LPOni induktori hisoblangan Fe2+/sitratdan foydalanildi.

I guruh kalamushlarining jigar mitoxondriyasini LPO induktori Fe2+/sitrat yordamida bo‘kishining optik zichlik ko‘rsatkichi 0,137 ΔA540 min. ni tashkil etdi. Alloksan diabetda II guruh kalamushlarning jigar mitoxondriyasini Fe2+/sitrat yordamida bo‘kishining optik zichlik ko‘rsatkichi 0,325 ΔA540x min. ni tashkil etib, nazoratga nisbatan 137,2% ga ortganligi aniqlandi (3-rasm).



3-rasm. Alloksan diabet sharoitida kalamush jigar mitoxondriyasining Fe2+/sitrat bilan chaqirilgan LPOga polifenollarningYaN-2 (6:1 nisbat) va YaN-2 (4:1 nisbat) ta’siri (original yozuv).

Alloksan diabet chaqirilgan kalamushlarning jigar mitoxondriyasi membranasi LPO ortishi, uning ion transport tizimlari buzilishi bilan bog‘liq bo‘lishi mumkin. Alloksan bilan chaqirilgan diabetda III guruh hayvonlarni polifenol YaN-2 (6:1 nisbat)birikma bilan farmakoterapiya qilganimizda ularning Fe2+/sitrat yordamida mitoxondriya bo‘kishi II guruh ko‘rsatkichlariga nisbatan 19.7% ga ingibirlaganligi aniqlandi. YaN-2 (4:1 nisbat)izoxinolin alkaloidi bilan davolangan IV guruh kalamushlarni jigar mitoxondriyasining Fe2+/sitrat yordamida bo‘kishi II guruhga nisbatan 21,8% ga ingibirlanganligi aniqlandi. Alloksan diabet chaqirilgan V guruh kalamushlarga kversetin flavonoidi yuborilganda ularning jigar mitoxondriyasini Fe2+/sitrat yordamida bo‘kishi patologik II guruhga nisbatan 26,8% ga ingibirlanganligi aniqlandi (4-rasm).



4-rasm. Alloksan diabet sharoitida kalamush jigar mitoxondriyasining Fe2+/sitrat bilan chaqirilgan LPOga polifenollarning YaN-2 (6:1 nisbat) va YaN-2 (4:1 nisbat) ta'siri. (*P<0,05; **P<0,01; n=5).

Demak, alloksan diabet sharoitida kalamush jigar mitoxondriyasining Fe2+/sitrat bilan chaqirilgan LPOga YaN-2 polifenol birikmalari tormozlovchi ta'sir etdi. Alloksan diabet sharoitida mPTP ochilishiga eng asosiy sabablar qilib stressning rivojlanishi, proooksidantlar, LPO induksiyasi, mPTP kompleksida tiol guruhlarini oksidlanishi keltiriladi. Izoxinolin alkaloidlarining LPO jarayonlarini tormozlash orqali mitoxondriyada erkin radikallar miqdorining kamaytirishi va CyP-D ning matriks domeni bilan bog'lanib, ЦsA ning ingibitorlik xususiyatini boshqarishi mumkin.

Xulosa va takliflar. Xulosa qilib aytish mumkinki, YaN-2 polifenol birikmalari alloksan diabet sharoitida jigar mitoxondriyasi zararlanishini qayta tiklaydi. Alloksan diabetda YaN-2 polifenol birikmalari jigar mPTP o'tkazuvchanligi ortishini ingibirlab blokator sifatida ta'sir etdi va Fe2+/sitrat yordamida chaqirilgan membrana LPOni tormozlashi aniqlandi.

Foydalanilgan adabiyotlar

1. Brenner C., Grimm S. The permeability transition pore complex in cancer cell death // Oncogene.– 2006. – V.25(34). – P. 4744-4756.
2. Haworth R.A., Hunter D.R. The Ca2+-in duced membrane transition in mitochondria. II. Natureofthe Ca2+ triggersite // Archivesof biochemistr yand biophysics. – 1979. – V.195(2). – P. 460-467.
3. Baines C.P., Gutierrez Aguilar M. The stillun certain identity of the channel formin gunit(s) of the mitochondrial permeability transition pore // Cell Calcium – 2018. – V.73. – P. 121–130.
4. Peixoto P.M., Ryu S.Y., Kinnally K.W. Mitochondrialion channel sas the rapeu tictargets // FEBS Letters. – 2010. – V.584(10). – P. 2142-2152.
5. Jezek J., Jaburek M., Zelenka J., Jezek P. Mitochondrial phospholipase A2 activated byre active oxygen speciesin heart mitochondri ain ducesmildun coupling // PhysiolRes. – 2010. – V. 59(5). – P. 737-747.
6. Halestrap A.P., McStay G.P., Clarke S.J. The permeability transition pore complex: ano therview // Biochimie. – 2002. – V.84(2). – P. 153-166.
7. Жилюк В.И., Мамчур В.И., Павлов С.В., Бухтиярова Н.В. Влияние средств в процессы энергетического метаболизма и проявления митохондриальной дисфункции в нейронах головного мозга крыс с аллоксановым диабетом. - Проб. Эндокрин. Пат. – 2010. – № 3. – С. 69-74.
8. Агзамов Х., Алматов К.Т., Рахимов М.М., Туракулов Я.Х. Функционирование митохондрий печени при аллоксановом диабете. - Вопросы мед.химии. –1983. - Т.29. – №1.– С. 61-65.
9. He L., Lemasters J.J. Heat shock suppres ses the permeability transition in ratliver mitochondria // J. Biol. Chem. – 2003. – V. 278(19). – P. 16755-16760.
10. Almeida A.M., Bertoncini C.R., Borecky J., Souza-Pinto N.C., Vercesi A.E. Mitochondrial DNA damage associated with lipid peroxidation of the mitochondrial membrane in ducedby Fe2+-citrat // An. Acad. Bras. Cienc. – 2006. – V. 78(3). – P. 505-514.
11. Schneider W.C., Hogeboom G.H. Cyto chemical studies of mammalion tissues: the is olation of cell componentsby differential centrifugation // Cancer. Res. – 1951. – 11. – P. 1-22.
12. GogvadzeV.,Walter P.B., Ames B.N. Theroleof Fe2+-in duced lipid peroxidation in the initiation of the mitochondrial permeability transition // Arch Biochem Biophys – 2003. – V.15 (2): – P. 255-260.

DKV-6 VA DKV-8 KONYUGATLARINING MUSBAT INOTROP TA'SIRIDA SR RyR2 NING ROLI

Boboyev Sadriddin Nurilla o'g'li
O'zMU huzuridagi Biofizika va biokimyo instituti
ORCID: 000-0003-0656-9663
Jumayev Inoyat Zulfiqorovich.,
O'zMU huzuridagi Biofizika va biokimyo instituti
ORCID: 0000-0002-5027-0274
Usmanov Po'lat Bekmuratovich
O'zMU huzuridagi Biofizika va biokimyo instituti
ORCID: 0000-0003-1635-616X
Juraqulov Sherzod Niyatkobulovich
O'zR FA O'simlik moddalar kimyosi instituti
sadriddin-2022@mail.ru
ORCID: 0000-0002-2857-946X
UDK: 576.32.36.(045)

Annotatsiya. Tadqiqotlarda DKV-6 va DKV-8 konyugatlarining kalamush yuragi papillyar muskul qisqarish faolligi dozaga bog'liq ta'siri tekshirildi. Bunda ushbu konyugatlar barcha dozalarda musbat inotrop ta'sir ko'rsatishi aniqlandi. DKV-6 va DKV-8 konyugatlarining musbat inotrop ta'sirda SR RyR2 ishtirokini baholash uchun RyR2 ning ingibitori ruteniy qizilidan foydalanildi. DKV-6 va DKV-8 konyugatlarining musbat inotrop ta'siri SR RyR2 funksiyasining qisman modulyatsiyasi orqali ta'minlanishi qayd qlindi. Tadqiqotlarda oq zotsiz (150-200 gr) kalamushlardan foydalanilgan. Tadqiqotlar *in-vitro* sharoitda kalamush yurak papillyar muskul qisqarish kuchini qayd qiluvchi mexanografik qurilma (Mayflower Tissue Bath System, Hugo Sachs Electronic, Germaniya) va apparat-dasturiy kompleksi (LabScibe 2, World Precision Instruments, USA) yordamida amalga oshirildi.

Kalit so`zlar. RyR2, papillyar muskul, post-rest potensiatsiya, ruteniy qizili, konyugat.

Abstract. The studies examined the dose-dependent effect of DKV-6 and DKV-8 conjugates on the contractile activity of rat heart papillary muscles. It was found that these conjugates had a positive inotropic effect at all doses. To assess the participation of SR RyR2 in the positive inotropic effect of DKV-6 and DKV-8 conjugates, the RyR2 inhibitor ruthenium red was used. It was noted that the positive inotropic effect of DKV-6 and DKV-8 conjugates is provided by partial modulation of SR RyR2 function. The studies used white-bred (150-200 g) rats. The studies were carried out in vitro using a mechanographic device (Mayflower Tissue Bath System, Hugo Sachs Electronic, Germany) and a hardware-software complex (LabScibe 2, World Precision Instruments, USA).

Keywords. RyR2, papillary muscle, post-rest potentiation, ruthenium red, conjugate.

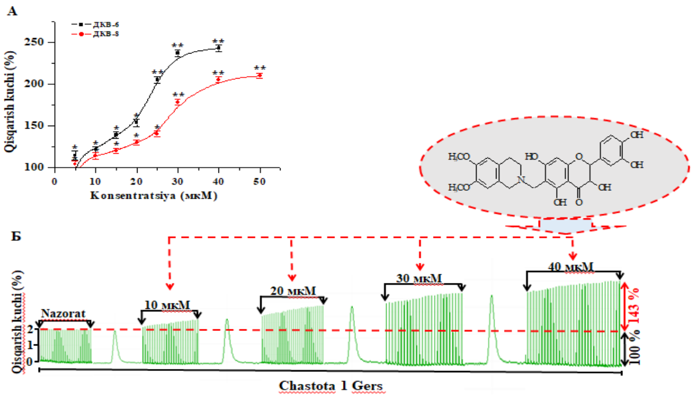
Kirish. Sarkoplazmatik retikulum (SR) ixtisoslashgan tizim bo'lib, u nafaqat hujayra ichidagi Ca^{2+} konsentratsiyasining regulyatsiyasida muhim rol o'ynaydi [1; 2;], balki ushbu hujayra organellasi bir nechta fosfolipidlardan va turli xil Ca^{2+}-bog'lovchi va tartibga soluvchi oqsillardan iborat bo'lib, ular kardiomiotsitlarda o'z funksiyasini muvofiqlashtirilgan tarzda bajaradi [3]. Yurak SR Ca^{2+}-transport tizimlariga Ca^{2+}- ATFaza (SERCA2a) va rianodin retseptorlar (RyR2) kiradi [4; 5;] Shuningdek, SR Ca^{2+}-transport tizimlariga protein kinaza A yoki Ca^{2+}-kalmodulinga bog'liq kinaza (CaMKII) tomonidan ham regulyatsiya qilinadi va SR Ca^{2+} chiqarilishi hamda yurak qisqarishi va bo'shashishini faollashtirish funksiyalari amalga oshiriladi [6]. SR Ca^{2+}-transport tizimlarining, jumladan, RyR2 funksiyasining buzilishi yurak muskul qisqarish faolligidagi buzilishlarga olib keladi va buning natijasida turli patologik jarayonlar yuzaga keladi [7; 8;]. Umuman olganda, RyR2 funksiyasini farmakologik modulyatsiya qilish usullarini izlab topish yurak-qon tomir tizimi kasalliklarining oldini olishda va davolashda samarali kardiprotektor vositalarni ishlab chiqarishda muhim ahamiyat kasb etadi. Hozirgi vaqtda yurak kasalliklarini davolash va oldini olish maqsadida butun dunyo yetakchi ilmiy tadqiqot markazlarida farmakologik preparatlar ishlab chiqarish yo‘nalishida bir qancha biologik faol birikmalar, jumladan, alkaloidlar va polifenollar istiqbolli manbalar ekanligi ta’kidlangan [9; 10; 11;]. Shuni inobatga olgan holda, tadqiqotlarimizda O‘zR FA O‘simlik moddalar kimyosi instituti xodimlari tomonidan taqdim etilgan F-4 va F-36 izoxinolin alkaloidlari hamda digidrokversetin flovanoidi asosida olingan DKV-6 va DKV-8 konyugatlarining SR RyR2 ga ta’siri tekshirildi.

Material metodologiyasi. Tadqiqotlar O‘zMU huzuridagi Biofizika va biokimyo instituti Hujayra biofizikasi laboratoriyasida amalga oshirildi. Tajribalarda zotsiz oq kalamushlardan (200–250 gr.) foydalanildi va tajriba hayvonlari bilan ishlashda xalqaro Xelsinki Deklaratsiyasi va xalqaro tibbiy ilmiy jamiyatlar kengashi (*CIOMS*) tomonidan ishlab chiqilgan (1985) qoidalariga amal qilindi.

In vitro sharoitida tajriba hayvonlari miokardi funksional faolligiga biologik faol moddalarning ta’sir mexanizmini o‘rganishda mexanografiya uslubidan foydalanildi. Papillyar muskul preparatining qisqarish faolligini qayd qilishda mexanografik qurilma (Mayflower Tissue Bath System, Hugo Sachs Electronic, Germaniya) va apparat-dasturiy kompleksi (LabScibe 2, World Precision Instruments, USA) yordamida amalga oshirildi. Kalamush yuragi chap qorinchasidan ajratib olingan papillyar muskuli 20 ml hajmdagi termostatga ulangan (36±1°S) kameraga o‘rnatiladi, Krebsa fiziologik eritmasi bilan doimiy perfuziya qilinadi: NaCl – 150; KSl – 4; $SaSl_2$ – 1,8; $MgCl_2$ – 1; $NaHCO_3$ –14; NaH_2PO_4 –1,8; $S_6N_{12}O_6$ –11,5; (rN=7,4).

Tadqiqotlar davomida o‘rganilayotgan birikmalarning SR Ca^{2+} dinamikasiga ta’sirini baholashda post-rest potensiatsiya (PRP) metodidan foydalanildi.

Natijalar va muhokama. Dastlabki tadqiqotlarda o‘rganilayotgan birikmalarning kalamush yuragi papillyar muskul qisqarish kuchiga DKV-6 (5-50 mkM) va DKV-8 (5-40 mkM) konyugatlarining dozaga bog‘liq ta’siri o‘rganildi (nazorat 100% deb olingan). Bunda DKV-6 va DKV-8 konyugatlari barcha dozalarda papillyar muskul qisqarish faolligiga musbat inotrop ta’sir ko‘rsatib nazoratga nisbatan muskul qisqarish kuchini mos ravishda 110,3±3,2% va 143,5±3,7% ga oshirishi aniqlandi (1-rasm A va B).



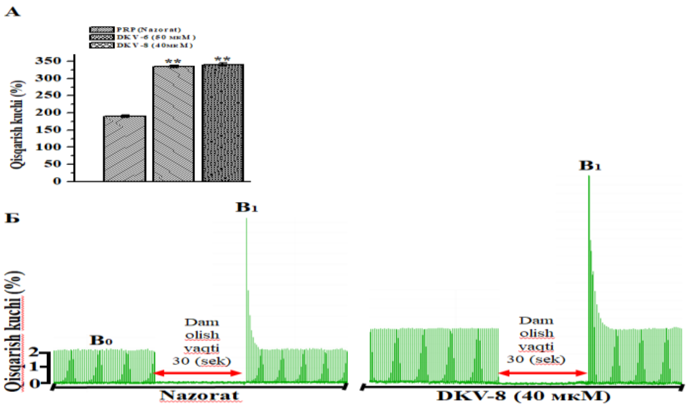
1-rasm A. DKV-6 va DKV-8 konyugatining papillyar muskul qisqarish faolligiga dozaga bog‘liq musbat inotrop ta’siri.

Ordinata o‘qida – 100% deb qabul qilingan maksimal qiymatga nisbatan foizda ifodalangan papillyar muskulning qisqarish kuchi ifodalangan. Abssissa o‘qida – konyugatlarning konsentratsiyasi ifodalangan. Stimulyasiya chastotasi 1 Gs (t=+36±0,5ºC); * –r<0,05, ** – r<0,01 n=4. **B.** DKV-8 konyugatining papillyar muskul qisqarish faolligiga dozaga bog‘liq musbat inotrop ta’siri (*original yozuv*)

Ma’lumki, yurak muskul hujayralari qisqarishida Ca^{2+} ionlari muhim rol o‘ynaydi. Qisqarish uchun lozim bo‘lgan Ca^{2+} ionlarining konsentratsiyasi asosiy qismi SR orqali ta’minlanadi [12]. Umuman olganda, o‘rganilayotgan birikmalarning kalamush yuragi papillyar muskul qisqarish kuchiga musbat inotrop ta’sirida SR Ca^{2+} transport tizimlarining ishtiroki orqali amalga oshayotgan bo‘lishi mumkin.

Ushbu taxminga aniqlik kiritish uchun navbatdagi tajribalarda SR Ca^{2+} transport tizimlari o‘rnini baholashda keng qo‘llaniladigan post-rest potensiatsiya (PRP) qiymatiga o‘rganilayotgan birikmalarning ta’siri tekshirildi. Bunda 30 sekund davomida qo‘zg‘atish to‘xtatilib keyin qo‘zg‘atish berilganda birinchi qisqarish kuchi (V_1) ortadi, bu esa SR dan chiqarilgan Ca^{2+} ionlari faollashtiruvchisining ko‘payishi natijasida yuzaga keladi [13]. Shuning uchun qo‘zg‘atish to‘xtatilib dam olishdan keyingi izometrik kuchga ta’siri SR chiqarilgan Ca^{2+} miqdori uchun indeks hisoblanadi.

SR dan chiqarilgan Ca^{2+} ionlarining ishtirokini tekshirish uchun papillyar muskul qisqarish kuchining post-rest potensiatsiya qiymatiga ta’sirini o‘rgandik. Ushbu tajribalarda DKV-6 DKV-8 konyugatining mavjud sharoitda muskul qisqarish kuchi dam olish davridan keyingi (30 sek) PRP qiymatiga nisbatan mos ravishda 145.3±4,1% va 150.4±3,8% ga ortishi aniqlandi (2-rasm A va B).

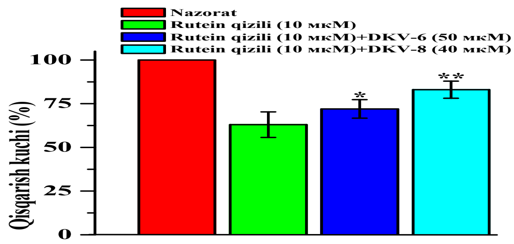


2-rasm A. DKV-6 va DKV-8 konyugatlarining papillyar muskul PRP qiymatiga ta’siri.

Ordinata o‘qida – maksimalga nisbatan foiz (%) hisobida ifodalangan qisqarish kuchining amplituda qiymati ifodalangan. Preparatni qo‘zg‘atish chastotasi 1 Gs. Barcha holatlarda * - p<0,05; ** - p<0,01.; n=5. **B.** DKV-8 konyugatining papillyar muskul PRP qiymatiga ta’siri. (*original yozuv*).

Olib borilgan tajribalar natijalari shuni ko‘rsatadiki, o‘rganilayotgan birikmalar ta’sirida SR da Ca^{2+} ionlarining qo‘shimcha to‘planishi yuzaga keladi va buning natijasida stimulyatsiyaga javoban ko‘proq Ca^{2+} ionlari sitozolga chiqadi. Umuman olganda, DKV-6 va DKV-8 konyugatining miokard qisqarish faolligi musbat inotrop ta’sirida SR Ca^{2+}-transport tizimlarining modulyatsiyasi natijasida yuzaga kelishidan dalolat beradi.

Shuningdek, SR dan sitozolga Ca^{2+} ionlarining chiqishi RyR2 orqali ta’minlanadi. Shu nuqtayi nazardan, keyingi tadqiqotlarda DKV-6 va DKV-8 konyugatlarining SR RyR2 funksiyasiga ta’siri tekshirildi. Ushbu tajribada RyR2 ning ingibitori rutein qizili inkubatsiyasi sharoitida PRP qiymatiga o‘rganilayotgan birikmalarning ta’siri tekshirildi. Bunda, DKV-6 va DKV-8 konyugatlari rutein qizili mavjud sharoitda PRP qiymati 72,4±4,1% va 83,1±3,8% ni tashkil qildi (3-rasm).



3-rasm. DKV-6 va DKV-8 konyugatlarining rutein qizili mavjud sharoitda papillyar muskul post-rest potensiatsiya qiymatiga ta'siri.

Qo'zg'atishni to'xtatilish vaqti 30 sek. Ordinata o'qida muskulning dam olishdan keyingi nazorat qisqarish kuchi (post-rest potensiatsiya) 100% deb olingan. Stimulyatsiya chastotasi 1 Gs (t=+36±0,5ºC). * - r<0,05, ** - r<0,01, (n=5).

Ushbu tajribalardan kelib chiqib shuni aytishimiz mumkinki, o'rganilayotgan biologik faol moddalardaning musbat inotrop ta'sirida RyR2 ning ishtiroki kam ekanligidan dalolat beradi.

Xulosa va takliflar. Umuman olganda, DKV-6 va DKV-8 konyugatlari kalamush yuragi papillyar muskul qisqarish faolligiga musbat inotrop ta'sir ko'rsatib, ushbu ta'sirida qisman SR RyR2 ishtiroki mavjud ekanligini taxmin qilish mumkin.

Foydalanilgan adabiyotlar

1. Nusier M., Shah A.K., and Dhalla N.S. Structure-Function Relationships and Modifications of Cardiac Sarcoplasmic Reticulum Ca^{2+}-Transport. Physiol Res. 2021 Dec; 70(Suppl 4): S443–S470.
2. Rani S., Park C.S., Sreenivasaiah P.K., Kim D.H. Characterization of Ca^{2+}-dependent protein-protein interactions within the Ca^{2+}release units of cardiac sarcoplasmic reticulum. Mol Cells. 2016;39:149–155.
3. Le Peuch C.J., Haiech J., Demaille J.G. Concerted regulation of cardiac sarcoplasmic reticulum by cyclic adenosine monophosphate-dependent and calcium-calmodulin-dependent phosphorylation. Biochemistry. 1979; 18: 5150–5157.
4. Le Peuch C.J., Le Peuch D.A., Demaille J.G. Covalent regulation of the cardiac sarcoplasmic reticulum calcium pump: Purification and properties of phospholamban, a substrate of cAMP-dependent protein kinase and Ca^{2+}-calmodulin-dependent phospholamban kinase. Methods Enzymol. 1983;102:261–278.
5. Maclennan D.H., Kranias E.G. Phospholamban: a crucial regulator of cardiac contractility. Nat Rev Mol cell Biol. 2003;4:566–577.
6. Netticadan T., Temsah R., Osada M., Dhalla N.S. Status of Ca^{2+}/calmodulin protein kinase phosphorylation of cardiac SR proteins in ischemic-reperfusion. Am J Physiol. 1999;277:C384–C391.
7. Belevych A.E., Radvanski P.B., Carnes C.A., Györke S. Ryanopathy: causes and manifestations of RyR2 dysfunction in heart failure. Cardiovasc Res. 2013 May 1; 98(2): 240–247.
8. Fabiato A. Calcium-induced release of calcium from the cardiac sarcoplasmic reticulum. Am J Physiol. 1983;245:C1–C14.
9. Andersson D.C., and Marks A.R. Fixing ryanodine receptor Ca^{2+} leak - A novel therapeutic strategy for contractile failure in heart and skeletal muscle. Drug Discov Today Dis Mech. 2010 ; 7(2): e151–e157.
10. Kalyanasundaram A., Lacombe V.A., Belevych A.E., Brunello L., Carnes C.A., Janssen P.M., Knollmann B.C., Gyørke S., Author Notes. Up-regulation of sarcoplasmic reticulum Ca^{2+} uptake leads to cardiac hypertrophy, contractile dysfunction and early mortality in mice deficient in CASQ2. *Cardiovascular Research*, Volume 98, Issue 2, 1 May 2013, Pages 297–306,
11. Atanasov A.G., Waltenberger B., Pferschy-Wenzig E.M., Linder T., Wawrosch C., Uhrin P., Temml V., Wang L., Schwaiger S., Heiss E.H., Rollinger J.M., Schuster D., Breuss J.M., Bochkov V., Mihovilovic M.D., Kopp B., Bauer R., Dirsch V.M., and Stuppner H. Discovery and resupply of pharmacologically active plant-derived natural products: A review. Biotechnol Adv. 2015 Dec; 33(8): 1582–1614.
12. Gehlert S., Bloch W., and Suhr F. Ca^{2+}-Dependent Regulations and Signaling in Skeletal Muscle: From Electro-Mechanical Coupling to Adaptation. Int J Mol Sci. 2015 Jan; 16(1): 1066–1095
13. Vieira F.F., Olivoto R.R., Silva P.O.D., Francisco J.C., Fogaça R.T.H. Functional Effects of Hyperthyroidism on Cardiac Papillary Muscle in Rats. Arq Bras Cardiol. 2016; 107(6):542-549

CAM-68 ALKALOIDINING SILLIQ MUSKUL HUJAYRALARI PLAZMOLEMMA Ca^{2+}_L- VA Ca^{2+}_R- KANALLARIGA TA'SIRI

Sobirov S.B.
Berdaq nomidagi Qoraqalpoq davlat universiteti tayanch doktoranti
ORCID 0009-0006-67952948
Zaripov A.A.
O'zMU huzuridagi Biofizika va biokimyo instituti katta ilmiy xodimi, biologiya fanlari bo'yicha falsafa doktori (PhD)
ORCID 0000-0003-3555-1542
Esimbetov A.T.
Samarqand davlat veterinariya meditsinasi,chorvachilik va biotexnologiyalar universiteti Nukus filiali direktori, biologiya fanlari doktori, professor
ORCID 0000-0002-6958-1873
Ibragimov E.B.
O'zMU huzuridagi Biofizika va biokimyo instituti tayanch doktoranti
ORCID 0000-0003-4862-4894
Usmanov P.B.
O'zMU huzuridagi Biofizika va biokimyo instituti "Hujayra biofizikasi" laboratoriyasi mudiri, biologiya fanlari doktori, professor
ORCID 0000-0003-1635-616X
Jo'raqulov Sh.N.
O'zR FA O'simlik moddalar kimyosi instituti katta ilmiy xodimi, kimyo fanlari doktori (DSc)
sobirovsardor1016@gmail.com
ORCID: 0000-0002-2857-946X
UDK 577.352+612.014

Annotatsiya. Yurak-qon tomir tizimi kasalliklari rivojlanishida silliq muskul hujayralari faoliyati, Ca^{2+} ionlari transporti regulyatsiyasi va qon tomirlar tonusining buzilishlari yotadi. Shu sababli silliq muskul hujayralarida Ca^{2+} tashuvchi tizimlar disfunksiyasini korreksiyalashning yangi yondashuvlarini qidirish kardiologiya va farmakologiyaning dolzarb muammosi hisolanadi. Tajribalarda CAM-68 alkaloidining kalamush aorta silliq muskul hujayralariga in vitro sharoitda vazorelaksant ta'siri o'rganilgan. Kalamush aortasi silliq muskul hujayrasining qisqarish faolligi FT.03 (Grass-Telefactor, AQSh) mexanotroni yordamida qayd qilinib olindi. Olingan natijalardan ma'lumki, CAM-68 alkaloidining vazorelaksant ta'siri silliq muskul hujayrasidagi Ca^{2+}_L- va Ca^{2+}_R- kanallari blokadasi bo'lishi mumkin, bu esa hujayra ichiga Ca^{2+} ionlari kirishining pasayishi bilan $[Ca^{2+}]_{in}$ konsentratsiyasining kamayishiga olib keladi va o'z navbatida qon tomirlarning kengayishiga sababchi bo'ladi. Ushbu alkaloidning verapamil inkubatsiyasi sharoitida aorta qisqarish kuchining qo'shimcha bo'shashtirishi Ca^{2+}_L–kanali blokadasidan tashqari hujayradagi boshqa ion transport tizimlariga ta'sir qilishi mumkinligini ko'rsatdi.

Kalit so'zlar. alkaloid, verapamil, Ca^{2+}-kanali, aorta, vazorelaksant.

EFFECT OF ALKALOID CAM-68 ON Ca^{2+}_L- AND Ca^{2+}_R- CHANNELS OF THE PLASMALEMMA OF SMOOTH MUSCLE CELLS

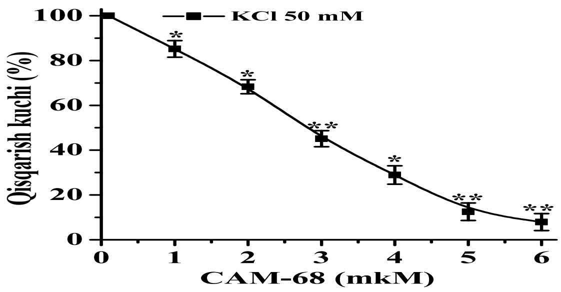
Abstract. In the development of diseases of the cardiovascular system, smooth muscle cell activity, regulation of Ca^{2+} ion transport and disorders of vascular tone lie. Therefore, the search for new approaches to correct the dysfunction of Ca^{2+} transport systems in smooth muscle cells is considered an urgent problem of cardiology and pharmacology. In experiments, the vasorelaxant effect of CAM-68 alkaloid on rat aortic smooth muscle cells was studied in vitro. Contractile activity of rat aorta smooth muscle cell was recorded using FT.03 (Grass-Telefactor, USA) mechanatron. From the obtained results, it is known that the vasorelaxant effect of CAM-68 alkaloid can be the blockade of Ca^{2+}_L- and Ca^{2+}_R- channels in smooth muscle cells, which leads to a decrease in the concentration of $[Ca^{2+}]_{in}$ with a decrease in the entry of Ca^{2+} ions into the cell and in turn causes dilation of blood vessels. The additional relaxation of aortic contraction force by this alkaloid under verapamil incubation conditions indicated that it may affect other ion transport systems in the cell in addition to Ca^{2+}_L-channel blockade.

Key words. alkaloid, verapamil, Ca^{2+} channel, aorta, vasorelaxant.

Kirish. Qon tomirlar funksiyasini ta’minlovchi silliq muskullarning qisqarishi va bo‘shashishida, shuningdek, qon tomir tonusining boshqarilishida Ca^{2+} ionlari asosiy vazifani bajaradi, bunda hujayra ichki Ca^{2+} konsentratsiyasi hujayra plazmolemmasi va sarkoplazmatik retikulum (SR) da joylashgan turli Ca^{2+}-tashuvchi tizimlar bilan ta’minlanadi [1]. Silliq muskul hujayra (SMH) larida Ca^{2+}-gomeostazini tartibga soluvchi ion transport tizimlari funksiyasining buzilishi qon tomirlar tonusining o‘zgarishiga va turli patologiyalarning, shu jumladan, arterial gipertenziyaning rivojlanishiga olib keladi [2]. Shu sababli ko‘pchilik gipotenziv vositalarning ta’siri, asosan, hujayra ichki Ca^{2+} kamayishi bilan bog‘liq bo‘lib, bu Ca^{2+} ionining SMH si potensialga bog‘liq $Ca^{2+}{}_{L}$- va retseptor boshqariluvchi $Ca^{2+}{}_{R}$- kanallari blokadasi bilan ta’minlanadi [3]. Hozirgi vaqtda farmakologiyada ushbu Ca^{2+} transport tizimlari faoliyatini modulyatsiya qilishda biologik faol birikmalar qo‘llanilmoqda va ular orasida alkaloidlar alohida o‘rin tutadi. Shu sababdan ishning maqsadi (3S,6S,6aS,7S,7aS,8S,9R,10S,11aS,12S,12aR,14S)- 1-ethyl-7a, 11a-dihydroxy-6,8,10- trimethoxydodecahydro- 2H-3, 6a, 12-(epiethane [1,1,2]triyl)-7,9-methanonaphtho [2,3-b] azocin- 3(4H)-yl 2-(ethylsulfonamido) benzoate (CAM-68) diterpenoid alkaloidining aorta SMH plazmolemma $Ca^{2+}{}_{L}$- va $Ca^{2+}{}_{R}$- kanallariga ta’sirini o‘rganishdan iborat.

Tadqiqot metodologiyasi. Tajribalar zotsiz oq kalamushlarning (200-250 g) aorta qon tomir preparatlarida olib borildi. Tajriba hayvonlari servikal dislokatsiya usulida jonsizlantirildi va ko‘krak qafasi ochilib, aorta qon tomiri jarrohlik usulida ajratib olindi va Krebs – Xenzelayt fiziologik eritmasi ((mM): NaCl -120,4; KCl -5; $NaHCO_3$ -15,5; NaH_2PO_4-1,2; $MgCl_2$-1,2; $CaCl_2$-2,5; $C_6H_{12}O_6$-11,5; pH=7,4.) bilan perfuziyalangan maxsus kameraga (5 ml) joylashtirildi [4]. Fiziologik eritmalar karbogen (95% O_2, 5% CO_2) bilan oksigenlandi va harorati U-8 ultratermostati yordamida +37°C da ushlab turildi. Aortani o‘rab turgan biriktiruvchi to‘qima va yog‘ qatlami olib tashlangandan so‘ng, aorta ~3-4 mm li halqa ko‘rinishida segmentlarga bo‘lindi. Aorta halqalari Grass FT.03 (Grass-Telefactor, AQSH) datchikiga platinali simdan yasalgan ilgaklar yordamida ulanadi. Bunday holatda aorta halqalari ~60 minut davomida muvozanatga kelgunga qadar ushlab turildi. Har bir preparatga 1 gr (~10 mN) ga mos keladigan boshlang‘ich kuchlanish berildi. Qisqarish kuchi mexanotrondan keluvchi signal kuchaytirgichga uzatiladi va kompyuterda maxsus programma yordamida yozib olindi. Ayrim tajribalarda potensialga bog‘liq Ca^{2+}-kanallarining spetsifik blokatori – verapamil va α-adrenoretseptorlar blokatori – fentolamin ishtirokida amalga oshirildi.

Natijalar va muhokama. Hujayra ichidagi Ca^{2+} miqdori hujayra tashqarisidan Ca^{2+} ni kirishi va uni sarkoplazmatik retikulumdan chiqishi hisobiga ortadi. Sitozolda Ca^{2+} konsentratsiyasi ortishini kalmodulin bilan bog‘lanishini stimullaydi va konformatsion o‘zgarishlar sodir bo‘ladi. Masalan, SMH larining mediatorlar yoki gormonlar bilan chaqirilgan qisqarishini ham hujayra ichidagi, ham hujayra tashqarisidagi depodan kiradigan Ca^{2+} ionlari ta’minlaydi [5]. KCl bilan indutsirlangan kontraktura sharoitida alkaloidning vazorelaksant ta’siri asosida yotadigan mexanizmlari quyidagi sxema bo‘yicha o‘rganildi. Amalga oshirilgan tajribalarda CAM-68 diterpenoid alkaloidining 1-6 mkM konsentratsiya diapazonida kalamush aorta qon tomiri preparatining me’yoriy tonusiga ta’sir ko‘rsatmasligi aniqlandi. Ammo aorta preparatiga 50 mM KCl bilan indutsirlangan qisqarish faolligiga CAM-68 alkaloidi 1 mkM konsentratsiyada qisqarish kuchini nazoratga nisbatan 14,8±2,3% ga kamayirishi kuzatilgan bo‘lsa, maksimal 6 mkM da 92,1±3,8% ga kamaytirishi aniqlandi (1-rasm).



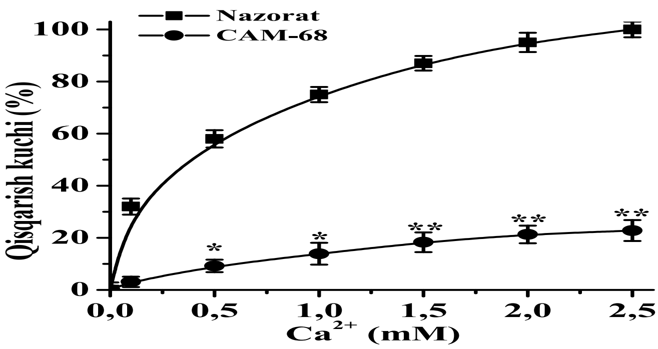
1-rasm. CAM-68 alkaloidining kalamush aorta qon tomiri silliq muskul preparatida KCl (50 mM) yordamida yuzaga keltirilgan qisqarish faolligiga konsentratsiyaga bog'liq vazorelaksant ta'siri.

KCl (50 mM) yordamida yuzaga keltirilgan qisqarish kuchi nazorat (100%) sifatida qabul qilingan (barcha holatlarda *$p<0,05$; **$p < 0,01$; n=5).

Yuqorida keltirilgan tajriba natijalaridan ko'rishimiz mumkinki, CAM-68 alkaloidining vazorelaksant faolligi yuqori qiymatga ega ekanligi aniqlandi.

Demak, in vitro sharoitda kalamush aorta qon tomir silliq muskul preparatining KCl yordamida yuzaga keltirilgan qisqarish faolligi plazmolemmada joylashgan potensialga bog'liq $Ca^{2+}{}_L$-kanali faollashuvi bilan izohlanishi [6], CAM-68 alkaloidining vazorelaksant ta'siri $Ca^{2+}{}_L$-kanali blokadasi va $[Ca^{2+}]_{in}$ konsentratsiyasining kamayishi bilan bog'liqligini taxmin qilish mumkin. Ushbu taxminni tekshirib ko'rish uchun navbatdagi tajribalarda Krebs-Xenzelayt fiziologik eritmasi tarkibida $CaCl_2$ konsentratsiyasini o'zgartirish asosida $[Ca^{2+}]_{out}$ konsentratsiyasi 0,1–2,5 mM diapazonda CAM-68 ning vazorelaksant ta'siri tahlil qilindi. Bunda $[Ca^{2+}]_{out}$=2,5 mM sharoitda silliq muskul preparatining izometrik qisqarish kuchi amplitudasi maksimal qiymatga chiqishi qayd qilindi [7]. CAM-68 diterpenoid alkaloidining vazorelaksant ta'sirini ta'minlashda potensialga bog'liq $Ca^{2+}{}_L$- kanallarning ishtiroki baholandi va bunda 50 mM KCl bilan kalsiysiz inkubatsiya muhitiga $CaCl_2$ ni kumulyativ qo'shish orqali chaqirilgan aorta preparatlari qisqarishlariga ularning ta'siri o'rganildi. Bu tajribalarda inkubatsiya muhitida $CaCl_2$ (0,1-2,5 mM) konsentratsiyasining ortishi $Ca^{2+}{}_L$-kanallari orqali Ca^{2+}-ionlarining kirishi natijasida aorta qisqarish kuchining pog'onali ko'tarilishiga sabab bo'ladi (2-rasm).

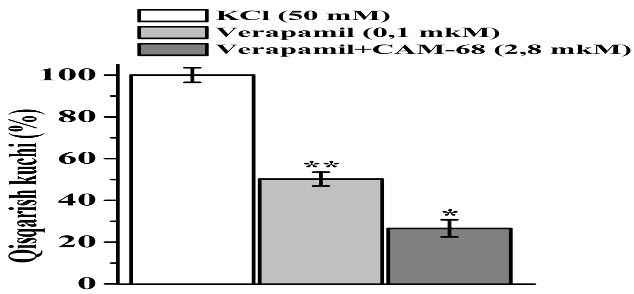
Tajribalarda CAM-68 alkaloidining vazorelaksant ta'siri $[Ca^{2+}]_{out}$ konsentratsiyasiga bog'liq amalga oshishi aniqlandi, bunda alkaloid mavjud sharoitda aorta preparatining qisqarish faolligini nazoratga nisbatan 71,3±3,9% gacha kamaytirdi (2-rasm), o'z navbatida ushbu olingan natijalar o'rganilgan alkaloidning vazorelaksant ta'siri $Ca^{2+}{}_L$-kanali blokadasi bilan bog'liqligini tasdiqlaydi.



2-rasm. CAM-68 alkaloidining kalamush aorta qon tomiri silliq muskul preparatida KCl (50 mM) yordamida yuzaga keltirilgan qisqarishiga $[Ca^{2+}]_{out}$ konsentratsiyasiga bog'liq relaksant ta'siri.

KCl (50 mM) yordamida yuzaga keltirilgan qisqarish kuchi nazorat (100%) sifatida qabul qilingan (barcha holatlarda *$p < 0,05$; **$p < 0,01$; n=4).

Alkaloidning KCl bilan indutsirlangan qisqarish sharoitida vazorelaksant ta'sir ko'rsatishida potensialga bog'liq Ca^{2+} kanallarining ishtirokini tekshirish uchun Ca^{2+}_{L}-kanalining spetsifik blokatori - verapamil (0,1 mkM) yordamida tajribalar amalga oshirildi. Bizga ma'lumki, verapamil SMH lari membranasidagi Ca^{2+}_{L}- kanallari spetsefik blokatori bo'lib, ushbu kanallarning aktivligini kamaytiradi va hujayraga Ca^{2+}-ionlarining kirishini kamaytirishi hisobiga vazorelaksant ta'sirini ko'rsatadi [8, 9]. Bunda verapamil (0,1 mkM) inkubatsiya sharoitida aorta silliq muskul preparatining qisqarish kuchini nazoratga nisbatan 50,2±3,3% ga kamaytirishi va ushbu sharoitda CAM-68 alkaloidi qo'shilganda (IC_{50}=2,8 mkM) qisqarish kuchini qo'shimcha 23,4±4,1% susaytirishi aniqlandi. (3-rasm).

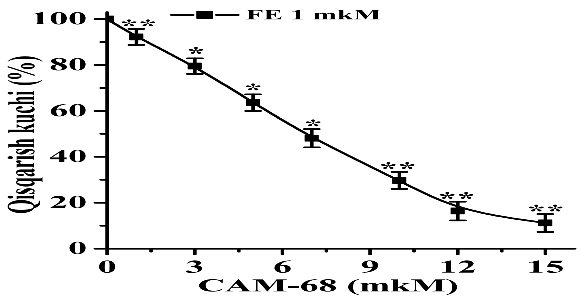


3-rasm. CAM-68 alkaloidining kalamush aorta qon tomiri silliq muskul preparatida Ca^{2+}_{L}-kanali spetsifik blokatori – verapamil (0,1 mkM) inkubatsiyasi sharoitida KCl (50 mM) yordamida yuzaga keltirilgan qisqarishiga relaksant ta'siri.

KCl (50 mM) yordamida yuzaga keltirilgan qisqarish kuchi nazorat (100%) sifatida qabul qilingan (barcha holatlarda *$p < 0,05$; **$p < 0,01$; n=5).

Ushbu olingan natijalarga asoslanib aytish mumkinki, CAM-68 alkaloidining vazorelaksant ta'siri Ca^{2+}_{L}-kanallarini ingibirlanishi bilan bog'liq bo'lib, bu hujayra ichiga Ca^{2+} ionlarining kirishi pasayishi bilan $[Ca^{2+}]_{in}$ konsentratsiyasini kamayishiga olib keladi va qon tomirlarning kengayishi bilan izohlanadi. Lekin alkaloidning verapamil inkubatsiyasi sharoitida aorta qisqarish kuchining qo'shimcha bo'shashtirishi Ca^{2+}_{L}–kanali blokadasidan tashqari boshqa ion transport tizimlariga ta'sir qilish mumkinligini ko'rsatdi.

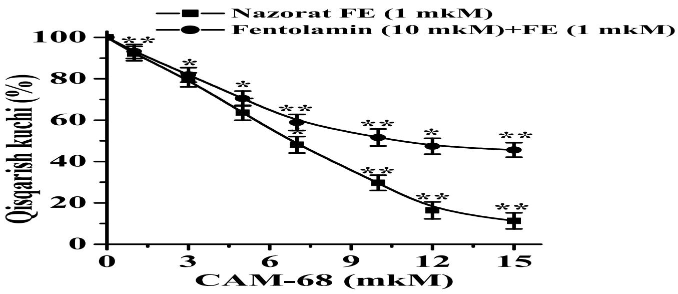
Qon tomir SMH larining funksional faolligini ta'minlashda plazmolemma-dagi potensialga bog'liq Ca^{2+}_{L}–kanallari bilan bir qatorda retseptor boshqariluvchi Ca^{2+}_{R}-kanallari ham muhim ahamiyat kasb etadi [10, 11]. Fenilefrin (FE) bilan indutsirlangan sharoitdagi yuzaga keladigan qisqarishi – bu SR dan ajraladigan hamda retseptor boshqariluvchi Ca^{2+}_{R}-kanallari orqali kiradigan Ca^{2+} ionlari hisobidan ta'minlanadi [12]. Tajribalarda FE bilan chaqirilgan aorta preparati qisqarishlariga CAM-68 alkaloidi kuchli vazorelaksant ta'sir qilishi aniqlandi. Yani alkaloid 1 mkM da aorta qisqarish kuchini nazoratga nisbatan 7,8±3,5% ga hamda 15 mkM konsentratsiyada 88,7±3,9% ga kamaytirishi aniqlandi va yarim maksimal konsentratsiyasi IC_{50}=6,7 mkM ga teng bo'ldi (4-rasm).



4-rasm. CAM-68 alkaloidining kalamush aorta qon tomiri silliq muskul preparatiga FE (1 mkM) yordamida yuzaga keltirilgan qisqarishi konsentratsiyasiga bog'liq relaksant ta'siri.

FE (1 mkM) yordamida yuzaga keltirilgan qisqarish kuchi nazorat (100%) sifatida qabul qilingan (barcha holatlarda *p < 0,05; **p < 0,01; n=6).

Tajribalarda FE bilan indutsirlangan aorta preparati qisqarish kuchiga CAM-68 alkaloidni dozaga bog‘liq bo‘shashtiruvchi ta’sir ko‘rsatishi aniqlandi. Yani o‘rganilayotgan alkaloidning bo‘shashtirvchi ta’siri retseptor boshqariluvchi Ca^{2+}-kanallari blokadasi bilan bog‘liq bo‘lish mumkinligi ilgari surildi. Tadqiqodlarda alkaloidning retseptor boshqariluvchi Ca^{2+}-kanallariga ta’sirini o‘rganish maqsadida α-adrenoretseptorlar blokatori – fentolamin ishtirokida tajribalar amalga oshirdik. Adabiyotlarda, qon tomir SMH si retseptor boshqariluvchi Ca^{2+}-kanallari blokatori sifatida fentolamindan foydalanilgan [13]. Shu sababli o‘tkazilgan tajribalarda fentolamin inkubatsiyasi sharoitida FE (1 mkM) bilan indutsirlangan aorta preparati qisqarish kuchiga CAM-68 alkaloidining vazorelaksant ta’siri nazoratga nisbatan 34,3±3,9% kamayganligi aniqlandi (5–rasm).



5-rasm. CAM-68 alkaloidining kalamush aorta qon tomir preparatida α-adrenoretseptorlar blokatori – fentolamin (10 mkM) inkubatsiyasi sharoitida FE (1 mkM) bilan indutsirlangan qisqarish faolligiga vazorelaksant ta’siri.

Ordinata o‘qida aorta preparati qisqarish kuchi foizda ifodalangan, 1 mkM FE bilan chaqirilgan qisqarish kuchi 100% deb olingan (barcha holatlarda *p < 0,05; **p < 0,01; n=4).

Olib borilgan tajribalardan CAM-68 alkaloidining vazorelaksant ta’siri retseptor boshqariluvchi Ca^{2+}-kanallari blokadasi bilan bog‘liq degan xulosa qilish mumkin, bunga α-adrenoretseptorlar blokatori – fentolamin yordamida olib borilgan tajriba natijasi ham misol bo‘la oladi.

Xulosa. Olingan natijalar CAM-68 alkaloidining vazorelaksant ta’siri SMHlari plazmolemmasida joylashgan potensialga bog‘liq Ca^{2+}_L- va retseptor boshqariluvchi Ca^{2+}_R- kanallari ingibirlanishi bilan hujayra ichki Ca^{2+} konsentratsiyasining kamayishi bilan izohlanadi. Bu natijalarni potensialga bog‘liq Ca^{2+}-kanali spetsifik blokatori verapamil va α-adrenoretseptorlar blokatori – fentolamin bilan olingan tajriba xulosalari ham qo‘shimcha tasdiqlaydi.

Foydalanilgan adabiyotlar

1. Karaki H., Ozaki H., Hori M., Mitsui-Saito M., Amano K., Harada K. Calcium movements, distribution, and functions in smooth muscle // Pharmacol Rev. – 1997. – V.49. – P.157-230.
2. Bkaily G., Jacques D. Calcium Homeostasis, Transporters, and Blockers in Health and Diseases of the Cardiovascular System // International Journal of Molecular Sciences–2023. – V.5. – P.3-25.
3. Knot H.J., Nelson M.T. Regulation of arterial diameter and wall [Ca^{2+}] in cerebral arteries of rat by membrane potential and intravascular pressure. J Physiol. – 1998. – V.508. – P.199-209.
4. Vandier C., Jean-Yves Le Guennec, Bedfer G. What are the signaling pathways used by norepinephrine to contract the artery? A demonstration using guinea pig aortic ring segments // Adv. Physiol. Educ. 2002. V.26. – P.195–203.
5. Laporte R., Hui A., Laher I. Pharmacological modulation of sarcoplasmic reticulum function in smooth muscle // Pharmacol. Rev. – 2004. – V.56(4). – P. 439-513.
6. RatzP., BergK., UrbanN., MinerA. Regulation of smooth muscle calcium sensitivity: KCl as a calcium–sensitizing stimulus // Am. J. Physiol. Cell Physiol. – 2005. – V.288. – P. 769–783.

7. Usmanov P.B., Jumayev I.Z., Rustamov Sh.Yu., Zaripov A.A., Esimbetov A.T., Zhurakulov Sh.N. and Vinogradova V.I. The Combined Inotropic and Vasorelaxant Effect of DHQ-11, a Conjugate of Flavonoid Dihydroquercetin with Isoquinoline Alkaloid 1-aryl-6,7-dimethoxy- 1,2.3,4-tetrahydroisoquinoline // Biomedical & Pharmacology Journal– 2021. – V. 14(2). –P. 651-661..

8. Cleary L., Vandeputte C., Kelly J.G., Docherty J.R. Actions of R– and S– verapamil and nifedipine on rat vascular and intestinal smooth muscle // Auton. Autacoid. Pharmacol. – 2004. – V.24. – P.63–67.

9. Esimbetov A., Zaripov A., Omonturdiev S., Sultankhodjaev M., Usmanov P. Vasorelaxant effect of the alkaloid 1-0-benzoylnappeline on isolated rat thoracic aorta // International Journal of Agriculture, Environment and Bioresearch–2020. – V. 5. – P.146-156.

10. McFadzean I., Gibson A. The developing relationship between receptor-operated and store-operated calcium channels in smooth muscle // British Journal of Pharmacology – 2002. – V.135. – P. 1-13.

11. Zaripov A., Esimbetov A., Usmanov P., Shokirova D., Zhurakulov Sh.N. Effects of F-18 on KCl and phenylephrine - induced contractions of rat aorta // The American Journal of Medical Sciences and Pharmaceutical Research–2021. – V.3. – P.100-108.

12. Wier W.G., Morgan K.G. Alpha-adrenergic signaling mechanism in contraction of resistance arteries // Rev.Physiol.Biochem.Pharmacol. – 2003.– V.150.– P.91-139.

13. Godfraind T. Calcium channel blockers in cardiovascular pharmacotherapy // J Cardiovasc Pharmacol Ther. – 2014. – V.19(6). – P. 501-515.

O‘ZBEKISTONDA ADVENTIV TUR SIFATIDA TARQALGAN *BIDENS FRONDOSA* VA MAHALLIY FLORA VAKILI *BIDENS TRIPARTITA* O‘SIMLIKLARI TARQALISHINI BIOIQLIMIY MODELLASHTIRISH

Abulfayzov Husniddin Shokhojayevich
husniddin.abulfayzov1@mail.ru
ORCID: 0009-0007-1142-2961
Daminova Nazokat Erkinboyevna
Kasimov Zakir Zikiryoyevich
Aliyeva is Kumush Bahadir's daughter
Natalia Beshko Yuryevna
Institute of Botany UAS
Norkhodjayeva Aziza Muzafarovna
Karshi State University, doctoral student
azizamuzaffarovna@mail.ru
ORCID:0000-0002-2094-9534
UDK: 581,93

Annotatsiya. Adventiv tur – bu o‘zining tabiiy hududidan tashqariga introduksiya qilingan va yangi hududlarda salbiy ta’sir ko‘rsatgan yoki ko‘rsatishi mumkin bo‘lgan tur. Invaziv turlar jamoa tarkibini o‘zgartiradi, hudud yoki resurslar uchun mahalliy turlardan ustun turadi va ularning yo‘q bo‘lib ketishiga olib kelishi mumkin. Hozirgi vaqtda invaziv turlar tabiiy ekotizimlardagi o‘zgarishlarning yetakchi omillaridan biri sifatida tan olingan. Invaziv o‘simliklar dunyodagi o‘simliklar xilmaxilligining aksariyat qismini tashkil qiladi va asosiy xavf hisoblanadi. O‘zbekistonda 228 ta invaziv o‘simlik turlari mavjudligi aniqlangan. Natijada o‘simlik dunyosining mahalliy floraga xos bo‘lmagan, birinchi navbatda, bevosita yoki bilvosita inson faoliyati oqibatida ma’lum bir hududga introduksiya qilingan invaziv qismi shakllanadi.

Ushbu maqolada O‘zbekiston uchun adventiv tur bo‘lgan *Bidens frondosa* L.va mahalliy florada keng tarqalgan *Bidens tripartita* L. o‘simliklarining tarqalish maydonini bioiqlim modellashtirish haqida ma’lumot berilgan.

Kalit so‘zlar. Adventiv tur, Bidens tripartita L., Bidens frondosa L., O‘zbekiston, areal.

BIOCLIMATIZATION OF THE SPREAD OF *BIDENS FRONDOSA*, AN ADVENTIVE SPECIES IN UZBEKISTAN, AND *BIDENS TRIPARTITA*, A LOCAL FLORA DISTRIBUTOR

Abstract. An adventive species is one that has been introduced outside of its natural range and has had or may have a negative effect on the new areas. Invasive species change community structure, outcompete native species for territory or resources, and may cause them to become extinct. Invasive species are now recognized as one of the leading drivers of natural ecosystem change. Invasive plants account for most of the world's plant diversity is one of the serious threats. The presence of 228 invasive plants in

Uzbekistan determined. An invasive part of the flora that is not characteristic of the local flora, primarily as a result of direct or indirect human activity to be introduced into a certain area is formed as a result. This article provides information on bioclimatic modeling of the distribution area of *Bidens frondosa* L., an adventive species for Uzbekistan, and *Bidens tripartita* L., which is widespread in the local flora.

Key words. adventive species, *Bidens tripartite* L., *Bidens frondosa* L., Uzbekistan, areal.

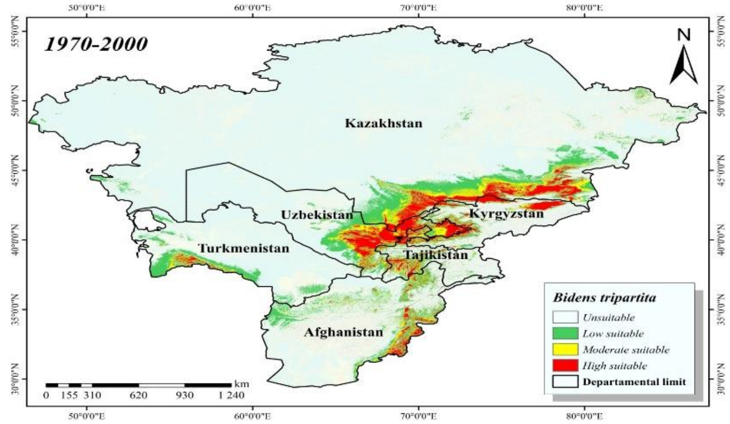
Kirish. Hozirgi kunda yer yuzida adventiv o‘simlik turlarining tarqalishi, rivojlanishi va keltiradigan zarar yoki foydasini o‘rganishga amaliy jihatdan chuqur e’tibor qaratilmoqda. Yevropa, Amerika va Osiyo mamlakatlarida chetdan kirib kelayotgan o‘simliklar to‘g‘risida ma’lumotlar yig‘ilib, tahlil amalga oshirilgan[1]. Begona o‘simliklarning boshqa hududlardan kirib kelishining bir omili transport vositalari hisoblanadi. Bu, ayniqsa, iqtisodiy aloqalari mavjud mamlakatlarning shaharlarida ko‘proq ko‘zga tashlanadi[2]. So‘nggi yillarda O‘zbekiston hududida ham juda ko‘plab o‘simliklar adventiv tur sifatida kirib kelgan. Bu o‘simliklardan *Bidens frondosa* L. o‘simligini keltirishimiz mumkin. Bu o‘simlik mahalliy florada tarqalgan *Bidens tripartita* L. o‘simligini arealidan siqib chiqaryapti. *Bidens tripartita* L. - Asteraceae oilasiga mansub, bir yillik o‘t o‘simlik. Poyasi bitta, tik, qizg‘ish, poyaning tepa qismi qarama-qarshi shoxlangan, balandligi 100 smgacha o‘sadi. Rossiyaning deyarli butun Yevropa qismi, Sibir, Markaziy Osiyo, Kavkaz va Uzoq Sharqda tarqalgan. U nam daryo qirg‘oqlari bo‘ylab, ko‘llar va ko‘llar yaqinida botqoqlarda, ariqlarda o‘sadi, u yerda ko‘pincha chakalakzorlarni hosil qiladi. Birinchi marta 1753-yilda Species Plantarium jurnalida nashr etilgan. Birinchi gerbariy namunasi M.G. Popov tomonidan 1920-yil 21-iyulda Toshkent tumanidagi Kaplanbek dahasidan terilgan.

Bidens frondosa L. - serbarg ittikanak. Bu tur Asteraceae oilasiga mansub, kelib chiqish vatani Shimoliy Amerika. Shimoliy Amerikada aholi yashash joylarida katta maydonlarda uchraydi. Masalan, uni nam o‘rmonlarda, o‘tloqlarda, chakalakzorlarda, dalalarda, yo‘l chetlarida, temir yo‘llarda, daryolar qirg‘oqlarida, ko‘lmaklarda, botqoqlarda, ariqlarning yoqalarida uchratish mumkin [3]. *Bidens frondosa* L. O‘zbekiston florasida birinchi marta 2005-yilda Farg‘ona vodiysi ruderal florasini o‘rganish mobaynida suv yoqasida o‘suvchi Bidentetea tripartiti sinfi Bidentetalia tripartiti tartibi Bidention tripartiti uyushmasi Bidentetum tripartiti assotsiatsiyasi tarkibida uchragan[4]. Poyasi 20–60(90–180) sm bo‘lgan bir yillik o‘t o‘simlik. Barglari naysimon-tuxumsimon, kontursimon, uch bargli yoki pinnatsimon, uzunligi 3-8 sm undan ortiq, eni esa 2-6 smni tashkil etadi. Shimoliy Amerikada keng tarqalgan, AQShning deyarli barcha shtatlarida va Kanadaning ko‘plab mintaqalarida uchraydi. 18-asrning boshlarida u Yevropaga olib kelingan, u yerda botanika bog‘larida yetishtirilgan. Taxminan, 1813-yilda u birinchi marta Rossiya imperiyasi Kremenetsda yetishtirila boshlandi. Bu o‘simlikning butun Yevropa bo‘ylab tez tarqalishi jahon urushi yillariga to‘g‘ri keladi. 1950-yillarda birinchi marta Yevropa va Rossiyada paydo bo‘ldi. Birinchi marta 1975-yilda Moskvadan topilgan. 1980-yillarda *Bidens frondosa* L. keskin kengaydi, ko‘plab mintaqalarda bu tur mahalliy florani deyarli butunlay siqib chiqardi. 20-asrning boshlariga kelib, o‘simlik Yangi Zelandiyaga kirib keldi, u yerda ham invaziv turga aylandi [5]. O‘zbekistonda birinchi gerbariy namunasi 2012-yil (город Ташкент, окр. Ботанического сада 07.08.2012 Мальцев) terilgan. Biz hozir va kelajakda bu o‘simliklarning tarqalish areallarini bashorat qilish uchun bioiqlimiy modellashtirdik.

Tadqiqot metodologiyasi. Dala tadqiqotlari natijalariga asoslanib yig‘ilgan materiallar, Milliy gerbariydan (TASH) olingan namunalar va ilmiy manbalar (O‘zbekiston florasi)dan foydalanildi. Tadqiqotimizda marshrut metodlari va ArcGIS 10.5, Google eart pro, Maxent, Global Biodiversity Information Facility (GBIF, www.gbif.org) , Plantarium.ru dasturlaridan foydalanildi.

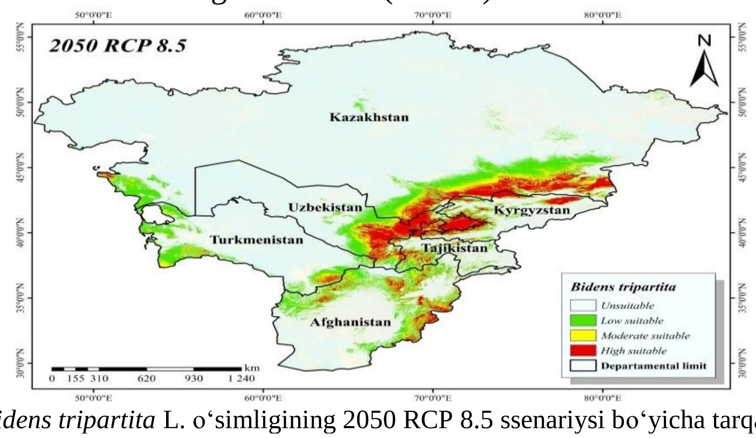
Bidens tripartita L. va *Bidens frondosa* L. bioiqlim modelini yaratishda S.J. Phillips tomonidan taklif qilingan MaxEnt uslubi (maksimal entropiya uslubi) dan hamda tadqiqotimiz uchun zarur boʻlgan atrof-muhit maʼlumotlarini olish uchun biz turli manbalardan foydalandik. Birinchidan, biz Worldclim maʼlumotlar bazasidan (https://www.worldclim.org/) 1970-yildan 2000-yilgacha boʻlgan davrni oʻz ichiga olgan 19 ta tarixiy global bioiqlim oʻzgaruvchilarini oldik. Kelajakdagi iqlim prognozlari uchun, xususan, 2050-yillar (2041–2060)va 2070 (2061–2080) yillar uchun RCP8.5 konsentratsiya yoʻllari (RCPs) maʼlumotlarini, iqlim oʻzgarishi, qishloq xoʻjaligi va oziq-ovqat xavfsizligi (CCAFS) portalidan oldik (https://ccafs-climate. org/data_spatial_scaling/).

Tadqiqot natijalari. Tadqiqotimiz davomida bu oʻsimliklarning hozirgi va kelajakdagi yashash areali qanday oʻzgarishini bilish maqsadida bioiqlimiy modellashtirdik, natijada quyidagi koʻrsatkichlar hosil boʻldi: *Bidens tripartita* L. uchun ekologik qulay hududlar Oʻzbekiston,Qozogʻiston va Qirgʻiziston nisbatan yuqori qulay muhit hisoblanadi, Afgʻoniston va Turkmaniston nisbatan kamroq qulay muhit hisoblanadi. Oʻzbekistonda bu turning oʻsishi uchun yuqori darajadagi qulay muhit sifatida Toshkent, Sirdaryo, Namangan, Andijon, Samarqand, Qashqadaryo viloyatlari hududi hisoblanib, Qoraqalpogʻiston Respublikasi, Buxoro, Xorazm, Navoiy viloyati qulay boʻlmagan, Surxondaryo viloyati qisman qulay muhit hisoblanadi. Hozirgi vaqtda *Bidens tripartita* L. oʻsimligining tarqalish areali noqulay muhit 3 985 858 km^2, past qulay muhit 366 878 km^2,oʻrtacha qulay muhit 138 057 km^2, qulay muhit 182 129 km^2 tashkil qildi (1-rasm).



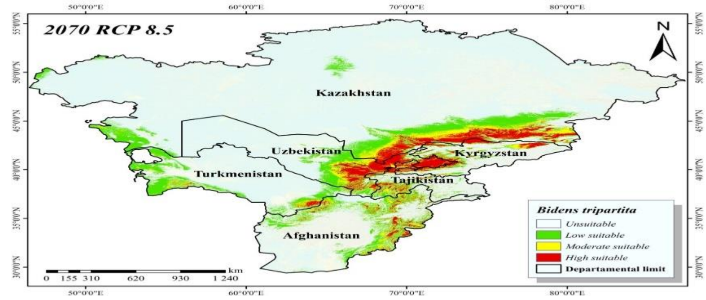
1-rasm. *Bidens tripartita* L.oʻsimligining hozirgi vaqtda tarqalish areali.

2050 PCP 8.5 ssenariyasi boʻyicha *Bidens tripartita* L. oʻsimligi uchun noqulay muhit 3 852 871 km^2, past qulay muhit 426 796 km^2,oʻrtacha qulay muhit 167 186 km^2, yuqori qulay muhit 226 013 km^2 ekanligini koʻrsatdi(2-rasm).



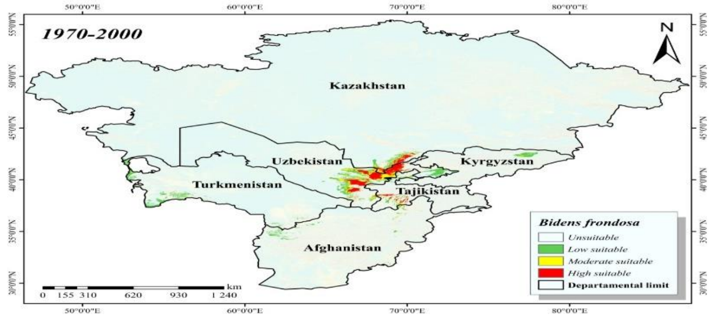
2-rasm. *Bidens tripartita* L. oʻsimligining 2050 RCP 8.5 ssenariysi boʻyicha tarqalish areali.

2070 PCP 8.5 ssenariyasi boʻyicha *Bidens tripartita* oʻsimligi uchun noqulay muhit 3 837 067 km^2,past qulay muhit 456 295 km^2,oʻrtacha qulay muhit 169 598 km^2,yuqori qulay muhit 209 885 km^2 ni koʻrsatdi(3-rasm).



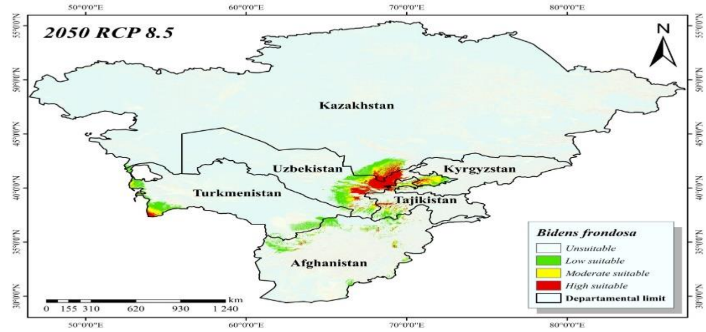
3-rasm. *Bidens tripartita* o‘simligining 2070 RCP 8.5 ssenariysi bo‘yicha tarqalish areali.

Hozirgi vaqtda *Bidens frondosa* L. o‘simligi invaziv tur sifatida progress holatida shuning uchun bu o‘simlikni hozirgi va kelajakdagi tarqalish arealini bashorat qilish maqsadida bioiqlimiy modellashtirildi, natijada hozirgi vaqtda bu o‘simlik uchun noqulay muhit 4 570 974 km^2,past qulay muhit 53 994 km^2, o‘rtacha qulay muhit 20 960 km^2, yuqori qulay muhit 27 010 km^2 ni tashkil qildi(4-rasm).



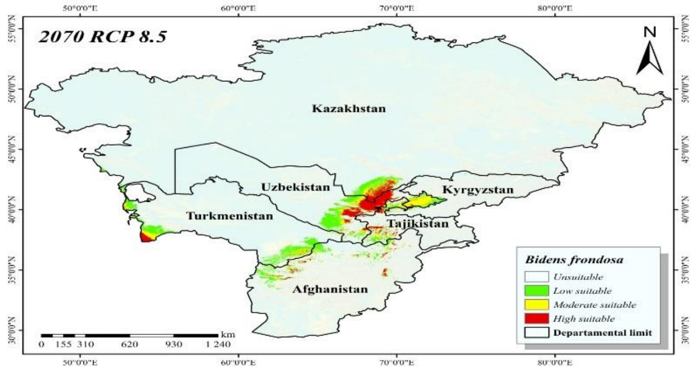
4-rasm. *Bidens frondosa* o‘simligining hozirgi vaqtda tarqalish areali.

2050 PCP 8.5 ssenariyasi bo‘yicha *Bidens frondosa* o‘simligi uchun noqulay muhit 4 477 654 km^2, past qulay muhit 107 376 km^2,o‘rtacha qulay muhit 42 805 km^2,yuqori qulay muhit 45 104 km^2 ekanligini ko‘rsatdi(5-rasm).



5-rasm. *Bidens frondosa* o‘simligining 2050 RCP 8.5 ssenariysi bo‘yicha tarqalish areali.

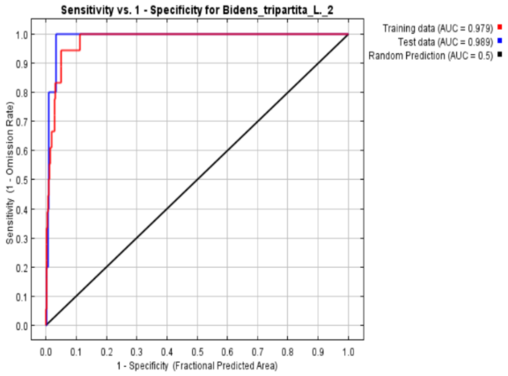
2070 PCP 8.5 ssenariyasi bo‘yicha *Bidens frondosa* o‘simligi uchun noqulay muhit 4 472 017 km^2,past qulay muhit 107 490 km^2,o‘rtacha qulay muhit 44 646 km^2, yuqori qulay muhit 48 785 km^2 ni ko‘rsatdi(6-rasm).



6-rasm. *Bidens frondosa* o‘simligining 2070 RCP 8.5 ssenariysi bo‘yicha tarqalish areali.

Bidens tripartita o‘simligi uchun MaxEnt modeli eng yuqori hissa qo‘shgan bioiqlim o‘zgaruvchisi haroratning mavsumiyligi (bio_4) aniqlandi(7-rasm).

Variable	Percent contribution	Permutation importance
wc2.1_30s_bio_4	36.2	0
gloslopescl2_30as	13.3	12.5
gloelev_30as	12	8.9
wc2.1_30s_bio_14	11	0.8
wc2.1_30s_bio_13	8.3	4.2
wc2.1_30s_bio_11	6.3	45.9
gloaspectcle_30as	2	0.4
gloaspectcls_30as	1.9	1.3
wc2.1_30s_bio_19	1.6	0
wc2.1_30s_bio_18	1.5	0
gloslopescl5_30as	1.2	0.5
wc2.1_30s_bio_2	1.2	0
wc2.1_30s_bio_7	0.8	14.7
gloslopescl8_30as	0.7	6
wc2.1_30s_bio_12	0.7	1.1



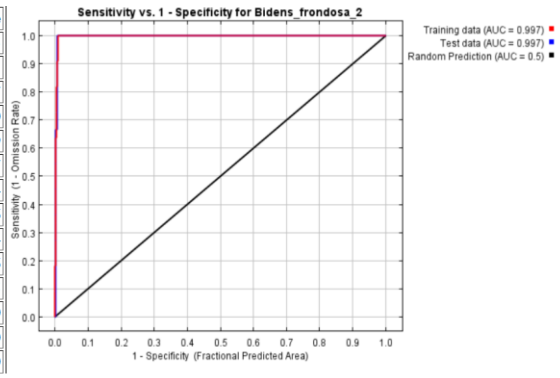
A. B

7-rasm. Modelga bioiqlim o‘zgaruvchilarining qo‘shgan hissasi. **B**. Modelning to‘g‘rilik darajasi (AUC).

Bidens frondosa o‘simligi uchun MaxEnt modeli eng yuqori hissa qo‘shgan bioiqlim o‘zgaruvchisi**;** Eng sovuq chorakdagi yog‘ingarchilik (bio_19) aniqlandi. (8-rasm).

A **B**

Variable	Percent contribution	Permutation importance
wc2.1_30s_bio_19	22.8	5
wc2.1_30s_bio_4	22.1	17.3
wc2.1_30s_bio_6	12.9	35.7
wc2.1_30s_bio_7	6.9	0
wc2.1_30s_bio_15	6.7	0.9
gloslopescl6_30as	4.9	0.7
gloslopescl8_30as	4.4	1.4
gloslopescl7_30as	3.7	2.6
gloaspectcls_30as	3	0.4
gloaspectcle_30as	2.8	1.6
wc2.1_30s_bio_11	2.7	33.5
gloelev_30as	1.8	0
wc2.1_30s_bio_18	1.4	0
gloslopescl2_30as	1.1	0



8-rasm. Modelga bioiqlim o‘zgaruvchilarining qo‘shgan hissasi. **B**. Modelning to‘g‘rilik darajasi (AUC).

Xulosa. Xulosa qilib aytganda, *Bidens tripartita* o‘simligi hozirgi vaqtda qulay muhit 182 129 km^2 tashkil qildi. 2050 PCP 8.5 ssenariyasi bo‘yicha yuqori qulay muhit 226 013 km^2 ekanligini ko‘rsatdi. 2070 PCP 8.5 ssenariyasi bo‘yicha yuqori qulay muhit 209 885 km^2 ko‘rsatdi, bu esa 2050-yilga borib bu *Bidens tripartita* o‘simligi uchun qulay muhit ko‘payadi va 2070-yilga borib bu o‘simlik uchun qulay muhit kamayishini ko‘rsatdi. *Bidens frondosa* o‘simligi uchun hozirgi vaqtda yuqori qulay muhit 27 010 km^2 bo‘lsa, 2050 PCP 8.5 ssenariyasi bo‘yicha yuqori qulay muhit 45 104 km^2, 2070 PCP 8.5 ssenariyasi bo‘yicha yuqori qulay muhit 48 785 km^2 ni ko‘rsatdi. Bu esa bundan keyin bu o‘simlikning kengroq tarqalishidan dalolat beradi.

Foydalanilgan adabiyotlar

1. Набиев М.М., Казакбаев Р.Ю. Определитель декоративных деревьев и кустарников.Узбекистана. - Ташкент, Фан,1975. - 156 с.
2. Olimova Subhiniso Oqil qizi, Esanov Husniddin Qurbonovich. Buxoro shahridagi introduksiya qilingan adventiv turlar. Journal of Advanced Research and Stability.Volume: 02 Issue: 10 | Oct - 2022 ISSN: 2181-2608.
3. Holter B. Bidens frondosa- devil's beggarticks. Northwestern Oregon Wetland Plants Project. Oregon, USA: Portland State University. 1999.or:
4. Trobjon Makhkamov. Bidens frondosa l. ning populyatsion xususiyatlari va reproduktiv mahsuldorligi. See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication /372257898.
5. Виноградова, Ю. К., Майоров, С. Р., Хорун, Л. В. Чёрная книга флоры Средней России. – М., 2009. – С. 135-144. - 494 с. ISBN 978-8-89119-487-9.

6. Тожибаев К.Ш., Эсанов Х. Современное состояние изученности инвазионных видов Узбекистана. - ResearchGate January 2022.
7. Lazkov G.A., Sennikov A.N. Tojiboev K.Sh., Sultonova B. Yangi va nodir adventiv o‘simliklardan Qirg‘iziston va O‘zbekiston // Tizim yangiliklari. yuqoriroq rast., 2011. – No 42. – B. 226-231
8. Mayorov S.R., Bochkin V.D., Nasimovich Yu.A., Shcherbakov A.V. Moskva va Moskvaning sarguzashtli florasi -skaya viloyati. – Moskva: KMK ilmiy nashrlari hamkorligi, 2012. – 412 p.
9. Эсанов Ҳ.Қ. Бухоро воҳаси флораси: Монография. – Бухоро: Дурдона, 2019. – 158 б.
10. Тожибаев К.Ш., Бешко Н.Ю., Шомуродов Х.Ф. и др. Кадастр флоры Узбекистана: Бухарская область. Монография. – Тошкент, Ўқитувчи, 2020. – 128 с.
11. Эсанов Ҳ.Қ. Антропоген муҳитлар флораси шаклланишининг долзарб муаммолари // Ўзбекистон ўсимликлар оламидаги биохилмахиллик: муаммо ва ютуқлар. Республика илмий-амалий анжуман материаллари. –Қарши, 2018. – Б. 29-30.
12. Sennikov A.N., Tojibaev K.Sh., Beshko N.Yu., Esanov H.K., Jenna Wong L., Pagad S. Global Register of Introduced and Invasive Species - Uzbekistan.2018. Invasive Species Specialist Group ISSG. Elektron resurs.
13. Verkhozina A.V., Anisimov A.V., Beshko N. Yu., Esanov H.K.,Tajetdinova D.M., Jabbarov A.M. et al.. Findings to the flora of Russia and adjacent countries: New national and regional vascular. Botanica Pacifica. A journal of plant science and conservation. 2022. 11(1): 129–157. (№3 Scopus, IF1.4).

QARSHI CHO‘LI O‘SIMLIKLAR QOPLAMIDAGI YULG‘UNZOR FORMATSIYASI (Tamariceta varia)

Chariyev R.R.
Qarshi davlat universiteti
“Mikrobiologiya va biotexnologiya” kafedrasi o‘qituvchisi
chariyev17@gmail.com
ORCID 0000-0003-4803-1175

УДК 581.55

Annotasiya. Maqolada Qarshi cho‘lida mavjud yulg‘unzor formatsiya (*Tamariceta varia*) haqida fikr yuritiladi. Qarshi cho‘li janubiy cho‘llardan, Qizilqum cho‘lining bir qismi. Hudud Buxoro okrugining Qarshi-Qarnobcho‘l rayoni tarkibiga kiradi. Hududda turli xil ko‘rinishdagi bo‘z tuproqlar, sur qo‘ng‘ir tuproqlar, qumli tuproqlar, gipsli singari tuproqlar tarqalgan. Qarshi cho‘li maydonlarida *Sophora conollyi, Haloxylon ammodendron, Haloxylon persicum Tamarix ramosissima, T.hispida,T. laxa, Artemisia diffusa, Aeluropus litoralis, Allium borszczowii, Alhagi pseudalhagi, Alhagi kirghisorum, Atriplex cana, Poa bulbosa, Salicornia europae, Strigosella grandiflora, Suaeda altissima, Suaeda microsperma* kabi o‘simlik turlari uchraydi. Hozirgi kunda mavjud maydonlarda tarqalgan yulg‘un turlari va ularni hosil qilgan assotsiatsiyalarining holati bayon etilgan. Qarshi cho‘lining o‘zlashtirilishi hisobidan yuzaga kelgan o‘zgarishlar va yulg‘unzor formatsiya tarkibidagi o‘simlik turlari haqida so‘z boradi. Mavjud o‘simliklarga ta’sir etadigan omillar haqida to‘xtalib o‘tiladi.

Kalit so‘zlar. Qarshi cho‘li, to‘qay o‘simliklari, Qarshi bosh kanali, gidrotexnika inshootlari, *Tamarix*, formatsiya, chorvachilik.

THE FORMATION OF THE DESERT VEGETATION COVER (Tamariceta varia)

Abstract. In the article, there is an opinion about the tamarind formation (*Tamariceta varia*) in the Karshi desert. Karshi desert is a part of the southern deserts, Kyzylkum desert. The area is part of Karshi-Karnobchol district of Bukhara district. Different types of gray soils, brown soils, sandy soils, gypsum-like soils are distributed in the area. *Sophora conollyi, Haloxylon ammodendron, Haloxylon persicum Tamarix ramosissima, T. hispida, T. laxa, Artemisia diffusa, Aeluropus litoralis, Allium borszczowii, Alhagi pseudalhagi, Alhagi kirghisorum, Atriplex cana, Poa bulbosa, Salicornia europae, Strigosella grandiflora, Suaeda altissima, Suaeda microsperma.* Currently, the types of sedges distributed in the existing areas and the state of the associations that formed them are described. The changes caused by the exploitation of the Karshi desert and the types of vegetation in the alluvial formation are discussed. Factors affecting existing vegetation are discussed.

Keywords. Karshi desert, forest vegetation, Karshi main channel, hydrotechnical facilities, *Tamarix*, formation, livestock.

Kirish. O‘zbekiston o‘simliklar qoplamida to‘qay o‘simliklar tiplari mavjud bo‘lib, ular uch xil ko‘rinishda namoyon bo‘ladi. Daraxtli, butali, o‘t o‘simlikli to‘qayzorlar. Bu o‘simlik jamoalari respublikaning tog‘li hududlaridan boshlanib, cho‘llarigacha yoyilgan. Buning asosiy sabablaridan biri to‘qaylarning daryo oqimlari atrofida hosil bo‘lishidir. Mavjud to‘qaylar quyi Amudaryo daryosi vodiysida, uning deltasida, Sirdaryo, Surxondaryo, Zarafshon va Chirchiq daryolari vodiylarida yoki kichik orollarida saqlanib qolgan. Angren, Qashqadaryo kabi daryolarning quyi qismida kanallar, ariqlar bo‘ylab, konlarda yoki o‘zlashtirish uchun noqulay bo‘lgan kichik maydonlarda, to‘qaylarning faqat alohida elementlarini uchratish mumkin [4]. Qarshi cho‘li maydonlarida hosil bo‘lgan yulg‘unzor formatsiyasini tabiatning bir bo‘lagi sifatida o‘rsanish, ularni sistematik tahlil qilish, jamoa tarkibidagi turlarni, ularga ta’sir etuvchi omillarni aniqlash shu bilan bir qatorda, xalq xo‘jaligida, ayniqsa, chorvachilikda yaylovlardan to‘g‘ri foydalanish va ularni qayta tiklash yo‘llarini rivojlantirishdan iborat.

Tadqiqot metodologiyasi. Tadqiqot hududi Qarshi cho‘li bo‘lib, O‘zbekistonning janubida, Qashqadaryo viloyatining g‘arbidagi qumli tekisliklarni o‘z ichiga oladi (1-rasm). Hudud Qashqadaryo fizik-geografik okrugining Sundukli rayoni hududida joylashgan [6;1].

Qarshi cho‘li sharqiy tomondan Hisor va Zarafshon tog‘larining tog‘oldi qiya tekisliklari, shimolda Qarnob-Malik cho‘llari, g‘arb va janubi-g‘arbda Devxona platosi, janub va janubi-sharqda Amudaryo va Qashqadaryo havzalarini ajratuvchi tepaliklar bilan chegaralangan. Hudud shimoldan Jom tog‘i, janubi-g‘arbiy tomondan Sandiqli cho‘l qumlari, shimoli-g‘arbiy tomondan Buxoro va Navoiy viloyatlari hamda Qizilqum bilan tutashadi [1].

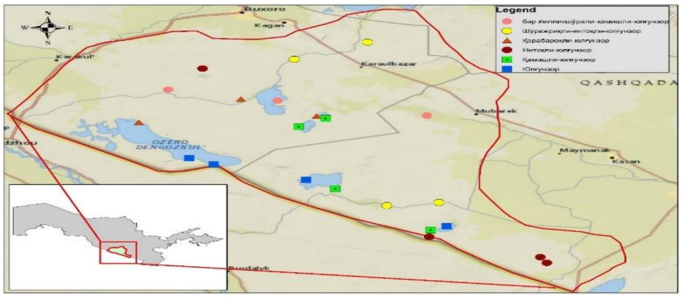
Qarshi cho‘li hududida taqir, qum cho‘lli, och-qo‘ng‘ir tuproqlar va o‘tloq botqoqliklari yaxshi rivojlangan [6]. Hudud Buxoro okrugining Qarshi-Qarnobcho‘l rayoni tarkibiga kiradi [8].

Qarshi cho‘lida yulg‘unzor jamoalarini aniqlash va ularning turlar spektrini tahlil qilish uchun umumqabul qilingan geobotanik, marshrutli va yarim statsionar metodlardan (Polevaya geobotanika, 1964; Shennikov, 1964; Chibrik va boshq., 2014) foydalanildi. O‘simlik turlar “O‘zbekiston florasi” (1941-1966), S.K. Cherepanov hamda plantarium.ru ma’lumotlari asosida keltirildi [14]. Turlarning hayotiy shakllarini “O‘rta Osiyo o‘simliklar aniqlagichi” (1982-1993), tarqalish areallari “SSSR florasi” (1934-1984) asosida berildi.

Natijalar va muhokama. Qarshi cho‘lining o‘zlashtirilishi 1960-yillarda boshlangan [13]. Unda cho‘l hududidan 200 ming ga gektar yer o‘zlashtirilgan. Buni yo‘lga qo‘yish uchun Qashqadaryo viloyati hududidan Qarshi bosh kanali uzunligi 290 km (100 km dan ko‘proq qismiga beton, betonplyonka qoplama yotqizilgan), Mirishkor kanali uzunligi 1011km, Buxoro viloyatida Amu-Buxoro kanali uzunligi 400 km. qazilib cho‘lga Amudaryodan suv keltirilgan. Adabiyot ma’lumotlarda to‘qaylar daryo oqimining yo‘nalishlari hisobidan yuzaga kelishi haqida bir qancha olimlar ta’kidlab o‘tishgan, jumladan, Zarafshon tekisligida V.V. Sedov (1959), Surxondaryo irmoqlari va tekisliklarida V.P. Drobov (1951), tekislik va tog‘ to‘qaylarining tuzilishi haqida Q.Z. Zokirov (1955), A.U.Usmanov (1953) asarlarida ham o‘z aksini topgan.

Yuqoridagi kanallarning har birining suvi qariyb bir daryo suviga teng [13]. Sug‘orish ishlari olib borish uchun suv omborlari, o‘nlab kanallar, beton ariqlar, ariqlar cho‘l maydonlarida qazilgan yoki yotqizilgan. Hozirgi kunda ariq va kanallarning ayrimlari ta’mirtalab bo‘lib qolgan, bu esa suvlarni yon atrofga chiqishi, sizot suvlar miqdorining oshishi bilan bir qatorda yulg‘un, yantoq, ajriq, qamish kabi o‘simliklarning rivojlanishiga imkon berayotganligi kuzatilmoqda (jadval).

Agrofitosenozlarda sug‘orish ishlari bilan bir qatorda kuz-qish mavsumida yerning sho‘r yuvish ishlarining bir necha yillardan beri olib borilishi va ulardan chiqqan ikkilamchi suvlar zovurlar, derenajlar orqali yig‘ilib Qarshi cho‘li maydonlarida sun’iy ko‘llarning hosil bo‘lishiga olib kelgan. Tabiatga texnogen aralashish tufayli bu maydonlarda suv bilan bo‘g‘liq holda o‘simliklar jamoalarining ma’lum darajada almashinuvi yuzaga kelgan. Sizot suvlar yig‘ilib botqoqliklarni hamda tuproq tarkibida sho‘rlanishlarni yuzaga keltirganligini ko‘llar atrofida kuzatish mumkin. Sizot suvlar sho‘rlanishdan tashqari, yuqori darajada ifloslanganligi bilan ham ajralib turadi [12].



1-rasm. Qarshi cho'lida yulg'unzor jamoalari tarqalgan maydonlar.

Qarshi cho'li maydonlarida ushbu kunga kelib Dengizko'l, Achinko'l Allanko'l, Sechanko'l, Zikriko'l kabi bir qancha katta-kichik ko'llar mavjud bo'lib, ular asosan qumliklar orasida joylashganligi bilan bir qatorda ajoyib manzara holil qiluvchi yulg'unzorga ega. Bundan tashqari Talimarjon suv ombori atrofida, kanal, zovur hamda mavsumiy suv to'planadigan, o'zlashtirilishi qiyin bo'lgan maydonlarda kichik-kichik, ba'zan lentasimon to'qay ko'rinishlarini hosil qiladi. Yulg'unzorga cho'l qumliklari orasida paydo bo'lgan tabiat mo'jizasi sifatida qarash mumkin. Cho'l zonasidagi to'qayzorlar, asosan, yulg'un hamda qora chingildan iborat [5]. Qarshi cho'lida mavjud yulg'unzor buta va o'tsimon o'simliklar jamoalaridan iborat ekanligi aniqlandi. O'zbekistonning to'qay o'simliklari ko'plab botanik-tadqiqotchilarning e'tiborini bir necha bor o'ziga tortgan. Ulardan Y.P. Korovin (1934, 1961, 1962) cho'l zonasidagi to'qay o'simliklarni alohida turiga kiritgan.

Bizning tadqiqot olib boradigan hududimizda butalardan yulg'un asosiy to'qay hosil qiluvchi o'simlik sifatida geobatanik qaydnomalarda qayd etilgan. Yulg'un, jing'il - yulg'undoshlar oilasiga mansub buta yoki daraxt. Bu o'simlik Janubiy Yevropa, Janubiy Afrikaning cho'l, chala cho'llarida va Hindistonda, Rossiyaning janubi, Kavkaz, Qozog'iston va O'rta Osiyoning daryo va soy bo'ylarida, to'qay, o'rmonlarida, chakalakzorlarda, ko'l va dengiz qirg'oqlarida uchraydi. Yulg'undoshlar (*Tamaricaceae*) oilasi vakillarining 125 dan ortiq turi Osiyo, Yevropa va Afrikada tarqalgan [10]. Yulg'unning yer yuzida 54 turi tarqalgan. O'zbekistonda 12 ta turini uchratish mumkin. Yulg'unzor respublikamizning hamma viloyatlarida mavjud bo'lib, qariyb 250 ming gektarni tashkil etadi [11].

Qarshi cho'li maydonlarida tarqalgan yulg'unzor farmatsiyasi bir qancha assotsiatsiyalarini o'z ichiga oladi, jumladan, yulg'unzor, qamishli-yulg'unzor, yantoqli-yulg'unzor, qorabaroqli-yulg'unzor, sho'rajriqli-yantoqli-yulg'unzor, bir yillik sho'rali-qamishli-yulg'unzordir. Mavjud assotsiatsiyalar orasidan nisbatan ko'proq tarqalganlari yulg'unzor, sho'rajriqli-yantoqli-yulg'unzor, bir yillik sho'rali-qamishli-yulg'unzor assotsiatsiyalari ekanligini kuzatishlarimizdan ma'lum bo'ldi.

Yulg'unzor assotsiatsiyalarini Talimarjon suv ombori atroflarida, Dengizko'lda, Alanko'lining janubi-g'arbida, Qarshi bosh kanali, Mirishkor kanali, Amu-Buxoro kanali atroflarida va turli xil maydonlarda uchratish mumkin. Ushbu assotsiatsiyalarda *Tamarix laxa, T.hispida* yetakchi o'rinni egallaydi. Yer yuzasining o'simliklar qoplash darajasi 20-90 foizgacha. *Tamarix laxa, T.hispida* hayotiy shakliga ko'ra buta yoki daraxt. Qarshi cho'li maydonlarida 50 santimetrdan 3-4 metr va ba'zan undan balandlarini ham Talimarjon suv ombori atroflarida uchratish mumkin. Barglari tanasini qoplab turadi, ularining rangi yashil, sarg'ish-yashil, ba'zan kulrang, yil davomida o'zgarib turadi. Kuzatishlarimizda bahorda u yashil rangga ega, yozda kulrang, kech kuz fasliga borib hatto oq rangga aylanadi. Bunga sabab o'simlikning krinogalofitligidir. Agar yulg'unzor oralab yursangiz, tuz kristallari liboslaringizga tegadi. Novdalari och yashil, qizil-jigarrang yoki binafsha-kulrang, eski poyalarning qobig'i kulrang ko'rinishda. *Tamarix laxa*da yosh novdalar kalta, ingichka va juda mo'rtligidan oson sindirish mumkin. Gullari mayda oq, och pushti, binafsharang, uzun shingilsimon to'pgulga yig'ilgan. *Tamarix hispida* iyul va oktyabr oylarida gullaca, *Tamarix laxa* aprel o'rtalarida gullaydi, ba'zida kuzda ham gullar hosil qiladi.

Yulg'unlar jamoasida *Alhagi pseudalhagi, Aeluropus repens, Karelinia caspia,* *Limonium gmelinii, Suaeda microsperma* va sho‘radoshlar vakillari keng tarqalgan (jadval).

Qamishli-yulg‘unzor cho‘lning o‘zlashtirilgan va o‘zlashtirilmay qolgan qismining suv yig‘iladigan hamda dengiz sathidan past sizot suvlari yuqori bo‘lgan maydonlarda keng tarqalgan. Bu assotsiatsiyalarda turlar soni 14 tadan 25 tagacha bo‘lib, yer yuzasining qoplanish darajasi 36-47 foizgacha. Qamishli yulg‘unzorda oz bo‘lsa-da, butalardan *Lycium ruthenicum, Nitraria schoberi* uchrasa, ko‘p yillik o‘tlardan *Alhagi pseudalhagi, Cardaria draba, Cyperes rotundus, Limonium otolepis, Limonium gmelinii, Typha angustifolia* singari turlar jamoani yanada to‘ldirib turadi (jadval).

Yantoqli-yulg‘unzor cho‘lning deyarli hamma ko‘llari va gidrotexnika inshootlari atrofida mavjud. Adabiyotlarda qayd etilgan ayrim yantoqzorlar hozirgi kunga kelib turli omillar ta’sirida yantoqli-yulg‘unzorlarga aylanganligini kuzatish mumkin. Ushbu jamoalarda yulg‘unning *Tamarix hispida, T. laxa* va yantoqning ham ikki turi *Alhagi pseudalhagi, A. kirghisorum* tarqalgan. Ayrim maydonlarda, jumladan, chorva mollari ko‘p boqiladigan hududlarda *Peganum harmala* ning son jihatidan ortganligini payqash qiyin emas. *Karelinia caspia, Zygophyllum oxianum, Chenopodium album, Climacoptera aralensis* kabi turlar kuz faslida assotsiatsiyada o‘ziga xos manzara hosil qiladi.

Qorabaroqli-yulg‘unzorni sho‘r tuproqli maydonlar bilan bir qatorda ko‘llar qirg‘oqlarida, sho‘r botqoqliklarda uchratish mumkin. Ular asosan tarqoq bo‘lib, ba’zan boshqa yulg‘unli assotsiatsiyalar bilan almashib yirik maydonlarni egallagan. O‘simliklarning yer yuzasini qoplash darajasi 40 foizdan kam emas, butalar bilan bir qatorda o‘t o‘simliklarning ham o‘z o‘rni bor. Qorabaroqli-yulg‘unli assotsiatsiyalarda *Halostachys belangeriana* umumiy ulushdagi foizi 10-15 ni tashkil etadi. Suvga yaqin maydonlarda *Phragmites australis, Aeluropus litoralis* ko‘proq uchrasa, suvdan uzoqlasib borganda *Limonium otolepis, Cardaria draba, Alhagi kirghisorum* va sho‘radoshlarning bir yillik vakillari ortib boradi (jadval).

Sho‘rajriqli-yantoqli-yulg‘unzorli assotsiatsiyalar yer yuzani qoplash darajasiga ko‘ra Qarshi cho‘li misolida eng yuqori ko‘rsatkichlarni tashkil etadi. Olib borgan kuzatishlarimizgan saksovulzor, shuvoqzor, qandimzor, cherkezzor va boshqa bir qancha jamoalardan hattoki ikki barobar ko‘p, 80 dan 92 foizgachani tashkil etadi. Turlar soni jihatidan ushbu assotsiatsiya 15-20 turni o‘z ichiga olsa-da, ayrimlari yil davomida chorva mollari uchun yaylov vazifasini bajaradi. Chorva mollari kam boqilganlari to‘qayni yoki chakalakzorlarni eslatadi. Ko‘llar qirg‘og‘ida hosil bo‘lganlari turli hayvonlar uchun boshpana vazifani o‘taydi. Sho‘rajriq yer yuzasiga sudralib yoki yastanib manzara hosil qilsa, yantoqlar o‘rta yarusni egallaydi. Baland va qalin yulg‘unlar ularga qo‘shilib to‘qay ko‘rinishini ifodalaydi (jadval).

Bir yillik sho‘rali-qamishli-yulg‘unzor assotsiatsiyalar yuqorida qayd etilgan gidrotexnika inshootlarining atroflarida, o‘zlashtirilib tuproq strukrurasi buzilgan, yoz faslida suv tanqisligi sezilib sug‘orish ishlari belgilangan darajada bo‘lmay qolgan maydonlarda, sho‘rlangan tuproqlarda tarqalgan. Bahor va yoz fasli boshlarida yer yuzasining qoplanishi 80 foizdan yuqori, yoz faslining oxiri va kuz faslida yer yuzasining qoplanishi 40-50 foizni tashkil etadi. Buning asosiy sababi o‘simliklar vegetatsiyasi bo‘lsa, boshqa tomondan antropogen omillardir. Bu jamoalarda *Phragmites australis* 15-25 foizni egallashi namlik darajasi bilan bog‘liq bo‘lsa, sho‘radoshlar oilasi vakillari tuproqning sho‘rlanishning darajasiga qarab jamoada 1-10 foizgacha o‘rin egallaydi (jadval).

Xulosa va takliflar. Kuzatishlarimizdan Qarshi cho‘li maydonlaridagi yulg‘unzor formatsiyasi turli xil ta’sirlarga uchramoqda. Avvalo, tabiatning noqulay sharoiti bo‘lsa, so‘nggi yillarda yog‘in miqdorining kamayishi, sug‘orish uchun suvning tanqislashib borishi, tuproq sho‘rlanishining ortishi yulg‘unzor jamoasining son va sifat jihatidan o‘zgarishlariga sabab bo‘lmoqda. Boshqa tomondan, chorva mollarining tartibsiz boqilishi, yulg‘unni ko‘p yillik poyalari qurilish hamda yoqilg‘i uchun, qamishlarning xo‘jalikning turli maqsadlarida qurilish, bezak va dag‘al xashak uchun yig‘ilishi, gidrotexnika inshootlarni, ariq, zovurlarni tozalash maqsadida yoqib yuborilishi ularning areali qisqarishiga sabab bo‘lmoq

1-jadval

		Assosiasiyalar																				
		Yulg'unzor				Qamishli-yulg'unzor			Yantoqli-yulg'unzor				Qorabaroqli-yulg'unzor			Sho'rajriqli-yantoqli-yulg'unzor				Bir yillik sho'rali-qamishli-yulg'unzor		
		qoplash darajasi, %																				
		61	20	24	87	47	36	39	41	61	45	31	58	42	46	87	82	92	74	83	59	52
Butalar																						
1.	Lycium ruthenicum		+				+		1					1	1		+					
2.	Nitraria schoberi						+						+		+							
3.	Tamarix ramosissima					15	+							25			+		+	+		+
4.	T.hispida				70		20	25	20		+	+				40	40	50	40	40	+	
5.	T. laxa	35	15	20						40	25	20	40		30						30	30
6.	Halostachys belangeriana	+						+					15	10	10		+					
7.	Halimodendron halodendron			+										+	+							
Butachalar																						
8.	Artemisia diffusa									+		+										
Ko'p yillik o'tlar																						
9.	Aeluropus repens		2				+							+							+	
10.	Aeluropus litoralis	+	+	+	+				+		+		+	2	2	15	10	10	10	+	+	+
11.	Allium borszczowii									+							+					
12.	Alhagi pseudalhagi	15			+	1		+	10					+		20	30	+	20			
13.	Alhagi kirghisorum						+	2		20	15	10			1			20			+	1
14.	Cardaria draba						1	1					1	1		+	1		1			
15.	Carex pachystilis		+				+			+					+			+		+		
16.	Cousinia resinosa	+		1				+	2		1			+			+					
17.	Cyperes rotundus					1	2	+								5		+	+	+	+	
18.	Plantago major					+	+															
19.	Phragmites australis	+		+	+	25	10	10			+		1	+		1	1			25	20	15
20.	Peganum harmala				+				5			1						+				
21.	Poa bulbosa						+			+				+							+	
22.	Karelinia caspia	10	+	2	+	5	+	1	+		2				+		+	1	1			
23.	Limonium otolepis				1	1							+	1	1		+		1		+	1
24.	Limonium gmelinii				4		2	+		+	+			1		+						+
25.	Typha angustifolia					1	1	+												3		
26.	Zygophyllum oxianum				+	+		+	1		+			+			+		+		+	
Bir yilliklar																						
27.	Anisantha tectorum								+		+					+		+				
28.	Astragalus campylotrichus		+							+		+		+								
29.	Atriplex cana					+				+					+			+			+	
30.	Bassia hissopifolia						+						+	1		+		1		+		+
31.	Bromus tectorum										+				+						+	
32.	Bromus danthoniae		+			+								+			+					
33.	Veronica campylopoda			+								+										
34.	Eremopyrum bonaepartis		+				+		+		+			+			+					
35.	Eremopyrum orientale	+				+				+			+								+	
36.	Eremopyrum triticeum		+								+					+	+			+	+	
37.	E. distans								+									+				
38.	Cousinia dichotoma		+		+									+								
39.	Ceratocarpus utriculosus		+		+			+		+		+	+	+				+		+		
40.	Chenopodium album			+			+		1		2				1			+				+
41.	Chenopodium sp	1	+							+				+		1						
42.	Climacoptera aralensis				+				1					+			+			+		
43.	Climacoptera lanata												1		+							
44.	Heteroderis pusilla		+				+					+		+				+				
45.	Heteracia szovitzii		+														+					
46.	Hordeum leporinum	+		+	+					1	+			+		+			1	+	1	
47.	Koelpinia linearis	+			+					+				+			+					

48.	Lactuca serriola	+				+	+			+	+	+	+	+			+	+	+		+	
49.	Tribulus terrestris			+					+					+						+		
50.	Microcephala lamellata				+						+											
51.	Papaver pavoninum	+	+				+			+			+				+					
52.	Roemeria hybrida			+										+								
53.	Polygonum aviculare	+			+		+						+				+	+				
54.	Plantago lagocephala				+	+	+	+														
55.	Salsola sclerantha		3						+			+		+		+		+		+	1	
56.	Salsola sp				10																	
57.	Salicornia europae	+		+												+				10	1	5
58.	Strigosella grandiflora				+									+				+				
59.	Suaeda altissima			+									+		+					5		+
60.	Suaeda microsperma	+			2																	
61.	S. heterophylla									+	+			+			+				6	
62.	Senecio subdenthatus	+											+			+						
63.	Schismus arabicus															5		+				

Foydalanilgan adabiyotlar

1. Баратов П. Ўзбекистон табиий географияси. – Тошкент: Ўқитувчи, 1996. – Б. 180-209.
2. Дробов В. П. Солончаковая растительность долин равнинных рек Узбекистана, Бюлл. - МОИП, 1951, отд. биол., т. 56, вып. 6.
3. Коровин Е.П. Растительность Средней Азии и Южного Казахстана. Книга– Ташкент: АН Узбекской ССР, 1961. – 452 с.
4. Майлун. З.А. Тугайная растительности. В кн.: Растительный покров Узбекистана.Т.2 – Ташкент, Фан, УзССР 1973. – С. 303-375.
5. Попов М.Г. Растительный покров Казахстана. – Москва–Ленинград, Изд-во Наука, 1940. – С.126-135.
6. Природные условия и ресурсы Юго-западного Узбекистана. – Ташкент, Наука, 1965. – С. 370-401.
7. Седов В. В. Пойменная растительность долины Зеравшана и пути ее реконструкции. - Самарканд—Нукус, Изд. Узб. ун-та, 1959.
8. Тожибаев К.Ш., Бешко Н.Ю., Шомуродов Х.Ф., Қодиров У.Х., Тургинов О.Т., Шарипова В.К. Кадастр флоры Узбекистана. Кашкадарынская область. – Ташкент, Издательство Фан, АНРУз., 2018. – С. 171-181.
9. Усманов А. У. Тугайная расдельность Долины реки Ангрен. - Ташкент, Изд-во АН УзССР, 1953.
10. Флора СССР. - Москва-Ленинград, Изд.АН ССР, Т. XV, 1949. - С. 295-306.
11. Флора Узбекистана. – Ташкент, Изд.АН УзССР, 1959. – Т. IV. –С. 192-206.
12. Храмцов Б. Н. Растительность солончаков / Ботаническая география Казахстана и Средней Азии (в пределах пустынной области). – Санкт-Петербург, 2003.– С. 112-118.
13. Худойқулов М. Қарши чўли.- Тошкент: Шарқ, 1998 320 б.
14. Чибрик Т.С., Глазырина М.А., Лукина Н.Б., Филимонова Е.И. Изучение фитоценозов техногенных ландшафтов. – Екатеринбург, Изд-во Уралскkого ун-та, 2014. - 166 с.
15. Шенников А.П. Введение в геоботанику. – Ленинград, 1964. – 447 с.

QASHQADARYO VOHASIDA LIPSKYA INSIGNIS VITALITETI KO‘RSATKICHLARI

Bo‘ranova M.O.
Qarshi davlat universiteti, dotsent
muhayyoxon@bk.ru
ORCID 0000-0003-4701-4322,

UO‘K 58.009

Annotatsiya. Maqolada O‘zbekistonning Qashqadaryo vohasida tarqalgan Chandir lipskiya (Lipskya insignis (Lipsky) Nevsky) senopopulyatsiyalarining vitalitet holati aniqlangan. Chandir lipskiya O‘rta Osiyoning dengiz sathidan 800-1300 m balandlikdagi tor mintaqasida tarqalgan endem tur hisoblanadi. Buning uchun Dehqonobod va Qamashi tumanlarida joylashgan 5 senopopulyatsiyadan 30 tadan model o‘simliklar ajratib olingan va ularda 3 ta ko‘rsatkich, ya’ni o‘simliklarning umumiy balandligi, eng katta ildiz oldi bargining uzunligi va eni mezon qilingan va vitalitet holati baholangan. Barcha senopopulyatsiyalar bo‘yicha olingan natijalar asosida senopopulyatsiyalarning vitalitet indeksi (IVC) hisoblab chiqildi. Vitalitet indeksidan senopopulyatsiyalardagi vitalitetning sifat indeksini aniqlashda foydalanildi.

O‘lchashlar natijasida birinchi senopopulyatsiyada deyarli barcha o‘simliklar a kategoriyada ekanligi, ikkinchi va to‘rtinchi senopopulyatsiyada esa c kategoriyadagi o‘simliklar ulushi ancha ko‘pligi aniqlandi. Faqat birinchi senopopulyatsiyaning vitalitet tipi yaxshi rivojlanayotgan bo‘lib, qolgan barcha senopopulyatsiyalar depressiv tipdagi ekanligi ma’lum bo‘ldi.

Yuqoridagilardan kelib chiqqan holda L. insignisni terib olishni vaqtincha cheklash hamda plantatsiyalarini yaratish tavsiya qilindi.

Kalit so‘zlar. Lipskya insignis, vitalitet indeksi, IVC, vitalitetning sifat indeksi, endem.

INDICATORS VITALITY OF LIPSKIA INSIGNIS IN KASHKADARYA OASIS

Abstract. In the article, the state of vitality of the coenopopulations of Lipskya insignis (Lipsky) Nevsky) widely found in Kashkadarya oasis of Uzbekistan is determined. L. insignis is an endemic species distributed in a narrow altitude belt of Central Asia at 800-1300 m above sea level. For this purpose, 30 model plants were selected from 5 coenopopulations located in Dehqonobod and Qamashi districts, and 3 indicators, i.e. the total height of plants, the length and width of the largest root leaf, and the state of vitality were evaluated. Based on the results obtained for all coenopopulations, the vitality index (IVC) of coenopopulations was calculated. Vitality index was used to determine the qualitative index of vitality in coenopopulations.

As a result of the measurements, it was found that in the first coenopopulation, almost all plants are in category a, and in the second and fourth coenopopulations, the proportion of plants in category c is much higher. It turned out that only the first coenopopulation has a well-developed vitality type, and all other coenopopulations are of a depressive type.

Based on the above, it was recommended to temporarily limit the collection of L. insignis and create plantations.

Key words. Lipskya insignis, vitality index, IVC, vitality quality index, endemic.

Kirish. O‘zbekistonning janubiy hududlarida joylashgan Qashqadaryo vohasida qurg‘oqchil iqlim hukm suradi. Vavilov N.I. va uning izdoshlari bu hududni madaniy o‘simliklarning kelib chiqish markazi deb hisoblaganlar [1].

Hozirda bu yerda bir qancha endem turlar tarqalgan. Ulardan biri, Lipskya insignis (Lipsky) Nevsky Soyabonguldoshlar oilasi vakillaridan biri bo‘lib, dengiz sathidan 800-1300 m balandlikdagi tor mintaqada o‘sadi.

Tadqiqotlar Qashqadaryo viloyatining Dehqonobod tumanida joylashgan 3 ta va Qamashi tumanida joylashgan 2 ta senopopulyatsiyada olib borildi.

Birinchi senopopulyatsiya Dehqonobod tumanining ma’muriy markazi bo‘lgan Qorashina shaharchasidan 10 km sharqda 1200 m balandlikda janubiy yonbag‘irda joylashgan. Bu yerda aralash o‘tli – dukkakli – qo‘ziquloqzor o‘simliklar jamoasi tarqalgan.

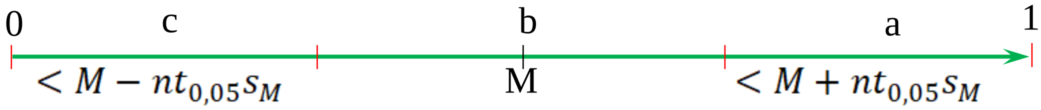
Ikkinchi senopopulyatsiya Dehqonobod tumanining Xo‘jamahmud qishlog‘ining 3 km shimolda, 1230 m balandlikda janubi-sharqiy yonbag‘irda joylashagn. Bu yerda aralash o‘tli – dukkakli – bodomchazor o‘simliklar jamoasi tarqalgan.

Uchinchi senopopulyatsiya Dehqonobod tumanining Oqrabot qishlog‘idan 6,5 km janubi-sharqda, 1270 m balandlikda janubi-sharqiy yonbag‘irda joylashgan. Bu yerda aralash o‘tli – kovrakli – shuvoqzor o‘simliklar jamoasi tarqalgan.

To‘rtinchi senopopulyatsiya Qamashi tumanining Yangiqishloq qishlog‘idan 2 km janubda, 1290 m balandlikda janubi-janubi-sharqiy yonbag‘irda joylashgan. Bu yerda siyrak bodomchazor orasidagi aralash o‘tli – javdarli – qo‘ziquloqzor o‘simliklar jamoasi tarqalgan.

Beshinchi senopopulyatsiya Qamashi tumanining Choygul qishlog‘idan 3,5 km shimoli-sharqda, 1280 m balandlikda janubi-sharqiy yonbag‘irda joylashgan. Bu yerda bug‘doyzorlar orasidagi aralash o‘tli – dukkakli – qo‘ziquloqzor o‘simliklar jamoasi tarqalgan.

Tadqiqot usullari. O‘simliklarning vitalitetini baholashda Y.A. Zlobin tomonidan tavsiya qilingan metodlardan foydalanildi [2]. Buning uchun ularning 3 ta ko‘rsatkichi, ya’ni o‘simliklarning umumiy balandligi, eng katta ildizoldi bargining uzunligi va eni mezon qilib olindi. Bunda o‘simliklar uchta kategoriyaga bo‘lindi: vitaliteti yuqori (a), vitaliteti o‘rtacha (b) va vitaliteti past (c) bo‘lgan o‘simliklar (1-rasm).



1-rasm. Vitalitet kategoriyalarining chegarasi.

Model o‘simliklar sifatida har bir senopopulyatsiya markazidan 2 m uzoqlikda o‘tkazilgan ikkita parallel gradiyenta bo‘ylab har 2 m da joylashgan 30 tadan o‘simlik tanlab olindi. Sanash va o‘lchash ishlari vegetatsiyaning generativ fazasi 3 fazachasida (yetilgan va yetilmagan mevalarning bir vaqtda mavjud bo‘lishi) amalga oshirildi.

Vitalitet kategoriyalarining chegarasi quyidagi formuladan aniqlandi:

$$M \pm nt_{0,05}s_M \qquad (1)$$

bundanM — o‘lchangan individlar balandligining o‘rtacha arifmetik qiymati, sm;
n — olingan natijalar orasidagi farq juda kichik bo‘lganligida qo‘llanilgan 1 dan 3 gacha koeffitsiyent;
$t_{0,05}$ — ishonch darajasi 95% bo‘lgandagi Styudent kriteriysi;
S_M — o‘rta arifmetikning xatoligi.

Barcha senopopulyatsiyalar bo‘yicha olingan natijalar asosida senopopulyatsiya-larning vitalitet indeksi IVC hisoblab chiqildi. Bunda A.R. Ishbirdin va M.M. Ishmuratovalar [3] taklif qilgan formuladan foydalanildi:

$$IVC = \frac{\sum_{i=1}^{N} \frac{x_i}{\bar{x}_i}}{N} \qquad (3)$$

bundanx_i — belgining senopopulyatsiyadagi o‘rtacha qiymati;
$\bar{x}_i$ — belgining barcha senopopulyatsiyalar uchun o‘rtacha qiymati;
N — belgilarning soni.

Senopopulyatsiyalarning vitalitetning sifat indeksi quyidagi formuladan hisoblandi:

$$Q = \frac{a+b}{2} \qquad (2)$$

bundan a — vitaliteti yuqori bo‘lgan o‘simliklar ulushi;
b —vitaliteti o‘rtacha bo‘lgan o‘simliklar ulushi;

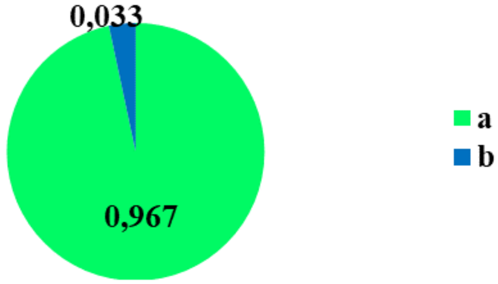
Yaxshi rivojlanayotgan senopopulyatsiyalar uchun $Q > c$ nisbat, muvozanatdagi senopopulyatsiyalar uchun $Q = c$, depressiv senopopulyatsiyalar uchun esa $Q < c$ nisbat xos.

Barcha senopopulyatsiyalarda o‘simliklarning ko‘rsatkichlari o‘lchab olingach, ular asosida 1-formulalardan Vitalitet kategoriyalarining chegarasi hisoblab olindi. Bizning holatimizda senopopulyatsiyalarning yakuniy bahosiga ta’sir qilmaganligi sababli n = 2, ya’ni o‘rtacha qiymat olindi.

Natijalar va muhokama. 1-formula bo‘yicha barcha senopopulyatsiyalar uchun vitalitet kategoriyalarining chegarasi aniqlab olindi, ya’ni $M\text{-}nt_{0,05}S_M$=0,901 ва $M\text{+}nt_{0,05}S_M$=1,094 ni tashkil qildi.

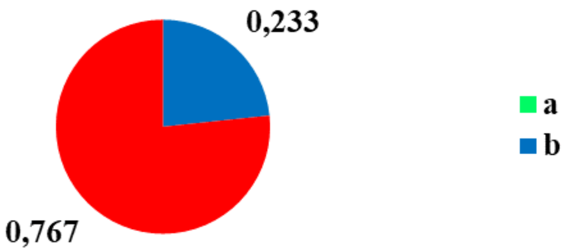
Birinchi senopopulyatsiyasida o‘simliklarning o‘rtacha bo‘yi 29,0±1,21 sm ga, ildiz oldi bargning o‘rtacha uzunligi 17,9±0,35 sm ga va eni 7,8±0,16 sm ga yetdi. L. insignis ning bu yerdagi vitaliteti 1,073 dan 1,896 gacha oraliqni tashkil qildi. Bu yerda a kategoriyadagi o‘simliklarning soni 29 tani, ularning ulushi esa 0,967 ni, b kategoriyadagi o‘simliklarning soni 1 tani, ularning ulushi esa 0,033 ni tashkil qildi. Birinchi senopopulyatsiyadagi model o‘simliklar orasidan c kategoriyadagi o‘simliklar aniqlanmadi (2-rasm). Olingan natijani 2-formulaga qo‘yib, ushbu senopopulyatsiyada

Q = 0,5, ya'ni Q > c bo'lganligi uchun bu senopopulyatsiyaning vitalitet tipi yaxshi rivojlanayotgan ekanligini ko'rish mumkin.



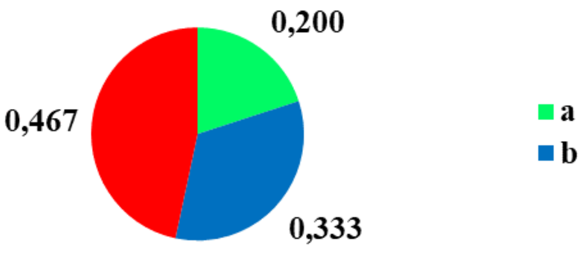
2-rasm. Birinchi senopopulyatsiyaning vitalitet strukturasi.

Ikkinchi senopopulyatsiyada o'simliklarning o'rtacha bo'yi 10,3±0,51 sm ga, ildizoldi bargning o'rtacha uzunligi 13,1±0,20 sm ga va eni 3,8±0,11 sm ga yetdi. L. insignis ning bu yerdagi vitaliteti 0,563 dan 1,012 gacha oraliqni tashkil qildi. Bu yerda a kategoriyadagi o'simliklar aniqlanmadi, b kategoriyadagi o'simliklarning soni 7 tani, ularning ulushi esa 0,233 ni, c kategoriyadagi o'simliklarning soni 23 tani, ularning ulushi esa 0,767 ni tashkil qildi (3-rasm). Olingan natijani 2-formulaga qo'yib, ushbu senopopulyatsiyada Q = 0,117, ya'ni Q < c bo'lganligi uchun bu senopopulyatsiyaning vitalitet tipi depressiv ekanligini ko'rish mumkin.



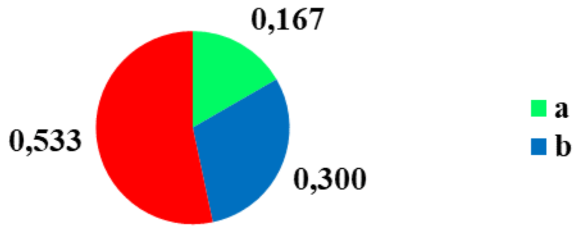
3-rasm. Ikkinchi senopopulyatsiyaning vitalitet strukturasi.

Uchinchi senopopulyatsiyada o'simliklarning o'rtacha bo'yi 15,1±0,91 sm ga, ildizoldi bargning o'rtacha uzunligi 15,7±0,29 sm ga va eni 5,2±0,20 sm ga yetdi. L. insignis ning bu yerdagi vitaliteti 0,648 dan 1,174 gacha oraliqni tashkil qildi. Bu yerda a kategoriyadagi o'simliklarning soni 6 tani, ularning ulushi esa 0,2 ni, b kategoriyadagi o'simliklarning soni 10 tani, ularning ulushi esa 0,333 ni, c kategoriyadagi o'simliklarning soni 14 tani, ularning ulushi esa 0,467 ni tashkil qildi (4-rasm). Olingan natijani 2-formulaga qo'yib, ushbu senopopulyatsiyada Q = 0,267, ya'ni Q < c bo'lganligi uchun bu senopopulyatsiyaning vitalitet tipi depressiv ekanligini ko'rish mumkin.



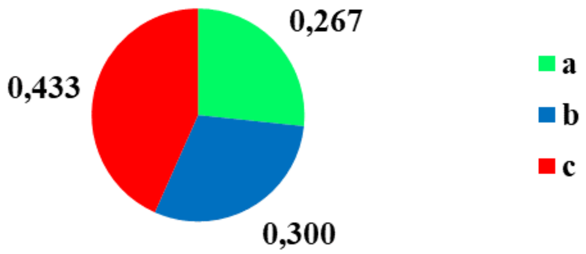
4-rasm. Uchinchi senopopulyatsiyaning vitalitet strukturasi

To'rtinchi senopopulyatsiyada o'simliklarning o'rtacha bo'yi 12,3±0,73 sm ga, ildizoldi bargning o'rtacha uzunligi 14,4±0,29 sm ga va eni 4,6±0,14 sm ga yetdi. L. insignis ning bu yerdagi vitaliteti 0,647 dan 1,203 gacha oraliqni tashkil qildi. Bu yerda a kategoriyadagi o'simliklarning soni 5 tani, ularning ulushi esa 0,167 ni, b kategoriyadagi o'simliklarning soni 9 tani, ularning ulushi esa 0,3 ni, c kategoriyadagi o'simliklarning soni 16 tani, ularning ulushi esa 0,533 ni tashkil qildi (5-rasm). Olingan natijani 2-formulaga qo‘yib, ushbu senopopulyatsiyada Q = 0,233, ya’ni Q < c bo‘lganligi uchun bu senopopulyatsiyaning vitalitet tipi depressiv ekanligini ko‘rish mumkin.



5-rasm. To‘rtinchi senopopulyatsiyaning vitalitet strukturasi.

Beshinchi senopopulyatsiyada o‘simliklarning o‘rtacha bo‘yi 12,8±0,70 sm ga, ildizoldi bargning o‘rtacha uzunligi 15,2±0,21 sm ga va eni 4,9±0,23 sm ga yetdi. L. insignis ning bu yerdagi vitaliteti 0,621 dan 1,218 gacha oraliqni tashkil qildi. Bu yerda a kategoriyadagi o‘simliklarning soni 8 tani, ularning ulushi esa 0,267 ni, b kategoriyadagi o‘simliklarning soni 9 tani, ularning ulushi esa 0,3 ni, c kategoriyadagi o‘simliklarning soni 13 tani, ularning ulushi esa 0,433 ni tashkil qildi (6-rasm). Olingan natijani 2-formulaga qo‘yib, ushbu senopopulyatsiyada Q = 0,283, ya’ni Q < c bo‘lganligi uchun bu senopopulyatsiyaning vitalitet tipi depressiv ekanligini ko‘rish mumkin.



6-rasm. Beshinchi senopopulyatsiyaning vitalitet strukturasi.

Barcha senopopulyatsiyalarning vitalitet ko‘rsatkichlari 1-jadvalda keltirilgan.

1-jadval

L. insignis senopopulyatsiyalarining vitalitet ko‘rsatkichlari

SP №	O‘rtacha balandligi, sm	Ildiz oldi bargning o‘rtacha uzunligi, sm	Ildiz oldi bargning o‘rtacha eni, sm	Vitaliteti bo‘yicha o‘simliklarning ulushi			Q	IVC	Senopopulyatsiya vitalitet tipi
				a	b	c			
1	25,8±1,32	17,0±0,26	7,7±0,16	0,967	0,033	0,000	0,500	1,462	yaxshi rivojlanayotgan
2	10,3±0,51	13,1±0,20	3,8±0,11	0,000	0,233	0,767	0,117	0,778	depressiv
3	13,9±0,72	14,0±0,19	4,6±0,15	0,200	0,333	0,467	0,267	0,927	depressiv
4	12,3±0,73	14,4±0,29	4,6±0,14	0,167	0,300	0,533	0,233	0,902	depressiv
5	12,8±0,70	15,2±0,21	4,9±0,23	0,267	0,300	0,433	0,283	0,953	depressiv

Xulosa va takliflar. Tadqiqotlar davomida faqat birinchi senopopulyatsiyada o‘simliklarning vitaliteti yaxshiligi aniqlandi. Bunga sabab ushbu senopopulyatsiyaning ekin maydonlari bilan to‘liq o‘ralganligi sababli chorva mollari boqishning imkoniyati yo‘qligi hamda mahalliy aholi tomonidan nisbatan kam yig‘ib olinishidadir.

Ikkinchi senopopulyatsiyada esa eng yuqori a kategoriyadagi o‘simliklar, umuman, aniqlanmadi. Faqat birinchi senopopulyatsiyada o‘rtacha vitalitet indeksi 1 dan katta bo‘ldi, qolgan senopopulyatsiyalarda esa Q < c bo‘lganligi uchun bu senopopulyatsiyaning vitalitet tipi depressiv ekanligini ma’lum bo‘ldi.

Yuqoridagilardan kelib chiqqan holda L. insignis ni terib olishni vaqtincha cheklash hamda plantatsiyalarini yaratish tavsiya qilinadi.

Foydalanilgan adabiyotlar

1. Вавилов Н. И. Центры происхождения культурных растений. — Л.: Тип. им. Гутенберга, 1926.
2. Злобин Ю.А. Популяционная экология растений. Монография. – Сумы: Университетская книга, 2009. – С. 137-138.
3. Ишбирдин А.Р., Ишмуратова М.М. Адаптивный морфогенез и экологоценотические стратегии выживания травянистых растений // Методы популяционной биологии; Сборник материалов VII Всероссийского популяционного семинара. 16-21 февраля 2004. Ч. 2. – Сыктывкар, 2004. – С. 113-120.
4. Зайцев Г.Н. Математическая статистика в экспериментальной ботанике. – М.: Наука, 1984. – 424 с.
5. Животовский Л.А. Популяционная биометрия. – М.: Наука, 1991. – 270 с.
6. Жўрақулов О., Муҳаммадиев Н. Қашқадарё вилояти // Ўзбекистон энциклопедияси.– Тошкент: Ўзбекистон миллий энциклопедияси, 2005. – Т. 10. – 622-б.
7. Мозговая О.А., Маслова Е.С., Шаронова И.В. Жизненность подроста пихты сибирской Abies sibirica Ledeb в условиях Самарской области. - Вестник Самарского государственного университета. – Самара, 2007. – №8 (58). – С. 162-171.
8. Родионова Г.Н. Виталитетная гетерогенность популяций эндемичных астрагалов // Экология, морфологические особенности и современные методы исследований живых систем. – Казань, 2003. – С. 52-54.
9. Тхазаплижева Л.Х., Чадаева В.А. Виталитетная структура ценопопуляций видов рода Allium L. в условиях Кабардино-Балкарии // Вестник Оренбургского государственного университета. – Оренбург, 2010. – № 6 (112). – С. 42-46.
10. IPNI. (2024): The International Plant Names Index. The product of a collaboration between The Royal Botanic Gardens, Kew, The Harvard University Herbaria, and the Australian National Herbarium. Available at: www.ipni.org/index.html, accessed 20 September 2024.

KOʻHITANG BOTANIK-GEOGRAFIK RAYONIGA OID FLORISTIK TOPILMALAR

Tajetdinova Dilarom Mnajatdinovna
Oʻzbekiston Respublikasi Fanlar akademiyasi Botanika instituti, katta ilmiy xodim
t-dilyia@mail.ru
ORCID 0000-0002-1711-7104
Ibragimov Akrom Javlonovich
Termiz davlat universiteti, dotsent
ORCID 0009-0000-1202-0795
Karimov Baxtiyor Qurbon oʻgʻli
Oʻzbekiston Respublikasi Fanlar akademiyasi Botanika instituti, kichik ilmiy xodim
baxtiyor.karimov.1994@mail.ru
ORCID 0009-0007-8150-5367
Gaziev Alim Djevdetovich
Oʻzbekiston Respublikasi Fanlar akademiyasi Botanika instituti, yetakchi mutaxassis
alim.gazieff@yandex.ru
ORCID 0000-0001-8886-5567
UOʻK 581.95/.96(575.1)

Annotatsiya. Ushbu maqolada Boraginaceae va Poaceae oilalariga mansub 2 ta oʻsimlik turining Koʻhitang botanik-geografik rayonida tarqalishi boʻyicha yangi maʼlumotlar keltirilgan. Koʻhitang botanik-geografik rayoni maʼmuriy jihatidan Surxondaryo viloyatining janubi-gʻarbiy hududida joylashgan. 2021-2024-yillardagi dala tadqiqotlari mobaynida tadqiqot hududining S190 va P190 indekslaridan *Lappula squarrosa* Pomir-Oloy uchun ilk marotaba qayd etilgan. Rossiya fanlar akademiyasiga qarashli V.L. Komorov nomidagi Botanika instituti (LE) gerbariy fondining Oʻrta Osiyo sektorida saqlanadigan gerbariy maʼlumotlarini oʻrganish natijasida tadqiqot hududining O188 indeksidan terilgan Surxondaryo florasi uchun yangi *Psathyrostachys juncea* gerbariy namunalari topilgan. Bu esa Toshkent, Fargʻona va Buxoro viloyatlarida tarqalgan mazkur turning Oʻzbekistonda tarqalishi haqidagi maʼlumotlarni toʻldiradi. Shuningdek, har bir tur uchun yangi joylari haqidagi maʼlumotlar hamda gerbariy namunalarining rasmlari keltirilgan. Google Earth, SAS.Planet.Release.191221 va ArcGis (10.5) dasturlaridan foydalanilgan holda aniqlangan tarqalish nuqtalari asosida to‘r tizimli xaritalari aks ettirilgan.

Kalit so‘zlar. LE, Pomir-Oloy, Surxondaryo, TASH, yangi turlar.

Abstract. This article presents new data on the distribution of two species of the families of Boraginaceae and Poaceae in the Kuhitang botaniko-geographical region. The Kuhitang botaniko-geographical region is administratively located in the southwestern part of Surxondaryo region. During field study in 2021-2024 yy, *Lappula squarrosa* was recorded for the first time in the Pamir-Alay from S190 and P190 indixes of the study area. Studying herbarium data stored in the Central Asian sector of the herbarium fund of the V.L. Komarov Botanical Institute (LE) of the Russian Academy of Sciences, herbarium specimens of *Psathyrostachys juncea*, a new species for the Surkhandarya flora, were found from O188 index of the study area. This complements information about the distribution of this species in Uzbekistan, which is known to occur in Tashkent, Fergana and Bukhara regions. The article also includes photos of herbarium specimens along with information about new locations for each species. Network system maps were generated based on distribution points identified using Google Earth, SAS.Planet.Release.191221 and ArcGis (10.5) software.

Keywords. Kuhitang, new species, Pamir-Alay, Surkhandarya, TASH.

Kirish. O‘simliklar bioxilmaxilligini tizimli tahlil qilishga oid O‘zbekiston Fanlar akademiyasi Botanika instituti O‘zbekiston florasi laboratoriyasi ishchi dasturidagi vazifalar bo‘yicha Tog‘lio‘rtaosiyo provinsiyasining Janubi-G‘arbiy Hisor, Hisor-Darvoz hamda Panjoldi okruglarini to‘r tizimli xaritalash doirasida Ko‘hitang botanik-geografik rayoniga oid ilgari nashr etilgan ishlarni [1; 2; 3; 4, 5; 9; 11; 14] tahlil qilish, yirik gerbariy fondlarida (ASH, LE, MW, TAD, TASH, VILR) saqlanayotgan namunalarni tanqidiy ko‘rib chiqish hamda dala tadqiqotlari (2021-2023)da olingan natijalar o‘rganilayotgan tadqiqot hududi uchun bir qator yangi turlarni aniqlash imkonini beradi.

Olingan ma’lumotlar o‘simlik turlarining zamonaviy tarqalishi haqidagi tushunchalarni to‘ldirib, Respublikamizda atrof-muhitni muhofaza qilishdagi ekologik maqsadlar uchun muhim hamda “O‘zbekiston Qizil kitobi” va “O‘zbekiston florasi”ning yangi nashrlarini tayyorlash uchun dolzarbdir.

Tadqiqot metodologiyasi. Ma’muriy jihatidan Ko‘hitang botanik-geografik rayoni hududi Surxondaryo viloyatining janubi-g‘arbida joylashgan bo‘lib, rayonlashtirishda flora tarkibi (xususan, polimorf oilalarning xususiyatlari), endemizm, o‘simliklar qoplamining tuzilishi va shu bilan bir qatorda landshaft strukturasi va geomorfologiyasi inobatga olinib, mazkur hudud K.Sh. Tojibayev va boshqalarning [8] botanik-geografik rayonlashtirishi asosida belgilab olindi.

O‘simlik turlarini aniqlashda 11 jildli “Opredelitel rasteniy Sredney Azii” [6], 6 jildli “Flora Uzbekistana” [10] asarlari hamda O‘zbekiston Milliy gerbariysi (TASH), ASH, LE, MW, TAD, VILR fondlarida saqlanayotgan namunlardan va https://www.plantarium.ru [16] saytidan foydalanildi. Yuksak o‘simliklarning oilalari APG IV [15] va turlari POWO [13], IPNI [12] asosida yozildi.

To‘r tizimli xarita ArcGIS version 10.6.1 dasturidagi WGS 1984 (World Geodetic System 1984) proyeksiya asosidagi geografik darajalar 2.7′ kenglik hamda 3.5′ uzoqlik (5x5 кm) bo‘yicha ingliz alifbosi va sonlardagi indekslar (PageName) 117 dona kvadratlarga (5x5 km^2) ajratildi. Tadqiqot hududidan terilgan o‘simlik namunalarining o‘sish nuqtalarini aks ettiruvchi geografik koordinatalari Google Earth, SAS.Planet.Release.191221 hamda ArcGis (10.5) dasturlaridan foydalanilgan holda amalga oshirildi.

Natijalar va muhokama. Ko‘hitang botanik-geografik rayoni hududidagi dala tadqiqotlari davomida S190 va P190 indekslaridan Pomir-Oloy uchun yangi turning tarqalish nuqtalari aniqlandi (1-2-rasmlar).

***Lappula squarrosa** (*Retz.) Dumort. Fl. Belg.: 40 (1827). — Липучка колючая, tikanli moviygul.

TASH namunalari: “Sherobod tumani, Xo‘janqon, Yoriqsoy massivi. 08 IV 2023. *Ibragimov, Karimov, Atoyev P190-074, P190-078*; Boysun tumani, Xomkon-

Tuynukkamar qishlogʻi. 22 VI 2023. *Ibragimov, Karimov, Atoyev S190-084*».

“Oʻzbekiston florasi”ni [7] yangi nashrida *L. squarrosa*ni Turon provinsiyasi okruglarida tarqalganligi haqida maʼlumotlar berilgan. Dala tadqiqotlari natijasidagi yangi maʼlumotlar esa, mazkur turning Oʻzbekistonda tarqalishi haqidagi maʼlumotlarni toʻldirish bilan birga, Togʻlioʻrtaosiyo provinsiyasi uchun ilk marta keltirilayotganligini koʻrsatdi. Mazkur turning Pomir-Oloy uchun S190 va P190 indekslaridan ilk marotaba tarqalish nuqtalarining aniqlanishi, mazkur tadqiqot hududi florasining Turon provinsiyasi yaʼniy, choʻl florasi bilan bogʻliqligidan dalolat beradi.

2024-yilda Rossiya fanlar akademiyasiga qarashli V.L. Komorov nomidagi Botanika instituti (LE) gerbariy fondini oʻrganish davomida, Oʻrta Osiyo sektorida saqlanadigan Koʻhitang botanika-geografik rayoniga oid boʻlgan, Qizilolma qishlogʻi yaqinidan (O188) terilgan *Psathyrostachys juncea* (Fisch.) Nevski

1-rasm. *Lappula squarrosa* (Retz.) Dumort.

2-rasm. ***Lappula squarrosa*ning Koʻhitang botanika-geografik rayonidagi tarqalishi indekslari.**

(*Elymus junceus* Fisch.) turi Surxondaryo florasi uchun ilk marta qayd etildi (3-4-rasmlar).

Psathyrostachys juncea (Fisch.) Nevski (*Elymus junceus* Fisch.) in Fl. URSS 2: 714 (1934) – Ломкоколосник ситниковий.

LE namunasi: «Шерабадская долина, против киш. Кызылалма. 27 VI 1927. *Попов 187*».

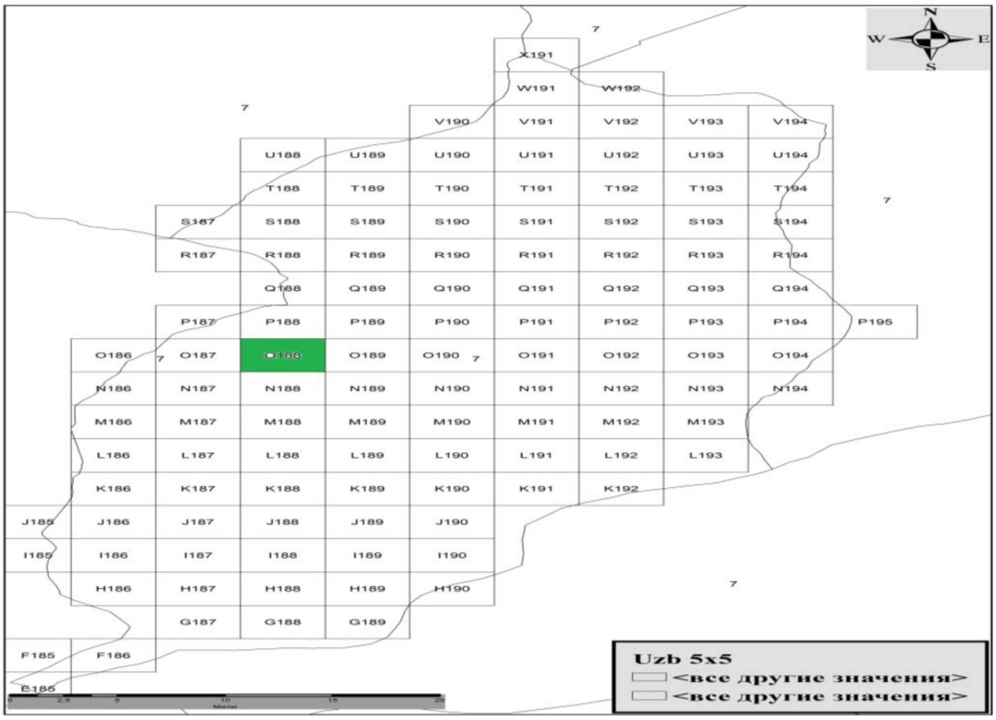
Mazkur turning tarqalish areallari "O'zbekiston florasi"da [10] Toshkent, Farg'ona va Buxoro viloyatlari uchun ko'rsatilgan. O'rta Osiyo esa Tojikistondagi Iskandarko'lda ham tarqalishi qayd etilgan [6]. Rossiya Fanlar akademiyasi Komarov nomidagi Botanika instituti gerbariy (LE) fondidagi yangi ma'lumotlar turning O'zbekistonda tarqalishi haqidagi ma'lumotlarni to'ldiradi va tarqalish arealini Tojikistondan Hisor tog'lari orqali O'zbekiston tomon kengaytiradi. Bu esa tadqiqot hududini qo'shni Tojikiston Respublikasi bilan bog'lovchi Hisor tog'lari florasi bilan bog'liqligini ko'rsatadi.

Tadqiqot hududi uchun yangi topilmalar hisoblangan *Lappula squarrosa* va *Psathyrostachys juncea* gerbariy ma'lumotlariga asoslangan holda Ko'hitang botanik-geografik rayoni florasini to'r tizimli xaritalash davomidagi shakllantirilayotgan ro'yxatiga kiritildi.

Xulosa. 2021–2024-yillardagi Davlat dasturi asosidagi Tog'lio'rtaosiyo provinsiyasining Janubi-G'arbiy Hisor, Hisor-Darvoz hamda Panjoldi okruglarini to'r tizimli xaritalash doirasida Ko'hitang botanik-geografik rayoni hududida olib borilgan dala tadqiqotlari va gerbariy fondlarini o'rganish natijasida O'zbekistonning flora boyligini oshiruvchi muhim ilmiy natijalarga erishildi. Xususan, *Lappula squarrosa* va *Psathyrostachys juncea* turlari Tog'lio'rtaosiyo provinsiyasi va Surxondaryo florasi uchun yangi kashfiyot sifatida qayd etildi. Bu ma'lumotlar o'simlik turlarining tarqalish chegaralarini kengaytirish va ularga oid avvalgi ma'lumotlarni boyitishga xizmat qiladi.

Tadqiqot natijalari Ko'hitang botanik-geografik rayoni hududining floristik boyligini yanada ko'proq ochib beradi va atrof-muhitni muhofaza qilish hamda biologik xilmaxillikni saqlashga qaratilgan tadbirlar uchun yangi imkoniyatlar yaratadi. Tadqiqot hududining ekologik o'ziga xosligini chuqurroq o'rganish va biologik resurslarni barqaror boshqarish strategiyalarini ishlab chiqishda muhim hissa qo'shadi. Shuningdek, natijalar "O'zbekiston florasi"ning kelgusidagi yangi nashrlari uchun yangi ma'lumotlar bo'lib, Respublika hududida o'simlik turlarining zamonaviy tarqalishi bo'yicha ilmiy-tadqiqot ishlarini boyitadi.

3-rasm. *Psathyrostachys juncea* (Fisch.) Nevski.



4-rasm. ***Psathyrostachys juncea*ning Ko'hitang botanika-geografik rayonidagi tarqalishi indekslari.**

Foydalanilgan adabiyotlar

1. Ачилова Н.Т. Сурхон-Шеробод ботаник-географик райони флораси: Биол. фан.фал.док. (PhD) дисс. – Қарши, 2021. – 120 б.
2. Ибрагимов И.Ж. Флора Сурханского государственного заповедника (система Кугитанг): Автореф. дисс... канд. биол. наук. –Ташкент, 2009. – 20 с.
3. Камелин Р.В. Флорогенетический анализ естественной флоры горной Средней Азии. – Л.: Наука, 1973. – 353 с.
4. Камелин Р. В. Флористическое районирование советской Средней Азии. - Turczaninowia, 2021. Т. 24, № 4. - С. 5–11.
5. Левичев И. Г., Бешко Н. Ю., Курбаниязова Г. Т., Тургинов О. Т. Новые находки видов рода *Gagea* в Узбекистане. - Turczaninowia, 2023. Т. 25, № 3. - С. 184–193.
6. Определитель растений Средней Азии. В 11 т. – Ташкент, Фан, 1963-2015.
7. Сенников А.Н. (ред.) Флора Узбекистана. Т. 4 – Ташкент, Навруз, 2022.
8. Тожибаев К.Ш., Бешко Н.Ю., Попов В.А. Ботанико-географическое районирование Узбекистана // Ботанический журнал. – Санкт-Петербург, Наука, – 2016. №10 (101). – С. 1105-1130.
9. Тургинов О.Т. Бойсун ботаник-географик райони флораси: Дис. ...канд биол наук.– Тошкент, 2017. – 120 б.
10. Флора Узбекистана. В 6 т. –Ташкент, изд. АН УзССР, 1941-1963.
11. Хасанов Ф.О. Ксерофильная древесно-кустарниковая растительность Кугитанг-тау: Автореф. дис. … канд. биол. наук. - Ташкент, 1987. - 20 с.
12. IPNI. International Plant Names Index. Kew: The Royal Botanic Gardens. Harvard University Herbaria; Libraries and Australian National Botanic Gardens. 2023. URL: http://www.ipni.org/ (Accessed 22 June 2024).
13. POWO**.** Plants of the World Online. Kew: Facilitated by the Royal Botanic Gardens. 2023. URL: http://www.plantsoftheworldonline.org (Accessed 22 June 2024).
14. Tajetdinova D.M., Ibragimov A.J., Karimov B.Q. Ko'hitang botanik-geografik rayoni florasini to'r tizimli xaritalashning dastlabki natijalari // NamDU ilmiy axborotnomasi. 2023. № 8. –B. 172-179.
15. The Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV // Botanical Journal of the Linnean Society, 2016. -Vol. 181 (1). -P. 1-2.
16. https://www.plantarium.ru

O‘RADARYO HAVZASI FLORASINING DASTLABKI RO‘YXATI (O‘zbekiston Milliy gerbariy fondi gerbariysi asosida)

Oybek Eshmirzayevich Omonov
Qarshi davlat universiteti tayanch doktoranti
omonovoybek1985@mail.ru,
ORCID 0009-0000-7145-3419,
UDK 581.93

Annotatsiya. Maqolada Katta va Kichik O‘radaryo havzalarida tadqiqot olib borgan olimlar tomonidan to‘plangan O‘zbekiston Milliy gerbariysi (TASH) fondida saqlanayotgan gerbariy namunalarining dastlabki tahlili keltirilgan. Natijada hudud florasi uchun shakllantirilgan ro‘yxat 256 turkum 55 oilaga mansub 606 turni o‘z ichiga oladi. Flora ro‘yxatida Katta va Kichik O‘radaryo havzalari uchun ushbu hududdan terilgan va aniqlangan o‘simlik turlari uchun kamida bitta gerbariy raqami keltirilgan. Polimorf oilalar yetakchi uchligi Asteraceae (78 tur), Fabaceae (73 tur), Apiaceae (58 tur), keyingi o‘rinlarda Poaceae (50), Lamiaceae (38), Boraginaceae (35), Liliaceae (19), Plantaginaceae (17), Amaryllidaceae (16), Brassicaceae (16), Ranunculaceae (16), Caprifoliaceae (15) egallaydi. Ushbu tadqiqot O‘zR FA Botanika institutining Janubi-G‘arbiy Hisor, Hisor-Darvoz va Panjoldi okruglari florasining to‘r tizimli xaritalash (Surxondaryo viloyati qismi) davlat dasturi hamda tadqiqotchining dissertatsiya mavzusi doirasida bajarildi.
Kalit so‘zlar. Katta O‘radaryo, Kichik O‘radaryo, endem, gerbariy, ekspeditsiyalar.

PRELIMINARY LIST OF THE FLORA OF THE ORADARYA BASIN

Abstract. The article presents a preliminary analysis of herbarium specimens stored in the collections of the National Herbarium of Uzbekistan (TAH), collected by scientists who conducted research in the basins of the Katta and Kichik Uradarya. As a result, the formed list of the flora of the region includes 606 species belonging to 256 genera and 55 families. The flora list contains at least one herbarium number of collected and identified plant species for the Katta and Kichik Uradarya river basins of the. The top three polymorphic families include Asteraceae (78 species), Fabaceae (73 species), Apiaceae (58 species), followed by Poaceae (50), Lamiaceae (38), Boraginaceae (35), Liliaceae (19), Plantaginaceae (17), Amaryllidaceae (16), Brassicaceae (16), Ranunculaceae (16), Caprifoliaceae (15). This study was carried out within the framework of the state program of the National Institute of Botany of the Federal Republic of Uzbekistan “Network system mapping of the flora of the South-Western Hisar, Hisar-Darvaz and Panjolda regions (part of the Surkhandarya region).” and the topic of the researcher's dissertation.
Key words. Katta Uradarya, Kichik Uradarya, endemic, herbarium, expeditions.

Kirish. Gerbariy materialini raqamlashtirish jahon gerbariy fondlarining ilmiy tadqiqotlar uchun saqlanayotgan o‘lkan kolleksiyalarining qimmatli boyliklaridan foydalanish imkoniyatlarini kengaytirish va osonlashtirishga katta yordam berdi. Raqamlashtirish deganda rasmlar kabi analog resurslarni jpeg fayllari kabi raqamli formatlarga aylantirish jarayoni tushuniladi. Raqamli nusxalar tarqatish va flora xilmaxilligini o‘rganish uchun juda qulay. Minglab botaniklar tomonidan to‘plangan va tasniflangan 390 milliondan ortiq gerbariy namunalari butun dunyo bo‘ylab joylashgan 3000 dan ortiq rasmiy gerbariy fondlarida saqlanadi [1,2,3,4]. Gerbariy kolleksiyalarining muhimligi, ularning tarixiy va ilmiy ahamiyati, o‘simliklar bioxilmaxilligining botanika bilimlari uchun tutgan o‘rni qayd etilgan [5].

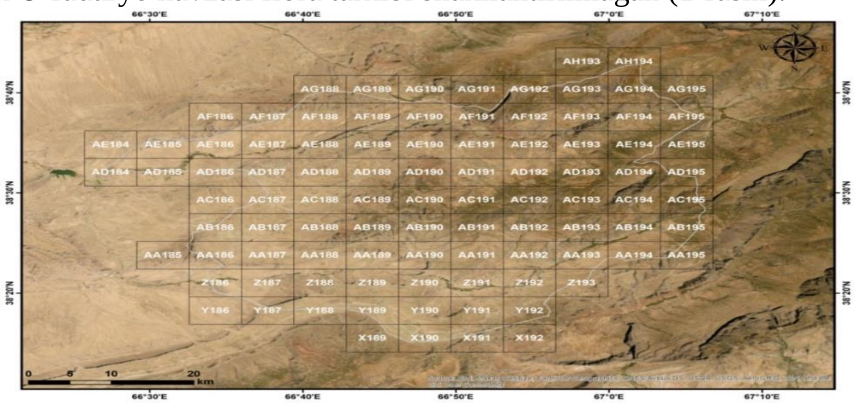
Dunyo florasini raqamlashtirish zamonaviy davrda ilmiy tadqiqotlar uchun ikkita asosiy sababga ko‘ra hal qiluvchi ahamiyatga ega: birinchidan, namunalar yo‘q qilingan yoki yo‘qolgan taqdirda ham ma’lumotlarning zaxira nusxasini saqlash va xavfsiz qayta tiklash imkonini beradi, ikkinchidan, ma’lumotlar almashishni tezlashtiradi va ulardan foydalanish imkoniyatini oshiradi [3].

Gerbariy noyob va yo‘qolib ketish xavfi ostida turgan o‘simliklar xilmaxilligini saqlashda hal qiluvchi rol o‘ynaydi. Ushbu tadqiqotda gerbariyning qo‘llanilishi va uning o‘simliklarning biologik xilmaxilligini saqlashdagi ahamiyati qisqacha tavsiflangan. Gerbariy turli ekologiyalardan olingan o‘simliklar namunalaridan tashkil topgan namunalar to‘plami hisoblanadi. U ma’lum bir joyning florasi tavsifi va ma’lumotini taqdim etadi. U bioxilmaxillikni saqlashda amaliy tadqiqotlar va faoliyat ko‘rsatish, ilmiy o‘rganish, o‘qish va o‘qitish vositasidir.

Osiyoda (Pekin PEdan keyin) ikkinchi o‘rinda turadigan O‘zbekiston Milliy gerbariysida (TASH) 1,5 milliondan ortiq gerbariy namunalari saqlanadi [5]. G‘arbiy Pomir-Oloyning boy va o‘ziga xos florasi xilmaxilligi to‘liq o‘rganilmagan. Hudud floraning xilmaxilligi nuqtayi nazaridan deyarli o‘rganilmagan. Katta O‘radaryo havzasi florasi o‘simliklarining ro‘yxati 1941-yil nashr etilgan bo‘lib, unga 399 tur kiritilgan [6]. Biroq keyingi yillarda ayrim turkum turlari ustida olib borilgan tadqiqotlar natijasida bir qator taksonomik o‘zgarishlar yuz bergan.

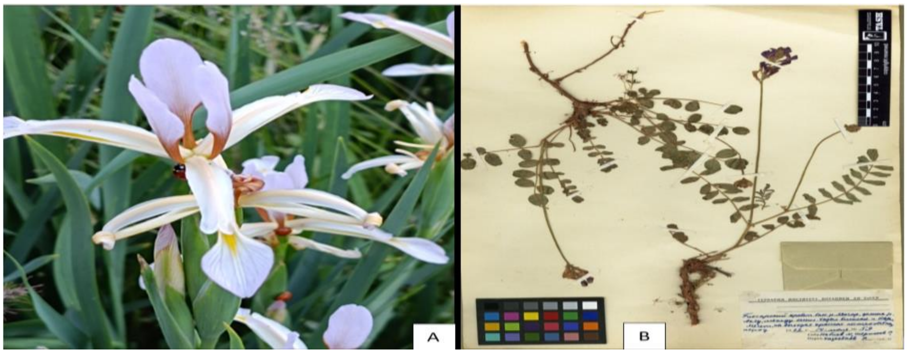
Tadqiqotning maqsadi Katta O‘radaryo va Kichik O‘radaryo havzasi florasining ro‘yxatini inventarizatsiya qilishda O‘zbekiston Milliy gerbariysi (TASH) fondida saqlanayotgan mavjud gerbariy materiallarini o‘rganishdan iborat.

Tadqiqot metodologiyasi. Tadqiqot hududi Katta O‘radaryo va Kichik O‘radaryo havzasi O‘zbekistonning botanik-geografik rayonlashtirish sxemasiga ko‘ra, G‘arbiy-Hisor okrugining Qashqadaryo botanik-geografik rayoniga kiradi [7]. Adabiyotlar tahliliga ko‘ra, mazkur hududga yaqin hududlarda ko‘plab tadqiqotlar olib borilgan bo‘lsa-da, ushbu daryolar havzalari maqsadli ravishda flora tarkibi o‘rganilmaganligini ko‘rsatdi. Katta va Kichik O‘radaryo havzasi flora tarkibi shakllantirilmagan (1-rasm).



1-rasm. Katta va Kichik O‘radaryolari havzasi florasining to‘r tizimli xaritasi

Floraning zamonaviy konspektini shakllantirishda hamda ularni tahlilini amalga oshirishda, kollektorlar tomonidan terilgan materiallar tahlili muhim ahamiyatga ega. O‘zbekiston Milliy gerbariysi (TASH) fondida saqlanayotgan namunalar shuni ko‘rsatadiki, Katta va Kichik O‘radaryolari hududida qator geobotanik tadqiqotlar olib borilgan. Yuqoridagilarni inobatga olib florani inventarizatsiya qilishga qaratilgan maqsadli tadqiqotlar olib borilmoqda. Mazkur tadqiqot O‘zR FA Botanika institutining Janubi-G‘arbiy Hisor, Hisor-Darvoz va Panjoldi okruglari florasining to‘r tizimli xaritalash (Surxondaryo viloyati qismi) davlat dasturi (2-rasm) hamda tadqiqotchining dissertatsiya mavzusi doirasida bajarildi [8].

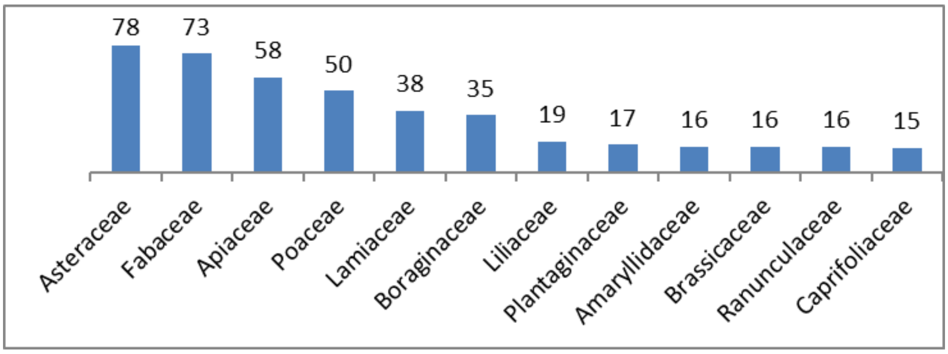


2-rasm. Katta va Kichik O‘radaryo havzasida tarqalgan turlar: A. *Iris magnifica* Vved. Qamashi tumani Qo‘shko‘l qishlog‘i atrofi (Omonov, 2024). B. *Hedysarum bucharicum* B.Fedtsch. (TASH).

Namuna to‘plamlari – Amalga oshirilgan ekspeditsiyalar

Floraning zamonaviy konspektini shakllantirishda hamda ularning tahlilini amalga oshirishda kollektorlar tomonidan terilgan materiallar tahlili muhim ahamiyatga ega. TASH fondida saqlanayotgan namunalar shuni ko‘rsatadiki, Katta va Kichik O‘radaryolari hududida qator geobotanik tadqiqotlar olib borilgan. Gerbariy ma’lumotlaridan shuni aytish mumkinki, tadqiqot hududidigi tadqiqotlar 125 yildan ortiq davrni o‘z ichiga oladi. A. Pyatayeva (1942-1980) 201 tur 495 namuna, E. Korotkova (1935-1972) 85 tur 143 namuna, A. Arnold (1942) 85 tur 114 namuna, S.N. Kudryashev (1935-1941) 53 tur 67 namuna, M.G. Popov (1914-1916) 49 tur 62 namuna, A. Gnezdillo (1935) 42 tur 61 namuna, A. Li, B. Niyozov (1950-1959) 39 tur 62 namuna, N. Koshurnikova (1941-1956) 37 tur 43 namuna, O. Turginovlar (2011-2022) 28 turga mansub 42 ta gerbariy namunalarini to‘plagan.

Olingan natijalar va muhokama. Biologik xilmaxillikni raqamlashtirish tirik organizmlar haqidagi turli ma’lumotlarni almashinish va tahlil qilish imkonini beradi. Bu yerda berilgan ro‘yxat 256 turkum 55 oilaga mansub 606 turni o‘z ichiga oladi. Katta va Kichik O‘radaryo havzalari uchun ushbu hududdan aniqlangan barcha o‘simlik turlari ro‘yxatga kiritilgan. Bunda har bir o‘simlik turi uchun kamida bitta yorliq namunasidagi qabul qilingan nomlar (IPNI bo‘yicha) va gerbariy raqamlari kiritilgan. Polimorf oilalar yetakchi uchligi Asteraceae (78), Fabaceae (73), Apiaceae (58), keyingi o‘rinlarda Poaceae (50), Lamiaceae (38), Boraginaceae (35), Liliaceae (19), Plantaginaceae (17), Amaryllidaceae (16), Brassicaceae (16), Ranunculaceae (16), Caprifoliaceae (15) egallaydi (3-rasm).



3-rasm. Katta va Kichik O‘radaryolar havzasi florasining yetakchi polimorf oilalar bo‘yicha tahlili (faqat TASH fondi gerbariylari asosida)

Gerbariy namunalarini yetakchi turkumlar bo‘yicha tahlil qilganimizda *Astragalus* (44) va *Cousinia* (27) turkumlari yetakchilik qilgan bo‘lsa, *Allium* (16), *Gagea* (15), *Ferula* (12) hamda *Salvia* (10) turkumlari esa 10 tadan kam bo‘lmagan turlarni o‘z ichiga olmoqda. Quyida O‘radaryo havzasi florasining birlamchi ro‘yxati keltirilgan. Bu yerda oilalar qora rangda oldida tartib raqami bilan, keyin turkumlar, ular ham tartib raqam bilan, keyin shu turkumlarga mansub turlar qavslar ichida va gerbariy fondidagi raqami bilan keltirilgan. Ayrim turlardan gerbariylar ko‘p bo‘lgani uchun faqat bittasi keltirilgan.

Katta va Kichik O‘radaryolari havzasi florasining birlamchi ro‘yxati

1. Cupressaceae Gray

1. *Juniperus (J. polycarpos* var. *seravschanica* (Kom.) Kitam. (1458), *J. semiglobosa* Regel. (1598)).

2. Ephedraceae Dumort

2. *Ephedra (E. equisetina* Bunge. (528), *E. ciliata* Fisch. & C.A.Mey. (3678), *E.intermedia* Schrenk & C.A.Mey. (877)).

3. Typhaceae Juss

3. *Typha (T. laxmannii* Lepech. (1586)).

4. Poaceae Barnhart

4. *Aegilops (A. crassa* var. crassa (617), *A. triuncialis* L. (465)). 5. *Aeluropus littoralis* (Gouan) Parl. (571). 6. *Agrostis (A. gigantea* subsp. Gigantean (199), *A. stolonifera* L. (sn)). 7. *Alopecurus arundinaceus* Poir. (210). 8. *Avena sterilis* subsp. *ludoviciana* (Durieu) Nyman (135). 9. *Bromus (B. macrostachys* Desf. (145), *B. danthoniae* Trin.ex C.A.Mey. (212), *B.oxyodon* Schrenk (161), *B. tectorum* L. (218)). 10. *Calamagrostis canadensis* (Michx.) P.Beauv. (710). 11. *Cynodon dactylon* (L.) Pers. (1625). 12. *Dactylis glomerata* L. (495). 13. *Elymus (E. gmelinii* (Trin.) Tzvelev (351), *E. repens* (L.) Gould (513)). 14. Poa (Eremopoa altaica (Trin.) Roshev., (532). 15. *Festuca* (*F. amethystina* subsp. amethystine (646). 16. *Henrardia (H. persica* (Boiss.) C.E.Hubb. (121)). 17. *Heteranthelium (H. piliferum* (Banks & Sol.) Hochst (1181). 18. *Hordeum (H. brevisubulatum* (Trin.) Link (1371), *H. murinum* subsp. *leporinum* (Link) Arcang. (992), *H.vulgare* subsp. *spontaneum* (K.Koch) Asch. & Graebn. (227)). 19. *Imperata (I. cylindrica* (L.) Raeusch. (50). 20. *Koeleria (K. splendens* C.Presl (293). 21. *Melica (M. inaequiglumis* Boiss. (481), *M. persica* Kunth (6755)). 22. *Nardurus (N. krausei* (Regel) V. Krecz. & Bobrov (349). 23. *Phleum (P. paniculatum* Huds. (2115). 24. *Piptatherum (P. ferganense* (Litv.) Roshev. (329), *P. laterale* (Regel) Nevski (31), *P. latifolium* (Roshev.) Nevski (754), *P. munroi* (Stapf ex Hook.f.) Mez (1134), *P. platyanthum* Nevski (315)). 25. *Polypogon (P. fugax* Nees ex Steud. (125), *P. monspeliensis* (L.) Desf. (93)). 26. *Pseudoroegneria (P. setulifera* (Nevski) Á.Löve (3). 27. *Puccinellia (P. nipponica* Ohwi (1420). 28. *Rhizocephalus (R. orientalis* Boiss. (sn). 29. *Schismus (S. arabicus* Nees (44). 30. *Setaria (S. italica* (L.) P.Beauv. (720), *S. viridis* (L.) P.Beauv. (407)). 31. *Sporobolus (S. schoenoides* (L.) P.M.Peterson (569). 32. *Stipa (S. conferta* Poir. (848), *S. hohenackeriana* Trin. & Rupr. (79)). 33. *Taeniatherum (T. caput-medusae* (L.) Nevski (196). 34. *Thinopyrum (T. intermedium* (Host) Barkworth & D.R.Dewey (126). 35. *Vulpia (V. myuros* (L.) C.C.Gmel. (113), *V. ciliata* St.-Lag. (164), *V. persica* (Boiss. & Buhse) V.I.Krecz. & Bobrov (163)).

5. Cyperaceae Juss.

36. *Bolboschoenus (B. maritimus* subsp. *affinis* (Roth) T.Koyama (514). 37. *Carex (C. diluta* M.Bieb. (606), *C. duriuscula* subsp. *duriuscula* (1169), *C. oederi* var. oederi (1419), C. orbicularis Boott (459), *C. songorica* Kar. & Kir. (1609), *C. turkestanica* Regel (375)). 38. *Cyperus (C. laevigatus* subsp. *distachyos* (All.) Ball (171), *C. rotundus* L. (72)). 39. *Eleocharis (E. mitracarpa* Steud. (275), *E. quinqueflora* (Hartmann) O.Schwarz (231), *E. uniglumis* (Link) Schult. (541)).

6. Araceae Juss.

40. *Arum (A. korolkowii* Regel (523).

7. Liliaceae Juss.

41. *Gagea (G. minutiflora* Regel (sn), *G. fragifera* (Vill.) E.Bayer & G.López (sn), *G. capusii* A.Terracc. (sn), *G. reticulata* (Pall.) Schult. & Schult.f. (58), *G. hissarica* Lipsky (738), *G. holochiton* Popov et Czug. (sn), *G. chomutovae* (Pascher) Pascher (9), *G. kunawurensis* (Royle) Greuter (481), *G. gageoides* (Zucc.) Vved. (sn), *G. kamelinii* Levichev (sn), *G. takhtajanii* Levichev (sn), *G. taschkentica* Levichev (1459), *G. reinhardii* Levichev (219), *G. tenera* Pascher (sn), *G. vegeta* Vved. (sn)). 42. *Tulipa (T. ingens* Hoog (65), *T. korolkowii* Regel (57), *T. undulatifolia* var. *micheliana* (Hoog) Wilford (58), *T. turkestanica* (Regel) Regel (310)).

8. Amaryllidaceae J.St.-Hil.

43. *Allium (A. oreodictyum* Vved. (sn), *A. drepanophyllum* Vved. (1711), *A. jodanthum* Vved. (722), *A. griffithianum* Boiss. (57), *A. crystallinum* Vved. (1409), *A. filidens* Regel (782), *A. sativum* L. (63), *A. verticillatum* Regel (554), *A. aroides* Popov & Vved. (726), *A. nevskianum* Vved. ex Wendelbo (1640), *A. alexeianum* Regel (sn), *A. stipitatum* Regel (190), *A. sarawschanicum* Regel (1033), *A. macleanii* Baker (48), *A. majus* Vved. (747), *A. protensum* Wendelbo (198)).

9. Iridaceae Juss.

44. *Iris (I. halophila* var. *sogdiana* (Bunge) Skeels (165) *I. stolonifera* Maxim. (1636), *I. narbutii* O.Fedtsch. (sn), *I. warleyensis* Foster (sn), *I. magnifica* Vved. (468), *I. svetlanae* (Vved.) T.Hall & Seisums (sn)).

10. Urticaceae Juss.

45. *Parietaria (P. judaica* L. (1246).

11. Santalaceae R.Br.

46. *Arceuthobium* (*A. oxycedri* (DC.) M.Bieb. (1089).

12. Polygonaceae Juss.

47. *Atraphaxis (A. spinosa* L. (1544), *A. pyrifolia* Bunge (365), *A. seravschanica* Pavlov (382), *A. pyrifolia* Bunge (365)). 48. *Polygonum (P. fibrilliferum* Kom. (sn), *P. hyrcanicum* Rech.f. (69), *P. aviculare* L. (761), *P. bornmuelleri* Litv. (775)).

13. Amaranthaceae Juss.

49. *Chenopodium (Ch. album* L. (1346). 50. *Spinacia (S. oleracea* subsp. *turkestanica* (I ljin) Del Guacchio & P.Caputo (903). 51. *Atriplex (A. sagittata* Borkh. (506), *A. flabellum* Bunge ex Boiss. (143), *A. moneta* Bunge ex Boiss. (419)). 52. *Ceratocarpus (C. arenarius* L. (531). 53. *Haloxylon (H. griffithii subsp.* griffithii (sn).

14. Caryophyllaceae Juss.

54. *Stellaria (S. neglecta* (Lej.) Weihe (sn). 55. *Saponaria (S. sewerzowii* Regel & Schmalh. (576). 56. *Acanthophyllum (A. gypsophiloides* Regel (374), *A. pungens* (Bunge) Boiss. (162)). 57. *Dianthus (D. darvazicus* Lincz. (46), *D. crinitus* subsp. *tetralepis* (Nevski) Rech.f. (145), *D. helenae* Vved. (521), *D. uzbekistanicus* Lincz. (71)).

15. Ranunculaceae Juss.

58. *Eranthis (E. longistipitata* Regel (58). 59. *Nigella (N. integrifolia* Regel (80). 60. *Aquilegia (A. vicaria* Nevski (509). 61. *Delphinium (D. batalinii* Huth (83), *D. longipedunculatum* Regel & Schmalh. (425), *D. ternatum* Huth (127), *D. biternatum* Huth (sn), *D. semibarbatum* Bien. ex Boiss. (690)). 62. *Anemone (A. tschernaewii* Regel (sn)). 63. *Clematis (C. orientalis* L. (663). 64. *Ranunculus (R. testiculatus* Crantz (1041), *R. rionii* Lagger (357), *R. arvensis* L. (393)). 65. *Thalictrum (T. sultanabadense* Stapf (1610), *T. isopyroides* C.A.Mey. (12)). 66. *Adonis (A. turkestanica* (Korsch.) Adolf (6).

16. Berberidaceae Juss.

67. *Bongardia (B. chrysogonum* (L.) Spach (58).

17. Papaveraceae Juss.

68. *Hypecoum (H. pendulum* var. *trilobum* (Trautv.) Cullen (1), *H. pendulum* var. *pendulum* (433)). 69. *Glaucium (G. elegans* Fisch. & C.A.Mey. (1557), *G. fimbrilligerum* Boiss. (26)). 70. *Roemeria (R. apula* (Ten.) Banfi, Bartolucci, J.-M.Tison & Galasso (sn). 71. *Corydalis (C. aitchisonii* Popov (sn).

18. Capparaceae Juss.

72. *Capparis (C. spinosa* L. (1553)). 73. *Cleome (C. gordjaginii* Popov (sn), *C. quinquenervia* DC. (154), *C. tomentella* Popov (180), *C. lipskyi* Popov (516)).

19. Brassicaceae Burnett

74. *Goldbachia (G. verrucosa* Kom. (88)). 75. *Strigosella (S. turkestanica* (Litv.) Botsch. (58). 76. *Cryptospora (C. falcata* Kar. & Kir. (454). 77. *Matthiola (M. integrifolia* Kom. (604). 78. *Chorispora (C. macropoda* Trautv. (sn), *C. tenella* (Pall.) DC. (5)). 79. *Euclidium (E. syriacum* (L.) W.T.Aiton (38)). 80. Alyssum (A. desertorum Stapf (119). 81. *Crambe (C. gordjaginii* Sprygin & Popov (sn), *C. hispanica* subsp. glabrata (456)). 82. *Conringia (C. orientalis* (L.) C.Presl (437), *C. persica* Boiss. (sn), *C. clavata* Boiss. (sn)). 83. *Eutrema (E. renifolium* (Boiss. & Hohen.) Al-Shehbaz, G.Q.Hao & (sn). 84. *Lepidium (L. chalepense* L. (256). 85. *Neslia (N. paniculata* subsp. *thracica* (Velen.) Bornm. (sn)).

20. Crassulaceae J.St.-Hil.

86. *Pseudosedum (P. bucharicum* Boriss. (349), *P. fedtschenkoanum* Boriss. (70).

21. Rosaceae Juss.

87. *Malus (M. sieversii* M.Roem. (1155). 88. *Crataegus (C. pontica* K.Koch (773). 89.

Sibbaldianthe (S. orientalis (Juz. ex Soják) Mosyakin & Shiyan (366). 90. *Potentilla (P. pedata* Willd. ex Hornem. (1335), *P. reptans* Georgi (144)). 91. *Rosa (R. webbiana* Wall. ex Royle (329), *R. kokanica* (Regel) Regel ex Juz. (424), *R. canina* L. (1591), *R. persica* Michaut ex Juss. (907), R. sumneviczii Korotkova (508)). 92. *Amygdalus (A. spinosissima* Bunge (705). 93. *Cerasus (C. verrucosa* (Franch.) Nevski (1655).

22. Fabaceae Lindl.

94. *Argyrolobium (A. aegacanthoides* (Vved.) Moteetee (sn). 95. *Trigonella (T. orthoceras* Kar. et Kir. (102). 96. *Melilotoides (M. aristata* (Vassilcz.) Sojăk (*Melissitus aristatus* (Vass.) Latsch.) (1687), *M. gontscharovii* (Vass.) Sojak (*Melissitus gontscharovii* (Vass.) Latsch.) (1523), *M. popovii* (Korovin) Sojăk (*Melissitus popovii* (Korovin) Golosk.) (1658)). 97. *Medicago (M. transoxana* Vass. (1193), *M. monantha* (C.A.Mey.) Trautv. (113), *M. lupulina* L. (1331), *M. denticulata* Willd. (60)). 98. *Trifolium (T. repens* L. (112), *T. fragiferum* var. *fragiferum* (460), *T. pratense* L. (1102), *T. lappaceum* L. (82)). 99. Lotus (L. *krylovii* Schischk. & Serg. (167). 100. Caragana (C. *halodendron* (Pall.) Dum.Cours. (940), *C. turkestanica* Kom. (149)). 101. *Astragalus* (*A. thlaspi* Lipsky (sn), *A. vicarius* Lipsky (sn), *A. filicaulis* Fisch. & C.A.Mey. ex Ledeb. (sn), *A. varius* subsp. *varius* (sn), *A. callistachys* subsp. *callistachys* (sn), *A. campylotrichus* Bunge (sn), *A. quisqualis* Bunge (sn), *A. stalinskyi* Širj. (sn), *A. eximius* Bunge (sn), *A. terrae-rubrae* Butkov (sn), *A. baissunensis* Lipsky (sn), *A. turkestanus* Bunge ex Boiss. (sn), *A. mucidus* Bunge ex Boiss. (sn), *A. densus* Popov (sn), *A. leiosemius* (Lipsky) Popov (sn), *A. lasiosemius* Boiss. (sn), *A. lasiostylus* Fisch. (sn), *A. subrosulariformis* Širj. & Rech.f. (sn), *A. farctissimus* Lipsky (sn), *A. neolipskyanus* Popov (sn), A.*angulosus* DC. (sn), *A. dissectus* B.Fedtsch. & N.A.Ivanova (sn), *A. bactrianus* Fisch. (sn), *A. pterocephalus* Bunge (sn), *A. kudrjaschovii* Korol. (sn), *A. juratzkanus* subsp. *juratzkanus* (sn), *A. margusaricus* Lipsky (sn), *A. baldshuanicus* Popov (sn), *A. cottonianus* Aitch. & Baker (sn), *A. taschkendicus* Bunge (sn), *A. kelleri* Popov (sn), *A. pseudomegalomerus* Popov (sn), *A. rumpens* Meffert (sn), *A. cyrtobasis* Bunge ex Boiss. (sn), *A. nobilis* Bunge & B.Fedtsch. (sn), *A. megalomerus* Bunge (sn), *A. xanthomeloides* Korovin & Popov (sn), *A. peduncularis* Benth. (sn), *A. sogdianus* Bunge (sn), *A. oldenburgii* B.Fedtsch. (sn), *A. squarrosus* Bunge (606), *A. macronyx* Bunge (sn), *A. stenocystis* Bunge (sn), *A. hissaricus* Lipsky (sn)). 102. *Oxytropis (O. michelsonii B.Fedtsch.* (34), *O. macrodonta* Gontsch. (172), *O. baissunensis* Vassilcz. (sn), *O. capusii* Franch. (1004), *O. lithophila* Vassilcz. (713), *O. chesneyoides* Gontsch. (174), *O. leptophysa* Bunge (1152)). 103. *Hedysarum* (*H. magnificum* Kudr. (686), *H. baldshuanicum* B.Fedtsch. (sn), *H. bucharicum* B.Fedtsch. (11), *H. plumosum* Boiss. & Hausskn. (11)). 104. *Alhagi (A. pseudalhagi* (M.Bieb.) Desv. ex Wangerin (537). 105. *Vicia (V. sativa* subsp. *nigra* Ehrh. (sn).

23. Geraniaceae Juss.

106. *Erodium (E. ciconium* (L.) L'Hér. (69)).

24. Biebersteiniaceae Schnizl.

107. *Biebersteinia (B. multifida* DC. (sn).

25. Linaceae DC. ex Perleb

108. *Linum (L. usitatissimum* var. usitatissimum (1351).

26. Zygophyllaceae R.Br.

109. *Zygophyllum (Z. atriplicoides* Fisch. & C.A.Mey. (541).

27. Euphorbiaceae Juss.

110. *Andrachne (A. telephioides* L. (744). 111. *Euphorbia (E. buhsei* Boiss. (sn), *E. cyrtophylla* (Prokh.) Prokh. (sn), *E. virgata* Waldst. & Kit. (sn), *E. falcata* L. (sn), *E. franchetii* B.Fedtsch. (sn), *E. schottiana* Boiss. (sn)).

28. Plantaginaceae Juss.

112. *Kickxia (K. elatine* subsp. *sieberi* (Rchb.) Hayek (112). 113. *Lagotis (L. korolkowii* (Regel & Schmalh.) Maxim. (212). 114. *Linaria (L. popovii* Kuprian. (328), *L. sessilis* Kuprian. (244)). 115. *Holzneria (H. spicata* (Korovin) Speta (76). 116. *Veronica (V. anagallis-aquatica* L. (115), *V. pusilla* Kit. (58), *V. oxycarpa* Boiss. (166), *V. beccabunga* L.

(23), *V. argute-serrata* Regel & Schmalh. (1712), *V. campylopoda* Boiss. (457), *V. capillipes* Nevski (788), *V. intercedens* Bornm. (194), *V. cardiocarpa* (Kar. & Kir.) Walp. (194)). 117. *Plantago (P. major* L. (83), *P. lanceolata* L. (5). 118. *Triaenophora (T. bucharica* B.Fedtsch. (89)).

29. Anacardiaceae R.Br.

119. *Pistacia (P. vera* L. (698)).

30. Sapindaceae Juss.

120. *Acer (A. platanoides* subsp. *turkestanicum* (Pax) P.C.de Jong (sn), *A. pentapomicum* J.L.Stewart (67)).

31. Rhamnaceae Juss.

121. *Rhamnus (R. integrifolia* DC. (41).

32. Vitaceae Juss.

122. *Ampelopsis (A. vitifolia* subsp. *vitifolia* (168)).

33. Malvaceae Juss.

123. *Malva (M. bucharica* Iljin (sn), *M. neglecta* Wallr. (1376)). 124. *Alcea (A. nudiflora* (Lindl.) Boiss. (7), *A. litvinovii* (Iljin) Iljin (454), *A. rhyticarpa* (Trautv.) Iljin (sn)).

34. Tamaricaceae Link

125. *Tamarix (T. ramosissima* Ledeb. (36).

35. Lythraceae J.St.-Hil.

126. *Lythrum (L. tribracteatum* Salzm. ex Spreng. (125), *L. silenoides* Boiss. & Noë (sn), *L. hyssopifolia* L. (sn)).

36. Onagraceae Juss.

127. *Dactylorhiza (D. salina* (Turcz. ex Lindl.) Soo (446). 128. *Epilobium (E. hirsutum* L. (sn), *E. minutiflorum* Hausskn. (104), *E. tianschanicum* Pavlov (1502)).

37. Apiaceae Lindl.

129. *Scandix (S. stellata* Banks & Sol. (sn), *S. pecten-veneris* L. (sn)). 130. *Kozlovia (K. paleacea* (Regel & Schmalh.) Lipsky (461). 131. *Torilis (T. arvensis* (Huds.) Link (99). 132. *Turgenia (T. latifolia* (L.) Hoffm. (765). 133. *Daucus (D. carota* L. (681). 134. *Lipskya (L. insignis* (Lipsky) Nevski (sn). 135. *Pseudotrachydium (P. dichotomum* (Korovin) Pimenov & Kljuykov (447). 136. *Aulacospermum (A. roseum* Korovin (10). 137. *Eremodaucus (E. lehmannii* Bunge (272). 138. *Prangos (P. fedtschenkoi* (Regel et Schmalh) Korovin (sn), *P. pabularia* Lindl. (654), *P. bucharica* O.Fedtsch. (231)). 139. *Bupleurum (B. exaltatum* M.Bieb. (474). 140. *Elaeosticta (E. allioides* (Regel & Schmalh.) Kljuykov, Pimenov & V.N.Tikhom. (1196), *E. hirtula* (Regel & Schmalh.) Kljuykov, Pimenov & V.N.Tikhom. (432), *E. conica* Korovin (sn), *E. bucharica* (Korovin) Kljuykov, Pimenov & V.N.Tikhom. (691)). 141. *Galagania (G. fragrantissima* Lipsky (454), *G. involucrata* (Korovin) Kljuykov (552), *G. neglecta* M.G.Vassiljeva & Kljuykov (sn), *G. tenuisecta* (Regel & Schmalh.) M.G.Vassiljeva & Pimenov (396)). 142. *Oedibasis (O. chaerophylloides* (Regel & Schmalh.) Korovin (sn). 143. *Elwendia (E. chaerophylloides* (Regel & Schmalh.) Pimenov & Kljuykov (6604), *E. capusii* (Franch.) Pimenov & Kljuykov (39), *E. setacea* (Schrenk) Pimenov & Kljuykov (6864), *E. hissarica* (Korovin) Pimenov & Kljuykov (321), E. persica (Boiss.) Pimenov & Kljuykov (94)). 144. *Falcaria (F. vulgaris* Bernh. (76). 145. *Apium (A. graveolens* L. (sn). 146. *Helosciadium (H. nodiflorum* (L.) W.D.J.Koch (307). 147. *Cuminum* (C. *setifolium* (Boiss.) Koso-Pol. (427). 148. *Aphanopleura (A. capillifolia* (Regel et Schmalh.) Lipsky (sn). 149. *Pimpinella (P. major* (L.) Huds. (sn)). 150. *Aegopodium (A. tadshikorum* Schischk. (727). 151. *Berula (B. erecta* (Huds.) Coville (307). 152. *Seseli (S. seravschanicum* Pimenov & Sdobnina (271), *S. korovinii* Schischk. (sn), *S. lehmannianum* Boiss. (457)). 153. *Foeniculum (F. vulgare* Mill. (696). 154. *Mediasia (M. macrophylla* (Regel et Schmalh.) Pimenov (98). 155. *Paulita (P. ovczinnikovii* (Korovin) Soják (581). 156. *Zeravschania (Z. regeliana* Korovin (300). 157. *Ferula (F. affinis* Besser (792), *F. diversivittata* Regel & Schmalh. (304), *F. tuberifera* Korovin (sn), *F. clematidifolia* Koso-Pol. (318), *F.*

bucharica Lipsky (sn), *F. tadshikorum* Pimenov (340), *F. kuhistanica* Korovin (710), *F. kelifi* Korovin (317), *F. nevskii* Korovin (356), *F. samarkandica* Korovin (6912), *F. moschata* (H.Reinsch) Koso-Pol. (387), *F. ovina* Boiss. (128)). 158. *Heracleum (H. lehmannianum* Bunge (726). 159. *Semenovia (S. pimpinellioides* (Nevski) Manden. (sn), *S. bucharica* (B.Fedtsch. ex Schischk.) Manden. (sn)).

38. Primulaceae Batsch ex Borkh.

160. *Primula (P. capitellata* Boiss. (30), *P. olgae* Regel (181), *P. fedtschenkoi* Regel (sn)). 161. *Androsace (A. dasyphylla* Bunge (317), *A. maxima* L. (40). 162. *Lysimachia (L. arvensis* (L.) U.Manns & Anderb. (1341)).

39. Plumbaginaceae Juss.

163. *Acantholimon butkovii* Lincz. (sn), *A. hissaricum* Lincz. (1176), *A. majewianum* Regel (310), *A. erythraeum* Bunge (547), *A. setiferum* Bunge (331)).

40. Gentianaceae Juss.

164. *Centaurium (C. erythraea* subsp. *turcicum* (Velen.) Melderis (686), *C. pulchellum* (Sw.) Hayek ex Hand.-Mazz., Stadlm., Janch. & Faltis (367)). 165. *Gentiana (G. olivieri* Griseb. (38). 166. *Geranium (G.rotundifolium* L. (318), *G. divaricatum* Ehrh. (sn), *G. collinum* Stephan ex Willd. (513), *G. himalayense* Klotzsch (sn), *G. saxatile* Kar. & Kir. (1690), *G. kotschyi* subsp. *charlesii* (Aitch. & Hemsl.) (216)).

41. Convolvulaceae Juss.

167. *Convolvulus (C. fruticosus* Pall. (sn), *C. hamadae* (Vved.) Petrov (sn), *C. oleifolius* var. *oleifolius* (sn), *C. leiocalycinus* var. *leiocalycinus* (sn), *C. pseudocantabrica* Sch renk ex Fisch. & C.A.Mey. (sn), *C. dorycnium* subsp. *subhirsutus* (Regel & Schmalh.) Sa'ad (sn), *C. arvensis* L. (sn)). 168. *Cuscuta (C. campestris* Yunck. (209), *C. pellucida* Butkov (695)).

42. Boraginaceae Juss.

169. *Anchusa (A. ochroleuca* M.Bieb. (1904). 170. *Buglossoides (B. arvensis* (L.) I.M.Johnst. (sn). 171. *Arnebia (A. euchroma* (Royle ex Benth.) (627), *A. coerulea* Schipcz. (134), *A. transcaspica* Popov (sn), *A. decumbens subsp. decumbens* (134)). 172. *Onosma (O. atrocyanea* Franch. (sn), *O. albicaulis* Popov (1000), *O. gmelinii* Ledeb. (sn), *O. baldshuanica* Lipsky (209), *O. dichroantha* Boiss. (424), *O. liwanowii* Popov (23), *O. macrorhiza* Popov (881)). 173. *Echium (E. biebersteinii* (Lacaita) Dobrocz. (68). 174. *Lappula (L. occultata* Popov (1012), *L. patula* (Lehm.) Menyh. (200), *L. microcarpa* (Ledeb.) Gürke (1168a), *L. subcaespitosa* Popov ex Golosk. (1150)). 175. *Asperugo (A. procumbens* L. (1207). 176. *Rochelia (R. retorta* (Pall.) Lipsky (455), *R. peduncularis* Boiss. (1619), *R. cardiosepala* Bunge (1014)). 177. *Rindera (R. tetraspis* Pall. (sn). 178. *Paracaryum (P. himalayense* (Klotzsch) C.B.Clarke (268). 179. *Solenanthus (S. circinnatus* Ledeb. (255), *S. hirsutus* Regel (280)). 180. *Lindelofia (L. capusii* (Franch.) Popov (sn). 181. *Caccinia (C. macranthera* (Banks & Sol.) Brand (sn). 182. *Myosotis (M. stricta Link ex Roem*. & Schult. (440). 183. *Pseudoheterocaryum (P. rigidum* (A.DC.) Kaz.Osaloo & Saadati (660), *P. szovitsianum* (Fisch. & C.A.Mey.) Kaz.Osaloo & Saadati (171)). 184. *Trichodesma (T. incanum* (Bunge) A.DC. (420). 185. *Microparacaryum (M. bungei* (Boiss.) Khat. (sn). 186. *Mattiastrum (M.himalayense* (Klotzsch) Brand (268), *M. emiri* (Popov) Czerep. (175)).

43. Lamiaceae Martinov

187. *Ajuga (A. turkestanica* (Regel) Briq. (372). 188. *Dracocephalum (D. diversifolium* Rupr. (1824). 189. *Drepanocaryum (D. sewerzowii* (Regel) Pojark. (1321). 190. *Phlomoides (P. canescens* (Regel) Adylov, Kamelin & Makhm. (1254), *P. kaufmanniana* (Regel) Adylov, Kamelin & Makhm. (414), *P. labiosa* (Bunge) Adylov, Kamelin & Makhm. (418), *P. lehmanniana* (Bunge) Adylov, Kamelin & Makhm. (351), *P. speciosa* (Rupr.) Adylov, Kamelin & Makhm. (312), *P. regeliana* (Aitch. & Hemsl.) Adylov, Kamelin & Makhm. (381)). 191. *Lagochilus (L. gypsaceus* Vved. (5). 192. *Lallemantia (L. royleana* (Benth.) Benth. (31). 193. *Leonurus (L. turkestanicus* V.I.Krecz. & Kuprian. (113). 194. *Nepeta (N. ouroumitanensis* Franch. (sn), *N. schtschurowskiana* Regel (718), *N.*

pungens Benth. (176)). 195. *Marrubium (M. anisodon* K.Koch (60). 196. *Mentha (M. longifolia* (L.) L. (494). 197. *Moluccella (M. bucharica* (B.Fedtsch.) Ryding (23), *M. fedtschenkoana* (Kudr.) Ryding (464)). 198. *Prunella (P. vulgaris* L. (1267). 199. *Salvia (S. aethiopis* L. (1273), *S. bucharica* Popov (14), *S. deserta* Schangin (664), *S. lilacinocoerulea* Nevski (23), *S. macrosiphon* Boiss. (421), *S. sarawschanica* Regel & Schmalh. (1236), *S. nilotica* Juss. ex Jacq. (528), *S. farinacea* Benth. (1588), *S. kudrjaschevii* (Gorschk. & Pjataeva) Sytsma(652), *S. scrophulariifolia* (Bunge) B.T.Drew (65)). 200. *Scutellaria (S. adenostegia* Briq. (93), *S. comosa* Juz. (642), *S. guttata* Nevski ex Juz. (162)). 201. *Sideritis (S. montana* L. (106). 202. *Ziziphora (Z. clinopodioides* Lam. (71), *Z. pamiroalaica* Juz. (27), *Z. tenuior* L. (800), *Z. persica* Bunge (725)).

44. Solanaceae Juss.

203. *Lycium (L. ruthenicum* Murray (786)).

45. Scrophulariaceae Juss.

204. *Scrophularia (S. oblongifolia* Loisel. (105), *S. vvedenskyi* Bondarenko & Filatova (1179), *S. striata* Boiss. (104), *S. kabadianensis* B.Fedtsch. (185), *S. sangtodensis* B.Fedtsch. 439), *S. glabella* Botsch. & Junussov (1203), *S. scoparia* Pennell (1203), *S. incisa* Weinm. (27)).

46. Orobanchaceae Vent.

205. *Orobanche (O. hansii* A.Kern. (942), *O. camptolepis* Boiss. & Reut. (1185), *O.coelestis* (Reut.) Boiss. & Reut. ex Beck (sn)). 206. *Pedicularis (P. dolichorrhiza* Schrenk (sn), *P. krylovii* Bonati (725)).

47. Rubiaceae Juss.

207. *Galium (G. parisiense* L. (6661). 208. *Callipeltis (C. cucullaris* (L.) DC. (201)).

48. Caprifoliaceae Juss.

209. *Lonicera (L. altmannii* Regel & Schmalh. (917), *L. bracteolaris* Boiss. & Buhse (sn), *L. nummulariifolia* Jaub. & Spach (498)). 210. *Dipsacus (D. azureus* Schrenk ex Fisch. & C.A.Mey. (440). 211. *Cephalaria (C. syriaca* (L.) Roem. & Schult. (57). 212. *Pterocephalus (P. afghanicus* (Aitch. & Hemsl.) Boiss. (496). 213. *Lomelosia (L. songarica* (Schrenk) Soják (353), *L. olivieri* (Coult.) Greuter & Burdet (463), *L. flavida* (Boiss. & Hausskn.) Soják (35), *L. rhodantha* (Kar. & Kir.) Soják (sn)). 214. *Valerianella (V. tuberculata Boiss.* (sn), *V. turkestanica* Regel & Schmalh. (265), *V. oxyrrhyncha* Fisch. & C.A. Mey. (488), *V. szovitsiana* Fisch. & C.A. Mey. (35), *V. muricata* (Stev. ex M. Bieb.) J.W. Loud. (sn)).

49. Campanulaceae Juss.

215. *Campanula (C. rapunculus* L. (380), *C. glomerata* L. (1137), *C. cashmeriana* Royle (163)). 216. *Codonopsis (C. bactriana* F.O.Khass., U.Kodyrov & A.Myrz. (365). 217. *Asyneuma (A. argutum* (Regel) Bornm. (352), *A. thomsonii* (Hook.f.) Bornm. (sn)). 218. *Sergia (S. regelii* (Trautv.) Fed. (310). 219. *Morina (M. coulteriana* Royle (733)).

50. Asteraceae Bercht. & J.Presl

220. *Garhadiolus (G. papposus* Boiss. & Buhse (134), *G. hedypnois* Jaub. & Spach (114)). 221. *Lagoseriopsis (L. popovii* (Krasch.) Kirp. (45). 222. *Chondrilla (Ch. aspera* Poir. (55), *Ch. lejosperma* Kar. & Kir. (812)). 223. *Lactuca (L. orientalis* (Boiss.) Boiss. (20). 224. Cicerbita (C. *crambifolia* (Bunge) Beauverd (6790). 225. *Crepidiastrum (C. serawschanicum* (B.Fedtsch.) Sennikov (710). 226. *Sonchus (S. transcaspicus* Nevski (6848), *S. asper* (L.) Hill (507)). 227. *Heteracia (H. szovitsii* Fisch. & C.A.Mey. (109). 228. *Crepis (C. kotschyana* (Boiss.) Boiss. (553). 229. *Carduus (C. arabicus* Jacq. ex Murray (456), *C. pycnocephalus* L. (sn)). 230. *Acanthocephalus (A. benthamianus* Regel (486), *A. amplexifolius* Kar. & Kir. (460)). 231. *Scorzonera (S. tragopogonoides* Regel & Schmalh. (331). 232. *Epilasia (E. hemilasia* (Bunge) C.B.Clarke (236). 233. *Tragopogon (T. capitatus* S.A.Nikitin (441), *T. vvedenskyi* Popov (1292), *T. malikus* S.A.Nikitin (sn)). 234. *Koelpinia (K. linearis* Pall. (374), *K. macrantha* C.Winkl. (153)). 235. *Oreoseris (O. kokanica* (Regel & Schmalh.) J.Wen & W.Zheng (772). 236. *Xeranthemum (X. longepapposum* Fisch. &

C.A.Mey. (1364). 237. *Picnomon (P. acarna* (L.) Cass. (1503). 238. *Onopordum (O. leptolepis* DC. (521). 239. *Arctium (A. leiospermum* Juz. & Ye.V.Serg. (1550), *A. anomalum* (Franch.) Kuntze (714), *A. aureum* Kuntze (25), *A. medians* (Juz.) S.López, Romasch., Susanna & N.Garcia (538), *A. umbrosum* (Bunge) Kuntze (350)). 240. *Cousinia (C. refracta* Juz. (66), *C. integrifolia* Franch. (364), *C. pseudomollis* C.Winkl. (413), *C. tenuispina* Rech.f. (656), *C. mollis* Schrenk (6592), *C. polycephala* Rupr. (168), *C. transoxana* Tscherneva (sn), *C. resinosa* Juz. (sn), *C. dichromata* Kult. (416), *C. subcandicans* Tschern. (421), *C. leptocladoides* Tschern. (sn), *C. kuekenthalii* Bornm. (477), *C. decurrentifolia* Juz. ex Tscherneva (520), *Cousinia spryginii* Kult. (6809), *C. pulchella* Bunge (1614), *C. microcarpa* Boiss. (247), *C. regelii* C.Winkl. (151), *C. radians* Bunge (39a), *C. coronata* Franch. (506), *C. outichaschensis* Franch. (1635), *C. rosea* Kult. (275), *C. tenella* Fisch. & C.A.Mey. (6832), *C. lanata* C.Winkl. (106), *C. verticillaris* Bunge (1657), *C. allolepis* Tscherneva & Vved. (sn), *C. newesskyana* C.Winkl. (499), *C. trichophora* Kult. (414)). 241. *Jurinea (J. trautvetteriana* Regel & Schmalh. (724), *J. maxima* C.Winkl. (419), *J. tapetodes* Iljin (318)). 242. *Amberboa (A. bucharica* Iljin (420). 243. *Senecio (S. olgae* Regel & Schmalh. (210). 244. *Monactinocephalus (M. paniculatus* Klatt (13). 245. *Inula (I. rhizocephala* Schrenk ex Fisch. & C.A.Mey. (1624)). 246. *Galatella (G. grimmii* (Regel & Schmalh.) Sennikov (487), *G. villosula* Novopokr. (sn)). 247. *Erigeron (E. acris* L. (1254). 248. *Tanacetopsis (T. botschantzevii* (Kovalevsk.) Kovalevsk. (sn). 249. *Artemisia (A. persica* Boiss. (1259), *A. dracunculus* L. (1622), *A. ferganensis* Krasch. ex Poljakov (81), *A. albicaulis* Nevski (769), *A. kochiiformis* Krasch. & Lincz. ex Poljakov (459), *A. lehmanniana* Bunge (444), *A. baldshuanica* Krasch. & Zopr. (780), *A. leucodes* Schrenk (6709)). 250. *Psychrogeton (P. andryaloides* var. *poncinsii* (Franch.) Grierson (618)).

51. Mazaceae Reveal

251. *Dodartia (D. orientalis* L. (115)).

52. Asphodelaceae Juss.

252. *Eremurus (E. regelii* Vved. (56), *E. soogdianus* (Regel) Benth. & Hook.f. (1278), *E. stenophyllus* (Boiss. & Buhse) Baker (651), *E. olgae* Regel (335), *E. kaufmannii* Regel (208), *E. aitchisonii* Baker (1), *E. alberti* Regel (626), *E. luteus* Baker (331)).

53. Asparagaceae Juss.

253. *Bellevalia (B. turkestanica* Franch. (527). 254. *Asparagus (A. persicus* Baker (912). 255. *Polygonatum (P. sewerzowii* Regel (527).

54. Hypericaceae Juss.

256. *Hypericum (H. scabrum* L. (394), *H. perforatum* L. (134)).

55. Ixioliriaceae Nakai

257. *Ixiolirion (I. tataricum* (Pall.) Schult. & Schult.f. (58).

Xulosa. Ushbu tadqiqotda Katta O‘radaryo va Kichik O‘radaryo florasi ro‘yxati hududda keng tarqalgan o‘simliklarning O‘zbekiston Milliy gerbariysi (TASH) fondi inventarizatsiyasidan foydalanildi. Ushbu natijalardan O‘zbekiston florasining to‘r xaritasida foydalanish imkoniyatini yaxshilash, tezroq ma’lumot almashinish va kelajakda foydalanish uchun oldingi va hozirgi flora ma’lumotlarini zaxiralash uchun gerbariy namunalarini raqamlashtirish geobog‘lash va rasmiylashtirish sohasidagi yutuqlarni ifodalaydi. Raqamli gerbariy yordamida an’anaviy gerbariydagi cheklovlarni yengib o‘tish mumkin. Muayyan hududlar uchun o‘simlik turlarining katalogi ko‘rinishida raqamli gerbariy yaratish osonroq bo‘lib, bu o‘simliklarning bioxilmaxilligini yaxshiroq aniqlash va ma’lumotlarni to‘plash imkoniyatini kengaytiradi.

Foydalanilgan adabiyotlar ro‘yxati

1. Besnard, G., Gaudeul, M., Lavergne, S., Muller, S., Rouhan, G., Sukhorukov, A. P., ... & Jabbour, F. (2018). Herbarium-based science in the twenty-first century. *Botany Letters*, *165*(3-4), 323-327.

2. Joye, D. A., E. Castella, and J. B. Lachavanne. 2002. “Occurrence of Characeae in Switzerland over the Last Two Centuries (1800–2000).” Aquatic Botany 72 (3): 369–385.

3. Nieva de la Hidalga A, Rosin PL, Sun X, Bogaerts A, De Meeter N, De Smedt S, Strack van Schijndel

M, Van Wambeke P, Groom Q (2020) Designing an Herbarium Digitisation Workflow with Built-In Image Quality Management. Biodiversity Data Journal 8: e47051.

4. Thiers BM 2021 The world’s herbaria2020: a summary reportbased ondata from Index Herbariorum. http://sweetgum.nybg.org/science/ih/.

5. Хасанов Ф.О., Турдибоев О.А. Ўзбекистон Миллий гербарийси (TASH) тарихи, хозирги ҳолати ва ривожланиш истиқболлари // Ёш олимлар ахборотномаси. №2 (4). – Б. 149-153.

6. Кудряшев С.Н. Растительность. Гузар–Ташкент. - Комитет наук УзФАН, 1941.- С. 5-237.

7. Тожибаев К.Ш., Бешко Н.Ю., Попов В.А. Ботанико-географическое районирование Узбекистана. - Ботанический журнал, 2016. Т. 101, №10. – С. 1105-1132.

8. Омонов О.Э. Катта ва Кичик Ўрадарё ҳавзаси флора ва ўсимликлар қопламининг ўрганилиш тарихи. QarDU xabarlari. 2024, 2/2. – Б. 154-160.

LALMI TIPIK BO‘Z TUPROQLARNING AYRIM XOSSALARIGA QO‘LLANILGAN AGROTEXNOGIYALARNI TA’SIRI

Shadiyeva Nilufar Iskandarovna
Toshkent davlat agrar universiteti
“Agrokimyo va tuproqshunoslik” kafedrasi professori,
nshadiyeva@gmail,com
Toshkanova Xulkar Askarovna
Toshkent davlat agrar universiteti tayanch doktoranti
xulkartoshkanova@mail.ru
ORCID 0009-0000-6809-9498

UDK: 631.417.+433.3

Annotatsiya. Maqolada lalmi tipik bo‘z tuproqlarining nafas olish jadalligi va unga bog‘liq holda suvda eruvchi gumus miqdorini qo‘llanilgan No-Till texnologiyasi ta’sirida o‘zgarishiga oid ma’lumotlar keltirilgan. Olingan ma’lumotlarga ko‘ra, tadqiqot hududi tuproqlarining nafas olish jadalligi miqdori orasida o‘zaro korellyativ bog‘liqlik aniqlangan. Tuproqlarda nafas olish jadalligi bevosita gumusning umumiy va labil shakllari miqdoriga bog‘liqligini ko‘rsatadi, unga ko‘ra, No-Til usuli bilan ishlov berilgan tuproq an'anaviy usul bilan ishlov berilgan tuproqqa nisbatan yaxshilangan va tuproqlarda ijobiy muvozanat kuzatilgan. Xususan ilmiy tadqiqot ishlari Qashqadaryo viloyati Qamashi tumani Savson tepa MFY “Jovli bobo o‘g‘li Baxtiyor” f/x maydonidagi eroziyalangan lalmi tipik bo‘z tuproqlarda olib borilgan hamda olingan najilar izohlangan.

Tayanch so‘zlar. eroziya,ekspozitsiya, nafas olish jadalligi, nafas olish xususiyatlari, biologik jarayonlar, qiyalik elementi, lalmi tuproqlar, suvda eruvchi gumus, No-Till

INFLUENCE OF APPLIED AGRICULTURAL TECHNOLOGIES ON SOME PROPERTIES OF TYPICAL RAINFOWED SEROZEM

Abstract. The article presents information about the change in the rate of respiration of rainfed typical serozems and, depending on it, the amount of water-soluble humus under the influence of No-Till technologies. According to the data obtained, a correlation was established between the intensity of soil respiration in the study area. It shows that the intensity of respiration in the soil is directly dependent on the amount of common and labile forms of humus. According to this, the No-Till treated soil was introduced, improved compared to the soil treated with the traditional method and a positive balance was observed in the soils.

Keywords. erosion, exposure, respiration intensity, respiration characteristics, biological processes, slope element, dry soils, water-soluble humus, *No-Till.*

Kirish. Ma’lumki, tuproqning biologik faolligiga antropogen hamda ekologik omillar katta ta’sir ko‘rsatadi. Tuproqga ishlov berish, madaniylashtirish, o‘g‘itlash, sug‘orish va eroziya jarayonlari kabi bir qator omillar tuproqning biologik faolligiga ta’sir ko‘rsatadi. Shu sababdan izlanishlar davomida o‘rganilgan tuproqlar biologik faolligining tuproq xossalari hamda tuproqga ishlov berish usullarini kuzatish maqsadida Savson tepa MFY “Jovli bobo o‘g‘li Baxtiyor” f/x No-Till texnologiyasini joriy etilishi lalmikor mintaqa tuproqlarida tuproqning yuqori haydov va haydov ostki qatlamlaridan biologik tahlillar uchun namunalar olindi.

Bizga ma’lumki eroziyalangan tuproqlarning biologik faolligini o‘rganishga ko‘pgina ishlar bag‘ishlangan bo‘lib, ushbu ishlarda ko‘rsatilishicha, eroziya ekologik muvozanatning buzilishiga sababchi omillardan hisoblanadi. Eroziya jarayonlari natijasida tuproqdagi asosiy xossalarning yomonlashuvi hamda biologik faollikning pasayishi kuzatiladi. [2,3,4,7,8,9,10].

Tadqiqot obyekt va metodologiyasi. Izlanishlar Qashqadaryo viloyati Qamashi tumani Savson tepa MFY "Jovli bobo o'g'li Baxtiyor" f/x maydonidagi eroziyalangan lalmi tipik bo'z tuproqlarda olib borildi. Tuproqning nafas olishi xususiyati Shtatnova usulida O.I.Koleshko modifikatsiyasi bo'yicha (1980) aniqlandi [6]. Suvda eruvchi gumus Kubel-Timan uslubida [1]

Natijalar va muhokama. Ma'lumki, nafas olish – tuproqning muhim hayotiy jarayonidir hamda biologik faollikni belgilovchi asosiy ko'rsatkich bo'lib sanaladi. Tuproqning nafas olishida atmosferadan kislorod olinadi va organik moddalarning murakkab oksidlanib parchalanishi natijasida o'simliklarni uglerod bilan ta'minlash manbai hisoblanuvchi karbonat angidrid gazi ajralib chiqadi. Tuproq yuzasidan CO2 ning atmosferaga ajralib chiqishi o'zaro uzviy aloqador holda kechadigan jarayonlarning natijasidir, bunda biologik omillar hal qiluvchi o'rin tutadi.

Tuproqning karbonat angidrid gazini ajratib chiqarishi tuproqning eng zarur biologik faolligini, ya'ni unumdorlik imkoniyatlarini aks ettirish bilan bir vaqtda turli sharoitda o'g'itlangan tuproqlarda turlicha bo'ladi va shunga bog'liq ravishda o'zgarib turadi.

Olingan ma'lumotlarga ko'ra, tuproqning nafas olish jadalligi bahaor faslida eng yuqori bo'lib, No-Till texnologiyasi asosida ishlov berilgan lalmi tipik bo'z tuproq, suv ayirgich qismining 0-30 va 30-50 smli qatlamlarida eng yuqori 4,9-3,2 mg/kg, mos holda qiyalikni o'rta qismi shimoliy ekspozitsiya tuproqlarida 4,4-3,6 mg/kg ni janubiy ekspozitsiya tuproqlarida 4,0-3,5 mg/kg CO2 miqdorni tashkil qildi. Tuproqga an'anaviy ishlov berillib ekilgan hudud tuproqlarida bir muncha kam bo'lib eroziyalanmagan suv ayirg'ich qismining 0-30 va 30-50 smli qatlamlarida 4,8-2,4 mg/kg, mos holda qiyalikni o'rta qismi shimoliy ekspozitsiya tuproqlarida 3,9-2,9 mg/kg ni janubiy ekspozitsiya tuproqlarida 4,1-2,7 mg/kg CO2 miqdorni tashkil qildi. Ushbu ko'rsatkichlarni eroziyalanganlik darajasiga qarab bunday o'zgarish qonuniyatni tuproqdagi gumus va oziqa elementlari miqdori, fizik xususiyatlari bilan ham bog'lash mumkin (jadval).

Jadval

Suvda eruvchi gumusni tuproqning nafas olish jadalligi bilan aloqadorligi

№	Variantlar	Qatlam chuqur ligi, sm	Suvda eruvchi gumus mg/kg	Нафас олиш жадаллиги (CO2 мг/100г 24 соат)		
				Баҳор	ёз	куз
1.	Tuproqga an'anaviy ishlov berilgan lalmi tipik bo'z tuproq, suv ayirgich (eroziyalanmagan)	0-30	139	4,8	2,8	3,9
		30-50	124	2,4	1,6	2,2
2.	Tuproqga an'anaviy ishlov berilgan lalmi tipik bo'z tuproq, qiyalikni o'rta qismi 70, janubiy sharqiy ekspozitsiya o'rtacha eroziyalangan	0-30	133	3,9	2,6	3,5
		30-50	118	2,9	1,4	2,8
3.	Tuproqga an'anaviy ishlov berilgan lalmi tipik bo'z tuproq, qiyalikni o'rta qismi 70, shimoliy g'arbiy ekspozitsiya o'rtacha eroziyalangan	0-30	136	4,1	2,7	3,9
		30-50	121	2,7	1,6	2,6
4.	No-Till texnologiyasi asosida ishlov berilgan lalmi tipik bo'z tuproq, suv ayirgich (eroziyalanmagan)	0-30	148	4,9	2,8	3,3
		30-50	139	3,2	2,0	2,0
5.	No-Till texnologiyasi asosida ishlov berilgan lalmi tipik bo'z tuproq, qiyalikni o'rta qismi janubiy ekspozitsiya	0-30	142	4,0	3,1	3,8
		30-50	137	3,5	2,6	2,4
6.	No-Till texnologiyasi asosida ishlov berilgan lalmi tipik bo'z tuproq, qiyalikni o'rta qismi, shimoliy ekspozitsiya	0-30	138	4,4	3,5	4,6
		30-50	127	3,6	3,1	3,2

Tuproqdan CO_2 ning ajralib chiqish jadalligi tuproq biologik faolligini hamda unumdorlik darajasini belgilab beruvchi umumiy koʻrsatkich boʻlib xizmat qiladi. Tuproq nafas olish jarayonining qay darajada borishiga qarab tuproqdagi organik moddalarning mineralizatsiyalanishini baholash mumkin. Oʻz navbatida tuproqning nafas olish xususiyati havo va tuproq harorati, tuproq namligiga bogʻliq ravishda oʻzgaradi.

Olingan natijalarga koʻra, tuproq nafas olish jadalligiga birinchi navbatda tuproqdagi organik moddalar miqdori, tuproqning kimyoviy va fizikaviy xossalari hamda uning gidrotermik sharoitlari ta’sir etishi kuzatildi.

Tadqiqot olib borilgan barcha tuproqlarda nafas olish jadalligining yuqoridan quyi qatlamlar tomon pasayib borishi kuzatildi.

Tadqiqotlarimizda shuningdek tuproq nafas olish jadalligini yil mavsumlari boʻyicha 0-30 va 30-50 sm li qatlamlarda oʻrgandik. Tuproqlarni nafas olish xususiyati bahor va undan keyingi oʻrinda kuz faslida jadal ketishi aniqlandi. Yoz mavsumida ushbu jarayon bir muncha pasayishini olingan natijalar isbotladi. Bunga asosiy sabab bahor va kuz mavsumlarida qulay gidrotermik sharoit mavjud boʻladi. Ayniqsa bahor mavsumida oʻsimliklar biomassasi jadal rivojlanish bosqichida boʻlib, harorat va namlik ham yetarli darajada boʻladi, bu vaqtda oʻz navbatida suvda eruvchi gumus miqdori ham ortishi kuzatildi. Suvda eruvchi gumus esa tuproq mikroorganizmalarini faoliyatini jadallashuviga ham ta’sir etadi. Suvda eruvchi gumus miqdorini eng yuqori koʻrsatkichi No-Till texnologiyasi asosida ishlov berilgan lalmi tipik boʻz tuproq, suv ayirgich qismining 0-30 smli qatlamida kuzatildi uning miqdori 148 mg/kg tashkil etgan.

Xulosa va takliflar. Olib borilgan tadqiqotlar natijalariga koʻra, oʻrganilgan tuproqlarda nafas olish jadalligi bevosita gumusning umumiy va labil shakllari miqdoriga bogʻliqligini koʻrsatadi unga koʻra, almashlab ekish tizimi joriy etilib, organik va mineral oʻgʻitlar berilgan variantlar tuproqlarida ushbu koʻrsatkichlarni ijobiy balansini koʻrishimiz mumkin.

Demak tuproqdan karbonat angidritning ajralib chiqishi bir qator murakkab omillar (tuproq gumusi, iqlim, hududning geografik joylashishi, tuproqning kimyoviy va fizikaviy koʻrsatkichlari, oʻgʻitlar turi va meyori, ekin turlari va b.) ta’siri oʻzgarishi kuzatildi. Tahlillar natijasida nafas olishning umumiy gumus va suvda eruvchi gumus miqdori bilan oʻzaro korrelyativ bogʻliqligi aniqlandi. Oʻrganilgan tuproqlarda organik modda bilan nafas olish oʻrtasida oʻzaro bogʻliqlik mavjudligi kuzatildi. Bu holatni gumus miqdorini biologik faollikni aks ettiruvchi koʻrsatkichlarga toʻgʻri proporsionalligi bilan tavsiflanadi. Tuproqlarni biologik faolligini ularning genetik barqaror xossalari oʻrtasidagi aniqlangan korrelyativ bogʻliqliklar tuproq hosil boʻlish jarayonlari yoʻnalishining oʻzgarishini diagnostika qilishda biologik test sifatida foydalanish mumkin boʻladi.

Foydalanilgan adabiyotlar

1. Аринушкина Руководство по химическому анализу почв -М., МГУ 1970, 487 с.
2. Галстян А.Ш. Ферментативная активность почв Армении. Труды НИИ почвоведения и агрохимии МСХ Арм. ССР. Вып.8. Ереван, Айастан, 1974. – 275 с.
3. Гафурова Л.А. Почвы, сформированные на третичных красноцветных отложениях их экологическое состояние и плодородие. дисс...д. б. н. – Ташкент, 1995, –С. 331–351.
4. Гафурова Л.А., Махсудов Х.М., Адел М.Ю. Эрозияга учраган, неоген ётқизиқларда шаклланган бўз тупроқларнинг биологик фаоллиги. – Тошкент: Ўзбекистон, 1999. – Б. 3–95.
5. Джумшудова Н.Ш. Биологическая активность серо-бурых почв Апшерона при внесении удобрений под культуру маслины. Автореф. дисс... канд. с-х наук. – Баку, 1987. – С. 10–18.
6. Звягинцев Д.Г. Методы почвенной микробиологии и биохимии. Изд. МГУ, 1980, - 350 с.
7. Кадирова Д.А. Эродированные почвы Туркестанского хребта и их биологическая активность. Авт. дисс…канд. биол. наук – Т.: 2010. – С. 3–20.
8. Набиева Г.М., Почвы Западных отрогов Чаткальского хребта и их ферментативная активность. Автореф. дисс…канд. биол. наук. – Ташкент, 2008. – С. 7–17.
9. Оландж‍ М.Ф. Влияние эрозионных процессов на биологическую и каталазную активность горно-серо-коричневых почв. В кн.: Почвенноэрозионные процессы и меры борьбы с эрозией почв. – Душанбе, Докши, 1991. – С. 31–35.
10. Содиқова Г.С. Бойсунтоғининг тупроқ-экологик шароитлари, тупроқларнинг биологик фаоллиги ва уларга эрозия жараёнларининг таъсири. Автореф. дисс.… б. н. – Тошкент, 2011. – С. 7–24.

QarDU XABARLARI

Ilmiy-nazariy, uslubiy jurnal

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