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1- бөлім

ҚОРШАҒАН ОРТАНЫ ҚОРҒАУ ЖӘНЕ ҚОРШАҒАН ОРТАҒА АНТРОПОГЕНДІК ФАКТОРЛАРДЫҢ ӘСЕРІ

Section 1

ENVIRONMENTAL IMPACT OF ANTHROPOGENIC FACTORS AND ENVIRONMENTAL PROTECTIONY

Раздел 1

ВОЗДЕЙСТВИЕ НА ОКРУЖАЮЩУЮ СРЕДУ АНТРОПОГЕННЫХ ФАКТОРОВ И ЗАЩИТА ОКРУЖАЮЩЕЙ СРЕДЫ

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ОЧИСТКА ВОДЫ ОТ ФАРМАЦЕВТИЧЕСКОГО ЗАГРЯЗНИТЕЛЯ ЦЕФТРИАКСОНА С ИСПОЛЬЗОВАНИЕМ МОДИФИЦИРОВАННОГО ПРИРОДНОГО ЦЕОЛИТА

В статье рассмотрена очистка воды от фармацевтических препаратов (цефтриаксона) путем сорбции модифицированным природным цеолитом. Модификация цеолита была проведена поверхностно активным веществом (цетилтриметиламмоний бромид или ЦТАБ) с разными концентрациями. В исследовании применения природного цеолита для очистки сточных вод от фармацевтических веществ было установлено, что степень адсорбции достигает 97,3% для цефтриаксона, при начальной концентрации 50 мг/л. Изотермы адсорбции соответствовали модели Ленгмюра, что подтверждает высокую эффективность цеолита в очистке воды от фармацевтических загрязнителей и его потенциал для промышленного применения. Результаты исследования подтверждают перспективность применения природных цеолитов в системах очистки воды.

Ключевые слова: природный цеолит, модифицированный цеолит, фармацевтическое вещество, изотерма адсорбции, кинетика адсорбции, очистка воды.

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Water purification from pharmaceutical contaminant ceftriaxone using modified natural zeolite

The article discusses the purification of water from pharmaceutical preparations (ceftriaxone) by sorption with a modified natural zeolite. The zeolite was modified with a surfactant (cetyltrimethylammonium bromide or CTAB) with different concentrations. In a study of the use of natural zeolite for wastewater treatment from pharmaceutical substances, it was found that the degree of adsorption reaches 97.3% for ceftriaxone, at an initial concentration of 50 mg/l. The adsorption isotherms corresponded to the Langmuir model, which confirms the high efficiency of zeolite in water purification from pharmaceutical pollutants and its potential for industrial applications. The results of the study confirm the prospects of using natural zeolites in water purification systems.

Key words: natural zeolite, modified zeolite, pharmaceutical substance, adsorption isotherm, adsorption kinetics, water purification.

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Модификацияланған табиғи цеолитті пайдалана отырып, цефтриаксонның фармацевтикалық ластауышынан суды тазарту

Мақалада өзгертілген табиғи цеолитпен сорбциялау арқылы суды фармацевтикалық ластаушылардан (цефтриаксоннан) тазарту қарастырылған. Цеолиттің модификациясы әр түрлі концентрациядағы беттік белсенді затпен (цетилтриметиламмоний бромиді немесе ЦТАБ) жүргізілді. Ағынды суларды фармацевтикалық заттардан тазарту үшін табиғи цеолитті қолдануды зерттеуде адсорбция дәрежесі Цефтриаксон үшін 97,3% – ға жететіні анықталды, бастапқы концентрациясы 50 мг/л. Адсорбция изотермалары Ленгмюр моделіне сәйкес келді, бұл цеолиттің суды фармацевтикалық ластаушы заттардан тазартудағы жоғары тиімділігін және оның өнеркәсіптік қолдану әлеуетін растайды. Зерттеу нәтижелері суды тазарту жүйелерінде табиғи цеолиттерді қолдану болашақ мүмкіндіктерін растайды.

Түйін сөздер: табиғи цеолит, модификацияланған цеолит, фармацевтикалық зат, адсорбция изотермасы, адсорбция кинетикасы, суды тазарту

1. Введение

Развитие фармацевтической промышленности вызванный растущим мировым спросом на лекарства, непреднамеренно привел к серьезной экологической проблеме: сбросу сточных вод фармацевтических предприятий. Сточные воды фармацевтических предприятий содержат сложную смесь активных фармацевтических веществ, органические загрязнители, токсичные тяжелые металлы и различные другие химические добавки, многие из которых являются стойкими и устойчивыми к традиционным методам очистки сточных вод [1]. Согласно литературным данным [2,3] в бытовых сточных водах Казахстана обнаружены различные группы фармацевтических веществ и их метаболиты, а также остатки средств личной гигиены, стероиды и другие соединения. Среди них присутствуют такие препараты, как антибиотики (тетрациклин, цефтриаксон, сульфаметоксазол, сульфаниламид), противовоспалительные и обезболивающие препараты (ибупрофен, диклофенак, ацетилсалициловая кислота, парацетамол). Эти вещества широко используются и востребованы как в Казахстане, так и во многих других странах [4].

Антибиотики широко используются для профилактики и лечения инфекционных заболеваний животных и человека. На протяжении нескольких десятилетий все более широкое применение антибиотиков продолжается благодаря их способности лечить различные заболевания, в основном бактериальные инфекционные заболевания. Из-за постоянного попадания антибиотиков в окружающую среду водные и почвенные организмы подвергаются хроническому воздействию этих препаратов. Более того, поскольку они активны в очень низких концентрациях, они оказывают токсическое воздействие на организмы, и при их совместном применении с другими лекарственными средствами и ксенобиотическими соединениями возникает синергетический эффект. Поэтому существует острая необходимость в инновационных и эффективных технологиях очистки, которые могут эффективно удалять эти загрязняющие вещества.

Для удаления этих компонентов в рамках очистки воды и сточных вод были использованы различные методы, такие как ионный обмен, осаждение, мембранная фильтрация, химическое осаждение и адсорбция, которая является одним из наилучших методов удаления токсичных веществ с использованием адсорбента. Одним из наиболее распространенных способов удаления загрязняющих веществ из сточных вод является адсорбция. Этот метод используется для устранения загрязняющих веществ в сточных водах благодаря своей простоте, высокой эффективности и экономичности. Среди материалов, используемых в процессе адсорбции, активированный уголь, природный цеолит или синтетический цеолит, наноматериалы [5].

Один из наиболее распространенных природных сорбентов используется природные цеолиты. Из-за своей большой площади поверхности и суммарного отрицательного заряда в структуре каналов цеолиты могут адсорбировать загрязняющие вещества, такие как пестициды и тяжелые металлы. Природные цеолиты, как правило, имеют отрицательно заряженную поверхность. Чтобы иметь возможность адсорбировать молекулы лекарственных средств крайне важно заменить отрицательный заряд на подходящий (положительно заряженная поверхность для адсорбции). Модификация природного цеолита катионными поверхностно-активными веществами (ПАВ), такими как гексадецилтриметиламмонийбромид (HDTMA, ЦТАБ) или бензалкония хлорид, заменяет катионы (Na^+, K^+, Ca^{2+}) на органические катионы ПАВ. Более того, цеолиты, модифицированные катионным поверхностно-активным веществом на основе HDTMA, были стабильны при высокой ионной силе и широком диапазоне pH среды [6,7].

В этом исследовании была проведена модификация поверхности цеолита с использованием поверхностно-активного вещества ЦТАБ, чтобы природный цеолит мог адсорбировать молекулы цефтриаксона. Молекулы цефтриаксона лучше адсорбируются на цеолитах, модифицированных катионным поверхностно-активным веществом ЦТАБ. Была проведена оценка адсорбционных свойств цефтриаксона на природном цеолите, модифицированном поверхностно-активным веществом, и проведено сравнение с адсорбционными свойствами без модификации поверхностно-активным веществом ЦТАБ.

Были изучены их структурные и морфологические особенности с описанием полученных материалов современными аналитическими методами, такими как рентгеноструктурный анализ (РСА), сканирующая электронная микроскопия (СЭМ) Это исследование позволяет оценить потенциал природного цеолита, расширить области их применения и создать новые композитные материалы.

Данная работа посвящена изучению адсорбционных свойств природного цеолита при удалении антибиотиков из водных растворов. Задачей исследования является оценка эффективности природного цеолита и с модифицированным цеолитом при адсорбции цефтриаксона. Это исследование оценивает эффективность и потенциал природного цеолита в очистке воды, учитывая его высокие адсорбционные свойства и практическую значимость для современных задач сфере химии и экологии. Благодаря уникальной структуре и возможности целенаправленной модификации функциональных характеристик, цеолит представляет перспективный материал для удаления фармацевтических загрязнителей из воды.

2. Материалы и методы исследования

2.1 Материалы. В качестве цеолита использовался природный цеолит (Шанканайское месторожденния (Алматинская область, Казахстан), Цефтриаксон натрия (Sigma Aldrich, 99.5%), ЦТАБ (Гексадецилтриметиламмоний бромид, Sigma Aldrich, ≥99%), деионионищированная вода особой чистоты.

Для характеристеризации цеолита использовался метод рентгенофазового анализа (РФА) с использованием дифракционной системы MPD XCEL-221 при параметрах 30 кВ и 10 мА, применяя излучение CuKα (λ = 1,540056 Å) со скоростью сканирования 0,02 °/s в диапазоне 2θ от 10° до 70°.

2.2 Модификация цеолита. Модификация природного цеолита проводилась следующим образом: 25 грамм природного цеолита помещалась в 250 мл раствора ЦТАБ и перемешивался со скоростью 200 об/мин при температуре 30 °C в течение 48 часов. После для удаления избытка остатков ЦТАБ цеолит промывали дистиллированной водой 5 раз. Модификация проводилась с концентрациями 10, 20, 30 mM ЦТАБ. Для определения оптимального условия для модификации цеолита, была проведены опыты по определению максимальной сорбционной емкости удаления цефтриаксона из водного раствора (рис. 1).

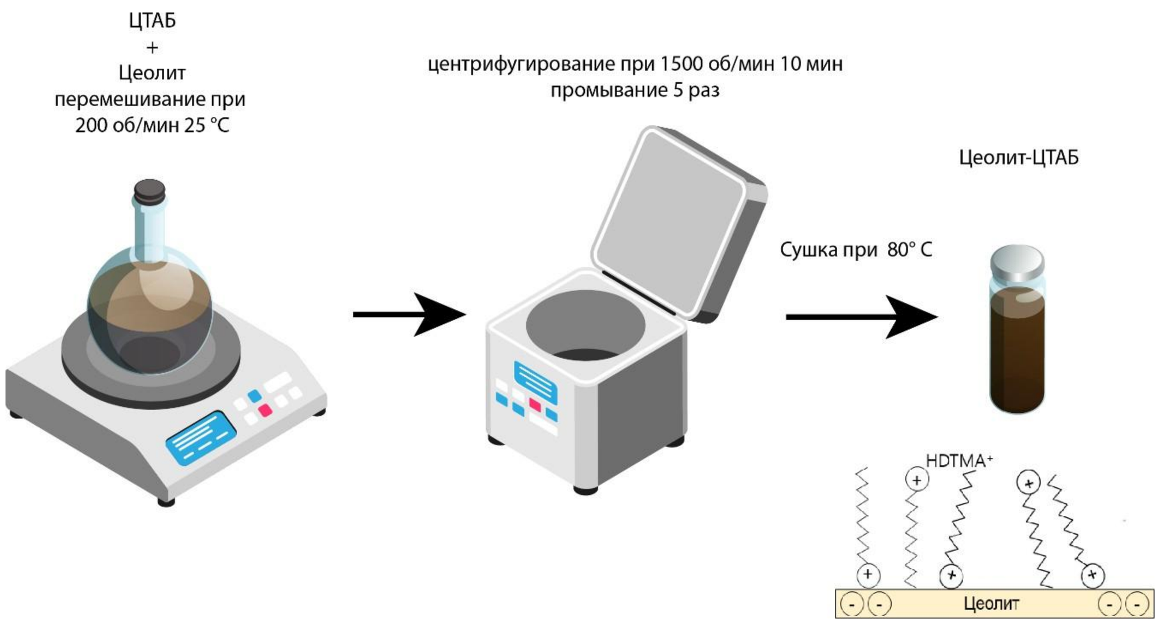

Рисунок 1 – Схематическая диаграмма модификации природного цеолита

2.3 Изотерма адсорбции. В этой работе были проведены периодические эксперименты для определения степени адсорбции цеф-триаксона. Для этого бралось 100 мг адсорбента размером 0,63 мм, который был помещен в 10 мл в раствор цефтриаксона. В каждую пробирку добавляли 10 мл раствора цефтриаксона с концентрацией 5, 10, 20, 30 и 40 мг/л. Растворы перемешивались на орбитальном шейкере со скоростью 350 об/мин в течение 24 часов для полного достижения равновесия изотермы. Образцы затем количество определялся с помощью УФ-спектрофотометра при длине волны 272 нм [8].

Сорбционная емкость q_e (мг/г) адсорбата было рассчитано с помощью уравнения (1) и эффективность удаления (%) уравнением (2):

$$q_e = \frac{(C_0 - C_e)}{m} \times V \quad (1)$$

$$ЭУ = \frac{C_0 - C}{C_0} \times 100 \quad (2)$$

где, q_e (мг/г) – равновестная сорбционная емкость вещества, C_0 и C_e (мг/л)– начальная и равновесная концентрация вещества соответ-ственно, V (мл) – общий объем раствора, а m (г) – масса используемого сорбента.

Исследование сорбционных характеристик делались моделями адсорбционной изотермы Ленгмюра и Фрейндлиха, для оценки дос-товерности экспериментальных данных и изучения адсорбционного поведения на однородных и гетерогенных поверхностях. Линейный тип изотермы Ленгмюра выражается в уравнении (2):

$$\frac{C_e}{q_e} = \frac{1}{q_{max} \times K_L} + \frac{C_e}{q_{max}}, \quad (2)$$

где, C_e (мг/л) – равновесная концентрация в водной фазе, q_e и q_{max} (мг/г) – равновесная и максимальная разрушающая способность, а K_L (л/мг) – постоянная Ленгмюра.

Линейный тип изотермы Фрейндлиха выражается в (3) уравнении.

$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e \quad (3)$$

где, C_e (мг/л) и q_e (мг/г)-адсорбционная способность равновесных концентраций, а n (безразмерные) и K_F-константы Фрейндлиха [5].

3. Результаты и обсуждение

3.1 Анализ образцов с использованием рентгеноструктурный анализа. Анализ XRD показал, что цеолит состоит из в основном из клиноптилолит является основным минералом в образце и имеет небольшой состав морденита. На рис. 2 представлены результаты рентгеност- руктурного анализа цеолитного материала, который использовался для определения химического состава. XRD картина цеолитового материала свидетельствует о существовании цеолита типа клиноптилолита. Индексы Миллера клиноптилолитов типов (-131), (-421), (-222), (151) и (-602) можно определить по пикам при 2θ= 22,8°, 26°, 30,1, 32,67° и 44,2 на основании карточек №JCPDS 00-025-1349 и 01-079-1460.

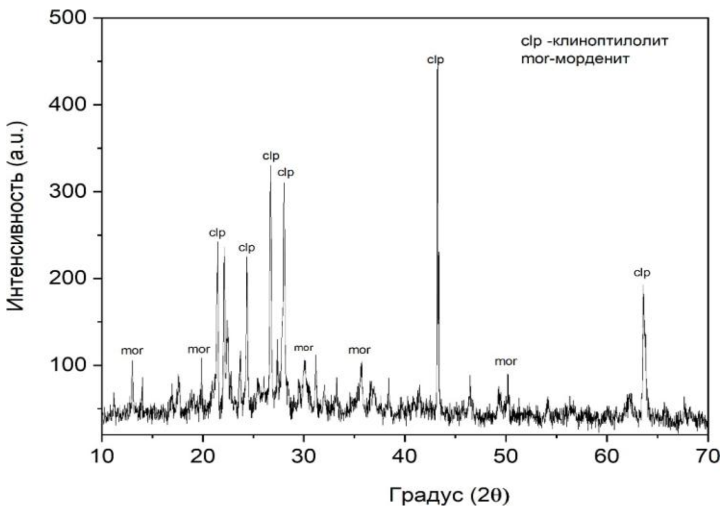

Рисунок 2 – Спектры рентгеноструктурного анализа природного цеолита

На таблице 1 представлена подробный анализ характеристик природного цеолита, основным компонентом которого является клиноптилолит. Массовая доля которого варьируется от 50 до 84%. Тем самым основная доля материала состоит из цеолита. Материал имеет твердость 4,5 по шкале Мооса, что указывает на его умеренную прочность, что дает возможность устойчивость к механическим воздействиям.

Таблица 1 – Основные физико-химические показатели природного цеолита

No.	Показатель	Характеристики
1.	Массовая доля цеолита, (%)	50-84
2.	Минеральная форма цеолита	клиноптилолит
3.	Твердость Моосу	4.5
4.	Химический состав (%): SiO_2 Al_2O_3 TiO_2 Fe_2O_3 MnO MgO CaO Na_2O K_2O P_2O_5 H_2O	 60-74 14-15 0.070-0.700 1.400-5.830 0.067-0.199 0-2.120 0.130-6.400 0.610-5.450 0.660-4.030 0.012-0.173 0-4.090
5.	Соотношение SiO_2/Al_2O_3	4.00-5.28

Соотношение SiO_2/Al_2O_3 указывает на умеренное количество алюминия (Al) и преобладает кремний (Si), это соотношение характерно для цеолитов с устойчивой кристаллической решеткой. Алюминий создает в структуре отрицательные заряды, которые компенсируются катионами и Функциональные группы цефтриаксона (например, карбоксильная и амино группы) могут образовывать водородные связи с поверхностью цеолита.

3.2 Исследование морфологии с помощью сканирующей электронной микроскопии и энергетической дисперсионной спектроскопии. Сканирующая электронная микроскопия (СЭМ) показывает, что природный цеолит имеет относительно гладкую поверхность с пористыми структурами. После модификации цеолита изображения СЭМ показывают значительное увеличение шероховатости поверхности и образование новых пор (Рис. 3). Модифицированный цеолит демонстрирует структурные изменения, такие как образование больших пор и трещин, что свидетельствует об улучшении его адсорбционных свойств. Если модификация включает добавление активных компонентов, можно наблюдать распространение новых функциональных групп или наночастиц. Эти изменения указывают на эффективность модифицированного цеолита в процессах адсорбции по сравнению с натуральным цеолитом.

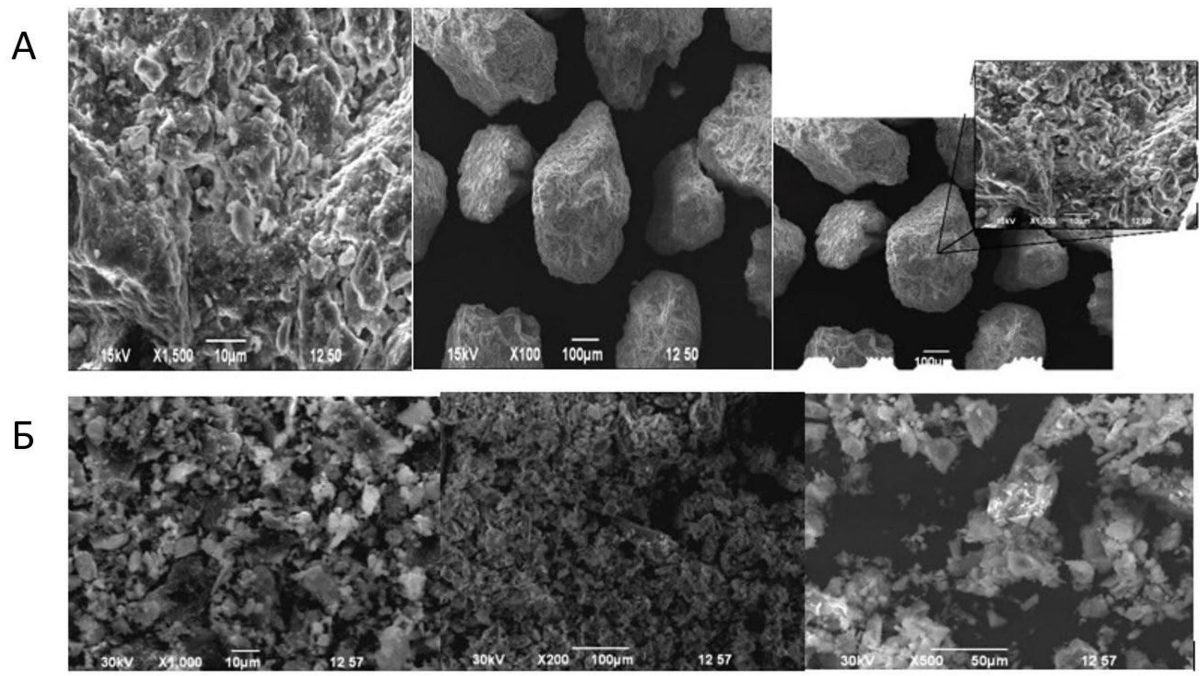

Рисунок 3 – СЭМ изображения природного(А) и модифицированного(В) цеолита

3.3 Исследование адсорбционных свойств материалов. Сорбцию проводили при pH 7 и при комнатной температуре перемешиванием при 200 об/мин. Изменения q_e в зависимости от C_e были проанализированы с помощью изотерм Ленгмюра и Фрейндлиха, которые представлены на рисунках 4-6. Параметры подгонки для обеих изотерм приведены в таблице 2. Данные о сорбции хорошо соответствует по модели Легнмюра (R^2>0.90). Значения N всех сорбентов в равновесном состоянии находились в диапазоне 0,30–0,73, что свидетельствовало о высокой нелинейности и благоприятности процесса сорбции. Коэффициенты корреляции (R^2) моделей Лангмюра были выше, чем у модели Фрейндлиха, что свидетельствует о монослойном механизме адсорбции. Максимальная сорбционная емкость близка к экспериментальному значению. Поэтому, исходя из средних значений обеих моделей, исследованных для всех образцов, модель Ленгмюра считается более приемлемой. Изотерма Ленгмюра предполагает монослойный характер процесса адсорбции. Модель предполагает, что скорости адсорбции и десорбции уравновешены и что все активные центры на поверхности адсорбента одинаковы.

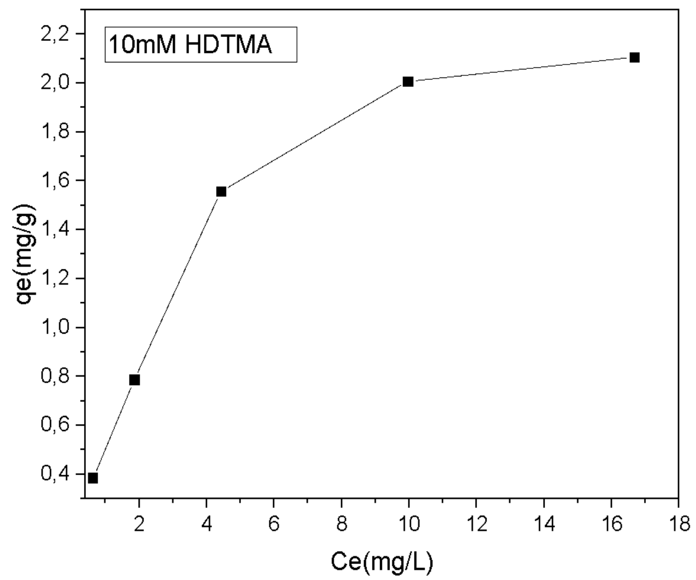

Рисунок 4 – Сорбционная изотерма цефтриаксона с модифицированным цеолитом ЦТАБ с раствором 10 мМ

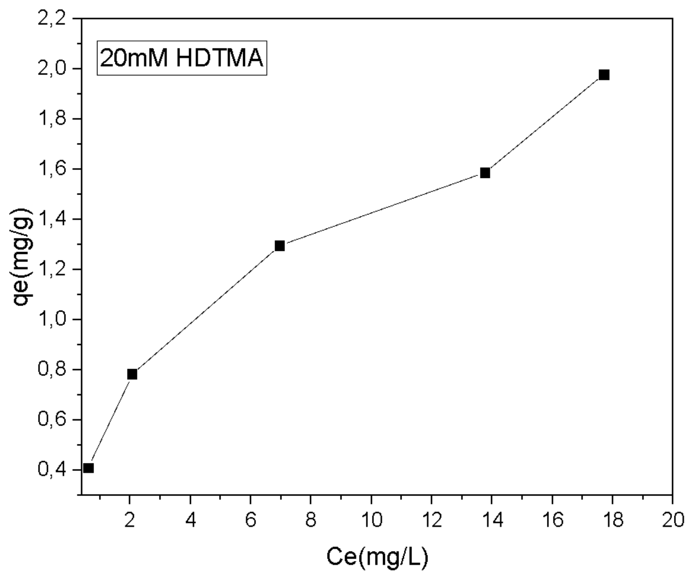

Рисунок 5 – Сорбционная изотерма цефтриаксона с модифицированным цеолитом ЦТАБ с раствором 20 мМ

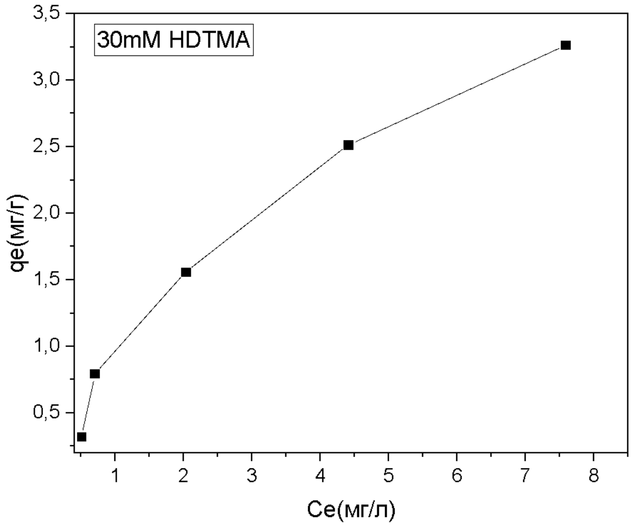

Рисунок 6 – Сорбционная изотерма цефтриаксона с модифицированным цеолитом ЦТАБ с раствором 30 мМ

Результаты расчетов по моделям Ленгмюра и Фрейндлиха указаны в таблице 2.

Для определения эффективности удаления сорбентов сорбенты помещались в раствор цефтиаксона с концентрацией 50 мг/л и измерялись в отрезке времени.

Сорбция цефтриаксона (Рис. 7) идут с высокой интенсивностью на первые 15 мин сорбции, далее эффективность удаления повышается 1-2%. Что свидетельствует о том, что поглощение идет только на поверхности сорбента и дальнейшие сорбция в микропорах не происходит.

Таблица 2 – Параметры модели для сорбции цефтриаксона

Сорбент	Модель Ленгмюра			Модель Фрейндлиха		
	q_{max} мг/г	K_L	R^2	N	K_F	R^2
Природный цеолит	0,0173	0,1834	0,9114	0,6194	0,5354	0,8559
10 mM ЦТАБ	3,5323	0,1862	0,9696	0,4614	2,6660	0,8373
20 mM ЦТАБ	4,2918	0,1605	0.8895	0,3078	3,8082	0,8547
30 mM ЦТАБ	2,5670	0,2979	0.9055	0,7397	2,8445	0,9029

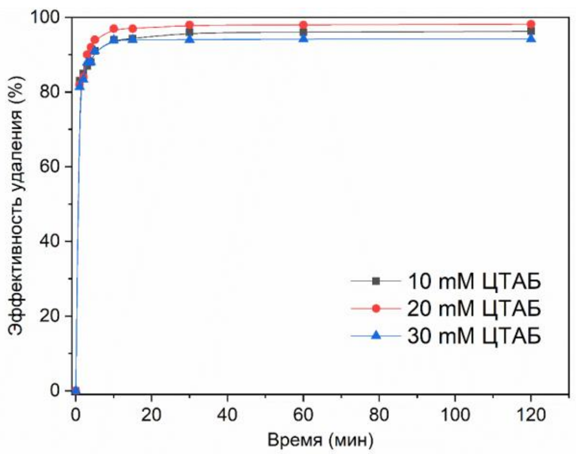

Рисунок 7 – Эффективность удаления цефтриаксона модифицированным цеолитом

Заключение

В данной работе был исследован сорбционные свойства природного цеолита Шанканайского месторождения (Алматинская область, Казахстан) и его модифицированных форм для удаления цефтриаксона из водных растворов. Адсорбент модифицированный с 20 мМ ЦТАБ-ом показал наибольшие сорбционные свойства с эффективностью удаления 97,3% за 15 мин сорбции и 93% для 30мМ, 95% для 10 мМ. Также были изучены физико-химические свойства минерала. Рентгенофазовый анализ подтвердил, что клиноптилолит являлся основ- ной минеральной фазой цеолита, а сканирую- щая электронная микроскопия показывала рост шероховатости поверхности и пористости после модификации. Экспериментальные изотермы адсорбции хорошо соответствуют модели Ленгмюра с коэффициентом детерминации более 0,90, что указывает на монослойный механизм сорбции. Основными механизмами взаимодействия цефтриаксона с модифицированными цеолитами являются электростатические силы, гидрофобные взаимодействия и межмолекулярные связи водородом. Есть несколько перспективных направлений для дальнейшего исследования с целью повышения эффективности: анализ влияния размера частиц цеолита; исследование влияния условий модификации; исследование опции восстановления сорбента.

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BIOTECHNOLOGICAL VALORIZATION OF PLANT BIOMASS FOR ECO-FRIENDLY PACKAGING VIA BACTERIAL PROCESSES

The growing environmental impact of petroleum-based plastic packaging has intensified the need for biodegradable and sustainable alternatives. Among these, bacterial cellulose stands out as a promising biomaterial due to its remarkable purity, mechanical strength, and nanofibrillar structure. Unlike plant-derived cellulose, bacterial cellulose is naturally synthesized by specific bacteria in a form free from lignin and hemicellulose, making it highly suitable for use in eco-friendly packaging and biomedical applications. This review highlights recent advances in the biotechnological valorization of plant biomass, particularly agricultural residues such as straw, stalks, and husks, for bacterial cellulose production. These lignocellulosic feedstocks are abundant, renewable, and offer significant potential as substrates for microbial fermentation. The paper explores the chemical composition of various biomass types and evaluates their suitability for bacterial cellulose synthesis based on their cellulose, hemicellulose, and lignin content. In addition, the review outlines the enzymatic steps involved in bacterial cellulose biosynthesis and the microbial strains primarily responsible for its production. Together, these insights provide a scientific foundation for converting plant-based waste into biodegradable cellulose-based materials, contributing to the development of sustainable packaging solutions and supporting the transition toward a circular bioeconomy.

Key words: bacterial cellulose; lignocellulosic biomass; sustainable packaging; agricultural residues; microbial fermentation.

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Өсімдік биомассасын бактериялық процестер арқылы экологиялық таза орауыш материалдарға биотехнологиялық бағалау

Мұнай негізіндегі пластикалық орау материалдарының қоршаған ортаға әсері артқан сайын, биодеградацияланатын және тұрақты баламалардың қажеттілігі күшейді. Осы баламалардың арасында бактериялық целлюлоза ерекше тазалығы, механикалық беріктігі және нано-талшықты құрылымы арқасында перспективалы биоматериал ретінде ерекшеленеді. Өсімдіктен алынған целлюлозадан айырмашылығы, бактериялық целлюлоза арнайы бактериялармен табиғи түрде синтезделеді және лигнин мен гемицеллюлозадан еркін түрде болады, бұл оны экологиялық таза орау материалдары мен биомедициналық қолданбалар үшін өте қолайлы етеді. Бұл шолу өсімдік биомассасын, әсіресе сабан, сабандық дәндер және қауыз сияқты ауылшаруашылық қалдықтарын бактериялық целлюлоза өндіруге арналған биотехнологиялық құндылығын арттырудағы соңғы жетістіктерге назар аударады. Бұл лигноцеллюлозды шикізаттар кеңінен таралған, жаңартылатын және микроорганизмдер арқылы ашыту үшін маңызды әлеуетке ие. Бұл жұмыс әртүрлі биомасса түрлерінің химиялық құрамын зерттейді және олардың целлюлоза, гемицеллюлоза және лигнин құрамына негізделген бактериялық целлюлоза синтезіне жарамдылығын бағалайды.

ғалайды. Сонымен қатар, шолу бактериялық целлюлоза биосинтезіндегі ферменттік қадамдарды және оның өндірісіне жауапты микроорганизмдер штамдарын сипаттайды. Осы мәліметтер өсімдік қалдықтарын биодеградацияланатын целлюлоза негізіндегі материалдарға айналдыру үшін ғылыми негізді қамтамасыз етіп, тұрақты орау шешімдерін дамытуға және айналмалы биоэкономикаға көшуге үлес қосады.

Түйін сөздер: бактериялық целлюлоза; лигноцеллюлозды биомасса; тұрақты орау; ауылшаруашылық қалдықтары; микроорганизмдер арқылы ашыту.

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Биотехнологическая утилизация растительной биомассы для экологичной упаковки через бактериальные процессы

Увеличение воздействия пластиковых упаковок на основе нефти на окружающую среду усилило потребность в биодеградируемых и устойчивых альтернативах. Среди них бактериальная целлюлоза выделяется как перспективный биоматериал благодаря своей замечательной чистоте, механической прочности и нановолокнистой структуре. В отличие от целлюлозы растительного происхождения, бактериальная целлюлоза синтезируется специфическими бактериями в форме, свободной от лигнина и гемицеллюлозы, что делает ее высоко пригодной для использования в экологичной упаковке и биомедицинских приложениях. Этот обзор освещает последние достижения в биотехнологической утилизации растительной биомассы, в частности сельскохозяйственных отходов, таких как солома, стебли и шелуха, для производства бактерийной целлюлозы. Эти лигноцеллюлозные сырьевые материалы обильны, возобновляемы и обладают значительным потенциалом в качестве субстратов для микроорганизмной ферментации. В статье рассматриваются химический состав различных типов биомассы и оценивается их пригодность для синтеза бактерийной целлюлозы на основе содержания целлюлозы, гемицеллюлозы и лигнина. Кроме того, обзор описывает ферментативные этапы, вовлеченные в биосинтез бактерийной целлюлозы, и микроорганизмные штаммы, которые в основном ответственны за ее производство. Совокупность этих данных предоставляет научную основу для преобразования растительных отходов в биодеградируемые материалы на основе целлюлозы, способствуя разработке устойчивых решений для упаковки и поддержке перехода к круговой биоэкономике.

Ключевые слова: бактериальная целлюлоза; лигноцеллюлозная биомасса; устойчивая упаковка; сельскохозяйственные отходы; микробная ферментация.

Introduction

Plastic packaging waste has emerged as a major global environmental concern [1]. Conventional petroleum-based polymers such as polyethylene (PE), polyethylene terephthalate (PET), and polypropylene (PP) are extensively utilized in food and consumer goods packaging due to their excellent mechanical strength and barrier properties [2,3]. However, the long-term persistence of these synthetic materials in the environment, along with their resistance to biodegradation, leads to the accumulation of plastic debris and the formation of microplastics both of which pose significant risks to ecosystems and human health [4]. In light of these issues, there is a growing demand for sustainable alternatives that are both biodegradable and environmentally benign. Among the most promising candidates is bacterial cellulose (BC) [5], a highly pure biopolymer synthesized by certain prokaryotic microorganisms [6]. Unlike plant-derived cellulose, which is typically extracted from wood or cotton and contains residual lignin and hemicellulose, BC is naturally produced by bacteria in a pristine form devoid of these impurities [7]. This results in an ultrafine nanofibrillar cellulose network with exceptional purity and structural integrity [8]. Such unique properties make BC an attractive material for a wide range of advanced applications, from biomedical engineering to the development of eco-friendly packaging solutions [9,10].

BC demonstrates a range of key attributes that make it highly suitable for use in packaging technologies [11]. Notably, its elevated degree of crystallinity and polymer chain alignment endow BC films with remarkable tensile strength reaching up to approximately 200 MPa in dry conditions while maintaining a high degree of flexibility [12,13]. Furthermore, BC exhibits exceptional resistance to oxygen and moisture permeation, often outperforming conventional bioplastic materials in barrier functionality [14]. The films produced from BC are typically transparent, flavourless, and inherently non-toxic, which renders them safe for direct contact with food products. In addition to these functional benefits, BC is fully biodegradable and compostable by nature; it undergoes decomposition in natural environments without generating harmful residues or microplastic particles [15]. These combined features position BC as a highly promising and environmentally responsible substitute for petroleum-based plastic packaging [16].

BC can be produced from renewable raw materials, particularly agricultural and industrial lignocellulosic residues [17]. Utilizing plant-based waste such as straw, stalks, and husks for BC synthesis aligns with circular economy principles by transforming low-value biomass into high-value bioproducts [18]. This review highlights recent advances in the biotechnological conversion of plant biomass into biodegradable packaging materials through bacterial processes. It begins with an overview of the chemical composition of common plant residues namely their cellulose, hemicellulose, and lignin content and evaluates their potential as substrates for microbial fermentation.

2 Plant biomass feedstocks: composition and availability

2.1. Agricultural lignocellulosic residues: composition and suitability for microbial conversion

Agricultural lignocellulosic residues refer to solid plant-based wastes generated as by-products of crop production that are not directly utilized for food or feed [19]. These biomass sources include the straw of cereal and leguminous crops such as wheat, barley, and rice; stalk and leaf residues of maize and sunflower; sugarcane bagasse; and the woody stems and hulls of cotton and other indus- trial crops [20,21]. Such residues are produced in enormous quantities annually, with global estimates reaching several billion tons of agricultural plant waste per year [22]. However, a significant portion of these materials remains underutilized, often being burned in open fields or left to decompose, leading not only to the loss of valuable resources but also to increased greenhouse gas emissions and air pollution [23]. Despite this, plant-derived lignocellulosic biomass holds substantial potential as an accessible and low-cost feedstock for renewable energy generation and bioproduct manufacturing [24].

Agricultural crop residues are primarily composed of lignocellulosic material, which is derived from the rigid cell walls of plant tissues [25]. Lignocellulosic biomass consists of three major structural components: cellulose, hemicellulose, and lignin (Figure 1). Cellulose is a long-chain polysaccharide made up of glucose monomers, forming the structural backbone of the plant cell wall and accounting for approximately 40–50% of the dry weight [26]. It assembles into microfibrils, providing high mechanical strength to plant fibers [27]. Hemicellulose, in contrast, is a branched heteropolymer composed of various pentose and hexose sugars; it binds cellulose microfibrils and, together with lignin, forms an amorphous matrix within the cell wall. In agricultural residues, hemicellulose typically makes up about 20–30% of the biomass [28]. Lignin is a complex, aromatic polymer built from phenylpropanoid units, conferring water resistance and structural rigidity to plant tissues, and is highly resistant to biological degradation [29]. The precise chemical composition of agricultural residues can vary significantly depending on the plant species, cultivar characteristics, and growing conditions [30].

The relative proportions of cellulose and lignin vary significantly among different types of agricultural residues. For instance, wheat straw contains a relatively low lignin content (~14%), whereas corn stover and sugarcane bagasse have higher lignin levels, around 20% [31, 32]. As reported by Fortunati et al. [33], the lignocellulosic profile of barley straw includes about 56.2% cellulose, 7% hemicellulose, and 9.2% lignin. The cellulose content also differs considerably: it exceeds 30–43% in rice straw [34], while in cotton stalks it typically ranges between 35% and 40% [35-37]. Cotton stalks exhibit even greater lignin content ranging from 20% to 31% which may contribute to their resistance to microbial degradation [38,39].

Environmental growing conditions also play a significant role; under stress conditions such as drought, plants tend to enhance lignin biosynthesis to reinforce their cell walls [40]. Daniel et al. [41] showed that water deficiency led to an approximately 18.4% increase in lignin content in Douglas-fir wood under drought-induced abiotic stress. Certain residues also contain distinct inorganic components for instance, rice straw can have up to ~18% ash content in the form of silicon dioxide, which further complicates microbial breakdown [42]. Overall, the high cellulose and hemicellulose content in agricultural residues highlights their potential as feedstocks for microbial conversion into fermentable sugars and various bioproducts. However, a high lignin content can act as a limiting factor, reducing the overall efficiency of bioconversion processes (Table 1) [43,44].

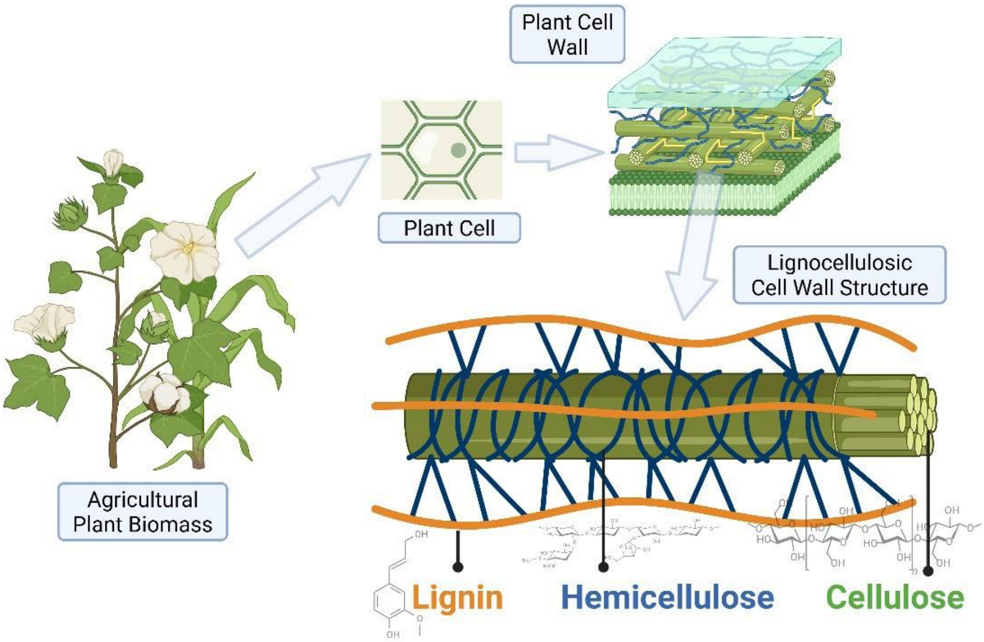

Figure 1 – Lignocellulosic structure of agricultural plant biomass. Cellulose microfibrils (green) are bound by hemicellulose chains (blue) and embedded in a lignin matrix (orange), forming a strong and integrated plant cell wall network.
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Table 1 – Composition of lignocellulosic components in various agricultural residues

Type of Residue	Cellulose, %	Hemicellulose, %	Lignin, %	References
Wheat straw	37	26.5	14	[31, 32]
Barley straw	56.2	7	9.2	[33]
Corn stover (stalks)	35.2	25.1	23.7	[31, 32]
Rice straw	30-43	27.9	17.2	[34]
Sugarcane bagasse	41.6	25.1	20.3	[31, 32]
Cotton stalks	35–40	20–25	20–31	[35-37], [38,39]
Hardwood stem	40–50	24–40	18–25	[45]
Softwood stem	45–50	25–35	25–35	[45]
Nut shells	25–30	25–30	30–40	[45]
Grasses	25–40	35–50	10–30	[45]
Leaves	15–20	80–85	0	[45]
Sorted refuse	60	20	20	[45]

Continuation of the table

Type of Residue	Cellulose, %	Hemicellulose, %	Lignin, %	References
Coastal Bermuda grass	25	35.7	6.4	[45]
Switch grass	30–50	10–40	5–20	[45]
Solid cattle manure	1.6–4.7	1.4–3.3	2.7–5.7	[45]
Swine waste	6	28	-	[45]
Primary wastewater solids	8–15	-	24–29	[45]
Paper	85–99	0	0–15	[45]
Newspaper	40–55	25–40	18–30	[45]
Waste papers from chemical pulps	60–70	10–20	5–10	[45]

To enable the efficient microbial conversion of lignocellulosic residues, it is first necessary to disrupt their complex structure, as cellulose microfibrils are tightly embedded within a matrix of lignin and hemicellulose in their natural state [46]. This arrangement acts as a physical barrier, significantly limiting enzyme access and hindering microbial degradation [47]. In a study by Mosier et al. [48] it was shown that lignin not only blocks enzymatic access but also adsorbs enzyme molecules onto its surface, thereby reducing their activity and decreasing bioconversion efficiency. Furthermore, phenolic compounds such as vanillin, ferulic acid, and furfuralgenerated during thermochemical pretreatment are known to exert toxic effects on microorganisms and inhibit fermentation [49]. Therefore, recent studies recommend pretreatment strategies to alter the lignocellulosic structure and improve substrate accessibility. For instance, Kumar et al. [50] demonstrated that acid, alkaline, and steam-based pretreatments enhance enzymatic access to cellulose. Following pretreatment, enzymatic hydrolysis is performed, breaking down polysaccharides into glucose and xylose monomers. According to Chandel et al. [51] the yeast *Saccharomyces cerevisiae* is the most widely used strain in fermentation processes. In addition, filamentous fungi such as *Aspergillus*, *Trichoderma*, and *Rhizopus*, as well as bacteria like *Clostridium* and *Lactobacillus*, are effectively employed to produce various biochemicals. In summary, the main challenge in converting agricultural lignocellulosic waste into bio-based products via microbial processes lies in their inherent resistance to biological degradation. However, modern biotechnological solutions such as optimized pretreatment methods, enzyme cocktails, and selected microbial strains offer promising strategies to overcome these limitations.

3. Microbiological synthesis of BC

3.1. Key bacterial strains responsible for cellulose biosynthesis

BC is an exopolysaccharide nanomaterial synthesized by specific microbial species. Unlike plant-derived cellulose, BC is characterized by its exceptional purity, high water-holding capacity, and robust three-dimensional fibrous architecture [52,53]. The most efficient BC-producing microorganisms are Gram-negative rods belonging to the acetic acid bacteria group. Among them, *Komagataeibacter xylinus* (*K. xylinus*) is widely recognized for its high cellulose productivity [54]. Other closely related strains such as *K. Hansenii* [55], *K. Rhaeticus* [56], *K. Sucrofermentans* [57], and *K. Medellinensis* [58] also exhibit strong cellulose-synthesizing capabilities and are extensively used in both fundamental research and industrial-scale BC production.

K. xylinus has been extensively studied as a model organism in this group due to its high cellulose-producing capacity and well-characterized biosynthetic pathways [59]. These bacteria are known to form thick surface layers often referred to as the “mother of vinegar” and are commonly found in sugar-rich substrates such as fermented tea (kombucha), fruit juices, and palm sap [60,61]. The cellulose forms a floating biofilm that enables the cells to remain at the air–liquid interface, thereby facilitating efficient oxygen uptake [62]. As a result, BC is typically synthesized at the interface between the liquid medium and the air, making oxygen availability a critical factor for optimal production. Species of *Komagataeibacter* are obligate aerobes that derive energy through partial oxidation of carbon sources [63,64]. For instance, glucose is converted to gluconic acid and ethanol to acetic acid, and these metabolic by-products lead to acidification of the culture medium. This metabolic behavior not only supports cellulose biosynthesis but also influences the physicochemical conditions of the surrounding environment [65,66].

The metabolic profile of *Komagataeibacter* strains is closely linked to their cellulose-producing ability [67]. Cellulose producers exhibit ~100-fold higher UDP-glucose pyrophosphorylase activity compared to non-producers, facilitating efficient synthesis of UDP-glucose a key precursor for cellulose biosynthesis [68]. Essential genes (*bcsA*, *bcsB*, *bcsC*, *bcsD*) are organized into operons. In *K. xylinus*, two operon types have been identified: type I includes the core *bcs* genes and regulatory elements (*cmcAx*, *ccpAx*, *bglAx*), while type II contains an additional acyltransferase gene, potentially involved in acylated cellulose production. These genetic features influence the quantity and quality of BC [69].

3.2 Biochemical pathway and regulation of BC biosynthesis

The biosynthesis of BC involves several sequential enzymatic steps [70]. When glucose is used as the carbon source, it is first phosphorylated to glucose-6-phosphate by the enzyme glucokinase upon entering the cell [71]. In the second step, glucose-6-phosphate (Glc6P) is isomerized to glucose-1-phosphate (Glc1P) through the catalytic action of phosphoglucomutase [72]. In the third step, Glc1P is converted into uridine diphosphate glucose (UDP-glucose) via the enzyme UDP-glucose pyrophosphorylase (UGPase) [73]. This reaction involves the condensation of Glc1P with UTP, releasing pyrophosphate and forming high-energy UDP-glucose [74]. UDP-glucose is an activated compound that serves as the direct precursor for cellulose biosynthesis [75]. While it is a common intermediate in the synthesis of various polysaccharides in many microorganisms, only certain specialized bacteria possess the ability to polymerize UDP-glucose into cellulose (Figure 2) [76]. In cellulose-producing bacteria, the exceptionally high activity of UGPase and the enhanced flux through associated pathways promote the accumulation and efficient utilization of UDP-glucose for polymerization [77]. The fourth and principal step is the polymerization of UDP-glucose. This process is catalyzed by a membrane-bound multienzyme complex known as cellulose synthase, which sequentially adds glucosyl residues from UDP-glucose to elongate the β-1,4-glucan chain [78,79].

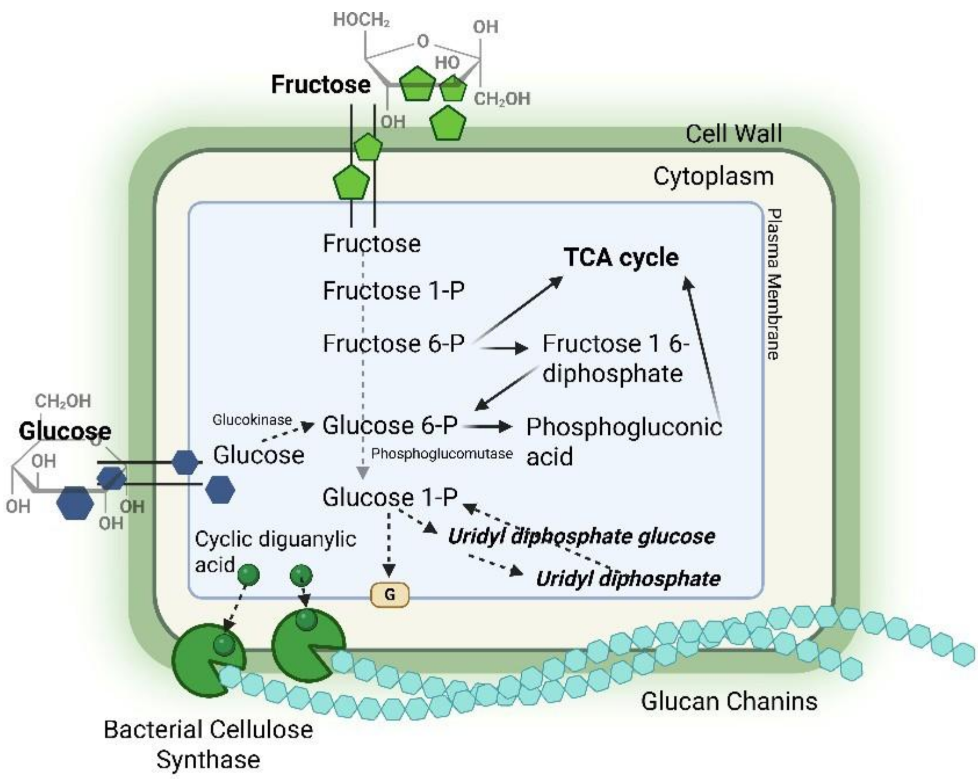

Figure 2 – Cellulose formation mechanism in K. xylinus
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The cellulose synthase complex is anchored in the inner cytoplasmic membrane and is composed of protein products encoded by the *bcs* operon. At the core of the complex are the BcsA and BcsB proteins [80]. BcsA is an integral membrane protein with multiple transmembrane domains; its cytosolic region contains a glycosyltransferase catalytic site and a PilZ domain that binds the second messenger cyclic di-GMP (c-di-GMP) [81]. BcsB is a periplasmic protein that non-covalently associates with BcsA and contains carbohydrate-binding domains, which assist in guiding the nascent glucan chain through the cell envelope. The activity of this enzyme complex is directly regulated by c-di-GMP, which allosterically binds to the PilZ domain of BcsA, thereby activating its glycosyltransferase function [82,83]. Studies in *Gluconacetobacter xylinus* (now *K. xylinus*) and other cellulose-producing bacteria have shown that elevated intracellular levels of c-di-GMP significantly enhance cellulose biosynthesis [84,85]. The concentration of c-di-GMP is dynamically controlled by the opposing activities of two types of enzymes: diguanylate cyclases (DGCs) and phosphodiesterases (PDEs), which respond to environmental cues and thus indirectly regulate the rate of cellulose synthesis [86,87].

BC biosynthesis begins with the synthesis of β-1,4-glucan chains on the inner membrane, which are transported through the periplasm and extruded via the BcsC pore in the outer membrane [88]. These chains self-assemble into protofibrils (~2–4 nm), microfibrils (~80 nm), and eventually ribbon-like nanofibers [89-91]. Core proteins (BcsA–C) drive synthesis, while BcsD aids in fibril crystallization its deletion in *K. xylinus* reduces yield by up to 90%. Auxiliary genes like *ccpAx*, *cmcAx*, and *bglAx* assist in cellulose modification. Biosynthesis is sensitive to environmental factors [68]. Optimal pH (~6.0) is essential, while byproducts like gluconic acid lower pH and inhibit production; buffering agents (e.g., sodium acetate) help stabilize conditions. Genetic modifications (e.g., *gdh* knockouts or chemically induced mutants) improve yield by minimizing acid production and optimizing NADH usage [68,92]. Oxygen availability is also critical: static cultures may suffer from limited diffusion, whereas aeration systems enhance productivity though excessive agitation can reduce yield [93]. Overall, BC synthesis is a highly regulated process influenced by genetics, metabolism, and culture conditions, with modern biotechnological advances enabling more efficient industrial-scale production.

4. BC derived from agricultural residues and its properties for packaging applications

BC is a highly pure polymer produced by certain bacteria, with nanofibers thinner and more ordered than those of plant cellulose [94]. As a natural biomaterial, BC offers an eco-friendly alternative to petroleum-based plastics. However, its industrial production traditionally relies on expensive carbon sources like glucose and yields remain relatively low [95]. To address this, recent studies have focused on using agricultural residues and by-products as cost-effective substrates to reduce production costs and enhance sustainability. These waste materials such as fruit peels, straw, bagasse, rice husks, corn cobs, and glycerol by-products contain abundant carbohydrates, nitrogen compounds, and micronutrients, making them viable substitutes for conventional media [96,97]. This section reviews recent advances in BC production from agro-waste, examines its packaging-related properties, and compares BC-based films to traditional plastics.

4.1 Research on BC production from agricultural waste

Recent studies have demonstrated that various agricultural and food industry wastes can serve as low-cost substrates for BC production. For example, Andritsou et al. [98] evaluated the potential of citrus waste, using unsold orange and grapefruit juices and their aqueous peel extracts as media for *Komagataeibacter sucrofermentans*. After 6–7 days of cultivation, BC yields reached 6.7 g/L and 6.1 g/L, respectively. Lower yields were observed when using lemon, grapefruit, and orange peel extracts—5.2, 5.0, and 2.9 g/L, respectively. BC produced from orange peel hydrolysate exhibited significantly higher water-holding capacity, degree of polymerization, and crystallinity compared to samples derived from purified plant cellulose [98,99]. Starchy vegetable waste can also serve as an effective substrate. Abdelraof et al. [100] reported that acid-pretreated potato peel hydrolysate supported the production of 4.7 g/L of BC by *Gluconacetobacter xylinus* after 6 days under optimal conditions (35 °C, pH 9, and 8% inoculum in the initial medium). Sugar industry and fruit processing residues have also been investigated as substrates. Abol-Fotouh et al. utilized a newly isolated strain, *Komagataeibacter saccharivorans* MD1, to produce BC from date juice waste, fig processing residues, and sugarcane molasses. After 168 hours of incubation, the highest yield was achieved using molasses-based medium (~3.9 g/L), compared to only ~1.1 g/L in conventional HS medium [101,102]. Researchers reported that BC produced in agro-waste-based media showed no significant differences in fiber diameter or branching structure compared to samples grown in glucose-based media, indicating that nutrient extraction from waste substrates does not adversely affect cellulose quality [102]. Cereal straw and other biomass-based substrates have also proven effective. In a study by Ishola et al., two natural *Komagataeibacter* strains isolated from rotten banana and kombucha were used for fermentation with enzymatic hydrolysates of corncob and sugarcane bagasse as substrates [103]. This study compared static, intermittent, and continuous agitation modes. Continuous stirring significantly improved BC yield: *Komagataeibacter sp*. (CCUG73629) produced 1.6 g/L in corncob hydrolysate under agitation, versus 0.9 g/L in static HS medium. Similarly, strain CCUG73630 yielded 1.2 g/L from sugarcane bagasse under agitation, compared to just 0.3 g/L under static conditions. Another promising direction is the use of food industry by-products, such as apple pomace from juice production and stale bread hydrolysate. Esmail et al. [104] demonstrated that sugar mixtures derived from these wastes significantly enhanced BC production by *K. xylinus* DSM 2004. Cultivation in apple pomace alone yielded ~1.5 g/L of BC, which increased to 3.38 g/L when supplemented with nitrogen sources. Similarly, BC yield from bread hydrolysate rose to 2.07 g/L with nutrient supplementation. The BC produced in this medium also exhibited distinctive structural and functional properties: films derived from apple pomace were thicker, showed slightly higher crystallinity (59–69% vs. 55%), greater tensile modulus and strength, and lower moisture absorption and oxygen/CO_2 permeability compared to those from bread hydrolysate.

4.2 Functional properties of BC for packaging applications

The structural features of BC provide it with several unique material properties. Most notably, BC forms a three-dimensional network of nanofibers with diameters in the nanometer range. It exhibits a very high degree of crystallinity typically between 70–90% or even higher contributing to its excellent mechanical strength and stability [102, 105]. High crystallinity and strong intermolecular hydrogen bonding provide BC with excellent mechanical strength. In dry conditions, pure BC films often surpass many polymers in tensile strength. For instance, compressed BC films can reach tensile strengths of 150–200 MPa, exceeding those of some conventional plastics such as PET. Additionally, BC exhibits a high elastic modulus, which can exceed 10 GPa [103,106]. BC is also favourable in terms of flexibility: thin cellulose films remain pliable and retain a certain degree of elasticity and stretchability without becoming brittle [107]. This property is also moisture-dependent: in a hydrated state, BC is very soft and elastic which is why it is widely used in wound dressings whereas in a fully dry state, it becomes stiffer. However, its flexibility can be adjusted by adding plasticizers or maintaining a humid environment.

In addition to mechanical strength, an essen- tial property for packaging materials is their barrier performance specifically, the ability to prevent the transmission of water vapor and gases [108]. BC demonstrates excellent oxygen barrier properties due to its dense nanofibrous structure, which effectively blocks oxygen molecules. In fact, its gas permeability is significantly lower than that of common plastics such as PE and PP [109]. For example, BC films derived from apple pomace have been experimentally shown to exhibit reduced permeability to both oxygen and carbon dioxide compared to standard samples [104]. BC-based films can also act as a barrier to microbes—its dense nanostructure is impermeable to bacteria. Moreover, incorporating natural antimicrobial agents into the cellulose matrix enables the development of active packaging capable of protecting food from spoilage microorganisms. Regarding moisture permeability, pure BC is a hydrophilic polymer, which limits its effectiveness as a water vapor barrier. It readily absorbs moisture, and under high ambient humidity, its gas barrier performance may decrease accordingly [110]. However, this limitation is being addressed through various scientific approaches. One strategy involves coating BC films with hydrophobic layers such as waxes or plant oil-based nanoparticles to create water-resistant composite materials [111]. Another approach is to blend the cellulose matrix with natural poly- mers like pectin or carboxymethyl cellulose, which reduces moisture sensitivity and enhances water vapor barrier properties [112,113]. For instance, researchers in China developed a composite BC film by incorporating soy protein and applying a thin oil-based surface layer. The resulting material was fully transparent, mechanically robust, and showed improved water resistance [114,115].

Another key advantage of BC is its biodegradability. As a pure form of cellulose, BC can be readily broken down by environmental microorganisms such as fungi and bacteria that produce cellulase enzymes into water, carbon dioxide, and biomass. Studies have shown that BC films undergo complete degradation in soil within a few weeks; in some cases, total breakdown has been observed within 40 days [107, 116]. Importantly, BC does not require specialized industrial composting conditions it decomposes naturally under ambient environmental conditions. In contrast, one of the most widely used commercial bioplastics, polylactic acid (PLA), degrades only under industrial composting settings and takes several months to break down; in soil or at room temperature, its degradation is extremely slow and may take years. On the other hand, polyhydroxyalkanoates (PHAs) can undergo complete mineralization in various natural environments, including marine settings, within a few months to a year [117-119]. BC, being structurally like plant cellulose, follows a comparable environmental degradation pathway like that of natural cellulose fibers found in paper or wood making its breakdown both rapid and non-toxic. This property enables BC-based packaging to be composted directly after use, allowing it to re-enter the biological cycle in a sustainable and circular manner (Figure 3).

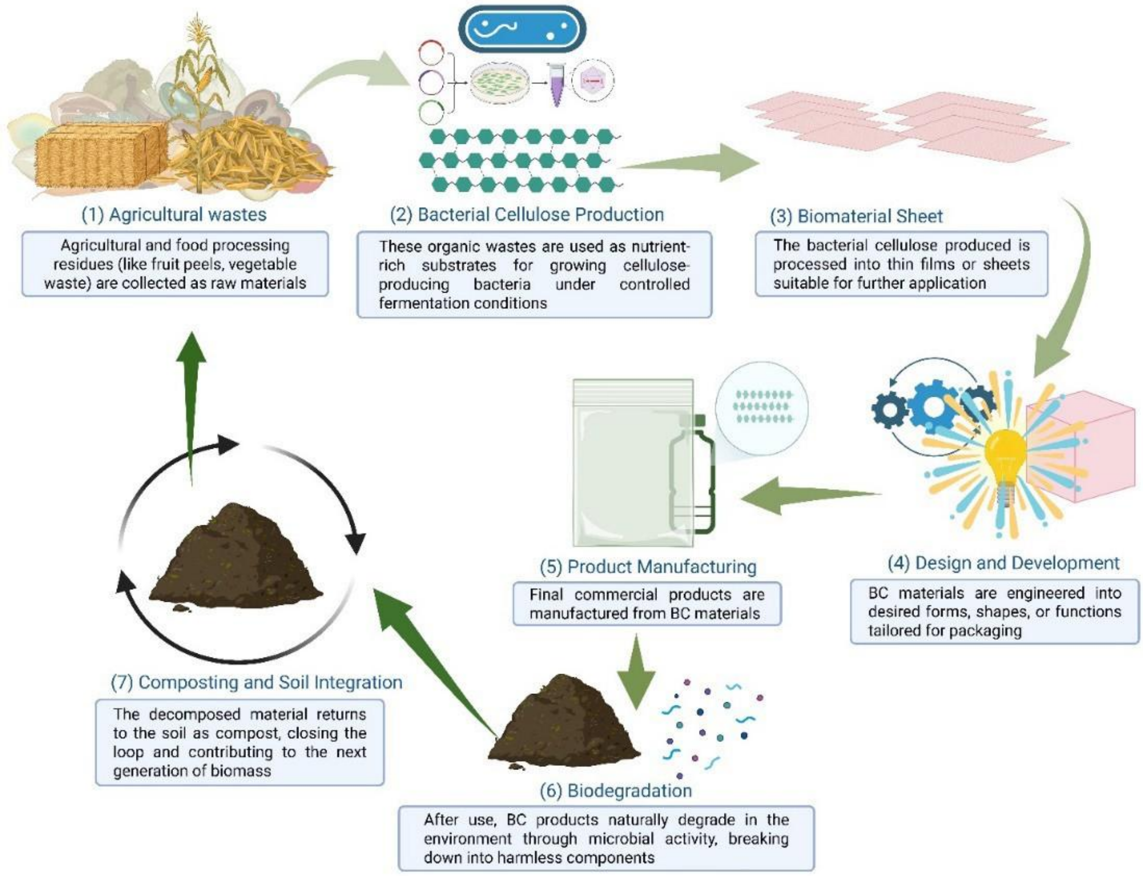

Figure 3 – The cycle of utilizing agricultural waste for the production and application of BC-based packaging materials
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4.3 Comparison with conventional plastics and other materials

BC-based packaging materials can be compared to conventional petrochemical plastics (e.g., PE, PET) and modern bioplastics (PLA and PHA) across several aspects. In terms of mechanical strength, BC matches or even surpasses many plastics. For instance, the tensile strength of high-density PE is approximately 20–30 MPa, and PET films range from about 50–70 MPa. In contrast, properly dried pure BC films typically reach 50–100 MPa and can be enhanced up to 150–200 MPa through specific processing techniques [107,120,121]. Thus, BC-based packaging can serve as a viable alternative to plastics in applications that require mechanical durability such as impact resistance or load bearing during transportation.

In terms of barrier properties, BC outperforms many polymers particularly in blocking oxygen and aroma compounds [122]. Polyolefins such as PE and PP allow relatively high permeability to oxygen and carbon dioxide due to their non-polar molecu- lar structure. In contrast, cellulose films are rich in polar hydroxyl groups, which can adsorb gas mol- ecules within their structure and significantly hin- der their diffusion [123,124]. Therefore, BC-based packaging demonstrates excellent protective capabilities in vacuum-sealed applications or for foods sensitive to oxidation. While polyesters like PET also provide moderate oxygen barrier properties, their effectiveness increases mainly with thickness [125,16]. In contrast, due to its nanostructured architecture, BC can offer high barrier performance even in very thin layers. As previously mentioned, hydrophobic plastics such as PE and PP have a clear advantage in water vapor resistance, they are virtually impermeable to moisture [127,128]. For this reason, moisture-sensitive products like dry foods, pharmaceuticals, and electronics are often packaged in such materials. In its pure form, BC is less effective in this aspect. However, water resistance is being successfully enhanced through the development of composite structures, such as BC combined with biodegradable polymers or coated with thin hydrophobic layers [129,130]. In terms of environmental and health safety, the advantages of BC and other biopolymers are clear (Figure 4) [131]. Petroleum-derived plastics such as PE, PET, and others persist in the natural environment for hundreds of years, contributing significantly to plastic pollution. Moreover, their production processes generate substantial amounts of greenhouse gas emissions [132,133]. There are also notable differences in production processes and practical applications. Conventional thermoplastics are processed through high-temperature techniques such as melt molding, blow molding, or extrusion [134]. In contrast, BC is produced through low-temperature fermentation, during which it grows directly into its final form typically as a surface membrane. This means that BC production consumes significantly less energy but proceeds more slowly, often requiring several days per batch [135,136]. Plastics, on the other hand, can be extruded and molded within minutes, allowing for rapid mass production. To address this limitation, current research focuses on intensifying BC fermentation through strategies such as agitated cultures and continuous feeding [137]. Additionally, emerging approaches include shaping BC into filaments via 3D printing or extrusion, which can then be woven into textile-like materials for various structural applications [138,139].

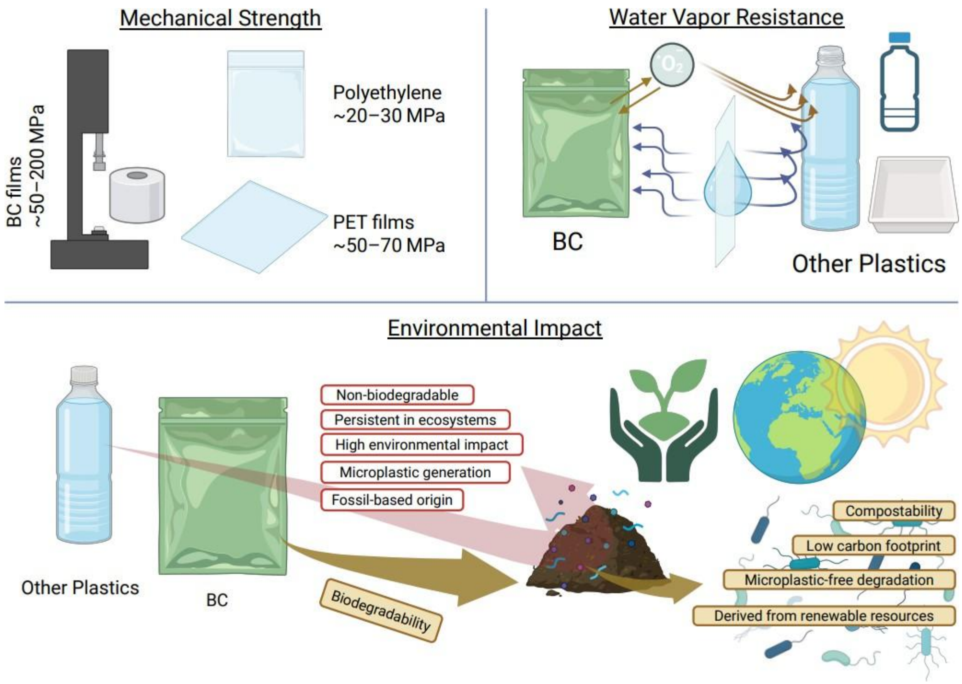

Figure 4 – Comparison of BC and conventional plastics in packaging applications
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BC derived from agricultural waste is emerging as a highly promising material for packaging applications due to its outstanding mechanical strength, excellent gas barrier properties, complete biodegradability, and the ability to be processed into thin, transparent films. By utilizing BC-based packaging, we can reduce plastic waste and contribute to environmental improvement, while also transforming agricultural and food industry residues into high-value, functional materials. However, for large-scale industrial implementation, several challenges remain such as enhancing fermentation productivity, accelerating production processes, improving moisture resistance, and increasing overall economic feasibility.

Conclusion

In conclusion, this review highlights the high potential of converting lignocellulosic plant biomass into environmentally friendly packaging materials through bacterial biotechnology. Monosaccharides derived from the hydrolysis of primary biomass components such as cellulose and hemicellulose can serve as carbon sources for bacteria during fermentation. Certain acetic acid bacteria can polymerize these sugars to produce extracellular BC. Utilizing agro-industrial residues as accessible carbon sources not only reduces the production cost of BC but also promotes process sustainability. Due to its high purity, strength, and biodegradability, BC represents a valuable and sustainable alternative for packaging. Compared to conventional plastics and some bioplastics, BC stands out for its complete biodegradability and origin from renewable waste materials. However, scaling BC production to an industrial level still faces several challenges, including high production costs and difficulties in upscaling and standardizing the process. Furthermore, the brittleness and moisture sensitivity of pure BC films complicate their direct substitution for plastic materials. To overcome these limitations, it is necessary to optimize bioreactor processes, improve high-yield bacterial strains through genetic engineering, and develop new BC-based composite materials. In addition, future directions should focus on industrial-scale implementation, comprehensive life cycle assessment to confirm environmental benefits, and integration of BC packaging into the circular bioeconomy. These efforts will significantly contribute to the development of zero-waste production and sustainable consumption systems.

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ECOLOGICAL SUSTAINABILITY AND ADAPTIVE POTENTIAL OF PEAR VARIETY 'TALGARSKAYA KRASAVITSA' UNDER AGROTECHNICAL APPROACHES

In the current conditions of the agricultural sector, improving the quality of fruit crops and opti- mizing agrotechnical cultivation methods are pressing tasks. This study investigates the ecological and biological characteristics of the pear variety "Talgarskaya Krasavitsa" grown in the botanical garden of Khoja Akhmet Yassawi International Kazakh-Turkish University (IKTU). The aim of the research is a comprehensive assessment of the impact of various agrotechnical methods on the growth, develop- ment, and productivity of this variety in order to enhance its economic efficiency. The study includes an analysis of domestic and international practices in pear cultivation, an examination of the morphological and physiological traits of the variety, and an evaluation of the impact of different agrotechnical meth- ods on plant productivity. Field and laboratory methods were employed to assess biometric indicators, including spectrophotometric analysis of photosynthetic pigments, biometric measurements of trees, and fruit quality analysis. The research results demonstrated that the application of updated agrotechni- cal technologies, including additional fertilization and growth stimulants, contributed to increased pro- ductivity, enhanced fruit mass, and improved chemical composition. A strong positive correlation was established between trunk diameter and plant productivity ($r \approx 0.986$), confirming the effectiveness of optimized agrotechnical practices. The scientific novelty of the study lies in the comprehensive analysis of the impact of various agrotechnical methods on the biometric and physiological parameters of the "Talgarskaya Krasavitsa" variety. The practical significance of the work is related to the development of recommendations for optimizing pear cultivation under continental climate conditions, which can be useful for farmers engaged in commercial horticulture and agronomists.

Key words: agrotechnical methods, phenology, spectrophotometry, correlation.

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«Талгарская красавица» алмұрт сортының агротехникалық тәсілдер жағдайындағы экологиялық тұрақтылығы мен бейімделу потенциалы

Қазіргі заманғы аграрлық сала жағдайында жеміс дақылдарының сапасын арттыру және оларды өсірудің агротехникалық әдістерін оңтайландыру өзекті міндет болып табылады. Бұл мақалада ХҚТУ ботаникалық бағында өсірілген «Талгарская красавица» алмұрт сортының экологиялық-биологиялық ерекшеліктері зерттелген. Зерттеудің мақсаты – экономикалық тиімділігін арттыру үшін осы сорттың өсуіне, дамуына және өнімділігіне әртүрлі агротехникалық әдістердің әсерін кешенді бағалау. Жұмыс барысында алмұрт дақылдарын өсірудің отандық және шетелдік тәжірибесіне талдау жүргізілді, сорттың морфологиялық және физиологиялық ерекшеліктері зерттелді, сондай-ақ өсімдіктердің өнімділігіне әртүрлі агротехникалық әдістердің әсері бағаланды. Биометриялық көрсеткіштерді бағалау үшін далалық және зертханалық әдістер қолданылды, соның ішінде фотосинтетикалық пигменттердің спектрофотометриялық талдауы, ағаштардың биометриялық өлшемдері және жеміс сапасын талдау. Зерттеу нәтижелері қосымша тамақтану мен өсу стимуляторларын қоса алғанда, жаңартылған агротехникалық технологияларды қолдану өнімділікті арттыруға, жеміс массасын арттыруға, сондай-ақ олардың химиялық құрамын жақсартуға ықпал ететінін көрсетті. Магистральдық диаметр мен өсімдік өнімділігі ($r \approx 0,986$) арасында күшті оң корреляция орнатылды, бұл оңтайландырылған агротехникалық шаралардың тиімділігін растайды. Зерттеудің ғылыми жаңалығы әртүрлі агротехникалық әдістердің

«Талгарская красавица» сортының биометриялық және физиологиялық параметрлеріне әсерін кешенді талдаудан тұрады. Жұмыстың практикалық маңыздылығы континентальды климат жағдайында алмұрт өсіруді оңтайландыру бойынша ұсыныстарды әзірлеумен байланысты, бұл өнеркәсіптік бау-бақша фермерлері мен агрономдары үшін пайдалы болуы мүмкін.

Түйін сөздер: агротехникалық тәсіл, фенология, спектрофотометрия, корреляция.

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Экологическая устойчивость и адаптивный потенциал сорта груши «Талгарская красавица» при агротехнических подходах

В современных условиях аграрного сектора повышение качества плодовых культур и оптимизация агротехнических методов их выращивания являются актуальной задачей. В данной статье рассмотрены экологические и биологические особенности сорта груши «Талгарская красавица», выращенного в ботаническом саду МКТУ. Цель исследования – комплексная оценка влияния различных агротехнических методов на рост, развитие и продуктивность данного сорта с целью повышения его экономической эффективности. В рамках работы проведён анализ отечественно- го и зарубежного опыта выращивания грушевых культур, изучены морфологические и физиологические особенности сорта, а также дана оценка влияния различных агротехнических приёмов на продуктивность растений. Для оценки биометрических показателей использовались полевые и лабораторные методы, включая спектрофотометрический анализ фотосинтетических пигментов, биометрические измерения деревьев и анализ качества плодов. Результаты исследования показали, что применение обновлённых агротехнических технологий, включая дополнительные подкормки и стимуляторы роста, способствует повышению продуктивности, увеличению массы плодов и улучшению их химического состава. Установлена высокая положительная корреляция между диаметром ствола и продуктивностью растений ($r \approx 0{,}986$), что подтверждает эффективность оптимизированных агротехнических мероприятий. Научная новизна исследования заключается в комплексном анализе влияния различных агротехнических методов на биометрические и физиологические параметры сорта «Талгарская красавица». Практическая значимость работы связана с разработкой рекомендаций по оптимизации выращивания груш в условиях континентального климата, что может быть полезно для фермеров, занимающихся промышленным садоводством, и агрономов.

Ключевые слова: агротехнические приёмы, фенология, спектрофотометрия, корреляция.

Introduction

In the current context, sustainable development of agriculture and improving the quality of fruit crops are especially relevant. One promising area is the study of the economic and biological characteristics of pear varieties that have high nutritional value, excellent taste, and significant economic potential [1,2].

The pear variety «Talgarskaya Krasavitsa» possesses favorable economic and biological characteristics, including high productivity (up to 35-40 kg per tree under optimal conditions). The fruits are medium-sized (180-220 g), contain high sugar levels (14-16%), and maintain good storage qualities for up to 4-5 months. Trees reach a height of 4-5 meters and are characterized by steady growth, drought resistance, and adapt- ability to various soil conditions. To increase productivity, it is recommended to use additional pollinators such as the varieties «Conference» or «Bogatyr» [3-5].

According to Zargar et al., their study demonstrated that foliar fertilizers under drought conditions contribute to improved pear tree productivity and efficient utilization of water resources. Additionally, fertilizers have a positive ecological impact by preserving soil fertility. Foliar feeding methods reduce harmful environmental effects, offering an effective solution for sustainable development in agriculture [6].

Sozaeva et al. studied the pectin content and physicochemical properties of various fruit crops. The researchers compared the pectin composition in different fruits and determined its role in enhancing the nutritional and functional characteristics of plant products. The results showed that pectin contributes to improving the structure, taste, and consistency of fruits, highlighting its significant applications in agronomy and the food industry [7].

In her study, Alekseenko S. investigated economically valuable traits of introduced and local pear varieties adapted to the climatic conditions of the Almaty region. The researcher compared yield, fruit quality, resistance characteristics, and adaptability of various varieties to environmental conditions, identifying the most efficient culti- vars. The findings revealed the most suitable pear varieties for the Almaty region, offering opportunities to increase productivity in pear cultivation [8].

According to Bondareva et al., the level of infestation by pests, specifically Eriophyes pyri PGST (Acari: *Eripphyoidea*), on different pear varieties (*Pyrus communis* L.) was studied in the Fomin Botanical Garden. The researchers assessed the resistance of various pear cultivars to pests and their impacts on productivity and fruit quality. The results allowed for identification of pest-resistant characteristics in each variety, providing valuable information for selecting effective pest control methods in pear cultivation [9].

Verbesselt et al., in their studies, explored the biological and pomological characteristics of certain pear varieties in the Republic of Macedonia. The authors analyzed growth patterns, fruiting processes, and productivity levels of different varieties. The research also considered variety adaptability and the influence of climatic conditions. Results indi- cated the importance of selecting pear varieties and considering their specific characteristics to improve fruit quality and cultivation efficiency [10].

In his study, Rubtsov examined the geographical distribution of the genus Pyrus, focusing on primary trends and factors in its evolution. The author analyzed the distribution of various pear species across different regions, emphasizing their adaptation to climatic, soil, and ecological factors. Evolutionary changes and their impacts on the biological characteristics and geographical localization of pear species were discussed. Furthermore, the article highlighted the agricultural importance of pears and their future development potential [11].

Despite substantial research by both international and domestic scientists on fruit crops, comprehensive assessment of the economic and biological indicators of specific varieties remains insufficiently studied [12-14].

The relevance of this research lies in the necessity to optimize agrotechnical methods and adapt current cultivation technologies to contemporary agricultural production demands. Such comprehensive research will not only deepen the understanding of ecological features of the «Talgarskaya Krasavitsa» pear variety but also identify promising directions for further investigation and implementation of innovative agrotechnical solutions in modern agriculture.

The aim of the research is a comprehensive study of the ecological stability and adaptive potential of the «Talgarskaya Krasavitsa» pear variety under various agrotechnical practices.

Materials and methods

Study area

The research was conducted at the Botanical Garden of the International Kazakh-Turkish University under continental climate conditions. The “Talgarskaya Krasavitsa” pear variety was selected as the research object. This variety was grown both in open field and greenhouse conditions, allowing for a comparative analysis of climatic influences.

Experimental materials

The research materials included fruits, leaves, and woody tissues collected from 30 randomly selected trees. Samples were gathered during the active fruiting period (September-October). The experiment was divided into three main groups:

Control group – plants grown without additional treatments.

Standard agricultural practice group – plants treated using conventional cultivation methods.

Modernized methods group – plants receiving additional fertilization, growth stimulators, and micronutrient treatments.

Research methods

Biometric measurements. Tree height, trunk diameter (at 1.3 m height), and shoot length were measured [15].

Fruit mass was determined using analytical scales [16].

Sugar content was measured using a refractometer, while total acidity was assessed by titrimetric analysis (GOST method).

Assessment of leaf condition. Spectrophotometric method [17]: Concentrations of chlorophyll a, b, and carotenoids were measured at wavelengths of 665 nm and 649 nm.

Morphological inspection [18,19]: The presence of disease or stress symptoms (spots, deformation, discoloration) on leaves was evaluated.

Levels of photosynthetic pigments were compared across the three groups, with higher values observed in the modernized methods group. This demonstrated the efficiency of agricultural enhancements aimed at increasing plant productivity and disease resistance.

Phenological observations

Key phenological phases (flowering, fruit setting, and ripening) were recorded throughout the vegetation period. Climatic indicators such as air temperature, humidity, and precipitation levels were monitored using a meteorological station [20,21].

Data processing and statistical analysis

The collected data were processed using MS Excel, SPSS 26.0, and STATISTICA software [22]. The following analytical methods were employed:

Correlation and regression analysis: to identify relationships between measured parameters.

ANOVA (Analysis of Variance): to assess statistical differences among groups at a significance level of $p < 0.05$ [23].

Results and discussion

Analysis of the obtained data allows concluding that agrotechnical methods significantly influence the development of the “Talgarskaya Krasavitsa” pear variety at the Botanical Garden of the International Kazakh-Turkish University (IKTU), confirming its high adaptability and productivity. Three groups were employed for a comprehensive evaluation: the control group (plants without additional interventions), the group applying standard agricultural practices, and the group using modernized methods (additional fertilization and growth stimulators). A comparative analysis of biometric indicators is presented in Figure 1.

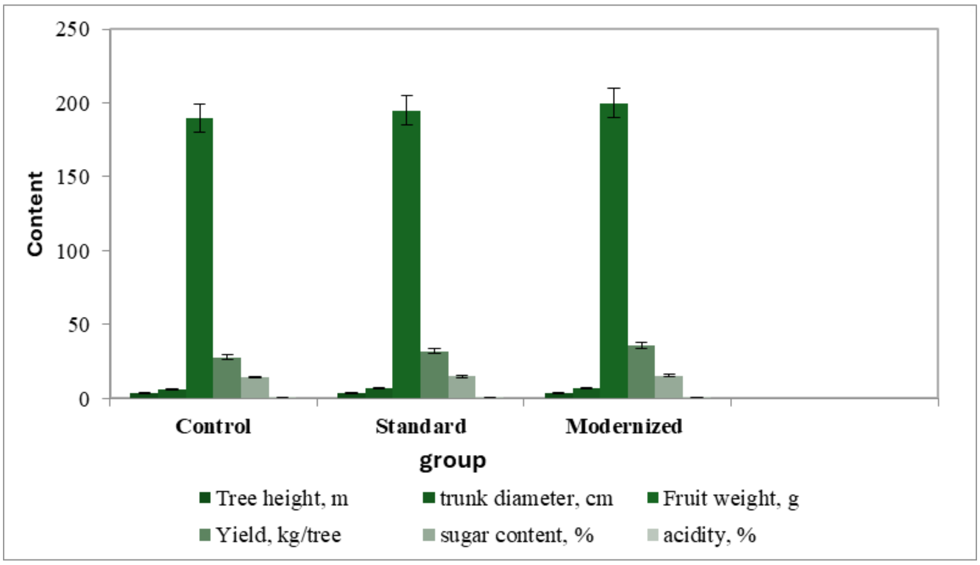

Figure 1 – Biometric indicators of the “Talgarskaya Krasavitsa” pear variety

The results presented in Figure 1 demonstrate that applying modern agrotechnical methods significantly and positively impacts the growth, development, and fruiting of the “Talgarskaya Krasavitsa” pear variety. Baseline measurements were observed in the control group without additional interventions: average tree height was 3.5 ± 0.2 m, trunk diameter was 6.5 ± 0.3 cm, fruit weight was 190 ± 10 g, productivity reached 28 ± 2 kg per tree, sugar content was 14.5 ± 0.3%, and acidity was 0.43 ± 0.05%. The use of standard agricultural practices improved all these indicators: tree height increased to 3.7 ± 0.3 m, trunk diameter to 6.7 ± 0.5 cm, fruit weight to 195 ± 15 g, yield to 32 ± 3 kg per tree, sugar content to 15.0 ± 0.4%, and acidity decreased to 0.42 ± 0.05%.

The most significant improvements occurred in the group employing modernized methods, including additional fertilization and growth stimulators. Here, the average tree height reached 4.0 ± 0.2 m, trunk diameter was 7.0 ± 0.4 cm, fruit weight reached 200 ± 10 g, productivity increased to 36 ± 3 kg per tree, sugar content rose to 15.5 ± 0.4%, and acidity decreased to 0.40 ± 0.04%. These results illustrate that enhanced agrotech- nical methods not only accelerate growth and biomass accumulation but also optimize plant nutrition and stimulate physiological processes, thereby significantly improving the qualitative characteristics of the fruit. Improvements in morphometric indicators such as growth and trunk diameter suggest more efficient resource accumulation essential for high-quality fruit formation. Furthermore, increased fruit weight and productivity confirm the beneficial effects of additional measures on plant productivity. Higher sugar content and reduced acidity in fruits from the modernized methods group indicate improved taste, enhancing their commercial value and suitabil- ity for processing. Thus, these findings confirm that integrating additional agrotechnical practices maximizes the biological potential of the "Talgarskaya Krasavitsa" variety, enhances adaptation to local climatic conditions, and ensures competitiveness in commercial horticulture.

Phenological observations further revealed improved synchronization of major developmental phases when applying modernized methods. Details of key phenological phases across the three study groups are presented in Table 1.

Table 1 – Phenological indicators of the three groups (flowering, seed development, and fruit ripening)

Phenological phase	Group	Start date	End date	Duration (days)
Flowering	Control	18.04.2024	25.04.2024	7
	Standard treatment	18.04.2024	25.04.2024	7
	Modernized treatment	17.04.2024	24.04.2024	7
Seed development	Control	05.06.2024	12.06.2024	7
	Standard treatment	05.06.2024	12.06.2024	7
	Modernized treatment	04.06.2024	11.06.2024	7
Fruit ripening	Control	22.09.2024	29.09.2024	7
	Standard treatment	22.09.2024	29.09.2024	7
	Modernized treatment	21.09.2024	28.09.2024	7

According to Table 1, data on the phenological phases–flowering, seed development, and fruit ripening–demonstrate high stability, with each phase consistently lasting 5 days across all groups: control, standard, and modernized. Despite identical durations, slight but systematic variations were observed in the start and end dates of these phases among the groups. Specifically, the flowering phase in the control group began on 18.04 ± 1.2 and ended on 25.04 ± 1.0, matching the standard group's results (start 18.04 ± 1.1, end 25.04 ± 1.0). However, in the group using modernized methods, flowering commenced one day earlier (17.04 ± 0.9) and concluded one day earlier (24.04 ± 0.8), indicating accelerated phenological cycles. A similar trend was evident during the seed formation phase: the control and standard groups registered the beginning on 05.06 (with slight deviations of 05.06 ± 1.5 and 05.06 ± 1.4, respectively) and concluded on 12.06 (10.06 ± 1.3 and 10.06 ± 1.2, respectively), while the modernized group recorded the start of seed formation as 04.06 ± 1.2, ending on 11.06 ± 1.1. The fruit ripening period further supported this pattern: the control and standard groups began ripening on 22.09 (22.09 ± 1.4 and 22.09 ± 1.3, respectively) and ended on 29.09 (29.09 ± 1.2), whereas the modernized group started ripening one day earlier (21.09 ± 1.3) and completed it on 28.09 ± 1.0. These consistent shifts suggest that the introduction of modernized agrotechnical measures, including additional fertilization and growth stimulators, influences the timing rather than duration of phenological phases, potentially optimizing pollination processes, seed formation, and fruit ripening, thereby positively impacting overall productivity and crop quality. Despite maintaining constant phase durations, these temporal adjustments offer valuable insights into effectively utilizing agrotechnical methods to regulate plant life cycles and enhance adaptability of the «Talgarskaya Krasavitsa» variety to varying climatic conditions.

Results from spectrophotometric assessments of photosynthetic pigments are presented in Table 2:

Table 2 – Content of photosynthetic pigments (mg/g of fresh mass)

Group	Chlorophyll a	Chlorophyll b	Carotenoids
Control	1.8 ± 0.1	0.8 ± 0.05	0.6 ± 0.03
Standard treatment	2.1 ± 0.1	1.1 ± 0.06	0.6 ± 0.04
Modernized treatment	2.6 ± 0.15	1.3 ± 0.08	0.8 ± 0.05

According to Table 2, the analysis of collected data demonstrates that agrotechnical practices positively impact the content of photosynthetic pigments in the leaves of the «Talgarskaya Krasavitsa» pear variety. In the control group without additional treatments, baseline pigment levels were recorded: chlorophyll a at 1.8 ± 0.1, chlorophyll b at 0.8 ± 0.05, and carotenoids at 0.6 ± 0.03 mg/g fresh mass. Applying standard agricultural practices increased these values to 2.1 ± 0.1 for chlorophyll a, 1.1 ± 0.06 for chlorophyll b, and 0.6 ± 0.04 for carotenoids, indicating improved photosynthetic activity compared to the control group. The group employing modernized methods, including additional fertilization and growth stimulators, exhibited significant increases in pigment concentrations: chlorophyll a reached 2.6 ± 0.15, chlorophyll b rose to 1.3 ± 0.08, and carotenoids increased to 0.8 ± 0.05 mg/g fresh mass. These findings suggest that additional agrotechnical measures such as growth stimulators and supplementary fertilization significantly enhance the content of major photosynthetic pigments, thereby improving light absorption efficiency and overall photosynthetic activity. Increased chlorophyll content directly correlates with higher potential for light energy absorption, while elevated carotenoid levels enhance protection against oxidative stress. Consequently, modernized methods not only improve the physiological condition of the leaves but also increase their resilience to adverse external factors, positively influencing productivity and fruit quality of the «Talgarskaya Krasavitsa» pear variety.

Visual assessment results for phytopathological symptoms are as follows:

Table 3 – Assessment of phytopathological symptoms (leaf damage index on a scale from 0 to 5)

Group	Mean damage index	Percentage of leaves with symptoms (%)
Control	2.7 ± 0.3	45%
Standard treatment	2.2 ± 0.2	35%
Modernized treatment	1.5 ± 0.2	20%

Data analysis from Table 3 indicates that agrotechnical measures significantly reduce the severity of phytopathological symptoms in leaves of the «Talgarskaya Krasavitsa» pear variety. In the control group without additional interventions, the average damage index was 2.7 ± 0.3, with 45% of leaves showing visible symptoms, highlighting high plant sensitivity to stress factors and diseases in the absence of additional care. In the group employing standard agricultural practices, including regular irrigation, basic fertilization, and standard protection measures, the damage index decreased to 2.2 ± 0.2, and the percentage of affected leaves reduced to 35%. This demonstrates that standard care positively impacts plant health but does not completely prevent damage.

The greatest reduction in leaf damage occurred in the group applying modernized methods, which included additional fertilization and growth stimulators. Here, the average damage index was notably lower at 1.5 ± 0.2, and the percentage of leaves exhibiting phytopathological symptoms decreased to 20%. These findings reflect a significant improvement in leaf condition, likely due to optimized nutrition and stimulated metabolic processes, enhancing plant resistance to pathogens and stress factors.

Thus, this study confirms that modernized agrotechnical practices not only increase photosynthetic activity but also significantly reduce the likelihood of phytopathological changes, thereby potentially enhancing the productivity and quality characteristics of the «Talgarskaya Krasavitsa» pear vari- ety. These results suggest promising prospects for broadly implementing these methods in agricultural production.

In conclusion, the following points summarize the overall findings:

Application of modernized agrotechnical methods significantly increased the content of photosynthetic pigments, indicating enhanced overall health of the photosynthetic apparatus and potential increases in plant productivity.

Visual inspection revealed fewer visibly damaged leaves and a lower damage index in plants receiving additional fertilization and growth stimulators, demonstrating the effectiveness of these methods in reducing the negative impacts of pathogenic factors and stresses.

The combination of spectrophotometric analysis and morphological assessment provided a comprehensive evaluation of plant conditions, correlating and validating the effectiveness of modernized agrotechnical practices in improving physiologi- cal conditions and reducing phytopathology in the «Talgarskaya Krasavitsa» variety.

A detailed correlation analysis, focusing on the relationship between trunk diameter and productivity based on group average biometric indicators presented in Figure 1, was conducted. Pearson's correlation coefficient (R) was calculated using the following formula:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}} \quad (1)$$

where, n – 3.

Thus, the correlation coefficient:

$$r = \frac{2{,}0}{2{,}027} \approx 0{,}986$$

The calculated coefficient of $r \approx 0.986$ indicates a very strong positive correlation between trunk diameter and productivity. This demonstrates that an increase in trunk diameter, indicative of biomass accumulation and overall plant health, is closely linked to higher productivity.

This result confirms that the integration of modern agrotechnical methods–specifically, the use of additional fertilizers and growth stimulators–effectively unlocks the potential of the «Talgarskaya Krasavitsa» pear variety. Improved biometric indicators directly contribute to increased yield quantity and quality, which are crucial for commercial gardening and further cultivation.

Thus, the conducted correlation analysis not only highlights the strong relationship between key indicators (trunk diameter and productivity) but also validates the effectiveness of modernized agrotechnical practices in enhancing the productivity and adaptability of the «Talgarskaya Krasavitsa» pear variety.

Discussion

In our study, the impact of modernized agrotechnical methods on the "Talgarskaya Krasavitsa" pear variety was clearly observed. These results demonstrate trends that are consistent with the findings of other researchers.

In our research, the use of growth stimulators and additional fertilizers increased tree height, trunk diameter, and productivity. These results are supported by other studies as well. For example, the application of Mival-Agro and Buton preparations has been shown to increase fruit weight by 5.2–10.7% and yield by up to 7.8–13.8 kg per tree [24].

In our study, modernized agrotechnical methods increased the concentration of chlorophyll a and b, as well as carotenoids. This led to enhanced photosynthetic activity. Other studies have also shown that growth stimulators improve the functioning of the photosynthetic apparatus and enhance the physiological condition of leaves [25].

Our study demonstrated that modernized agrotechnical methods significantly reduced the leaf damage index and the percentage of leaves showing phytopathological symptoms. This may be associated with increased plant resistance to pathogens and stress factors. Other research has confirmed that growth stimulators strengthen the plant immune system and improve disease resistance [26].

Overall, the results of our study are in line with the findings of other researchers and confirm that modernized agrotechnical methods have a positive effect on the growth and productivity of the "Talgarskaya Krasavitsa" pear variety.

Conclusion

The study's findings confirm that optimizing agrotechnical methods significantly enhances the productivity and biological characteristics of the «Talgarskaya Krasavitsa» pear variety. Results demonstrated that introducing updated agrotechnical practices substantially optimizes morphological and physiological indicators.

Comparative analysis revealed that increased plant biomass, enhanced photosynthetic activity, and reduced phytopathological symptoms were directly related to additional agrotechnical interventions, such as the application of growth stimulators and balanced nutrition. These practices not only accelerate tree growth and development but also ensure high-quality fruits by increasing mass, sugar content, and reducing acidity.

Comparing the results with previous research confirms the effectiveness of modern agrotechni- cal solutions in fruit cultivation. Unlike traditional cultivation methods, updated technologies optimize plant development, resulting in stable and high-quality yields.

The scientific novelty of this study lies in its comprehensive approach to evaluating the impact of various agrotechnical methods on the «Talgarskaya Krasavitsa» variety. For the first time, a detailed correlation assessment between biometric indicators and productivity was conducted, revealing a strong positive relationship between trunk diameter and plant productivity.

The practical significance of this research is in providing recommendations to enhance cultivation technologies for this variety, beneficial to farmers and agronomists involved in commercial horticulture. Optimized agrotechnical practices improve plant adaptability to changing climatic conditions, reduce disease risk, and ensure stable and competitive yields.

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Conflict of interest

All authors have read and agreed to the content of the manuscript and declare no conflict of interest.

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2-бөлім

ҚОРШАҒАН ОРТА ЛАСТАУШЫЛАРЫНЫҢ БИОТАҒА ЖӘНЕ ТҰРҒЫНДАР ДЕНСАУЛЫҒЫНА ӘСЕРІН БАҒАЛАУ

Section 2

ASSESSMENT OF ENVIRONMENTAL POLLUTION ON BIOTA AND HEALTH

Раздел 2

ОЦЕНКА ДЕЙСТВИЯ ЗАГРЯЗНИТЕЛЕЙ ОКРУЖАЮЩЕЙ СРЕДЫ НА БИОТУ И ЗДОРОВЬЕ НАСЕЛЕНИЯ

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ОПИСТОРХОЗ. НОВЫЕ ДАННЫЕ ОБ ЭКОЛОГИИ И ЭПИДЕМИОЛОГИИ

Возбудитель описторхоза, трематода *Opisthorchis felineus* (Rivolta, 1884) – один из наиболее распространенных видов паразитов человека и животных на территории России, Казахстана, стран Восточной Европы. Вместе с близкородственными видами печеночных трематод *O. viverrini* (Poirier, 1886) и *Clonorchis sinensis* (Loos, 1907), ареалы которых расположены в Юго-Восточной Азии и на Дальнем Востоке, *O. felineus* составляет триаду эпидемиологически значимых трематод семейства Opisthorchiidae. Половозрелые особи *O. felineus* паразитируют в гепатобилиарной системе млекопитающих, включая человека и при длительной инфекции провоцируют развитие тяжелых осложнений. Однако, несмотря на значимость, описторхоз относится к группе забытых заболеваний (neglected tropical diseases). Данные заболевания, поражающие 1,65 миллиарда человек в мире, получили свое название не просто так: эти заболевания, люди и регионы, которые они поражают, обычно остаются без внимания.

В обзоре кратко суммированы результаты современных исследований биологии и эпидемиологии трематод семейства Opisthorchiidae, обсуждены результаты исследований, полученных как на модельных животных, так и данные по пациентам. Актуальность исследований трематод подчеркивается их сложным жизненным циклом, длительным бессимптомным периодом заболевания; отсутствием достаточной информации о влиянии гельминтов на органы, не относящиеся к местам их непосредственной локализации, широкое распространение в эндемичных регионах. Открытая миграционная политика и гастрономический туризм расширяет географию проблемы этих инфекций за пределы локальных очагов, когда пациенты с описторхозом и клонорхозом могут обнаруживаться вдали от эндемичных территорий.

Ключевые слова: трематоды, описторхоз, системное заболевание.

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Opisthorchiasis. Updates on ecology and epidemiology

The causative agent of opisthorchiasis, the trematode *Opisthorchis felineus* (Rivolta, 1884) is one of the most common species of human and animal parasites in Russia, Kazakhstan, and Eastern European countries. Together with closely related species of liver flukes *O. viverrini* (Poirier, 1886) and *Clonorchis sinensis* (Loos, 1907), the species endemic to Southeast Asia and the Far East, *O. felineus* makes up a triad of epidemiologically significant trematodes of the Opisthorchiidae family. Adult worms of *O. fel- ineus* parasitize the hepatobiliary system of mammals, including humans, and provoke the development of severe complications during chronic infection. However, despite its importance, opisthorchiasis is considered a neglected tropical disease (NTDs). NTDs, affecting 1.65 billion people around the world, are so named for a reason: these diseases, the people and regions they affect, are usually have been overlooked, receiving very little global attention for research, prevention, and control efforts.

The review briefly summarizes the results of latest research of the biology and epidemiology of trematodes of the Opisthorchiidae family, discusses the results of studies obtained both on model animals and on patients. The significance the research is emphasized by the complex life cycle of the liver flukes, a prolonged time of the human infection with no apparent symptoms; lack of sufficient information on the effect of helminths on organs not related to the places of their immediate localization, wide distribution of trematodes in endemic geographical areas. Open migration policy and gastronomic tourism expands the geography of the problem of these infections beyond local foci, when patients with opisthorchiasis and clonorchiasis can be found far from endemic areas. Overall, opisthorchiasis can be a serious drain on a country’s economy.

Key words: trematodes, opisthorchiasis, systemic disease.

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Описторхоз. Экологиясы мен эпидемиологиясы жөніндегі жаңа деректер

Описторхоз қоздырғышы, *Opisthorchis felineus* (Rivolta, 1884) трематодасы – Ресей, Қазақстан және Шығыс Еуропа елдерінде адамдар мен жануарлар арасында кең таралған паразиттер- дің бірі болып табылады. Бұл түр Оңтүстік-Шығыс Азия мен Қиыр Шығыста кездесетін бауыр трематодаларына жататын *O. viverrini* (Poirier, 1886) және *Clonorchis sinensis* (Loos, 1907) түрлерімен бірге *Opisthorchiidae* тұқымдасының эпидемиологиялық маңызы бар үштігін құрайды. *O. felineus*-тің жыныстық жетілген даралары адам мен сүтқоректілердің гепатобилиарлық жүйесінде паразиттік тіршілік етеді және ұзақ мерзімді инфекция кезінде ауыр асқынуларға әкелуі мүмкін. Алайда, осы маңыздылығына қарамастан, описторхоз ұмыт қалған тропикалық аурулар (neglected tropical diseases) тобына жатады. Бұл аурулар әлем бойынша 1,65 миллиард адамды зақымдайды және «ұмыт қалған» деп аталуы да бекер емес: бұл аурулармен ауырған адамдар мен олардың өмір сүретін аймақтары көбіне назардан тыс қалып жатады.

Бұл шолуда *Opisthorchiidae* тұқымдасына жататын трематодалардың биологиясы мен эпидемиологиясы бойынша заманауи зерттеу нәтижелері қысқаша жинақталған, сондай-ақ модельді жануарлар мен науқастарға жүргізілген зерттеу деректері қарастырылған. Трематодаларды зерттеудің өзектілігі олардың күрделі даму циклдерімен, аурудың ұзақ уақыт бойы симптомсыз өтуімен, паразиттердің тікелей орналасу орындарынан тыс ағзаларға әсері туралы жеткіліксіз ақпаратпен, сондай-ақ эндемиялық аймақтарда кең таралуымен байланысты. Ашық көші-қон саясаты мен гастрономиялық туризм бұл инфекциялар проблемасының географиясын кеңейтуде, описторхоз және клонорхоз деректері эндемиялық емес аймақтарда да тіркелген.

Түйін сөздер: трематодалар, описторхоз, жүйелі ауру.

Введение

Описторхоз является антропозоонозным паразитарным заболеванием гепатобилиарной системы, которое приводит к выраженной патологии печени [1,2]. Причиной заболевания являются трематоды семейства Opisthorchiideae, которое включает три эпидемиологически значимых паразитических вида: *Opisthorchis felineus*, *Opisthorchis viverrini* и *Clonorchis sinensis*.

Основной очаг инфекции *O. felineus* локализован на территории Обь-Иртышского бассейна, в Западной Сибири. Однако, случаи заражения кошачьей двуусткой регулярно отмечаются на территории Западно – Казахстанской области и на севере Республики Казахстан. Кроме того, имеются сведения о единичных случаях инфицирования в Италии, Испании, Португалии и Германии [3], а также Украине и Белоруссии [4,5]. Уровень заражения *O. felineus* оценива- ют в 1 млн., однако эта оценка, по-видимому, является сильно заниженной. От описторхоза страдает преимущественно сельское население: так уровень заражения сельского населения в Томской области может достигать 60% в отдельных деревнях [6], что значительно превышает среднерегиональную оценку [4]. При этом единственным препаратом для лечения описторхоза остается празиквантел [7,8], хотя и имеются сведения о новых эффективных препаратах, например, трибендимидин [9].

O. viverrini преимущественно распространен на территории Юго-Восточной Азии. Основной очаг инфекции локализован в Таиланде, однако высокий уровень заражения также отмечается в Лаосе, Камбоджи, Мьянме (Бирме), а также во Вьетнаме [10,11]. Уровень заражения в этом регионе достигает 12 млн. человек [12].

C. sinensis наиболее распространен на территории Восточной Азии, в первую очередь в Китае и Южной Корее. На данный момент количество людей, зараженных этой трематодой, оценивается в 15 млн. человек [13,14].

Трематоды семейства Opisthorchiidae имеют схожий жизненный цикл, включающий двух промежуточных и одного окончательного хозяина. В роли первого промежуточного хозяина выступают пресноводные брюхоногие моллюски, вторым – рыбы семейства карповых (Cyprinidae), которые имеют сельскохозяйственное и промысловое значение. Известно, также, что при заражении 1-2% моллюсков в водоеме, инфицирование язей в том же водоеме может доходить до 98% [4].

Актуальность исследования трематод подчеркивается их сложным жизненным циклом, длительным бессимптомным периодом заболевания; отсутствием достаточной информации о влиянии гельминтов на органы, не относящие- ся к местам их непосредственной локализации, широкое распространение в эндемичных регионах. Открытая миграционная политика и гастрономический туризм расширяет географию проблемы этих инфекций за пределы локальных очагов, когда пациенты с описторхозом или клонорхозом могут обнаруживаться вдали от эндемичных территорий.

В данной работе рассмотрены основные сходства и отличия между тремя близкородственными видами семейства Opisthorchiideae, основные клинические признаки заболевания и патологические изменения в органах, в том числе в почках, при описторхозе.

Описторхоз: сходства и различия

Описторхоз – паразитарное заболевание гепатобилиарной системы, которое приводит к патологии печени [1,2]. Причиной заболевания выступают трематоды семейства Opisthorchiideae: *Opisthorchis felineus*, *Opisthorchis viverrini* и *Clonorchis sinensis*. Описторхиды обладают рядом сходств и различий. В целом, жизненный цикл описторхид сходен у всех трех видов, хотя и обладает некоторыми видоспецифическими особенностями. Жизненный цикл включает двух промежуточных хозяев и одного окончательного (Рис. 1A-F) [1]. Начинается цикл с поглощения брюхоногим моллюском семейства Bithyniidae (Рис. 1B и 1C) яиц паразита, попавших в окружающую среду с фекалиями окончательного хозяина. Для *Opisthorchis felineus* первым промежуточным хозяином является пресновод- ные *Bithynia leachi*, *Bithynia troscheli* и *Bithynia inflate* [1], а для *Opisthorchis viverrini* – *Bithynia funiculata* и *Bithynia siamensis* [2]. Для *Clonorchis sinensis* в этой роли выступают моллюски *Parafossarulus manchouricus* и *P. striatulus*. [15].

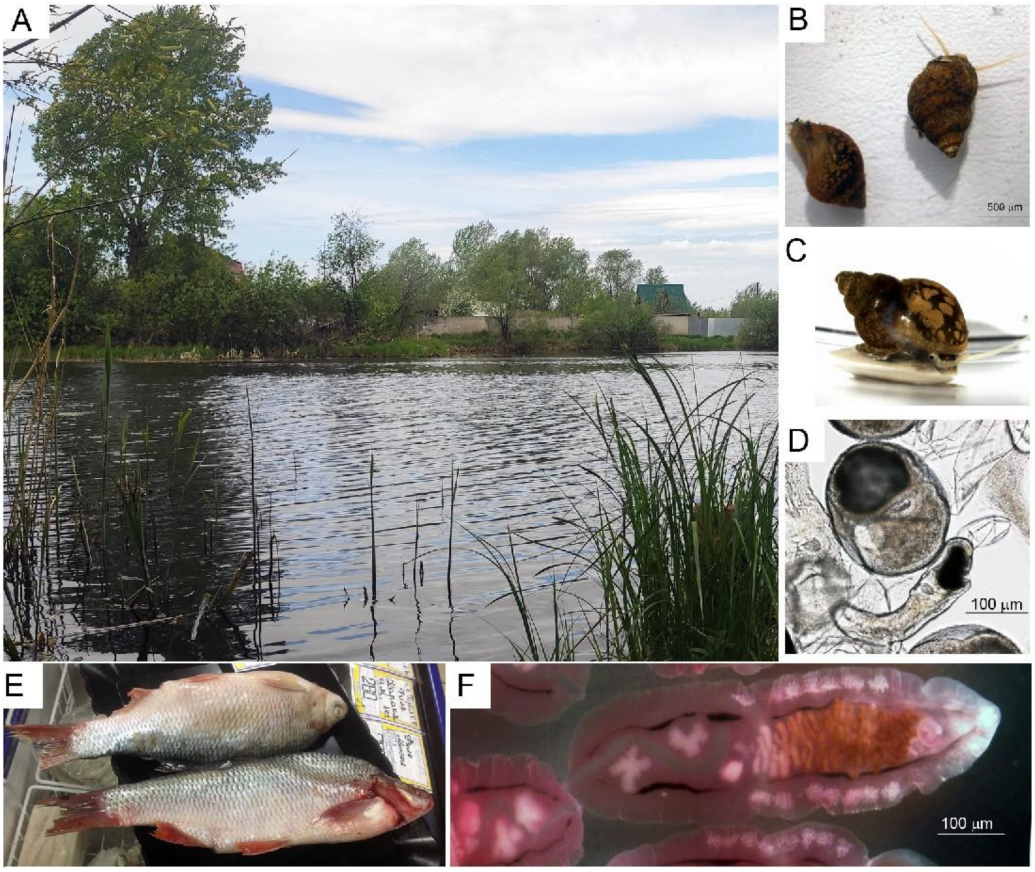

Рисунок 1 – Экология кошачьей двуустки *Opisthorchis felineus*
Примечание – A. Пресноводный водоем г. Новосибирск, Западная Сибирь, среда обитания моллюсков и рыбы. B. Моллюски рода Bithynia. C. Моллюск рода Bithynia, крупный план. D. Метацеркария. E. Язи. F. Взрослые особи.

В организме моллюска из яйца высвобождается мирацидия, которая через несколько стадий развития превращается в церкарию. Церкария является свободноживущей стадией, она проникает в мышцы и под чешую рыбы семейства карповых, где превращается в метацеркарию – цистную форму паразита (Рис. 1D) [1]. Для *O. viverrini* и *O. felineus* в качестве второго промежуточного хозяина может выступать только рыба семейства карповых (Рис. 1E), в отличие *C. sinensis* круг вторых промежуточных хозя- ев которого шире и включает также креветок *Macrobrachium nipponense* [15]. Спектр окончательных хозяев для *C. sinensis* также существенно шире, и включает, в том числе, крупнорогатый скот [4].

В качестве окончательных хозяев могут выступать многие виды рыбоядных млекопитающих, преимущественно хищников, хотя заражение описторхозом бурундуков, бобров, каспийской нерпы и др. также возможно. В роли окончательного хозяина выступает и человек, заражение которого происходит при употреблении в пищу недостаточно термически обработанной зараженной рыбы семейства карповых – язь, плотва, карась и др. [4]. В желудочно-кишечном тракте окончательного хозяина происходит высвобождение паразита из цисты, после чего он проникает в желчные протоки систему печени, реже в протоки поджелудочной железы.

Помимо особенностей жизненного цикла, между видами описторхид существует ряд более существенных отличий. В первую очередь стоит отметить, что ареалы описторхид географически удалены друг от друга и практически не пересекаются. Другим важным отличием является хромосомный набор. Количество хромосом у *O. viverrini* 12, при этом у *O. felineus* и *C. sinensis* 14 хромосом [16].

Самое важное отличие заключается в канцерогенном потенциале описторхид. Согласно данным, которые представлены международным агентством по исследованию рака (IARC) [17,18], *O. viverrini* и *C. sinensis* признаны канцерогенами 1-ой группы, то есть существуют убедительные доказательства того, что эти трематоды являются канцерогенами для человека, в то время как *O. felineus* был отнесен к группе 3, то есть его канцерогенный потенциал для человека не установлен [17], хотя при исследованиях на модельных животных канцерогенный потенциал описторхид сходен [19].

Клинические признаки описторхоза

Клиническая картина описторхоза зача- стую стерта и не имеет каких-либо характер- ных признаков. В острый период инфекции, наиболее распространённым проявлением опи- сторхоза является развития гепатобилиарно- го синдрома, который характеризуется болью в правом подреберье (стоит отметить, что эта боль может иррадиировать в область лопатки или даже ключицы, таким образом смазывая клиническую картину), диспепсическими симптомами, например, тошнотой, рвотой и/или изжогой. Заболевание может сопровождаться развитием диареи. При описторхозе возможно развитие холестаза, который обусловлен обтурацией желчных протоков описторхидами. Это приводит к развитию обтурационной желтухи с повышением уровней клинически значимых маркеров (щелочной фосфатазы, гамма-глутамилтранспептидазы и конъюгированного билирубина) в сыворотке крови. Преимущественно в острый период заболевания, до 4-х недель, возможно развитие интоксикационного синдрома, который характеризуется, повышением температуры, колебания которой обычно находятся в диапазоне от 37°C до 39°C и длительностью от трех дней до нескольких недель. Лихорадка часто сопровождается болью в мышцах, суставах и развитием кожных реакций, например, экзантем [3].

Хроническая стадия описторхоза зачастую протекает бессимптомно. При этом описторхоз нередко сочетается с развитием гастродуоденальной патологии. Гастриты, гастродуодениты, язвенная болезнь желудка и 12-ти перстной кишки часто сопровождают описторхоз. Стоит отметить, что на данный момент не до конца очевидно, приводит ли непосредственно заражение описторхидами к заболеваниям желудка и 12-ти перстной кишки или их сочетание связано с особенностями образа жизни людей, страдающих описторхозом. Стоит отметить, что желудок и 12-ти перстная кишка лежат на путях миграции паразита, а заражение описторхами приводит к аномалиям в составе микробиоты желчных протоков [20]. При этом, описторхозом страдают преимущественно люди, проживающие в сельский районах, где качество профилактики, диагностики и медицинской помощи не всегда является оптимальным.

Изменения в печени при описторхозе

Основные патоморфологические проявления описторхоза включают: пролиферацию желчных протоков, которая, в динамике инфекции, приводит к развитию холангиофиброза; развитие фиброза в перидуктальной зоне; выраженную инфильтрацию печени воспалительными клетками; неопластическими изменениями эпителия желчных протоков [2, 17, 21, 22, 19].

При длительном течении заболевания в зонах пролиферации желчных протоков развивается хроническое воспаление и разрастается соединительная ткань – холангиофиброз и перидуктальный фиброз (образование соединительной ткани вокруг крупных желчных протоков). Перидуктальный фиброз опасное состояние, нарушающие трофику и регенеративный потенциал ткани. Помимо этого, при заражении *O. viverrini* было показано, что наличие крупных очагов перидуктального фиброза может быть ассоциировано с повышенным риском развития холангиокарциномы [23].

Холангиокарцинома – это злокачественная опухоль эпителия желчных протоков, которая характеризуется сложностью ранней диагностики и высокой летальностью [21]. Ранним предвестником холангиокарциномы выступает неоплазия эпителия желчных протоков. При неоплазии клетки утрачивают связь с базальной мембраной, межклеточные контакты, а также приобретают высокую пролиферативную активность, что способствует онкогенезу в печени [22, 19, 24].

Описторхоз как системное заболевание

Системные заболевания – это группа патологий, в которую с каждым годом включают новые заболевания. Традиционно, к системным патологиям относят заболевания иммунной системы или метаболической систем. Например, аутоиммунные заболевания, включая системную красную волчанку [25, 26] или ревматоидный артрит [27,28] носят системный характер поражая многие органы. Метаболический синдром также наносит ущерб всему организму в целом, включая печень, почки, сетчатку глаза и др. Появляется все больше сведений, что инфекционные агенты также могут воздействовать на организм системно, и несмотря на то, что многие инфекции обладают специфичностью к какому-либо органу, воздействие может быть обнаружено и за его пределами. Обычно это воздействие опосредованное и связано с аномалиями со стороны иммунной системы или обмена веществ. Почки в этом плане заслуживают особого внимания. В настоящее время накапливается все больше доказательств об их вовлеченности в патологический процесс при паразитарных заболеваниях, даже если они не являются очагом инфекции. Было продемонстрировано, что заражение *Fasciola hepatica* может приводить к развитию почечной патологии несмотря на то, что эта трематода паразитирует в печени [29]. *Schistosoma mansoni*, которая паразитирует в сосудах брыжейки, и пути миграции которой никак не связаны с почками, тем не менее оказывает на них воздействие. При этом патологический процесс может быть достаточно выражен, вплоть до развития протеинурии, главного признака гломерулонефрита [30].

Воздействие описторхид на почки

Описторхиды, по-видимому, тоже могут оказывать системное воздействие на организм человека. Тем не менее, количество исследований, способных раскрыть описторхоз как системную патологию, крайне ограничено. Существуют отдельные свидетельства развития патологии почек у людей при заражении всеми тремя видами. В 2013 году, при заражении *O. viverrini* было обнаружено повышение уров- ня IgG против описторха в моче. Его уровень коррелировал с выраженностью фиброза печени [31]. Недавно, команда из Таиланда продемонстрировала отложение антигенов паразита в гломерулах [32]. Данные о воздействии *C. sinensis* за пределами печени крайне ограничены. В частности, в рамках проведенного популяционного исследования в Китае изучили связь клонорхоза и повреждения почек у 4122 человек, из которых 33.8% были заражены исключительно *C. sinensis*, а 5% имели сочетанное заражение *C. sinensis* и *Helicobacter pylori*. Как в группе с моноинфекцией, так и при заражении двумя инфекционными агентами были отмечены изменения уровня креатинина и сывороточного β2-микроглобулина. Скорость клубочковой фильтрации была снижена, но только в группе с коинфекцией [33].

Имеются данные о патологии почек при описторхозе *O. felineus* как на экспериментальной модели *Mesocricetus auratus*, так и при анализе аутоптатов, полученных от пациентов [34,35]. Было обнаружено повышение содержания белка в моче и креатинина в сыворотке крови, которое зависело от длительности инфекции, что указывало на вероятность повреждения почек. Были выявлены расширения пространства капсулы Боумена, образование цилиндров в канальцах почки (Рис. 1), соединительная ткань в межканальцевом пространстве почки – интерстициальный фиброз. Окраска с помощью импрегнации серебром позволила выявить пролиферацию мезангиального матрикса, преимущественно за счет отложения коллагена, что является крайне важным признаком, который сопровождает повреждение гломерулярного фильтра и объясняет развитие протеинурии [34]. Повреждающим фактором в гломеруле нефрона могут выступать циркулирующие иммунные комплексы, состоящие из антигена и комплементарного ему антитела, что и было обнаружено по повышенному уровню IgA в гломеруле нефрона. Аналогичным образом патология почек развивается при заражении трематодами *S. mansoni* [30] и *F. hepatica* [36, 29]. Маркеры почечной патологии при описторхозе удалось также валидировать при анализе материала почек пациентов. У людей были обнаружены пролиферация соединительной ткани в гломеруле нефрона, которая сопровождалась отложением IgA и развитие интерстициального фиброза [35].

Сравнительный анализ трех видов описторхид *Opisthorchis felineus*, *Opisthorchis viverrini* и *Clonorchis sinensis* позволил сделать вывод, о том, что именно *O. felineus* оказывает наибольшее патологическое воздействие на мочевыделительную систему. Именно при заражении этой трематодой уровни мезангиального матрикса, интерстициального фиброза и IgA были выше [37].

В совокупности, представленные в научной литературе данные указывают на то, что заражение описторхозом может быть ассоциировано с развитием патологии почек, при этом патологические процессы, лежащие в его основе, связаны с воздействием иммунной системы.

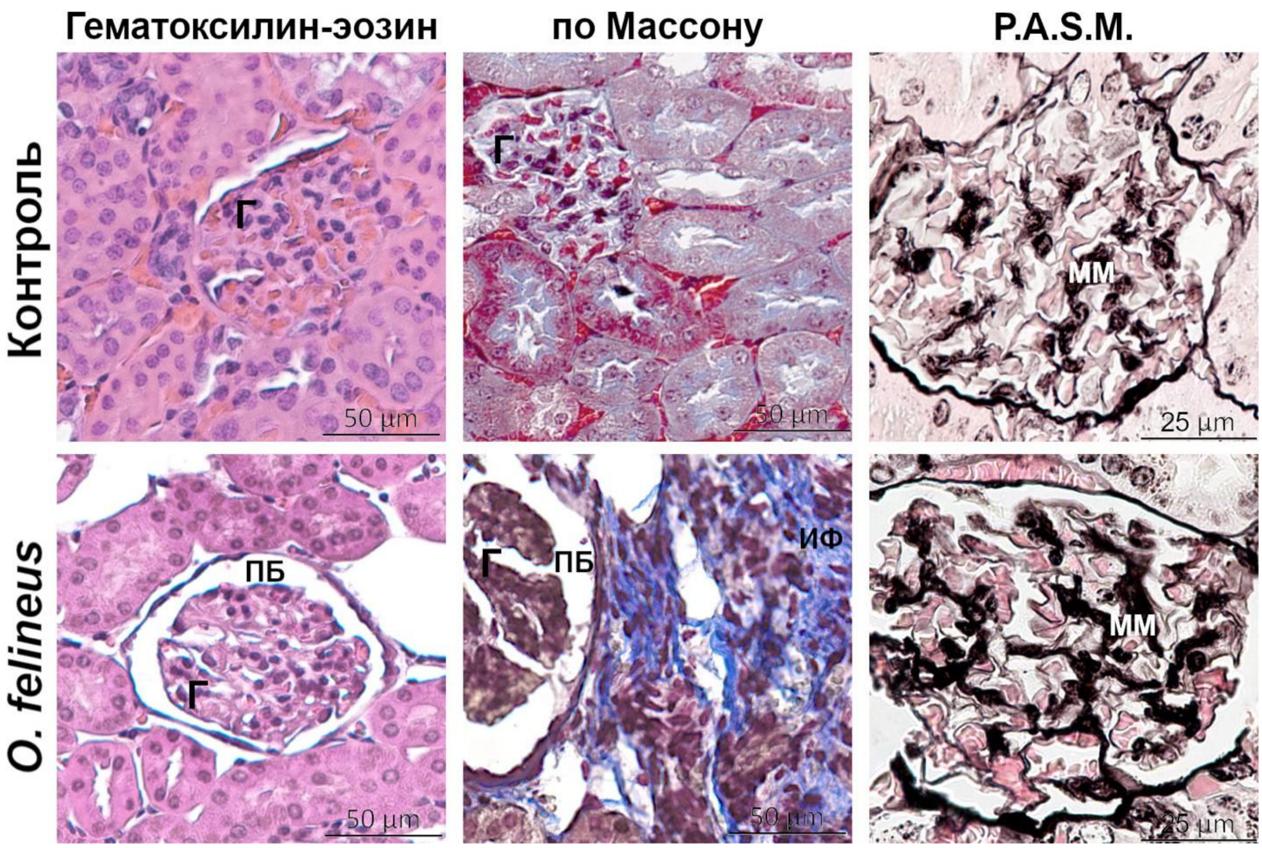

Рисунок 2 – Гистологические признаки развития почечной патологии у хомячков *M. auratus* при заражении *O. felineus*

Примечание – Г – гломерула. Окраска с помощью гематоксилин-эозина позволила выявить расширение пространства Боумена (ПБ). При окраске по Массону на соединительную ткань были обнаружены очаги интерстициального фиброза (ИФ). Импрегнация серебром с помощью P.A.S.M. выявила увеличение мезангиальной зоны (ММ).

Описторхоз и метаболические изменения

В литературе описано, что вторым очагом локализации трематод внутри человека может выступать поджелудочная железа. Это связано с тем, что метацеркарии описторхид могут проникать не только в протоки печени, но и в протоки поджелудочной железы и выживать там на протяжении длительного времени. Потенциально, это может приводить к нарушению структуры поджелудочной железы. Более того, воздействие на метаболические процессы может быть опосредовано, в том числе и за счет хронического воспаления, которое характерно для описторхозной инвазии.

Данные по взаимосвязи инфекции *O. felineus* и метаболических нарушений крайне ограничены. Тем не менее, было обнаружено, что заражение этой трематодой может сопровождаться дислипидемией с повышенным уровнем холестерола [38]. В другом исследовании также были обнаружены аномалии липидного обмена, которые зависели от уровня инфицированности животных [39].

На потенциальный продиабетический потенциал кошачьей двуустки *O. felineus* указывают данные, полученные на экспериментальных животных. Так, уровень глюкозы зависел от длительности хронической инфекции и превышал уровень контроля уже с 1-го месяца [34]. Уровень холестерина, хоть и был повышен, но не изменялся в динамике. При исследовании ткани поджелудочной железы только у 10% животных была обнаружена хотя бы одна трематода в просвете протока поджелудочной железы. Вероятно, такое ограничение связано с особенностями анатомического строения органа. В отличие от человека и других, крупных млекопитающих, у хомячков протоки поджелудочной железы не объединены в один общий крупный проток. Потенциально, это может затруднять попадание метацеркарий описторхид в орган.

Тем не менее, в поджелудочной железе этих животных были выявлены изменения, аналогичные тем, что наблюдаются в печени, а именно фиброз в перидуктальной зоне, инфильтрация воспалительными клетками и изменения эпителия протоков поджелудочной железы. Также было обнаружено слабо выраженное увеличение среднего количества клеток в островках Лангерганса и изменение формы некоторых из них. В отдельных островках были выявлены очаги дистрофии (не опубликованные данные).

На данном этапе данных, указывающих на наличие причинно-следственных связей между описторхозом и развитием метаболических нарушений недостаточно. На текущий момент сложно сделать однозначные выводы, тем не менее эта проблема заслуживает подробного изучения в будущем.

Заключение

Описторхоз – это широко распространенное заболевание, которое, в первую очередь, ассоциировано с патологией печени. Тем не менее, в настоящее время накапливается все больше данных, указывающих на его системное воздействие. На данном этапе изучения проблемы, с достаточно высокой уверенностью можно утверждать, что описторхиды могут оказывать воздействие на почки. Вопрос о влиянии описторхид на метаболический профиль остается дискуссионным и требует дальнейшего бо- лее глубокого изучения. Вероятно, заражение описторхидами не может вызывать метаболический синдром само по себе, однако тяжесть проявления уже имеющихся метаболических нарушений может быть выше, таким образом выступая в качестве отягчающего фактора. Тем не менее, изучение этого аспекта патологии находится на начальном этапе и будет развиваться в будущем.

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СВЯЗЬ ФЕРРИТИНА С ТЯЖЕЛЫМ ТЕЧЕНИЕМ COVID-19

В настоящей статье приводятся и анализируются результаты завершенных и продолжающихся исследований по гематологическим данным для идентификации связи между ухудшением состояния пациентов и уровнем сывороточного ферритина в крови госпитализированных с COVID-19. Как известно, возбудитель инфекции, вирус SARS-Cov-2, имеет высокий вирулентный характер. В связи с этим ВОЗ объявила вспышку COVID-19 пандемией. Повышенный уровень ферритина был обнаружен у пациентов с тяжелым течением коронавирусной инфекции. Следовательно, целью данного исследования было определить взаимосвязь ферритина с критическим состоянием и летальными исходами у больных COVID-19. В процессе исследования были включены в сумме 32 работ, в которых были собраны гематологические данные 9459-ти госпитализированных. Для анализа взаимосвязи ферритина со смертностью и критическим состоянием были взяты 13 исследовании, в которых были рассмотрены данные 6306 инфицированных. Уровень ферритина был значительно повышен у пациентов с тяжелым состоянием по сравнению с уровнем ферритина у пациентов с менее тяжелым течением заболевания. Инфицированные с летальным исходом имели высокий уровень ферритина по сравнению с таковым у пациентов с не летальным исходом. Пациенты с одной или несколькими сопутствующими заболеваниями, включая диабет, тромботические осложнения и рак, имели более высокий уровень ферритина, чем пациенты без сопутствующих заболеваний. А также повреждение печени и развитие острого респираторного дистресс-синдрома (ОРДС) было ассоциировано с высоким уровнем ферритина, а его уровень был связан с попаданием пациентов в отдел интенсивной терапии (ОИТ) и нужду в искусственной вентиляции легких. Гиперферритинемия связана с неблагоприятным прогнозом и может быть маркером ухудшения состояния пациентов с COVID-19.

Ключевые слова: COVID-19, коронавирус, ферритин, критические случаи, летальные исходы.

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The association of ferritin with the severe course of COVID-19

This article reports and analyzes the results of completed and ongoing studies on hematologic data to identify the association between patient deterioration and serum ferritin levels in COVID-19 hospitalized patients. The infectious agent, SARS-Cov-2 virus, is known to be highly virulent. Therefore, WHO has declared the COVID-19 outbreak as a pandemic. Elevated ferritin levels have been found in patients with severe coronavirus infection. Hence, the aim of this study was to determine the relationship of ferritin with critical condition and mortality in COVID-19 patients. A total of 32 papers that collected hematologic data from 9459-hospitalized patients were included in the study process. Thirteen studies were taken to analyze the relationship of ferritin with mortality and critical status, in which data from 6306 infected individuals were reviewed. Ferritin levels were significantly elevated in critically ill patients compared with ferritin levels in patients with less severe disease. Fatal infected patients had high ferritin levels compared with those of non-fatal patients. Patients with one or more comorbidities, including diabetes, thrombotic complications, and cancer, had higher ferritin levels than patients without comorbidities. And also liver injury and the development of acute respiratory distress syndrome (ARDS)

were associated with high ferritin levels, and its levels were associated with patients being admitted to the intensive care unit (ICU) and needing ventilator support. Hyperferritinemia is associated with an unfavorable prognosis and may be a marker of deterioration in COVID-19 patients.
Key words: COVID-19, coronavirus, ferritin, critical cases, fatalities.

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COVID-19 ауыр жағдайлары мен ферритин байланысы

Бұл мақалада COVID-19 диагнозы бар науқастардың жай-күйінің нашарлауы мен ферритин деңгейі арасындағы байланысты анықтау үшін гематологиялық деректер бойынша зерттеулердің нәтижелері келтіріліп, талданған. SARS-Cov-2 вирусы адамнан адамға өте жылдам таралатын сипатқа ие. Осыған байланысты ДДСҰ COVID-19 індетін пандемия деп жариялады. Ауыр жағдайдағы коронавирустық инфекцияны бастан кешірген науқастарда ферритин деңгейінің жоғарылауы анықталды. Сондықтан, бұл зерттеудің мақсаты ферритиннің COVID-19 науқастарындағы ауыр жағдай мен өліммен байланысын анықтау болды. Зерттеу барысында 32 ғылыми жұмыс талданды, онда 9459 ауруханаға жатқызылғандардың гемотологиялық мәліметтері жиналды. Ферритиннің өлім-жітіммен және ауыр жағдаймен байланысын талдау үшін 13 зерттеу алынды, онда 6306 вирусты жұқтырған адамның деректері қарастырылды. Ферритин деңгейі жеңіл түрде ауырған пациенттермен салыстырғанда жағдайы ауыр пациенттерде айтарлықтай жоғарылаған. COVID-19 әсерінен қазаға ұшырағандарда тірі қалғандармен салыстырғанда да ферритин деңгейі айтарлықтай жоғары мөлшерде болған. Бір немесе бірнеше қатар жүретін аурулары бар науқастарда, соның ішінде қант диабеті, тромботикалық асқынулар және қатерлі ісік аурулары бар науқастарда ферритиннің едәуір жоғары деңгейіне ие болғаны анықталды. Сондай-ақ бауырдың зақымдануы және жедел респираторлық дистресс синдромының дамуы ферритиннің жоғары деңгейімен айтарлықтай байланысты болды. Оның деңгейі пациенттердің қарқынды терапия бөліміне ауыстырылуымен және жасанды тыныс алу аппаратының қажеттілігімен байланысты болды. Гиперферритинемия COVID-19 диагнозы бар пациенттердің ауруының асқынуын болжаушы биомаркер ретінде қарастырылуы мүмкін.
Түйін сөздер: COVID-19, коронавирус, ферритин, ауыр жағдайлар, өлім жағдайы.

Введение

В декабре 2019 года в городе Ухань, расположенном в центральном регионе Китая, была впервые обнаружена коронавирусная инфекция (COVID-19), вызванная вирусом SARS-Cov-2,которая имеетвысокий вирулентный характер [1].11 марта 2020 года ВОЗ объявила вспышку COVID-19 пандемией, болезнь включает в себя симптомы респираторных заболеваний, как: повышение температуры (89-93%), кашель (76-82%) и затруднение дыхания (31-55%) . Однако у 39% людей болезнь прогрессирует, вызывая острую дыхательную недостаточность, характеризующиюся цитокиновым штормом, которая в половине случаев ведет к летальному исходу [2, 3].

При тяжелых течениях коронавирусной инфекции было выявлено увеличение уровня ферритина, D-димера, лактат-дегидрогеназы, воспалительных цитокинов IL-6, IL-8, IL-12и TNFα [4,5]. Увеличение уровня сывороточного ферритина в плазме крови, гиперферритинемию, связывают с поступлением пациентов в отделение интенсивной терапии, высоким риском смертности и рассматривают как индикатор в выявлении у пациентов тяжелого течения болезни, чтобы вовремя предотвратить цитокиновый шторм [5, 6].

Вследствие того, что данные исследования проводились в относительно малой выборке пациентов, прогнозируемая роль ферритина в активации цитокинового шторма и как биомаркера в преждевременном определениитяжелого течения коронавирусной инфекции требует дальнейшей верификации. Определение уровня сывороточного ферритина представляет особый интерес в связи его потенциальной прогностической и диагностической ролью [7,8].

Целью данного обзора является раскрыть взаимосвязь уровня сывороточного ферритина с критическим состоянием и смертностью у пациентов с COVID-19.

Материалы и методы

Материалы для данной обзорной статьи были собраны из базы данных рецензированных медицинских и биологических публикации, в том числе PubMed, Scopus, CNKI, CambridgeCoreи глобальной базы данных исследовании по коронавирусу WHOCOVID-19. Ключевыми словами для поиска релевантных статей были следующие: coronavirus, n-cov, Sars-Cov-2, COVID, cytokinestorm, ferritin. Не было введено никаких ограничений в отношении региона исследовании или этнической пренадлежности населения.

Результаты и обсуждение

Взаимосвязь уровня ферритина с критическим состоянием пациентов с COVID-19

Показатель нормы уровня ферритина у мужчин считается 30-310 мкг/мл, а у женщин 22- 180 мкг/мл. При анализе соотношения уровня ферритина с критическим состоянием у больных с COVID-19 релевантными сочлись семь независимых исследовании, в которых в сумме собраны гематологические данные 3310-и пациентов (табл. 1) [8].

Из них анализы 3245 пациентов были классифицированы по двум клиническим типам: 1) легкая и средняя степень тяжести; 2) тяжелые и критические случаи [9]. По итогам исследовании уровень ферритина был значительно высок у пациентов критическим течением заболевания.

201 результата анализов были проанализированы по двум критериям: 1) с ОРДС; 2) без ОРДС. По показателям уровень ферритина был выше у пациентов с ОРДС [10].

Таблица 1 – Уровень ферритина у разных групп больных COVID-19

Исследования	Случаи	Менее тяжелые	Ферритин (мкг/мл)	Более тяжелые	Ферритин (мкг/мл)	value
BoZhouetal	20	9	291.13 (102.1-648.42)	11	1006.16(408.265-1988.25)	<0.05
Chuan Qin et al	452	166	523.7 (299.1-840.4)	286	800.4 (452.9-1451.6)	<0.001
Sumeyye Kazancioglu et al	120	85	84.9 (5.2-823)	35	330 (30.8-1580)	<0.001
Holler, J.G.	2431	2072	417 (189.5-910.5)	359	1018,50 (545,00–1907,50)	0.001
Wu C, Chen X et al	201	117	457.66 (223.73-702.65)	84	1029.28 (546.26-2000)	<0.001
Guang Chenet al	21	10	337.4 (286.2-1275.4)	11	1598.2 (1424.6-2036)	<0.049

Остальные данные 65-и инфицированных были разделены по трем клиническим типам: 1) легкая степень тяжести; 2) средняя степень тяжести; 3) тяжелая степень тяжести. Также по результатом этих исследовании было выявлено, что уровень ферритина значительно высше в корреляции с тяжелым течением заболевания. Данные показали, что средний уровень ферритина у пациентов с легким течением COVID-19 составлял – 821 мкг/мл, у пациен- тов с средней степенью тяжести заболевания в среднем уровень ферритина – 1331 мкг/мл, у больных с тяжелой степенью тяжести сред- ний уровень ферритина составлял – 1368 мкг/ мл [10,11].

По итогам исследовании, у больных с тяжелым течением COVID-19 значительно повышен уровень сывороточного ферритина, в сравнении с легким и средним степенями тяжести болезни. Этот факт позволяет предположить, что повышенный уровень ферритина свидетельствует о более тяжелой вторичной бактериальной инфекции и обострении COVID-19 [11].

Взаимосвязь уровня ферритина и смертностью от COVID-19

Для обзора взаимосвязи уровня сывороточного ферритина в плазме крови с уровнем смертности инфицированных были взяты данные 6-ти исследовании, в которых собраны анализы 3061 пациентов (табл. 2).

Таблица 2 – Сравнение уровня ферритина у пациентов с не летальным и летальным исходами

Исследования	Случаи	Не летальные исходы	Ферритин	Летальные исходы	Ферритин	value
Fei Zhouetal	191	137	503.2 (264.0–921.5)	54	1435.3 (728.9–2000.0)	<0.01
Chen Taoet al	274	161	481.2 (265.1-871.5)	113	1418.3 (915.4-2236.2)	<0.05
WuC.etal	84	40	853 (330.33-1968.57)	44	1096.21 (559.4-2000)	<0.34
WangZH. etal	59	18	1369.8±1138.2	41	3065.7±6331.4	<0.12
Holler J.G et al	2431	1976	469,00 (199,00–1047,50)	455	596,50 (214,75-1269,25)	<0.084
Fei F etal	22	11	874.36±852.14	11	968.27±1285.54	0.842

Значимый скачок уровня ферритина у пациентов с летальным исходом можно заметить в исследованиях FeiZhou, Chen Tao, Wang ZH. Примечательно, что изменения уровня ферритина у пациентов с COVID-19 не только выше у не выживших, но и увеличиваются с ухудшением течения заболевания.Не менее важным фактором является сопутствующие заболевания. 48% пациентов в исследовании FeiZhou имели сопутствующую патологию, причем наиболее распространенной была артериальная гипертензия (30% пациентов), за которой следовали диабет (19% пациентов) и ишемическая болезнь сердца (8% пациентов). Синтез данных показал, что увеличение случаев смерти связано с преклонным возрастом, а также более высоким показателем пороков при поступлении [12,13]. В исследованиях Holleretalc повышением уровня ферритина был связан возраст пациентов и пол. Результаты показали, что летальные исходы были высоки у пожилых людей и мужчин. Также по показателям 405 летальных случаев: средний уровень ферритина у мужчин (710 (314.50–1474.50) μg/L) был значительно высок чем у женщин (329.00 (161.13–709.25) μg/L)[13-14].В работе WuC. Etal было выявлено, что пожилой возраст (≥65 лет), высокая температура (≥39 °C), сопутствующие заболевания (например, артериальная гипертензия, сахарный диабет), нейтрофилия, лимфоцитопения, а также снижение количества CD3 и CD4 Т-клеток, повышенные показатели воспаления (высокочувствительный С-реактивный белок и сывороточный ферритин) были достоверно связаны с более высоким риском развития ОРДС.Из 201 пациентов со средним возрастом 51 год, у 41,8% развился ОРДС, из них у 52,4% был летальный исход [15]. Безусловно, данные расмотренных исследований показывают, что у пациентов с летальным исходом уровень ферритина выше, чем у остальных инфицированных.

В этом обзоре были рассмотрены показатели ферритина у разных групп инфицированных вирусом SARS-CoV-2. У госпитализированных был зарегестрирован существенно высокий уровень ферритина. Ферритин-это белок, выполняющий функцию депо железа. Уровень этого белка в сыворотке крови отражает нормальный уровень железа и помогает диагностировать железодефицитную анемию [16-20]. Уровень циркулирующего ферритина повышается во время вирусных инфекций и может быть маркером репликации вируса [21]. Повышенный уровень ферритина из-за цитокинового шторма также был зарегистрирован в тяжелых случаях [22, 23]. Во время цитокинового шторма при COVID-19 быстровырабатываются многие воспалительные цитокины, включая IL-6, TNF-α, IL-1β, IL-12 и IFN-γ, которые стимулируют гепатоциты,клетки Купфера и макрофаги секретировать ферритин [24-26]. А также повышение уровня ферритина связывают с воспалением, вызванным инфекцией COVID-19, которая повышает уровень гепцидина, основного регулятора запаса железа в тканях [27-29]. По последним исследованиям W. Liu и H. Li изучили патогенез SARS-CoV-2 и получили доказательства, указывающие на его ключевой патогенный механизм. Эта стратегия включает в себя атаку на 1-бета-цепь гемоглобина, которая, следовательно, инициирует диссоциацию порфиринов от железа и выброс железа в кровоток. В результате разрушается способность гемоглобина связываться с кислородом, что отрицательно сказывается на его доставке к основным органам организма. Это показывает, почему случаи тяжелой гипоксии не меняются с кислородом, а вместо этого связана с быстрой полиорганной недостаточностью. Кроме того, помимо окислительного повреждения легких, свободное железо также вызывает воспаление альвеолярных макрофагов. Нарушение гем-пути может привести к повышению уровня ферритина в сыворотке крови, лимфопении и повышению уровня моноцитов. Кроме того, повышенная нагрузка железом и выработка гемоглобина способствуют повышению вязкости крови при диффузном микроциркуляторном и макроциркуляторномтромбозе. Это приводит к повышенному уровню D-димера, что в некоторых случаях может быть причиной внезапного ухудшения состояния и смерти [30].

Более того, по теоритическим данным новый спайковый белок коронавируса (SARS-CoV-2) обладает гепцидиноподобным действием, а это означает, что вирус может непосредствен- но повышать уровень ферритина независимо от воспалительного эффекта. Однако эти дан- ные нуждаются в более детальных и практиче- ских доказательствах.Тем не менее гиперферритинемия оказывает отрицательное влияние на течение заболевания. У многих пациентов с COVID-19 с повышенным уровнем сывороточного ферритина (>300 мкг/л) вероятность летального исхода до выписки увеличивались в 9 раз.А также предыдущее исследования показали, что уровень ферритина в сыворотке крови связан как с активностью заболевания, так и с активацией макрофагов [31]. В другом исследовании также была представлена выборка из 39 пациентов с COVID-19, у которых уровень ферритина в сыворотке крови достоверно коррелировал с тяжестью заболевания. Еще одной важной особенностью сывороточного ферритина, помимо активной секреции во время воспалительной реакции, является гибель клеток печени. После высвобождения ферритин теряет часть внутреннего содержания железа, производя чрезвычайно высокий уровень свободного железа. Внутриклеточное свободное железо генерирует активные формы кислорода в легких, взаимодействуя с молекулами кислорода, которые могут предрасполагать к развитию респираторного дистресс-синдрома взрослых (ОРДС). Кроме того, внутриклеточное железо и гиперферритинемия повышают риск развития коагулопатии и окислительного стресса, индуцируют эндотелиальное воспаление, которое может предрасполагать к диссеминированной коагуляции и полиорганной недостаточности [31].

Данные исследовании показали, что у пациентов с COVID-19, имеющих одно или несколько сопутствующих заболеваний, уровень ферритина был значительно выше,чем у пациентов без сопутствующих заболеваний.Это подтверждает неблагоприятныйисход у пациентов с сопутствующими заболеваниями. Wang et al впервыес оообщили в своем исследовании,что пациенты с диабетом COVID-19 имеют более высокую смертность, в то время как другие исследования показали,что пациенты с диабетом имели более высокий уровень ферритина, чем те, у кого егоне было [32]. Meng et al впервые исследовали уровень ферритина у пациентов с COVID-19, больных раком, которые показали значительно более высокий уровень ферритина по сравнению с теми, у кого его не было [33-37]. По анализу данных летальных исходов и тяжелых случаев, была замечена корреляция между уровнем ферритина и ухудшением состояния у пациентов с COVID – 19 [38, 39].

Заключение

Данная обзорная статья выявила связь между уровнем ферритина в сыворотке крови и клиническими характеристиками пациентов с COVID-19, включая тяжесть заболевания, смертность и сопутствующие заболевания. У лиц с сопутствующими заболеваниями инфицированных SARS-Cov-2, а также у лиц с тяжелым течением и в случаях летального исхода заметен высокий уровень ферритина. Однако тест на ферритин часто недоступен в экстренных случаях. Мы рекомендуем провести скрининг ферритинового теста у пациентов с COVID-19 для оценки наличия гиперферритинемии и прогнозирования ухудшения состояния и смертности у госпитализированных с COVID-19 пациентов. Будущие клинические исследования должны быть проведены для дальнейшего уточнения его прогностической и патогенетической роли в COVID-19, а также выявления потенциальной терапевтической ценности в контроле воспаления до повреждения жизненно важных органов.

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СЫНАППЕН УЛАНУ КЕЗІНДЕГІ ЭРИТРОЦИТТЕРДІҢ МЕМБРАНАЛАРЫНЫҢ КҮЙІНЕ Е ВИТАМИНІНІҢ ӘСЕРІН ЗЕРТТЕУ

Сынап жер бетінде кездесетін ең қауіпті заттардың бірі болып саналады. Сынап ауаға,суқоймалары мен топыраққа әртүрлі көздерден түсіп,түрлі химиялық өзгерістерге ұшырайды, нәтижесінде қоршаған ортаға және адам денсаулығына уытты әсер етеді. Сынаптың ағзаға жағымсыз әсерлері ең алдымен сынаптың түріне байланысты, өйткені сынаптың саналуан формаларының биожетімділігі, биоаккумуляциясы және токсикокинетикасы әртүрлі болады. Сынап қосылыстарының токсикалық әсерлеріне іштің ауыруы, жүрек айну, құсу, қан токсинемиясы, бүйректің, өкпенің, ас қорыту, жүйке жүйесінің зақымдануы, есте сақтау қабілетінің бұзылуы, шаршау, бұлшықет әлсіздігі, трі мен көздің шырышты қабаттарының тітіркенуі, репродуктивті жүйе қызметіне теріс әсері, иммундық жүйе қызметінің бұзылуы жатады. Биологиялық жүйелерде сынап тотығу және тотықсыздануреакциялары арқылы өзгерістерге ұшырап,нәтижесінде оның тірі ағзаларда сіңірілу қасиеттері ауысады. Бейорганикалық сынап қосылыстаруыттылығының молекулалық механизмінің негізіндежасуша тұтастығы мен өткізгіштігінің бұзылуы, антиоксиданттық қорғаныс механизмдеріне қатысатын ферменттер белсенділігінің жоғалуы нәтижесінде туындайтын тотығу стресінің салдарынан жасуша мембраналарының зақымдануы жатады.Осыған орай, сынаппен уланудың және оның организмге зиянды ықпалының алдын алу және улану салдарынан пайда болатын бұзылыстарды қалпына келтірудің тиімді тәсілдерін табудың маңызы зор. Бұл мақалада жедел және созылмалы сынаптық интоксикация жағдайына түскен жануарлардың эритроциттер мембраналарының күйі, сондай-ақ, Е витаминін пайдалану арқылы клетка мембраналарының төзімділігін арттыру мүмкіндігін зерттеу нәтижелері келтірілді. Жасалған зерттеу нәтижелері бойынша сынаппен жедел және созылмалы интоксикация кезіндегі эритроциттердің мембраналарының бұзылуы орын алатындығы және сынаптың теріс әсерінтөмендету мақсатында антиоксиданттық қасиеті танымал Е витаминін қолдану тиімділігі жайлы қорытынды жасалды.

Түйін сөздер: эритроциттер мембранасы, сынап, интоксикация, гемолиз, Е витамині, төзімділік.

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Investigations of the vitamin e impact on erythrocyte membranes' state in mercury poisoning

Mercury is considered as one of the most dangerous substances found on the Earth surface. Various sources can release mercury into the air, waterways and soils,which is chemically transforms result in further toxic effects on the environment and human health. The negative effects of mercury depend primarily on the type of mercury, because different forms of mercury have different levels of bioavailability, bioaccumulation, and toxicokinetics. The toxic effects of mercury compounds include abdominal pain, nausea, vomiting, blood toxicity, kidney, lung, digestive and nervous system damage, memory disorders, fatigue, muscle weakness, skin and eye irritation, toxic effects on the reproductive system, impaired immune system. In biological pathways, mercury undergoes both oxidation and reduction reactions, leading to changes in its appearance and affecting its biological uptake. The molecular mechanism of toxicity caused by inorganic mercury compounds includes disruption of cell membranes, disruption of cell integrity and permeability, inhibition of enzymes involved in antioxidant defense mechanisms, and promotion of oxidative damage. In this regard, it is important to find effective ways to prevent and treat state of erythrocyte membranes during acute and chronic mercury intoxication, as well as the possibil- ity of increasing the resistance of membranes with the help of vitamin E. The research results obtained indicate the effectiveness of the use of vitamin E in order to achieve an antioxidant effect that prevents damage and destruction of erythrocyte membranes, as for acute and chronic mercury intoxication.

Key words: erythrocyte membrane, mercury, intoxication, hemolysis, vitamin E, resistance.

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Исследование влияния витамина Е на состояние мембран эритроцитов при ртутной интоксикации

Ртуть считается одним из самых опасных веществ, обнаруженных на поверхности земли. Различные источники могут привести к выбросам ртути в воздух, водоемы и почву, которая впоследствие претерпевает химические превращения, что приводит к дальнейшему возрастанию токсичного воздействия на окружающую среду и здоровье человека. Отравляющее действие соединений ртути зависит главным образом от его вида, поскольку разные формы ртути имеют разные уровни биодоступности, биоаккумуляциии токсикокинетики.Токсическийэффект соединений ртути на организм выражается болями в животе, тошнотой, рвотой, токсинемией, поражением почек, легких, пищеварительной и нервной систем, нарушением памяти, утомляемостью, мышечной слабостью, вызывают раздражение кожи и глаз, токсическивлиют на репродуктивную систему,нарушают функцию иммунной системы. В биологических системах ртуть подвергается реакциям как окисления, так и восстановления, что приводит к изменениям ее формы, что в результате влияет на процессы биологического поглощения. Молекулярный механизм токсичности, вызванной неорганическими соединениями ртути, включает повреждение клеточных мембран, посредством ингибирования ферментов, участвующих в механизмах антиоксидантной защиты приводя к активации окислительных процессов, ведущих к нарушению целостности липидного бислояи свойства избирательной проницаемости мембраны. В связи с этим важен поиск эффективных способов снижения токсической нагрузки на организм соединений ртути, устранения и коррекции ее вредного воздействия на организм. В данной статье представлены результаты исследованиясостояния мембран эритроцитов при острой и хронической ртутной интоксикации, а также возможность повышения резистентности мембран с помощью витамина Е.

Ключевые слова: мембрана эритроцитов, ртуть, интоксикация, гемолиз, витамин Е, резистентность.

Кіріспе

Дүниежүзілік денсаулықсақтау ұйымы (ДДҰ) ең көп таралған токсиканттарды талдай отырып, негізгі химиялық заттар мен қосылыстардың тізімінің ішінде сынапты ең улы және кең тараған элементтердің қатарына кіргізді [1-3].

Қазіргі уақытта сынап мөлшері қоршаған ортаға айтарлықтай электр энергиясын өндіру кезінде электр станцияларында көмірді жағу кезінде бөлініп шығады. Электр қуатын өндірудің атаулы әдісі көптеген дамушы елдер үшін қаржылық тұрғыдан ең тиімді және арзан болып табылады, алайда электр энергиясысынаптың ілеспе буының шығарылуымен қатар жүріп қоршаған ортаның ластануына әкеледі [4-7]. Қоршаған ортаға түскен соң сынап (ауа, топырақ, су, күл түріндегі шөгінділер) тотығады және күрделі және улылығы жоғары қосылыстарға айналады. Сынап топыраққа, суға түскенде немесе күл түрінде шөккенде, бактериялар және басқа тірі организмдер (балықтар, балыққоректі жануарлар түрлері және т.б.) метаболизміне ену арқылы түрленіп метил сынапқа айналады [8-16].

Сынаптың ерекше зиянды қасиеті – оның уытты әсері болып табылады, микромолярлық концентрациядағы болмашы дозалардың өзітірі жасушалардың органоидтарының зақымдалуына алып келеді. Сынаптың түрлі клеткаларға улы әсерін зерттеуге бағытталған бірқатар тәжірибелер нәтижесінде атаулы элемент қосылыстарымен уланған ағза тіндерінде жасуша өлімінің себебі митохондриялар қызметін бұзылу екендігі анықталды [17-21]. Сынап әсерінен зардап шеккен тіндердегі жасушалардың бойында липопероксидация мен тотығу стрессініңасқынуы орын алады [22-24]. Сынап күшті тиолды улардың қатарына жатады және организмге түскен кезде тіндік ферменттердің сульфгидрильді топтарымен байланысып, тиол ферменттерін инактивациялайды және ақуыз синтезін тежейді, нәтижесінде тіндерде дистрофиялық және некроздық процестер етек жаяды. [25-27].

Сынап адам ағзасына асқазан-ішек жолдары арқылы енеді, аш ішекте адсорбцияланады және шырышты қабат арқылы қан айналым жүйесіне сіңеді, қан ағысымен бауырға түсіп, метаболизмге ұшырайды. Сондай ақ, токсиканттың едәуір бөлігі организмнен табиғи жолмен шығарылмайды, бауыр мен бүйрек сияқты ішкі органдарда жинақталып, бүкіл ағзаға зиянды, теріс әсерін тигізеді [28-31]. Демек, сынап қосылыстарының ағзаға уытты әсерінің алдын алу және салдарын емдеудің тиімді жолдарын іздестіріп зерделеу бүгінгі күннің өзекті мәселесі болып табылады. Аталған деректерді ескере отырып біздің зерттеулеріміздің мақсаты болып сынаппен жедел және ұзақ мерзімді улану кезінде эритроциттер мембраналырының күйіне баға беру және танымал антиоксидант Е витаминін пайдалану арқылы сынап әсерінің ауыртпашылығын едәуір азайту мүмкіндігін қарастыру болып табылады.

Зерттеу материалдары мен әдістері

Алға қойылған мақсатымызға сәйкес тәжірибелер *in vivo* жағдайында салмақтары 200-280 г болатын 20 ересек (12 айлық) егеуқұйрықтармен жүргізілді. Жануарлар виварий жағдайында стандартты күтімде болды. Тәжірибе барысында жануарлар 5 топқа бөлінді: 1- бақылау тобы, 2-ші және 4-ші топ егеуқұйрықтары жедел және созылмалы сынап интоксикациясына ұшыратылды. Сынаппен улану моделін іске асыру үшін жануарларға сынап хлориді пероралды жолмен жануардың 100 грамм салмағына шаққанда жіті улану моделін туғызу үшін 0,1 мг және созылмалы улану моделін туғызу үшін 0,05 мг болатындай мөлшерде енгізілді. Жедел улану моделі үшін сынап тұздары 1 рет және созылмалы интоксикация туғызу мақсатында 14 күн бойы беріліп келді. Е витамині 3-ші және 5-ші топ жануарларына сынап хлоридімен қосып ауыз қуысынан енгізілді. Тәжірибелерді іске асыру үшін егеуқұйрықтардың қаны зерттелді.

Зерттеу барысында эритроциттер мембраналарының күйіне баға беру үшін эритроциттердің осмостық резистенттілігін (ЭОР), эритроциттер мембраналарының өткізгіштігін (ЭМӨ) анықтау әдістері қолданылды.

Эритроциттерді бөліп алу. Егеуқұйрықтардың қаны ұйып қалмауы үшін гепарин ерітіндісі қолданылды. Қанды 1000g жылдамдықпен центрифугада 10 мин айналдыру арқылы эритроциттер бөлініп алынды. Плазма мен қанның ақ клеткаларынан ажыратылған эритроциттер құрамында 150мМ NaCl, 5мМ Na_2HPO_4 (pH-7,4) бар инкубация ортасы (ИО) буферлі ерітіндімен екі қайтара шайылды. Алынған қанның қызыл түйіршіктері тәжірибе жұмыстарында пайдаланылды. Тәжірибе жасалмас бұрын алдын ала эритроциттер 20 есе буферлі ерітіндімен сұйылтылып, 37^{o}C температурада 5 мин термостатта қыздырылды.

Эритроциттердің осмостық төзімділігі натрий хлоридінің ерітінділеріндегі (0,35-0,9г/100мл) 20 мин термостатта 37°C температурада қыздырылған эритроциттер гемолиз деңгейі бойынша анықталды. Na_2CO_3-тің 0,1г/100мл концентрациялы ерітіндідегі эритроциттердің толық гемолиз деңгейін 100%-ға бағалап, қанның қызыл түйіршіктерінің гемолиз деңгейі пайыздық қатынаста есептелінді. Оптикалық тығыздығы 540 нм толқын ұзындығында PD 303-UV спектрофотометрінің көмегімен тіркелді.

Эритроцит мембраналарының өткізгіштігі (ЭМӨ) Колмаков В.Н., Радченко В.Г. әдісі бойынша анықталды [32].

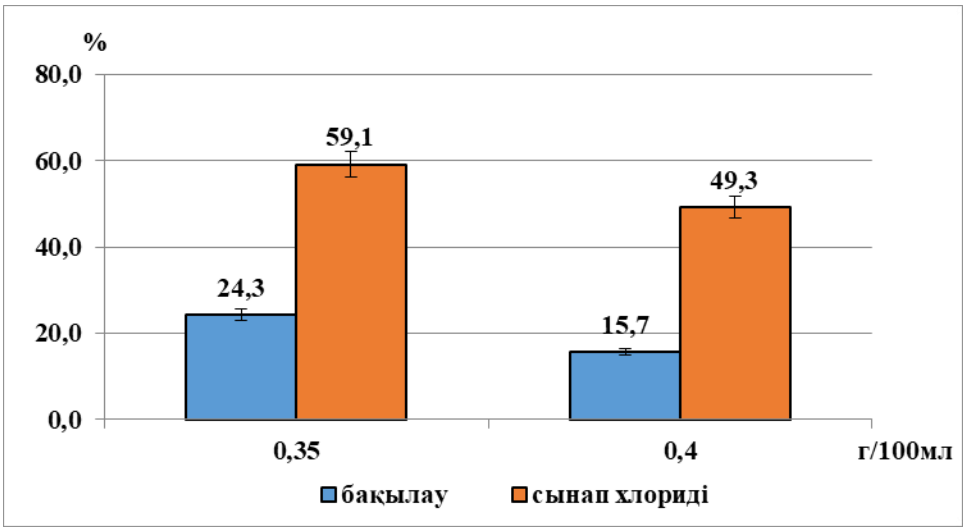
Бұл әдіс мочевина мен натрий хлориді ерітінділеріндегі гемолизіне негізделген. Мочевина эритроцит ішінде гиперосмостық концентрация туғызып, эритроциттерді ісіндіру нәтижесінде гемолизге ұшыратып, клетка мембранасынан гемоглобиннің шығуына жол береді. Эритроциттердің суспензиясын мочевина (18 г/л) мен натрий хлоридінің (0,9 г/100 мл) әртүрлі қатынасындағы (65:35; 60:40; 55:45; 50:50; 45:55; 40:60) ерітінділерінде 3 минут аралығында инкубацияланып, центрифугада 1000g жылдамдықпен 10 минут бойы айналдырылды. Тұнбаның бетінен алынған ерітіндінің оптикалық тығыздығы 540 нм толқын ұзындығында тіркелді. Na_2CO_3-тің 0,1г/100мл концентрациялы ерітіндісіндегі эритроциттердің толық гемолизі 100% болып есептеліп, эритроциттер гемолизінің деңгейі пайыздық қатынаста анықталды.

Мәліметтерді статистикалық өңдеу. Алынған нәтижелер параметрдің орташа арифметикалық мәнін, орташа квадраттық ауытқуын және арифметикалық ортаның қателігін есептей отырып, Microsoft Excel бағдарламасының көмегімен статистикалық өңдеуден өтті. Фишер-Стьюдент критериін ескере отырып, көрсеткіштердің тіркелген өзгерістері $p \leq 0{,}05$ болғанда дұрыс деп саналды.

Зерттеу нәтижелері және талқылау

Биологиялық мембраналар физиологиялық процестерді жүзеге асыруда және реттеуде маңызды рөл атқарады, сондықтан сынаптың ағзаға әсерін анықтау үшін сынаппен улану кезіндегі эритроциттер мембраналарының күйінің өзгеруі зерттелді.

Токсианттың эритроциттердің мембраналарының күйіне әсерін анықтау үшін *in vivo* жағдайында сынап иондарының әртүрлі концентрацияларының эритроциттердің осмостық төзімділігіне әсеріне зерттеулер жүргізілді. Тәжірибелердің бірінші кезеңінде сынап хлоридін ағзаға бір рет енгізгендегі оның клетка мембраналарына әсері анықталды (сурет 1).



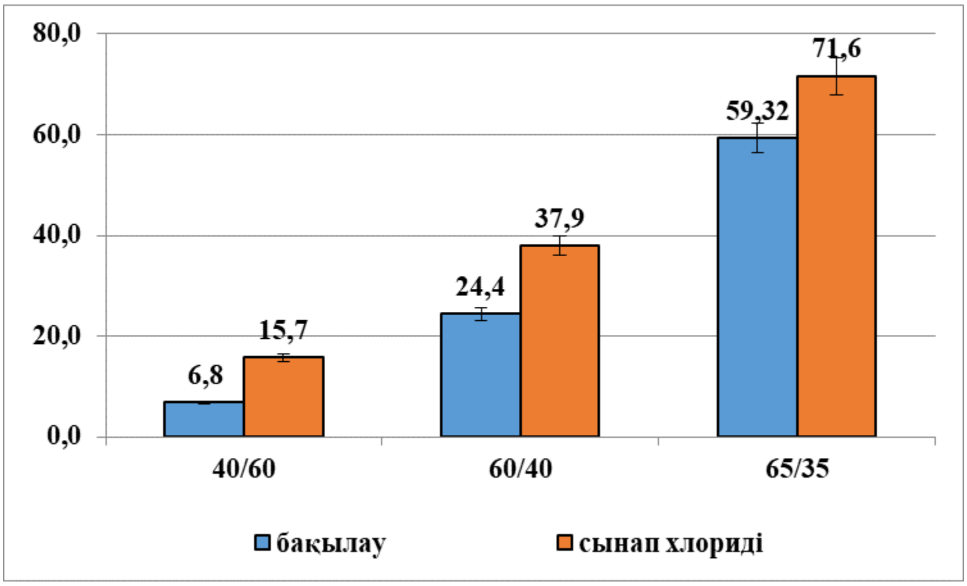
Абсцисс өсі: NaCl концентрациялары, г/100 мл;ординат өсі: гемолиз деңгейі, %.

1-сурет – Сынап хлоридін бір реттік енгізудің зертханалық егеуқұйрықтар эритроциттерінің осмостық резистенттілігіне әсері

1-суретте келтірілген диаграммадан натрий хлориді концентрациясының төмендеуіне сәйкес гемолиз мәнінің жоғарылауын байқауға болады. Натрий хлоридінің гипотониялық ерітінділерінде су молекулаларының эритроцит мембранасы арқылы осмостық қысым әсерінен енуі нітижесінде мембрана жыртылып, клетка гемолизге ұшырайды. Гемолиздің жоғары көрсеткіштері NaCl ерітіндісінің 0,35 г/100 мл концентрациясында байқалды. Алайда барлық зерттелген натрий хлоридінің концентрацияларында бақылау тобындағы егеуқұйрықтардың эритроциттер гемолиз деңгейі сынаппен уланған жануарлардың клеткаларынан 2,5-3 есе төмен болды. Натрий хлоридінің 0,35 мг/100 мл концентрациясында бақылау тобында гемолиз көрсеткіші 24,3%, ал тәжірибелік топта – 59,1%, тұз концентрация- сы 0,4 г/100 мл ерітіндіде гемолиз, сәйкесінше 15,7% және 49,3% құрады.

2-суретте мочевина мен натрий хлориді- нің түрлі қатынасындағы ерітінділері әсерінен туындаған жедел сынаптық интоксикация кезіндегі эритроцит мембраналарының өткізгіштігін анықтау барысында алынған мәліметтер көрсетілген.

Жедел сынаптық интоксикация кезінде эритроцит мембраналарының өткізгіштігін анықтау мочевина мен натрий хлоридінің арақатынасы 65/35 болғанда эритроциттердің гемолиз деңгейінің күрт жоғарылайтыны анықталды.



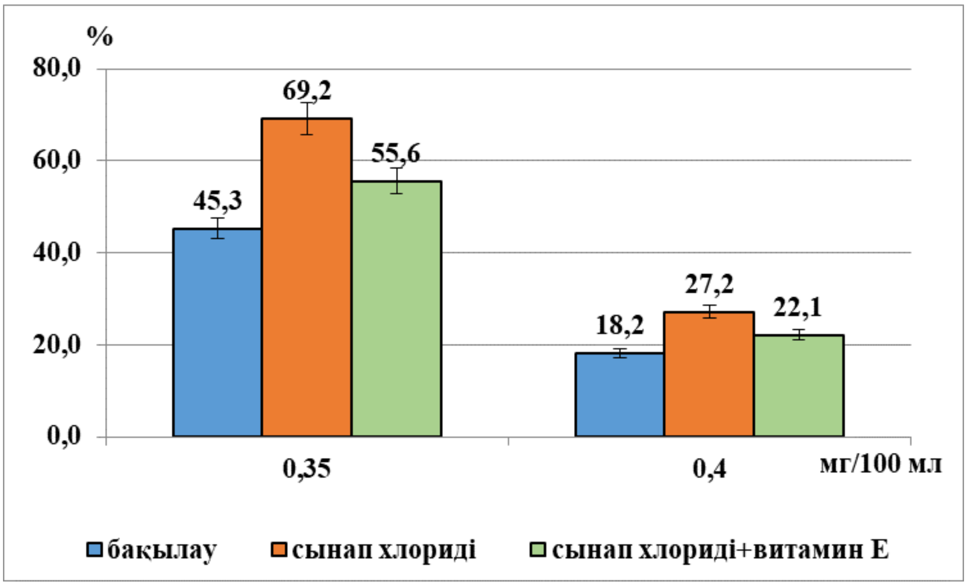
Абсцисс өсі:мочевина/NaCl ерітінділерінің қатынасы;ординат өсі: гемолиз деңгейі, %.

2-сурет – Сынап хлоридін бір реттік енгізудің зертханалық егеуқұйрықтардың эритроцит мембраналарының өткізгіштігіне әсері

Суретте мочевина концентрациясының жоғарылауымен және инкубациялық ортадағы NaCl мөлшерінің төмендеуімен эритроциттердің гемолизі күшейетіні көрінеді. Эритроцит гемолизінің ең жоғары көрсеткіші мочевина/NaCl ерітіндісінің 65/35 қатынастағы концентрациясында қол жеткізілді. Бұл концентрацияда бақылау тобындағы гемолиз көрсеткіші 59,3%, ал тәжірибелік топта – 71,6% құрады, ал басқа ерітінділерде мочевина концентрациясының төмендеуі және NaCl концентрациясының жоғарылауы кезінде гемолиз көрсеткішінің төмендеуі байқалды, мочевина мен NaCl ерітінділерінің 60/40 қатынасында сәйкесінше, 24,4% және 37,9%, ал мочевина мен NaCl ерітінділерінің қатынасы 40/60 болғанда, тиісінше, бақылау және тәжірибе топтарында – 6,8% және 15,7% көрсетті. Дегенмен, алдындағы тәжірибелердегідей сынаппен уландырылған егеуқұйрықтардың мембрана өткізгіштігі жоғары болды, мочевина-натрий хлориді ерітінділерінің 40/60 және 60/40 қатынасында бақылау мен тәжірибе топтарындағы гемолиз айырмашылығы дерліктей 50 % құраса, 65/35 қатынасында ол көрсеткіш 15% құрады, демек мембрана қасиеттері токсикант әсерінен бұзылысқа ұшырады.

Зертханалық егеуқұйрықтардағы эритроциттердің осмостық төзімділігіне Е витамині мен сынап хлоридінің бірлескен әсерін зерттеу жұмыстарының нәтижелері 3-суретте келтірілген.

Суретте келтірілгендей, гемолизге ұшыраған клетка саны NaCl концентрациясы 0,35 г/100 мл болғанда ең жоғары деңгейде болатыны байқалды. Натрий хлоридінің берілген концентрациясында бақылау тобында гемолиз көрсеткіші 49,3%, ал тәжірибелік топтарда – 69,2% және 55,6%, ал басқа 0,4 г/100 мл ерітіндіде гемолиз, сәйкесінше 18,2% және 27,2% бен 22,1% құрады. Натрий хлоридінің гипотониялық ерітінділерінде гемолиз дәрежесі айтарлықтай болғанымен сынап хлоридімен уланған жануарлардың эритроциттерінің осмостық төзімділігі бақылаумен салыстырғанда 1,5 есе төмендейді Егеуқұйрықтардың рационына Е витаминін қосу арқылы эритроциттердің осмостық төзімділігін біршама арттыруға болатындығы дәлелденді. Е витамині және сынап хлориді ағзаға қатар түскенде сынап иондарының зақымдаушы әсері біршама төмендегені анықталды. Токсикант әсеріне ұшыратылған егеуқұйрықтар клеткаларының осмостық төзімділігінің көрсеткіші Е витаминін қолданғанда 25% артатындығы белгілі болды.



Абсцисс өсі: NaCl концентрациялары, г/100 мл;ординат өсі: гемолиз деңгейі, %

3-сурет – Сынап хлориді мен Е витаминін бір реттік енгізудің зертханалық егеуқұйрықтар эритроциттерінің осмостық төзімділігіне бірлескен әсері

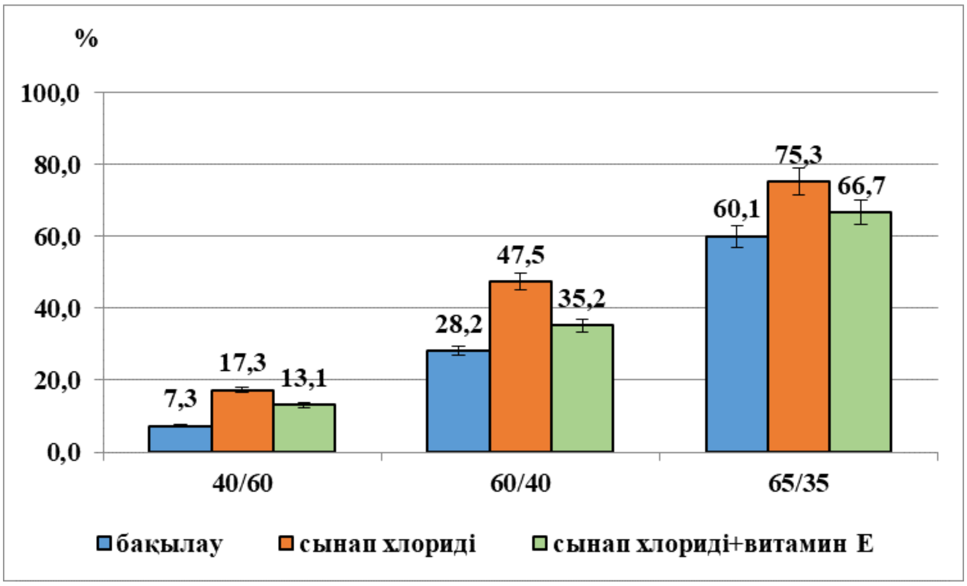
Е витамині мен сынап хлоридінің эритроциттердің мембраналарының өткізгіштігіне бірлескен әсерін анықтау тәжірибелерінің нәтижелері 4-суретте келтірілді.

Инкубациялық ортадағы мочевина концентрациясының жоғарылауымен және NaCl мөлшерінің төмендеуімен эритроциттердің гемолизі күшейетіні заңдылық. Эритроцит гемолизі дәрежесінің ең жоғары сандық көрсеткіші алдындағы тәжірибедегідей мочевина/NaCl қатынасы 65/35 болғанда қол жеткізілді. Бұл концентрацияларда бақылау тобындағы гемолиз көрсеткіші 60,1%, ал тәжірибелік топтарда – 75,3% және 64,4% құрады, ал басқа ерітінділерде мочевина концентрациясының төмендеуі және NaCl концентрациясының жоғарылауы кезінде гемолиз көрсеткіштерінің төмендеуі байқалды, мочевина мен NaCl ерітінділерінің 60/40 қатынасында, сәйкесінше 28,2% , 47,5% және 35,2% құрады, ал мочевина мен NaCl ерітінділерінің қатынасы 40/60 болғанда, бақылау және тәжірибе топтарында, тиісінше, 7,3% ,17,3% және 13,1 % көрсетті.

Алдындағы тәжірибе сияқты Е витамині берілген жануарлар эритроциттерінің өткізгіштігі сынаппен уландарылған топ клеткаларымен салыстырғанда мембрана өткізгіштігі 30% төмен болғанымен бақылау топтарына қарағанда 1,5 есе жоғары екені анықталды.

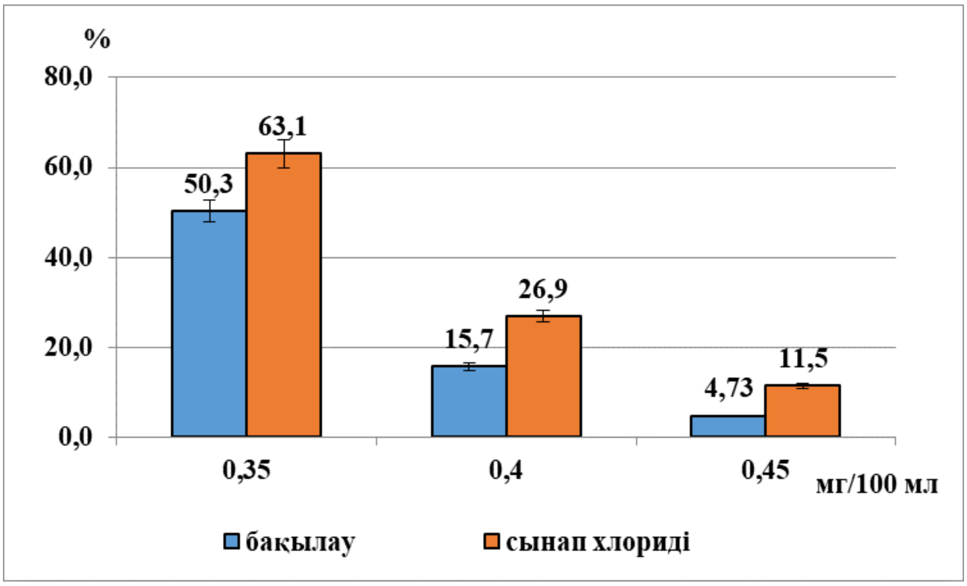
Эксперименттердің келесі кезеңінде сынап хлоридінің 14 күндік әсері кезіндегі зертханалық егеуқұйрық эритроциттерінің осмостық төзімділігі мен мебрана өткізгіштік қасиеті анықталды. Зерттеу нәтижелері 5-6 суреттерде келтірілді.

5-суретте токсиканттың әсерінен қолданылған NaCl ерітіндісінің барлық концентрацияларында зертханалық егеуқұйрықтар эритроциттерінің гемолиз деңгейінің жоғарылайтыны көрсетілген. Эритроциттердің гемолизге ұшырау дәрежесі NaCl ерітіндісінің 0,35 г/100 мл концентрациясында бақылау тобында 50,3%, ал тәжірибелік топта – 63,1%, басқа 0,4 г/100 мл концентрациядағы ерітіндіде гемолиз,сәйкесінше 15,7% және 26,9% болды, ал 0,45 г/100 мл концентрациядағы ерітіндіде гемолиз, сәйкесінше 4,73% және 11,5% құрады. Сынапмен уландырылған жануарлар эритроциттерінің төзімділігі 15% шамасында төмен болған.



Абсцисс өсі: мочевина/NaCl ерітінділерінің қатынасы; ординат өсі: гемолиз деңгейі %

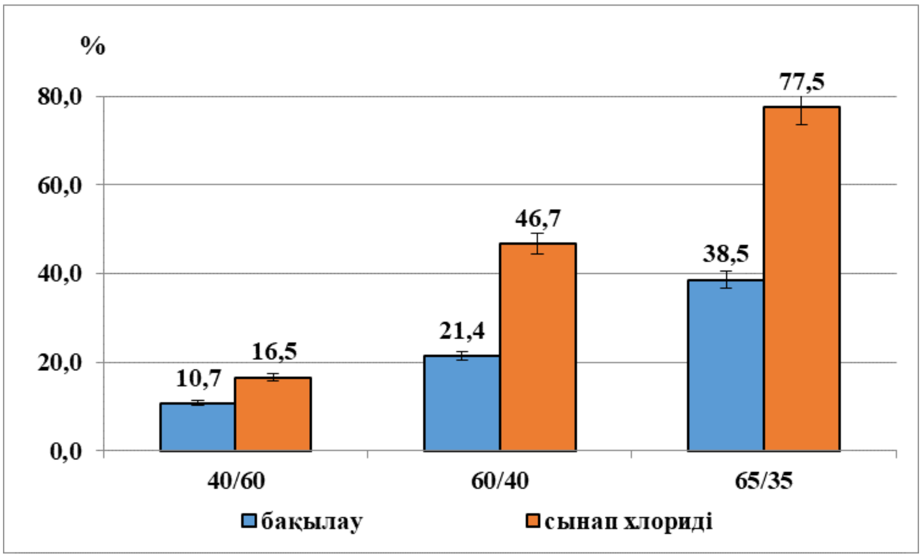
4-сурет – Сынап хлориді мен Е витаминін бір реттік енгізудіңзертханалық егеуқұйрықтардың эритроцит мембраналарының өткізгіштігіне бірлескен әсері



Абсцисс өсі: NaCl концентрациясы г/100 мл; ординат өсі: гемолиз деңгейі %

5-сурет – Зертханалық егеуқұйрықтардың эритроцит мембраналарының осмостық төзімділігіне сынап хлоридінің созылмалы әсері

6-суретте келтірілген нәтижелерге сүйене отырып, сынап хлоридінің созылмалы әсері кезінде эритроциттердің мембрана төзімділігінің төмендеуі мембраналарының өткізгіштігінің жоғарылуымен қатар жүретіндігін атап өтуге болады.

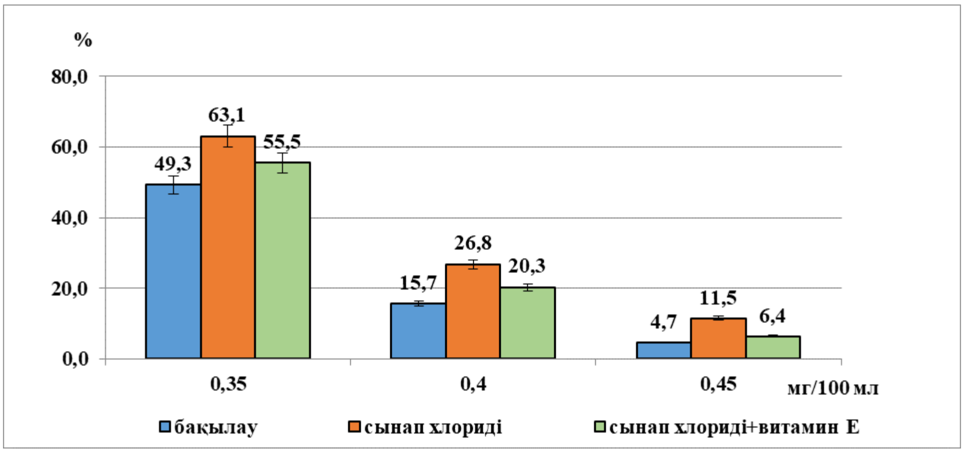


Абсцисс өсі: мочевина/NaCl ерітінділерінің қатынасы; ординат өсі: гемолиз деңгейі, %

6- сурет – Сынап хлоридінің созылмалы интоксикациясының зертханалық егеуқұйрықтардың эритроцит мембраналарының өткізгіштігіне әсері

Қолданылған мочевина мен NaCl ерітінділерінің барлық арақатынастарында гемолиз- дің орын алуы байқалды. Алдындағы тәжіри- бедегі сияқты гемолиз деңгейі мочевина мен натрий хлоридінің 65/35 арақатынасында жо- ғары болды. Барлық зерттелген концентрация- ларда уытты металл әсеріне түскен жануарлар эритроциттерінің мембрана өткізгіштігі 50% артқан.

Алдындағы тәжірибелердегідей сынап хлоридінің 14 күндік созылмалы әсеріне ұшыратылған егеуқұйрықтарға Е витамині қатар берліп отырғанжағдайдағы оладың эритроциттерінің мембраналарының күйі зерттелді (сурет 7).

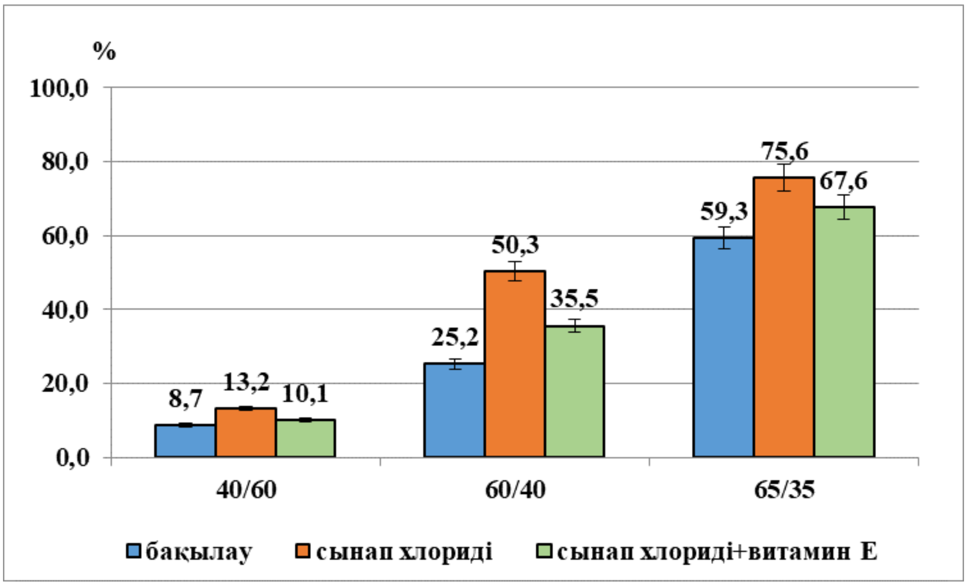


Абсцисс өсі: NaCl концентрациясы г/100 мл; ординат өсі: гемолиз деңгейі %

7- сурет – Зертханалық егеуқұйрықтарға 14 күн бойысынап хлориді мен Е витаминін енгізудің эритроциттердің осмостық төзімділігіне бірлескен әсері

Алынған нәтижелерден сынаптың созылмалы интоксикациясында Е витаминін бірлесе қолданудың зертханалық егеуқұйрықтар эритроциттерінің осмостық төзімділігіне оң әсерін байқауға болады.Натрий хлоридінің түрлі концентрацияларын қолданса да, жалпы тенденция ортақ, яғни бақылау тобымен салыстырғанда сынаптың созылмалы әсеріне түскен егеуқұйрықтар клеткаларының мембраналарының құрылымы біртұтастығы біршама бұзылып, осмостық қысымға деген төзімділігінің төмендеуімен сипатталды. Бұл эксперименттерде тәжірибе тобында гемолиз мөлшері бақылауға қарағанда 15-20% артқан. Е витамині сынап хлоридімен уландыру барысында қатар беріліп отырған топтарда гемолиз дәрежесі 12% төмендегенін айтып өтуге болады.

Мембрана өткізгіштігін анықтау нәтижелері 8 суретте көрсетілген. Бұл жағдайда да созылмалы түрде сынаппен уланған жануарлардың эритроцит клеталарының мембрана өткізгіштігі Е витамині әсерінен айтарлықтай қалпына келгенін байқауға болады. Мембраналардың өткізгіштігі 30% төмендеп бақылау тобына біршама жақындай түсті. Дегенмен бақылау тобымен салыстырғанда натрий хлор мен мочевинаның 40/60 қатынасында 20%, 60/40 қатынасында 40% және 65/35 қатынасында 24% төмен болды.



Абсцисс өсі: мочевина/NaCl ерітінділерінің қатынасы; ординат өсі: гемолиз деңгейі, %

8-сурет – Зертханалық егеуқұйрықтарға 14 күн бойы сынап хлориді мен Е витаминін енгізудің эритроцит мембраналарының өткізгіштігіне бірлескен әсері

Алынған нәтижелерді саралай кетсек, жедел және созылмалы улану кезінде эритроцит мембранасының қасиеттері жедел улану барысында созылмалы улану кезіндегі күйіне қарағанда қарқынды түрде зақымдалған, жедел интоксикация кезінде мембрананың осмостық төзімділігі 2,5 есе төмендесе, өткізгіштігі 2 есе артады, ал созылмалы улану жағдайында жануарлар эритроциттерінің өткізгіштігі мен төзімділігі бақылау тобымен салыстырғанда 1,5 есе өзгерген. Бұл біздің пайымдауымызша ағзада бейімделушілік механизмдердің іске қосылуына байланысты. Алайда Е витаминінің детоксикациялаушы әсерін салыстырса, жедел улану кезінде Е витаминінің оң эффектісі айқындау көрінді.

Қорытынды

Тәжірибе нәтижелері көрсеткендей, *in vivo* жағдайда сынап хлоридімен жедел және созылмалы улану кезінде эритроциттер мембраналарының өткізгіштігі жоғарылап, эритроциттердің осмостық төзімділігі төмендеді. Е витаминін сынап хлоридімен улану кезінде бірлесе қолдану эритроциттердің осмостық төзімділігінің жоғарылауына әкелетін эритроциттердің мембраналарының өткізгіштігін төмендететіні анықталды. Антиоксидант ретінде қолданған Е витамині және сынап хлориді ағзаға қатар түскенде сынап иондарының зақымдаушы әсері айтарлықтай төмендетіп, токсикант әсеріне ұшыратылған егеуқұйрықтар клеткаларының осмостық төзімділігі мен эритроциттер мембраналарының өткізгіштігі жоғарылап, Е витаминін қолданғанда детоксикациялаушы әсері артатындығы белгілі болды. Зерттеу нәтижелерінде сынап хлоридімен жедел және созылмалы интоксикация кезінде эритроциттердің мембраналарының құрылымдық және функционалдық жағдайын жақсартатын антиоксидант ретінде Е витаминін қолданудың тиімділігі көрсетілді.

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КОРРЕКЦИЯ *TARAXACUM OFFICINALE* ГИСТОМОРФОЛОГИЧЕСКИХ ИЗМЕНЕНИЙ СЕМЕННИКОВ, ВЫЗВАННЫХ ХЛОРИДОМ КАДМИЯ

Настоящее исследование посвящено оценке гистоморфологических изменений, возникающих в семенниках лабораторных крыс под влиянием хлорида кадмия в различных концентрациях, а также поиску эффективного способа коррекции данных нарушений с помощью экстракта Taraxacum officinale. Цель работы заключается в определении степени повреждения сперматогенного эпителия и интерстициальной ткани при токсическом воздействии металла, а также в выявлении потенциальной гонадопротекторной роли растительного экстракта. Научная и практическая значимость исследования связана с актуальной проблемой металлотоксикозов, приводящих к ухудшению репродуктивных функций, и необходимостью разработки профилактических мер для сохранения фертильности. В ходе эксперимента использовались три различные дозы хлорида кадмия, после чего часть животных получала коррекцию экстрактом одуванчика. Методология включала морфологическое исследование срезов семенников, окрашенных гематоксилином и эозином, где оценивались состояние эпителия канальцев, степень отёчности межканальцевых пространств и наличие некротических изменений. Результаты показали, что низкие концентрации кадмия вызывали лишь начальные признаки токсического воздействия, тогда как более высокие приводили к некрозу эпителиальных клеток и заметной дезорганизации структуры канальцев. При этом введение экстракта Taraxacum officinale значительно снижало уровень повреждений. Вклад данного исследования в область знаний заключается в подтверждении антиоксидантных и противовоспалительных свойств экстракта, что открывает возможности для будущего применения растительных средств в профилактике и лечении кадмиевой интоксикации. Практическая ценность работы связана с перспективой использования Taraxacum officinale в качестве эффективного компонента комплексной терапии, направленной на сохранение мужской репродуктивной функции.

Ключевые слова: семенники, хлорид кадмия, Taraxacum officinale, гистоморфология, репродуктивное здоровье.

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Correction of testes histomorphological changes induced by cadmium chloride using Taraxacum officinale extract

This research investigates the histomorphological alterations in rat testes under varying doses of cadmium chloride exposure, as well as explores the effectiveness of Taraxacum officinale extract in correcting these observed tissue disruptions. The primary objective is to assess the degree of damage to the spermatogenic epithelium and interstitial tissue caused by the toxic metal, while also determining the potential gonadoprotective function of the herbal extract. The scientific and practical significance of this research is grounded in the pressing issue of metal-induced toxicity leading to impaired reproductive capacity, underlining the need for preventive measures that safeguard fertility. Three different doses of cadmium chloride were administered, followed by the introduction of the dandelion extract to a subset of experimental animals. Methodologically, hematoxylin and eosin staining of testicular sections provided a means to evaluate the state of the seminiferous tubules, measure edema in the interstitial space, and detect necrotic changes. Findings indicated that lower doses of cadmium prompted only minor toxic effects, whereas higher concentrations resulted in notable epithelial necrosis and disruption of tubule morphology. Meanwhile, Taraxacum officinale extract significantly reduced these adverse effects. The contribution of this work lies in verifying the extract's antioxidant and anti-inflammatory properties, paving the way for expanded use of plant-based interventions in preventing and treating cadmium intoxication. The practical relevance is reflected in the prospect of incorporating Taraxacum officinale as a viable component of therapeutic strategies aimed at preserv- ing male reproductive function.

Key words: testes, cadmium chloride, Taraxacum officinale, histomorphology, reproductive health.

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Taraxacum officinale сығындысы арқылы кадмий хлоридімен туындаған аталық жыныс безін гистоморфологиялық өзгерістерді түзету

Бұл жұмыста зертханалық егеуқұйрықтардың аталық жыныс бездерінде хлорлы кадмийдің әртүрлі концентрациялары әсерінен орын алатын гистоморфологиялық өзгерістер зерделеніп, сонымен қатар Taraxacum officinale сығындысын пайдалану арқылы осындай бұзылыстарды түзетудің тиімді тәсілі анықталды. Зерттеудің негізгі мақсаты – металдың улы ықпалына ұшыраған сперматогендік эпителий мен аралық тіндердің зақымдану дәрежесін бағалау және өсімдік сығындысының ықтимал қорғаныстық рөлін анықтау. Жұмыстың ғылыми және тәжірибелік маңыздылығы металлотоксикоздар салдарынан туындайтын репродуктивтік қызметтің нашарлау мәселесінің өзектілігімен, сондай-ақ жемістілікті сақтауға арналған алдын алу шараларын әзірлеу қажеттілігімен түсіндіріледі. Тәжірибе барысында хлорлы кадмийдің үш түрлі дозасы қолданылды, артынан кейбір жануарларға одуванчик сығындысы енгізілді. Әдістеме ретінде гематоксилин және эозинмен боялған ұрық тіліктерінің морфологиялық сараптамасы жүргізіліп, өзекшелер эпителийінің жағдайы, канальцааралық кеңістіктегі ісіну көрінісі мен некроз белгілері бақыланды. Нәтижелер көрсеткендей, кадмийдің төмен мөлшері аздаған уытты әсер тудырса, жоғары деңгейлері эпителийлік жасушалардың некрозына және тін құрылымының бұзылуына әкелді. Taraxacum officinale сығындысын енгізу көптеген жағымсыз өзгерістердің айтарлықтай азаюына септігін тигізді. Бұл зерттеудің жетістігі сығындының қабынуға қарсы және антиоксиданттық қасиеттерін растау арқылы кадмий интоксикациясының алдын алу мен емдеуде өсімдік құралдарын кеңінен қолдануға жол ашады. Алынған деректер аталық бездің қызметін қорғау мақсатында Taraxacum officinale препаратын емдік кешеннің бір бөлшегі ретінде пайдалануға мүмкіндік береді.

Түйін сөздер: аталық бездер, кадмий хлориді, Taraxacum officinale, гистоморфология, репродуктивтік денсаулық.

Введение

Бурное развитие промышленности и рост антропогенной нагрузки на окружающую среду способствуют всё более широкому распространению тяжёлых металлов, в том числе и кадмия. Кадмий, обладающий длительным периодом полураспада и способностью накапливаться в живых организмах, признан одним из наиболее опасных токсикантов, поскольку его попадание в организм (через пищу, воду, вдыхание аэрозолей) коррелирует с полиорганным повреждением, включая репродуктивную систему. В частности, ряд исследований указывает на негативное влияние кадмия на семенники, вплоть до серьёзных морфологических и функциональных изменений, которые способны привести к нарушениям сперматогенеза, снижению фертильности и гормональным дисбалансам.

Актуальность выбранной темы объясняется как медицинской, так и экологической значимостью данной проблемы. Во-первых, кадмиевая интоксикация в низких и субтоксичных дозах может долгое время оставаться незамеченной, вызывая при этом постепенную деградацию тканей семенника и репродуктивных функций организма в целом. Во-вторых, накапливающиеся в организме тяжёлые металлы оказывают окислительный стресс, нарушают барьерные механизмы (например, гемато-тестикулярный барьер), что в совокупности препятствует нормальному развитию и дифференцировке половых клеток.

Одним из перспективных направлений в токсикологии является поиск и тестирование растительных экстрактов, обладающих антиоксидантными и гепато- либо гонадопротекторными свойствами. В частности, экстракт *Taraxacum officinale* (одуванчик лекарственный) рассматривается многими исследователями как источник биологически активных веществ, способных нейтрализовать свободные радикалы, снижать воспалительные реакции и защищать ткани от повреждающего действия токсикантов. Однако в литературе пока недостаточно сведений о том, как именно экстракт данного растения влияет на гистоморфологические изменения семенников при отравлении хлоридом кадмия и способствует ли он полной или частичной регенерации сперматогенного эпителия.

Исходя из вышесказанного, объектом настоящего исследования являются гистоморфологические изменения в семенниках лабораторных животных под воздействием хлорида кадмия. Предмет исследования – коррекционное влияние экстракта Taraxacum officinale на выявленные повреждения семенников.

Цель работы – провести оценку гистоморфологических изменений в семенниках крыс, вызванных пероральным воздействием хлорида кадмия, и выявить способность экстракта Taraxacum officinale восстанавливать структуру семенных канальцев и межканальцевой ткани.

Для достижения поставленной цели сформулированы следующие задачи:

1. Охарактеризовать структуру семенников (на гистологическом уровне) при воздействии кадмия в разных концентрациях.
2. Определить степень выраженности дегенеративных и некротических процессов, а также наличие изменений в клетках Лейдига и в кровеносных сосудах интерстиция.
3. Изучить динамику восстановления семенников при дополнительном введении экстракта Taraxacum officinale, сопоставив данные гистологического анализа с контрольной группой и группами, подвергшимися токсическому воздействию.
4. Сделать вывод о целесообразности применения экстракта Taraxacum officinale в качестве корректора повреждений, вызванных тяжёлыми металлами.

Гипотеза исследования заключается в том, что экстракт Taraxacum officinale, обладая выраженным антиоксидантным и противовоспалительным действием, способствует частичной или полной нормализации структуры семенников и функций сперматогенеза, нарушенных действием хлорида кадмия.

В работе применялись морфологические и гистологические методы исследования (стандартные окраски тканей, световая микроскопия), а также сравнительный подход (оценка результатов в разных группах животных).

Практическая значимость проведённой работы состоит в расширении представлений о механизмах и степени повреждения репродуктивной системы токсическими металлами, а также в определении возможностей растительных экстрактов как перспективного средства профилактики и терапии при кадмиевой интоксикации. Накопленные данные могут быть использованы в фармакологии, экологической биологии и биомедицине для разработки дальнейших исследований и потенциальных лечебных рекомендаций.

Обзор литературы

Многочисленные исследования подтверждают, что кадмий (Cd) выступает одним из наиболее коварных тяжёлых металлов, способных аккумулироваться в организме животных и человека, вызывая широкий спектр токсических эффектов. Кадмий обнаруживается практически на всех уровнях экосистемы и поступает в биосистемы главным образом через загрязнённую воду и пищевые продукты [1,2]. Длительный биологический период полураспада (до нескольких десятилетий) приводит к хроническим воздействиям даже при относительно низком содержании металла в окружающей среде [3].

Согласно данным ряда зарубежных авторов, механизм токсичности кадмия во многом обусловлен генерацией свободных радикалов, что приводит к окислительному стрессу, повреждению клеточных мембран и формированию некротических и воспалительных изменений [4-6]. В тестикулах хлорид кадмия нарушает сперматогенез, вызывает воспаление и отёк межканальцевой ткани и негативно воздействует на клетки Лейдига [7-10]. По мнению Chen и соавт., даже низкие концентрации кадмия могут приводить к патоморфологическим изменениям семенных канальцев, снижать уровень тестостерона и увеличивать число дегенеративных клеток в герминативном эпителии [5].

При этом важную роль играют не только непосредственно радикальные процессы, но и сосудистые нарушения: повышенная проницаемость гемато-тестикулярного барьера, расширение кровеносных сосудов и экссудация, что создаёт благоприятную среду для вторичных повреждений [11]. Считается, что итогом является снижение фертильности и ухудшение общей репродуктивной способности [12].

С другой стороны, перспективным направлением современной токсикологии и репродуктивной биологии остаётся поиск растительных антиоксидантов, которые могли бы ослаблять негативное влияние кадмия. Среди природных средств изучались различные экстракты (расторопши, куркумы, зелёного чая и др.), обладающие антиоксидантными свойствами и способностью улучшать параметры сперматогенеза. В частности, экстракт Taraxacum officinale (одуванчика лекарственного) известен высоким содержанием полифенольных соединений, витаминов и других биологически активных компонентов, снижающих перекисное окисление липидов и воспалительную реакцию тканей [13].

Однако большинство существующих работ сосредоточены на гепатопротекторном действии Taraxacum officinale или же на его антиоксидантном эффекте при сахарном диабете и других метаболических патологиях [14]. Конкретное влияние экстракта одуванчика на гистологию семенников, особенно при экспериментальной кадмиевой интоксикации, пока исследовано фрагментарно. Отдельные авторы указывают на потенциальную пользу экстракта, но приводят ограниченные данные о степени восстановления структуры канальцев, клеточном составе сперматогенного эпителия и улучшении функциональных показателей [15].

Таким образом, в существующей научной литературе вырисовывается ряд не до конца изученных аспектов, в частности:

- Каковы точные патоморфологические изменения, возникающие в семенниках при разных дозах хлорида кадмия (от минимальной ПДК до субтоксичной и «ударной»)?
- Насколько выражен и быстр коррекционный эффект экстракта Taraxacum officinale и на какие элементы семенника (сперматогонии, клетки Сертоли, Лейдига, сосудистое русло) он воздействует в первую очередь?
- Каким образом антиоксидантное и противовоспалительное действие экстракта влияет на восстановление сперматогенеза?

Ответ на эти вопросы позволит восполнить выявленные пробелы в исследованиях и расширить имеющиеся научные представления о возможностях фитокоррекции токсических повреждений, что придаёт дальнейшим экспериментам и клиническим изысканиям особую актуальность.

Материалы и методы

Материалом для исследования послужили белые лабораторные крысы обоего пола массой тела от 150 до 200 граммов, которых содержали в стандартных условиях вивария при температуре 22–24 °С и 12-часовом световом дне. Животных кормили сбалансированным комбикормом промышленного производства и обеспечивали свободным доступом к питьевой воде. Перед началом эксперимента провели карантинный период длительностью 7 дней, чтобы животные успели адаптироваться к условиям содержания и исключить возможные скрытые патологии.

Все особи были случайным образом разделены на несколько групп: контрольная группа, которой вводили эквиобъёмное количество воды без добавления токсиканта или экстракта, а также три экспериментальные группы, подвергавшиеся воздействию хлорида кадмия в виде водного раствора в различных концентрациях: 0,001 мг/л, 0,01 мг/л и 0,1 мг/л. Эти дозы были выбраны на основании данных о предельно допустимых, субтоксичных и высоких концентрациях кадмия. После окончания периода интоксикации часть животных из каждой группы получала коррекцию экстрактом Taraxacum officinale, который готовили из высушенных и измельчённых корней растения, экстрагируя их в 70%-ном этаноле с последующим упариванием до получения густого экстракта. Дозировку и продолжительность введения экстракта определяли с учётом предварительных данных о его безопасности и эффективности в аналогичных опытах, чтобы оценить его потенциальное гонадопротекторное действие.

В течение эксперимента ежедневно контролировали общее состояние подопытных крыс, обращая внимание на их поведение, аппетит, прирост массы и внешний вид шерсти. Для гистологических исследований через установленный промежуток времени животных выводили из эксперимента с соблюдением принципов гуманного обращения и регламента, одобренного локальным этическим комитетом. Немедленно после эутаназии извлекали семенники, затем промывали их в физиологическом растворе, подсушивали фильтровальной бумагой и фиксировали во влагалищной оболочке в 10%-ном нейтральном формалине в течение не менее 24 часов.

Забранный материал проводили через батарею этанола возрастающей концентрации для дегидратации и помещали в ксилол для просветления. Далее образцы заливали в парафин, формируя блоки, из которых при помощи ротационного микротома изготавливали срезы толщиной 4–5 мкм. Полученные срезы монтировали на предметные стёкла, обезвоживали, прокрашивали гематоксилином и эозином по классической методике, промывали дистиллированной водой и заключали в синтетическую среду. Каждую серию срезов изучали под световым микроскопом с различными увеличениями, регистрируя морфологические изменения, характер повреждений, а также наличие дегенеративных или некротических участков.

Во время микроскопического анализа учитывали, в каком состоянии пребывает герминативный эпителий семенных канальцев, насколько целостна их базальная мембрана, и присутствуют ли отёчные явления в интерстициальной ткани. Также изучали кровеносные сосуды, выявляя факты расширения, переполнения кровью или застойных явлений, и обращали внимание на особенности клеток Лейдига, следя за сохранностью их структуры. Полученные данные заносили в специальные протоколы для последующего сопоставления с результатами контроля, а также с морфологической картиной у животных, получавших экстракт Taraxacum officinale. Такой подход позволил оценить не только степень токсического повреждения, но и потенциальный восстановительный эффект растительного экстракта.

Результаты и их обсуждение

При проведении эксперимента была проанализирована гистологическая структура семенников лабораторных животных, подвергшихся воздействию хлорида кадмия в разных концентрациях (от предельно допустимой до ударной), а также отмечено, как менялась микроскопическая картина после дополнительной коррекции экстрактом Taraxacum officinale. Первоначально, в контрольной группе (Рисунок 1) гистологическое строение семенника выглядело абсолютно сохранным: семенные канальцы в срезах имели чёткие границы, хорошо дифференцированные клетки сперматогенного ряда, расположенные упорядоченно в базальных и более дифференцированных отделах, а также не обнаруживалось никаких признаков дегенерации или некроза эпителия. В межканальцевых пространствах визуализировались нормально развитые кровеносные сосуды, чьё просветное пространство было умеренно заполнено кровью, и присутствовали клетки Лейдига, морфология которых свидетельствовала об отсутствии фиброзных изменений или скоплений воспалительных клеток. Подобная морфологическая картина подтверждала, что сперматогенез у животных из контрольной группы протекал полноценно и никакого внешнего токсического или стрессового воздействия на ткань семенника не оказывалось.

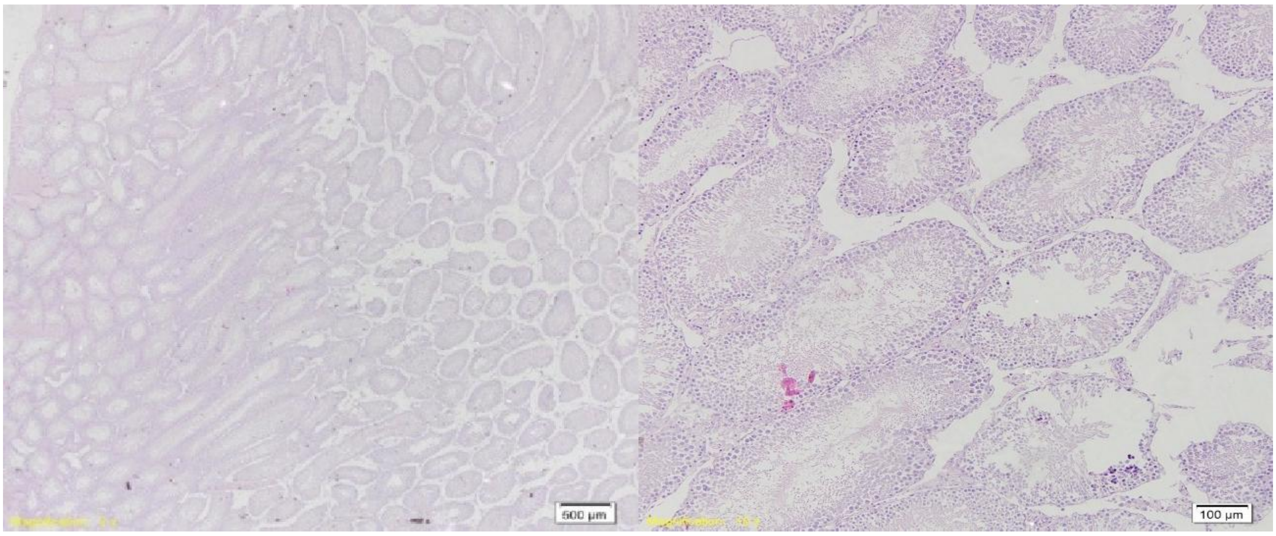

Рисунок 1 – Контрольная группа

Когда речь шла о первой экспериментальной группе, в которой применялась предельно допустимая концентрация хлорида кадмия (0,001 мг/л), макроструктурно, согласно гистологической оценке (Рисунок 2), значительных изменений в архитектуре семенника выявлено не было.

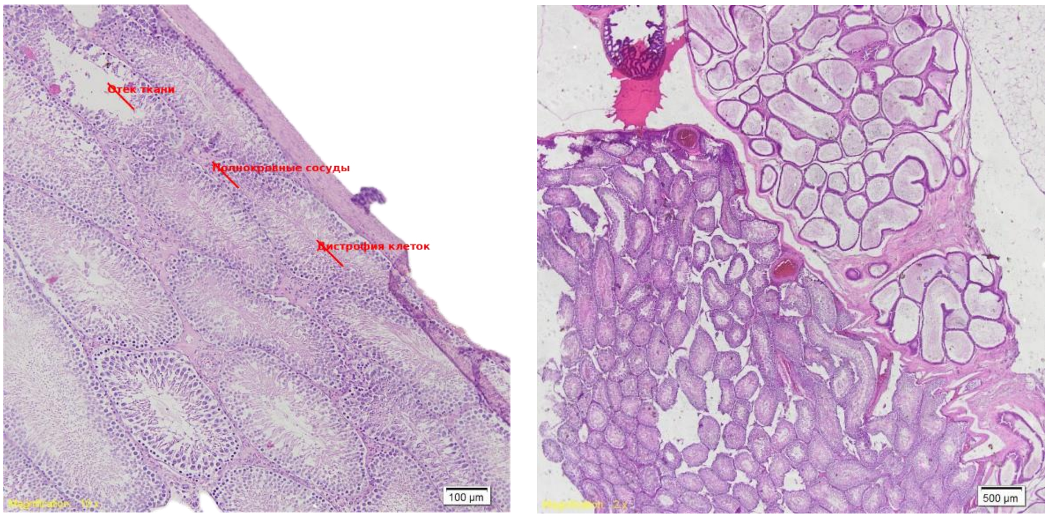

Рисунок 2 – Предельно допустимая концентрация – 0,001 мг/л

Гистоархитектоника и контуры семенных канальцев сохранялись без выраженных патологических признаков. Наблюдались сперматогонии, сперматоциты и сперматиды на разных стадиях дифференцировки, что указывало на сохранность как сперматогенеза, так и деятельности клеток Сертоли, способствующих нормальному ходу клеточного цикла в канальцах. Тем не менее, в интерстициальной ткани этой же группы были замечены незначительные отёчные явления и некоторые расширенные сосуды, указывавшие на наличие умеренной воспалительной реакции либо на первоначальные сдвиги в гемоциркуляции, что могло служить ранним индикатором токсического влияния даже такой низкой дозы кадмия. Несмотря на то что сам сперматогенез оставался полноценным, подобная отёчность косвенно свидетельствовала о том, что инородные ионы кадмия уже начали нарушать микроокружение тканей семенника. Однако дегенеративных изменений в самих клетках сперматогенного ряда не выявлялось, что позволило говорить о пороговой адаптации тканей.

При более высоком содержании хлорида кадмия (0,01 мг/л), относящемся к субтоксичной дозе (Рисунок 3), общая морфологическая целостность ткани семенника тоже не была драматически нарушена, однако проявлялись некоторые чётко визуализируемые изменения, которые отличались от картины контрольной группы и предыдущей дозировки. В частности, сохранялся нормальный сперматогенез, но усиливались признаки отёчности и кровеносные сосуды в межканальцевом пространстве становились полнокровными, иногда заметно расширенными и переполненными.

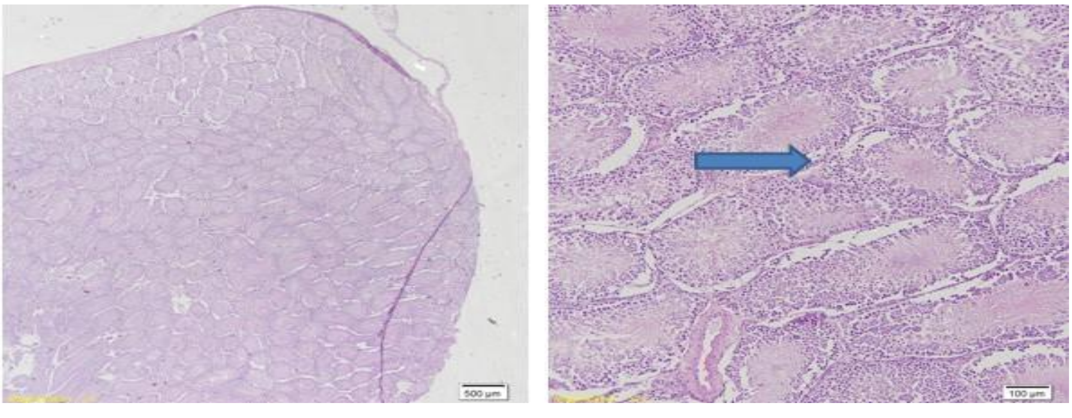

Рисунок 3 – Концентрация 0,01 мг/л

Подобное кровенаполнение и отёк следует рассматривать как реакцию на растущий окислительный стресс, вызванный кадмием, ведь этот токсикант известен своей способностью индуцировать перекисное окисление липидов, а также оказывать негативное воздействие на эндотелий сосудов. Дополнительно некоторые авторы, изучавшие влияние Cd на семенники, указывали, что при более высоких концентрациях он способен подавлять деятельность клеток Лейдига. Наши наблюдения косвенно это подтверждали, поскольку присутствие полнокровия нередко коррелирует с локальным воспалительным процессом и нарушением клеточных взаимодействий. Тем не менее, эпителиальные структуры в канальцах ещё сохраняли более или менее нормальную организацию: сперматогонии располагались на базальной мембране, сперматоциты первого и второго порядка можно было различить в толще эпителия, а ближе к просвету канальцев концентрировались сперматиды с признаками формирования жгутиков. В просветах некоторых канальцев находились зрелые сперматозоиды, хотя в небольших областях могли встречаться участки дезорганизации эпителия, что указывало на локальные эффекты токсиканта. В конечном итоге, можно говорить о том, что 0,01 мг/л уже является достаточно значимой дозой, способной приводить к появлению отчётливых признаков нарушения гистологической структуры, хотя и не вызывающей тотального разрушения.

В более высокой, «ударной» концентрации 0,1 мг/л (Рисунок 4), негативное влияние кадмия на гистологическую организацию семенников становилось ещё более очевидным. Несмотря на сохранение в некоторых канальцах сперматогенеза и присутствие зрелых сперматозоидов в просвете, в ряде случаев отмечались некротические изменения герминативных клеток, появлялись фрагменты клеточных ядер, а также формировались неправильные контуры канальцев с дезорганизованными слоями эпителия. Это указывало на то, что при высокой дозировке Cd токсический эффект реализуется через гибель клеток сперматогенного ряда или за счёт повреждения клеток Сертоли, ответственных за обеспечение структурной организации и трофики.

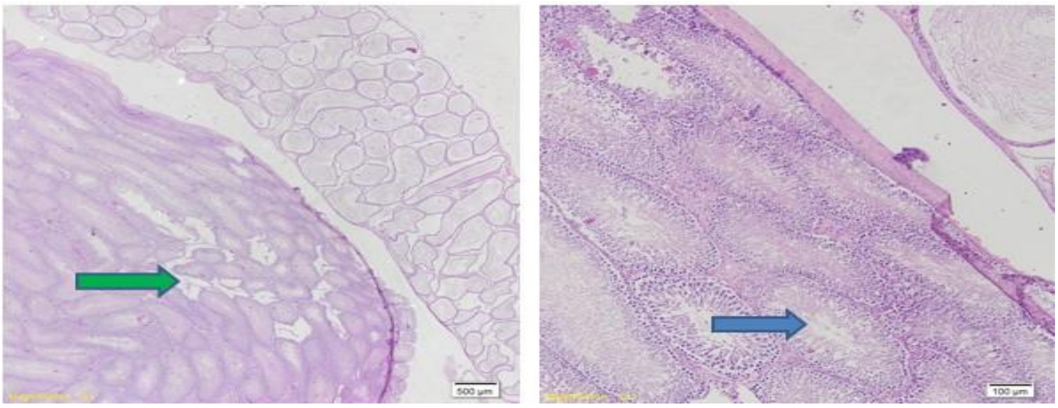

Рисунок 4 – Концентрация 0,1 мг/л

В дополнение к этому выявлялось и некоторое снижение числа полноценных сперматозоидов в повреждённых канальцах, а также сильный отёк в межканальцевом пространстве. Дегенерация эпителиальных клеток и изменение формы канальцев сопровождались выпадением клеточных комплексов в просвет. Сопутствующая потеря клеток Лейдига хотя и не носила тотального характера, но, возможно, приводила к пониженной секреции тестостерона, что могло усиливать общие репродуктивные нарушения. Сильное расширение и сгущение кровеносных сосудов, а также повреждение барьера кровь-тестис и кровь-эпидидимис создавали морфологические предпосылки для ишемии семенников, вследствие которой, по данным других исследователей, происходит некроз и более обширные нарушения сперматогенеза. Подобные структурные сдвиги указывают на то, что ударная доза кадмия провоцирует системное нарушение микроциркуляции, гибель клеток и, как следствие, негативно сказывается на фертильности.

После того как часть животных подверглась воздействию экстракта Taraxacum officinale, были отмечены изменения в гистологической структуре семенников, свидетельствующие о благоприятной динамике и частичном восстановлении морфологии. Если говорить о животных, получавших предельно допустимую концентрацию кадмия (0,001 мг/л) с последующей коррекцией экстрактом одуванчика (Рисунок 5), то гистологическая картина демонстриро- вала почти полную нормализацию структуры семенных канальцев. Сперматогенез оставался сохранным, клетки сперматогенного ряда чёт- ко дифференцировались, а отёчные явления в межканальцевом пространстве либо исчезли, либо были настолько незначительны, что не могли расцениваться как выраженное патологическое изменение. Судя по всему, антиоксидантная активность Taraxacum officinale, заключающаяся в нейтрализации свободных радикалов и снижении воспаления, способствовала тому, что даже при наличии токсических доз Cd организм животных смог более эффективно восстанавливать микросреду внутри семенников и поддерживать функциональность клеток Лейдига, Сертоли и герминативного эпителия.

Во втором случае, то есть у крыс, подвергшихся субтоксической дозе (0,01 мг/л) и впоследствии пролеченных экстрактом одуванчика (Рисунок 6), ситуация тоже значительно улучшалась, однако здесь сохранялся небольшой выраженный отёк, присутствовавший в межканальцевых пространствах.

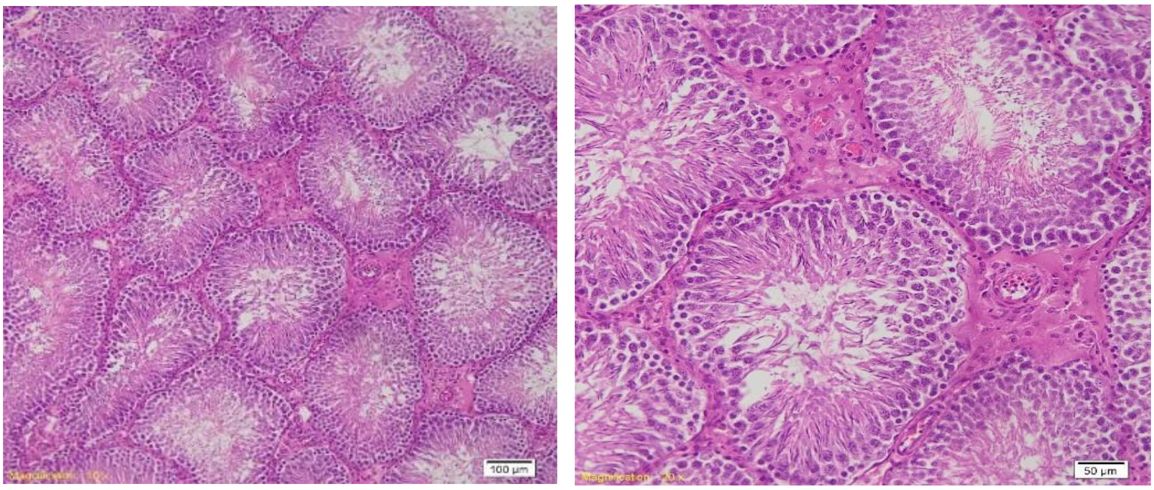

Рисунок 5 – Предельно допустимая концентрация – 0,001 мг/л после коррекции *Taraxacum officinale*

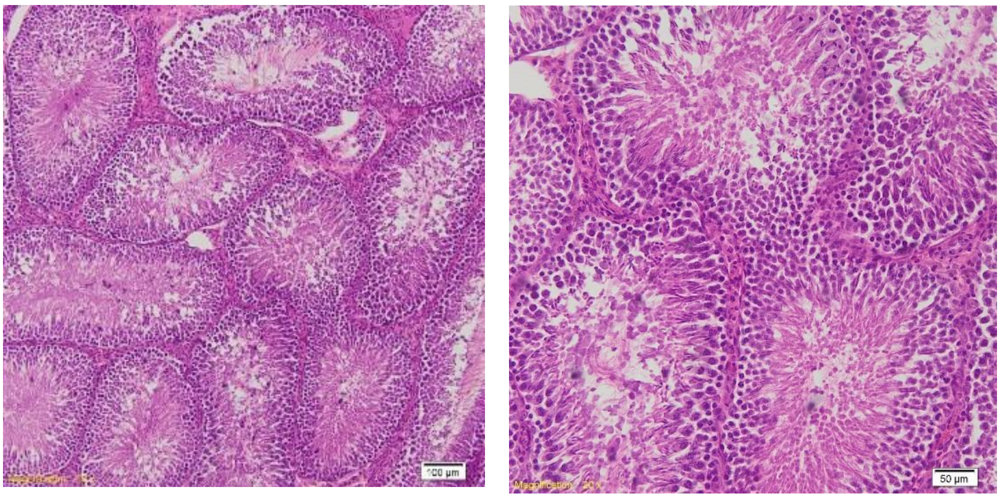

Рисунок 6 – Субтоксичная доза – 0,01 мг/л после коррекции *Taraxacum officinale*

Заметная отёчность, вероятно, свидетельствовала о том, что накопленный кадмий вызвал более сильные изменения сосудистой проницаемости и интерстициального гомеостаза, и эти процессы не до конца нивелировались даже при введении растительного экстракта. Тем не менее, само строение семенника по-прежнему оставалось достаточно сохранным: в канальцах наблюдался полноценный сперматогенез, разница по сравнению с контролем сводилась в основном к количественному увеличению полнокровных сосудов, сопровождающемуся умеренной инфильтрацией либо застойными явлениями. В ядрах клеток сперматогоний и сперматоцитов не наблюдалось грубых некротических изменений, что позволяет предположить, что Taraxacum officinale оказывал выраженный защитный эффект, однако полное восстановление требовало либо более продолжительного времени, либо более высокой дозы самого экстракта.

Наконец, в группе с «ударной» дозировкой кадмия (0,1 мг/л), но прошедшей курс коррекции с использованием Taraxacum officinale (Рисунок 7), также выявлялось улучшение морфологической структуры по сравнению с животными, получавшими кадмий без коррекции.

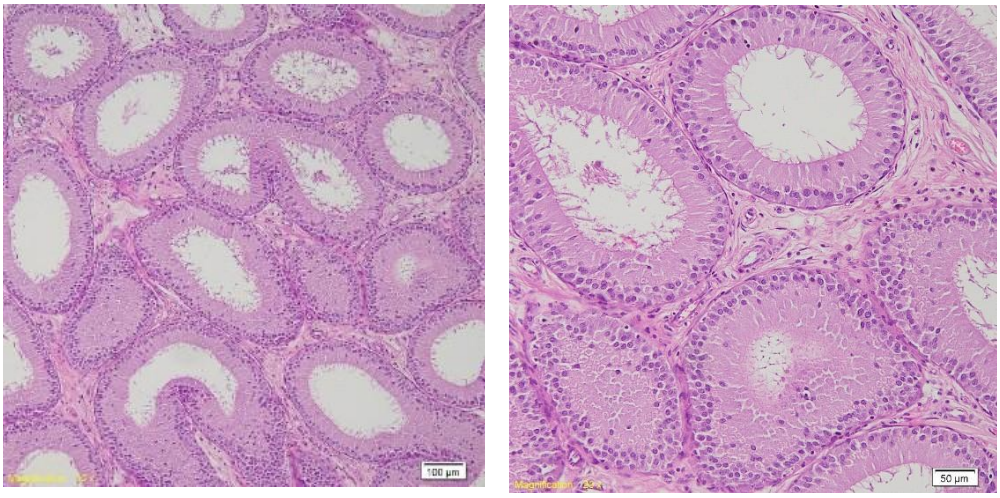

Рисунок 7 – Ударная доза – 0,1 мг/л после коррекции *Taraxacum officinale*

В большинстве канальцев наблюдалась сохранная организация эпителия, регистрировались все основные типы клеток сперматогенного ряда, а клетки Сертоли выглядели целостными и морфологически полноценными. Количество некротизированных клеток, ранее описанных, было заметно меньше, а просветы семенных канальцев содержали зрелые сперматозоиды в достаточном количестве, что указывало на позитивные изменения в гаметообразовании. Однако, если сравнивать этот результат непосредственно с нормой (контрольной группой), то оставались некоторые признаки нарушения циркуляции и остаточного воспаления в интерстициальной ткани, в частности иногда отмечались едва различимые элементы деструкции в эпителии, а мелкие сосуды могли быть несколько расширенными. При этом отёк был выражен в меньшей степени, чем без коррекции, но тем не менее не полностью исчезал у отдельных особей, что согласуется с предположением о сохранении части токсических эффектов при достаточно сильном начале интоксикации. Всё вместе указывало на то, что экстракт одуванчика, хотя и смягчал повреждающее действие металла, но на полное восстановление при ударной дозе требовался больший временной промежуток либо комплексная терапия.

Следует упомянуть, что при оценке общего состояния животных, помимо гистологического анализа, учитывались и внешние характеристики: у крыс, получавших экстракт Taraxacum officinale, наблюдалось увеличение массы тела и улучшение внешнего вида (окрас шерсти становился более светлым и ровным, движения – более активными). Это, с одной стороны, указывает на системный эффект экстракта как на антиоксидант, способствующий повышению общего тонуса, а с другой стороны, может отражать снижение токсического воздействия кадмия на внутренние органы, в том числе на печень и почки, о чём неоднократно сообщали предыдущие авторы, работающие с этим токсикантом. Возможно, улучшение функциональных показателей печени, в частности, связано с более быстрой инактивацией токсических продуктов и более эффективным восстановлением метаболических процессов, что в итоге положительно сказывается и на репродуктивной системе.

Важно также отметить, что механизм, через который Taraxacum officinale мог проявлять свои защитные свойства, связан с наличием в его составе антиоксидантных соединений (например, флавоноидов, фенольных кислот), а также с противовоспалительными компонентами, снижающими секрецию провоспалительных цитокинов. В сочетании с этим положительный эффект может быть обусловлен способностью экстрак- та поддерживать нормальный обмен веществ в клетках Лейдига, тем самым способствуя сохранению уровня тестостерона и предотвра- щая дисфункцию стероидогенеза. Сохранение стероидогенной функции критически важно для поддержания сперматогенеза, так как муж- ские половые гормоны определяют продукцию и созревание сперматозоидов, а также влияют на активность клеток Сертоли, формирующих гемато-тестикулярный барьер. В литературе встречаются данные, указывающие, что именно благодаря поддержке клеток Лейдига некоторые фитосоединения могут препятствовать резкому угнетению сперматогенеза при интоксикации тяжёлыми металлами. Наблюдавшиеся у нас улучшения морфологии в группах, получавших экстракт, подтверждают данную гипотезу, хотя полной нормализации, особенно при наивысшей дозе кадмия, не происходило.

Суммируя результаты, можно утверждать, что низкие концентрации хлорида кадмия (0,001 мг/л) вызывают лишь начальные признаки стрессового воздействия на ткань семенника, в основном выражающиеся в небольшом отёке и расширении сосудов. При этом сперматогенез продолжает протекать относительно полноценно. Однако уже при дозе 0,01 мг/л наблюдаются более заметные изменения, включающие полнокровие сосудов, активацию воспалительных процессов, а в части канальцев – локальную деструкцию герминативных клеток. Ударная доза 0,1 мг/л значительно усиливает патологические процессы, что проявляется выраженными очагами некроза, дезорганизацией эпителия, нарушением формы семенных канальцев и возможным снижением общего уровня сперматозоидов. Коррекция экстрактом Taraxacum officinale оказывает положительный эффект во всех трёх случаях, но при низких дозах кадмия ткань семенника восстанавливается практически до нормы, тогда как при более высоких дозировках всё же сохраняются остаточные повреждения или отёчные явления. Следовательно, экстракт улучшает микроциркуляцию, снижает выраженность окислительного стресса и замедляет развитие некротических процессов, однако полного подавления токсического действия при экстремально высоких концентрациях достичь не удалось.

При этом наблюдалась не только морфологическая, но и внешняя, поведенческая положительная динамика: крысы лучше набирали вес, были более активны, что лишний раз свидетельствует о комплексном благотворном влиянии экстракта одуванчика. На основании упомянутых данных можно предположить, что Taraxacum officinale в определённой мере защищает гемато-тестикулярный барьер, стабилизирует функцию клеток Сертоли и Лейдига, а также способствует сохранению структуры эпителия канальцев, что препятствует критическому снижению фертильности. Эти выводы согласуются с результатами некоторых исследователей, которые использовали различные растительные антиоксиданты для коррекции металлотоксикозов и сообщали о схожих положительных результатах на уровне гистологии.

Поскольку изучение отдельных компонентов экстракта одуванчика показывает их способность подавлять перекисное окисление липидов и повышать антиоксидантный потенциал, предполагается, что они могут блокировать или значительно уменьшать повреждения, вызываемые активными формами кислорода, генерируемыми кадмием. При этом возможны и другие механизмы протекции: в частности, связывание кадмия и выведение его из тканей, а также модуляция иммунных клеток, которая предотвращает избыточное воспаление в интерстиции. Полное понимание молекулярных путей требует дополнительных биохимических исследований, однако морфологические и визуальные данные явно подтверждают, что одуванчик является фитосредством с выраженными гонадопротекторными свойствами.

Тем самым общая концепция проведённых экспериментов демонстрирует, что хлорид кадмия оказывает токсическое действие на ткань семенников уже в относительно низких дозах, а при наращивании концентрации наносит значительный ущерб сперматогенезу, вызывая некроз отдельных участков, дегенерацию эпителия и возможное падение фертильности. Введение же экстракта Taraxacum officinale смягчает негативные процессы и частично или практически полностью восстанавливает нормальную гистологическую картину, в зависимости от уровня интоксикации. Уместно полагать, что данная тенденция к восстановлению имела бы более выраженный характер при более долгосрочном введении экстракта либо при дополнительном комбинировании его с другими природными антиоксидантами.

Несомненно, в дальнейшем понадобятся исследования, направленные на уточнение оптимальных доз экстракта, продолжительности терапии и механистического обоснования его защитного эффекта. Однако уже сейчас ясно, что доза 0,001 мг/л хлорида кадмия поврежда- ет семенники несильно, позволяя Taraxacum officinale восстанавливать морфологическую картину практически до контрольного уровня, а при более высоких дозировках коррекция не столь тотальна, хотя заметно снижает выраженность некроза и воспаления. Это даёт широкие перспективы для применения одуванчика в качестве вспомогательного средства при детоксикации организма и защиты репродуктивной системы.

Заключение

Проведённое исследование выявило, что воздействие хлорида кадмия на ткань семенников лабораторных животных приводит к ряду морфологических изменений, зависящих от дозировки токсиканта. Минимальная концентрация (0,001 мг/л), хотя и не вызывает выраженных структурных нарушений, всё же провоцирует небольшие отёчные явления и тенденцию к расширению кровеносных сосудов. Субтоксичная доза (0,01 мг/л) усиливает негативные явления и может вызывать локальную дезорганизацию герминативного эпителия и более заметный отёк межканальцевых пространств. Ударная доза (0,1 мг/л) приводит к формированию некротических участков, деструкции клеток сперматогенного ряда и аномалиям структуры семенных канальцев, что потенциально грозит серьёзным снижением фертильности. Введение экстракта Taraxacum officinale способствовало восстановлению нормальной гистоструктуры и снижало выраженность патологических процессов, особенно при более низких дозах кадмия, когда обнаруживалось почти полное исчезновение отёка и сохранение сперматогенеза на высоком уровне. При самых высоких дозировках Cd растительный экстракт заметно ослаблял повреждающие эффекты, однако не обеспечивал стопроцентного возвращения ткани к контрольной норме, что может говорить о сильной тяжести токсического воздействия. Таким образом, применение экстракта одуванчика демонстрирует явный гонадопротекторный потенциал, который, по всей видимости, реализуется благодаря антиоксидантным и противовоспалительным свойствам, а также возможному стимулированию деятельности клеток Лейдига. Данное исследование подчёркивает актуальность разработки фитотерапевтических подходов к коррекции металлотоксикозов и подтверждает, что, помимо снижения общего уровня окислительного стресса, экстракт Taraxacum officinale сохраняет структуру и функцию сперматогенного эпителия даже при наличии выраженных признаков интоксикации.

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БИОАЛУАНТҮРЛІЛІК ЖӘНЕ ӨСІМДІК АУРУЛАРЫНА ҚАРСЫ КҮРЕС: ЖҮГЕРІ ДАҚЫЛДАРЫНЫҢ ТӨЗІМДІЛІГІН АРТТЫРУ ТӘСІЛДЕРІ

Жүгері – дүниежүзілік азық-түлік қауіпсіздігін қамтамасыз ететін негізгі дақылдардың бірі. Жүгерінің биоалуантүрлілігін сақтау үшін дәстүрлі селекция әдістерін молекулалық генетикамен үйлестіру, тұқым банктерін кеңейту және фермерлердің біліктілігін арттыру қажет. Бұл азық-түлік қауіпсіздігін қамтамасыз етуге және климаттық өзгерістерге бейімделуге мүмкіндік береді. 2023 жылы жүгері сүрлемі алқаптарында қуықтың ластануы (Ustilago zeae) мен агроөнімділік көрсеткіштерінің тұрақтылығын зерттеу мақсатында 12 үлгіге комплексті талдауы жүргізілді. Нәтижелер бойынша ауру ауырлығының үлгілер арасында айтарлықтай айырмашылықтар ($p < 0,001$), сонымен қатар ауруға төзімділіктің жоғары тұқым қуалаушылық индексі ($HbZ = 0,82$) анықталды. Өсімдік биіктігі 182–330 см аралығында өзгерді, ең биік 4 үлгі (Туран 680 SV, Туран 480 SV, Қазақстанский 700 SV, Қазақстанский 705 S0) бөлінді. *Ustilago zeae*-ге төзімділік бойынша үлгілер екі топқа бөлінді: 5 үлгіде өте әлсіз залалдану (1% дейін) және 7 үлгіде әлсіз залалдану (1–10%). 1000 дәннің массасы 226–330 г аралығында, ең жоғарғы өнімділік Алтай 250 MV (330 г) және Будан 237 MV (310 г) үлгілерінде байқалды. Зерттеу нәтижелері жүгері селекциясын жетілдіру және аурумен күресудің тиімді әдістерін әзірлеу бағыттарына негіз болып табылады.

Түйін сөздер: жүгерінің биоалуантүрлілігі, устойчивость, 1000 дәннің массасы, астық өнімділігі, сипаттамалық статистика.

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Biodiversity and plant disease management: methods to increase the resistance of corn

Maize is one of the main crops that ensures global food security. To preserve maize biodiversity, it is necessary to combine traditional breeding methods with molecular genetics, expand seed banks and improve the skills of farmers. This will ensure food security and adaptation to climate change. To study the resistance of bladder wrack (*Ustilago zeae*) infestation and agronomic performance indicators in maize silage fields in 2023, a comprehensive analysis of 12 accessions was carried out. The results revealed significant differences in disease severity between accessions ($p < 0.001$), as well as a high heritability index of disease resistance ($HbZ = 0.82$). Plant height varied from 182 to 330 cm, among which the 4 tallest specimens stood out (Turan 680 SV, Turan 480 SV, Kazakhstan 700 SV, Kazakhstan 705 S0). The samples were divided into two groups according to the degree of resistance to Ustilago zeae: 5 samples had very slight damage (up to 1%) and 7 samples had slight damage (1–10%). The weight of 1000 grains was 226–330 g, the highest yield was noted in the varieties Altai 250 MV (330 g) and Budan 237 MV (310 g). The research results create a basis for improving corn breeding and developing effective meth- ods for disease control.

Key words: corn biodiversity, resistance, 1000-kernel weight, grain yield, descriptive statistics.

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Биоразнообразие и борьба с болезнями растений: методы повышения устойчивости кукурузы

Кукуруза – одна из основных культур, обеспечивающих мировую продовольственную безопасность. Для сохранения биоразнообразия кукурузы необходимо сочетать традиционные мето- ды селекции с молекулярной генетикой, расширять семенные банки и повышать квалификацию фермеров. Это обеспечит продовольственную безопасность и адаптацию к изменению климата. Для изучения устойчивости заражения фукусом пузырчатым (*Ustilago zeae*) и агрономических показателей эффективности на полях кукурузного силоса в 2023 году был проведен комплексный анализ 12 образцов. Результаты выявили значительные различия в тяжести заболевания между образцами (p <0,001), а также высокий индекс наследуемости устойчивости к болезням (H_bZ = 0,82). Высота растений варьировала от 182 до 330 см, среди которых выделялись 4 самых высоких экземпляра (Туран 680 SV, Туран 480 SV, Казахстан 700 SV, Казахстан 705 S0). Образцы были разделены на две группы по степени устойчивости к *Ustilago zeae*: 5 образцов имели очень слабые повреждения (до 1%) и 7 образцов имели слабые повреждения (1–10%). Масса 1000 зерен составила 226–330 г, наибольшая урожайность отмечена у сортов Алтай 250 МВ (330 г) и Будан 237 МВ (310 г). Результаты исследований создают основу для совершенствования селекции кукурузы и разработки эффективных методов борьбы с болезнями.

Ключевые слова: биоразнообразие кукурузы, устойчивость, масса 1000 зерен, выход зерна, описательная статистика.

Кіріспе

Жүгері дүниежүзіндегі ең көп өсірілетін және тұтынылатын дақылдардың бірі (шамамен 1,2 млрд. тонна), адам мен жануарлардың рационында энергия мен ақуыздың маңызды көзі болып табылады. Африка мен Латын Америкасының барлық дерлік елдерінде жүгері адамдардың күнделікті тұтынатын жалпы калориясының шамамен 15% құрайды. Жүгері жоғары биоалуантүрлілікке ие және кең ауқымды агроэкологиялық жағдайларда өсіріледі. Әлемдік нарықта жүгері өндірісінің өсуі байқалды, әсіресе гибридтер мен жоғары технологиялық өсіру әдістері қолданылатын қалыпты климаттық аймақтарда. Жүгерінің негізгі өндірушіле- рі мен экспорттаушылары АҚШ (әлемдегі бар- лық жүгерінің 1/3 бөлігін өндіреді), Аргентина, Франция, Корея, Венгрия, Канада және Оңтүстік Африка Республикасы болып табылады. Қытай соңғы кездері олардан қалыспай, көрші Азия елдеріне негізгі жеткізушіге айналды. Дамушы елдерде азық-түлік ретінде жүгеріге деген сұраныс 2020 жылға дейін жылына 1,3%-ға өсті. 2025 жылға қарай жүгері дамушы елдерде ең көп өндірілетін дақыл болады, ал 2050 жылға қарай дақылға әлемдік сұраныс екі есе өседі деп күтілуде [1].

Мал шаруашылығы өнімдеріне, әсіресе сүт пен етке сұраныстың артуы мал азығы рационының жетекші құрамдас бөлігі – астық пен сүрлемге арналған жүгері өндірісін ұлғайту қажеттілігін талап етеді. Бұл тапсырманы ресурс үнемдейтін технологияны қолдана отырып өсіру үшін жүгері будандарын интенсивті түрде пайдалану арқылы шешуге болады. Жаңа гибридтердің маңызды критерийлерінің бірі ресурс үнемдейтін технологиялардың негізін құрайтын астық өндіруге жұмсалатын энергия шығындарын азайту болып табылады. Жүгері өсіру технологиясының перспективалы және жаңа бағыты зерттеу және минималды өңдеуге көшу болып табылады.

Жүгерінің биологиялық әртүрлілігін сақтауға көмектесетін заманауи технологиялар бірнеше негізгі бағыттарды қамтиды:

Молекулярлық-генетикалық әдістер және биотехнология – молекулярлық маркерлерді (SSR, SNP), геномдық талдауды және маркер көмегімен таңдау әдістерін қолдану жүгерідегі генетикалық әртүрлілікті дәл анықтауға және сақтауға, сондай-ақ құнды агротехникалық белгілері бар жаңа сорттарды құруды жеделдетуге мүмкіндік береді56. Гендік инженерияны қолдану және аурулар мен зиянкестерге төзімді трансгенді будандар құру да қолжетімді генетикалық ресурстардың ауқымын кеңейтеді, бірақ дәстүрлі формалардың сақталуына және экологиялық тепе-теңдікті сақтауға ерекше бақылауды қажет етеді.

Биологиялық қорғау және микробиологиялық технологиялар – пайдалы микроорганизмдерді (ризобактериялар, энтомопатогендік саңырауқұлақтар, бактериялар және вирустар) пайдалана отырып, зиянкестер мен аурулармен күресудің биологиялық әдістерін енгізу, сондай-ақ *Bacillus, Pseudomonas, Trichoderma* және басқа штаммдар негізіндегі биопрепараттарды қолдану агроэкожүйедегі тұрақты әртүрлілікті сақтауға және тұрақты агроэкожүйеге химиялық жүктемені азайтуға көмектеседі.

Генетикалық ресурстардың коллекцияларын құру және жүргізу – жүгерінің дүниежүзілік және ұлттық генофондтарын қалыптастыру және ұтымды пайдалану, сондай-ақ генетикалық ресурстарды зерттеу және сақтау бойынша зертханаларды ұйымдастыру сирек және құнды нысандарды сақтауға ғана емес, сонымен қатар ауыл шаруашылығы дақылдарының бейімділігі мен тұрақтылығын арттыру үшін оларды селекцияда белсенді пайдалануға мүмкіндік береді.

Ресурс үнемдейтін және экологиялық ауыл шаруашылығы технологиялары – топырақты минималды өңдеуді, ұтымды себу үлгілерін енгізу, экологиялық икемділігі жоғары және ресурстарды аз талап ететін будандарды пайдалану сыртқы әсерлерге төзімді агроэкожүйелерді сақтауға және жүгері популяциясының әртүрлілігін сақтауға ықпал етеді [2-4].

Дәнді дақылдар, оның ішінде жүгері өндірісінің тұрақты өсуі және осы негізде жем-шөптің теңгерімді қорын құру бүкіл әлемде, соның ішінде Қазақстанда азық-түлік қауіпсіздігін қамтамасыз етудің негізгі басымдықтарының бірі болып табылады. Жүгерінің жемдік дақыл ретіндегі экономикалық маңызы және оның бірқатар биологиялық ерекшеліктері ұзақ уақыт бойы селекциялық зерттеулердің жоғары қарқындылығын анықтады. Сонымен қатар, ұзақ мерзімді селекциялық бағдарламаларда құнды белгілері бар бастапқы материалдардың шектеулі жиынтығын пайдалану *Zea mays L* түрінің генетикалық тарылуына алғышарты болып табылады [5].

2023 жылы Қызылорда облысының облыстық ауыл шаруашылығы басқармасының мәліметінше, Қазалы ауданында жүгері 615 гектарға, Жаңақорған ауданында – 1111 гектарға, Шиелі ауданында – 174 гектарға, Жалағаш ауданында – 700 гектарға, Қармақшы ауданында – 39 гектарға егілген. Жүгері Сырдария, Арал аудандары мен Қызылордада отырғызылмаған.

Қазіргі уақытта аурулар мен зиянкестерге қарсы тұру үшін дақылдарды өсірудің ұтымды стратегиясы өсірілетін сорттар мен будандардың генетикалық әртүрлілігін кеңейтуді қамтуы керек екені анық. Селекциялық зерттеу бағдарламаларын іске асыру, ең алдымен, құнды белгілердің генетикалық көздерін анықтауға, қарсылықтың тұқым қуалауын зерттеуге және жаңа жоғары төзімді бастапқы материалды жасауға негізделген [6].

Өсімдіктердің вегетациялық кезеңіндегі тұрақты температуралық режим жүгерінің өнімділік әлеуетін іске асыруға ықпал етеді. Жауын-шашын мөлшерінің бір мезгілде өзгеруімен немесе вегетациялық кезеңде, әсіресе жаздың екінші жартысында оның біркелкі емес түсуімен ауа температурасының жоғарылауы жүгерінің өсуіне әсер етеді. Оның ішінде ауруға байланысты тәуекелдерді арттырады. Жүгерінің ең зиянды ауруы-бұл көпіршікті қара күйе (*Ustilago zeae* (Beckm.) Unger саңырауқұлағынан туындайды. Жүгері өсімдігіне аурудың мына белгілері тән: вегетативті және репродуктивті органдарда диаметрі 30 см-ге жететін және саңырауқұлақ споралары пайда болатын өсіп кеткен өсімдік тіндерін білдіретін патологиялық ісіктер (өттер) пайда болады [7].

Аурудың өршуі жыл сайын жүгері өсімдіктерінің орта есеппен 3-6% қамтиды. Кейбір жылдары ауру өсімдіктердің саны 10-12%-ға дейін артады, ал өнімділіктің төмендеуі 25-30%-ға жетуі мүмкін. Аурудың қарқынды дамуына вегетациялық кезеңнің екінші жартысында ауа температурасының жоғарылауымен (25-30°с) бірге қысқа мерзімді жауын-шашынның көп түсуі қолайлы жағдай тудырады [8].

Жалпыға белгілі көпіршікті қара күйенің қоздырғышы-термофильді түр; телиоспоралардың өну температурасы мен ұзақтығы 0-ден +35°с- қа дейін, оңтайлы көрсеткші-20-30°с. Споралар қоршаған орта факторларына байланысты топырақта 1-3 жыл сақталуы мүмкін. Жүгері өсімдіктері инфекция басталғаннан кейін бірінші жапырақ пайда болғаннан бастап өсімдік тозаңы тозаңдарда саралана бастағанға дейін дамиды. Жүгері инфекцияға 10-14 күн қалғанда, өсу конустарының тақырыптық тіндерінің шаралары ең ашық және телиоспоралармен инфекцияға қол жетімді болған кезде инфекцияға ең сезімтал. Жүгері басының инфекциясының қосымша көзі-споралы тұқымдар. Қуық басының зияндылығы дәнді дақылдар мен жасыл массаның күрт төмендеуінен көрінеді. Жүгерінің пісуі соңында шығымдылақтың жоғалуы 50-100%, вегетативті мүшелер – 25-50% құрауы мүмкін.

Жүгерідегі селекциялық жұмыстардың соңғы әдістері өсімдіктердің күрделі төзімділігі мен бейімделуіне бағытталған және әртүрлі экологиялық-географиялық шығу тегі бар бастапқы материалды кешенді иммунологиялық зерттеуді қамтамасыз етеді [9-11].

Осылайша, молекулярлық, биотехнологиялық, агрономиялық және ұйымдастырушылық шешімдердің үйлесімі қазіргі жағдайда жүгерінің биологиялық әртүрлілігін сақтаудың кешенді тәсілін қамтамасыз етеді.

Аурумен күресудің ең перспективалы әді- сі – көпіршікті қара күйеге төзімді өздігінен тозаңданатын линиялар мен будандарды іріктеу. Ауруға төзімділік бойынша селекциялық жұмыстың бастапқы кезеңі төзімділіктің жаңа көздерін анықтау болып табылады. Қазіргі кезде қолданылып жүрген формалардың тиімділігінің жоғалуына байланысты, уақыт өте келе жаңа төзімді формаларды іздеудің өзектілігі артып келеді, сондықтан, зерттеу жұмысының мақсаты – Қазақстандағы селекциялау тәлім бақтарынан алынған жүгері коллекциясының табиғи инфекциялық фонында ластануға төзімділігін зерттеу және көпіршікті қара күйеге төзімді будандарды іріктеп алу.

Материал және әдістер

Зерттеу Қызылорда облысының жағдайында, 2023 жылы «РЗА Агро» ЖШС-нің ғылыми ауыспалы егіс алқабында *Ustilago zeae* төзімділігі үшін жүгері үлгілерін зерттеу және іріктеп алу бойынша жүргізілді.

Зерттеу аймағының климаты орташа жылы және барлық климаттық элементтердің тұрақсыздығымен сипатталады. Зерттеу кезіндегі метеорологиялық жағдайлар жүгері өсімдіктерін қоздырғышпен жұқтыруға ықпал етті. Қызылорда облысының климаттық режимі аймақтың Еуразия құрлығының ішінде орналасуымен, оның оңтүстік аймақта орналасуымен, атмосфералық айналым сипаттамаларымен, жер бетінің табиғатымен және басқа факторлармен анықтала- ды. Континентальды климат метеорологиялық элементтердің үлкен ауытқуларында, олардың күнделікті, айлық және жылдық циклдарында көрінеді. Бұл кезеңде температураның күрт өзгеруі байқалмайды. Зерттеу аумағында шілденің орташа температурасы 33-37°С құрайды, облыстың басым бөлігіндегі абсолютті максималды температура 45-47°С. Орташа тәуліктік ауа температурасы 0° с-тан жоғары кезең 250-275 күнге созылады. Жауын-шашынның орташа жылдық мөлшері 90-160 мм-ден аспайды және жыл мезгілдері бойынша біркелкі бөлінбейді: барлық жауын-шашынның 60%-ы қысқы-көктемгі кезеңде болады. Жауын-шашын және тәуліктік температураның өзгеруі аурулардың қарқынды дамуына әсер еткен: жиналған үлгілерде жоғары сезімталдық жағдайлары байқалды (9 балл, учаскедегі өсімдіктердің 50%-дан астамының залалдануын көрсетеді).

Коллекциялық үлгілердің өнуін сақтау үшін жалпы қабылданған агротехнологияны қолданылды. Зерттелген үлгілерді себу оңтайлы уақытта, сәуірдің үшінші онкүндігінде қолмен жүргізілді, оның алдында алқапта күздік бидай болды. Егіс тереңдігі 5-6 см, тіркеу учаскесінің ауданы 4,9 м². Тәжірибелік схема бойынша өсімдіктердің тығыздығы (50-55 мың өсімдік/га) 4-5 жапырақ фазасында қолмен бақылау арқылы анықталды.

Табиғи инфекциялық жағдайда сабақтың ластануының дәрежесі Қызылорда және Жамбыл облыстарында бейімделген *Zea mays L* негізгі 12 үлгісі бағаланды. Жүгерінің түрлері эндоспермнің морфологиялық сипаттамасымен де, биологиялық қасиеттерімен де (суыққа төзімділігі, ыстыққа төзімділігі, ауруға төзімділігі), сондай-ақ астықтың химиялық құрамы мен технологиялық параметрлерімен ерекшеленеді. Жинау үлгілерін зерттеу кезінде келесі стандарттар қолданылды: Целиный 160 SV сорты, өздігінен тозаңданатын F2 гибридті линиялары.

Фитопатологиялық баға беру әдісі. Жүгерінің көпіршікті күйемен залалдану дәрежесін далалық бағалау үлгілердің жаппай гүлденуі басталғаннан кейін 15 күннен кейін және масақтарды жинау кезінде жүргізілді. Зардап шеккен өсімдіктердің саны мен зардап шеккен масақтардың саны, зардап шеккен өсімдіктердің пайызы ескерілді, жинау үлгілерінің залалдану дәрежесі SEV *Z. mays* халықаралық классификаторының шкаласы бойынша баллмен бағаланды [12, 13], мұндағы: 1 – балл – өте әлсіз залалдану (зардап шеккен өсімдіктердің 1% – дан азы); 3 балл – әлсіз залалдану (1-10%); 5 балл – орташа залалдану (11-25%); 7 балл – жоғары залалдану (26-50%).; 9 балл – өте ауыр залалдану (50% – дан астам өсімдік залалданған). Залалданудың негізгі шкаласы бойынша қосымша балл (0 балл) учаскелердегі үлгілерге берілді, олардың ішінде өсімдікке патогендердің залалдану мүлде болмаған.

Мәліметтерді статистикалық талдау әдістері. R-studio бағдарламалық жасақтамасы генотиптер арасындағы кірістілік пен көпіршікті күйеге төзімділігінің айырмашылығын бағалау үшін дисперсияның бір жақты талдауын (ANOVA) орындау үшін пайдаланылды. Генетикалық факторларға байланысты фенотиптік өзгергіштіктің үлесін көрсететін кең мағыналы тұқымқуалаушылық индексі (H_b^2) ANOVA нәтижелері бойынша келесі формула бойынша есептелді:

$$H_b^2 = SSg/SSt,$$

мұндағы:

SSg – генотип үшін квадраттардың қосындысы,

SSt – квадраттардың жалпы сомасы. Бұл тәсіл әртүрлі жүгері үлгілерінің төзімділік деңгейлері туралы құнды ақпарат бере отырып, аурудың өршуін уақыт бойынша сандық бағалауға мүмкіндік береді.

Нәтижелер мен талқылаулар

ANOVA талдауына сәйкес ($p < 0.001$), жүгері сүрлемі алқаптарындағы қуықтың ластануының *(Ustilago zeae)* ауырлығы үлгілер арасында әртүрлі. 2023жылы үлгілер арасында ауруға төзімділік индексінің тұқым қуалаушылықтың жоғары деңгейі (H_b^2 – 0,82) көрсетілді (Кесте 1).

1- кесте – Жүгері коллекциясындағы *Ustilago zeae* үшін далалық бағалаудың дисперсиялық талдауы (ANOVA)

Source	DF	Sum of squares	Mean squares	F	Pr > F	p-values signification codes	H_b^2, %
Model	1,000	4370,083	4370,083	4,292	0,065	***	0.82
Error	10,000	10182,833	1018,283				
Corrected Total	11,000	14552,917					
Computed against model Y=Mean(Y)							
Signification codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1							

Екінші кестеде жүгері *(Ustilago zeae)* үшін өсімдік биіктігін, өнімділік қасиеттерін және далалық фитопатологиялық бағалау нәтижелері берілген. Өсімдіктің биіктігіне қарай үлгілер 182тен 330 см-ге дейін ауытқиды. Өсідік биіктігі бойынша төрт үлгі жоғары көрсеткіштерімен анықталды: Туран 680 SV (290 см), Туран 480 SV (295 см), Казахстанский 700 SV (290 см) және Казахстанский 705 S0 (330 см).

2- кесте – Өнімділік белгілері және алқаптың *Ustilago zeae* қара күйеге төзімділік көрсеткіштері

#	Үлгінің атауы	Өсімдік биіктігі, см	1000 дәннің масасы, г	Астық өнімділігі, %	*Ustilago zeae* үшін далалық бағалау, балл
1	Алтай 250 MV	230	330	82	3
2	Будан 237 MV	263	310	85	1
3	Казахстанский 587 SV	255	295	82	3
4	Казахстанский 700 SV	290	290	81	3
5	Казахстанский 705 SV	300	305	83	1
6	Тәтті-2012	210	256	85	3
7	Тәуелсіздік-20 SV	270	305	83	1
8	Туран 480 SV	295	310	81	3
9	Туран 559 SV	277	298	82	3
10	Туран 680 SV	290	290	82	1

11	Береке -2017	182	226	85	3
12	Целиный 160 SV	265	305	83	1

Жүгерінің зақымдану дәрежесін далалық бағалау нәтижелері бойынша жүгерінің он екі сынамасы екі топқа бөлінді. Бірінші топқа өте әлсіз зақымданулары бар бес үлгі (41,7%) (зардап шеккен өсімдіктердің 1%-дан азы) тағайындалды: Будан 237 MV, Казахстанский 705 SV, Тәуелсіздік-20 SV, Туран 680 SV және Целиный 160 SV.

Екінші топқа жүгерінің жеті сынамасы (58,3%) әлсіз зақымданумен (1-10%) кірді. Олардың құрамына Алтай 250 MV, Казахстанский 587 SV, Казахстанский 700 SV, Казахстанский 705 SV, Тәтті-2012, Туран 480 SV, Туран 559 SV және Береке -2017.

Зерттеу нәтижесінде жүгерінің 1000 дәнінің массасы 226 г-нан 330 грамға дейін ауытқыды. Келесі үлгілер ең жоғары өнімділікпен сипатталды: Алтай 250 MV (330 гр), Будан 237 MV (310 гр), Казахстанский 705 SV (305 гр), Тәуелсіздік-20 SV (305 гр), Туран 480 SV (310 гр) және Целиный 160 SV (305 гр). Зерттелген жүгері үлгілерінің астық өнімділігі 81% – дан 85% – ға дейін болды.

Өсімдік биіктігі, 1000 дәннің массасы, астық өнімділігі және Ustilago zeae саңырауқұлақ ауруына далалық бағалау көрсеткіштерінің статистикалық талдауы негізінде келесі қорытындылар мен ұсыныстар жасалды. Өсімдік биіктігі бойынша 12 бақылау нәтижесінде орташа мән 260,6 см, стандартты ауытқу 36,4 см, ал вариация коэффициенті 14% шамасында. Бұл көрсеткіш өсімдік биіктігінің орташа деңгейде тұрақты екенін, бірақ кейбір үлгілерде айтарлықтай өзгерістер бар екенін көрсетеді. Биіктіктің ең төменгі мәні 182 см, ең жоғарғысы 300 см болды. 1000 дәннің массасы бойынша орташа мән 293,7 г, стандартты ауытқу 26,6 г, вариация коэффициенті 9% шамасында. Бұл көрсеткіш дән массасының салыстырмалы түрде тұрақты екенін білдіреді, яғни дәннің сапасы мен көлемінде айтарлықтай ауытқулар жоқ. Астық өнімділігі бойынша орташа көрсеткіш 82,8%, стандартты ауытқу 1,47%, вариация коэффициенті өте төмен – 1,8%. Бұл өнімділіктің өте тұрақты екенін және бақылау кезеңінде өнімнің сапасы мен көлемінің біркелкі екенін көрсетеді. *Ustilago zeae* саңырауқұлақ ауруына далалық бағалау бойынша орташа балл 2,0, стандартты ауытқу 1,04, вариация коэффициенті 52,2%. Бұл көрсеткіш аурудың таралуы мен әсерінің әртүрлі екенін, яғни кейбір үлгілерде ауру деңгейі жоғары, ал кейбірінде төмен екенін білдіреді (3-кесте, 1-сурет).

3-кесте – Зерттелген жүгері үлгілерінің белгілері бойынша сипаттамалық статистикасы (сандық деректер)

Statistic	Өсімдік биіктігі, см	1000 дәннің масасы, г	Астық өнімділігі, %	*Ustilago zeae* үшін далалық бағалау, балл
Nbr. of observations	12	12	12	12
Nbr. of missing values	0	0	0	0
Obs. without missing data	12	12	12	12
Sum of weights	12	12	12	12
Breakdown per subsample (%)	100,000	100,000	100,000	100,000
Minimum	182,000	230,000	81,000	1,000
Maximum	300,000	330,000	85,000	3,000
Freq. of minimum	1	1	2	6
Freq. of maximum	1	1	3	6
Range	118,000	100,000	4,000	2,000
1st Quartile	248,750	290,000	82,000	1,000
Median	267,500	301,500	82,500	2,000
3rd Quartile	290,000	306,250	83,500	3,000
Sum	3127,000	3524,000	994,000	24,000
Mean	260,583	293,667	82,833	2,000
Variance (n)	1212,743	646,556	1,972	1,000
Variance (n-1)	1322,992	705,333	2,152	1,091

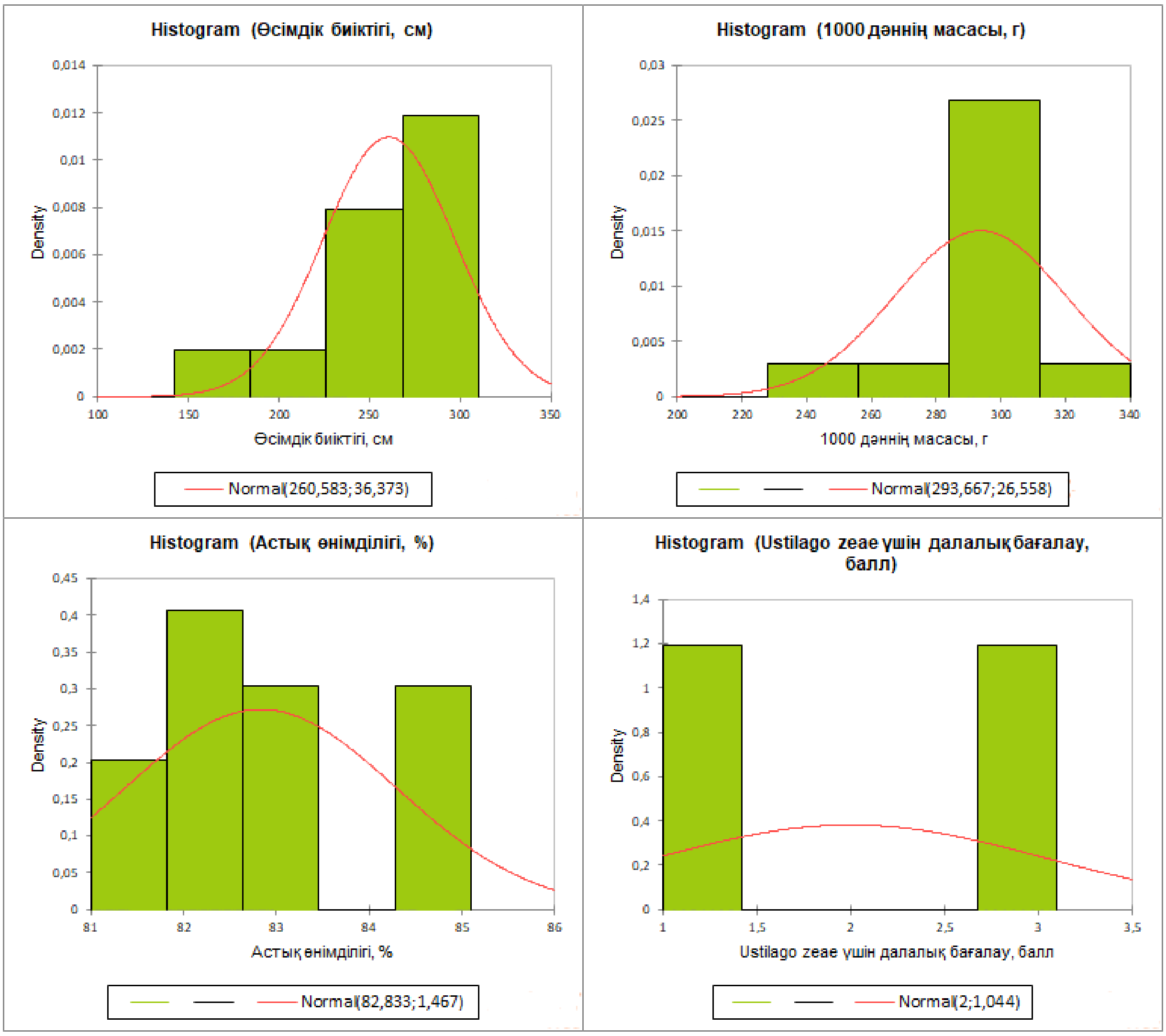
Кестенің жалғасы

Statistic	Өсімдік биіктігі, см	1000 дәннің массасы, г	Астық өнімділігі, %	*Ustilago zeae* үшін далалық бағалау, балл
Standard deviation (n)	34,824	25,427	1,404	1,000
Standard deviation (n-1)	36,373	26,558	1,467	1,044
Variation coefficient (n)	0,134	0,087	0,017	0,500
Variation coefficient (n-1)	0,140	0,090	0,018	0,522
Skewness (Pearson)	-0,957	-1,270	0,478	0,000
Skewness (Fisher)	-1,100	-1,459	0,549	0,000
Skewness (Bowley)	0,091	-0,415	0,333	0,000
Kurtosis (Pearson)	-0,113	1,062	-1,058	-2,000
Kurtosis (Fisher)	0,554	2,421	-0,948	-2,444
Standard error of the mean	10,500	7,667	0,423	0,302
Lower bound on mean (95%)	237,473	276,792	81,901	1,336
Upper bound on mean (95%)	283,694	310,541	83,765	2,664
Standard error of the variance	564,126	300,755	0,917	0,465
Lower bound on variance (95%)	663,909	353,953	1,080	0,547
Upper bound on variance (95%)	3813,909	2033,328	6,202	3,145
Mean absolute deviation	27,556	18,111	1,167	1,000
Median absolute deviation	22,500	8,500	0,500	1,000
Geometric mean	257,995	292,468	82,821	1,732
Geometric standard deviation	1,164	1,101	1,018	1,775
Harmonic mean	255,128	291,162	82,810	1,500
nIQR	30,579	12,046	1,112	1,483
Qn	33,616	16,808	1,681	0,000

Қисықтық (скьюнес) көрсеткіштері бойынша өсімдік биіктігі мен 1000 дәннің массасы теріс қисықтыққа ие, яғни деректер солға қарай қисайған, ал астық өнімділігі оң қисықтықпен сипатталады, яғни оңға қарай қисайған. Ustilago zeae бағалауында қисықтық нөлге тең, бұл деректердің симметриялы таралғанын білдіреді. Куртозис көрсеткіштері бойынша өсімдік биіктігі мен астық өнімділігі деректері қалыпты таралымнан сәл төмен (плоская таралым), ал 1000 дәннің массасында жоғары шыңдылық байқалады.

Осылайша, өсімдік биіктігі мен 1000 дәннің массасы көрсеткіштері орташа деңгейде тұрақты, бірақ өсімдік биіктігінде вариация сәл жоғары болғандықтан, оны жақсарту үшін селекциялық жұмыстарды жалғастыру қажет. Астық өнімділігі өте тұрақты және жоғары деңгейде, бұл дәннің сапасы мен өнімділігінің тұрақтылығын көрсетеді. *Ustilago zeae* саңырауқұлақ ауруының деңгейі әртүрлі, бұл ауруға қарсы шараларды күшейту қажеттігін білдіреді. Жалпы, алынған статистикалық мәліметтер өсімдік өнімділігін және сапасын жақсарту бағытындағы жұмыстардың тиімділігін бағалауға мүмкіндік береді.

Жүгерінің қара күйеге қарсы тиімді шаралары егудің оңтайлы мерзімдері, ауыспалы егіс- ті сақтау, тұқымдарды өңдеу және топырақты сапалы өңдеу, өсімдік қалдықтарын қосуды қамтиды. Жүгерінің жемдік дақыл ретіндегі экономикалық маңызы және оның бірқатар биологиялық ерекшеліктері ұзақ уақыт бойы селекциялық зерттеулердің жоғары қарқындылығын анықтайды.



1-сурет – Өсімдіктің биіктігі, 1000 дәннің салмағы, астық өнімділігі және ауруға далалық бағалауы бойынша гистограммасы

Қорытынды

Осылайша, далалық зерттеулер жүгері жинау үлгілеріндегі полиморфизмді *Ustilago zeae*-ге төзімділік үшін анықтауға мүмкіндік берді. Ауруға төзімді формалар коллекциялық үлгілердің кез-келген кіші түрінің ассортиментінде, әсіресе қоздырғыштың дамуына қолайлы кезеңдерде оқшаулануы мүмкін. Жүгері дәнінің құрамында ақуыз мөлшері салыстырмалы түрде жоғары (16% – ға дейін) және оны дәнді дақылдар, үлпектер және басқа да өнімдерді өндіру үшін тамақ өндірісінде кеңінен қолдануға болады. Жүгері коллекциясының табиғи инфекциялық фондағы көпіршікті қара күйемен ластануға төзімділігін зерттеу нәтижелері бойынша өсімдіктерінде аурудың белгілері анықталмаған сынамалар алынды, олар: Altay 250 MV, Budan 237 MV, Tatty-2012 and Tayelsizdik-20 SV. Анықталған үлгілердің өнімділігі мен астық өнімділігі де жоғары болды. Селекционерлер масақтың ластануынан топырақты жақсарту үшін жүгері дақылдарын дәнді және көкөніс дақылдарынан, көпжылдық шөптерден, соядан, картоптан және басқа да алдыңғы егілген өсімдіктерден кейін егуді ұсынады. Жүгері дақылдарын саңырауқұлақ және қара күйеден ластанудан кешенді қорғау құрамында карбоксил мен тирам бар Vitavax 200 FF немесе жүйелік – Maxim XL біріктірілген препаратымен тұқымдарды өңдеуді қамтиды.

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HYDROCHEMICAL STUDIES OF SALT LAKES IN THE NORTHERN PART OF THE CASPIAN LOWLAND

The article presents a hydrochemical analysis and heavy metal content of salt lakes of Atyrau region on the example of salt lakes Inder, Karabatan and lake near Kh.Dospanova International Airport. Analysis of heavy metals shows that the content of chromium, manganese, cobalt, nickel, copper, lead, zinc and cadmium does not exceed the maximum permissible concentrations. The analysis of cations in all salt lakes shows data that are identical in all three lakes and the lowest values are typical for potassium and sodium ions, whose contents are about 3 mg/l and 9 mg/l, respectively. The content of calcium and magnesium cations exceeds hundreds and thousands of mg/l. The content of calcium ions in the lake near the airport is almost twice as high as in other lakes and amounts to 1059 mg/l. The magnesium ion content is minimal for Lake Karabatan and amounts to 801 mg/l, whereas in the other two salt lakes it exceeds 1.5 times. For anions, the lowest values are typical for hydrocarbonates and are in the range of 200-300 mg/l. The indicators for sulfates and chlorides are very diverse, as for sulfates they vary from 500 mg/l in the lake near the airport to almost 8000 mg/l in Lake Karabatan. The maximum values are typical for chlorides, while their contents are also diverse in all lakes and range from more than 4,000 mg/l to more than 63,000 mg/l. At the same time, the following ratios of HCO_3:SO_4:Cl anions are noted – in Lake Inder 1:4:32; in Lake Karabatan 1:39:316; and in the lake near Kh.Dospanova International Airport 1:1.8:14.8. Thus, salts of magnesium and calcium chlorides, magnesium and calcium sulfates are formed in all lakes, and the salt contents of sodium and potassium bicarbonates are the most minimal.

Key words: salt lake, Atyrau region, hydrochemical analysis, heavy metals, cations, anions.

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Каспий маңы ойпатының солтүстік бөлігіндегі тұзды көлдерді гидрохимиялық зерттеу

Мақалада Индер, Қарабатан және Х.Доспанов атындағы Халықаралық әуежай маңындағы тұзды көлдердің мысалында Атырау облысының тұзды көлдерінің ауыр металдарына талдау және гидрохимиялық сараптау жүргізілді. Ауыр металдарды талдау хром, марганец, кобальт, никель, мыс, қорғасын, мырыш және кадмийдің мөлшері рұқсат етілген шекті мөлшерден аспайтынын көрсетеді. Барлық тұзды көлдердегі катиондарды талдау барлық үш көлде бірдей деректерді көрсетеді және ең төменгі мәндер калий мен натрий иондарына тән, олардың мөлшері сәйкесінше шамамен 3 мг/л және 9 мг/л құрайды. Кальций мен магний катиондарының мөлшері жүздеген және мыңдаған мг/л-ден асады. Әуежай маңындағы көлдегі кальций иондарының мөлшері басқа көлдердегі мөлшерден екі есе дерлік және 1059 мг/л құрайды. Қарабатан көлі үшін магний иондарының мөлшері минималды және 801 мг/л құрайды, ал қалған екі тұзды көлде 1,5 есе көп. Аниондар бойынша ең төменгі мәндер гидрокарбонаттарға тән және 200-300 мг/л аралығында болады. Сульфаттар мен хлоридтер бойынша көрсеткіштер өте алуан түрлі, сондықтан сульфаттар бойынша олар Әуежай маңындағы көлде 500 мг/л-ден Қарабатан көлінде 8000 мг/л-ге дейін өзгереді. Максималды мәндер хлоридтерге тән, олардың құрамы барлық көлдерде де әр түрлі және 4000 мг/л – ден 63000 мг/л – ге дейін өзгереді. Бұл жағдайда аниондарының келесі қатынасы атап өтіледі HCO_3:SO_4:Cl-Индер көлінде 1:4:32; Қарабатан көлінде 1:39:316; және Х.Доспанов атындағы Әуежайының жанындағы көлде 1:1,8:14,8. Осылайша, барлық көлдерде магний мен кальций хлоридтерінің тұздары, магний мен кальций сульфаттары түзіледі, ал натрий мен калий гидрокарбонаттарының тұздары ең аз болады.

Түйін сөздер: тұзды көл, Атырау облысы, гидрохимиялық талдау, ауыр металдар, катиондар, аниондар.

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Гидрохимические исследования соленых озер северной части Прикаспийской низменности

В статье проведен гидрохимический анализ и содержание тяжелых металлов соленых озер Атырауской области на примере соленых озера Индер, Карабатан и возле Международного аэропорта имени Х. Доспанова. Анализ по тяжелым металлам показывает, что содержание хрома, марганца, кобальта, никеля, меди, свинца, цинка и кадмия не превышает предельно-допустимые концентрации. Анализ катионов во всех соленых озерах показывает данные, которые идентичны во всех трех озерах и самые минимальные значения характерны для ионов калия и натрия, содержание которых находятся около 3 мг/л и 9мг/л соответственно. Содержания катионов кальция и магния превышают сотни и тысячи мг/л. Содержание ионов кальция в озере возле аэропорта почти в два раза превышает содержания в других озерах и составляет 1059 мг/л. Содержание ионов магния минимально для озера Карабатан и составляет 801 мг/л, тогда как в двух других соленых озерах превышают в 1,5 раза. По анионам самые минимальные значения характерны для гидрокарбонатов и находятся в пределах 200-300 мг/л. По сульфатам и хлоридам показатели очень разнообразны, так по сульфатам они меняются от 500 мг/л в озере возле аэропорта до почти 8000 мг/л в озере Карабатан. Максимальные значения характерны для хлоридов, при этом их содержания также разнообразны во всех озерах и варьируются от более 4000 мг/л до более 63000 мг/л. При этом отмечается следующие соотношения анионов HCO_3: SO_4: Cl – в озере Индер 1:4:32; в озере Карабатан 1:39:316; и в озере возле Х. Доспанова аэропорта 1:1,8:14,8. Таким образом, во всех озерах образуются соли хлоридов магния и кальция, сульфатов магния и кальция, а содержания солей гидрокарбонатов натрия и калия самые минимальные.

Ключевые слова: соленое озеро, Атырауская области, гидрохимический анализ, тяжелые металлы, катионы, анионы.

Introduction

Due to the fact that salt lakes are widespread in the World, they are important and valuable natural objects for the economy, culture, recreation and scientific research, but at the same time: in some regions of the World, salt lakes are intensively degraded and are not objects of active conservation to the extent that they deserve due to their unique resources.

Currently, there is no universal classification scheme of lakes that allows us to consider natural reservoirs based on any single limnological characteristics. This is due to the existence of such a wide variety of constantly changing (under the influence of natural and anthropogenic factors) natural limnic parameters.

The Caspian basin is a flat loamy plain with extensive development within its limits of sorov (shore) and estuarine basins occupied by mineral lakes and salt marshes. The chain of estuaries and sores of the Caspian lowland is a relic of the previously existing river hydrographic network [1], the topographic surface of the seabed, coastal ramparts and terraces of the retreating sea. The coastline of the Caspian Sea within the Caspian lowland is strongly indented by small bays (kultuks) and deltas of the Kura, Terek, Kuma, Volga, Ural, Emba and other smaller rivers. In the Caspian basin, there are sub-basins: Primorsky, Delta, Mangyshlak, Kara-Bogaz, Chagishlyar, etc. These landscape facies are stretched out in a narrow strip 10-12 km wide around the Caspian Sea, and the delta basins have a peculiar landscape of the primary surface of the accumulative marine plain, modified by the work of "blind" rivers that do not have runoff into the sea. These are the landscapes of the delta sub-basins of the Volga, Kura, and Ural rivers [2].

The Ural-Embinsky basin occupies the northern part of the Caspian lowland, which is a negative relief form made of sedimentary rocks, among which the thickness of marine brackish clays, loams and sands of Neogene and Quaternary age has the greatest thickness. In the southeastern part of the lowland, the sifted sands represent barkhanno-bumpy and ridge massifs. Salt domes are widespread in the central part of the basin.

The conditions of salt accumulation and the formation of the chemical composition of the salt lakes of this basin are influenced by the recent regression of the sea, salt domes and waste waters of oil fields. All the waters of the Ural-Emben basin, both surface and underground, are saline to one degree or another. Halite, mirabilite, tenardite, glauberite, astrakhanite, epsomite and others are common in the bottom sediments of lakes. Many lakes are characterized by an increased content of potassium, bromine, iodine, etc.

An integral part of the landscapes of the giant salt domes of the Caspian Lowland are dry (root) lakes [3]. Depending on the ratio of the water level and tectonic activity, lakes in salt dome structures can be divided into three groups. With sufficient water supply to the lake and a weak manifestation of the activity of salt dome structures, rapine and silt lakes with low bottom sediment capacity and unstable water-salt regime are formed. The low water content of the territory, accompanied by an active growth of salt dome uplifts, leads to the fact that the salt mirror is raised above the groundwater level, as a result of which drying lakes are formed. A sufficient amount of water entering the lake basin, together with the high activity of salt dome structures, is the reason for the formation of dry (root) salt lakes with powerful layers of lake salts filling deep compensatory mulches. The Caspian lowland is a vast area of salt lakes. These are unique aquatic ecosystems, characterized by alkaline conditions and high salt concentrations. It should be noted that, despite numerous studies, the salt lakes of the region have not been sufficiently studied, especially with the use of modern scientific methods and methodology.

The purpose of this work was to study the hydrochemical characteristics of some salt lakes of the Caspian lowland located in the Atyrau region. These lakes have different volumes and are located both in the city of Atyrau, in the immediate vicinity of the airport, 30 km from the city, next to the Bolashak plant on Karabatan and 180 km from the city of Atyrau near the village of Inder, called Inder Lake.

Methods

Sampling was carried out in June 2023 from the reservoirs of the Inderbor and Kabatan salt lakes. The cation content was carried out in accordance with GOST 26449.1-85 "Stationary distillation desalination plants. Methods of chemical analysis of salt water", potassium – chapter 18.1, sodium – chapter 17.1, calcium – chapter 11, magnesium – chapter 12. The anion content was carried out on the basis of the following documents: chloride – ST RK ISO 9297-2008 "Water quality Determination of chloride content", sulphates – ST RK 1015-2000 "Graphimetric method for determining sulfate content in natural wastewater", bicarbonates – HDPE F 14.1:2:4.190-03 "Quantitative chemical analysis of waters. The method of measuring bichromate oxidizability (chemical oxygen consumption) in samples of natural, drinking and wastewater by photometric method using a liquid analyzer "Fluorat-02". Sampling was carried out in accordance with ST RK GOST R 51592-2003 "Water. General requirements for sampling." and ST RK GOST R 51593-2003 "Drinking water. Sampling."

Salty continental reservoirs, in particular lakes, are very numerous. Their origin is quite clear. Any lake, unless it is flowing, closed, i.e. has no runoff, sooner or later must become salty due to evaporation of water, especially .if it is located in arid areas and on highly saline rocks. The degree of salinity of such reservoirs can be very significant, up to the precipitation of salts from a saturated solution. The waters of the lakes are very diverse in their chemical composition and mineralization. In contrast to seawater, lake waters do not have constant ratios between basic ions. According to the degree of salinity, lake waters are divided into the following types: fresh (up to 1‰), brackish (from 1 to 24.7%0), salty (from 24.7 to 47%o), mineral or salt (over 47%0).

The first person who tried to create a classification for salt lakes was M.G.Valyashko, 1952 [4], who identified the main classification features of salt (salt) lakes, considering the specifics of their development as an emerging mineral deposit. He classified the lakes by:

1. Concentrations of lake solution characterizing the general course of salt accumulation. At the same time, a group of fresh waters was distinguished – with a sum of dissolved substances less than or equal to 0.1% (by weight), a group of brackish wa-

ters – with a sum of dissolved substances from 0.1 to 3.5%, a group of salt waters – with a sum of dissolved substances higher than 3.5%.

2. According to the chemical composition of the lake solution, when, depending on the predominance of that Lakes are divided into carbonate ($Na_2CO_3^-$, $NaHCO_3^-$, $Ka_2CO_3^-$, $NaCO^-$, H_2O), sulfate ($2Na^{3+}$, $2K^+$, $S0_4^{2-}$, Cl^-, H_2O) and chloride ($CaCl^-$, $FeCl^{3-}$, $NaC1^-$, H_2O).

3. According to the state of the lake solution (brine). At the same time, rapnye, dry and sub-sandy lakes differ. Rapnoe Lake is characterized by the year-round presence of water in the lake, in a dry lake brine occurs only during the wet season, and the sub-sandy lake is characterized by the complete absence of surface brine throughout the year, when the level of bottom brine lies below the surface of solid lake sediments. At the same time, the stratification of sediments is abnormal.

To determine the type of salt lakes, the Dobrovskiy and Todorov classifications were applied, the basis of which is aimed at the content of anions and cations in saline reservoirs. According to the Dobrovskiy classification, it is necessary to take into account the contents of the most maximally significant cations and anions, the content of which exceeds 25% of the total of all ions. For designation, the formulas are used first for the anion, then for the cation. According to the Todorov classification, cationic and anionic series are distinguished and determined in descending order of ion concentration. It is often used in engineering geology, hydrogeology and hydrology.

According to the total number of ions of chemical elements that determine the salinity of water, in 1958 the Venetian system was adopted, accord- ing to which natural waters are divided into fresh (up to 0.5%), mixogaline or brackish (0.5-30%), eugaline or marine (30-40%), and hypergaline or saline (>40%). Mixohaline are divided, in turn, into oligohaline (0.5-5%), mesohaline (5-18%) and polyhaline (18-30%). However, this classification has not been widely used in modern limnological research.

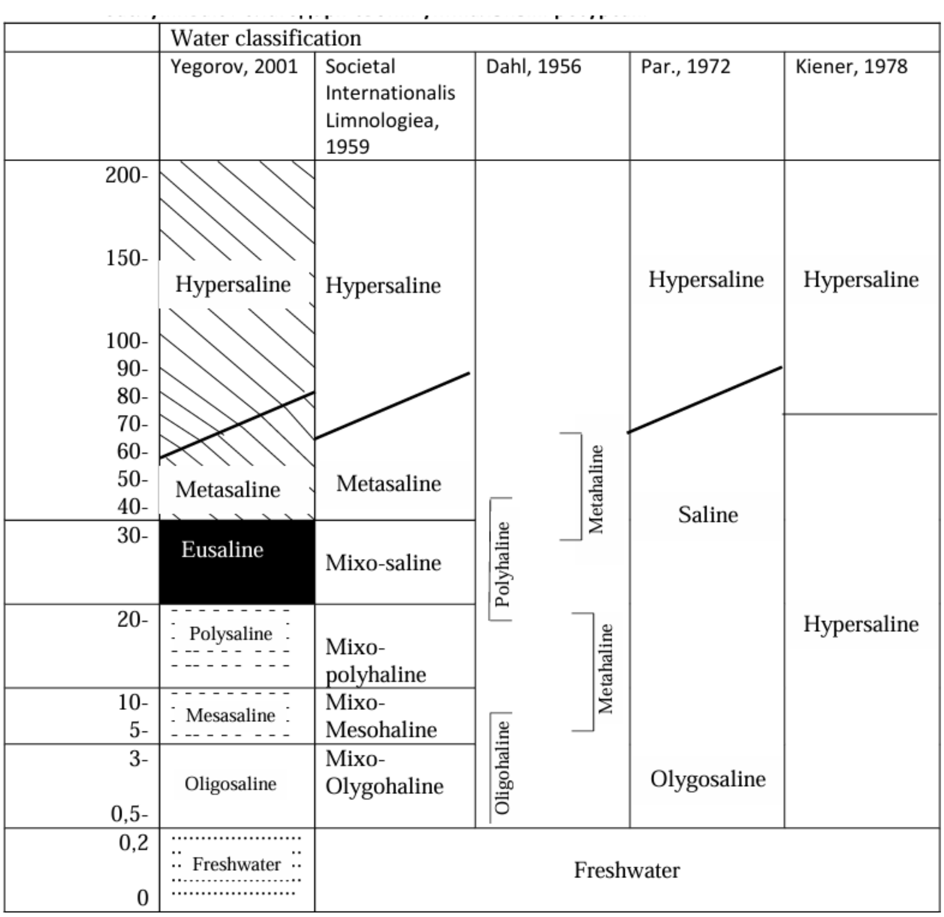

Figure 1 – Classifications of salt lakes by various authors in terms of mineralization

One of the latest classifications of natural waters by their mineralization and the corresponding classification of biological species for the pur- poses of paleogeographic analysis was proposed by Gasse et al. (1987) and presented in Figure 1 [5]. As can be seen from the data in Table b, the classification boundaries differ from those proposed by other authors, for example Ham- mer U.T. (1986), which divides salty waters into hyposalted (3-20 g/l), unsalted (20 – 50 g/l) and hypersalted (>50 g/l) and coincide with the data of Javor (1989), which refers lakes with a min- eralization above 70 g/l to hypersalted lakes, but many researchers consider lakes with a salinity exceeding 35 g/l to be hypersalted (i.e. , the min- eralization of seawater) .

When managing water resources (for agriculture, industry and drinking water supply), specific salinity gradations are used: “fresh water” – less than 0.3 g/l, “slightly salty” – 0.3-1.0 g/l, “salty” – 1.0-3.0 g/l and “strongly salty” – more than 3.0 g/l.

Thus, the total salinity of salt lakes is considered in the range from 3 to more than 500 g/l (Williams, 1998) and the author rightly believes that there are no universal criteria for determining on the basis of biological and physico-chemical characteristics of “fresh” and “salty” waters. However, given the fact that there are certain differences between the biological and physico-chemical properties of fresh and salty waters, W.D.Williams considers it possible to accept a threshold value of mineralization of 3 g/l, below which water is considered fresh, and above – salty. As it turned out, this threshold of mineralization corresponds to the loss of calcium from natural waters and the possibility of taste determination of salinity [6].

Results

Therapeutic mud of salt lakes is formed under certain geological conditions. Brines accumulated on low-lying areas of the earth, fed by precipita- tion and other various water sources, mainly in arid conditions, evaporate and form various mineral salts in some parts, and therapeutic silt mud accumulates under them for a long time.

To assess the prospects for increasing resources, the conditions of formation and patterns of their placement in the salt lakes of the Ural-Emba district of the Caspian region, such as Inder, in the Karabatan area and near the Atyrau airport, were analyzed.

Inder Lake (Fig. 2) is located in Atyrau region, 170 km north of Atyrau and 1.2km from the left bank of the Ural River. The length is 13.5 km, the maximum width is 11 km. Its area is 123 km^2 [7].

Figure 2 – Inder Lake

The Karabatan group of lakes (Fig. 3) is located 45 km from Atyrau, directly near the Atyrau-Kandahach railway line. The area of the Northern Karabatan is 1.08 million m^2, the southern one is 0.14 million m^2. The therapeutic mud on the lakes of Karabatan lies at a depth of 45 cm and has a capacity of 40 cm. Lake Karabatan is located on the left bank of the river. The Urals is located 150 km south of Inder Lake, near the paved Inder-Atyrau road [8].

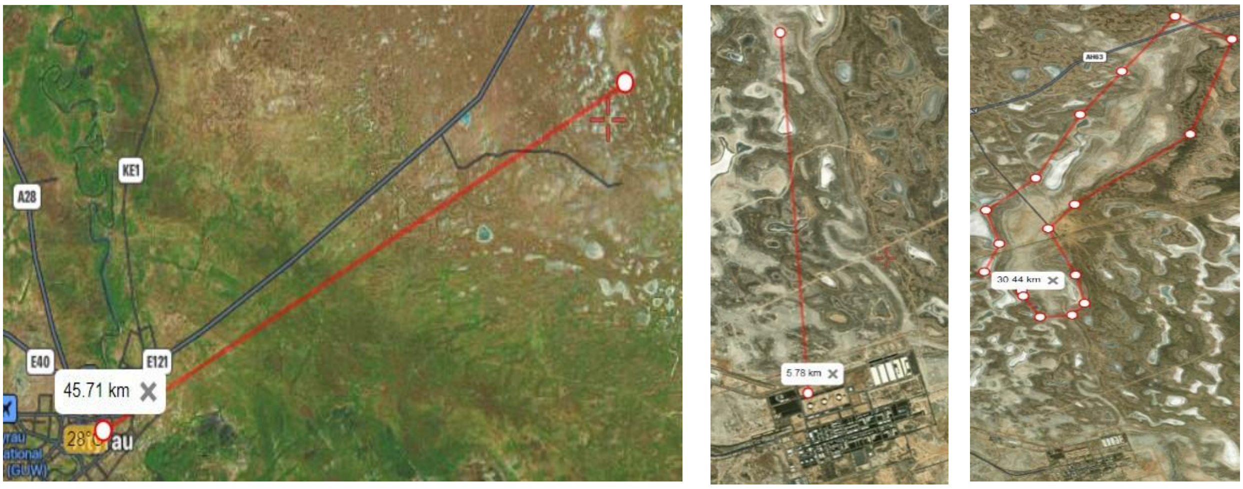

Figure 3 – The Karabatan group of lakes

Not far from the Kh.Dospanova International Airport in Atyrau (Fig. 4), at a distance of 1.33 km, there is a salt lake. The length is 1.72 km, the maximum width is 0.77 km. Its area is about 1.3 km^2 or 4.36 km in circumference.

Hydrochemical analysis of heavy metal ions was carried out in all three salt lakes [9].

Data on the content of heavy metals are presented in Table 1.

As can be seen from Table 1, the content of heavy metals in all salt lakes of the Atyrau region does not exceed the maximum permissible concentrations.

Figures 5 and 6 show analyses of the content of cations and anions in the waters of the Inder Salt Lake [10].

Figure 4 – Salt lake near Kh.Dospanova International Airport in Atyrau

Table 1 – The content of heavy metals in the salt lakes of the Atyrau region.

Name of the indicator to be determined	MPC, mg/l	Salt Lake Inder	Salt Lake Karabatan	Salt lake near Kh.Dospanova International Airport in Atyrau
Chrome	0,5	<0,005	<0,005	<0,005
Manganese	0,1	<0,002	<0,002	<0,002
Cobalt	0,01	<0,0005	<0,0005	<0,0005
Nickel	0,1	<0,005	<0,005	<0,005
Copper	0,1	<0,0005	<0,0005	<0,0005
Lead	0,03	<0,002	<0,002	<0,002
Zinc	1,0	<0,1	<0,1	<0,1
Cadmium	0,001	<0,0001	<0,0001	<0,0001

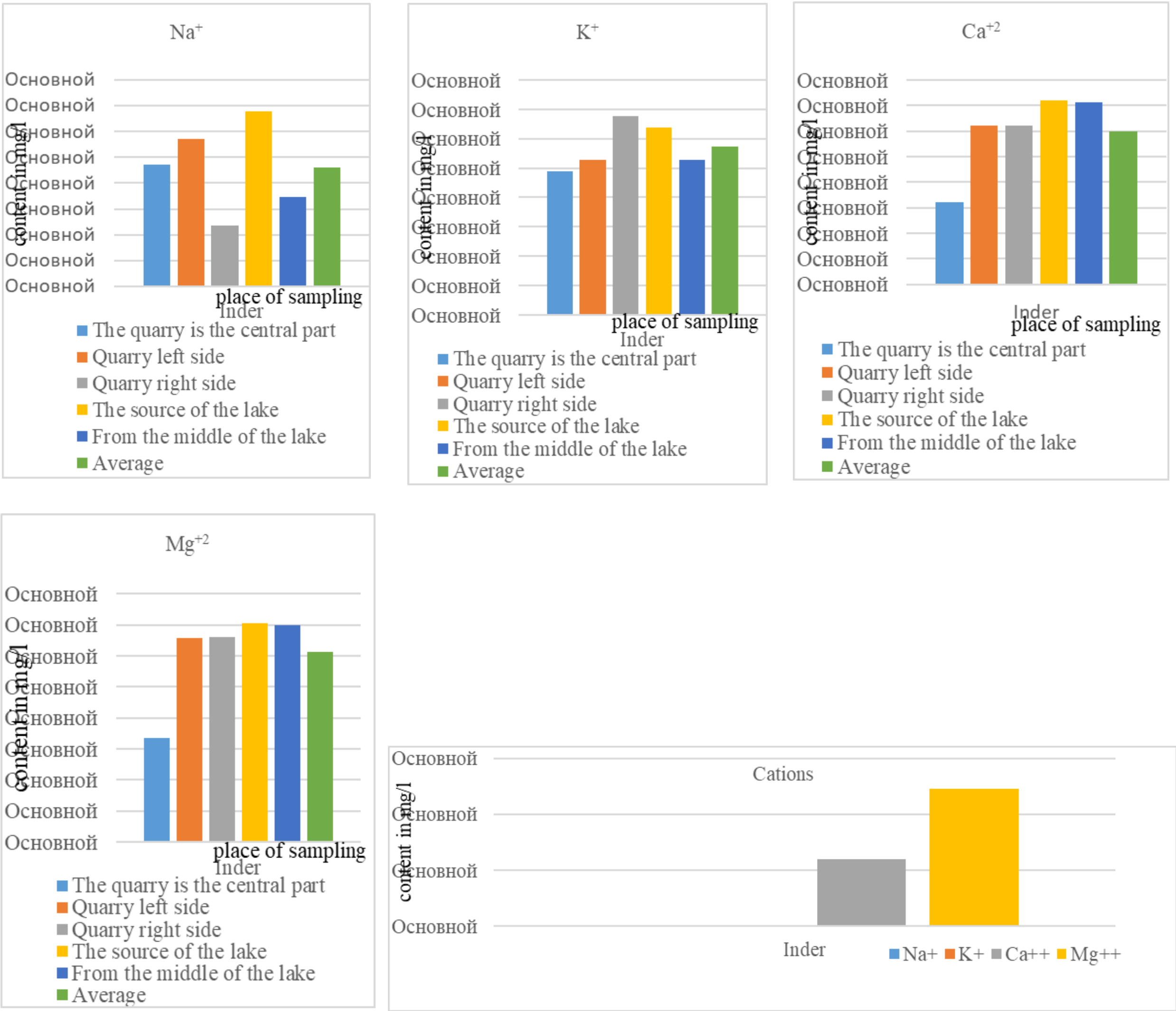

Figure 5 – The content of cations in the salty waters of Lake Inder, mg/l

In the Inder salt lake, the minimum values were noted for potassium ions, the content of which is about 3 mg/l (2.45-3.38 mg/l), sodium slightly more than 8-9 mg/l. The calcium content is much higher than the previous two cations and ranges from 320 to 720 mg/l. The maximum values were noted for magnesium cations, the content of which is in the range of 670-1412 mg/l. The average content of all cations shows that the magnesium content is more than 300 times higher than the content of potassium ions, sodium by 70-100 times and calcium by 2-3 times. Thus, the main predominant cations in the water of the Inder Salt Lake are magnesium and calcium cations.

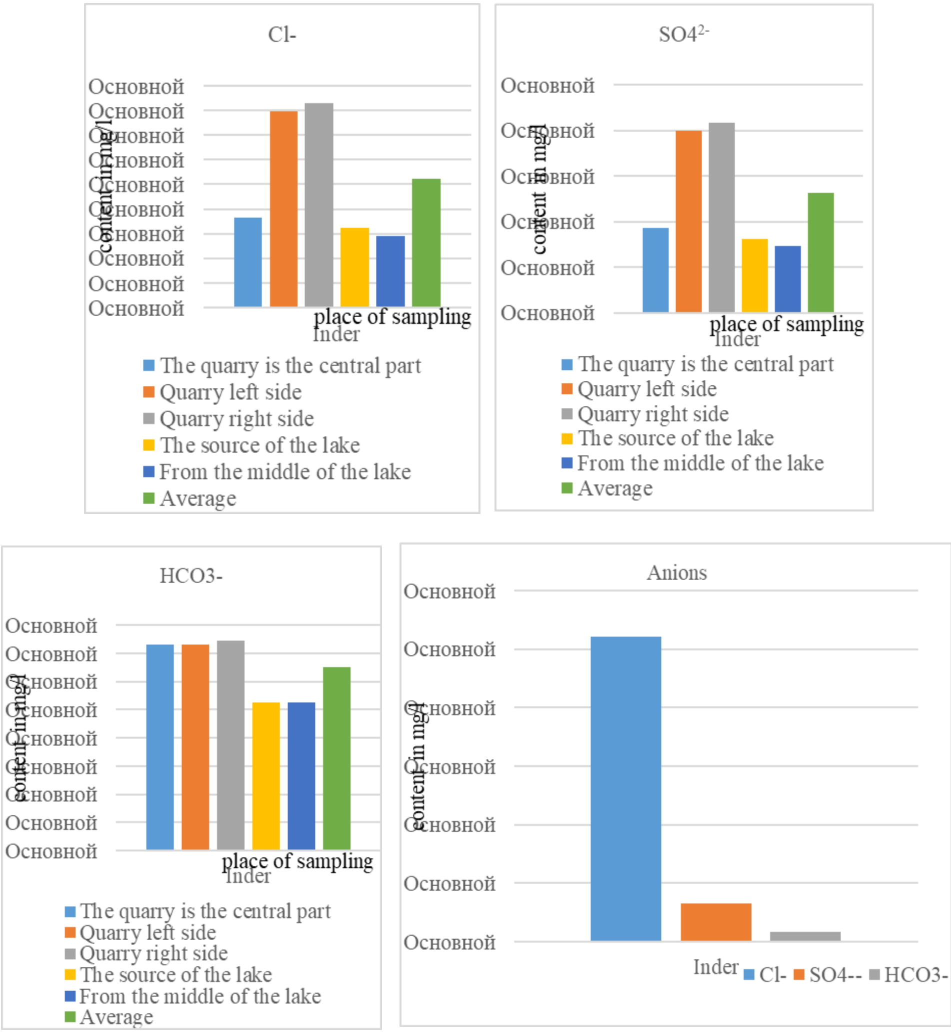

Figure 6 – The content of anions in the salty waters of Lake Inder, mg/l

Among the anions in Inder Lake, the minimum values are typical for bicarbonate ions ranging from 262.3 to 366 mg/l, the second place is occupied by sulfate ions with a content from 736.6 to 2086.2 mg/l, with an average content of 1310.5 mg/l. And the maximum concentrations are typical for chloride ions with a content from 5814 to 16592 mg/l. The content of chloride ions is more than 20-45 times higher than that of bicarbonate ions, and 7-8 times higher than that of sulfate ions [11].

Thus, calcium and magnesium cations, as well as sulfate and chloride anions, predominate in the Inder salt lake, which indicates that the main salts in the salty waters of Inder Lake are magnesium and calcium chlorides, as well as magnesium and calcium sulfates. Thus, according to the classification of Dobrovskoye Lake Inder, chlorides and sodium — Cl–Na predominate. The chloride content is more than 80% of the total volume of anions and sodium cations, the content of which is more than 65% of the total content of cations. According to Todorov's classification, the water of Lake Inder belongs to the sodium chloride series. Thus, the waters of Lake Inder are characterized by the highest mineralization due to the high concentration of chlorides and sodium. Figures 7 and 8 show analyses of the content of cations and anions in the waters of the salt lake of the Karabatan territory.

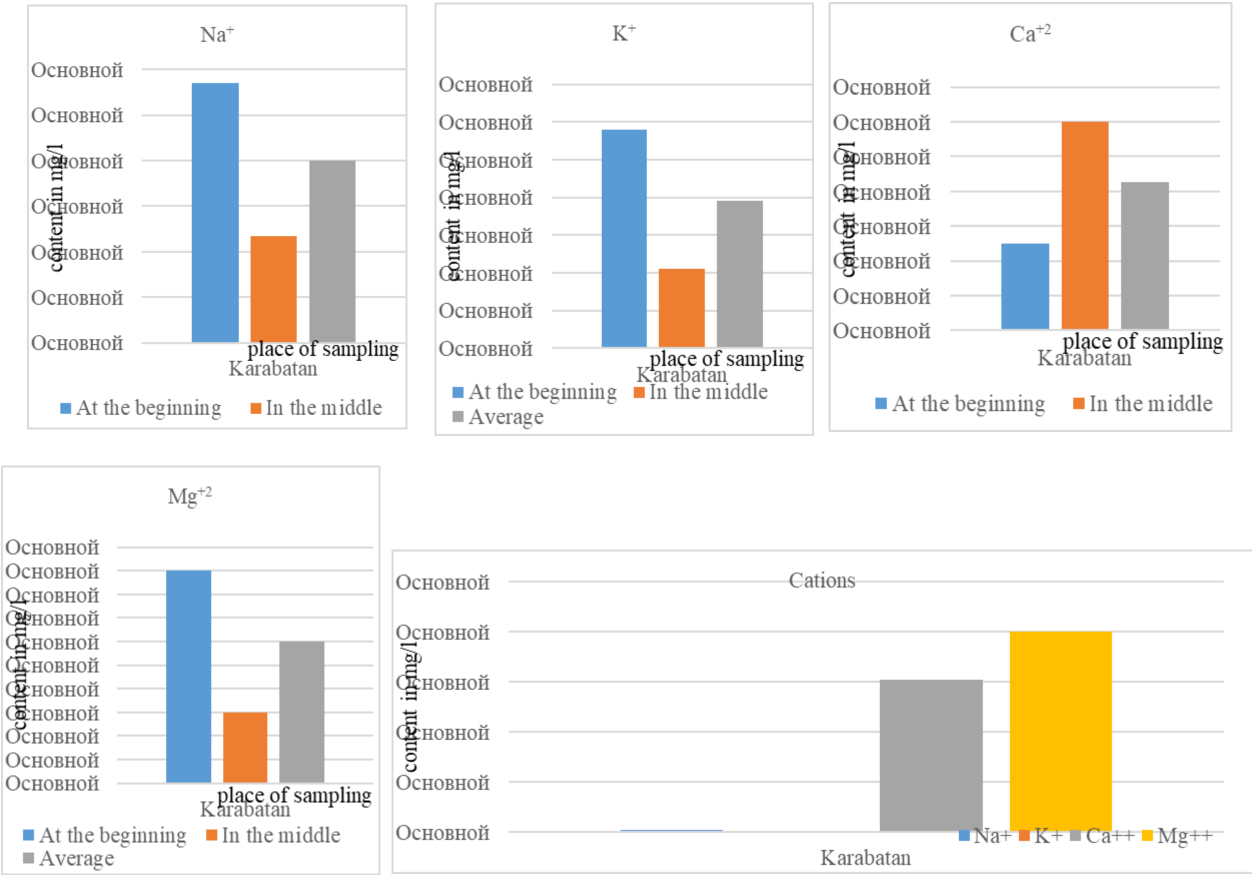

Figure 7 – The content of anions in the salty waters of the Karabatan area

In salt lake Karabatan, a low content of potassium and sodium cations was observed, and their content in Lake Inder ranges from 3.01-3.38 mg/l (K+) to 8.67-9.34 mg/l (Na+). The calcium con- tent is higher and ranges from 605 to 612 mg/l. The maximum value is the magnesium cation, whose content ranges from 798-804 mg/l. According to the average content of all cations, the content of magnesium is more than 237-266 times higher than the content of potassium ions, sodium 86-92 times and calcium 1.3 times. Thus, the main cations in the water of Salt Lake Karabatan are magnesium and calcium cations.

Among Salt Lake Calabatan anions, the minimum value of bicarbonate ions is 109.8 to 292.8 mg/L, followed by sulfate ions with a content of 7700.3 to 8254.5 mg/l, with an average content of 7977.4 mg/l, and the maximum concentration is chloride ions with a content of 61888 to 65234 mg/l. the content of chloride ions is more than 223-568 times higher than that of bicarbonate ions and sulfate ions.

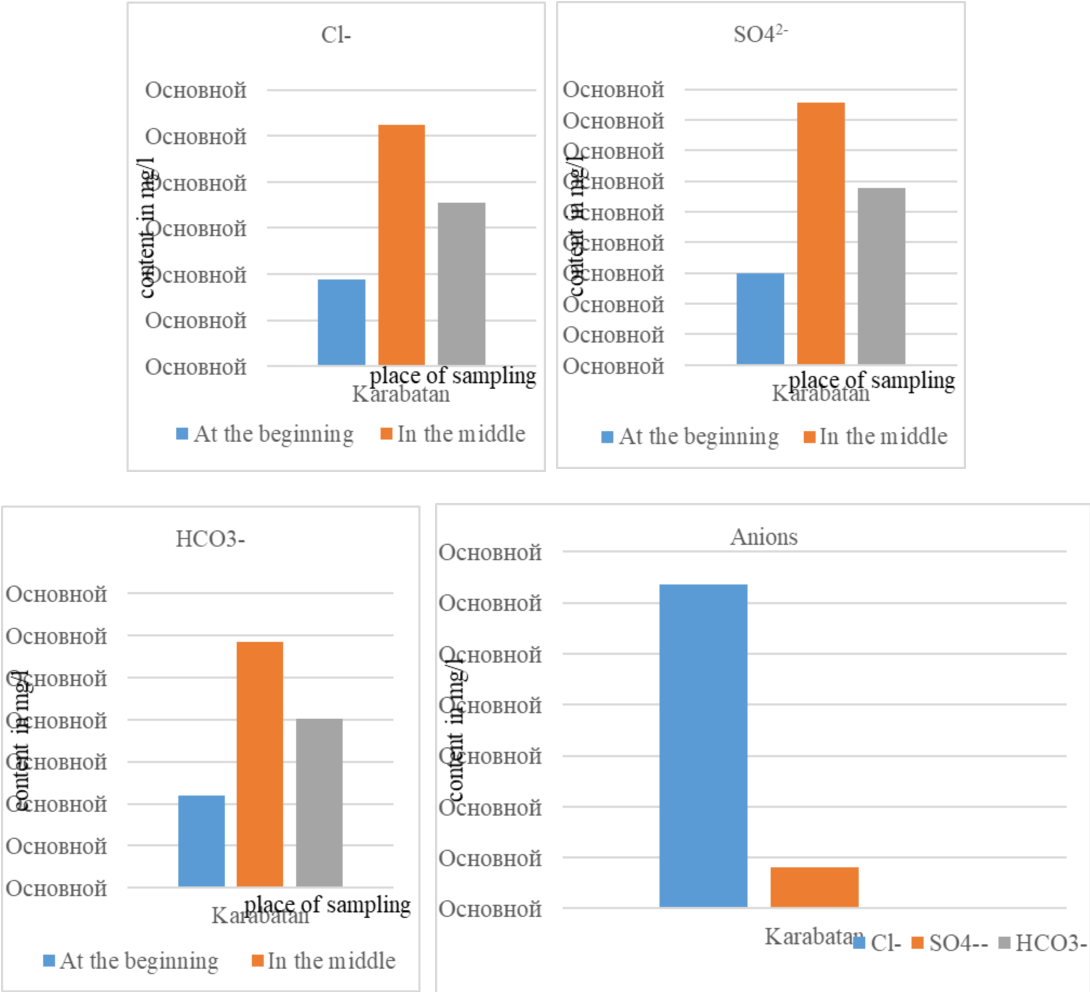

Figure 8 – The content of anions in the salty waters of the Karabatan area

Therefore, calcium and magnesium cations, as well as sulfate and chloride ions, dominate the salty lake Kalabatan, which indicates that the main salts in the salt water of Lake Kalabatan are magnesium and calcium chlorides, as well as magnesium and calcium sulfates. Therefore, according to Dombrovsky's classification, chloride and magnesium Cl–Mg dominate the water of Lake Karabatan, and according to Todorov's classification, it will belong to the chloride-magnesium series. Therefore, due to the high concentration of chloride and magnesium, the waters of Lake Karabatan have the highest degree of mineralization.

Figures 9 and 10 show analyses of the content of cations and anions in the waters of the salt lake near the airport.

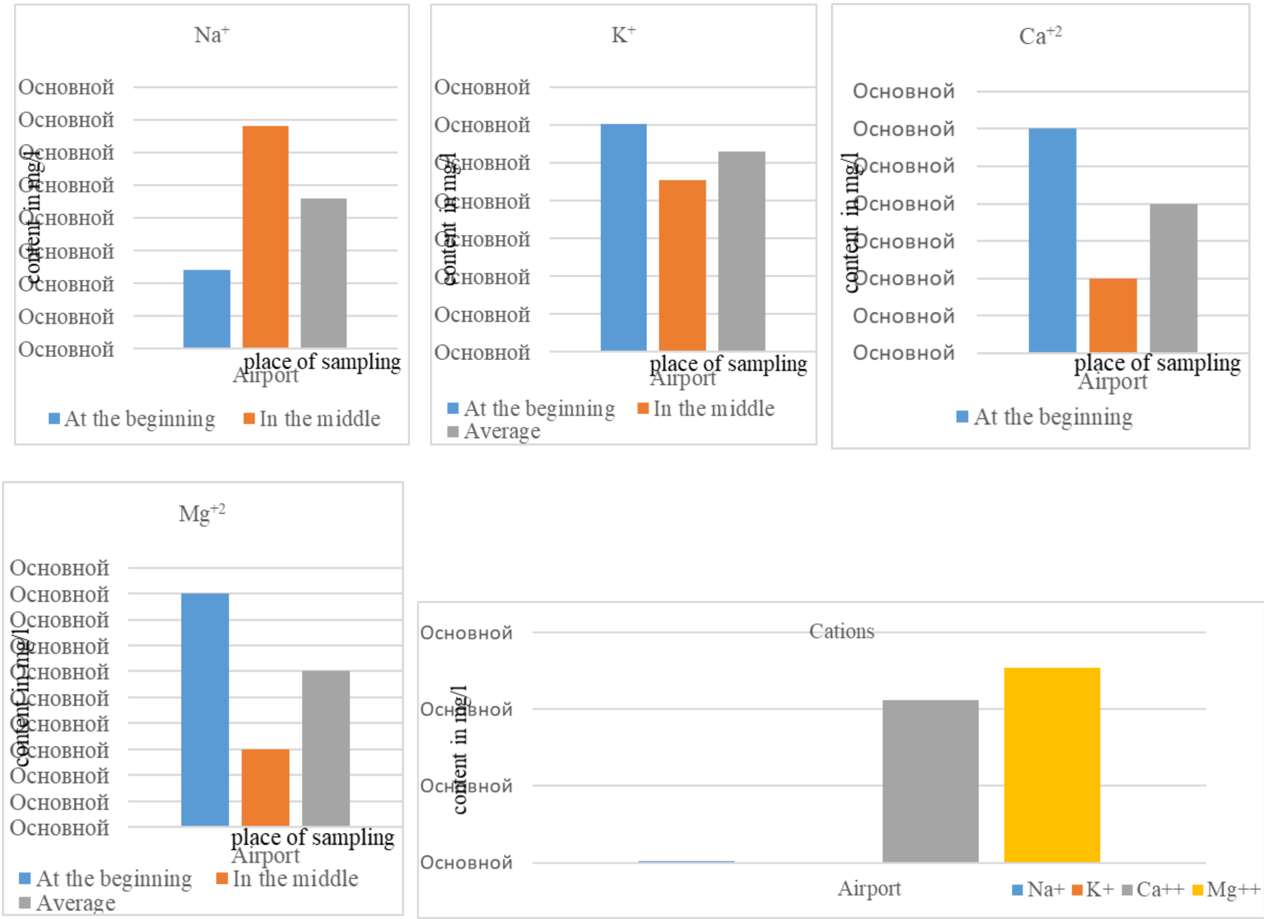

Figure 9 – The content of anions in the salty waters near the Atyrau airport

In the Salt Lake near the airport, the lowest values of potassium and sodium cations are characteristic, ranging from 2.27-3.01 mg/L (K+) to 8.67-8.89 mg/L (Na+). The calcium content is high, from 1058 to 1060 mg/l.the maximum value of the magnesium cation is from 1266 to 1272 mg/liter.The average content of all cations indicates that magnesium is 422 to 557 times more than potassium ion, 143 to 146 times more than sodium, and 1.2 times more than calcium. Therefore, the main cations in Salt Lake water near the airport are magnesium and calcium cations.

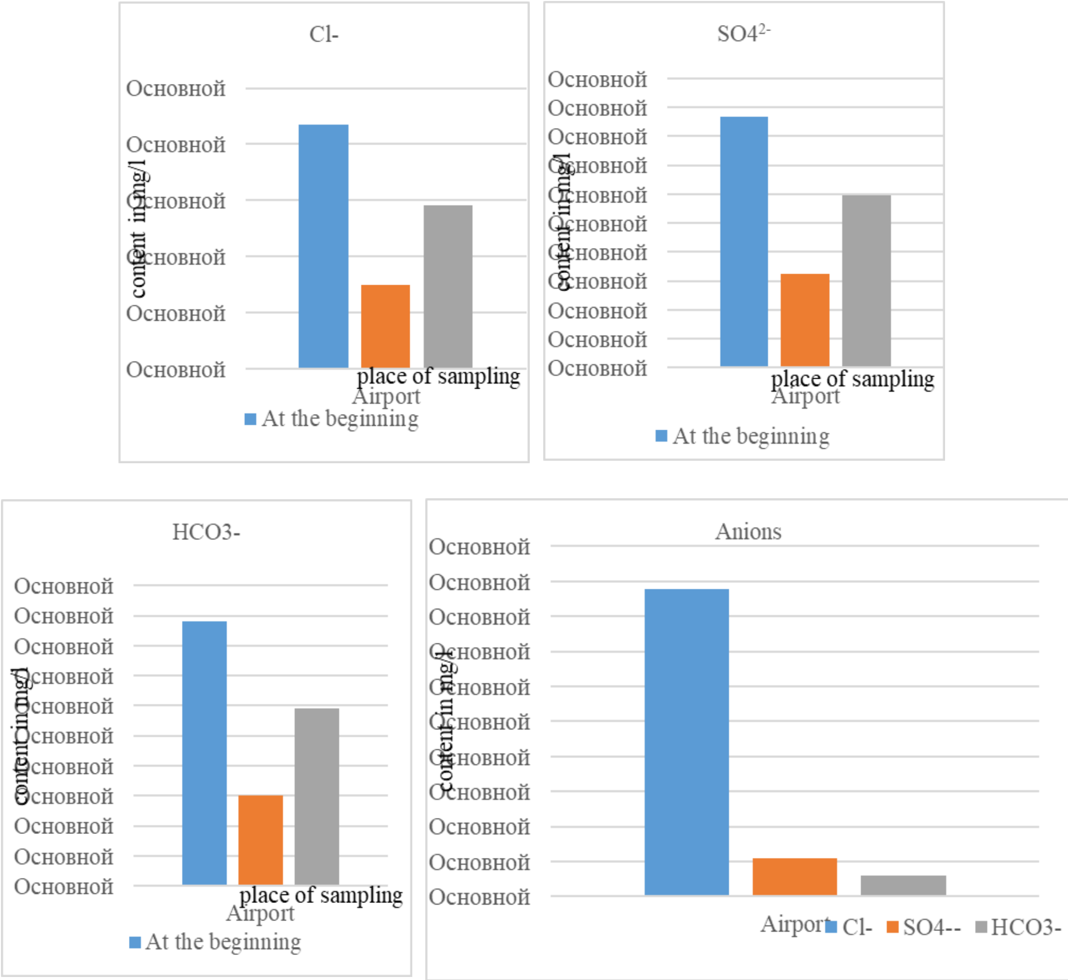

Figure 10 – The content of anions in the salty waters near the Atyrau airport

Among the anions in the salt lake near the airport, the minimum values are typical for bicarbonate ions ranging from 296 to 298.9 mg/l, the second place is occupied by sulfate ions with a content from 531.2 to 558.4 mg/l. And the maximum concentrations are typical for chloride ions with a content from 4325 to 4467 mg/l. The content of chloride ions is more than 14 times higher than bicarbonate ions and 8 times higher than sulfate ions.

Thus, the salt lake near the airport is dominated by calcium and magnesium cations, as well as sulfate and chloride anions, which indicates that the main salts in the salty waters of the lake near the airport are magnesium and calcium chlorides, as well as magnesium and calcium sulfates. Thus, according to Dombrowski's classification, water in the salt lakes near the airport belongs to Cl-Mg- Ca and according to Todorov's classification, it belongs to the chloride-magnesium-calcium series. Thus, the waters of the lake near the airport are characterized by the highest mineralization due to the high concentration of chlorides, magnesium and calcium.

Figures 11 and 12 show analyses of the content of cations and anions in the waters of the salt lakes of Atyrau region.

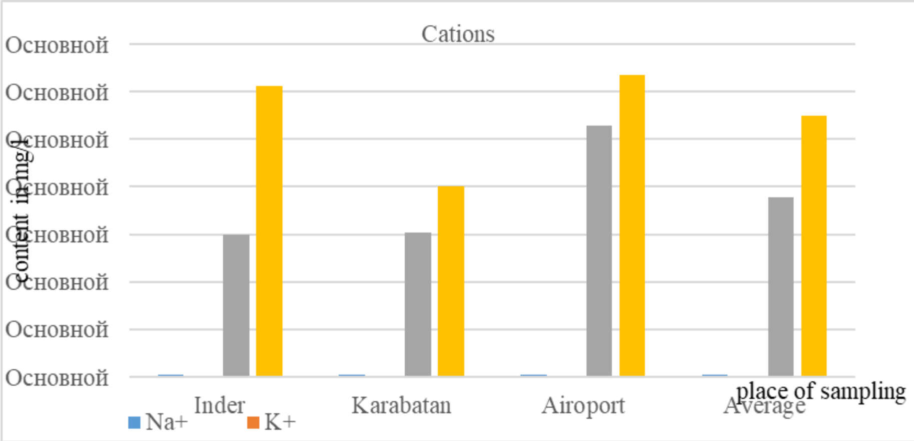

Figure 11 – The content of anions in the salt lakes of Atyrau region

In terms of the content of cations in all salt lakes, the minimum values are typical for potas- sium and sodium cations, the contents of which are identical for all salt lakes and range from 2.64 to 3.19 mg/l for potassium ions and from 8.78 to 9.12 mg/l for sodium ions. The content of calcium and magnesium ions is maximum in the salt lake near the Kh.Dospanova Aeroport, amounting to 1059 calcium and 1269 mg/l magnesium ions, are minimal in salt lake Karabatan, respectively 608.5 mg/l calcium ions and 801 mg/l magnesium ions, and in salt Lake Inder low content of cal- cium ions, i.e. 599.4 mg/l, whereas the content of magnesium ions is close to the content in the salt lake near the Kh.Dospanova Aeroport and is equal to 1223 mg/l.

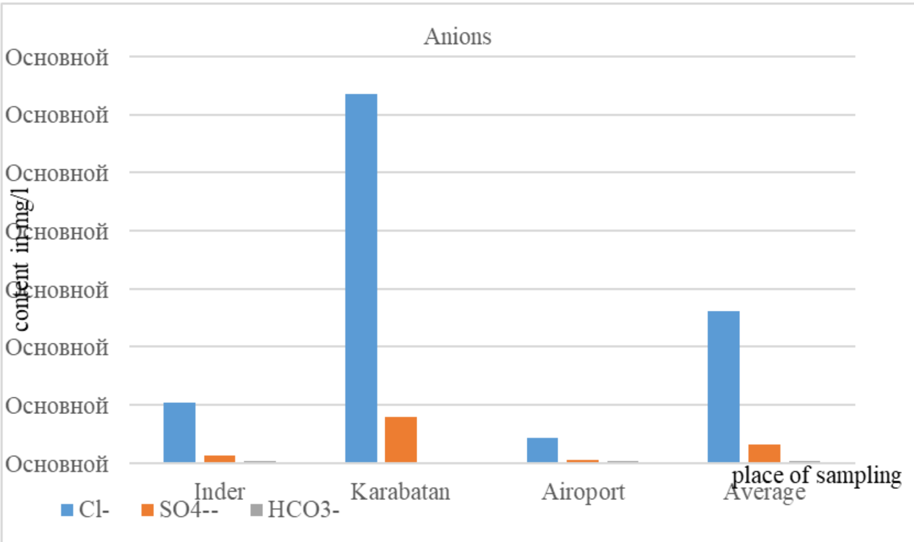

Figure 12 – The content of anions in the salt lakes of Atyrau region

Analysis of the cation content in salt lakes by three anions shows that the minimum values for all three lakes are characteristic of the bicarbonate ion and range from 201.3 to 325.74 mg/l, in sec- ond place are sulfate ions, the content of which is very diverse, so the lowest values in a salt lake are about Kh.Dospanova Airport and is 544.8 mg/l, then in the salt lake Inder 1310.5 mg/l, which is 2.5

times higher than previous data and is increased by Lake Karabatan and is 7977.4 mg/l, which is more than 14 times higher than in the salt lake about Kh.Dospanova Airport and 6 times salt lake Karabatan. The highest values are typical for chloride ions, while among the three lakes the content of chloride ions is the minimum value typical for the salt lake near the airport 4396 mg/l, in second place in the salt lake Inder 10410.8 mg /l, which is 2.3 times higher than the previous lake, and the maximum values are typical for the salt lake Karabatan, the content of which It is 63561 mg/l, which is 14.4 times higher than the data for the salt lake near the airport and 6.1 times higher than the salt lake Inder. Thus, in all three salt lakes, according to the maximum contents, it can be concluded that they contain the following salts in descending order: magnesium chloride→calcium chloride→magnesium sulfates →calcium sulfate, and the remaining salts in smaller quantities.

Discussion

The analysis results show that salt lakes in the Atyrau region are mostly transparent due to chemical analysis of water and are characterized by an increase in the content of cations and anions of the same composition [12].

In general, there are high values of such cations as magnesium and calcium and chloride and sulfate anions. If we look at each lake, the magnesium cation content is the same in Lake Inder and the lake near Kh.Dospanov Airport and 1.5 times higher than the magnesium content in Lake Karabatan. The content of calcium ions is higher in the lake near Kh.Dospanov Airport and is almost twice as high as the calcium content in the other two salt lakes. The contents of potassium and sodium ions are in close values in all three salt lakes.

At the same time, different indicators were observed for anions, especially chloride ions, the highest of which is typical for salt Lake Karabatan, which is 6-14 times higher than in the other two lakes. There is also a sulfate-ion structure in Lake Karabatan, the content of which is 6-14 times higher than the content of sulfate ions in the other two lakes. However, compared with chlorides, their content is almost 8 times lower than that of chloride ions. In all three lakes, the hydrocarbon content is close, and compared to other chloride anions, it is 14 times less than in lakes near the airport, 32 times less than in Lake Inder, and 316 times less than in Lake Karabatan, compared to sulfates.

These studies have shown that the main salts formed in these three salt lakes are magnesium chloride and calcium chloride, followed by magnesium sulfate and calcium sulfate, as well as the least amount of sodium bicarbonate and potassium.

Conclusion

In conclusion, it can be concluded that in three salt lakes of the Atyrau region of different volume and nature of origin, as well as located in different territories of the Atyrau region, there is a similar hydrochemical composition, the predominant cations in which are magnesium and calcium ions and chloride and sulfate ions from anions. At the same time, cations show almost the same indicators for all cations, especially for potassium and sodium, the content of which is close to 3 mg/l for potas- sium and about 9 mg/l for sodium. The values for calcium are diverse, while in the Inder and Kara- batan lakes they amount to about 600 mg/l, and in the salt lake near the Atyrau airport they exceed 1000 mg/l. In terms of magnesium, the indicators differ from those of calcium ions and similar indi- cators are typical for Lake Inder and the lake near the airport and above 1200 mg/l, whereas in Lake Karabatan it is slightly above 800 mg/l. Ratio of contents Ca:Mg in Lake Inder is 1:2, in Lake Kara- batan 1:1.3 and Salt lake near Kh.Dospanova In- ternational Airport in Atyrau 1:1,2. For anions, the lowest values are typical for bicarbonate ions and are in the range of 200-300 mg/l. The indicators for sulfates and chlorides are very diverse, as for sulfates they vary from 500 mg/l in the lake near the airport to almost 8000 mg/l in Lake Karabatan. The maximum values are typical for chlorides, while their contents are also diverse in all lakes and range from more than 4,000 mg/l to more than 63,000 mg/l. At the same time, the following ratios of HCO_3: SO_4:Cl anions are noted – in Lake Inder 1:4:32; in Lake Karabatan 1:39:316; and in the Salt lake near Kh.Dospanova International Airport in Atyrau 1:1.8:14.8. Thus, salts of magnesium and calcium chlorides, magnesium and calcium sul- fates are formed in all lakes, and the salt contents of sodium and potassium bicarbonates are the most minimal.

Conflict of interest

All authors have read and are familiar with the content of the article and have no conflict of interests.

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3-бөлім

БИОЛОГИЯЛЫҚ АЛУАНТҮРЛІЛІКТІ САҚТАУДЫҢ ӨЗЕКТІ МӘСЕЛЕЛЕРІ

Section 3

ACTUAL PROBLEMS OF BIODIVERSITY CONSERVATION

Раздел 3

АКТУАЛЬНЫЕ ПРОБЛЕМЫ СОХРАНЕНИЯ БИОЛОГИЧЕСКОГО РАЗНООБРАЗИЯ

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MAIN CHARACTERISTICS OF PHYTO- AND ZOOPLANKTON OF LAKE TALDYKOL IN 2022

Lake Taldykol is a water body that experiences significant anthropogenic impact, which is reflected in its hydrochemical and hydrobiological state. In this paper, a comprehensive analysis of water quality is carried out, including a study of the chemical composition, saprobity and structure of plankton communities. The aim of this work was to assess the species composition, abundance and biomass of phytoplankton and zooplankton of Lake Taldykol, as well as to determine possible changes in the structure of these communities under the influence of hydrological and environmental factors, in particular, under conditions of fluctuating water levels. The scientific significance of the work lies in the comprehensive study of anthropogenic impact on the reservoir and determination of its ability to self-purify. The practical significance lies in the possibility of using the obtained data to develop measures to protect and restore the lake ecosystem. The study revealed that the maximum permissible concentrations were exceeded for a number of pollutants, such as COD, suspended solids, phosphates, nitrites and iron, which indicates a high anthropogenic load. The dynamics of the number and biomass of phytoplankton and zooplankton indicate seasonal changes in the trophic level of the reservoir. Saprobic indices showed that the lake belongs to the β-mesosaprobic zone, but in spring and autumn there is a deterioration in water quality.

Key words: phytoplankton, zooplankton, hydrochemistry, hydrobiocenosis.

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Талдыкөл көлінің фито- және зоопланктонының 2022 жылғы негізгі сипаттамасы

Талдыкөл көлі-оның гидрохимиялық және гидробиологиялық жағдайына әсер ететін айтарлықтай антропогендік әсерге ие су айдыны. Бұл жұмыста планктондық қауымдастықтардың химиялық құрамын, сапробтылығын және құрылымын зерттеуді қамтитын су сапасына кешенді талдау жүргізілді. Бұл жұмыстың мақсаты Талдыкөл көлінің фитопланктоны мен зоопланктонының түрлік құрамын, саны мен биомассасын бағалау, сондай-ақ гидрологиялық және экологиялық факторлардың әсерінен, атап айтқанда су деңгейінің ауытқуы жағдайында осы қауымдастықтардың құрылымындағы ықтимал өзгерістерді анықтау болды. Жұмыстың ғылыми маңыздылығы су қоймасына антропогендік әсерді кешенді зерттеу және оның өзін-өзі тазарту қабілетін анықтау болып табылады. Практикалық маңыздылығы-алынған деректерді көлдің экожүйесін қорғау және қалпына келтіру шараларын әзірлеу үшін пайдалану мүмкіндігі. Зерттеу нәтижесінде КПК, тоқтатылған заттар, фосфаттар, нитриттер және темір сияқты бірқатар ластаушы заттар бойынша ШРК-ның асып кетуі анықталды, бұл антропогендік жүктеменің жоғары екендігін көрсетеді. Фитопланктон мен зоопланктонның көптігі мен биомассасының динамикасы су қоймасының трофикалық деңгейінің маусымдық өзгеруін көрсетеді. Сапробтық индекстер көлдің β-мезосапробты аймаққа жататынын көрсетті, бірақ көктемде және күзде су сапасының нашарлауы байқалады.

Түйін сөздер: фитопланктон, зоопланктон, гидрохимия, гидробиоценоз.

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Основные характеристики фито- и зоопланктона озера Талдыколь в 2022 году

Озеро Талдыколь представляет собой водоём, испытывающий значительное антропогенное воздействие, что отражается на его гидрохимическом и гидробиологическом состоянии. В данной работе проведён комплексный анализ качества воды, включающий исследование химического состава, сапробности и структуры планктонных сообществ. Целью настоящей работы являлась оценка видового состава, численности и биомассы фитопланктона и зоопланктона озера Талдыколь, а также определение возможных изменений в структуре этих сообществ под влиянием гидрологических и экологических факторов, в частности, в условиях колебания уровня водности. Научная значимость работы заключается в комплексном исследовании антропогенного влияния на водоём и определении его способности к самоочищению. Практическая значимость заключа- ется в возможности использования полученных данных для разработки мероприятий по охране и восстановлению экосистемы озера. В результате исследования выявлено превышение ПДК по ряду загрязняющих веществ, таких как ХПК, взвешенные вещества, фосфаты, нитриты и железо, что свидетельствует о высокой антропогенной нагрузке. Динамика численности и биомассы фитопланктона и зоопланктона указывает на сезонные изменения уровня трофности водоёма. Индексы сапробности показали, что озеро относится к β-мезосапробной зоне, однако весной и осенью наблюдается ухудшение качества воды.

Ключевые слова: фитопланктон, зоопланктон, гидрохимия, гидробиоценоз.

Introduction

Hydroecosystems are characterized by variable hydrological and hydrochemical regimes, therefore, the study of species diversity, abundance dynamics, biomass and structural characteristics of plankton communities is important for assessing the status and sustainability of water bodies [1]. Phyto- and zooplankton are bioindicators of water quality, reflecting both natural fluctuations in environmental conditions and the level of anthropogenic impact. Their qualitative and quantitative parameters react sensitively to changes in the hydrological regime, trophicity and degree of pollution of a water body [2].

The object of the study was Lake Taldykol, located within the city of Astana. This lake is the largest body of water in the system of lakes, which have become very shallow in recent years. The reservoir is of natural origin, belongs to closed shallow lakes with an already formed ecosystem, but in recent years it has been subject to significant anthropogenic and technogenic loads [3]. Lake Taldykol is an important natural site that, despite its urban environment, retains significant biodiversity and performs important ecological functions. Taldykol is an important stopover for migratory birds, making the lake a key ornithological zone, which gives special conservation significance to this water body in the context of fulfilling the requirements of the Ramsar Convention and the Convention on Biological Diversity [4].

However, against the backdrop of increasing anthropogenic impact and transformation of natural conditions, changes are occurring in the ecosystem structure of the lake [5]. The effects of the water level fluctuations recorded in 2022 were particularly noticeable. The reduction in water volume can significantly affect biogeochemical processes, including nutrient circulation and oxygen balance, which in turn affects the state of plankton communities [6, 7].

The aim of this work was to assess the species composition, abundance and biomass of phytoplankton and zooplankton of Lake Taldykol, as well as to determine possible changes in the structure of these communities under the influence of hydrological and environmental factors.

The conducted research allows us to better understand the ecological state of Lake Taldykol and serves as a basis for further work on monitoring and ecological rehabilitation of the reservoir. The results can be used by environmental organizations to assess and reduce anthropogenic impact on water bodies.

Materials and methods

The study of hydrochemical parameters of water was carried out in 2022-2023 in the spring, summer and autumn periods using the methods of State Standards [8-12] for reservoirs based on the analytical laboratory of sewage treatment facilities of the State Enterprise “Astana-su Arnasy”.

Study of species diversity of phytoplankton

To collect phytoplankton, Apshteyn net gas No. 77 was used (Kiselev, 1969; Wasser et al., 1989) [13, 14]. Samples were taken from the surface of the reservoir with a capacity of 10 liters and passed through the Apshteyn net – a total of 10 times. The sample was fixed at the rate of 20-40 ml of 40% formalin per 1 liter of sample. The pH of the fixative was first adjusted to 7 by adding a small amount of Na2CO3 solution. After that, the sample was concentrated by the precipitation method to 100 ml over 24 hours.

Phytoplankton identification was carried out by microscopy using a 90 (2 mm) immersion objective on an Olympus CX-31 microscope.

Determination of saprobity of water bodies

The saprobity of water bodies was determined by the composition of phytoplankton using the Pantle and Buck method as modified by V. Sladechek [15-20].

For this purpose, lists of pollution indicator organisms were used.

Indicator significance S_i for oligosaprobes is 1.0; beta-mesosaprobes – 2; alpha-mesosaprobes – 3; and polysaprobes – 4.

The relative number of h_i individuals was assessed on a three-point scale: random finds – 1; frequent occurrence – 3; mass occurrence – 5.

The saprobity index is calculated based on the individual saprobity characteristics of the species represented in the aquatic phytoplankton community using the formula (1):

$$S = \sum S_i h / \sum h_i \qquad (1)$$

where S is the saprobity index, dimensionless;

S_i is the saprobity value of the aquatic organism (according to special tables);

h_i is the relative occurrence of indicator organisms in the microscope field;

n is the number of selected indicator organisms.

In the polysaprobic zone, the saprobity index is – 4.0-3.5; in the α-mesosaprobic zone – 3.5-2.5; in the β-mesosaprobic zone – 2.5-1.5; in the oligosaprobic zone – 1.5-1.0.

Study of species diversity of zooplankton

To identify zooplankton species, water was scooped from a 100-liter boat and passed through an Apshteyn net with gas No. 55 [20, 21]. The collected samples were immediately fixed with 4% formalin. To prevent shell deformation and eggs from falling out of the brood chambers, sucrose (40 g/l) was added to the samples. The sample was left to settle until 200 ml.

Microscopy of zooplankton samples and identification of species was carried out with a 90 (2 mm) objective on an Olympus CX-31 microscope.

Результаты и обсуждения

Study of hydrochemical analysis of water in Lake Taldykol

Hydrochemical analysis of the water of Lake Taldykol was carried out from autumn 2022 to summer 2023, where such indicators as pH, BOD_5, COD, suspended solids, chlorides, sulfates, phosphates, ammonium nitrogen, nitrites, nitrates, iron, surfactants, dry residue, oil products, chromium, nickel, zinc, manganese, fluorides, hardness, alkalinity were determined.

The Taldykol lake system has been heavily impacted by anthropogenic factors in recent decades, which has significantly affected the hydrochemical parameters.

The results showed that Lake Taldykol is a reservoir with a variable hydrochemical composition. In 2022, the water in the lake had high mineralization, but in 2023, the mineralization decreased, which corresponds to brackish wa- ter. In 2022, the lake had a chloride-sulfate type of water with very high mineralization, but in 2023, a decrease in the content of chlorides and sulfates was observed, indicating a change in the water type towards hydrocarbonate, which may indicate dilution of the lake with fresh wa- ter.

An analysis of hydrochemical indicators for two years showed that pollution with organic substances has decreased, but the COD_5 value still shows an excess of the MAC by 1.4 times, and in the summer of 2023, a jump in the concentration of biogenic elements (phosphates and nitrites) was observed, which may indicate the influx of wastewater. The content of heavy metals and oil products has decreased, but the iron level still exceeds the permissible values (Figure 1).

Analysis of water quality indicators for the period under study shows a change in the hydrological regime of the lake. This may indicate an increase in anthropogenic load on the reservoir.

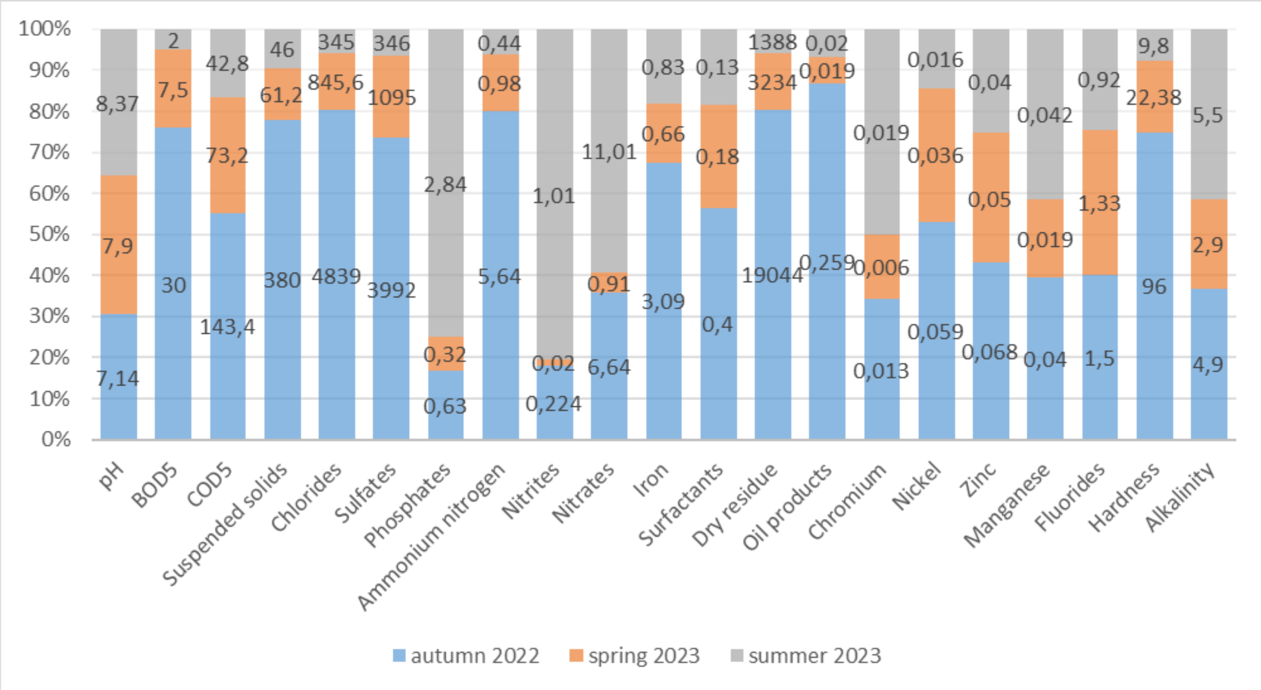

Figure 1 – Hydrochemical indicators of water in Lake Taldykol for 2022 and 2023.

The self-purification capacity of a reservoir can be assessed by the ratio of free oxygen content R to BOD5. The ratio of these indicators can reflect the relationship of photosynthetic activity in a reservoir to its destructive capacity: R/BOD5. The higher this ratio, the higher the potential for self-purification in reservoirs, and vice versa – the lower the ratio, the lower the capacity of the reservoir for self-purification [22]. In our studies, this ratio in 2023 was 1.5, which indicates a moderate capacity of the reservoir for self-purification.

Hydrobiological analysis of water in Lake Taldykol

Among the main types of aquatic flora in Lake Taldykol we can highlight:

Common reed (*Phragmites australis*, (Cav.) Trin. ex Steud) is the dominant plant growing along the shoreline. Lake bulrush (*Schoenoplectus lacustris*, (L.) Palla) is an important species that supports local aquatic biotopes. Broadleaf cattail (*Typha latifolia* L.) is often found in the coastal zones of the lake. These species play a key role in stabiliz- ing the banks, creating habitat for aquatic animals, and maintaining water quality [23, 24]. Of the submerged plants, the most widespread are various species of pondweed and water rhizome. The area of overgrowth of the lake as a whole is 30%.

Quantitative indicators of phytoplankton in Lake Taldykol

The studied reservoir contained individual species from the following classes of phytoplankton: Diatoms (*Bacillariophyta*, Haeckel, 1878) are one of the main groups of phytoplankton in reservoirs; Green algae (*Chlorophyta*, Haeckel, 1894); Blue-green algae (*Cyanobacteria*) are well adapted to extreme conditions, including high salinity, and can cause “water blooms” [25].

Diatoms were predominant in spring – 62%, in summer – 53% and in autumn – 58% (Table 1). Green algae also formed a large group: they made up 24% in spring, 35% in summer and 29% in autumn. The share of blue-green algae was 7% in spring, 6% in summer and 9% in autumn.

In total, 62 species of phytoplankton were identified in the lake for the studied seasons of the year. Species identification in the lakes showed the following results (Table 2):

Table 1 – Dominant classes of phytoplankton in Lake Taldykol

Phytoplankton	Share, %		
	Spring	Summer	Autumn
Bacillariophyta	65	53	58
Chlorophyta	24	35	29
Cyanobacteria	7	6	9

Table 2 – Phytoplankton species in Lake Taldykol

Types of phytoplankton	Spring	Summer	Autumn
*Bacillariophyt*a			
Melosira varians Agardh	+	-	+
Cyclotella species Kützing	+	+	-
Diatoma sp Müller	+	+	+
Diatoma anceps Ehrenberg, Kirchn.	+	+	+
Synedra acus Kütz.	-	+	-
Synedra tabulata (Ag.) Kütz.	+	+	-
Meridion circulare Ag.	-	+	+
Melosira arenaria Moore	+	-	+
Fragilaria construens (Ehr.) Grun.	-	+	+
*Synedra ulna (*Nitzsch.) Ehr.	-	-	+
Cocconeis pediculus Ehr.	+	-	-
Cocconeis placentula Ehr.	-	+	+
Rhoicosphenia curvata (Kütz.) Grun.	-	+	-
Navicula cuspidate Kütz	-	+	-
Navicula sp Bory de Saint-Vincent	+	+	-
Navicula gracilis Kütz	+	+	-
Navicula viridula Kütz	-	+	+
Navicula radiosa Kütz	+	+	-
Navicula exigua (Greg.) J.Müll.	-	+	-
Navicula prostrata Ehr	-	+	-
Navicula amphibola Brebisson	+	+	+
*Caloneis silicula (*Ehr.) Cl.	-	+	-
Girosigma Spenseri (W.Sm.)Cl.	-	+	-
Girosigma balticum (Ehr.)Rabenh.	-	-	+
Caloneis amphisbaena (Bory) Cl.	-	-	+
Gyrosigma acuminatum Bory de Saint-Vincent	+	-	-
Amphora ovalis Kütz.	+	-	-
Cymbella prostata (Berkley) Cl.	-	+	-
Cymbella affinis Kütz.	-	+	+
Cymbella lanceolata (Ehr.) V.H.	-	-	+
*Cymbella cistula (*Hemp.) Grun.	+	-	-
Cymbella stigmafora Grunow	-	+	+
*Nitzschia Sigma (*Kütz.) W.Sm.	+	-	-

Continuation of the table

Types of phytoplankton	Spring	Summer	Autumn
Nitzschia acicularis Kütz	+	+	+
Surirella Capronii Breb.	-	+	-
Surirella ovalis Ehr.	+	+	+
Gomphonema constrictum Ehr.	-	+	-
Gomphonema intricatum Ehr.	-	+	+
Bacillaria paradoxa Gmelin	+	-	-
*Symatopleura solea (*Breb.) W.Sm.	-	-	+
Pinnularia subgibba Ehr.	+	+	+
Pinnularia Ehr.	-	+	-
Tabellaria Ehr.	+	-	-
Chlorophyta			
Lagerheimia Alder	+	-	+
Geminella sp Ehr.	+	+	+
Chlorella Beijerinck	+	+	-
Oocystis Bory de Saint-Vincent	-	+	+
Spirogira Weberi (Kütz.) Czurda	+	-	-
Pediastrum Bory de Saint-Vincent	-	+	+
Scenedesmus Corda	-	+	-
Stigeoclonium tenue Kütz	+	+	-
Ulotrix subtilis Kütz	-	+	-
Cyanophyta			
Microcoleus tenerrimus Mertens ex Gomont	-	+	-
Aphanizomenon *Lemm.*	-	+	-
Anabaena sp. Bory de Saint-Vincent	-	+	+
Oscillatoria brevis Kützing *ex* Gomont	+	-	-
Oscillatoria chalybea Mertens ex Gomont	+	+	-
Oscillatoria princeps Vaucher ex Gomont	+	+	+
Spirulina fusiformis Voronichin	+	+	-
Euglenophyta			
Euglena gracilis Klebs	+	+	-
Trachelomonas volvocina Ehrenberg	-	-	+
Peridinium Ehrenberg	-	+	+

The primary productivity of phytoplankton varied at different times of the year: in spring the total number was 12.19 thousand cells/cm³, and the total biomass was 3.1 mg/dm³; in summer the total number reached 24.6 thousand cells/cm³, the total biomass was 7.6 mg/dm³; in autumn the total number was 27.9 thousand cells/cm³, the total biomass was 12.93 mg/dm³ (Table 3).

In all the studied seasons, the lake waters were classified as β-mesosaprobic zone, however, in autumn, saprobity increases and is on the border closer to the L-mesosaprobic zone. Thus, most lakes have a tendency to eutrophication of waters, and therefore have a low self-purification potential. Despite the overall high productivity of algae in water bodies, the function of saprophytes remains low.

However, in terms of the total number of algal flora, the trophicity of the lake in the selected areas is mesotrophic, as it is in the range of 3.85-20 million cells/l.

Table 3 – Quantitative indicators of phytoplankton in Lake Taldykol

Indicators	Spring	Summer	Autumn
Total number of algal flora (thousand cells/cm³)	12,19	24,6	27,9
Total biomass mg/dm³	3,1	7,6	12,93
Saprobity index	1,70	1,81	2,5

Quantitative indicators of zooplankton in Lake Taldykol

Zooplankton in the lake is an important component of the ecosystem, playing a key role in the food chain of water bodies. It serves as an important link between phytoplankton (algae) and larger organisms such as fish [26]. The main groups of zooplankton that are found in Lake Taldykol are:

- Cladocera (*Cladocera* G. O. Sars), in particular small crustaceans such as *Daphnia* (Linnaeus (1758), *Bosmina* (Baird (1850), and *Chydorus* (Baird (1850);

- *Copepods* (Copepoda Linnaeus (1758). Of the representatives of this group, *Cyclops* (Linnaeus (1758) and *Diaptomus* (Koch (1837) predominate) play an important role in maintaining the balance of the ecosystem of water bodies;

- *Rotators* (*Rotifera*, Bory de Saint-Vincent (1824). Such as *Brachionus*, Bory de Saint-Vincent (1824), *Keratella* (Gosse, 1851) have been discovered.

Zooplankton plays an important role in regulating the abundance of phytoplankton, which helps maintain balance in aquatic ecosystems. In addition, zooplankton is the main food source for many fish species, especially juveniles [27].

The composition and abundance of zooplankton varied depending on the season and the availability of nutrients. A total of 22 species of zooplankton were identified in the studied lakes (Table 4).

Table 4 – Zooplankton species in Lake Taldykol

Types of zooplankton	Spring	Summer	Autumn
Rotifera			
Asplanchna silvestris Daday	+	+	-
Synchaeta sp. Linnaeus	-	-	+
Euchlanis sp. Linnaeus	+	-	+
Lepadella patella Gosse	+	-	-
Brachionus quadridentatus hyphalmyros Tschugunoff	+	+	+
B.angularis Gosse	+	+	-
B.calyciflorus spinosus Wierzejski	+	+	-
Keratella cochlearis Gosse	+	+	+
Testudinella trilobata Gosse	-	+	-
Keratella quadrata Gosse	-	+	+
Euchlanis triquetra Müller	+	+	+
Cladocera			
Rhynchotalona falcatasp Koch	+	+	+
Daphnia cucullata Sars	+	-	+
Daphnia longispina Muller	-	-	+
Magna sp. Straus	+	-	-
Ceriodaphnia sp. Richardson	+	+	-
Bosmina sp. Baird	+	+	+
Chydorus sphearicus Muller	+	+	+

Continuation of the table

Types of zooplankton	Spring	Summer	Autumn
Leptodora kintii Focke	+	+	+
Pleuroxus striatus Baird	-	-	+
Copepoda			
Cyclops sp. Linnaeus	+	+	+
Eurytemora velox Sars	+	-	+
Acanthocyclops vernalis Fischer	-	-	-
Cyclop strenuous Sars	-	-	-

The abundance of cladocerans in May was 22.07%, in August 38%, in October 34% (Table 5).

The content of rotifers was 0.03% in May, 28% in August, and 5% in October. Copepods were the most abundant in May – 77%, 51% in August, and 41% in October.

In terms of abundance and biomass, zooplankton was most abundant in summer (total abundance – 4.89 thousand specimens/m³, total biomass – 50.29 mg/m³) and spring (total abundance – 4.61 thousand specimens/m³, total biomass – 44.1 mg/m³); then in autumn – the total number is 3.33 thousand specimens/m³, the total biomass is 32.37 mg/m³.

Based on the calculation of saprobity indices for different groups of hydrobionts, it can be concluded that in all seasons the lake is classified as moderately saprobic (β-mesosaprobic) in terms of water quality. However, in spring and autumn, saprobity is higher than in summer, which indicates a decrease in the reservoir's ability to cope with organic pollution.

Table 5 – Dominant classes of zooplankton in Lake Taldykol

Zooplankton indices	Spring	Summer	Autumn
Cladocera, %	22,07	38	34
Rotifers, %	0,03	28	5
Copepods, %	77	51	41
Total number, thousand specimens/m³	4,61	4,89	3,33
Biomass, mg/m³	44,1	50,29	32,37
Saprobity index	1,92	1,85	2,3

As the results of our work show, the composition of species in the reservoir varies by season, although the lake is located within the β-mesosaprobic zone. The composition of zooplankton is not rich and is represented by species typical for this region, most of which have a wide range of tolerance.

Conclusion

Lakes are key components of natural ecosystems, performing important ecological functions: regulating water balance, maintaining biological diversity and providing the population with fresh water. However, under conditions of increasing anthropogenic load, many water bodies, including Lake Taldykol, are facing increasing environmental problems. Pollution of water bodies with organic and chemical compounds coming from agricultural, industrial and domestic sources negatively affects the quality of water and the biodiversity of the lake, which leads to a decrease in its environmental sustainability.

Key findings:

1. According to the results of hydrochemical analysis of water in Lake Taldykol, a sharp decrease in mineralization and water hardness was recorded over the year, which indicates dilution of the lake with fresh water and a change in the type of water from chloride-sulphate to hydrocarbonate. At the

same time, a decrease in organic and chemical pollution is observed, with the exception of a summer surge in phosphates and nitrites, which may indicate a local influx of wastewater.

2. The phytoplankton of the lake is represented mainly by diatoms, green, and blue-green algae. A total of 62 species of algae were identified in the lake over the studied seasons. Seasonal variability in productivity was established: in spring (total abundance – 12.19 thousand cells/cm³, total biomass – 3.1 mg/dm³), in summer (total abundance – 24.6 thousand cells/cm³, total biomass – 7.6 mg/dm³), in autumn (total abundance – 27.9 thousand cells/cm³, total biomass – 12.93 mg/dm³).

3. 22 species have been identified in the lake's zooplankton. The maximum values of abundance and biomass were recorded in summer (total abundance – 4.89 thousand specimens/m³, total biomass – 50.29 mg/m³), followed by spring (total abundance – 4.61 thousand specimens/m³, total biomass – 44.1 mg/m³); and autumn (total abundance – 3.33 thousand specimens/m³, total biomass – 32.37 mg/m³), which confirms the seasonal features of zooplankton community development.

4. Calculations of saprobity indices for various groups of hydrobionts showed that Lake Taldykol retains the status of a moderately polluted water body throughout the year (β-mesosaprobic zone). However, in spring and autumn, saprobity is on the border closer to the L-mesosaprobic zone, significantly higher than in the summer period, which indicates a decrease in the reservoir's ability to cope with organic pollution. But in general, the reservoir retains a moderate ability to self-purify based on the ratio of free oxygen to BOD_5.

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ASSESSMENT OF THE CURRENT STATE OF CENOPOPULATIONS OF *VERONICA SPICATA* L. AND *VERONICA SPURIA* L. IN THE FLORA OF THE KASKELEN GORGE, ILE ALATAU

This article examines the current state of the cenopopulations of *Veronica spicata* and *Veronica spuria* within the flora of the Kaskelen Gorge, Ile Alatau. A taxonomic, ecological, and geographical analysis of the populations' flora is presented. The age structures of the cenopopulations of both species reveal stable structures, predominantly composed of virginile and generative plants. The proportion of undergrowth in the studied cenopopulations is relatively low, ranging from 2% to 9%. Most cenopopulations of *V. spicata* and *V. spuria* lack juvenile plants and have a small proportion of immature individuals. This phenomenon is attributed to insufficient seed renewal in recent years, a rapid transition of immature individuals to the virginal stage, and the absence of senile plants in the dominant part of the cenopopulations. The viability of individuals in these cenopopulations is primarily influenced by habitat type. The age structure analysis indicates that the cenopopulations of *V. spicata* and *V. spuria* are in satisfactory condition as part of the mountain-meadow and forb phytocenoses of the Kaskelen Gorge, Ile Alatau.

Key words: *Veronica spicata, Veronica spuria,* populations, cenopopulations, Kaskelen Gorge, Ile Alatau.

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Іле Алатауының Қаскелең шатқалының флорасындағы *Veronica spicata* L. және *Veronica spuria* L. түрлерінің ценопопуляцияларының қазіргі жағдайын бағалау

Мақала Іле Алатауының Қаскелең шатқалының флорасындағы *V. spicata* L. және *V. spuria* L. түрлерінің қазіргі жағдайын зерттеуге арналған. Бұл мақалада *Veronica spicata* және *V. spuria* түрлері популяцияларының флорасына таксономиялық, экологиялық және географиялық талдау жасалған. Қаскелең флорасындағы *V. spicata* және *V. spuria* ценопопуляцияларының жастық құрылымдарының талдауы. Іле Алатауының шатқалдары олардың құрылымы біршама тұрақты және тың және генеративті өсімдіктер тобының басым екенін көрсетті. Зерттелетін ценопопуляциялардағы төменгі өсінділердің үлесі салыстырмалы түрде төмен және 2-ден 9%-ға дейін. *V. spicata* және *V. spuria* ценопопуляцияларының көпшілігі жас өсімдіктердің болмауымен және жетілмеген даралардың аз ғана пайызымен сипатталады, бұл соңғы бірнеше жылда жеткілікті тұқым жаңартуының болмауымен және жетілмеген өсімдіктердің тез ауысуымен байланысты. даралардың тың күйге ауысуы және ценопопуляциялардың басым бөлігінде кәрілік өсімдіктердің болмауы. Ценопопуляциялардағы *V. spicata* және *V. spuria* дараларының өміршеңдігіне негізінен тіршілік ету ортасының түрі әсер етеді. *V. spicata* және *V. spuria* ценопопуляцияларының ген жастық құрылымы олардың Іле Алатауының Қаскелең шатқалының таулы-шалғындық және форб фитоценоздарының құрамындағы қанағаттанарлық жағдайын көрсетеді.

Түйін сөздер: *Veronica spicata, Veronica spuria,* популяциялар, ценопопуляциялар, Қаскелең шатқалы, Іле Алатауы.

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Оценка современного состояния популяций видов *Veronica spicata L.* и *Veronica spuria L.* во флоре Каскеленского ущелья Заилийского Алатау

Статья посвящена изучению современного состояния популяций видов *Veronica spicata* и *Veronica spuria* во флоре Каскеленского ущелья Заилийского Алатау. В статье представлен таксономический, экологический и географический анализ флоры популяций этих видов. Анализ возрастной структуры ценопопуляций *V. spicata и V. spuria* показал, что их структура относительно стабильна, с преобладанием виргинильных и генеративных растений. Доля подроста в исследуемых ценопопуляциях невысока и составляет от 2 до 9 %. Для большинства ценопопуляций характерно отсутствие ювенильных растений и низкий процент имматурных особей, что связано с недостаточным семенным возобновлением в последние годы, быстрым переходом имматурных особей в виргинильное состояние и отсутствием сенильных растений в доминирующей части популяций. На жизнеспособность особей *V. spicata и V. spuria* в ценопопуляциях в основном влияет тип местообитания. Возрастная структура ценопопуляций указывает на их удовлетворительное состояние в составе горно-луговых и разнотравных фитоценозов Каскеленского ущелья Заилийского Алатау.

Ключевые слова: *Veronica spicata, Veronica spuria,* популяции, ценопопуляции, Каскеленское ущелье, Заилийский Алатау.

Introduction

The Kaskelen Gorge is located in the western part of the Ile Alatau, a section of the Northern Tien Shan mountain system. This system forms a latitudinally oriented, northern folded region within the extensive Tien Shan mountain chains. The entrance to the Kaskelen Gorge is situated on the Upper Kaskelen Highway, 28 km from Almaty. A limestone quarry is located within the gorge. The forest spruce belt in this area lies between altitudes of 1900–2700 meters. The gorge itself is gently sloping and extends upwards for an additional 25 km beyond the end of the asphalt road.

The most notable side gorges are Kozhai, Emegen, Kasymbek (Sai), and South Kazachka. At an altitude of 2900 m, the Kaskelen Gorge branches into two large gorges: Right and Left Kaskelen. The relief of the high mountains in most parts of these gorges transitions to gentler slopes, forming alpine meadows and moraine lakes. The majority of peaks in the Kaskelen Gorge, ranging from 3800–3900 m in height, are not glaciated. They exhibit significant rock erosion, with abundant fragmented rocks and steep northern slopes. At the headwaters of the Kaskelen Gorge, there are approximately six peaks with glaciers that exceed 4000 m in height.

The Ile Alatau Range, part of the Northern Tien Shan system, is located in southeastern Kazakhstan within the boundaries of Almaty and Almaty region. It is one of the most picturesque and geographically diverse mountain formations in Central Asia. The Ile Alatau lies between the Ile and Chu rivers, forming a natural border between Kazakhstan and Kyrgyzstan. To the south, it is bounded by the Ile Valley, and to the north, by a large foothill plain. The Ile Alatau is divided into several ridges, including the main ridge, which is the highest and longest, and where Zhambyl Peak is located. The northern ridge is notable for its height and diverse landscapes, including deep gorges like Malaya Almatinka Gorge.

The predominant altitudes of the range are 4000–4600 m, with Talgar Peak (4973–4979 m) as the highest point. The Gorodetsky Glacier is situated on the northern slope. Mountain peaks are frequently covered by glaciers, which serve as key sources of water for the region. The primary rivers flowing from the Ile Alatau are the Ile, Chu, and their tributaries. The highest part of the Ile Alatau, surrounding Talgar Peak and the headwaters of the Talgar and Chilik Rivers, is known as the Talgar Massif.

The climate of the Ile Alatau is sharply continental, characterized by significant temperature fluctuations between winter and summer. Average winter temperatures can drop to -10°C or lower, while summer temperatures can reach +30°C. Precipitation is predominantly in the form of snow during winter, while thunderstorms are common in summer. The Ile Alatau Range consists of diverse rock types, including granites, marbles, and limestones. The range was formed during the Caledonian orogeny and was extensively reshaped during the Quaternary period. Key rock formations include granites, conglomerates, limestones, and shales.

Numerous lakes, primarily of glacial origin, are associated with the region's active mudflow processes. The most significant and well-known lakes are the Big Almaty Lake and Lake Issyk. These lakes, along with glaciers, are crucial water sources for the region.

The vegetation of the Ile Alatau is diverse, including spruce forests (*Picea schrenkiana* Fisch. & C.A. Mey) and deciduous forests comprising species like *Malus sieversii* (Ledeb.) M. Roem., *Populus tremula* L., and *Crataegus songarica* K. Koch. The middle and lower mountain zones are characterized by shrub-steppe vegetation, including species such as *Atraphaxis muschketowii* Krasn., Cotoneaster uniflorus Bunge, *C. melanocarpus* Fisch. ex Blytt., *C. oliganthus* Pojark., *Cotoneaster soongoricus* (Regel & Herder) Popov., *Rosa alberti* Regel, *R. beggeriana* Schrenk, *Lonicera hispida* Pall. ex Schult., and *Ribes meyeri* Maxim [1].

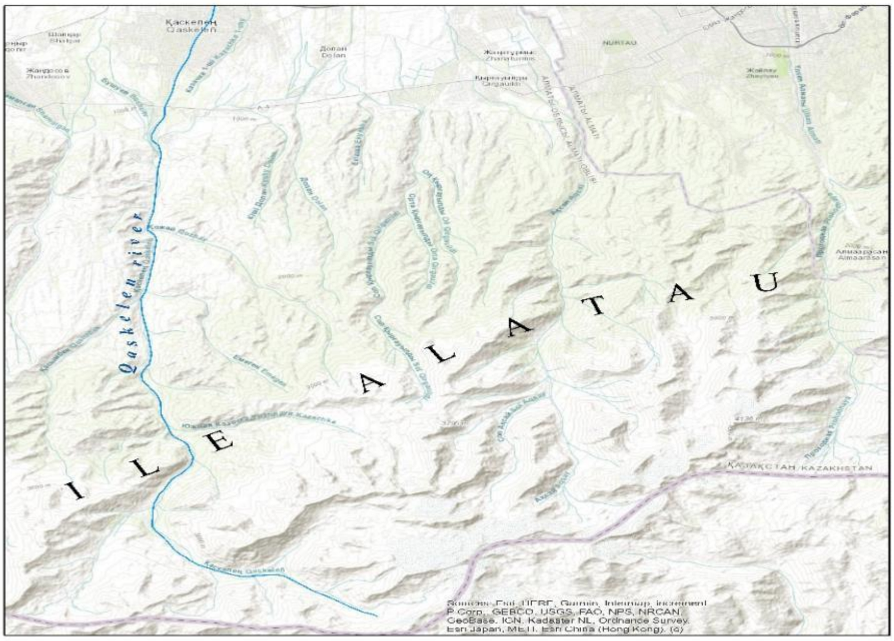

Figure 1 – Map-scheme of the Kaskelen Gorge of Ile Alatau

The study focuses on the current state of populations of *V. spicata* and *V. spuria*,, as well as the floristic composition of their cenopopulations in the Ile Alatau.

The studied species, *V. spicata* and *V. spuria*, belong to the genus *Veronica* L., subgenus *Veronicella* (Fourr.) Boriss., section *Pseudolysimachia* (W. Koch) Opiz. Within this classification, *V.spicata* is part of subsection *Spuriae* (Holub) A. Jelen., while *V. spuria* belongs to subsection *Pseudo-Lysimachium* Koch.

The genus *Veronica* L. is a member of the Plantaginaceae (formerly Scrophulariaceae). It is one of the largest and most widespread genera, encompassing up to 300 species that primarily inhabit temperate and cold regions of the Northern Hemisphere, often at high altitudes [2]. In the flora of Kazakhstan, the genus *Veronica* L. is highly polymorphic, displaying significant diversity in systematic, biomorphological, geographical, and ecological-cenotic parameters. Within the Ile Alatau Range, the genus represents a minor component of the regional flora.

The genus *Veronica* L. is among the oldest of the steppe flora in the Eurasian steppe region, originating from preboreal elements of the Altai-Mongolian steppe during the Tertiary Pliocene period. Within the steppe flora, *Veronica* L. species are considered easily recognizable florogenetic elements, categorized by M.G. Popov as ancient Mediterranean steppe elements. This group includes *V. spicata* and *V. spuria*, [3]. Globally, the genus consists of approximately 300 species, predominantly found in Mediterranean regions. In Kazakhstan, the genus is represented by 47 species, including three endemics: *Veronica arenosa* (Serg.) Boriss., *Veronica chantavica* Pavlov, and *Veronica luetkeana* Rupr. [4].

Several species of *Veronica* L. are valuable medicinal plants. Traditionally, plants of this genus have been widely used in folk medicine. Decoctions of the aerial parts of *Veronica spicata* L. are used to treat neuroses, respiratory infections, pulmonary tuberculosis, liver diseases, metrorrhagia, diarrhea, and bladder disorders. Externally, the decoction acts as a wound-healing and styptic agent, while it is also used as an analgesic for pain and headaches. Dried herb powder is applied to treat panaritium, typically healing within 3–4 days. Fresh leaves are used to alleviate severe sweating when placed between toes. Additionally, herbal infusions are employed to wash wounds and snake bites, while the herb itself is applied directly to the bite site. Preparations of *V. spicata* exhibit anti-inflammatory properties and are utilized to treat colds, cardiovascular diseases, and skin conditions.

Studies of the methanol extract of *V. spicata* herb using adsorption chromatography have isolated four flavonoid compounds. The herb contains flavonoids, iridoids, phenolcarboxylic acids, nitrogenous compounds, vitamin C, and trace elements. These findings highlight the plant's traditional and official medicinal applications in Kazakhstan and other countries, driving increasing interest in its potential uses [5].

Decoratively, *V. spicata* is highly valued in horticulture. It is widely cultivated in gardens worldwide, thriving in both warm and cold regions. The species is celebrated for its vibrant colors, dense foliage, and long flowering period. It is frequently used in mixed borders and single plantings, complementing other flowers. Through selective breeding, numerous varieties with varying sizes and flower colors have been developed.

V. spicata is a perennial meadow-steppe species of the Palaearctic region. It is a grayish-green plant with erect or ascending stems, 10–50 (75) cm tall, and a woody rhizome. The stems, either solitary or few, are stout, ascending at the base, and pubescent with short, detached hairs mixed with glandular hairs, especially in the inflorescence. Leaves are grayish, with lower ones petiolate, oblong-ovate, or broadly elliptical (3–8 cm long, 0.9–1.3[3] cm wide), and obtuse. Middle and upper leaves are oblong-lanceolate, nearly sessile, sparsely toothed, and entire-edged towards the apex. The inflorescence is a terminal, dense, elongated raceme, usually solitary, with narrowly lanceolate bracts equal to or slightly longer than the sessile calyx.

The corolla is blue or violet, occasionally pink or white, and measures 2–3 times the calyx length (0.5–0.7 cm wide), with a short hairy tube and four deflected lobes. Stamens are nearly as long as the corolla, and seeds are flatly convex, broadly ovate, and smooth. The species flowers from June to October, with fruiting occurring from July to October [6].

It grows in dry steppe and forest meadows, steppe hollows, shrubs, pine forests, sandy areas, stony and steppe slopes of plains and foothills, and rises to the forest belt of mountains [6].

Range of distribution in Kazakhstan: Spurs of the Common Syrt, Tobol-Ishim Plain, Irtysh Plain, Semipalatinsk Pine Forest, Kokshetau Upland, Caspian Lowland, Ulytau Mountains, Eastern Small Hills, Karkaraly Mountains, Altai Mountains, Tarbagatai Ridge, Dzhungar Alatau, Ile and Kungei Alatau, Ketmen and Terskey Alatau.

General distribution: The European part of the USSR, Caucasus, Central Asia, Western and Eastern Siberia (southern regions), Scandinavia, Western Europe, the Mediterranean, and Western China [6].

General information about cenopopulations of *V. spicata* highlights its significant polymorphism, indicating the need for further study. *V. spicata* is a perennial herbaceous plant with xeromorphic features and broad ecological plasticity. However, its distribution in the study area is limited. It is a typical mesoxerophyte with a Palaearctic habitat, adapted to varying light and moisture conditions. It grows in open areas, including dry steppe and forest meadows, steppe hollows, shrubs, and pine forests, as well as sandy, stony, and steppe slopes, extending to the forest belt at altitudes of 900–2600 m above sea level.

Modern studies indicate that *V. spicata* is not homogeneous. It exhibits significant polymorphism, forming populations that differ in minor morphological, physiological, and ecological traits. These variations underscore its classification as a highly variable species, as noted by many researchers [2–4].

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Modern studies indicate that *V. spicata* is not homogeneous. It exhibits significant polymorphism, forming populations that differ in minor morphological, physiological, and ecological traits. These variations underscore its classification as a highly variable species, as noted by many researchers [7–10].

Grows in meadow steppes, meadow-steppe and meadow slopes, birch forests, depressions of sparse pine forests, and on chernozem-like limestone and loamy, sometimes saline soils [11–15].

Distribution in Kazakhstan: Occurs in all regions of Kazakhstan except for the most arid deserts.

General distribution: Found in the European part of the former USSR, the Caucasus, Central Asia, Western Siberia, and Middle and Southern Europe [6].

The species *V. spicata* and *V. spuria*, belonging to the genus *Veronica* L., are perennial polycarpics. These species are similar in growth habits and vegetation types but differ significantly in their geographical distribution [16–21]. Despite the relatively comprehensive study of the vascular plant flora of the Ile Alatau, specific population studies of *V. spicata and V. spuria* have not yet been conducted. Consequently, the existing literature on these species is scattered, incomplete, and not always accurate.

Currently, the population structure and morphological and biological characteristics of *V. spicata* and *V. spuria* growing in natural conditions in the Ile Alatau region remain largely unstudied. In the last decade, scientific interest in *V. spicata* and *V. spuria* has increased significantly [21–26].

Materials and research methods

Representatives of the Plantaginaceae (formerly Scrophulariaceae) family, *V. spicata* and *V. spu- ria*, from natural cenopopulations were the objects of this study. The research was conducted in 2024 within natural phytocenoses in the western part of the Ile Alatau Range, specifically in the Kaskelen Gorge, Kaskelen District, Almaty Region (Table 1).

Table 1 – Cenopopulations of *V. spicata* and *V. spuria* were identified during field studies.

Species name, cenopopulation number	Geographical location	Coordinates location
Veronica spicata L. and *Veronica spuria* L. CP 1.	Almaty region, Kaskelen district, Kaskelen gorge, Ile Alatau, forest belt, north-eastern slope.	43°00´983´´N, 76°36´827´´E, 1856 m.a.s.l.
Veronica spicata L. and *Veronica spuria* L. CP 2.	Almaty region, Kaskelen district, Kaskelen gorge, Ile Alatau, forest belt, north-eastern slope, slope of western exposure.	43°00´983´´N, 76°36´485´´E, 1756 m.a.s.l.
Veronica spicata L. and *Veronica spuria* L. CP 3.	Almaty region, Kaskelen district, Kaskelen gorge, Ile Alatau, forest belt, north-eastern slope.	43°00´983´´N, 76°36´ 658´´E, 1796 m.a.s.l.

To study the current state of populations of *V. spicata* and *V. spuria* in their natural habitats, expeditionary fieldwork was planned using the route-reconnaissance method in the Kaskelen Gorge. The abundance of species in phytocenoses was determined using the Drude abundance scale. For each cenopopulation, the following parameters were assessed: number of generative and vegetative individuals, height of generative shoots, number of leaves on generative shoots, peduncle length, number of leaves per individual, inflorescence size, and number of flowers. These indices were determined with 20-fold repetition.

Methodology of sample plots. The methodology for estimating the density and abundance of the studied species corresponds to the programme and methodology for observing species cenopopulations. Population studies of *V. spicata* and *V. spuria*, including plant morphology, ecological and phytocoenotic characteristics of populations, age composition, seed productivity, and vitality of cenopopulations and individuals, were conducted following established methods.

To study the geographical distribution of *V. spicata* and *V. spuria*, the route-reconnaissance method was applied, supplemented by classical methods for studying plant morphology, phytocenoses, ecology, and biology.

Determination of species composition of plant communities. The species composition of plants in phytocenoses was determined using relevant botanical references and identifiers, such as Flora of Kazakhstan and Central Asia Plant Identifier. The structure of plant families follows the classification system of A. L. Takhtajyan, with species and genera listed alphabetically within families.

Route-reconnaissance method. This field method involves walking along predetermined routes to discover and collect plants, enabling the coverage of large areas and the study of species diversity.

Collection and processing of herbarium material. Specimens of *V. spicata* and *V. spuria* were collected, labeled with information about the location, date, and collector, and placed in herbarium folders. After fieldwork, the specimens were dried and examined under binocular loupes. Herbarium collection and processing followed the standard methodology of A. K. Skvortsov [27].

Species identification and systematics. Species identification was carried out in the laboratory using multi-volume reports and botanical reference books, such as Flora of the USSR, Flora of Kazakhstan, Central Asia Plant Identifier, and Illustrated Plant Identifier of Kazakhstan. Taxonomic classifications follow the Plants of the World Online (POWO) database and works by S. K. Cherepanov and S.A.Abdulina. The life forms were analyzed using the classifications of K. Raunkier and I. G. Serebryakov [28].

During the field studies in the Kaskelen Gorge, three cenopopulations of *V. spicata* and *V. spuria* were identified. Morphological characteristics of these species were studied on living plants and herbarium specimens.

Purpose. The purpose of this work is to study the population features of V. spicata and V. spuria in natural populations within the Kaskelen Gorge of the Ile Alatau [29].

Results and their discussion

To clarify the natural locations of *V. spicata* and *V. spuria* cenopopulations in the Ile Alatau, Kaskelen Gorge, to plan the routes for expedition trips, to establish flowering dates, and to identify occupied ecological niches, a study was conducted using herbarium material from the main herbarium collection of the Institute of Botany and Phytointroduction, as well as literary floristic data.

The results of the study on *V. spicata* and *V. spuria* indicate that these species, found in vari- ous habitats of the Kaskelen Gorge in the Ile Alatau, exhibit structural differences related to zonality, climatic conditions, and their abundance in plant communities. The study also revealed the ecological confinement of these plants to specific hydrological regimes. For both *V. spicata and V. spuria*, the optimal habitat is the broad middle belt of the forest-steppe zone. However, within the study area, the density of individuals is low. This is attributed to low seed productivity, dif- ficulty in seed germination, high seedling mortal- ity, and the elimination of individual specimens due to natural factors. These factors make both species rare and in need of conservation measures in their natural habitats.

a) b) c) d)

Figure 2 – Populations of *V. spicata* and *V.spuria* in the Kaskelen Gorge
of the western part of Ile Alatau (a,b – *Veronica spuria* L., c,d – *Veronica spicata* L.).

Table 2 – Characteristics of the locations of the *V. spicata* and *V. spuria* cenopopulations in the Kaskelen gorge

Name of the Cenopopulation and its locality	Ecological phytocenotic confinement	Area of CP, m^2	Number of pregenerative individuals per 10 m^2	Vitality indicators CP
Kaskelen population of *V. spicata and V. spuria* L.				
1. Cenopopulation of woody-shrub-forb-grass phytocenosis. Almaty region, Kaskelen district, Kaskelen gorge, Intermountain valley of Ile Alatau, northwestern slope. 43°00´983´´N, 76°36´ 827´´E, 1856 m above sea level. Cenopopulation (1) was produced in open habitats (northern slopes), forming a sparse cover.	Kaskelen Gorge, northern slopes. In small, few groups, in moist meadow habitats.	50	5	17 generative individuals. Young, slowly progressing, capable of self-sustaining by seed and vegetative means, stably maintaining its territory.
2. Cenopopulation of geranium-seseli-forb phytocenosis. Almaty region, Kaskelen district, Kaskelen gorge, Ile Alatau, north-eastern slope. 43°00´209´´N, 76°37′ 150′′E, 1987m above sea level. Cenopopulation (2) grows in open habitats (northern slopes), forming a sparse cover.	The slope of the northern exposure is geranium-seseli-forb. The species is located in small groups along the slope of the northern exposure.	150	11	98 generative individuals. Normal type, actively progressing, reproducing both by seed and vegetative means

Continuation of the table

Name of the Cenopopulation and its locality	Ecological phytocenotic confinement	Area of CP, m^2	Number of pregenerative individuals per 10 m^2	Vitality indicators CP
3. Cenopopulation of oregano-cereal-forb phytocenosis. Almaty region, Kaskelen district, Kaskelen gorge, Ile Alatau, northwestern slope. 43°01´505´´N, 76°36′ 758′E, 1802 m above sea level.	Oregano-cereal-forb community on the western-northern slope.	100	7	47 generative individuals. Weakly progressing, with a right-sided spectrum, aging, but with satisfactory renewal.

The age structure of cenopopulations of *V. spicata and V. spuria* was studied across four test plots. The density of cenopopulations varied from 17 to 105 specimens per square meter. Individuals of vegetative origin comprised 50 to 73% of the populations. Analysis of the age spectra showed that the age structure is relatively stable, with the age index ranging from 0.210 to 0.299. Generative plants accounted for 17 to 39% of the populations, while the virginile group represented the maximum proportion (37-58%) in all cenopopulations. The share of undergrowth (juvenile and immature stages) ranged from 15 to 23%, with individuals of vegetative origin prevailing, likely due to the deep degree of rejuvenation of vegetative rudiments. All studied cenopopulations can be classified as normal (homeostatic), indicating high vitality and stability of these species in the studied phytocenoses.

The Kaskelen population (Pop 1) of *V. spicata and V. spuria* is located in the western part of the Ile Alatau, within the forest belt of the Kaskelen Gorge, at an altitude of 1875 m above sea level. The projective cover of this population is 30-35%, and it occupies sporadic loci in meadow mesophytic and mesoxerophytic plant communities. These sites are characterized by full or diffused illumination, weak wind exposure throughout the year, and annual precipitation levels of 800-1000 mm, primarily occurring in spring and autumn. Typical habitats include mountain forest forb-meadow plant communities at altitudes of 1800-2800 m, on dark-colored soils of the forest-meadow-steppe zone.

In the study area of the Kaskelen population, three spatially isolated cenopopulations were identified within different types of phytocenoses. These cenopopulations share similar environmental conditions and floristic composition. The vegetation cover is diverse, comprising 76 species. The most represented families are Poaceae (14%), Asteraceae (7%), Rosaceae (5%), Ranunculaceae (4%), and Fabaceae (3%). Herbaceous species dominate the phytocenosis, accounting for 97% of the life forms, with woody and shrub species comprising 3%. Ecologically, mesophytic species dominate (63%), with mesoxerophytes constituting 23%. The synanthropization coefficient is 29%, indicating a moderate degree of anthropogenic pressure.

Cenopopulation (1) of woody-shrub-forb-grass phytocenosis includes species such as *Picea schrenkiana* Fisch. et Mey., *Crataegus songarica* K. Koch., *Salix alatavica* Kar. ex Stschegl., *Rosa alberti* Regel., *Cichorium intybus* L., *Ligularia narynensis* (C. Winkl.) O. Fedtsch. & B. Fedtsch., *Elytrigia repens* Nevski, and *Alopecurus pratensis* L. It is located in the Almaty Region, Kaskelen District, Kaskelen Gorge, within the intermountain valley of the Ile Alatau on a northwestern slope, at an altitude of 1856 m above sea level. The cenopopulation grows in open habitats (northern-facing slopes), forming a sparse cover.

The cenopopulation of *V. spicata and V. spuria* occurs as isolated individuals within the intermountain forest zone in the middle spruce belt. The site is characterized by complex relief, forming an open space within the intermountain valley. Tree species include *Picea schrenkiana* Fisch. et Mey. and *Salix alatavica* Kar. ex Stschegl. Among shrubs, the most common species are *Ribes meyeri* Maxim., *Spiraea lasiocarpa* Kar. & Kir., and Cotoneaster uniflorus Bunge, with a density of about 0.1–0.2. Less common is *Betula tianschanica* Rupr., forming the first tier.

The first tree tier is formed by *Picea schrenkiana* Fisch. et Mey. and *Salix alatavica* Kar. ex Stschegl. The second shrub tier includes *Juniperus sabina* L. and *Rosa alberti* Regel. Other shrubs include *Cotoneaster uniflorus* Bunge and Lonicera stenantha Pojark. The ground tier features a well-developed herbaceous cover, accounting for 90–95% of the vegetation. The herbaceous vegetation exhibits clear tiering due to the high density of individuals and species.

The dominant species in the herbaceous layer include *Alopecurus pratensis* L., *Cichorium intybus*

L., *Ligularia narynensis* (C. Winkl.) O. Fedtsch. & B. Fedtsch., Rumex acetosa L., Dactylis glomerata L., *Achillea asiatica* Serg., and *Achillea millefolium* L. A wide range of secondary species is present, such as *Elytrigia repens*, *Rumex tianschanicus* Losinsk., *Taraxacum officinale* F.H. Wigg., *Melandrium apetalum* (L.) Fenzl, and others.

The woody-shrub-forb-grass cenopopulation of *V. spicata and V. spuria* is characterized as young, weakly progressing, but capable of self-sustenance through seed and vegetative means. Its ability to maintain territory is unstable. The ecological conditions of the habitat, including illumination, moisture levels, and altitude, are optimal for these species.

No traces of pests, diseases, or sunburn were observed during the examination. The regeneration of *V. spicata and V. spuria* is satisfactory, with many healthy young vegetative individuals. Adequate moisture is essential for their growth, reflecting their life strategy.

Among the limiting factors, it is important to note regular grazing of cattle in the areas of settlement of *V. spicata and V. spuria* During the initial description, it was established that the state of the species in the population is not threatened. In addition, in similar ecological areas, the species may well settle and occupy new territories.

Cenopopulation (2) of geranium-seseli-forb (*Geranium collinum* Steph., *Geranium transversale* (Kar. & Kir.) Vved., *Seseli schrenkianum* (C.A. Mey. ex Schischk.) *Pimenov* & Sdobnina, *Origanum vulgare* L., Thalictrum collinum Wallr.) phytocenosis. Almaty Region, Kaskelen District, Kaskelen Gorge, Ile Alatau, northeastern slope. 43°00´209´´N, 76°37′150′′E, 1987 m above sea level. This population of *V. spicata and V. spuria* is located in the upper belt of the northeastern slope of the northern exposure of the western part of the Ile Alatau. The description was carried out in the early flowering phase. The cenopopulation of *V. spicata* and *V. spuria* is located on the northeast- ern slope, northern exposure. The soils are meadow light chestnut. The phytocenosis is polydominant in composition. The grass stand is quite dense, without noticeable bald spots. The total coverage of the phytocenosis is about 95-100%. *V. spicata and V. spuria* play practically no significant role in the formation of the phytocenosis. The studied species account for 1.1% of the community. The basis of the grass stand is made up of several species, including *Elytrigia repens* (L.) Nevski (soc).

The first tier is represented by shrubs of *Lonicera microphylla* Willd. ex Schult. (sol) and *Juniperus sabina* L. (sp). The second tier consists of the following species: *Geranium collinum* Steph. (sol), *Geranium transversale* (Kar. & Kir.) Vved. (sp), *Achillea asiatica* Serg. (sol), *Achillea millefolium* L. (sp), *Seseli schrenkianum* (C.A. Mey. ex Schischk.) Pimenov & Sdobnina (cop3), *Carum carvi* L. (sol), and *Origanum vulgare* L. (cop3). *Dactylis glomerata* L. (sol) and *Vicia sepium* L. (sol) are also present.

There is a great diversity of secondary accompanying species: *Poa pratensis* L. (cop1), *Dracocephalum origanoides* Stephan. (sol), *Artemisia absinthium* L. (sol), *Plantago major* L. (sol), *Plantago lanceolata* L. (sol), *Prunella vulgaris* L. (sp), *Artemisia annua* L. (sp), Geranium albiflorum L. (cop1), *Elytrigia repens* (L.) Nevski (soc), *Agropyron pectiniforme* Roemer & Schultes (cop), *Dactylis glomerata* L. (cop3), *Erigeron acris* L. (sp), *Galium aparine* L. (sol), *Senecio nemorensis* L. (sp), *Myosotis suaveolens* Waldst. & Kit. ex Willd. (sp), *Thalictrum petaloideum* L. (sp), *Daucus carota* L. (sp), *Berteroa incana* (L.) DC. (sp), *Astragalus chlorodontus* Bunge (sol), *Trifolium repens* L. (cop3), *Trifolium pratense* L. (cop2), *Veronica spuria* L. (sp), *Veronica spicata* L. (sp), *Verbascum thapsus* L. (sol), *Pedicularis alberti* Regel. (sol), *Vicia tenuifolia* Roth. (sol), *Vicia subvillosa* (Ledeb.) Boiss. (sol), *Origanum vulgare* L. (cop1), and *Dracocephalum integrifolium* Bunge (sol).

Cenopopulation (3) of oregano-cereal-forb (*Origanum vulgare* L., *Elytrigia repens* Nevski, *Dactylis glomerata* L.) phytocenosis. Almaty Region, Kaskelen District, Kaskelen Gorge, Ile Alatau, northwestern slope. 43°01´505´´N, 76°36′758′′E, 1802 m above sea level. The studied species stably occupy a place in this community. *V. spicata and V. spuria* account for 1.3% of the area occupied by the phytocenosis.

Adult specimens are medium-sized, up to 40 cm in height. Flowers are in terminal solitary, rarely also lateral, racemes narrowed to the top and pointed, 5-20 cm long and 0.5-1.3 cm wide. Flowers are on very short pedicels, rarely almost sessile, with bracts almost equal to the calyx. The axis of the inflorescence, bracts, and calyx are pubescent with glandular, less often with simple hairs. The species prefers to settle in small groups, in sufficiently moist places in the middle grass stand.

The existing habitat conditions are completely optimal for *V. spicata and V. spuria* According to the altitudinal structure, it is indistinctly three-tiered. The first tier, 75-170 cm high, is very sparse. The shrub tier is located along the outskirts of the community and consists of *Rosa alberti* Regel. (sp), *Rosa beggeriana* Schrenk. (sp), *Lonicera microphylla* Willd. (sp), and *Rubus idaeus* L. (cop1).

The herbage is fairly well formed, with a total cover of 90-95%. The second tier, 40–90 cm high, is fairly dense. Dominant species include *Origanum vulgare* L. (sol) and *Elytrigia repens* Nevski. Associated species include *Elymus tianschanigenus* Czerep. (sp), *Elymus caninus* (L.) L. (sp), and others.

Studies of *V. spicata and V. spuria* cenopopulations growing in the Kaskelen Gorge, located in the western part of the Ile Alatau, and the analysis of herbarium material have shown that these species exhibit a good ecological amplitude and are relatively well distributed in this area. However, the cenotic habitat of these species is somewhat narrower, as the dominant part of *V. spicata* and *V. spuria* cenopopulations is found mainly in herbaceous-grassy groupings. These habitats provide more favourable conditions, including both open and shaded areas with adequate moisture.

As a result of expedition studies, three large localities of *V. spicata* and *V. spuria* cenopopulations were recorded in different ecological and phytocoenotic conditions. These species were predominantly found in moist habitats among meadow-grass and shrub-grass vegetation. Typical habitats for *V. spicata* and *V. spuria* in the Kaskelen Gorge of the Ile Alatau are open light forests and sufficiently humidified herbaceous meadows of the middle forest belt.

Below is the geobotanical characterisation of plant communities containing *V. spicata* and *V. spuria* species found in the Kaskelen Gorge, Kaskelen District, Almaty Region. The Kaskelen Gorge is located along the Upper Kaskelen Highway, 28 km from Almaty city (Table 3).

Table 3 – Geobotanical characterisation of plant communities with *V. spicata* and *V. spuria* species in the Kaskelen river gorge:

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Tree layer (Projective cover: 10–20%).					
Picea schrenkiana Fisch. & C.A. Mey.	*Pinaceae*	sol (1-3%)	In groups, unevenly.	30-40	Vegetative, flowering, fruiting.
Crataegus songarica K. Koch	*Rosaceae*	sol (1-3%)	Individually, unevenly.	6-8	Vegetative, flowering, fruiting.
Salix alatavica Kar. ex Stschegl.	*Salicaceae*	sol (5-10%)	In groups, unevenly.	6-8	Vegetative, flowering, fruiting.
Salix hastata L.	*Salicaceae*	sol (3-5%)	In groups, unevenly.	8-10	Vegetative, flowering, fruiting.
Shrubs (Projective cover: 10–20%)					
Cotoneaster uniflorus Bunge	*Rosaceae*	sol (1-3%)	Individually, unevenly.	1,5-2	Vegetative, flowering, fruiting.
Cotoneaster melanocarpus Fisch. ex Blytt	*Rosaceae*	sol (1-3%)	Individually, unevenly.	1,5-2	Vegetative, flowering, fruiting.
Rosa alberti Regel	*Rosaceae*	sol (1-3%)	In groups, unevenly	1,5	Vegetative, fruiting.
Rosa beggeriana Schrenk	*Rosaceae*	sol (1-3%)	In groups, unevenly	1,5	Vegetative, fruiting.
Spiraea lasiocarpa Kar. & Kir.	*Rosaceae*	sol (1-3%)	In groups, unevenly	1,5	Vegetative, fruiting.
Lonicera hispida Pall. ex Schult.	*Caprifoliaceae*	sol (1-2%)	Individually, unevenly.	1,5-2	Vegetative, fruiting.

Continuation of the table

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Lonicera stenantha Pojark.	*Caprifoliaceae*	sol (1-2%)	Individually, unevenly.	1,5-2	Vegetative, fruiting.
Lonicera microphylla Willd. ex Schult.	*Caprifoliaceae*	sol (1-2%)	Individually, unevenly.	1,5-2	Vegetative, flowering
Rubus idaeus L.	*Rosaceae*	sol (1-3%)	In groups, unevenly	1,5-2	Vegetative, flowering
Ribes meyeri Maxim.	*Grossulariaceae*	sol (1-3%)	In groups, unevenly	1,5-2	Vegetative, flowering
Atragene sibirica L.	*Ranunculaceae*	sol (1-3%)	In groups, unevenly	1,5-2	Vegetative, flowering
Herbaceous-shrub layer (Projective cover: 15–20%)					
Euonymus semenovii Regel & Herder	*Celastraceae*	sp- sol (5-15%)	diffusely.	0,5-1,5	Vegetative
Polygonum aviculare L.	*Polygonaceae*	sol (1-5%)	Individually	50	Vegetative
Sisymbrium loeselii L.	*Brassicaceae*	sol (1-5%)	unevenly	35	Vegetative, flowering
Pyrola rotundifolia L.	*Ericaceae*	sol (2-5%)	Individually, unevenly.	10	Vegetative, flowering
Goodyera repens (L.) R. Br.	*Orchidaceae*	sol (1-5%)	Individually	7	Vegetative
Rheum wittrockii Lundstr.	*Polygonaceae*	sol (1-5%)	Individually	50	Vegetative
Poa nemoralis L.	*Poaceae*	sp (10-15%)	unevenly.	30-40	Vegetative, flowering
Fragaria vesca L.	*Rosaceae*	sol (1-5%)	unevenly.	35	Vegetative, flowering, fruiting.
Mentha asiatica Boriss.	*Fabaceae*	sol (1-5%)	In groups	70	Vegetative, flowering, fruiting.
Alchemilla vulgaris L.	*Rosaceae*	sol (1-5%)	unevenly.	35	Vegetative, flowering, fruiting.
Poa pratensis L.	*Poaceae*	sol (1-5%)	In groups	70	Vegetative, flowering, fruiting.
Dracocephalum origanoides Stephan.	*Lamiaceae*	sol (1-5%)	In groups	35	Vegetative, flowering, fruiting.
Artemisia absinthium L.	*Asteraceae*	sol (1-5%)	unevenly.	70	Vegetative, flowering,
Plantago major L.	*Plantaginaceae*	sol (1-5%)	In groups	35	Vegetative, flowering,
Plantago lanceolata L.	*Plantaginaceae*	sol (1-5%)	In groups	55	Vegetative, flowering,
Prunella vulgaris L.	*Lamiaceae*	sol (1-5%)	unevenly.	70	Vegetative, flowering,
Artemisia annua L.	*Asteraceae*	sol (1-5%)	In groups	35	Vegetative, flowering,
Geranium albiflorum L.	*Geraniaceae*	sol (1-5%)	In groups, unevenly	70	Vegetative, flowering,

Continuation of the table

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Geranium transversale (Kar. & Kir.) Vved.	*Geraniaceae*	sol (1-5%)	In groups, unevenly	35	Vegetative, flowering,
Geranium collinum Stephan ex Willd.	*Geraniaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,
Elytrigia repens (L.) Nevski	*Poaceae*	sol (1-5%)	In groups, unevenly	70	Vegetative, flowering,
Agropyron pectiniforme Roemer & Schultes	*Poaceae*	sol (1-5%)	In groups, unevenly	80	Vegetative, flowering,
Dactylis glomerata L.	*Poaceae*	sol (1-5%)	In groups, unevenly	90	Vegetative, flowering,
Erigeron acris L.	*Asteraceae*	sol (1-5%)	In groups, unevenly	55	Vegetative, flowering,
Galium aparine L.	*Rubiaceae*	sol (1-5%)	Individually, unevenly.	70	Vegetative, flowering,
Senecio nemorensis L.	*Asteraceae*	sol (1-5%)	In groups, unevenly	65	Vegetative, flowering,
Myosotis suaveolens Waldst. & Kit. ex Willd.	*Boraginaceae*	sol (1-5%)	In groups	85	Vegetative, flowering,
Thalictrum petaloideum L.	*Ranunculaceae*	sol (1-5%)	Individually, unevenly.	65	Vegetative, flowering,
Daucus carota L.	*Apiaceae*	sol (1-5%)	In groups, unevenly	95	Vegetative, flowering,
Berteroa incana (L.) DC.	*Brassicaceae*	sol (1-5%)	In groups, unevenly	85	Vegetative, flowering,
Astragalus chlorodontus Bunge	*Fabaceae*	sol (1-5%)	In groups, unevenly	85	Vegetative, flowering,
Trifolium repens L.	*Fabaceae*	sol (1-5%)	In groups, unevenly	15	Vegetative, flowering,
Trifolium pratense L.	*Fabaceae*	sol (1-5%)	In groups, unevenly	10	Vegetative, flowering,
Veronica spuria L.	*Scrophulariaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,
Veronica spicata L.	*Scrophulariaceae*	sol (1-5%)	In groups, unevenly	35	Vegetative, flowering,
Verbascum thapsus L.	*Scrophulariaceae*	sol (1-5%)	In groups, unevenly	25	Vegetative, flowering,
Pedicularis alberti Regel.	*Scrophulariaceae*	sol (1-5%)	In groups, unevenly	45	Vegetative, flowering,
Vicia tenuifolia Roth.	*Fabaceae*	sol (1-5%)	In groups, unevenly	85	Vegetative, flowering,
Vicia subvillosa (Ledeb.) Boiss.	*Fabaceae*	sol (1-5%)	In groups, unevenly	85	Vegetative, flowering,
Origanum vulgare L.	*Lamiaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,
Dracocephalum integrifolium Bunge.	*Lamiaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,
Phlomoides pratensis (Kar. & Kir.) Adylov, Kamelin & Makhm.	*Lamiaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,

Continuation of the table

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Saxifraga sibirica L.	*Saxifragaceae*	sol (1-5%)	In groups, unevenly	7	Vegetative, flowering,
Bromus squarrosus L.	*Poaceae*	sol (1-5%)	In groups, unevenly	45	Vegetative, flowering,
*Anisantha tectorum (*L.) Nevski.	*Poaceae*	sol (1-5%)	In groups, unevenly	100	Vegetative, flowering,
Veronica chamaedrys L.	*Scrophulaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,
Cortusa brotheri Pax ex Lipsky	*Primulaceae*	sol (1-5%)	In groups, unevenly	10	Vegetative, flowering,
Solenanthus circinnatus Ledeb.	*Boraginaceae*	sol (1-2%)	In groups, unevenly	40	Vegetative, flowering, fruiting
Echium vulgare L.	*Boraginaceae*	sol (1-2%)	In groups, unevenly	45	Vegetative, flowering, fruiting
Viola acutifolia (Kar. & Kir.) W. Becker	*Violaceae*	sol (1-7%)	In groups, unevenly	10	Vegetative, flowering, fruiting
Viola altaica Ker Gawl.	*Violaceae*	sol (1-7%)	In groups, unevenly	10	Vegetative, flowering, fruiting
Achillea millefolium L.	*Asteraceae*	sol (1-7%)	In groups, unevenly	70	Vegetative, flowering, fruiting
Achillea asiatica Serg.	*Asteraceae*	sol (1-4%)	In groups, unevenly	75	Vegetative, flowering, fruiting
Marrubium vulgare L.	*Lamiaceae*	sol (1-2%)	In groups, unevenly	40	Vegetative, flowering, fruiting
Rúmex confértus Willd.	*Polygonaceae*	sol (1-5%)	In groups, unevenly	90	Vegetative, flowering,
Onopordum acanthium L.	*Asteraceae*	sol (1-3%)	In groups, unevenly	25	Vegetative, flowering,
Phlomoides oreophila (Kar. & Kir.) Adylov, Kamelin & Makhm.	*Lamiaceae*	sol (1-6%)	In groups, unevenly	40	Vegetative, flowering,
Polygonum songaricum Schrenk	*Polygonaceae*	sol (1-5%)	In groups, unevenly	35	Vegetative, flowering,
Bistorta vivipara (L.) Delarbre	*Polygonaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering,
Lithospermum officinale L.	*Boraginaceae*	sol (1-3%)	In groups, unevenly	50	Vegetative, flowering,
Astragalus fedtschenkoanus Lipsky	*Fabaceae*	sol (1-3%)	In groups, unevenly	20	Vegetative, flowering, fruiting
Thalictrum minus L.	*Ranunculaceae*	sol (1-5%)	In groups, unevenly	35	Vegetative, flowering, fruiting

Continuation of the table

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Ephedra equisetina Bunge	*Ephedraceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering, fruiting
Hesperis sibirica L.	*Brassicaceae*	sol (1-2%)	In groups, unevenly	20	Vegetative, flowering, fruiting
Achoriphragma.lancifolium (M.Pop.) Sojak.	*Brassicaceae*	sol (1-6%)	In groups, unevenly	45	Vegetative, flowering, fruiting
Asperugo procumbens L.	*Boraginaceae*	sol (1-5%)	In groups, unevenly	30	Vegetative, flowering, fruiting
Ferula akitschkensis B. Fedtsch. ex Koso-Pol.	*Apiaceae*	sol (1-3%)	In groups, unevenly	50	Vegetative, flowering, fruiting
*Rhytispermum tenuiflorum (*L. f.) Link	*Boraginaceae*	sol (1-5%)	In groups, unevenly	30	Vegetative, flowering, fruiting
Cardaria draba (L.) Desv.	*Brassicaceae*	sol (1-7%)	In groups, unevenly	20	Vegetative, flowering
Arctium lappa L.	*Asteraceae*	sol (1-2%)	In groups, unevenly	20	Vegetative, flowering
*Capsella bursa-pastoris (*L.) Medik.	*Brassicaceae*	sol (1-7%)	In groups, unevenly	15	Vegetative, flowering
Xanthium strumarium L.	*Asteraceae*	sol (1-2%)	In groups, unevenly	30	Vegetative, flowering
Taraxacum officinale F.H. Wigg.	*Asteraceae*	sol (1-12%)	In groups, unevenly	25	Vegetative, flowering
Rumex tianschanicus Losinsk.	*Polygonaceae*	sol (1-5%)	In groups, unevenly	85	Vegetative, flowering
Melandrium apetalum (L.) Fenzl	*Caryophyllaceae*	sol (1-5%)	In groups, unevenly	15	Vegetative, flowering
Descurainia sophia (L.) Webb ex Prantl	*Brassicaceae*	sol (1-7%)	In groups, unevenly	35	Vegetative, flowering
Schulzia crinita (Pall.) Spreng.	*Apiaceae*	sol (1-7%)	In groups, unevenly	10	Vegetative, flowering
Gentiana turkestanorum Gand.	*Gentianaceae*	sol (1-7%)	In groups, unevenly	45	Vegetative, flowering
Eritrichium villosum (Ledeb.) Bunge	*Boraginaceae*	sol (1-5%)	In groups, unevenly	40	Vegetative, flowering
Codonopsis clematidea (Schrenk ex Fisch. & C.A. Mey.) C.B. Clarke	*Campanulaceae*	sol (1-7%)	In groups, unevenly	30	Vegetative, flowering, fruiting
*Cirsium arvense (*L.) Scop.	*Asteraceae*	sol (1-7%)	In groups, unevenly	70	Vegetative, flowering, fruiting
Hyoscyamus niger L.	*Solanaceae*	sol (1-5%)	In groups, unevenly	30	Vegetative, flowering, fruiting

Continuation of the table

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Helictotrichon pubescens (Huds.) Pilg.	*Poaceae*	sol (7-10%)	In groups, unevenly	90	Vegetative, flowering, fruiting
Helictotrichon tianschanicum (Roshev.) Henrard	*Poaceae*	sol (5-10%)	In groups, unevenly	95	Vegetative, flowering, fruiting
Ligularia macrophylla (Ledeb.) DC.	*Asteraceae*	sol (1-7%)	In groups, unevenly	95	Vegetative, flowering, fruiting
*Anthriscus nemorosa (*M.Bieb.) Spreng.	*Apiaceae*	sol (1-5%)	In groups, unevenly	65	Vegetative, flowering, fruiting
Aconitum leucostomum Vorosch.	*Ranunculaceae*	sol (1-7%)	In groups, unevenly	95	Vegetative, flowering
Setaria viridis (L.) P. Beauv.	*Poaceae*	sol (1-5%)	In groups, unevenly	85	Vegetative, flowering
*Ligularia narynensis (*C. Winkl.) O. Fedtsch. & B. Fedtsch.	*Asteraceae*	sol (1-10%)	In groups, unevenly	110	Vegetative, flowering
Gentiana tianschanica Rupr.	*Gentianaceae*	sol (1-7%)	In groups, unevenly	45	Vegetative, flowering
Phleum pratense L.	*Poaceae*	sol (1-5%)	In groups, unevenly	75	Vegetative, flowering, fruiting
Solidago dahurica Kitag.	*Asteraceae*	sol (1-5%)	In groups, unevenly	90	Vegetative, flowering, fruiting
Linum perenne L.	*Linaceae*	sol (1-3%)	In groups, unevenly	100	Vegetative, flowering, fruiting
Cirsium polyacanthum Kar. & Kir.	*Asteraceae*	sol (1-5%)	In groups, unevenly	75	Vegetative, flowering, fruiting
*Phalaroides arundinacea (*L.) Rauschert	*Poaceae*	sol (1-7%)	In groups, unevenly	65	Vegetative, flowering, fruiting
Anthoxanthum odoratum L.	*Poaceae*	sol (1-5%)	In groups, unevenly	50	Vegetative, flowering
Cichorium intybus L.	*Asteraceae*	sol (1-7%)	In groups, unevenly	110	Vegetative, flowering
*Hierochloe odorata (*L.) P. Beauv.	*Poaceae*	sol (1-5%)	In groups, unevenly	60	Vegetative, flowering, fruiting
Stipa zalesskii Wilensky	*Poaceae*	sol (1-3%)	In groups, unevenly	40	Vegetative, flowering, fruiting
Brachypodium pinnatum (L.) Beauv.	*Poaceae*	sol (1-3%)	In groups, unevenly	55	Vegetative, flowering
Elymus tianschanigenus Czerep.	*Poaceae*	sol (1-5%)	In groups, unevenly	65	Vegetative, flowering

Continuation of the table

Floristic diversity					
Species name.	Family.	Abundance according to Druce	Distribution according to B.A.Bykov	Height, m/cm	Phenophase
Elymus caninus (L.) L.	*Poaceae*	sol (1-3%)	In groups, unevenly	70	Vegetative, flowering
Rumex acetosa L.	*Polygonaceae*	sol (1-7%)	In groups, unevenly	115	Vegetative, flowering, fruiting
Stellaria soongorica Roshev.	*Caryophyllaceae*	sol (1-5%)	In groups, unevenly	15	Vegetative, flowering, fruiting
Potentilla chrysantha Trevir.	*Rosaceae*	sol (1-7%)	Individually, unevenly.	25	Vegetative, flowering
Astragalus alpinus L.	*Faabaceae*	sol (1-7%)	Individually, unevenly.	15	Vegetative, flowering
Astragalus lepsensis Bunge	*Faabaceae*	sol (1-5%)	In groups, unevenly	25	Vegetative, flowering
Hedysarum semenowii Regel & Herder	*Faabaceae*	sol (1-7%)	In groups, unevenly	45	Vegetative, flowering
Euphorbia alatavica Boiss.	*Euphorbiaceae*	sol (1-5%)	In groups, unevenly	30	Vegetative, flowering
*Anthriscus sylvestris (*L.) Hoffm.	*Apiaceae*	sol (1-5%)	Individually, unevenly.	105	Vegetative, flowering
Aulacospermum rupestre Popov.	*Apiaceae*	sol (1-5%)	Individually, unevenly.	75	Vegetative, flowering
Bupleurum aureum Fisch. ex Hoffm.	*Apiaceae*	sol (1-7%)	In groups, unevenly	115	Vegetative, flowering
Carum carvi L.	*Apiaceae*	sol (1-9%)	In groups, unevenly	125	Vegetative, flowering
Carum atrosanguineum Kar. & Kir.	*Apiaceae*	sol (1-7%)	In groups, unevenly	135	Vegetative, flowering
Aegopodium alpestre Ledeb.	*Apiaceae*	sol (1-3%)	In groups, unevenly	45	Vegetative, flowering
Pedicularis macrochila Vved.	*Scrophulariaceae*	sol (1-5%)	Individually, unevenly.	55	Vegetative, flowering

The flora of the studied population of *V. spicata* and *V. spuria* in the Kaskelen Gorge of the Ile Alatau includes 132 species, representing 105 genera and 31 families. Characteristic species include *Elytrigia repens* (L.) Nevski, *Dactylis glomerata* L., *Trifolium repens* L., *Trifolium pratense* L., *Geranium transversale* (Kar. & Kir.) Vved., *Artemisia vulgaris* L., *Arctium lappa* L., *Berteroa incana* (L.) DC., *Poa pratensis* L., *Poa annua* L., *Capsella bursa-pastoris* (L.) Medik., and *Xanthium strumarium* L.

The presence of weedy species such as *Urtica cannabina* L., *Arctium lappa* L., and *Xanthium strumarium* L. indicates significant anthropogenic pressure on the natural phytocenoses.

Ecological analysis revealed the mesoxerophytic and mesophytic nature of the mountain flora in the meadow habitats of the populations of *V. spicata* and *V. spuria* The main limiting factors for species distribution are high competition in phytocenoses, anthropogenic load, and strict ecological requirements.

According to I.G. Serebryakov's classification of plant life forms, *V. spicata* and *V. spuria* are perennial herbaceous polycarpics. Based on K. Raunkier's classification, these species are classified as mesophytes and mesoxerophytes. Their typical habitats in the surveyed area are meadow-grass communities of the forest belt, predominantly located on the northern exposures of mountain slopes (Table 4).

Table 4 – Main ecological groups of plants occurring in *V. spicata and V. spuria* populations.

№	Ecological groups	Number of species	% of total number of species
1	Mesophytes	106	80,3
3	Mesoxerophytes	24	18,8
5	Mesohygrophytes	2	1,5
Total:		132	100

The majority of *V. spicata* and *V. spuria* cenopopulations in the Kaskelen Gorge of the Ile Alatau are predominantly composed of immature and virginile age groups. This is primarily due to the predominance of vegetative reproduction, with no senile plants observed in these populations. In these cenopopulations, the dominance of the immature age group is particularly notable, accounting for 45% to 65% of individuals.

An analysis of field data revealed that all cenopopulations of *V. spicata* and *V. spuria* ex- hibit minimal differences in floristic composition and growing conditions. Furthermore, an exami- nation of the leading families within the flora of *V. spicata* and *V. spuria* populations identified the nine largest families based on the number of species (Table 5).

Table 3 shows that the largest family in the flora of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge of the Ile Alatau is Poaceae, comprising 18 species, which accounts for 13.6% of the total flora. The second-largest family is Asteraceae, with 17 species (12.8%). The third and fourth places are occupied by Rosaceae and Apiaceae, each containing 10 species. Together with Fabaceae, Lamiaceae, Brassicaceae, Boraginaceae, and Polygonaceae, these nine families include more than 58 species (44.0%), representing 70.4% of the total flora of *V. spicata* and *V. spuria* populations. The remaining 22 families account for only 39 species (29.5%).

Table 5 – Taxonomic composition of the largest families of *V. spicata* and *V. spuria* populations.

№	Families	Number of genera	Number of species	% of total number of species
1	Poaceae	15	18	13,6
2	Asteraceae	14	17	12,8
3	Rosaceae	8	10	7,5
4	Apiaceae	8	10	7,5
5	Fabaceae	4	9	6,8
6	Lamiaceae	7	8	6,0
7	Brassicaceae	7	7	5,3
8	Boraginaceae	7	7	5,3
9	Polygonaceae	5	7	5,3
Total:		*75*	*93*	70,4
The remaining 22 families:		30	39	29,5

Thus, the largest families of the flora in *V. spicata* and *V. spuria* populations in the Kaskelen Gorge include 75 genera and 93 species, contributing significantly to the flora composition at 70.4% of the total species. This composition of leading families, distinguished by their high species richness, is characteristic of the flora in the eastern part of the Ancient Mediterranean. However, it also exhibits unique features influenced by both Old Mediterranean and boreal elements.

Analysis of the life forms of the flora of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge, based on the classifications of I.G. Serebryakov and K. Raunkier [30], indicates that floristic diversity is largely shaped by ecological conditions, particularly climate and territorial heterogeneity. The dominant life form is perennial grasses or hemicryptophytes, which account for 70.6% of the flora. Shrubs and semi-shrubs (chamaephytes and microphanerophytes) constitute a smaller share at 11.3% (Table 6).

The flora of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge of the Ile Alatau includes a small group of therophytes (5 species) and geophytes (3 species). In general, the flora of these populations is dominated by species typical of mountain meadows, shrub-grass, and meadow-grass habitats. As noted earlier, the leading life forms in the studied area are herbaceous perenni- als and annuals, which are characterized by a wide ecological range. Shrubs are well-represented with 13 species, while woody life forms are represented by only 2 species due to narrowly limited environmental conditions.

Table 6 – Spectrum of major plant life forms found in *V. spicata and V. spuria* populations.

№	Life form	Number of species	% of total number of species
1	Hemicryptophytes	107	81,0
2	Therophytes	5	3,7
3	Chamaephytes	2	1,5
4	Microphanerophytes	13	9,8
5	Phanerophytes	2	1,5
6	Geophytes	3	2,2
Total:		132	100

The life form composition of the flora in the populations of *V. spicata* and *V. spuria* in the Kaskelen Gorge is indicative of the climatic conditions of the region, highlighting its mesoxerophytic nature.

A geographical analysis based on available data on the current distribution of flora representatives shows that species within the populations of *V. spicata* and *V. spuria* in the Kaskelen Gorge are distributed across 30 habitat types, grouped into 8 categories with similar distribution characteristics. As is well known, each regional flora consists of species with varying ranges in both area and geographical location. Therefore, the geographical analysis follows a classification system widely used in Central Asia by authors such as E.P. Lavrenko, M.S. Baitenov, V.P. Goloskokov, A.I. Tolmachev, and R.V. Kamelin.

In the Kaskelen Gorge, the geographical distribution of the studied species is predominantly confined to mountain habitats (Table 7).

Table 7 – Geographical relationships of plant species occurring in populations of *V. spicata* and *V. spuria* with the flora of other regions.

Group of distribution types	Distribution types	Number of species (% of total number)	Species
1	2	3	4
Palaearctic	East Palaearctic	18 (13,6)	*Salix hastata* L. *Cotoneaster uniflorus* Bunge *Cotoneaster melanocarpus* Fisch. ex Blytt *Rubus idaeus* L. *Plantago major* L. *Prunella vulgaris* L. *Geranium albiflorum* L. *Dactylis glomerata* L. *Senecio nemorensis* L. *Myosotis suaveolens* Waldst. & Kit. ex Willd. *Thalictrum petaloideum* L. *Bromus squarrosus* L. *Thalictrum minus* L. *Hyoscyamus niger* L. *Anthriscus nemorosa* (M.Bieb.) Spreng. *Brachypodium pinnatum* (L.) Beauv. *Aegopodium alpestre* Ledeb. *Anthriscus sylvestris* (L.) Hoffm.
	West Palaearctic	11 (8,3)	*Geranium collinum* Stephan ex Willd. *Elytrigia repens* (L.) Nevski *Berteroa incana* (L.) DC. *Veronica spicata* L. *Vicia tenuifolia* Roth. *Marrubium vulgare* L. *Echium vulgare* L. *Helictotrichon pubescens* (Huds.) Pilg. *Phleum pratense* L. *Solidago dahurica* Kitag. *Elymus caninus* (L.) L.
Irano-Turanian	Mountainous Central Asian	3 (2,2)	*Rosa beggeriana* Schrenk *Pedicularis macrochila* Vved. *Elymus tianschanigenus* Czerep.
	Mountainous Central Asian-Irano-Himalayan	3 (2,3)	*Lonicera stenantha* Pojark. *Vicia subvillosa* (Ledeb.) Boiss. *Cortusa brotheri* Pax ex Lipsky
	Mountainous Central Asian-Mountainous Central Asian.	1 (0,75)	*Stipa orientalis* Trin.
Pamir-Alai-Tian Shan	Altai-Tian Shan-Pamir-Alai	4 (3,0)	*Spiraea lasiocarpa* Kar. & Kir. *Euonymus semenovii* Regel & Herder *Saxifraga sibirica* L. *Schulzia crinita* (Pall.) Spreng.
	Tian Shan-Pamir-Alai	2 (1,5)	*Codonopsis clematidea* (Schrenk ex Fisch. & C.A. Mey.) C.B. Clarke *Euphorbia alatavica* Boiss.
	Kashgar-Tian Shan-Pamir-Alai	1 (0,75)	*Rheum wittrockii* Lundstr.
	Tarbagatai-Tian Shan-Pamir-Alai	2 (1,5)	*Galium aparine* L. *Gentiana tianschanica* Rupr.

Continuation of the table

Group of distribution types	Distribution types	Number of species (% of total number)	Species
1	2	3	4
Tian Shan	Proper Tian Shan	3 (2,3)	*Picea schrenkiana* Fisch. et Mey. *Rumex tianschanicus* Losinsk. *Stellaria soongorica* Roshev.
	Mountainous Siberian-Altai-Tian Shan	1 (0,75)	*Mentha asiatica* Boriss.
	Northern Tian Shan	4 (3,0)	*Crataegus songarica* K. Koch *Pedicularis alberti* Regel *Helictotrichon tianschanicum* (Roshev.) *Henrard* *Astragalus* lepsensis Bunge
	Dzhungar-Ile	1 (0,75)	*Aulacospermum rupestre* Popov.
	Pannonian-Kazakhstan	1 (0,75)	*Linum perenne* L.
	Dzhungar-Eastern Tian Shan	3 (2,3)	*Phlomoides pratensis* (Kar. & Kir.) Adylov, Kamelin & Makhm. *Ligularia narynensis* O. Fedtsch. & B. Fedtsch. *Hedysarum semenowii* Regel & Herder
	Tarbagatai-Tian Shan	2 (1,5)	*Viola acutifolia* (Kar. & Kir.) W. Becker *Ferula akitschkensis* B. Fedtsch. ex Koso-Pol.
	Dzhungar-Northern Tian Shan	2 (1,5)	*Astragalus chlorodontus* Bunge *Achoriphragma.lancifolium* (M.Pop.) Sojak.
	Altai-Northern Tian Shan	1 (0,75)	*Potentilla chrysantha* Trevir.
	Altai-Tian Shan	5 (3,7)	*Viola altaica* Ker Gawl. *Achillea asiatica* Serg. *Ligularia macrophylla* (Ledeb.) DC. *Cirsium polyacanthum* Kar. & Kir. *Bupleurum aureum* Fisch. ex Hoffm.
Altai-Mountainous Central Asian	Altai-Pamir-Alai-Mountainous Central Asian	7 (5,3)	*Salix alatavica* Kar. ex Stschegl. *Rosa alberti* Regel *Lonicera hispida* Pall. ex Schult. *Ribes meyeri* Maxim. *Dracocephalum origanoides* Stephan. *Gentiana turkestanorum* Gand. *Aconitum leucostomum* Vorosch.
	Altai-Mountainous Central Asian-Mountainous Central Asian	2 (1,5)	*Dracocephalum integrifolium* Bunge. *Carum atrosanguineum* Kar. & Kir.
	Mountainous Central Asian	5 (3,7)	*Geranium transversale* (Kar. & Kir.) Vved. *Polygonum songaricum* Schrenk *Astragalus fedtschenkoanus* Lipsky *Ephedra equisetina* Bunge Arctium lappa L.
	Altai-Mountainous Central Asian	1 (0,75)	*Phlomoides oreophila* (Kar. & Kir.) Adylov, Kamelin & Makhm.
	Mountainous Siberian-Mountainous Central Asian-Mongolian	1 (0,75)	*Atragene sibirica* L.
	Altai-Iranian	1 (0,75)	*Solenanthus circinnatus* L.

Continuation of the table

Group of distribution types	Distribution types	Number of species (% of total number)	Species
1	2	3	4
Holarctic	Proper Holarctic	26 (19,6)	*Polygonum aviculare* L. *Pyrola rotundifolia* L. *Goodyera repens* (L.) R. Br. *Poa nemoralis* L. *Fragaria vesca* L. *Alchemilla vulgaris* L. *Poa pratensis* L. *Artemisia absinthium* L. *A. vulgaris* L. *A. annua* L. *Erigeron acris* L. *Verbascum thapsus* L. *Anisantha tectorum* (L.) Nevski. *Bistorta vivipara* (L.) Delarbre *Xanthium strumarium* L. *Taraxacum officinale* F.H. Wigg. *Melandrium apetalum* (L.) Fenzl. *Descurainia sophia* (L.) Webb ex Prantl *Eritrichium villosum* (Ledeb.) Bunge *Cirsium arvense* (L.) Scop. *Phalaroides arundinacea* (L.) Rauschert *Anthoxanthum odoratum* L. *Hierochloe odorata* (L.) P. Beauv. *Rumex acetosa* L. *Carum carvi* L. *Astragalus alpinus* L.
	Pluriregional	4 (3,0)	*Daucus carota* L. *Trifolium repens* L. *Setaria viridis* (L.) P. Beauv. *Capsella bursa-pastoris* (L.) Medik.
Ancient Mediterranean	European-Ancient Mediterranean	1 (0,75)	*Sisymbrium loeselii* L.
		9 (6,8)	*Plantago lanceolata* L. *Trifolium pratense* L. *Origanum vulgare* L. *Veronica chamaedrys* L. *Achillea millefolium* L. *Onopordum acanthium* L. *Lithospermum officinale* L. *Asperugo procumbens* L. *Cichorium intybus* L.
	European-Ancient Mediterranean	1 (0,75)	*Rhytispermum tenuiflorum* (L. f.) Link
	Eastern Mediterranean		*Cardaria draba* (L.) Desv.
	Eurasian	3 (2,3)	*Agropyron pectiniforme* Roemer & Schultes *Veronica spuria* L. *Rúmex confértus* Willd. *Hesperis sibirica* L.

A geographical analysis of the species constituting the flora of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge of the Ile Alatau revealed a spectrum ranging from widespread cosmopolitan or pluri-regional species to narrowly endemic species. In the study area, 30 habitat types were identified and grouped into 8 broader habitat categories: Ancient Mediterranean, Holarctic, Altai-Mountain-Middle

Asian, Tianshan, Pamir-Alai-Tianshan, Iranian-Mountain-Middle Asian, and Palearctic (Table 5).

The Old Mediterranean habitat group comprises 14 species confined to mountain habitats, representing the Southern Old Mediterranean, Eastern Mediterranean, and European-Alder Mediterranean subtypes. These account for 17.8% of the species.

The Holarctic group includes two range types: Holarctic proper and pluri-regional. The Palaearctic group encompasses East Palaearctic and West Palaearctic ranges. Species with wide distributions dominate these groups, accounting for approximately 44.6% of the flora of the studied populations (59 species).

Species widespread across Mountain Central Asia contribute significantly to the flora of *V. spicata* and *V. spuria* populations, with 73 species (55.3%) identified. Of these, 23 species (17.4%) are restricted to the Tianshan mountain province, with 13 species (9.8%) belonging to Tianshan proper. The Altai-Mountain-Middle Asian, Pamir-Alai-Tianshan, and Iranian-Mountain-Middle Asian habitat groups are well-represented, comprising 31 species (23.4%).

The predominance of *V. spicata* and *V. spuria* populations in the mountainous flora of the Kaskelen Gorge underscores the Mountain Middle Asian character of the studied flora. The significant presence of species with Holarctic and Palaearctic distributions highlights historical connections with Northern Hemisphere floras.

With the intensive economic development of natural resources in the Ile Alatau, particularly in recent decades, the importance of plant-based products has grown. The flora of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge is rich in wild useful plants, including species with fodder, food, medicinal, ornamental, tannin, honey, vitamin, dye, and oil-producing properties, offering potential as natural plant raw materials (Table 8).

Table 8 – Occurrence in populations of *Veronica spicata* L. and *Veronica spuria* L., useful plant groups

№	Group of Raw Material Plants	Number of species	% of total species
1	Fodder	100	75,7
2	Medicinal	27	20,4
3	Poisonous	4	3,0
4	Honey-bearing	80	60,0
5	Food	20	15.5
6	Essential oil	20	15,5
7	Ornamental	45	34,0
8	Dyes	6	4,5
9	Technical	14	10,6
10	Vitaminiferous	15	11,3
11	Weeds	25	19,0

Useful groups of plants occurring in the flora of populations of *V. spicata* and *V. spuria* species of the Kaskelen Gorge in Ile Alatau were compiled according to the classification of H.M. Ilyin and N.V. Pavlov. These groups are quantitatively represented as follows: weeds – 25 species (19%), food – 20 species (15.5%), medicinal – 27 species (20.4%), honey-bearing – 80 species (60%), essential oilseeds – 20 species (15.5%), fodder – 100 species (75.7%), ornamental – 45 species (34%), dyeing – 6 species (4.5%), vitamin-bearing – 15 species (11.3%), technical (rubber plants, resinous plants, gum trees, paper plants, wicker plants, etc.) – 14 species (10.6%).

As can be seen from Table 6, the largest group is represented by fodder species. To create a solid fodder base for livestock breeding, forage crops are of primary importance. The vegetation of the Kaskelen Gorge in Ile Alatau is rich in forage plant species, which serve as high-quality fodder for domestic animals. The richest pastures and hayfields are concentrated here. The best fodder species are recognized as members of the families Fabaceae, Poaceae, Asteraceae, and others. Cereal grasses are particularly valuable forage grasses for several reasons: high nutrient content, good digestibility, high yield, environmental tolerance, fibre content, and species diversity. These factors make cereal grasses an essential part of livestock feed.

Among them are *Dactylis glomerata* L., *Bromus squarrosus* L., *Brachypodium pinnatum* (L.) Beauv., *Elytrigia repens* (L.) Nevski, *Helictotrichon pubescens* (Huds.) Pilg., *Phleum pratense* L., *Elymus caninus* (L.) L., *Setaria viridis* (L.) P. Beauv., *Elymus tianschanigenus* Czerep., *Stipa omentalis* Trin., *Helictotrichon tianschanicum* (Roshev.) Henrard, *Poa nemoralis* L., *Poa pratensis* L., *Anisantha tectorum* (L.) Nevski., *Phalaroides arundinacea* (L.) Rauschert, *Anthoxanthum odoratum* L., *Hierochloe odorata* (L.) P. Beauv.

Legumes are also valuable forage plants, with species such as *Hedysarum semenowii* Regel & Herder, Medicago falcata, *Trifolium pratense* L., *Vicia subvillosa* (Ledeb.) Boiss., *Vicia crassa*, and *Vicia tenuifolia*. Among herbs, many species are readily consumed by cattle and sheep, such as Ajania fastigiata, Geranium saxatile, and many spe- cies of Asteraceae (e.g., Taraxacum, Tragopogon). These include *Ajania fastigiata, Geranium saxatile*, and many Asteraceae species (such as Taraxacum and Tragopogon). Among food-palatable plants, the family Rosaceae is notably represented with five species, categorized as vitamin-sugar-bearing. These are primarily fruit and berry plants, including strawberry (*Fragaria vesca L.*), raspberry (*Rubus idaeus L.*), hawthorn (*Crataegus songarica K. Koch.*), and rosehip (*Rosa beggeriana Schrenk*, *Rosa alberti Regel.*). The family Grossulariaceae includes the fruit-berry species currant (*Ribes meyeri Maxim.*).

Food species are also abundant in families such as Polygonaceae, Apiaceae, Asteraceae, and Fabaceae. Notable examples of food plants include *Rumex tianschanicus*, *Ephedra equisetina Bunge*, *Rumex acetosa L.*, *Cichorium intybus L.*, *Rheum wittrockii Lundstr.*, and *Carum atrosanguineum Kar. & Kir.*

Medicinal plants are particularly significant among the flora, with species like *Ephedra equisetina*, *Inula macrophylla*, *Arctium lappa L.*, *Origanum vulgare L.*, *Aconitum leucostomum Vorosch.*, *Achillea asiatica Serg.*, *Capsella bursa-pastoris (L.) Medik.*, *Daucus carota L.*, *Aegopodium alp- estre Ledeb.*, *Anthriscus sylvestris (L.) Hoffm.*, and *Plantago major L.*offering wide-ranging therapeutic properties.

The flora of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge of Ile Alatau highlights significant potential for medicinal, alkaloid-bearing, essential oil, tannidaceous, and honey-bearing plants. Plants of the *Veronica* genus, particularly *V. spicata* and *V. spuria* are characterized by their diverse chemical composition. These species contain flavonoids, anthocyanins, nitrogenous compounds, phenolic compounds (including coumarins, iridoids, alkaloids, amino acids, pectin substances, saponins, cardenolides, choline, and phenolcarboxylic acids such as caffeic, ferulic, isoferulic, lilac, p-coumaric, protocatechuic, and veratric acids), tannins, coumarin, carbohydrates, and many other bioactive substances.

Additionally, *V. spicata* and *V. spuria* contain 12 to 20 trace elements. Trace elements detected in *V. spicata* include K, Ca, Mg, Si, P, Al, Fe, Mn, Na, Sr, Ti, Zn, Pb, Cu, and Mo.

Herbal infusions of *V. spicata* and *V. spuria* are traditionally used for treating respiratory infections, bronchitis, tuberculosis, bronchial asthma, liver diseases, kidney and bladder ailments, peptic ulcers, and as a cardiotonic and detoxifying agent in snake bites. They also exhibit antibacterial activity. Externally, these infusions are applied for washing and baths to treat various skin conditions, such as acne, pustules, fungal skin infections, itchy rashes, cuts, abrasions, and burns.Beekeeping in the Kaskelen Gorge study area, with its favorable natural conditions, has the potential to become a vital part of agriculture. Mountainous beekeeping significantly impacts both the ecosystem and the economy. Bees, as primary pollinators, enhance crop yields and support biodiversity conservation. In mountain areas, where unique plant species thrive, beekeeping can yield high-quality honey with distinctive flavors and medicinal properties.

Technical plants hold significant importance across various sectors. Tannin plants produce tannins, which are essential in the leather industry and dye production. Dyeing plants serve as sources of natural dyes used in textiles and food production. Essential oil plants are widely used in perfumery, cosmetics, and medicine due to their versatile chemical properties. Rubber-bearing plants supply natural rubber, critical for manufacturing rubber products and related materials. Saponin-bearing plants contain saponins, utilized in medicine and as foaming agents in various industries. Gutta-percha-bearing plants yield gutta-percha, used in manufacturing rubber-like products.

Essential oils, which are extracted from various plant parts such as flowers, leaves, needles, seeds, roots, and rhizomes, display a wide range of pharmacological activities depending on their chemical compositions. Examples include plants from the Umbelliferae family, such as *Daucus carota* and A*egopodium alpestre*, Asteraceae family, including *Conyza canadensis*, *Achillea millefolium*, *Arctium* *tomentosum*, *Artemisia vulgaris*, and *Artemisia absinthium*, and Lamiaceae, including *Origanum vulgare.*

Plants in the Kaskelen Gorge exhibit remarkable ornamental potential, making them suitable for landscaping. Their use enhances the aesthetic value of landscapes and creates a favorable ecological environment. Among these ornamental species, *V. spicata* and *V. spuria* stand out. Commonly known as spiked speedwell (*V. spicata*) and false speedwell (*V. spuria*), these species boast attractive flowers and forms, making them excellent choices for landscaping projects. Their inclusion in gardens and landscapes can add diversity and beauty while attracting beneficial pollinators like bees and butterflies.

Conclusion

The comprehensive assessment of *V. spicata* and *V. spuria* populations in the Kaskelen Gorge of the Ile Alatau revealed that the first cenopopu- lation (CP) is in good condition, while the second and third CPs are in satisfactory condition. Most of the studied CPs are classified as normal, non-degenerated populations, with no senile individuals present. These populations are found sporadically, often as single specimens or in small patches within herbaceous meadows of the forest zone, primarily in moist meadow-herbaceous habitats with good light conditions.

Analysis of the age spectra of the studied cenopopulations revealed a dominance of young and generative plants. *V. spicata* and *V. spuria* which belong to the ecological group of mesophytes and mesoxerophytes, are primarily distributed in the middle forest zone. Their populations demonstrate strong adaptive capabilities, indicating significant ecological flexibility.

Both species are notable for their ornamental qualities and resilience, making them attractive for landscaping applications. They exhibit high winter hardiness, allowing them to adapt to adverse conditions successfully. Their excellent seed and vegetative reproduction capabilities make them suitable for cultivation and use in various landscape designs. Additionally, their natural resistance to diseases reduces the need for chemical treatments, thereby preserving ecosystem balance.

The characteristic habitus and decorative value of *V. spicata* and V. *spuria* make them excellent candidates for creating flower compositions, borders, and other landscape elements. Their appeal extends to both public and private landscaping projects, where they serve as valuable resources for attracting bees and other pollinators. These attributes make *V. spicata* and *V. spuria* highly recommended for use in sustainable and aesthetically pleasing landscaping practices.

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РАЗНООБРАЗИЕ ГИДРОБИОНТОВ ГОРНЫХ РЕК АЛАТАУ С ЕСТЕСТВЕННЫМ ГИДРОЛОГИЧЕСКИМ РЕЖИМОМ НА ПРИМЕРЕ РЕКИ КЕНСУ (Балкашский бассейн, Центральная Азия)

Биологическое разнообразие горных экосистем формируется в суровых климатических условиях и географической изоляции. По этой причине горные экосистемы являются одним из самых уязвимых компонентов биосферы. От благополучия горных реки зависит состояние крупных водосборных бассейнов. Для оценки благополучия горных рек необходимо установить их естественное разнообразие или разнообразие в условиях минимальной антропогенной нагрузки. С этой целью в 2023-2024 гг. нами была исследована р. Кенсу, расположенная в юго-восточной части Кунгей Алатау. Сбор и обработка гидрохимических, гидробиологических и ихтиологических проб проведены стандартными методами. Вода в реке характеризуется низкой минерализацией и мутностью, однако выявлено повышение значений pH и содержания нитратов. Фауна донных беспозвоночных состоит из кольчатых червей, водных личинок насекомых и моллюсков и меняется в разные годы. Основу макрозообентоса составили личинки Trichoptera, Ephemeroptera, Plecoptera, Diptera. Ихтиофауна представлена тремя реофильными видами рыб: чешуйчатый осман, голый осман, тибетский голец. Условия обитания благоприятны для питания и воспроизводства данных видов рыб. Несмотря на растущую рекреационную нагрузку, состояние экосистемы р.Кенсу остается в состоянии близком к естественному.

Ключевые слова: горные реки, биоразнообразие, гидрохимия, бентос, ихтиофауна.

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The diversity of hydrobionts of the Alatau mountain rivers with a natural hydrological regime on the example of the kens river (Balkash basin, Central Asia)

The biological diversity of mountain ecosystems is formed in harsh climatic conditions and geographical isolation. For this reason, mountain ecosystems are one of the most vulnerable components of the biosphere. The condition of large catchment areas depends on the well-being of mountain rivers. To assess the well-being of mountain rivers, it is necessary to establish their natural diversity or diversity under conditions of minimal anthropogenic load. To this end, in 2023-2024, we explored the Kensu River, located in the southeastern part of Kungei Alatau. The collection and processing of hydrochemical, hydrobiological and ichthyological samples were carried out using standard methods. The water in the river is characterized by low mineralization and turbidity, however, an increase in pH and nitrate content has been revealed. The fauna of benthic invertebrates consists of annelids, aquatic insect larvae and mollusks and varies over the years. The basis of the macrozoobenthos was made up of larvae of Trichoptera, Ephemeroptera, Plecoptera, Diptera. The ichthyofauna is represented by three rheophilic fish species: scaly osman, naked Osman, and Tibetan char. The habitat conditions are favorable for the nutrition and reproduction of these fish species. Despite the growing recreational load, the state of the ecosystem of the Kens River remains in a state close to natural.

Key words: mountain rivers, biodiversity, hydrochemistry, benthos, ichthyofaunal.

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Кенсу өзенінің мысалында табиғи гидрологиялық режимі бар Алатау таулы өзендерінің гидробионттарының алуантүрлілігі (Балқаш бассейні, Орталық Азия)

Тау экожүйелерінің биологиялық алуантүрлілігі күрделі климаттық жағдайларда және географиялық оқшаулануда қалыптасады. Сол себепті тау экожүйелері биосфераның ең осал компоненттерінің бірі болып табылады. Ірі су жинаушы бассейндердің жағдайы тау өзендерінің жағдайына тікелей байланысты. Тау өзендерінің жағдайын бағалау үшін олардың табиғи алуантүрлілігін немесе минималды антропогендік жүктеме жағдайындағы алуантүрлілігін анықтау қажет. Осы мақсатта 2023-2024 жылдары Күнгей Алатауының оңтүстік-шығыс бөлігінде орналасқан Кенсу өзені зерттелді. Гидрохимиялық сынамаларды, гидробиологиялық және ихтиологиялық сынамаларды жинау және өңдеу стандартты әдістермен жүргізілді. Кенсу өзеніндегі судың минералдануы мен лайлану деңгейі төмен, бірақ pH пен нитрат құрамының жоғары екені анықталды. Су асты омыртқасыздарының фаунасы жұмыр құрттардан, жәндіктердің личинкаларынан және моллюскалардан тұрады және тұрақты емес, әр жылдары өзгереді. Макрозобентостың негізін Trichoptera, Ephemeroptera, Plecoptera, Diptera личинкалары құрады. Ихтиофауна балықтың үш реофильді түрімен ұсынылған: қабыршақты көкбас, қабыршақсыз көкбас, Тибет талма балығы. Тіршілік ету ортасы осы балық түрлерінің қоректенуіне және көбеюіне қолайлы болып табылады. Рекреациялық жүктеменің артуына қарамастан Кенсу өзенінің экожүйесінің жағдайы табиғиға жақын күйде қалады.

Түйін сөздер: тау өзендері, биоразнообразия, гидрохимия, бентос, ихтиофауна.

Введение

Неблагоприятное антропогенное воздействие на биосферу в конце прошлого века приняло глобальный масштаб [1-3]. Изменение климата влечет за собой перестройки в водных и наземных экосистемах, которые угрожают не только существованию многих видов животных и растений, но также здоровью и благосостоянию людей [4]. Одной из главных проблем современности становится дефицит пресной воды [5,6]. В пресноводных экосистемах происходит стремительное сокращение естественного биологического разнообразия [7,8]. Несмотря на удаленность и труднодоступность большинства горных водоемов, они также оказались в угрожаемом состоянии [9-13]. Горные ледники сокращают свою площадь в результате повышения температуры Земли и уменьшения количества осадков [14-16].

Формирование разнообразия горных растений животных происходило в суровых климатических условиях при естественной географической изоляции [17,18]. По этой причине для горной флоры и фауны характерны высокая степень эндемизма и большая чувствительность к изменениям климата, загрязнению, чрезмерному выпасу скота, росту рекреационной нагрузки и другим видам прямого и косвенного воздействия человека [19-22]. Сооружение гидроэлектростанций, водохранилищ ирригационного назначения и других видов регулирования горных рек еще более усугубляет проблему выживания гидробионтов и сохранения оказываемых ими экосистемных услуг [23-25]. Проблема сохранения горных водоемов и их биоразнообразия уже более десяти лет остро ощущается во многих странах мира [26-30].

Для Балкашского бассейна, расположенного в центре Азии, проблема сохранения горных рек имеет жизненную важность по нескольким причинам: горные реки и ледники здесь являются единственным источником пресной воды (пополнение подземных вод происходит также за счет поверхностных), в этом бассейне образовалась наибольшая для Республики Казахстан численность населения, на сопредельной территории Китайской Народной Республики численность населения и водопотребление также стремительно растут. От полноты и достоверности полученных данных о состоянии водных экосистем зависит обоснованность научных рекомендаций по устойчивому сохранению и рациональному использованию горных водоемов, являющихся необходимой основой для принятия адекватных управленческих решений. В последнее десятилетие внимание казахстанских исследователей было сосредоточено на оценке состояния водоемов города Алматы и его ближайших окрестностей [31-34] и Кольсайских озер [34-

38], как имеющих наибольшее социально-экономическое и эстетическое значение и испытывающих наибольшую антропогенную нагрузку. Биологическому разнообразию других горных водоемов Северного Тянь-Шаня уделяли гораздо меньше внимания. Быстрая урбанизация и вовлечение все больших площадей в зону активной хозяйственной деятельности в Балкашском бассейне диктуют необходимость установления естественного биологического разнообразия и изучения закономерностей функционирования экосистем горных рек для определения их нормального состояния, устойчивости и критических нагрузок.

Для решения первой из перечисленных задач нами было проведено изучение р.Кенсу, расположенной в юго-восточной части Кун- гей Алатау. Долина этой реки находится вне охраняемых природных территорий и начала пользоваться популярностью у туристов лишь в последнее десятилетие [39-41]. Верховья реки привлекают внимание туристов своими живописными пейзажами: на большой высо- те недалеко друг от друга расположены много мореных озер. Ниже широкая долина используется местными жителями для выпаса скота. В отличие от большинства других рек на р.Кенсу отсутствуют гидротехнические сооружения, поэтому сохраняется естественный гидрологический режим.

Материалы и методики

Истоки р.Кенсу находятся на высоте выше 3000 мБС на границе с Республикой Кыргызстан, на высоте около 1600 м р.Кенсу впадает в р.Шарын. Общая протяженность реки около 45 км. На берегу реки в среднем течении расположено одноименное село с населением не более 200 человек. Основным видом деятельности является пастбищное скотоводство, поскольку в долине реки имеются большие площади, покрытые сочной растительностью. Визуально следов перевыпаса, деградации растительности и почвы мы не обнаружили. Сбор материала проводили в июле 2023 и июне 2024 г. на среднем участ- ке реки, расположенном примерно в 1 км ниже посёлка. Среднее течение является наиболее репрезентативным для изучения разнообразия горных рек.

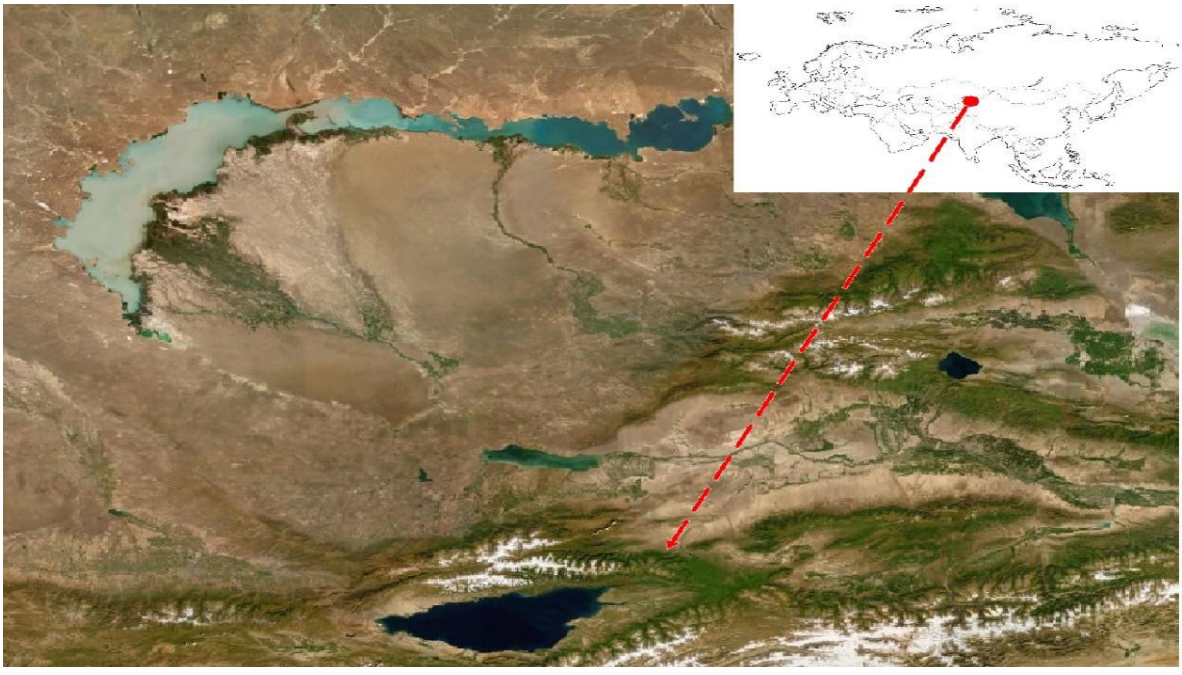

Рисунок 1 – Карта-схема района исследований

Температуру воды, общую минерализацию и pH воды определяли с помощью прибора Combo pH & EC, «Hanna Instruments». Мутность рек является одним из важнейших физических показателей, влияющих на разнообразие и состояние водных животных [42], поэтому её измеряли с помощью прибора турбонефриметра HI 93703. Большое негативное влияние на водных беспозвоночных оказывают ионы аммония, нитриты и нитраты. Растворенные в воде соединения азоты могут не только увеличить её кислую реакцию, но также вызывать отдаленные негативные изменения в экосистемах водоемов и служат ранними предупреждениями быстрых и радикальных изменений в будущем [43-45]. Содержание растворенных ионов аммония и нитратов измеряли с помощью приборов "HI 96700. Ammonia LR" и Nitrate protable photometer HI96728 фирмы "Hanna Instruments".

Для сбора проб макрозообентоса на мелководьях использовались сачки и скребки. Скребком захватывали верхний слой грунта (2–4 см), процеживали через сито из мельничного газа №5 и затем производили разбор осадка вручную с помощью пинцета. Также производили сбор водных беспозвоночных с камней, мха и погруженных в реку веток. Такой способ сбора позволяет учесть все группы макрозообентоса, включая мелких олигохет и личинок комаров. Пробы фиксировались в 4% растворе формальдегида. В лабораторных условиях проводилось определение видового состава и расчет количественных показателей. Для выявления видового состава сообществ макрозообентоса использовались определители [46,47]. В качестве интегральной характеристики разнообразия и выровненности сообществ водных беспозвоночных рассчитывали индекс Шеннона с основанием логарифма 2 [48].

Отлов рыб проведен с помощью рыболовного сачка. После отлова рыб фиксировали в 4% растворе формальдегида, дальнейшую обработку проводили в лаборатории по традиционной схеме [49]. Для обозначения признаков приняты следующие символы: полная длина – TL в мм, стандартная длина (длина тела) – SL (мм), полная масса – Q (г). На основании показателей массы и стандартной длины тела рассчитывали коэффициент упитанности по Фультону – Fulton [50, 51].

Полученные данные обработаны с помощью методов унивариантного статистического анализа [52]. Статистические показатели обозначены: min – минимальное значение, max –максимальное значение, M – среднее значение, ±s – стандартное отклонение. Для оценки достоверности различий между выборками тибетского гольца использован U-критерий Манна-Уитни (Критерий Уилкоксона).

Результаты и обсуждение

Русло реки Кенсу на исследованном участке течет в типичном для горных рек канализированном русле с небольшими изгибами, местами разделяется на 2-3 русла, окружающие небольшие островки, поросшие ивой. Дно каменистое с редкими и небольшими по площади (30-50 м^2) песчаными отмелями. В июне 2024 г. вода в реке была прозрачной, бесцветной, температу- ра 15.8 ^{o}C. Мутность небольшая – 2.35 FTU. Об- щая минерализация очень низкая – около 100 мг/дм^3. Вода имела слабощелочную реакцию (8.01-8.03), что не характерно для горных рек. Ионы аммония не выявлены, но обнаружена большая концентрация нитрат-ионов – до 21.71 мг/дм^3, значительно превышающая ПДК (9.1 мг/дм^3). Основными источниками нитратов в реках являются разлагающиеся органические остатки, минеральные удобрения и трансвоз- душный перенос. Поскольку в водосборном бассейне р.Кенсу скопления органических остатков не образуются из-за стремительного течения, выращивание сельскохозяйственных культур (преимущественно картофеля) ведется только на небольших участках вблизи домов в поселке Кенсу, то наиболее вероятным ис- точником повышенного содержания нитратов может быть трансвоздушный перенос из близкорасположенного мегаполиса [43-45, 53]. В городской среде нитраты в большом количестве образуются в результате сложного взаимодействия продуктов сгорания автомобильного горючего с атмосферным воздухом и солнечным светом [53]. Для установления источника нитратов нужны специальные исследования горных рек, расположенных на различном удалении от г.Алматы.

Фауна донных беспозвоночных состоит из небольшого числа таксонов. В таблице 1 представлены результаты нашего исследования в сравнении с данными О.Е.Лопатина [54] для участка р.Иле, расположенного выше Капшагайского водохранилища.

Таблица 1 – Разнообразие зообентоса р. Кенсу

Объекты	Кенсу, 2023 г.		Кенсу, 2024 г.		Р.Иле [54]
	экз.\м^2	%	экз.\м^2	%	
Vermes-Черви					0
Тип Annelida – Кольчатые черви					
Lumbricina	0	0	0.1	0.52	0
Тип Artrophoda- Членистоногие					
Crustacea-Ракообразные	0	0	0	0	+
Класс Insecta-Насекомые					+
Trichoptera-Ручейники					
Trichoptera sp.	0.5	9.25	0	0	нд
Microsema sediterum	0	0	2.4	12.69	нд
Brachycentrus subnubilus	0.6	11.11	4.0	21.16	нд
Ephemeroptera -Поденки					
Hydropsyche sp.	0	0	0,9	4.76	нд
Ephemerella ignita	1.3	24.07	0	0	нд
Ephemerella electrogena	2.7	50.00	1.3	6.87	нд
Oligoneuriella pallida	0	0	0.1	0.52	нд
Baetis sp.	0	0	0.4	2.11	нд
Plecoptera- Веснянки					
Perlodidae sp.	0.2	3.7	0	0	нд
Perlodidae isoperla	0	0	0.3	1.58	нд
Diptera – Двукрылые					+
Chironomus sp.	0	0	5.9	31.21	нд
Simullium sp.	0	0	3.5	18.51	нд
Odanata-Стрекозы	0	0	0	0	+
Coleoptera **-Жесткокрылые**	0	0	0	0	+
Heteroptera -Клопы	0	0	0	0	+
Mollusca – Моллюски					+
Gastropoda – Брюхоногие моллюски	0.1	1.85	0	0	нд
+ – Таксон обнаружен, нд – нет данных					

В 2023 году идентифицировано 6 видов беспозвоночных животных, принадлежащих к 2 типам. Наибольше количественные показатели зообентоса принадлежал насекомым (98% численности от всего зообентоса). В составе сообщества явно доминировала подёнка *Ephemerella electrogena,* другим многочисленным видом была подёнка *Ephemerella ignita*. Плотность организмов была невысокой – около 5.4 эк./м^2. Индекс разнообразия Шеннона составил 1.34. В 2024 году разнообразие бентоса значительно выросло и состояло из 10 видов беспозвоночных животных, относящихся к 2 типам. Плотность организмов в прибрежье составила около 18.9 экз./м^2. Основу сообщества зообентоса составили насекомые (99% численности от всего зообентоса). В 2024 г. доминирующим видом стал *Chironomus sp.*, *Simullium sp*. и ручейник *Brachycentrus subnubilus*, доминирование было выражено слабее у подёнок и веснянок. Индекс разнообразия Шеннона составил 1.79. В р.Кенсу обнаружены все типы донных беспозвоночных, представленные в р.Иле [54]. Видовой состав крупных таксонов различается из-за особенностей среды обитания в горной реке и равнинном участке р.Иле.

Обнаруженные нами в р. Кенсу подёнки *Baetis sp., Ephemerella ignita, Oligoneuriella pallida*, ручейник *Brachycentrus subnubilus, двукрылые Chironomus sp., Simullium sp.,* а также ручейники *Trichoptera sp., Microsema sediterum, подёнки Hydropsyche sp., Ephemerella electrogena, веснянки Perlodidae sp, Perlodidae isoperla* ранее были отмечены Д.А.Смирновой [55] в других горных реках Алатау. Вопреки ожиданиям, сообщество зообентоса р.Кенсу имеет большее сходство с равнинными, а не горными участками рек Большая Алматинка, Малая Алматинка и Каскелен [55]. Выявлен- ные различия в составе фауны беспозвоночных представляют большой интерес как для понимания экологической пластичности перечисленных видов, так и для экологической индикации антропогенных воздействий и заслуживают более подробного изучения в будущем.

Рыбное население р.Кенсу состоит из 3 видов: голого османа *Gymnodiptychus dybowskii,* чешуйчатого османа *Diptychus maculatus* и тибетского гольца *Triplophysa stolickai*. Все три вида являются типичными обитателями горных рек бассейна р.Иле [56]. В 2023 г. были взяты для анализов 16 экземпляров и одна годовалая особь голого османа и 9 экземпляров тибетского гольца, в 2024 г. – 1 неполовозрелая особь чешуйчатого османа и 11 тибетских гольцов разного размера. Морфобиологические показатели исследованных рыб представлены в таблице 2 в сравнении с опубликованными для данного региона данными. Морфологическая изменчивость обоих видов османов хорошо изучена [57]. Тибетский голец в Балкашском бассейне остается мало изученным видом, для которого известна лишь большая морфологическая изменчивость [56,58,59].

Таблица 2 – Морфобиологические показатели рыб из р. Кенсу в сравнении с известными для других водоемов Алатау

Вид рыб	Река, год, источник данных	Статистические показатели	Морфобиологические показатели			
			TL, мм	SL, мм	Q, г	Fulton
Голый осман	Кенсу, 2023 г., наши данные, молодь	Min	22.7	19.4	0.086	1.12
		Max	29.4	23.8	0.206	1.67
		M	23.0	19.1	0.108	1.38
		±SD	4.22	3.31	0.0537	0.251
	годовик, 1 экз.		71	58	3.36	1.72
	Ассы, 1983 [57]		nd	210	nd	2.17
Чешуйчатый осман	2024 г., наши данные, 1 экз.		108	90	11.97	1.64
	Каркара, 1983 [57]	Max	nd	254.5	nd	1.59
Тибетский голец	2023 г., наши данные	Min	60	50	1.31	1.02
		Max	135	116	16.31	1.29
		M	86.1	72.0	5.5	1.13
		±SD	27.94	24.06	5.459	0.090
	2024 г., наши данные	Min	46	38	0.64	1.08
		Max	99	83	8.22	2.49
		M	69.7	58.9	3.31	1.44
		±SD	17.00	14.65	2.163	0.441
		U	31	32	36	**1**
	Оз.Нижний Кольсай, 1989 г., [56]	Max	170	143	nd	nd

Представленные в таблице 2 данные показывают, в реке Кенсу популяции всех видов рыб находятся в благоприятных для воспроизводства и питания условиях. Максимальные размеры голого османа, чешуйчатого османа и тибетского гольца из р.Кенсу меньше известных для этих видов из других рек Алатау. Вероятной причиной этого является элективность применявшегося нами орудия лова: крупным рыбам легче избежать рыболовного сачка, особенно в реках с каменистым дном и стремительным течением.

Заключение

По результатам проведенного исследования вода в р.Кенсу слабо минерализована и обладает большой прозрачностью, что указывает на хорошую сохранность почвы и растительного покрова в водосборном бассейне этой реки. Однако выявлены повышенные значение pH и концентрации нитратов не характерные для горных рек. Возможным источником загрязнения может быть воздушный перенос нитратов из города Алматы. Для установления источника нитратного загрязнения удаленных горных рек нужны дополнительные исследования.

Выявлена бедность видового состава организмов зообентоса. Видовой состав не остается постоянным в разные годы. В целом разнообразие водных личинок насекомых, представленных на горном участке р.Кенсу, более характерно для равнинных участков других рек Алатау. Выявленные различия в составе фауны беспозвоночных представляют большой интерес как для понимания экологической пластичности перечисленных видов, так и для экологической индикации антропогенных воздействий и заслуживают более подробного изучения в будущем.

Рыбное население представлено тремя видами рыб (голый осман, чешуйчатый осман, тибетский голец), характерными для других горных рек Северного Тянь-Шаня. Условия обитания в р.Кенсу благоприятны для питания и воспроизводства данных видов рыб.

В целом разнообразие водных организмов указывает на большую близость экосистемы р.Кенсу с естественному состоянию.

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SPECIES DIVERSITY OF FOREST-STEPPE FLORA OF AKKOL DISTRICT OF AKMOLA REGION

This article presents the results of studies of species diversity of floristic complex of Akkol district. This district is located in the north-eastern part of Akmola region, Republic of Kazakhstan. The studied area is characterised by forest-steppe and steppe vegetation growing mainly on chernozem soil. The research was carried out in spring and summer during field expeditions. The standard methodology of ecological profiles was used to describe plant communities. Plots of 15x15 m were laid out. Then the spectrum of plant communities characteristic for each zone was determined. Geobotanical indices were determined at each site. The Drude scale was used to estimate abundance. The inventory revealed that the flora of the forest-steppe complex is represented by 138 species belonging to 87 genera and 30 families. There are 120 species of dicotyledonous plants, which is 87 %, and 18 species of monocotyledonous plants, which is 13 % of the total species diversity. The ratio of monocotyledons to dicotyledons is 1:6.6. Most genera in this floristic complex are represented by one species, respectively the average value is 1.5. The autochthonous tendency of flora formation in Akkol district of Akmola region is confirmed by the complete absence of endemic species in the studied area.

Key words: species diversity, steppe flora, forest flora, floristic complex, taxonomic composition

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[2]Қазақстан Республикасы экология және табиғи ресурстар министрлігі орман шаруашылығы және жануарлар дүниесі комитеті, Астана, Қазақстан
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Ақмола облысы Ақкөл ауданының орманды-дала флорасының түр алуандығы

Бұл мақалада Ақкөл ауданының флористикалық кешенінің түрлік әртүрлілігін зерттеу нәтижелері келтірілген. Бұл аудан Қазақстан Республикасы, Ақмола облысының солтүстік-шығыс бөлігінде орналасқан. Зерттелетін аймақ негізінен қара топырақты топырақта өсетін орманды-дала және дала өсімдіктерімен сипатталады. Зерттеулер 2024 жылдың вегетациялық кезеңінде көшпелі экспедициялар кезінде жүргізілді. Өсімдіктер қауымдастығын сипаттау кезінде экологиялық профильдердің стандартты әдісі қолданылды. Көлемі 15х15 м болатын алаңдар салынды, содан кейін әр аймаққа тән өсімдіктер қауымдастығының спектрі анықталды. Әр алаңда геоботаникалық көрсеткіштер анықталды. Молшылықты бағалау үшін Друде шкаласы қолданылды. Түгендеу барысында орманды-дала кешенінің флорасы 87 ұрпақ пен 30 отбасына жататын 138 түрден тұратындығы анықталды. Қосжарнақты өсімдіктердің 120 түрі бар, бұл 87 %, біржарнақты өсімдіктердің 18 түрі, бұл барлық түрлердің 13 % құрайды

Түйін сөздер: түрлердің әртүрлілігі, дала флорасы, орман флорасы, флористикалық кешен, таксономиялық құрамы

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Видовое разнообразие лесостепной флоры Аккольского района Акмолинской области

В данной статье приведены результаты исследований видового разнообразия флористического комплекса Аккольского района. Данный район расположен в северо-восточной части Акмолинской области, Республики Казахстан. Изучаемый участок характеризуется лесостепной и степной растительностью, произрастающей преимущественно на черноземной почве. Исследования проводились в вегетационный период 2024 года во время выездных экспедиций. При описании растительных сообществ применялась стандартная методика экологических профилей. Закладывались площадки размером 15х15 м. Затем определялся характерный для каждой зоны спектр растительных сообществ. На каждой площадке определялись геоботанические показатели. Для оценки обилия использовались шкала Друде. В ходе инвентаризации выявлено, что флора лесостепного комплекса представлена 138 видами, которые относятся к 87 родам и 30 семействам. Двудольных растений насчитывается 120 видов, что составляет 87 %, однодольных 18 видов, что составляет 13 % от всего видового разнообразия. Соотношение однодольных растений к двудольным растениям составляет 1:6,6. Большинство родов в данном флористическом комплексе представлено одним видом, соответственно среднее значение составляет 1,5. Автохтонная тенденция формирования флоры Аккольского района Акмолинской области подтверждается полными отсутствием эндемичных видов на исследованной территории.

Ключевые слова: видовое разнообразие, степная флора, лесная флора, флористический комплекс, таксономический состав

Introduction

The study of species diversity of the flora is currently of great scientific interest. The study of steppe flora of some poorly studied regions of Akmola region is the most actual [1-3].

One of the actual aspects of studying species diversity of plants in natural habitats is continuous monitoring of species. At present, it is necessary to study the floristic list of plants, which has not been updated for several decades. To date, large-scale studies in Akmola region date back to the early 1980s, reflected in the works of T.A. Ten [4]. The literature review revealed scattered data devoted to the study of individual floristic groups of plants and ecological biotopes in different areas [5-7].

In-depth floristic researches of separate natu- ral regions acquire special urgency also in connec- tion with excessive and long-term exploitation of steppe pastures, leading in some cases to irrevers- ible changes of primordial biocenoses, reduction of areas and disappearance of rare plant species. For the rational use and conservation of plant wealth of a particular area it is extremely important to identify, if possible, the full composition of its flora. Studies of regional floras are of primary importance in this case, allowing to characterise the flora both qualitatively and quantitatively

The analysis of species diversity of the flora of the Akkol district allowed to reveal the features of its heterogeneous flora, which is the result of the impact of different floristic centres and different-age formation of individual taxa, as well as the impact on it sharp-continental climate. One of the important conditions for the study of a particular flora is the identification of floristic complexes. According to the classification of A. I. Tolmachev [1], a floristic complex formed on a certain territory and space with further dynamics of plant development combines elements of the main four directions:

1. Vestiges of a flora of a different type, preserved locally in a more or less unchanged state, preserved in the area in an unchanged state and to some extent not combined with the new conditions of the flora and its appearance (relict elements of the flora). These elements are much older than the present floristic complex;

2. Ancient core of the flora – species harmonising with the modern appearance of the flora and conditions of its development, representing earlier local flora, in which they could occupy a low-noticeable position, due to adaptation to specific habitat condi-

tions and formed in connection with its formation. Such species are partly older than the flora of the complex and do not always correspond to the moment of its formation.

3. Migratory elements that are of different ages, both in terms of the time of their origin and the period of their introduction into the flora. However, as its components, younger than species of the earlier categories.

4. Autochthonous neoplasms that emerged as second- and third-order derivatives. Such species are much younger than the time of the initial forma- tion of the flora.

The first two groups can be conventionally grouped into primary elements of the flora, the next two groups are secondary

The species diversity of the flora of the study area is strongly influenced external factors such as climate and water balance. Climate change is a regulating factor and the main cause of extinction, transformation and establishment of new floras. All this in the course of a long time has led to the extinction of some species and the formation of new ones. The complex of external influences caused progressive and regressive changes of habitats forming flora. In the course of evolution in Akkol district of Akmola region of Akmola region, a typical floristic complex was formed, represented by forest-steppe, meadow-steppe and grass-meadow flora [8]

The aim of this study is to investigate the species diversity of forest-steppe flora of Akmola region on the example of Akkol district.

Materials and methods of research

The main methods of field studies of the flora of Akkol district of Akmola region were generally accepted classical methods of botanical and floristic studies: field expeditions, in the field traditional route-reconnaissance for the study of plant communities and plant collection [9]. Collection and processing of herbarium material was carried out according to generally accepted methods [10-12]. Plant specimens were collected in clear, dry weather in herbarium folders with a description of collection sites, date and name of the collector. Drying and processing of herbarium sheets were carried out according to standard methods. Identifiers [13- 21] were used to determine the species affiliation of plants.

Standard methodology of ecological profiles was used to describe plant communities. Plots of 15x15 m were laid out. Then the spectrum of plant communities characteristic for each zone was determined. On each ecological profile, the main geobotanical indices were determined: vitality, abundance, and coverage area. The index of projective cover provides an indication of the overall connectivity of the vegetation cover, as well as of the proportion of participation of its constituent species. The Drude scale was used to estimate abundance [22, 23].

The results of the study and their discussion

Location of Akmola Region. Akmola region is located in the north-central part of Kazakhstan. The territory of the region is vast and makes up 146, 2 thousand square metres. The region includes two large cities of regional significance – Kokshetau and Stepnogorsk. There are eight cities of district subordination. The Akkol district under study is located in the north-eastern part of Akmola region.

The area of the territory is 9.4 thousand km², which is 6.43% of the total territory of the Region, the 6th district in terms of the size of the territory in the Region. Its length from north to south is 95 km, from west to east – 160 km. It borders: the north with Birzhan sal district, in the north-east, east with Stepnogorsk city administration, in the south-east with Ereimentau districtShortanda district, in the south with , in the west with Astrakhan districtdistrict, in the north-west with Bulandyn

The relief is plain-shallow-sloping, with altitudes ranging from 200 to 400 metres. The highest central part of the mountain Dombyraly, 471 m. The climate is continental. Winter is cold, long, aver- age temperature of January 17-18°C; summer, hot, short, average temperature of July 20°C. Annual precipitation is 350-400 mm. The territory of Akkol district is located within the steppe zone. Chernozem soils prevail.

Taxonomic composition of flora. According to the results of long-term field studies in Akmola region on the territory of Akmola district we have identified the following types of landscape vegetation: steppe, typechak-pollen, desert-steppe, mixed grass-meadow, forest-steppe, deciduous-forest and shrub vegetation.

In general, the vegetation cover is characterised by complexity and mosaicism. The flora of vascular plants in the forest-steppe floristic complex includes 138 species belonging to 87 genera and 30 families. The overwhelming majority of species belong to flowering plants, of which 120 species (87 %) are dicotyledonous and 18 species (13 %) are unicotyledonous. The ratio of monocotyledonous plants to dicotyledonous plants is 1:6.6. The numerical ratio of the flora of Akkol district is 30:87:138. On average, there are 1.5 species per genus, which is due to the large number of genera represented by only one species. The autochthonous tendency of floristic complex development on the example of Akkol district is practically not expressed, which is confirmed by the absence of endemic species.

Figure 1 – Location map of Akkol district, Akmola region

The leading position in the species diversity of the flora is occupied by families containing from 3 to 17 species. The greatest species richness is characterised by *Asteraceae, Rosaceae, Poaceae, Fabaceae, Ranunculaceae, Brassicaceae, and Cyperaceae*. The 7 leading families account for more than half of the total species diversity. Other families are represented by 1-3 species.

At the level of genera in the floristic complex of Akkol district the following genera are most richly represented: *Artemisia* (8 species), *Agropy- ron, Stipa, Poa, Avena, Festuca, Hordeum, Allium, Achillea, Aster* (5-3 species) other genera contain 1-2 species each. Steppe flora of the Akkol district was formed as a result of long-term aggregation of different florogenetic complexes with different ecological origin.

As presented in Table 1, the greatest species diversity in the floristic complex of Akkol district is characterised by the families *Asteraceae* (26; 18.8%), *Rosaceae* 24; 17.4%), *Fabaceae* (17; 12.3%), *Poaceae* (14; 10.1%), *Brassicaceae* (13; 9.4%), *Ranunculaceae*, and *Cyperaceae* (9; 6.5%), *Chenopodiaceae* (8; 5.8%).

Table 1 – The largest families of the floristic of the Akkol district complex

№	Families	Number of Genera	Number of Species	% of Total Species
1	*Asteraceae*	18	26	18,8
2	*Rosaceae*	11	24	17,4
3	*Poaceae*	9	17	12,3
4	*Fabaceae*	9	14	10,1
5	*Brassicaceae*	11	13	9,4
6-7	*Ranunculacea*e	8	9	6,5
6-7	*Cyperaceae*	7	9	6,5
8	*Chenopodiaceae*	5	8	5,8

The first two families are the most diverse in terms of species composition and in total represent 50 species or 36.2% of the studied floristic complex. The contribution of *Poaceae* family is 17 species or 12, 3 %, *Fabaceae* 14 species or 10,1 %.

During the inventory of species composition of the floristic complex of the steppe zone, the greatest biodiversity was revealed for 12 dominant genera presented in Figure 2. These genera belong to the families: *Asteraceae, Poaceae, Amaryllidaceae* and others.

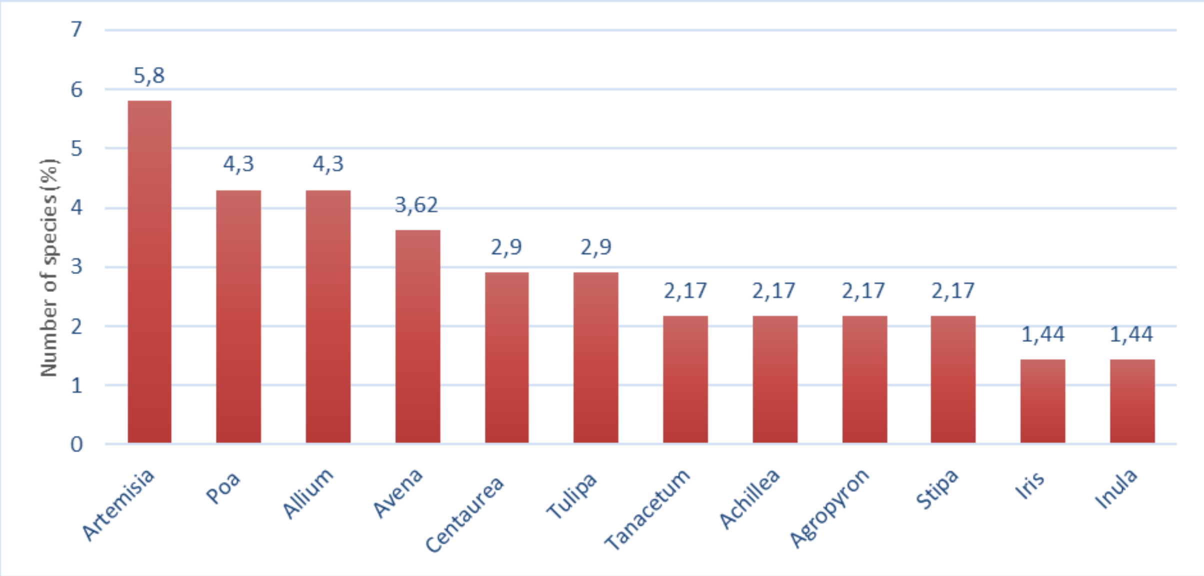

Figure 2 – Species diversity of dominant genera of the steppe zones of Akkol district

Thus, the maximum species diversity is characteristic for genus Artemisia, represented by 8 species or 5.8%; two genera *Poa* and *Allium*, represented by 6 species of steppe plants or 4.3%; genus Avena 5 species or 3.62%; equal contribution to the species diversity of the flora made two species *Centaurea* and *Tulipa* 4 species each, which is 2.9% of the total flora. The following equal contribution to the formation of flora of Akkolsky area falls on four genera – *Tanacetum, Achillea, Agropyron and Stipa*, each genus is formed by 3 species or 2.17%; the smallest species assortment is established for genera *Iris* and *Inula* on 2 species on the studied sites or 1.44%

The forest zone of the studied area is characterised by a great diversity of representatives of the following families: *Rosaceae, Fabaceae, Lamiaceae, Caryophyllaceae, Chenopodiaceae, Boraginaceae, Apiaceae, Liliaceae and Ranunculaceae.*

According to the figure, the maximum amount of species diversity in the forest zone of the floristic complex of Akkol district is represented by the following genera:

Filipendula – this genus is represented by 8 species or 5,79 %; 7 species or 5 % is characterised by the genus *Rosa*, the genera *Ranunculus* and *Astragalus* are represented by 6 species, which makes 4,34 %; the genus Gagea in the forest-steppe zone is represented by 4 species, making 2,89 % of the total number of species diversity; same number of species is characteristic for genera *Sanguisorba, Euphorbia* and *Spirea* with 3 species in one genus or 2,17 %; the following three genera *Convolvus, Eringium* and *Cerasus* have 2 species in their genera, that makes 1,44 % from the total assortment of species.

The conducted research allowed to identify the most frequently occurring plant species growing in the floristic complex of Akkol district, Akmola region, Akmola region. The analysis of sites revealed the most frequently occurring mesophytic species for the forest zone – *Rosa majalis herrm., rosa canina L., Ranunculus acris L., R. repens L., Filipendula ulmaria (L.) Maxim, Fragaria vesca, Potentilla anserina L., Sanguisorba officinalis L.* and other species.

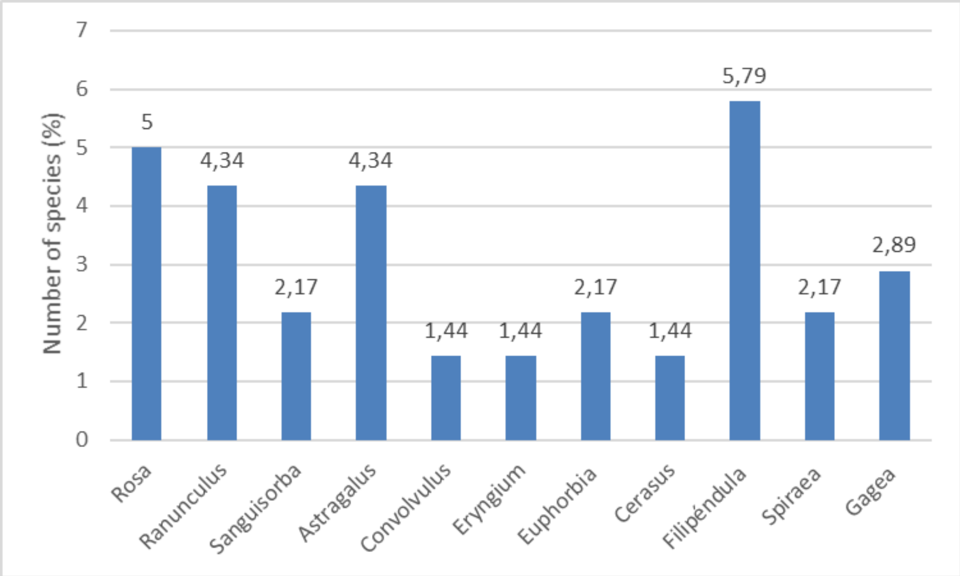

Figure 3 – Species diversity of dominant forest genera zones of Akkol district

The steppe zone is characterised by xerophytes growing abundantly, forming continuous covers such *Artemisia absinthium* L., A. *vulgaris* L., A. *cina* Berg., A. *nitrosa* Weber ex Stechm., *Stipa capillata* L., *Stipa pennata* L., *Agropyron repens* (L.) Beauv.

Plant species (*Filipendula vulgaris, Sanguisorba officinalis, Spiraea crenata, Cerasus fruticosa, Eryngium foetidum. Euphorbia milii*, etc.) included in the above genera make a significant contribution to the formation of forest-steppe zone of the study area (Table 2).

Life forms. Analysis of life forms of plants of Akkol district showed that forest-steppe floristic complex is characterised by dominance of herbaceous plants (121 species – 87.7 %), most of which are herbaceous polycarpic (103 species – 74.6 %), which is typical for temperate floras. Herbaceous monocarpics are represented by a smaller number of representatives (18 species – 13%). The assortment of shrubs and bushes is quite diverse, totalling 12 species – 8.7 %, the woody life form is represented by 5 species – 3.6 %.

Table 2 – Frequency of occurrence of dominant species in steppe and forest-steppe zone of Akkol district

№ п/п	Symbol according to O. Drude	Abundance Characteristics	Main Representatives of the Steppe Zone	Main Representatives of the Forest Zone
1	*Socialis (Soc.)*	Plants forming a continuous cover, merging with their aerial parts to create a general background	*Stipa pennata, Stipa lessingiana, Elytrigia repens*	*Filipéndula vulgáris*
2	*Copiosae (Cop.)*	Plants occurring in large quantities, but their aerial parts do not merge	*Serratula cardunculus (Pall.) Schischk, Artemisia annua L., Artemisia vulgaris L., Artemisia pontica L., Artemísia absínthium*	*Sanguisorba officinalis, Spiraea crenata*
3	*Cop.3*	Very abundant, but does not form a background	*Polygonum aviculare L., Poa annua L.,*	*Cerasus fruticosa*
4	*Cop.2*	Abundant, with many individuals of this species	*Ranunculus polyanthemos L., Poa pratensis L.*	*Prunus cerasus, Gagea lutea*
5	*Cop.1*	Abundant	*Rosa canina L., Rosa majalis Herrm., Rumex confertusWilld., Salix acutifoliaWilld, Salix alba L., Salvia stepposa Des.-Shost., Avena sativa*	*Eryngium campestre L.*

Continuation of the table

№ п/п	Symbol according to O. Drude	Abundance Characteristics	Main Representatives of the Steppe Zone	Main Representatives of the Forest Zone
6	*Sparsae (Sp.)*	Plants occur occasionally, scattered, in small numbers	*Inula britannica L., Potentilla anserina L., Potentilla bifurca L., Pulsatilla orientali-sibirica Stepanov., Pulsatilla patens., Avena strigose, Avena byzantica K. Koch.*	*Eryngium foetidum., Euphorbia milii* *Rubus saxatilis*
7	*Solitaria (Sol.)*	Plants occur rarely, as isolated individuals	*Iris halophila Pall., Potentilla humifusa Willd. ex Schltdl.*	*Rubus saxatilis*
8	*Unicum (Un.)*	Species represented by a single specimen within the sample plot	*Psylliostachys suworowii (Regel) Roshkova.*	*Equisetum arvense* L.

Conclusion

As a result of long-term research we have revealed the species composition of floristic complex of Akkol district of Akmola region. Taxonomic analysis of the flora was carried out, forest and steppe flora of the study area was characterised. In general, the vegetation cover is characterised by complexity and mosaicism. The flora of vascular plants in the forest-steppe floristic complex includes 138 species belonging to 87 genera and 30 families. The overwhelming majority of species belong to flowering plants, of which 120 species (87 %) are dicotyledonous and 18 species (13 %) are unicotyledonous. The ratio of monocotyledonous plants to dicotyledonous plants is 1:6.6. The numerical ratio of the flora of Akkol district is 30:87:138. On average, there are 1.5 species per genus, which is due to the large number of genera represented by only one species. The autochthonous tendency of floristic complex development on the example of Akkol district is practically not expressed, which is confirmed by the absence of endemic species.

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SEMI-AQUATIC MAMMALS OF THE IRTYSH RIVER FLOODPLAIN AS BIOINDICATOR SPECIES AND THEIR ECOSYSTEM SERVICES

The Irtysh River floodplain in Kazakhstan is home to diverse semi-aquatic mammals that serve as key bioindicators of ecosystem health. This study investigates six species: the muskrat (*Ondatra zibethicus*), Eurasian beaver (*Castor fiber*), water vole (*Arvicola amphibius*), American mink (*Neogale vison*), Eurasian otter (*Lutra lutra*), and Eurasian water shrew (*Neomys fodiens*). These species play critical roles in ecosystem services, contributing to water purification, extreme events mitigation, pest control, retention of greenhouse gases, ecosystem engineering, increase in riverside's recreational potential, prey base, seed dispersal. However, invasive species such as the American mink and muskrat pose threats through competition with native fauna and alteration of local biodiversity.

Field surveys conducted in 2023 along the Black Irtysh and Pavlodar Irtysh recorded 168 activity traces from four key species. Population densities of Eurasian otter and American mink in the Black Irtysh and the Eurasian beaver and American mink in the Pavlodar Irtysh were assessed. The studied section of the Black Irtysh River hosts 6-8 otters, with approximately 10 individuals found from the China border to Lake Zaysan, at a density of 1-1.2 otters/10 km. In the Kalzhyr River near Boran, the otter density is at least 2 animals/10 km. The mink inhabits the Black Irtysh (river and tributaries) area at 0.3-0.5 individuals/km, and the Kalzhyr River at up to 1 individual/km. In the Pavlodar Irtysh, the mink density is lower, at 0.2-0.3 individuals/km. In suitable habitats along the Irtysh River, beaver settlements occur every 3-4 km, and if there are three beavers per settlement, the total population in the Pavlodar Irtysh region is estimated at 300–400 individuals. Overall, our studies reveal a high species density in areas with preserved habitats, while human disturbances negatively impacted their presence in certain regions. More data are necessary to better understand ecosystem services provided by semiaquatic mammals.

Key words: Irtysh River floodplain, river ecosystem, semi-aquatic mammals, bioindicators, ecosystem services, population densities.

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Ертіс өзенінің жайылмасының жартылай су сүтқоректілері және олардың биоиндикатор ретіндегі және экожүйелік қызметтері

Қазақстанда орналасқан Ертіс өзенінің жайылмасы – ерекше аумақ, ол қоршаған орта сапасын көрсететін негізгі биоиндикаторлар ретінде қызмет ететін жартылай суда мекендейтін сүтқоректілердің мекен ету ортасы болып табылады. Бұл зерттеуде алты түр зерттелінді: ондатр (*Ondatra zibethicus*), құндызы (*Кастор талшығы*), сутышқан (*Arvicola amphibius*), Американдық күзен (*Neogale vison*), кәмшат (*Lutra lutra*) және су жертесері (*Neomys fodiens*). Бұл түрлер суды тазартуға, төтенше жағдайларды азайтуға, зиянкестермен күресуге, парниктік газдарды жинауға, экожүйені жасауға, жайылманың рекреациялық әлеуетіне, жемдік база болу және тұқымдарды таратуға үлес қосу арқылы экожүйе қызметтерінде маңызды рөл атқарады. Дегенмен, күзен және ондатр сияқты инвазивті түрлер жергілікті түрлермен бәсекелестікке және тіршілік ету ортасының өзгеруіне байланысты белгілі бір қауіп төндіреді.

2023 жылы біз Қара Ертіс пен Павлодар Ертісінің бойынан төрт жартылай суда мекендейтін түрдің тіршілік әрекетінің 168 ізін анықтадық. Қара Ертістегі кәмшат пен күзеннің, сонымен қатар Павлодар Ертісіндегі құндыз бен күзенінің популяциясының тығыздығын бағаладық. Біздің деректеріміз бойынша Қара Ертісті зерттелген учаскесінде 6–8 кәмшат кездеседі, шекаралы Зайсанға дейінгі аумақта 10 шақты кәмшат (популяция тығыздығы 1–1,2 дара/10 км) мекендейді. Боран ауылының маңындағы Қалжыр өзені учаскесіндегі кемінде 2 кәмшат/10 км кездеседі. Американдық күзен популяциясының тығыздығы Қара Ертісте (негізгі өзен мен арналары) 0,3–0,5 дара/км, Қалжыр өзені маңында 1 дара/км құрады. Павлодар Ертісінде күзен сирек кездеседі, популяцияның тығыздығы 0,2–0,3 дара/км аспайды. Ертістегі құндыздарға қолайлы мекендейтін жерлерде 3–4 км арна бойында бір құндыздар қонысы орналасады. Бір қоныста орташа есеппен үш құндыз болса, олардың жалпы саны Павлодар Ертіс өңірінде 300-400 дараға дейін жету мүмкін. Біздің зерттеулеріміз негізінде, тіршілік ету ортасы жақсы аумақтарда осы түрлердің популяция тығыздығы жоғары екені байқалынды, ал адамның негативті әрекеті олардың белгілі бір аймақтардан жойылуына әкеліп соғады. Жартылай сулы түрлердің экожүйелік қызметтерді егжей-тегжейлі зерттеу үшін қосымша деректер қажет.

Түйін сөздер: Ертіс өзенінің жайылмасы, жайылманың экожүйесі, жартылай су сүтқоректілері, биоиндикаторлар, экожүйе қызметтері, популяцияның тығыздығы.

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Полуводные млекопитающие поймы реки Иртыш как биоиндикаторные виды и их экосистемные услуги

Казахстанская часть поймы реки Иртыш является уникальным регионом, местом обитания для полуводных млекопитающих, служащих ключевыми биоиндикаторами качества среды. В данном исследовании рассмотрены шесть видов: ондатра (*Ondatra zibethicus*), речной бобр (*Castor fiber*), водяная полевка (*Arvicola amphibius*), американская норка (*Neogale vison*), речная выдра (*Lutra lutra*) и кутора (*Neomys fodiens*). Эти виды играют важнейшую роль в экосистемных услугах, способствуя очистке воды, смягчению последствий экстремальных явлений, борьбе с вредителями, удержанию парниковых газов, экосистемной инженерии, повышению рекреационного потенциала поймы реки, составлению кормовой базы и распространению семян. Однако инвазивные виды, такие как норка и ондатра, представляют некоторую угрозу из-за конкуренции с нативными видами и изменения местообитаний.

Нами в 2023 обнаружено 168 следов жизнедеятельности четырех видов полуводных вдоль Черного Иртыша и Павлодарского Иртыша. Оценена плотность популяции выдры и американской норки в Черном Иртыше, а также бобра и норки в Павлодарском Иртыше. По нашим данным, на исследованном участке р. Черный Иртыш обитает 6–8 особей выдры, а на всем участке от границы с Китаем до оз. Зайсан около 10 выдр (плотность населения 1–1,2 особи/10 км русла). Плотность населения на участке р. Калжыр выше пос. Боран составляет не менее 2 выдр/10 км русла реки. На Черном Иртыше (основное русло и протоки) американская норка населяет с плотностью 0,3–0,5 особи/км русла, а у р. Калжыр до 1 особи/км русла. В Павлодарском Прииртышье норка встречается реже, плотность населения не превышает 0,2–0,3 особей/км русла. В пригодных для бобра местообитаниях на р. Иртыш одно поселение встречается на 3–4 км русла реки. При среднем расчетном количестве три бобра в одном поселении, их общая численность на участке Павлодарского Прииртышья может составлять 300–400 особей. Наши исследования показывают высокую плотность этих видов в районах с сохранившимися местообитаниями, в то время как антропогенное вмешательство негативно повлияло на их присутствие в определенных регионах. Необходимо больше данных для детального изучения экосистемных услуг, предоставляемых полуводными млекопитающими.

Ключевые слова: пойма реки Иртыш, пойменная экосистема, полуводные млекопитающие, биоиндикаторы, экосистемные услуги, плотность популяции.

Introduction

The Irtysh River floodplain is located in the northeastern part of Kazakhstan, spanning the East Kazakhstan, Abai and Pavlodar regions of the country [1]. The floodplain is formed by spring floods and water from the Upper Irtysh cascade of reservoirs [2]. Furthermore, according to the geomorphological zoning of Kazakhstan, the Black Irtysh River belongs to the region of accumulative and denudation plains of the Zaisan Depression of the orogenic belt. As a result, the river's wide valley is characterised by high and low floodplains as well as accumulative terraces.

Several semi-aquatic species, including native and invasive species, are present in the Irtysh River floodplain: the Eurasian beaver (*Castor fiber*), muskrat (*Ondatra zibethicus*), water vole (*Arvicola amphibius*), Eurasian otter (*Lutra lutra*), American mink (*Neogale vison*), and Eurasian water shrew (*Neomys fodiens*). Moreover, native species, such as the Eurasian otter and Eurasian beaver, contribute positively to ecosystem services such as water purification, habitat creation, and flood mitigation. In contrast, invasive species such as the American mink can alter native biodiversity and ecosystem functions, sometimes providing negative ecosystem services through predation or competition with native species.

Ecosystem services include various ecosystem functions and products that are necessary or beneficial to humans [3], and, from an ecological perspective, should be based on healthy ecosystem functioning [4]. Assessing the ecosystem services provided by the semi-aquatic mammals is essential for understanding their ecological roles and for the future planning of conservation strategies. Native and invasive species must be evaluated not only for their positive contributions but also for their potential negative impacts, especially in light of the ecological changes and anthropogenic pressures affecting the Irtysh River floodplain.

In this study, we analysed positive (beneficial to humans and the ecosystem) and negative (harmful to humans and/or the ecosystem) ecosystem services provided by semi-aquatic species and their bioindicator roles. We determined the population densities of three key species: the Eurasian beaver, Eurasian otter, and American mink in the Black (Upper) Irtysh and the Pavlodar (Lower) Irtysh. By understanding the balance of positive and negative ecosystem services provided by these species, we can better inform conservation efforts and the sustainable use of biological resources in the region.

Materials and methods

In February-May and September-October 2023, we surveyed the Kazakhstani part of the Black Irtysh River and the Pavlodar Irtysh – two parts of the Irtysh River in the north and northeast of Kazakhstan. The total length of the routes by car and foot tracks was greater than 1000 km. Approximately 220 km of the Black Irtysh and Pavlodar Irtysh floodplains were surveyed. All traces of vital activity of semi-aquatic mammals were noted along the routes, their sizes were measured, and, if possible, individual individuals were identified.

We estimated otter population density using the method of recording individual habitat areas [5] with additions by other researchers (Rodikov, 1978; Sidorovich, 1992) and our modifications [6]. The numbers of American mink and beaver were also estimated on the same routes. The study was based on the method proposed by D.V. Ternovsky [7]. To determine the beaver population, we used an ecological method with elements of population density assessment [8, 9].

We carried out a detailed analysis of the literature data on lifestyle and biocenotic role based on the works of Afanasyev et al. [10], Heptner and Naumov [11], Chanin [12], Bazarbekov and Lyakhov [13], Kruuk [14], and others. We considered the ecosystem services provided by mammals in the Irtysh River floodplain based on the combination of anthropocentrism (benefits to humans) and biocentrism (benefits to the ecosystem as a whole) [15, 16]. In our study, we modified the classification in respect to semi-aquatic mammals by combining some aspects of anthropocentrism and biocentrism and divided ecosystem services into positive and negative. Positive ecosystem services include water purification, mitigation of extreme events (floods, droughts, and floodplain overgrowth), control of the number of other species, retention of greenhouse gases, increased recreational activity, ecosystem engineering, a food source for other species, and seed dispersal and storage. Negative services include the impact on the number of other species, destructive competition with other species, impact on infrastructure, and harm to agriculture. Recreational activities include providing conditions for increased tourism, hunting, and fishing in the region, including the species themselves. Ecosystem engineering involves the direct or indirect provision of resource access by organisms to other species by modifying, maintaining, and creating habitats [17].

Results and discussion

The Kazakhstan part of the Irtysh River floodplain is home to 6 species of semi-aquatic mammals, comprising both native (Eurasian beaver, water vole, Eurasian otter, water shrew) or invasive (muskrat, American mink) species. In 2023, we discovered 168 traces of the life activity of four species of semi-aquatic mammals (Table 1).

Table 1 – Recorded traces of semi-aquatic mammal activity in two areas of the Irtysh River

Scientific name	Traces found		
	Black Irtysh	Pavlodar Irtysh	Total
Muskrat *Ondatra zibethicus* Linnaeus	2	21	23
Eurasian beaver *Castor fiber* Linnaeus	0	24	24
American mink *Neogale vison* Schreber	54	7	61
Eurasian otter *Lutra lutra* Linnaeus	60	0	60
TOTAL	116	52	168

The most frequently encountered tracks of the American mink and the Eurasian otter were on the Black Irtysh (n = 54 and n = 60, respectively), while we also registered tracks of the mink in the Pavlodar Irtysh region (n = 7). Tracks of the muskrat and the Eurasian beaver were noted in the Pavlodar Irtysh region (n = 21 and n = 24, respectively). There are also rare encounters of muskrat tracks on the Black Irtysh (n = 2). We have not confirmed the presence of the Eurasian beaver on the Black Irtysh and the Eurasian otter in the Pavlodar Irtysh region.

Below, we provide brief information on the biology of these species, consider their ecological features and ecosystem services, and analyse their density in the studied areas of the Irtysh River.

Brief information on the biology of semi-aquatic mammal species and their use as bioindicator species for the state of floodplain ecosystems

Semi-aquatic mammals play an important role in assessing the state of the Irtysh River floodplain ecosystems. The Eurasian otter, American mink, and European beaver are highly sensitive to changes in water quality and habitat conditions, which al- lows them to be used as bioindicators in assessing the ecological state of the floodplain.

Muskrat (*Ondatra zibethicus*) was first introduced into the Black Irtysh basin in 1944, and into the Pavlodar region in 1952 [18]. In the fall of 2023 and summer of 2024, we confirmed the presence of muskrat in the Black Irtysh. After release, the muskrat spread very widely, occupying suitable water bodies almost throughout the entire territory of the Pavlodar region. It is most numerous in the Irtysh valley and along the Irtysh-Karaganda canal. Breeding of muskrats in captivity is widely practised in many fresh water bodies on the right bank [13]. The distribution of muskrats in the Pavlodar part of the Irtysh, according to our data for 2023-2024, is uneven and mosaic. Despite the presence of suitable water bodies with abundant herbaceous vegetation in the river floodplain, not all of them are populated by muskrats. Probably, the mosaic distribution of muskrats in potentially favourable habi- tat conditions may be associated with the chemical composition of the water [18]. Muskrats have been harvested in small quantities in the Irtysh floodplain since 1947. Currently, the resources of this fur animal are used insignificantly. The Tarbagatai subspecies of the water vole (*Arvicola amphibius kuznetzovi* Ognev 1933) lives in the floodplain of the Irtysh River [19]. According to I.G. Schubin [20], the vole was especially numerous here, and up to 40-50 animals or more were often caught per 1 km of the coastline. The water vole feeds on aquatic and coastal vegetation (for example, it gnaws the lower parts of the trunks and branches of the willow Salix sp.) [20]. In the 1960s, the fertility of the voles was high, where 48.1-53% of females were pregnant in June-July, with an average of 7.1 embryos per female. At present, we have not found any water voles in the floodplain of the Irtysh River.

The Eurasian otter (*Lutra lutra*) is one of the most specialised species of near-water ecosystems among terrestrial carnivorous mammals [14]. Despite the plasticity of its diet, its diet consists mainly of aquatic and near-water animals. In different habitats, fish make up 50 to 95% of its prey; the main components of its diet also include amphibians, crustaceans, aquatic insects, mammals, and birds [21]. The otter visits all accessible floodplain water bodies (rivers, channels, lakes, oxbow lakes), and uses intermittent water bodies and small rivers (less than 10-15 km long) only temporarily. Its habitat is located along the shoreline of water bodies. The otter is active all year round and moves around its territory, avoiding areas with intense anthropogenic impact.

The otter was indicated for the Black Irtysh and Zaysan Lakes [10, 22]. Later, it was noted here by I.G. Schubin [23] as a rare species. The Irtysh River is inhabited by the northern subspecies, *L. l. lutra*

[24]. In the Black Irtysh River section, we observed the otter everywhere in May and October 2023. Traces of its life activity were noted on the routes on the Black Irtysh and on the Kalzhyr River. The otter prefers sections of the river with forested banks, bays and channels, and avoids open steppe areas and areas frequently visited by people and cattle.

The otter is mentioned as a rare game species in the Pavlodar Irtysh region [10, 11, 13]. At the time of our research in 2023, there were no signs of otters on the river. The Irtysh River has not been found in the Pavlodar Irtysh region. We can only guess at the real reasons for the otter's disappearance, but we will cite some factors that could have contrib- uted to this. The economy of the Pavlodar region has been developing intensively since the beginning of the last century thanks to the construction of the railway and the development of shipping along the Irtysh. The population has grown sixfold since the beginning of the 20th century by the 1980s, facto- ries and manufacturing plants were launched, and the rapid development of virgin lands began in the 1950s. Most of the settlements in the region are concentrated in the Irtysh floodplain. In addition, since 1949, tests have been conducted at the Semipalatinsk nuclear test site on the border of the Pavlodar and East Kazakhstan regions.

The American mink (*Neogale vison*) is somewhat less specialised to a semi-aquatic lifestyle than the otter. Its diet also includes fish, amphibians, aquatic insects, mammals and birds [25, 26]. Since the American mink is several times smaller than the otter, it consumes smaller prey on average, and there are differences in the species composition of its prey. In the event of a shortage of aquatic prey, it easily switches to using terrestrial prey (in winter); in some periods, voles and other small mammals can form the basis of its diet. Unlike the otter, the mink is able to occupy smaller and drying up or freezing bodies of water, and goes further from the water, the length of its territory is 1.5-3.5 km of the coastal strip.

Mink were first noted on the rivers of the East Kazakhstan region in 1945, where the animals had penetrated from the Altai region, where they were released in 1933 [27, 28]. Later, in 1952, mink were released on the Uba River [28]. Currently, mink has populated all suitable habitats in the surveyed areas of the Irtysh River. Due to trophic plasticity, the species has adapted well to new habitats.

The Eurasian beaver (*Castor fiber*) plays a key role in the formation and maintenance of aquatic biome ecosystems and is recognized as a key indicator of coastal ecosystem health throughout the Holarctic and an ecosystem engineer [29-31]. Beavers are able to exist in certain ecological conditions and are therefore an important indicator organism responding to human intervention [32].

Their presence or absence can serve as an early sign of environmental disturbance in coastal ecosystems [29, 33]. An increase in beaver numbers and expansion of their range may indicate improved environmental conditions, including the availability of suitable burrow sites and an adequate food supply.

The main reason for the disappearance of beavers on the river The Irtysh, as in most of its range, was under commercial pressure [34] as a result of high demand for beaver furs and products made from it [22, 35-37]. The restoration of the historical range occurred gradually. In the early to mid-1980s, the beaver from the Urals was reacclimatised in the upper reaches of the Malaya Ulba and Uba rivers. Beavers began to appear on the Irtysh about 20 years ago, settling upstream along the Irtysh River and along the Altai rivers [38].

The absence of beavers in the Black Irtysh River section at present is not a sign of its poor ecological condition. Moreover, the water quality is better here, the degree of ecosystem disturbance is less, and there are more channels with abundant coastal vegetation and tributaries suitable for the species. According to our expert assessment, the beaver population density here may be higher than in the Irtysh River section in the Pavlodar Irtysh region. In our opinion, the reason for the absence of beavers on the Black Irtysh is the cascade of hydroelectric power plants built on the Irtysh River in the 20th century. The dams of hydroelectric power plants and the banks of reservoirs, subject to significant drawdowns of the water level, are an artificial barrier to the settlement of beavers. The Black Irtysh is separated from the Russian part of the population by the high Altai Mountains.

An ecological feature of the life of beavers living in the Pavlodar Irtysh region is the absence of dams in their areas. Obviously, this is due to the absence of tributaries, small streams and quiet channels here. Most beaver settlements are found in channels, but they are quite full-flowing and unsuitable for building dams. Because of this feature, beavers on the Irtysh do not play a water-regulat- ing role and do not contribute to the flooding of large areas. By building canals, huts and burrows, they play a role in enriching the environment with shelters and new habitats for other species of vertebrates and invertebrates.

The common water shrew (*Neomys fodiens*), if it lives in the Irtysh River valley, is rare. In the 1980s, it was observed 300 km away from the Irtysh River near the village of Berezovka (oral communication by N.N. Berezovikov [39]). The water shrew is an insectivorous animal, highly specialised to a semi-aquatic lifestyle. During our research, no traces of the water shrew were found.

Semi-aquatic mammals are closely associated with aquatic ecosystems and respond quickly to changes in water quality and pollution levels [12, 40]. Their presence can serve as an indicator of a healthy environment and be used as an indicator of the state of water bodies [12, 14]. These species are susceptible to pollutants such as pesticides, heavy metals, and polychlorinated biphenyls, which can accumulate in their bodies over time through food chains [12, 41, 42]. Analysis of their tissues and faeces provides insight into the levels and types of pollutants in freshwater ecosystems [40, 43]. Semi-aquatic mammals have limited home ranges and are not prone to long-distance migrations, so they are exposed to pollutants year-round [44]. Concentrations of pollutants in their faeces and tissues can be used to assess environmental pollution for humans [45].

Ecosystem services provided

As a result of the analysis, we found that 6 species of semi-aquatic mammals provide 26 positive and 7 negative ecosystem services (Table 2 and Figure 1).

Table 2 – Positive and negative ecosystem services provided by semi-aquatic mammals in the Irtysh River floodplain

Types	Positive ecosystem services								Negative ecosystem services			
	Water purification	Mitigation of extreme events (floods, drought, over-vegetation)	Population control of other species	Retention of greenhouse gases	Increasing recreational activities	Ecosystem engineering	Food source for other species	Seed dispersal and storage	Impact on the abundance of other species	Destructive competition	Influence on infrastructure	Harm to agriculture
Eurasian otter			+		+		+					
American mink			+		+		+		+	+		
Eurasian beaver	+	+	+	+	+	+	+		+		+	
Vole water			+			+	+	+				+
Muskrat		+	+		+	+	+	+	+	+		
Eurasian water shrew			+		+	+	+					
Total	1	2	6	1	5	3	6	2	3	2	1	1
TOTAL	26								7			

As shown in Table 2, all semi-aquatic species participate in population control of other species and serve as prey for birds of prey and carnivorous mammals.

Beavers improve habitat for fish and waterfowl, create filtration zones to improve water quality, and attract tourists to the area, promoting recreation [32, 46]. However, it is also important to consider the sustainability of their populations and possible negative consequences of their activities, such as flooding and changes in the composition of coastal communities, to maintain ecosystem integrity and rational use of the species [47]. The presence of species such as the Eurasian beaver and the otter in the floodplain ecosystems of the Irtysh River serves as an important indicator of the state of the environment.

Ecosystem engineering refers to the environment-forming role of certain species. For example, the burrow system of the shrew ensures the existence of various species of invertebrates and small vertebrates. In the floodplain of the Irtysh River, the Eurasian beaver and the common muskrat are two excellent ecosystem engineers of wetland biotopes.

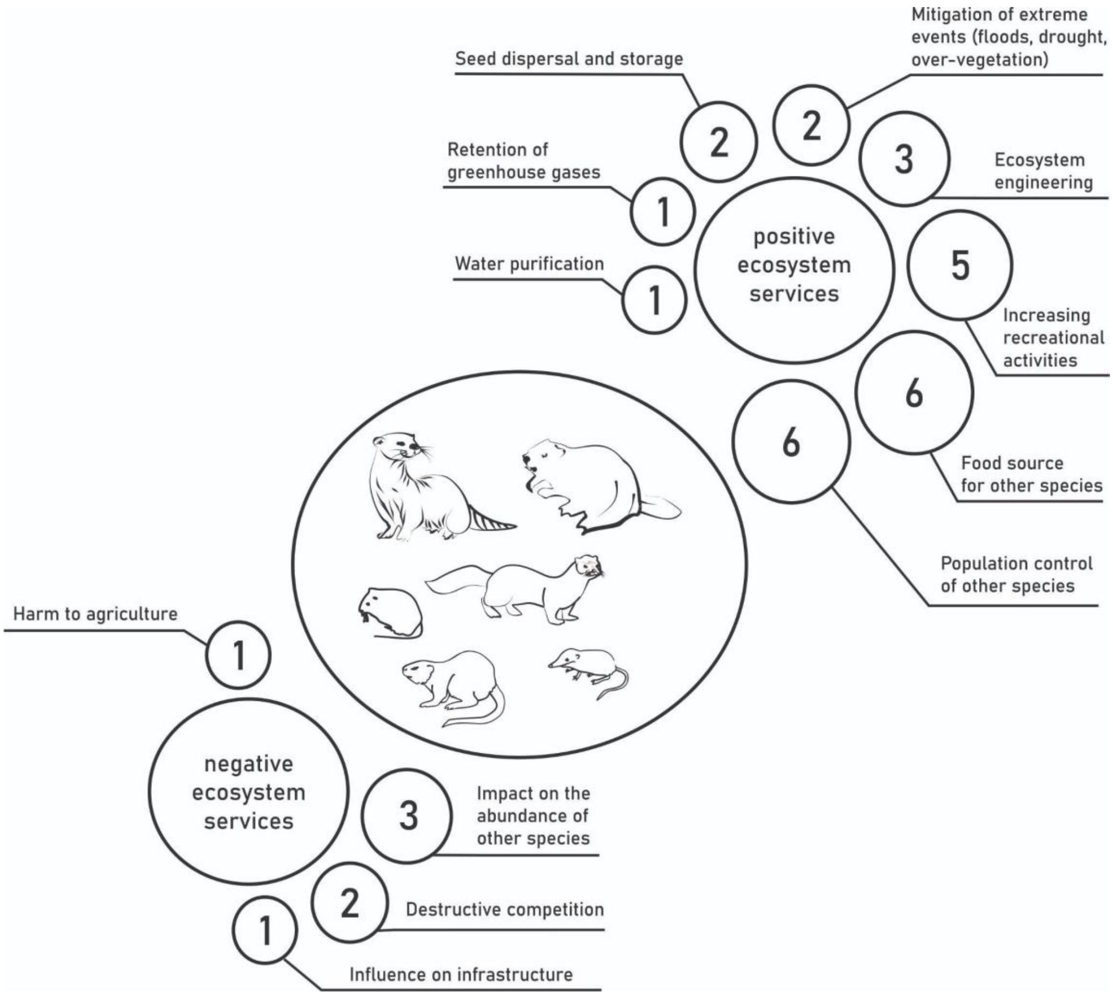

Figure 1 – Ecosystem services provided by semi-aquatic mammals in the Irtysh River floodplain. Drawing by N. Bizhanova

The otter, as a semi-aquatic species, plays an important role in near-water ecosystems, maintaining the natural balance and diversity of aquatic communities. Moreover, research and monitoring of otter populations can help determine levels of water pollution and detect changes in the ecosystem [12]. Otters are an object of interest for observation in nature and ecotourism. Their presence can attract tourists and promote the development of ecotourism in their habitat. Given the declining population and limited distribution in Kazakhstan, it is necessary to consider the inclusion of the northern subspecies in the Red Book.

Some aquatic mammals of the Irtysh River floodplain can also cause ecosystem damage. In addition to the damage to pastures described above, the Irtysh River floodplain is a natural source of dangerous infectious diseases, with ticks regularly arriving here with livestock during their spring migration to pastures and pastures. The water vole and muskrat are intermediate hosts of infectious disease carriers, where the ticks' habitat is the network of burrows. The water vole and muskrat are pests of agricultural crops and pastures on the Irtysh, feeding on fruits, flowers, plant shoots and gnawing at their root systems [20, 48]. Nevertheless, these animals, like all other semi-aquatic animals, form the basis of the diet of a large number of birds of prey and carnivorous mammals, including economically important ones (Eurasian ermine, steppe polecat, fox, corsac fox, etc.).

As an invasive species, the American mink provides negative ecosystem services in the Irtysh River floodplain by preying on native spe- cies such as fish and small mammals, as well as competing with other carnivores for resources. This predatory behaviour threatens vulnerable populations, potentially exacerbating the decline of other semi-aquatic mammals and altering local food web dynamics.

Until the 1970s, the water vole was a secondary object of fur trade in the Irtysh River floodplain, and the muskrat was a particularly valuable commercial animal. The Eurasian beaver, Eurasian otter and American mink were also highly valued for their fur. Due to population decline and intense poaching, the fur trade for most species stopped completely. For the future restoration of the fur trade, more com- plete information on the current state and distribu- tion of animal populations is needed.

Bioindicator mammals' population density

For the relative ecological assessment of the Irtysh River floodplain condition, we estimated the complex population density indicator of two pairs of indicator species of semi-aquatic mammals and plotted them on a map (Figures 2-3). Since each site is home to only two species of semi-aquatic mammals, we estimated the density of otter and mink for the Black Irtysh, and beaver and mink for the Pavlodar Irtysh region. To assess the entire length of the sites, we extrapolated the data obtained in Black and Pavlodar Irtysh and in their vicinity. As a density gradation, we identified three indicators for each species: high, medium, and absent, and five gradations of complex comparison of the density of two species in each of the sites (Figures 2-3).

For the beaver, we classified having one or more individuals per kilometre of the riverbed as sites with a high population density. For the mink, high population density is considered for more than 5 individuals per 10 km; and for the otter, it is more than 1 individual per km. Between 6-8 otters inhabit the studied section of the Black Irtysh River (58 km), and approximately 10 otters occur in the entire section from the border with China to Lake Zaysan (population density is 1-1.2 individuals/10 km of the riverbed). The population density in the section of the Kalzhyr River above the settlement of Boran is at least 2 individuals/10 km of the riverbed.

We observed otter tracks on a channel in the vicinity of this village. Otters avoid the section of the Black Irtysh River near the automobile bridge (the Zaisan-Kurchum automobile road), areas of intensive cattle grazing in the river floodplain, and areas lacking forest or shrubby riverside vegetation.

The American mink inhabits the Black Irtysh (main channel and branches) with a density of 0.3-0.5 individuals/km of the floodplain, and the Kalzhyr River up to 1 individual/km of the floodplain. Near the village of Boran, the mink is less common, likely due to the presence of stray dogs and human disturbance.

In the Pavlodar Irtysh, the mink is less abundant. We found signs of their presence along the banks of the Irtysh River and its tributary with better protective conditions in the Pavlodar Irtysh. Here, the population density does not exceed 0.2-0.3 individuals/km of the riverbed. Minks are more often found on the tributaries, but also on the main channel, particularly in wooded banks with shelters. The reason for the low number of minks in the lower section of the Irtysh River is probably due to the lack of quality habitats.

We also observed traces of beaver activity in the vicinity of the Irtysh River. The successful settlement of beavers on the Irtysh indicates sufficient preservation of habitats and favourable conditions for the species. In habitats suitable for beavers on the Irtysh River, we found one beaver settlement per 3-4 km of the riverbed.

With an average estimated number of three beavers in one settlement, their total population in the Pavlodar Irtysh region may be 300–400 individuals. Beavers are rarely found in the main riverbed and we have not found their permanent dwellings here. In the Irtysh floodplain, they prefer to inhabit channels with wooded banks.

In the Black Irtysh section, the population density of semi-aquatic mammals (otter and mink) is predominantly high (Figure 2). The habitats, in general, can be assessed as favourable, they are well preserved. The section of the Kalzhyr riverbed near the village of Boran and the section of the Black Irtysh in the area of the automobile bridge are less favourable for semi-aquatic predators, which is probably due to the high disturbance factor from the proximity of a populated area, intensive livestock grazing and automobile traffic.

In the Irtysh River in the Pavlodar Irtysh region, we observed areas with a high population density of semi-aquatic mammals between the villages of Prirechnoye and Zhanabet and below the village of Zhelezinka to the border with Russia (Figure 3). Here, tree and shrub vegetation is well developed; there is a low density of livestock and many channels. The greater length refers to areas with an average density. We also observed areas with absent or very low density of semi-aquatic mammal populations near the cities of Pavlodar and Kurchatov, where channels are very poorly developed, human population density is high, and vegetation is sparse.

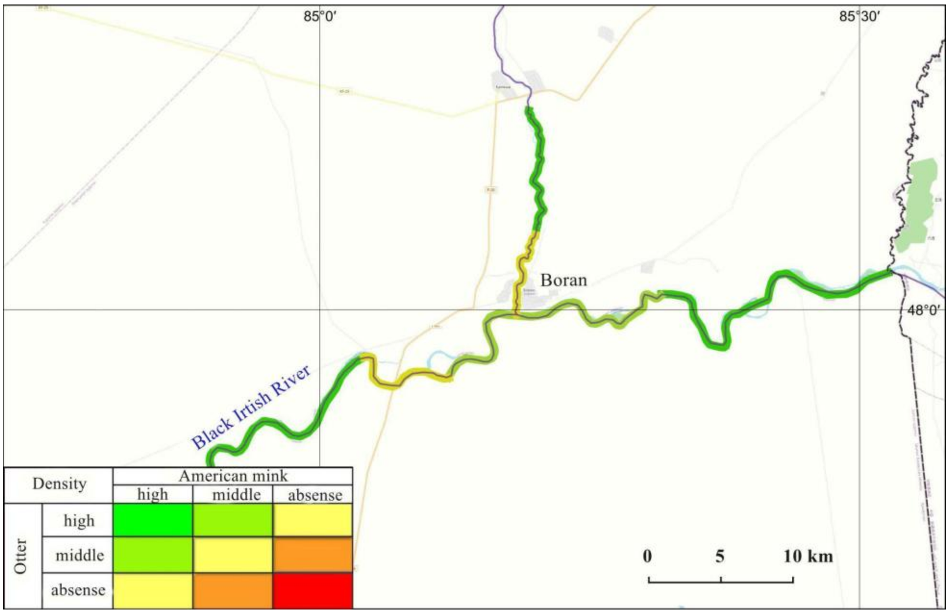

Figure 2 – Population density of semi-aquatic mammals (Eurasian otter, American mink) in the Black Irtysh area
Note – High population density = beaver > 1 individual/km of watercourse bed, otter > 0.1 individual/km of watercourse bed.
Medium population density = beaver < 1 individual/km of watercourse bed, otter ˂ 0.1 individual/km of watercourse bed.

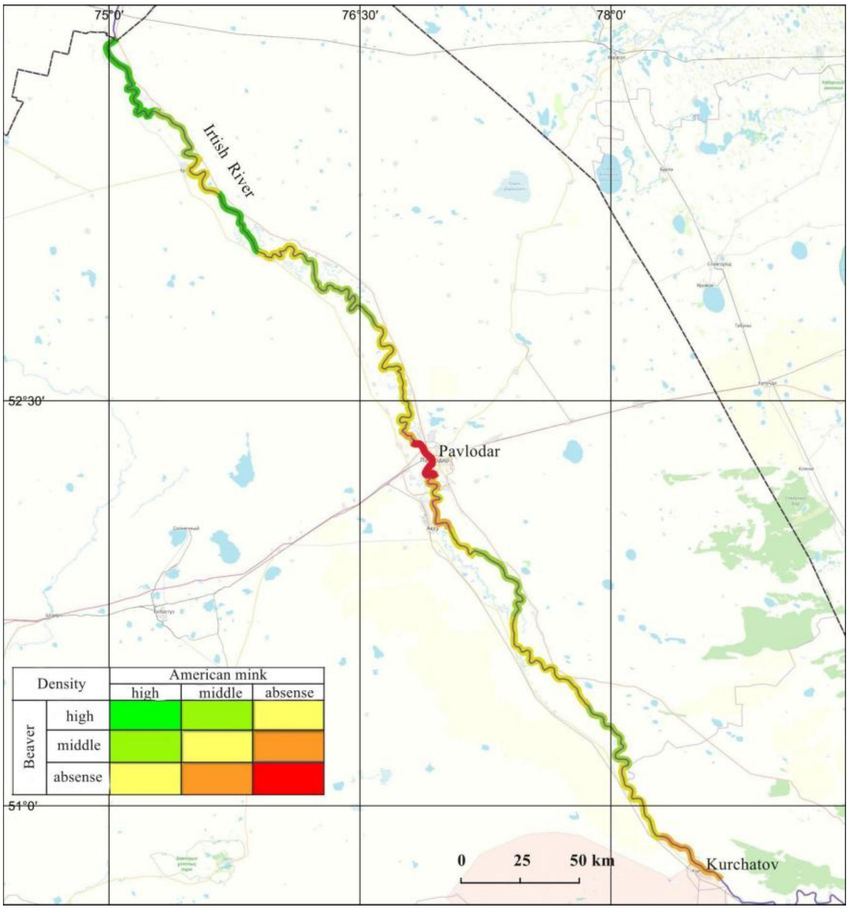

Figure 3 – Population density of semi-aquatic mammals (European beaver, American mink) in the Pavlodar Irtysh region
Note – High population density = beaver > 1 individual/km of watercourse bed, mink > 0.5 individuals/km of watercourse bed.
Medium population density = beaver ˂ 1 individual/km of watercourse bed, mink ˂ 0.5 individuals/km of watercourse bed.

Thus, mammals provide invaluable positive ecosystem services, but they can also have a negative impact on humans and the environment. Given that the status of their populations is unknown, it is currently impossible to assess the scale of their damage to pastures or their possible hunting and commercial value. More data are needed to identify and study in detail the types of ecosystem services provided by these indicator species.

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REVIEW OF GENETIC STUDIES OF MASTIF-LIKE DOG BREEDS

Currently the genetic studies of dogs are carried out quite widely. However, there are more than 400 varieties and breeds of dogs in the world, and not all of them are equally well studied. Thus, the genetical characteristics of mastiff dogs, which include the Kazakh national breed of herding dogs Tobet, have not been sufficiently studied. The purpose of this work is to review the genetic studies available in the scientific literature in varieties of mastiff-like dogs. The review examines the genetic diversity of mastiff dogs, the mechanisms of adaptation of breeds to living conditions, genetic factors of predisposition to diseases, as well as phylogenetic relationships between different breeds. Revealing phylogenetic connections of aboriginal dog breeds allows us to trace the correlation with the history and phylogeography of the peoples who inhabited the areas where these breeds were formed. Analysis of the parameters of genetic diversity and the level of inbreeding will allow us to apply science-based approaches to preserve and improve national dog breeds. Genetic research will improve breeding programs, reduce the number of hereditary diseases in dogs, help preserve the gene pool of the breed, as well as restore local breeds, including Tobets, which are on the verge of extinction.

Key words: mastiff dog breeds, Tobet, genetic diversity, phylogeny.

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Мастиф тәрізді ит тұқымдарының генетикалық зерттеулеріне шолу

Қазіргі уақытта иттерге генетикалық зерттеулер кеңінен жүргізілуде. Дегенмен, әлемде 400-ден астам түрлері мен тұқымдары бар, және олардың бәрі бірдей жақсы зерттелмеген. Мәселен, қазақтың ұлттық төбет иттеріне жататын мастиф тәрізді иттер генетикалық тұрғыдан жеткілікті зерттелмеген. Бұл жұмыстың мақсаты – ғылыми әдебиеттердегі мастиф тәрізді иттердің әртүрлі түрлері бойынша генетикалық зерттеулерге шолу жасау. Шолуда мастиф тәрізді иттердің генетикалық алуантүрлілігі, тұқымдардың тіршілік ету жағдайларына бейімделу механизмдері, ауруларға бейімділіктің генетикалық факторлары, сондай-ақ әртүрлі тұқымдар арасындағы филогенетикалық байланыстар қарастырылған. Жергілікті ит тұқымдарының филогенетикалық байланыстарын анықтау, осы тұқымдар қалыптасқан аймақтарды мекендеген халықтардың тарихымен және филогеографиясымен байланысын қадағалауға мүмкіндік береді. Генетикалық әртүрлілік параметрлерін және инбридинг деңгейін талдау ұлттық ит тұқымдарын сақтау және жетілдіру үшін ғылыми негізделген тәсілдерді қолдануға, оларды өсіру жөніндегі бағдарламаларды жақсартуға, иттердегі тұқым қуалайтын аурулардың санын азайтуға, тұқымның генофондын сақтауға, сондай-ақ, жойылу шегінде тұрған жергілікті тұқымдарды, соның ішінде Төбеттерді қалпына келтіруге мүмкіндік береді.

Түйін сөздер: мастиф тәрізді ит тұқымдары, Төбет, генетикалық әртүрлілік, филогения.

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Обзор генетических исследований мастифообразных пород собак

Генетические исследования собак в настоящее время проводятся достаточно широко. Однако, в мире насчитывается более 400 разновидностей и пород собак, и не все они изучены одинаково хорошо. Так, мастифообразные собаки, к которым относится казахская национальная порода пастушьих собак Тобет, в генетическом плане исследованы недостаточно. Целью данной работы является обзор имеющихся в научной литературе генетических исследований у различных разновидностей мастифообразных собак. В обзоре рассмотрены генетическое разнообразие мастифообразных собак, механизмы приспособленности пород к условиям обитания, генетические факторы предрасположенности к заболеваниям, а также филогенетические связи между различными породами. Установление филогенетических связей аборигенных пород собак позволяет проследить корреляцию с историей и филогеографией народов, населявших районы формирования данных пород. Анализ параметров генетического разнообразия и уровня инбридинга позволит применить научно-обоснованные подходы для сохранения и совершенствования национальных пород собак, улучшить программы по их разведению, уменьшить число наследственных заболеваний у собак, способствовать сохранению генофонда, а также восстановлению местных пород, в том числе и Тобетов, находящихся на грани исчезновения.

Ключевые слова: мастифообразные породы собак, Тобет, генетическое разнообразие, филогения.

Introduction

Mastiff-type dogs have been faithful companions of man since ancient times and were used mainly as guard and hunting dogs. Images of mastiff-type dogs have been found on Egyptian monuments dating back to 3000 BC. During archaeological excavations in the city of Nineveh, a vase dating back to 612 BC was discovered; the vase depicts a massive dog with a large square head and armor [1]. Julius Caesar mentioned the huge dogs of the Britons who fought with their masters against the Roman legions in 55 BC. [2]. These dogs came to Great Britain together with the Celtic tribes who came from Asia Minor in the 4th-3rd centuries BC. There are different points of view on the origin of the breed, but the exact origin is unknown. According to many researchers, Tibetan mastiffs, which lived in the mountains of Central Asia two thousand years ago, are the most likely ancestors of modern mastiffs. Considering that in ancient times the most important trade routes passed through Asia, Asian dog breeds could have spread throughout the world.

The beginning of purebred breeding of mastiffs dates back to the 15th century. The breed underwent various changes several times, as well as periods of decline in numbers up to almost complete extinction, and periods of recovery. Thanks to thoughtful selection, it was possible to recreate and significantly improve the breed. Now mastiffs are widespread throughout the world, the breed is gaining popularity, and all new varieties are achieving official recognition.

In modern cynological science, there is a tendency to reorient research of various dog breeds to the genetic level of analysis, which contributes to a deeper understanding of the genetic mechanisms that determine the health, behavioral characteristics and evolutionary development of dogs. And in general, it should be noted that genetic research of dogs is carried out quite widely. However, genetic studies of mastiffs are few and far between, and many of their varieties, including the Kazakh Tobet, have still been virtually unstudied at the molecular genetic level. At the same time, the results of genetic analysis can influence such important aspects as reducing the genetic load and decreasing hereditary diseases, improving the health and well-being of breeds, and improving breeding and restoration programs.

In this paper, we reviewed literature on genetic studies of mastiff-like dog varieties common in different countries of the world.

Literature review

Currently, the mastiff-like group of dogs includes 24 breeds, 14 of which are internationally recognized and another 10 are not officially recognized yet. All mastiffs are large, well-proportioned and powerful animals, with an average weight of

50 kg and an average height of at least 60 cm. All varieties have a muscular build, a large head and a flat, wrinkled forehead, a square muzzle with pronounced flews, a powerful neck, a wide mouth, a thick tail, slightly outwardly turned paws, and V-shaped hanging ears. The length of the coat, color, eye and nose color depend on the breed variety.

The Kazakh Tobet [3] also belongs to the mastiff-like group of dogs. This is an ancient breed of large and strong shepherd dogs, which was known even before our era. Tobets are described in the books of Marco Polo as large, donkey-sized, assistant dogs for nomads. Tobets are strong, hardy, unpretentious dogs, adapted to harsh climatic conditions and a nomadic way of life. The coat is thick, coarse, with a well-developed undercoat, the color is black, brown, red, gray, their combinations are possible. Height at the withers is 66-76 cm, weight is 45-65 kg. The average life expectancy is 11-14 years. Tobets were faithful assistants of nomads, they have long been used for grazing and guarding livestock and protecting them from wolf attacks. These are calm, balanced dogs with a pronounced territorial instinct, natural guard dogs. They bark little. One of the characteristic differences of the Tobets from other wolfhounds is friendliness to a peacefully minded person and a child. In an unfamiliar environment, the behavior is calm, confident. It has a high intelligence, is able to assess the situation and make decisions.

Unfortunately, in recent years the population of Tobets has significantly decreased. Today, the breed is on the verge of extinction. To preserve the breed, it is necessary to study it thoroughly, including genetic research to study the genetic structure of the population.

The appearance of some breeds from the Mastiff-like dog group is shown in Figure 1.

A B C

D E F

Figure 1 – Appearance of some mastiff-type dog breeds.
A – Turkish Mastiff (Akbash), B – English Mastiff, C – Neapolitan Mastiff,
D – Kazakh Tobet, E – Bullmastiff, F – Tibetan Mastiff.

One of the most studied genetically among mastiff-like breeds is the Tibetan Mastiff (TM), which is considered to be the ancestor of all mastiffs.

The TM is a breed of domestic Chinese dogs well adapted to the high-altitude conditions of Tibet, considered one of the most archaic, ferocious and largest dogs in the world. There are a number of studies, mainly by Chinese scientists, devoted to the genetic mechanisms of adaptability of this breed to the extreme environmental conditions of the Qinghai-Tibet Plateau, such as low oxygen concentration, very cold and dry climate, strong UV radiation. At high altitudes, high levels of UV radiation can cause direct DNA damage. In addition, hypoxia increases the production of reactive oxygen species, which increase DNA damage. A number of studies have revealed that the mechanisms of TM adaptation to high altitude are determined by several genes associated with adaptation to hypoxia, in particular EPAS1 and HBB [4-7]. Based on genome-wide data analysis, Cai C et al. identified, that families of DNA repair and damage response genes are expanded in TM [8]. Contrariwise, the authors revealed a limitation of the gene families associated with ATPase activity. This allows cells to reduce ATP production and oxidative phosphorylation of mitochondria, and thus reduce ATP consumption under hypoxic conditions. Genes involved in the regulation of RNA polymerase II transcription (p65, ATF3, EHF, Loc4981817, ZNF280D, MYPOP, ATF5, and FOXI2), as well as some genes involved in the hypoxia response and α/β-oxidation of fatty acids, were shown to be under positive selection in the Tibetan Mastiff [8].

Based on the SNP polymorphism studies, Li Y. et al. conducted a comparative analysis of TM, aboriginal Chinese dogs and gray wolves to identify candidate genes for high-altitude adaptation [9]. The investigation also confirmed the important role of genes associated with the response to hypoxia in adaptation to the Tibetan Plateau environment in different groups of organisms. Of the 16 genes that showed positive selection signals, 12 genes were associated with the body’s response to hypoxia, including the genes EPAS1, SIRT7, PLXNA4 and MAFG .

Studies of altitude adaptation in TM are mainly related to genes localized in autosomes. However, Hong Wu et al. focused on the X chromosome [10]. The advantage of this approach is the reduced population size and the ability to analyze the hemizygous state in males. Based on publicly available genome-wide data from five TM and five dog populations living at altitudes from 300 to 4000 m, the authors identified five genes localized in the X chromosome and showing signs of selection. One of these genes was angiomotin (AMOT), which is associated with the process of angiogenesis.

A number of investigations are also devoted to the study of genetic diversity and structure of TM populations. In the work of Ren D.R. et al., using 10 microsatellite loci, an assessment of the genetic diversity of TM from 4 populations (Tibet, Gansu, Qinghai and Beijing) was carried out [11]. The results of microsatellite analysis showed high genetic diversity in all studied TM populations. Thus, the number of alleles per locus (Na) ranged from 6 to 13, the observed heterozygosity Ho = 0.69, the expected heterozygosity He = 0.79, the average PIC value was 0.758. Interestingly, within the populations there was a significant deficit of heterozygotes (the average FIS value = 0.11,), as well as fairly high inbreeding rates (the average FIT value = 0.12, bootstrap 95% CI (0.06, 0.18)). Thus, inbreeding has occurred quite frequently in TM populations, so the breed needs effective breeding projects based on genetic research.

In the work of Miao B. et al. the origin of genes of high-altitude adaptation in TM was studied [12]. Comparative analysis of canine genomes showed that the differences in haplotypes of the EPAS1 and HBB loci in high-mountain dogs and dogs from lowland areas are much greater than in high-mountain dogs and wolves. Based on the calculation of the recombination rate, the authors excluded the influence of ancestral polymorphisms in the EPAS1 and HBB loci. Lower sequence divergence compared to the genomic background indicates a relatively recent splitting of alleles and confirms the introgression hypothesis. Thus, introgression of the EPAS1 and HBB loci in mountain dogs helped them adapt to a hypoxic environment in a relatively short period of time.

Research is underway to study the genetic polymorphism of STR loci to create a gene polymorphism database for the Tibetan Mastiff. Using fluorescent multiplex amplification of STR loci, Xiong X et al. analyzed the polymorphism of 16 STR loci in 449 TM [13]. As a result, it was shown that all the studied loci are highly polymorphic. Thus, the FH2010 locus had 10 alleles, the PEZ21 locus had 12 alleles, and the PEZ05 locus had 13 alleles. The remaining 13 loci had more than 15 alleles. Thus, the analysis of polymorphic STR loci provides the opportunity for individual identification and can be used to determine paternity in TM. The high degree of polymorphism of the studied loci provides the basis for the creation of a TM gene polymorphism database.

The mitochondrial genome of Tibetan Mastiffs has been extensively studied. Since mitochondrial DNA is not highly conserved and has a fairly high mutation rate, the mitochondrial genome sequence can be used to identify and reveal phylogenetic relationships between different groups of organisms, and in particular, between dog breeds.

Deng LX and He S. revealed the complete sequence of the TM mitochondrial genome [14]. The authors showed that the TM mitochondrial genome consists of 16,729 bp and has a typical structure: 13 protein-coding genes, 22 transfer RNA genes, 2 ribosomal RNA genes, and a non-coding region. The non-coding region (D-loop region) has common features with the mitochondrial genomes of other mammals, and the largest number of variable sequences is located in this region.

The complete mitochondrial genome sequence of TM was also characterized by Guo X. et al. in another study using Illumina high-throughput sequencing technology [15]. The authors showed that the total length of the circular mitochondrial DNA included 16,730 bp. Similar to the previous study the mitogenome structure was characterized as typi- cal for vertebrates and included the same genomic components. The authors identified transcription initiation codons, as well as 3 types of stop codons for mitochondrial genes. According to the nucleotide composition, the mitogenome of TM is distributed as follows: 31.6% A, 25.5% C, 14.2% G and 28.7% T. Thus, TM mtDNA is significantly enriched in A-T pairs, which make up 60.3%.

In a study of mtDNA of purebred Chinese Tibetan Mastiffs by Li YX et al., the mtDNA control region (D-loop region), which is non-coding but regulates the processes of mitochondrial replication and transcription, was analyzed [16]. The authors found that this region in TM contained blocks of conserved sequences, a central domain, and sequences associated with termination, and the length of the sequence varied due to a different number of 10-nucleotide repeating units. In the control region of TM mtDNA, the authors identified 75 polymorphic sites that constitute 37 haplotypes; the diversity of the haplotype was 0.990, and the diversity of nucleotides was 1.201. Based on the sequences of the control regions, a phylogenetic tree was constructed in which Chinese TM were divided into three categories according to the origin and geographical classification of TM. Phylogenetic analysis of the hypervariable sequence HVR-I showed a close relationship between TM and Labrador retrievers.

Cai Z.F. et al. analyzed the mtDNA genomes of TM using long-range sequencing technology [17]. Since this technology increases the accuracy of reads, the authors were able to analyze high-quality reads from the mitochondrial genomes of 79 TMs. As a result, it was found that Tibetan Mastiffs living outside the Tibetan Plateau have hybridized with other dogs.

To preserve the population of TM, studies on their genetic diversity are of great importance. Ren Z. et al. conducted a comparative analysis of mtDNA of individuals from Gansu Province and the Tibetan region [18]. As a result of sequencing the hypervariable region I of mtDNA, the authors identified twelve polymorphic sites and eight haplotypes. Haplotypes H4 and H8 were found only in the Tibetan population. In Gansu Province, the genetic diversity of the TM population was higher than in the Tibetan region. Genetic variability in the general population was low, which indicates the need for measures to protect the TM gene pool. Based on the results of sequencing the hypervariable region I of mtDNA, the authors constructed a phylogenetic tree and found that TM originated from gray wolves and had different maternal lines.

The work of Zhang S. and co-authors is devoted to the study of biological characteristics of mesenchymal stem cells of TM bone marrow [19]. As is known, pluripotent stem cells can differentiate into various cell types and have great potential for use in therapy and restoration of tissues and organs. The authors cultured TM bone marrow stem cells for 23 passages and then analyzed their karyotype. As a result, it was shown that the mesenchymal stem cells were diploid, genetically stable and had the potential to differentiate into adipocytes, hepatocytes, osteoblasts, cartilage cells and insulin-secreting cells. Using semi-quantitative PCR and ELISA, it was shown that TM stem cells express cluster of differentiation (CD) 73, CD90, CD105, CD166 and vimentin. It was revealed that these cells can self-renew, but their proliferation rate decreases with age. The study showed the potential of TM stem cells for therapy and regeneration processes.

There are far fewer published studies on other mastiff varieties, even for common breeds such as the English Mastiff and Bullmastiff. The available studies focus primarily on health issues related to longevity and mortality. Health issues may be the result of complex interactions between many genes, or may be due to limited genetic variation within a breed, which favors the inheritance of defective genes.

A study by Bell L et al. reported morbidity and mortality data for mastiffs based on a survey of dog owners [20]. According to the survey results, the average age at death was 8 years, with the average age at death in Europe being 7.72 years and in North America 8.17 years. The most common causes of death for all dogs were cancer (47%), old age (16%), heart problems (8%), and stomach problems (7%). The average age at death from cancer in dogs was 7.85 years, with 23 types of cancer identified, the most common being osteosarcoma, especially in neutered animals.

Familial cerebellar ataxia with hydrocephalus in Bullmastiffs has been previously described as a monogenic autosomal recessive trait [21]. Christen M. et al. examined two bullmastiffs with disease-onset traits at a young age [22]. They sequenced the affected bullmastiff's genome and compared it with genomes from different dog breeds, as well as with archival samples from two other affected bullmastiffs. They found that the affected dogs had a pathogenic homozygous frameshift variant in the MFF gene that shortens the wild-type open reading frame and is the most likely cause of the disease. Because the phenotype of this disease in bullmastiffs is similar to that in humans, the authors propose renaming it "mitochondrial fission encephalopathy (MFE)".

Lymphoma is a fairly common disease among bullmastiffs. Lymphoma is a disease with a hereditary predisposition. The study by Mortlock S.A. et al. was devoted to identifying risk loci predisposing to the disease in this breed [23]. Based on a genome-wide association analysis (GWAS) of 49 sick mastiffs and 281 control cases, the authors identified genomic regions associated with the risk of lymphoma, localized to CFA13 and CFA33. SNPs with both genome-wide and chromosomal significance were identified in these regions. The authors identified potential candidate genes associated with lymphoma, including the MYC proto-oncogene, the bHLH (MYC) transcription factor, the Pvt1 lncRNA oncogene (PVT1), and a region syntenic with human and mouse lncRNA Pvt1. The authors suggest that the increased risk of developing lymphoma may also be due to a predisposing genetic background.

Among other tumors in mastiff-like dogs, cases of sarcoma have been described, the incidence rate is also quite high [24-25]. Genetic factors are also involved in the development of this disease, since familial cases of the disease have been described. Based on the expression of the CD28, abca5, CCDC3 and SMOC2 genes, three molecular subgroups of lymphoma were identified and demonstrated the possibility of predicting the development of the disease and a correlation with survival. Prognostic factors also include the expression of the p53 and p16 genes, as well as the expression of the VH1-44 gene, encoding the variable region of the immunoglobulin heavy chain [26-28].

There are a number of works in the literature devoted to the study of hereditary ophthalmological diseases. This is a rather heterogeneous group of eye diseases described in various dog breeds. Ki- jas J.W. and co-authors studied the inheritance of progressive retinal atrophy (PRA) in the English Mastiff [29-30]. The disease has a dominant type of inheritance. Analysis of candidate genes allowed to characterize two synonymous and one non-synonymous mutation in the canine rhodopsin gene. The authors found that the non-synonymous mutation (T4R) causes progressive retinal atrophy in the English Mastiff. At the same time, this mutation was not detected among dogs suffering from PRA and belonging to other studied breeds. Thus, testing of bullmastiffs for the presence of T4R revealed that one of them was heterozygous for this mutation, and the second was homozygous for the wild type. This fact allowed the researchers to conclude that the T4R mutation is specific to the English Mastiff breed. The authors described the disease phenotype in the English Mastiff as similar to the phenotype of people with mutations in the rhodopsin gene. Thus, studying this disease on a canine model will allow us to better understand the mechanisms of disease development and open up new prospects for the development of therapeutic methods.

Caduff M. et al. studied the mechanisms of oculocutaneous albinism development in bullmastiffs [31]. It is known that this disease in humans and many animal species is caused by variants of the SLC45A2 gene. Caduff M et al. analyzed the genome sequence of a highly inbred bullmastiff with oculocutaneous albinism. As a result of the genomic data analysis, the authors were able to identify a single nucleotide deletion in exon 6 of the SLC45A2 gene (NM_001037947.1:c.1287delC), previously not registered in known databases. According to the predictors, this deletion will lead to an early premature stop codon. The authors validated the obtained result using the Sanger sequencing method, the results of which coincided with the phenotypes of the family members of the affected bullmastiff. Genotyping results from 174 unrelated dogs of different breeds showed that they were homozygous for the wild type. This allowed the authors to conclude that SLC45A2:c.1287delC is the cause of oculocutaneous albinism in the affected bullmastiff.

Overall, it should be noted that studies of inherited ophthalmologic diseases in dogs are important for the search for candidate genes responsible for the development of the disease, as well as for the development of animal models that mimic human diseases.

Among other inherited diseases, familial juvenile glomerulonephropathy has been described in French Mastiffs [32]. In addition to analyzing clinical and histological data, the authors also studied the pedigrees of the affected mastiffs. It was found that individuals of both sexes were affected by glomerulopathy with the same frequency, therefore, the genes associated with the development of the disease are not linked to the X chromosome, but are inherited autosomal. Analysis of the inheritance of glomerulonephropathy in a number of generations allowed the authors to assume an autosomal recessive type of inheritance, although more complex variants cannot be ruled out, for example, autosomal dominant with incomplete penetrance or polygenic.

Since mastiffs are large dogs, they are susceptible to various joint diseases. Cases of elbow and hip dysplasia have been reported in various dog breeds [33-35]. These diseases often occur together with osteoarthritis. Ginja M. et al. searched for candidate SNPs to identify associations with various joint diseases and assess genetic risk, but did not identify significant polymorphisms [35]. Presumably, this is due to the complex multifactorial nature of the diseases under study, which may include polygenic inheritance and significant influence of environmental factors. Research to identify the molecular genetic basis of joint dysplasia continues, but progress in this direction is slow.

A number of studies have been devoted to the investigation of the genetic diversity of different dog breeds. Thus, in the study by Mortlock S.A. et al., the genomic diversity of Bullmastiffs was stud- ied using genealogical and molecular analysis. [36]. The genealogical analysis took into account the data on the pedigrees of Bullmastiffs for more than 30 years. The inbreeding coefficient based on the genealogical analysis averaged 0.044, the number of common founders (142) was greater than the effective number of founders (79). The assessment of genetic diversity and population structure was based on the analysis of genome-wide genotyping data of 170,000 single nucleotide polymorphisms in 185 Bullmastiffs. Main indicators were calculated on the basis of the molecular analysis of SNPs. The average inbreeding coefficient was 0.033, multilocus heterozygosity (MLH) – 0.206, the effective population size (Ne) – 29.1. In general, it can be noted that the molecular and genealogical estimates of the inbreeding coefficients for genotyped dogs show a positive correlation. Given the relatively small effective population size, reducing the level of inbreeding may be beneficial to the overall welfare of the breed. To determine the phylogenetic relationships of the Bullmastiff, the authors constructed a neighbor joining tree, which showed a close relationship with the English Bulldog, one of the ancestors of the Bullmastiff breed.

In another study by the same authors [37], genetic variants specific to the Bullmastiff breed were identified using high-density signal intensity data and whole genome sequencing. The genome-wide analysis identified approximately 3000 copy number variants (CNVs) in Bullmastiffs. After sequence alignment, 82 CNV regions were identified, of which 50 regions had not been previously identified in other dog breeds and are potentially breed-specific. Finding specific genetic markers may be important for future studies of breed-specific characteristics or diseases.

In recent years, the number of studies devoted to the phylogenetic relationships and the evolution of various dog breeds has increased.

In the study by Cai C et al., a comparative analysis of the genomes of Tibetan Mastiff, Mongolian Mastiff and Canis Lupus was carried out [8]. The authors performed de novo sequencing of the Tibetan and Mongolian mastiffs and Canis Lupus genomes and conducted a comparative analysis of repetitive sequences in their genomes. Based on the genomic sequence data, the authors constructed a maximum likelihood phylogenetic tree and determined the taxonomic status of the studied dog breeds. As a result, a close relationship was revealed between the Tibetan and Mongolian mastiffs, which turned out to be very close in phylogenetic terms. In addition, TM and Mongolian mastiff formed a common clade with Canis Lupus, despite the diversity of their habitats. This suggests that the Tibetan and Mongolian mastiffs originated from Canis Lupus.

Similar results were obtained when analyzing the results of mtDNA sequencing of TM. The work of Li Q. et al., based on the analysis of mitochondrial DNA sequences, is devoted to the study of the origin of Tibetan mastiffs [38]. The authors determined the complete mitochondrial genome (mtDNA) sequence of the Tibetan mastiff and analyzed the phylogenetic relationships between the Tibetan mastiff and other Canidae species using the coyote (Canis latrans) and The gray wolves (Canis lupus) as the outgroups. As a result, the authors showed that TM and other dog breeds are grouped together with the gray wolf, while coyotes are grouped separately. This proves the origin of TM and other dog breeds from the gray wolf. At the same time, TM is grouped with large dog breeds, while smaller ones are grouped separately. Therefore, the origin of large breeds such as the Old English Sheepdog, Leonberger, and Saint Bernard from TM seems quite likely. The authors also showed that the approximate time of TM divergence from the gray wolf turned out to be 16,000 years earlier than in other breeds.

Similar data on the origin of the Tibetan Mastiff were obtained using DNA barcoding, which is also an effective method for species identification and analysis of phylogeny and evolutionary relationships [39]. For the first time, the authors applied the method of DNA encoding of the cytochrome oxidase C gene subunit I in various representatives of the canine family. The authors constructed a phylogenetic tree and identified 4 different maternal lineages in dogs (A-D). They revealed, that TM is of East Asian origin, as it belongs to the A line, and is probably the ancestor of a number of large dog breeds.

The study by Australian scientists Hsu WT, Williamson P, Khatkar M is devoted to the analy- sis of genomic differences and similarities between groups of individuals of many breeds. [40]. The authors combined the available genetic resources of their own laboratory biobank with publicly available data on the genotypes and phylogenetic structure of 23 breed clades to detect genomic regions specific to bullmastiffs. In total, more than 8,000 dogs belonging to 250 breeds were examined. As a result, significant genomic regions specific to bullmastiffs were identified on 15 chromosomes and the similarity of bullmastiffs with the ancestors of the breed: mastiffs and bulldogs was shown. The most specific regions were found on chromosomes CFA1, CFA9 and CFA18. Significant regions were identified on 15 chromosomes, with the most differentiated regions found on CFA1, CFA9 and CFA18. The study contributes to the understanding of the processes of genetic drift in the formation of a breed, as well as the relationship of genetic determinants with its characteristic features and morphological traits.

The population structure of Chinese dog breeds was studied in the work of Yang Qiu et al. [41]. To analyze genetic diversity and determine family relationships, the authors genotyped 157 unrelated dogs belonging to 15 different Chinese breeds. For comparison with some Western breeds (Rottweiler, Papillon) and the Asian wolf, data from open sources (LUPA database) were used. As a result, it was found that the indigenous breeds of Chinese dogs had a lower LD index, as well as a lower level of heterozygosity. When constructing a phylogenetic tree, a clear division of Chinese and Western dog breeds into two clades was found. The authors included Kazakh Shepherd Dogs and Mongolian Si Dogs among the indigenous Chinese breeds. Evidence of introgression of Western dogs into the genomes of Chinese and Kazakh Shepherd Dogs and Mongolian Si Dogs was obtained. It is noteworthy that the largest number of polymorphic SNPs were found in Kazakh Shepherd Dogs. The authors identified candidate genes that may be responsible for certain phenotypic traits of Chinese indigenous dog breeds. All the dog breeds studied that inhabit the Qinghai-Tibet Plateau, including the TM, were grouped together and showed signs of genetic adaptation to high altitude. At the same time, breeds belonging to the moun- tain hound group had the genes KRT9, CAMTA1, NOL8 and RORB, which are supposedly candidate genes that affect running speed. The authors also calculated the genetic distances between the breeds, which turned out to be greater between Chinese breeds than between Western breeds. This suggests greater differences between Chinese breeds, which is likely due to earlier domestication and less strict breeding programs for Chinese dogs. Based on the results of the phylogenetic analysis, the authors suggested that Western breeds such as the Papillon, Eurasier and Greenland Sled Dog may have Chinese origins, since these dogs were grouped with Chinese populations.

Genetic studies of the Kazakh Tobet breed of dogs were initiated by Perfilieva A. et al. To date, studies of the genetic structure of the Tobet population from southern Kazakhstan have been conducted using minisatellite markers. Based on the analysis of allele frequencies of 19 microsatellite loci recommended by the International Society of Animal Genetics for dogs, the authors determined the main indicators of genetic variability in the studied sample [42]. The obtained data were analyzed in a comparative aspect with other dog breeds. The authors revealed a high level of heterozygosity and polymorphism in the studied population. The percentage of polymorphic loci was 100%, with 5-10 alleles per locus. The Hardy-Weinberg equilibrium assessment showed a deviation for two loci AHT137 and AHTh260. The average number of alleles and the average effective number of alleles in Tobets were higher than in other molossoid dog breeds. The level of PIC polymorphism exceeded 60% for all loci. The high level of genetic diversity and the overall low level of inbreeding, quantitatively assessed using microsatellite loci, were comparable with similar indicators characteristic of mongrel dogs. According to the authors, the high observed heterozygosity indicates the presence of crossbreeding processes in the studied sample [42].

These data were confirmed by the authors on a larger sample, including dogs from different regions of Kazakhstan and Mongolia [43]. In addition to the microsatellite analysis data, this work analyzed the results of whole-genome sequencing of two Tobet dogs. The authors confirmed the high level of heterozygosity and polymorphism characteristic of the Tobet breed. The analysis of genomic data showed a complex genetic structure of Tobets, characterized by seven different clusters found in all studied populations from three regions of Kazakhstan and Mongolia. Based on the genomic data of 45 dogs from 25 breeds, including two Tobets, the authors constructed a phylogenetic tree that showed a genetic relationship between the Kazakh Tobets, Central Asian Shepherd Dog, and Turkish Akbash. The presence of the A18 haplotype in Kazakh Tobets confirms the hypothesis of the ancient origin of the breed, which was previously suggested based on archaeological finds and written sources.

To summarize, it can be noted that the Tibetan Mastiff is the most studied genetically among mastiff-like dog breeds. It is followed by the Bullmastiff, English Mastiff, Kazakh Tobets, Neapolitan Mastiff, and French Mastiff, with a fairly large gap (Figure 2). For many other mastiff-like breeds, there is no information on genetic studies in the scientific literature.

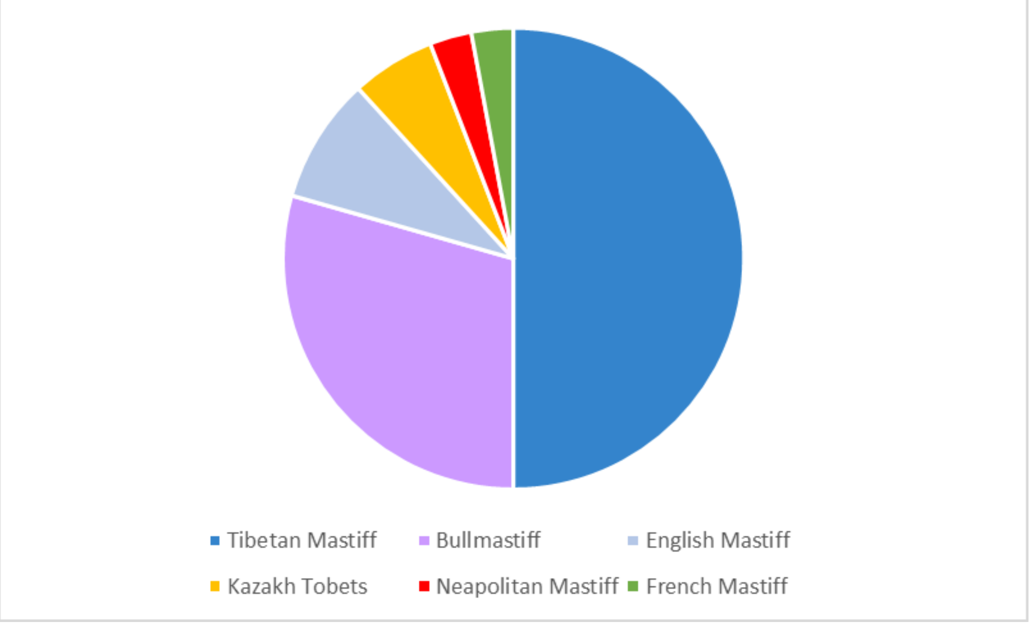
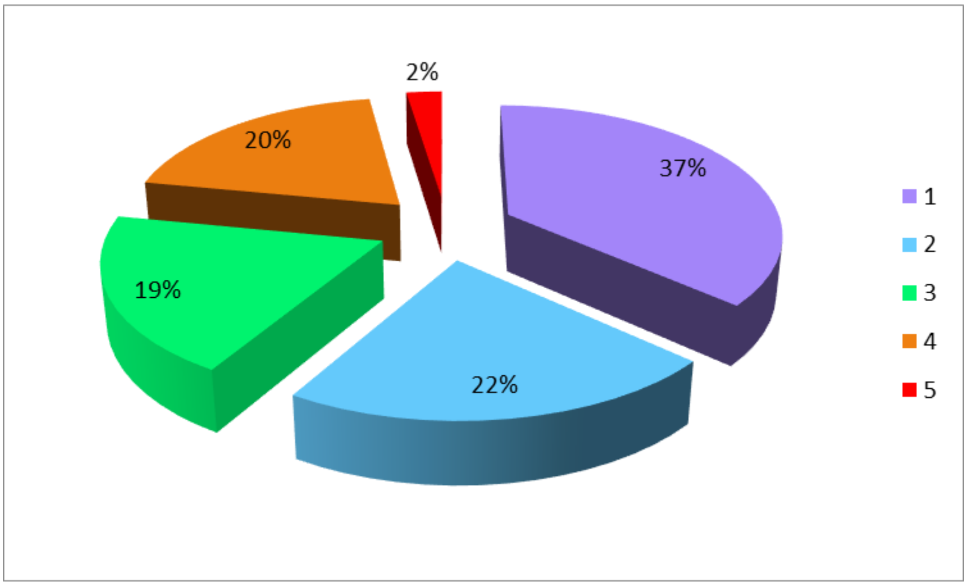


Figure 2 – Number of genetic studies for different mastiff-type dog breeds

The largest number of studies are devoted to the study of diseases among different dog breeds, since hereditary pathology can play an important role in selection work to improve breed characteristics. Researchers are also interested in the origin and phylogenetic relationships with other breeds, since these aspects help to better understand the processes of ancient migrations. Many works are devoted to the study of genetic diversity and population structure, as well as adaptation resources (Figure 3).



1 – diseases; 2 – phylogenetic relationships; 3 – genetic diversity and population structure;
4 – adaptive capabilities; 5 – stem cell research.

Figure 3 – Share of research on different topics.

Conclusion

Thus, genetic studies of dogs allow us to identify genetic markers specific to a particular breed, characterize the population structure, assess genetic diversity and trace phylogenetic relationships between different breeds, and assess the contribution of genetic variants to the development of diseases. In most cases, known dog breeds have limited genetic diversity, which is a consequence of a small founder population, selection for exterior appearance, and minimal geographic locations for breeding. In addition, inbreeding used in dog breeding to preserve breed characteristics increases the genetic load of the population, contributing to the accumulation of mutations and the spread of hereditary diseases. Genetic studies contribute to an increase in knowledge about mastiff diseases and determine future prospects for the treatment of pets. The results of genetic studies can also be used to improve the welfare of the breed. Assessing the genetic diversity and identifying phylogenetic relationships of dog breeds can significantly complement and improve breeding and restoration programs.

In conclusion, it should be noted that the aboriginal dog breeds in Kazakhstan, which are a unique historical heritage, have not yet been studied at the molecular genetic level. Meanwhile, knowledge of the genetic structure and identification of genetic markers of a particular breed are important for the preservation and improvement of the breed, as well as for the conservation of the biodiversity of the region. The results of genetic studies can be used in drawing up programs for the preservation and breeding of dog breeds adapted to local conditions and the characteristics of human economic activity.

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Conflict of interest

The authors of the article confirm the absence of a conflict of interest.

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АВТОРЛАРҒА АРНАЛҒАН АҚПАРАТ

«ҚазҰУ хабаршысы. Экология сериясы» журналы 1992 жылы құрылған. Журналдың құрылтайшысы және шығарушысы әл-Фараби атындағы Қазақ ұлттық университеті болып табылады. Журналдың жоғары оқу орны көрсетілген мұқабасы мен титулдық парақтары, шығыс деректері, ISSN, eISSN, редакциялық алқа құрамы, редакциялық саясаты, жарияланымдық этикасы және веб-сайты бар.

Журнал жылына 4 рет шығарылады.

Журнал авторлардың жарияланымдарының ақпараттық ашықтығы және қол жетімділігі саясатына сәйкес келеді, мақалалар журналдың сайтында орналастырылады https://bulletin-ecology.kaznu.kz үш тілде толық мәтінді қолжетімділікте

Журналдың мақсаты – экология және табиғи ресурстар саласындағы алдыңғы қатарлы зерттеулердің нәтижелері мен жан-жақты көрсетілімін қамтамасыз ету. Журнал экологиялық проблемалар мен қоршаған ортаны қорғауға ғылыми қызығушылық танытатын ғылыми қызметкерлерге, оқытушыларға, докторанттар мен түрлі мамандықтағы студенттерге арналған.

Журнал міндеттері:

- Экология және қоршаған ортаны қорғау бойынша фундаменталды және қолданбалы ғылымның түрлі салаларында маңызды мәнге ие жаңа ғылыми нәтижелерді жариялау.
- Диссертацияларды қорғауға және ғылыми мамандықтар бойынша ғылыми дәрежелер алуға үміткер магистранттар мен докторанттардың ғылыми жұмыстарының нәтижелерін кең жариялаудың ашықтығы мен қол жетімділігі ортасын құру.
- Ғылыми қоғамдастықтың, сондай-ақ жас және жаңа бастаған ғалымдардың журналға деген тұрақты қызығушылығын қалыптастыру, оның экология мәселелерін зерттейтін мамандардың кәсіби ортасында өсіп келе жатқан қажеттілігін қалыптастыру.

Журнал материалдары экология және қоршаған ортаның ластануы саласындағы проблемалардың кең ауқымын қамтиды. Мақалалар **экологияның келесі тақырыптық бөлімдері** бойынша жарияланады:

- Жер туралы ғалым;
- Қоршаған ортаны ластау және қорғау;
- Экологиялық биотехнология;
- Адам, өсімдіктер, жануарлар және микроорганизмдер экологиясы;
- Климаттың ғаламдық өзгеруі, су ресурстарын басқару,
- Бұзылған экожүйелерді қалпына келтіру;
- Қоршаған орта және көші-қон;
- Қалалар және климаттың өзгеруі;
- Экологиялық ойлау және адамзат стратегиясы.

«ҚазҰУ хабаршысы. Экология сериясы» журналының тақырыптық бағыттарына сәйкес келетін және қолжазбаны ресімдеу талаптары бойынша қатаң ресімделген, автордың (авторлардың) қазақ, орыс немесе ағылшын тілдерінде бұрын жарияланбаған мақалалары қабылданады.

«ҚазҰУ хабаршысы. Экология сериясы» журналы авторлардың ғылыми жұмысқа құқығын сақтайды және журналға бірінші жариялау құқығын жұмыспен бірге береді, оны бір уақытта Creative Commons Attribution License (CC BY-NC-ND 4.0) бойынша лицензиялайды.

Жариялау процесінің барлық қатысушылары, атап айтқанда, әрбір автор, ғылыми редактор, рецензент, жауапты хатшы, «ҚазҰУ хабаршысы. Экология сериясы» ғылыми журналының редакциялық алқасының мүшелері міндетті түрде жариялау этикасының қағидаларын, нормалары мен стандарттарын ұстануға міндетті. Этикалық қағидаларды сақтау ғылыми журналдың сапасын қамтамасыз ету және сақтау үшін де, жариялау процесіне қатысушылар арасында сенімді және құрметті қарым-қатынас құру үшін де маңызды.

Мақаланы жариялау төлемі тек редакцияның мақаланың қабылданған шешімі хабарламасынан кейін ғана жүргізіледі. Жарияланым құны – 2000 теңге/бет WORD форматында (шрифт 12, Times New Roman).

Реквизиттер:
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БИК TSESKZKA

INFORMATION FOR AUTHORS

Journal «Vestnik KazNU. Ecological Series» was founded in 1992. In 2007 was renamed as **«Eurasian Journal of Ecology»** (in the English version). The founder and publisher of the journal are the Al-Farabi Kazakh National University. The journal has a developed and approved cover and title pages with an indication of the institution, imprint of the issue, ISSN, eISSN, editorial board, editorial policy, publication ethics, and website. The journal is published 4 times a year.

The journal follows the policy of information openness and accessibility of authors' publications, articles are posted on the journal's website https://bulletin-ecology.kaznu.kz in three languages in full-text access.

The aim of the journal is to provide a comprehensive presentation and results of cutting-edge research in the field of ecology and natural resources. The journal is intended for researchers, teachers, doctoral students, and students of various specialties who show scientific interest in environmental problems and environmental protection.

Journal objectives:

- To highlight new scientific results of significant importance in various fields of fundamental and applied science in ecology and environmental protection.
- To create an environment of openness and accessibility of wide coverage of the results of scientific work of undergraduates and doctoral students applying for the defense of dissertations and obtaining academic degrees in scientific specialties of dissertation councils in various fields of ecology.
- To form a constant stable interest among the scientific community, as well as among young and novice scientists in the journal, its growing demand in professional circles of specialists researching environmental issues.

The journal's materials cover a wide range of problems in the field of ecology and environmental pollution. Articles are published in the following thematic sections of ecology:

- Earth Science;
- Pollution and environmental protection;
- Environmental biotechnology;
- Ecology of humans, plants, animals and microorganisms;
- Global climate change, water resources management,
- Restoration of damaged ecosystems;
- Environment and migration;
- Cities and climate change;
- Environmental thinking and human strategy.

For publication in the «Eurasian Journal of Ecology» articles previously unpublished by the author (authors) are accepted – in Kazakh, Russian or English, which correspond to the thematic areas of the journal and are designed strictly according to the requirements of the manuscript format.

Authors of articles in the «Eurasian Journal of Ecology» retain the author's right to scientific work and transfer to the journal the right of first publication along with the work, licensing it at a time under the Creative Commons Attribution License (CC BY-NC-ND 4.0).

All participants in the publication process, namely, each author, scientific editor, reviewer, executive secretary, members of the editorial board of the scientific «Eurasian Journal of Ecology» are obliged to unconditionally adhere to the principles, norms and standards of publication ethics. Compliance with ethical principles is important both to ensure and maintain the quality of a scientific journal, and also to create trust and respect between participants in the publication process.

Payment is made only after the article is accepted for publication and the editors have notified it. Publication cost – 2000 tenge/page in WORD format (font 12, Times New Roman)

Requisites:

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ИНФОРМАЦИЯ ДЛЯ АВТОРОВ

Журнал «Вестник КазНУ. Серия экологическая» был основан в 1992 году. Учредителем и издателем журнала является Казахский национальный университет имени аль-Фараби. Журнал имеет разработанные и утвержденные обложку и титульные листы с указанием вуза, выходные данные номера, ISSN, eISSN, состава редколлегии, редакционную политику, публикационную этику и веб-сайт. Журнал выпускается периодичностью 4 раза в год.

Журнал следует политике информационной открытости и доступности публикаций авторов, статьи размещаются на сайте журнала https://bulletin-ecology.kaznu.kz на трех языках в полнотекстовом доступе.

Цель журнала – обеспечить всестороннее представление и результаты передовых исследований в области экологии и природных ресурсов. Журнал предназначен для научных сотрудников, преподавателей, докторантов и студентов различных специальностей, проявляющих научный интерес к экологическим проблемам и охране окружающей среды.

Задачи журнала:

- Освещать новые научные результаты, имеющие существенное значение в различных областях фундаментальной и прикладной науки по экологии и охране окружающей среды.
- Создавать среду открытости и доступности широкого освещения результатов научных работ магистрантов и докторантов, претендующих на защиту диссертаций и получение ученых степеней по научным специальностям диссертационных советов в различных областях экологии.
- Формировать постоянный устойчивый интерес у научной общественности, а также у молодых и начинающих ученых к журналу, его растущую востребованность в профессиональных кругах специалистов, исследующих вопросы экологии.

Материалы журнала освещают широкий круг проблем в области экологии и загрязнения окружающей среды. Статьи публикуются по следующим **тематическим разделам экологии:**

- Наука о земле;
- Загрязнение и охрана окружающей среды;
- Экологическая биотехнология;
- Экология человека, растений, животных и микроорганизмов;
- Глобальное изменение климата, управление водными ресурсами,
- Восстановление нарушенных экосистем;
- Окружающая среда и миграция;
- Экологическое мышление и стратегия человечества.

Для публикации в журнале «Вестник КазНУ. Серия экологическая» принимаются ранее не опубликованные автором (авторами) статьи на русском, казахском или английском языке, которые соответствуют тематическим направлениям журнала и оформлены строго по требованиям оформления рукописи.

Авторы статей журнала «Вестник КазНУ. Серия экологическая» сохраняют за собой право автора на научную рабо- ту и передают журналу право первой публикации вместе с работой, единовременно лицензируя ее по лицензии Creative Commons Attribution License (CC BY-NC-ND 4.0).

Все участники процесса публикации, а именно, каждый автор, научный редактор, рецензент, ответственный секретарь, члены редакционной коллегии научного журнала «Вестник КазНУ. Серия экологическая» обязаны безусловно придерживаться принципов, норм и стандартов публикационной этики. Соблюдение этических принципов является важным как для обеспечения и поддержания качества научного журнала, также и для создания доверительных и уважительных отношении между участниками процесса публикации.

Оплата производится только после принятия статьи к публикации и сообщения редакции. Стоимость публикации – 2000 тенге/страница в формате WORD (шрифт 12, Times New Roman).

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МАЗМҰНЫ – CONTENTS – СОДЕРЖАНИЕ