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ARTS

NEURAL NETWORKS AND THEIR IMPACT ON CONTEMPORARY AUDIOVISUAL ART

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НЕЙРОМЕРЕЖІ ТА ЇХ ВПЛИВ НА СУЧАСНЕ АУДІОВІЗУАЛЬНЕ МИСТЕЦТВО

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Abstract

This article explores the impact of neural networks, a core component of artificial intelligence (AI), on the development of contemporary audiovisual art, with a focus on photography. Neural networks are shown to not only automate image processing but also generate new forms of artistic expression and expand the creative capabilities of artists. The analysis includes recent research highlighting the role of generative AI in enhancing creativity, design quality, and artistic thinking. Practical applications such as computational photography, image stylization, and intelligent filters are examined, as well as the work of contemporary artists Mario Klingemann, Refik Anadol, and Anna Ridler, who integrate AI into their artistic practice. The study concludes that neural networks serve as both a technical tool and a cognitive partner in artistic processes, shaping a new visual language in the digital age.

Анотація

У статті розглядається вплив нейромереж і генеративного штучного інтелекту на розвиток сучасного аудіовізуального мистецтва, зокрема фотомистецтва. Проаналізовано наукові праці, що висвітлюють потенціал нейромереж у креативній освіті, дизайні та художній співтворчості людини з машиною. Особливу увагу приділено використанню AI в автоматичній обробці зображень, генерації нових візуальних форм, художній стилізації, а також обчислювальній фотографії. Наводяться приклади творчості сучасних митців — Маріо Клінгемана, Рефіка Анадола та Анни Рідлер, які інтегрують штучний інтелект у свої роботи. Матеріал демонструє, як нейромережі трансформують технічні й естетичні підходи до створення мистецьких продуктів, відкриваючи нові горизонти у візуальній культурі.

Keywords: neural networks, generative AI, audiovisual art, photographic art, computational photography, creativity, digital art, image generation, visual language, modes of expression, visual effects

Ключові слова: нейромережі, штучний інтелект, генеративний AI, аудіовізуальне мистецтво, фотомистецтво, художня стилізація, обчислювальна фотографія, креативність, цифрове мистецтво, співтворчість, генерація зображень, образ, засоби виразності, візуальні ефекти

Постановка проблеми. Нейромережі - це алгоритми машинного навчання, які спроектовані для виконання завдань, що вимагають розпізнавання патернів в даних, включаючи фотографії. Штучний інтелект (ШІ) - це загальна концепція, яка охоплює розвиток програм і систем, які можуть виконувати завдання, властиві людському інтелекту, включаючи розуміння і генерацію зображень. Нейромережі або штучні нейронні мережі - це складні математичні моделі, які намагаються відтворити роботу людського мозку у вирішенні завдань штучного інтелекту. Вони складаються з багатьох штучних "нейронів", які взаємодіють між собою, обробляють вхідні дані і генерують вихід. Нейромережі використовуються в багатьох галузях, включаючи обробку зображень, розпізнавання об'єктів, створення мистецьких творів та багато інших. В аудіовізуальному мистецтві нейромережі зараз широко використовуються для вдосконалення фотографій, редакції, генерації нових зображень та

навіть створення повноцінних мистецьких творів. Вони можуть автоматично виправляти дефекти, додавати спеціальні ефекти, а також аналізувати зображення для розпізнавання об'єктів або створення нових мистецьких ідей. Фотомистецтво є важливим аспектом сучасної культури і має великий вплив на спосіб, яким ми сприймаємо світ навколо нас. Воно допомагає зафіксувати моменти, висловлювати емоції, розповідати історії та досліджувати красу та складність життя. Фотомистецтво - це не лише спосіб зафіксувати миті в часі, але й мистецтво виразити ідеї, емоції, історії та концепції через образи і композицію. У сучасному світі фотомистецтво відіграє важливу роль у культурному житті, візуальному сприйнятті світу і важливе засіб виразу для багатьох фотографій. Нейромережі відкривають безліч можливостей для фотомистецтва. Вони можуть бути використані для автоматичного виправлення дефектів на фотографіях, таких як ретуш або покращення якості, а також для додавання спеціальних ефектів та фільтрів. Наприклад, інтелектуальні фільтри можуть покращити колірну гаму, контраст і різкість фотографій. Нейромережі також можуть бути використані для створення мистецьких творів. Вони можуть генерувати нові зображення на основі вже існуючих, перетворювати фотографії в стилі відомих художників або навіть створювати абстрактні мистецькі твори. Використання нейромереж впливає на творчість фотографів, розширюючи їхні можливості і надаючи нові інструменти для виразу та експериментації. З іншого боку, за допомогою нейромереж фотографи можуть експериментувати з новими стилями, реалізовувати абстрактні ідеї, створювати мистецькі інтерпретації своїх робіт і більше. Нейромережі можуть надати фотографам нові способи підходу до своєї творчості. Майбутнє використання нейромереж у фотомистецтві виглядає захопливим. Можливість автоматичної обробки фотографій і створення мистецьких творів стане ще більш потужною та доступною. Алгоритми глибокого навчання будуть постійно вдосконалюватися, що дозволить фотографам та митцям використовувати їх для реалізації своїх творчих ідей.

Аналіз останніх досліджень і публікацій. Серед праць опублікованих на тему нейромереж та їх впливу на розвиток аудіовізуального мистецтва, можна відзначити роботу Хсін Хуанг "Promoting Students' Creative and Design Thinking with Generative AI". У дослідженні розглядається використання генеративного штучного інтелекту (AI) у навчальних проєктах, зокрема у створенні цифрових ігор. Автор доводить, що нейромережі можуть значно покращити креативність, мотивацію та якість дизайну студентських робіт. Це демонструє потенціал AI як інструменту для розвитку творчого мислення, що має прямий зв'язок із сучасним мистецтвом [10]. Анна Мілс у праці "Artificial Intelligence and Education: A Reading List" робить бібліографічний огляд, який включає статті про вплив AI на освіту, зокрема на мистецьку освіту. Деякі з них аналізують філософські та етичні аспекти використання AI у творчості, а також потенціал генеративних моделей у формуванні нових форм художнього вираження [4].

Хоча дослідження Бингченг Ван, Пэй-Луен Патрик Рау та Тіані Юань "Measuring User Competence in Using Artificial Intelligence" зосереджене на вимірюванні обізнаності користувачів щодо AI, воно також торкається теми взаємодії людини з нейромережами в креативних середовищах. Це важливо для розуміння того, як художники та дизайнери можуть ефективно використовувати AI у своїй практиці [5]. Дослідники Бочен Ванга, Джі Ханб, Ксяоянг Жаоа, Юан Їна, Ліукін Ченк та Петер Чілдс опублікували статтю "Creative AI: Machine Learning for Creativity and Design". У праці розглядаються приклади використання машинного навчання та нейромереж у творчих індустріях — від дизайну до образотворчого мистецтва. Автори аналізують, як алгоритми можуть не лише імітувати людську творчість, а й генерувати нові, несподівані форми мистецького вираження. Особлива увага приділяється взаємодії між художником і машиною як формі співтворчості [6].

Метою роботи є аналіз впливу використання нейромереж під час створення сучасного аудіовізуального мистецького продукту.

Виклад основного матеріалу. На сьогодні спостерігається зростаючий інтерес до технік генерації зображень за допомогою нейромереж. Можливо, в майбутньому ми побачимо все більше мистецьких творів, створених в співпраці між художниками та штучним інтелектом. Фотомистецство відіграє важливу роль в розвитку аудіовізуального мистецтва, це великий світ взаємодії технологій та людського бачення. Нейромережі значно вплинули на розвиток фотомистецтва, забезпечуючи нові можливості та підходи до обробки та створення фотографій. Серед основних способів впливу нейромереж на фотомистецтво можна виділити обробку та виправлення зображень.

У фотографії нейромережі можуть бути використані для автоматичної обробки та виправлення фотографій. Наприклад, вони можуть розпізнавати та видаляти шуми на зображеннях, виправляти рівень експозиції, покращувати колірну гаму і навіть автоматично кадрувати фотографії. Так, наприклад, у програмі Adobe Photoshop, з'явилася функція «Генеративної заливки» Генеративна заливка — частина революційного нового набору генеративних можливостей ШІ на базі технології Firefly, заснованого на людській уродженій креативності, що дозволяє додавати, розширювати або видаляти вміст зі своїх зображень неруйнівним чином, використовуючи прості текстові підказки на більш ніж 100 мовах. За допомогою Генеративної заливки можнастворювати об'єкти, фону, розгортати зображення, видалияти об'єкти та інше [1].

Одним із найважливіших способів впливу ШІ на пейзажну фотографію є використання методів обчислювальної фотографії. Обчислювальна фотографія – це процес зйомки та обробки зображень за допомогою передових алгоритмів, а не "покладатися" виключно на апаратне забезпечення камери. Це дозволяє фотографам створювати зображення,

які раніше були неможливими або надзвичайно складними. Наприклад, програмне забезпечення на базі штучного інтелекту тепер може автоматично змішувати кілька експозицій, створюючи зображення з широким динамічним діапазоном (HDR), які демонструють повний діапазон світла та деталей сцени. Це може бути особливо корисним у пейзажній фотографії, де сцени часто мають широкий діапазон рівнів освітлення, від яскравого неба до темних тіней [8].

Нейромережі також можуть бути використані для створення нових мистецьких творів. Вони можуть генерувати унікальні зображення, що уже є витвором мистецтва. Художники можуть використовувати ці твори як вихідний матеріал для подальших творчих проектів.

До використання ШІ у своїй творчості звертається такий відомий митець як Маріо Клінгеманн. Маріо Клінгеманн — художник, який працює з алгоритмами та даними. Він досліджує можливості, які пропонують машинне навчання та штучний інтелект, щоб зрозуміти, як працюють творчість, культура та їхнє сприйняття. Важливою частиною цього дослідження є його робота з цифровими культурними архівами, такими як Британська бібліотека, Інтернет-архів або колекція Google Arts & Culture, де він зараз працює як художник-резидент. Він є постійним доповідачем на міжнародних конференціях з мистецтва, дизайну та медіа, лауреатом креативної премії Британської бібліотеки 2015 року, а його роботи були представлені на фестивалі Ars Electronica, у Галереї фотографів у Лондоні, Центрі Помпіду, Парижі, Met та Показано MoMA, Нью-Йорк. Робота Клінгемана Memories of Passby I створює портрети в реальному часі за допомогою нейронних мереж. Це комп’ютерна система, захована всередині старовинного предмета меблів, який виглядає як щось середнє між сучасною шафою середини століття та старомодним радіо [2,11].

Рефік Анадол — медіа-художник і режисер зі Стамбула, чиї масштабні та інтерактивні проекти штучного інтелекту надихнули глядачів у всьому світі. Роботи Рефіка Анадола присвячена викликам і можливостям повсюдних обчислень, а також тому, що означає бути людиною в епоху машинного інтелекту. Його проекти, відзначені нагородами, також досліджують, як сприйняття та досвід часу та простору радикально змінюються тепер, коли машини домінують у нашому повсякденному житті [3].

Анна Рідлер — художниця та дослідниця, яка працює із системами знань і тим, як створюються технології, щоб краще зрозуміти світ. Її особливо цікавлять ідеї щодо вимірювання та кількісної оцінки, а також те, як це пов’язано зі світом природи. Її процес часто передбачає роботу з колекціями інформації чи даних, зокрема наборами даних, для створення нових і незвичайних наративів. Її роботи виставлялися в культурних установах по всьому світу, включаючи Музей Вікторії та Альберта, Центр Барбікан, Центр Помпіду, HeK Basel, ZKM Karlsruhe , Ars Electronica та Шеффілдський фестиваль документального кіно. Artnet відзначила Рідлер як одного з дев’яти «митців-новаторів», які досліджують творчий потенціал штучного інтелекту, і отримала почесну згадку на премії Ars Electronica Golden Nica у 2019 році в категорії «ШІ та мистецтво життя». Її номінували на «Дизайн року Бізлі». » у 2019 році від Музею дизайну за її роботу над наборами даних і категоризацією. Анна Рідлер живе і працює в Лондоні, Великобританія [7].

Нейромережі можуть застосовувати різні фільтри та стилізацію до фотографій, змінюючи їхній вигляд і настрій. Наприклад, можна створити зображення у стилі відомих художників, як Вінсент Ван Гог або Пабло Пікассо. Компроміс між змістом і стилем зображення звичайно, зміст і стиль зображення не можуть бути повністю розплутати. При синтезі образу, який поєднує в собі зміст одного зображення зі стилем іншого, зазвичай не існує зображення, яке б ідеально відповідало обом обмеженням одночасно. Однак, оскільки функція втрат, яку ми мінімізуємо під час синтезу зображення, є лінійною комбінацією між функціями втрат для контенту та стилю відповідно, ми можемо плавно регулювати акцент на відтворенні або змісту, або стилю [13]. Художня стилізація зображень традиційно вивчається в комп'ютерній графіці під назвою нефотореалістичної візуалізації рендерингу. Окрім роботи над передачею текстури, поширені підходи концептуально відрізняються підходи концептуально відрізняються від нашої роботи тим, що надають спеціалізовані алгоритми для візуалізації зображень [9].

Деякі нейромережі можуть генерувати фотореалістичні зображення об'єктів або сцен, які можуть бути важко або дорого зняти насправді. Наприклад, це може бути корисним для виробництва продуктових фотографій або візуалізації архітектурних проектів.

Висновки. Дослідження підтверджують, що використання нейромереж має значний вплив на розвиток сучасного аудіовізуального мистецтва. Генеративний штучний інтелект активно інтегрується у творчі процеси, стимулюючи креативність, підвищуючи якість дизайнерських рішень і сприяючи формуванню нових форм художнього вираження. Як показують праці Хсін Хуанг, Анни Мілс та інших дослідників, нейромережі не лише розширюють технічні можливості митців, але й змінюють саму суть взаємодії людини з творчим процесом, відкриваючи нові перспективи для співтворчості між людиною і машиною.

У сфері фотомистецтва нейромережі значно вдосконалили методи обробки зображень, створення композицій, стилізації та генерації нових візуальних об'єктів. Обчислювальна фотографія, автоматизоване ретушування, генеративні функції, такі як у Photoshop, суттєво змінюють підходи до візуального мислення та реалізації художніх задумів.

Практика провідних митців, таких як Маріо Клінгеманн, Рефік Анадол і Анна Рідлер, доводить, що штучний інтелект стає не просто інструментом, а повноцінним учасником мистецького процесу.

Їхні проєкти демонструють нові можливості естетики, структури наративу й взаємодії глядача з мистецтвом.

Загалом, нейромережі не лише оптимізують технічні аспекти створення аудіовізуального продукту, але й відкривають нові горизонти художнього пошуку, сприяючи трансформації мистецтва у відповідь на виклики цифрової доби. Вони формують нову мову візуального висловлювання, що об'єднує інновації, технології та людську уяву.

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ON ART APPRECIATION: AN AESTHETIC JOURNEY FROM PERCEPTUAL INTUITION TO RATIONAL DECONSTRUCTION

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Abstract

Art appreciation is a advanced,complex aesthetic re-creative activity for humans. It is far more than simply "looking" and "liking," but rather a multidimensional and dynamic process that integrates perceptual experience, rational cognition, cultural interpretation, and emotional resonance. This paper aims to systematically explore the essence of art appreciation, analyzing its complete process from intuitive sensory reception to deep cultural and historical deconstruction. The article will first define the core connotations of art appreciation, then delve into an analysis of its four key dimensions: perception, emotion, cognition, and understanding. On this basis, the paper will discuss various methodological tools for appreciation, such as formal analysis, iconology, historical context, and psychoanalytic criticism, and elaborate on the important value of art appreciation at the levels of personal cultivation, cultural transmission, and social critique. Finally, the paper will also confront the challenges posed by contemporary art, arguing for the necessity of constructing an open, dialogical paradigm of appreciation within a multicultural context.

Keywords: Art Appreciation,Aesthetic Experience, Formal Analysis, Iconology, Historical Context, Critical Thinking

Introduction

When we stand before Leonardo da Vinci's “Mona Lisa”, listen to Beethoven's *Symphony No. 5*, or gaze upon a corner of a Suzhou garden, we undergo a profound experience—art appreciation—that is both internal and intimate, yet connected to the universal human spirit. Art, as the crystallized product of the human spiritual world, has yearned since its inception to be seen, heard, and understood. Appreciation is the bridge through which the audience responds to this yearning, engaging in a dialogue with the creator across time and space.

However, in popular conception, art appreciation is often misunderstood as an innate talent or privilege, seemingly reserved for "experts" alone. This notion leads many to feel intimidated in front of artworks, believing that "not understanding" equates to failure. This is not the case. Art appreciation is not about finding a single correct answer but about embarking on a personalized journey of exploration. It contains both instantaneous, perceptual aesthetic pleasure and conscious, rational knowledge seeking. This paper aims to demystify art appreciation, presenting it as an analyzable, learnable, and deepenable process of thought and practice, arguing how it proceeds from instinctive perceptual intuition to ultimately arrive at rich rational deconstruction and reconstruction of meaning.

1. Defining Art Appreciation and its Core Connotations

Art Appreciation refers to the complex mental activity wherein the appreciating subject (the viewer) utilizes their own perceptual abilities, knowledge reservoir, life experiences, and emotional understanding to feel, experience, associate, analyze, and judge the art object, thereby obtaining aesthetic enjoyment, comprehending the work's connotations, and forming value judgments. Its core connotations include the following aspects:

1.1 An Active Re-creation

Art appreciation is not the passive reception of information. The artist creates the "first text" of the work, while each viewer, based on their own background, constructs a unique "second text" in their mind. As reception theory emphasizes, the meaning of a work is only ultimately completed in the reader's reading . Therefore, appreciation is an active, creative participation.

1.2 The Unity of the Perceptual and the Rational

Appreciation begins with the direct impact on the senses—the brilliance of color, the fluency of line, the melodiousness of melody, the roughness of texture. This perceptual experience is the foundation of everything. However, deep appreciation necessarily requires the intervention of rationality, including the analysis of formal techniques, the recognition of subjects and allusions, and the understanding of historical background. The perceptual brings pleasure, the rational deepens understanding; the two are intertwined and indispensable.

1.3 A Dynamic Dialogical Process

Appreciation is a dialogue between the viewer and the work, with the artist, and even with the entire era from which the work was born. This process is full of questioning, probing, understanding, and resonance. It has no endpoint; as the viewer's life experience and knowledge structure grow, their appreciation of the same work will continuously deepen and renew.

1.4 The Dialectic of Subjectivity and Universality

Appreciation is highly subjective—"a thousand readers see a thousand Hamlets." Personal preferences,

moods, and memories all influence the outcome of appreciation. However, the reason art can communicate across different individuals is that behind it lie universal formal principles (such as balance, rhythm), shared cultural symbols, and emotions common to humanity (love, fear, joy). Great art reveals its charm precisely in this tension between subjective interpretation and universal value.

2.Analysis of the Multidimensional Process of Art Appreciation

A complete process of art appreciation typically interweaves the following (layered and progressive) yet (cyclical and recurring) dimensions.

2.1 The Perceptual Dimension: Initial Sensory Contact and Aesthetic Intuition

This is the starting point of appreciation, the stage of intuitively grasping the formal elements of an artwork purely through the senses of sight, hearing, etc. Facing a painting, we first notice its color, light and dark, line, composition, space, and texture; facing a sculpture, its volume, material, texture, and play of light and shadow; facing music, its melody, rhythm, harmony, and timbre.

At this stage, rational knowledge temporarily recedes, and aesthetic intuition dominates. We might feel "this painting is harmonious" or "this melody is sad," even if we cannot clearly explain why yet. This intuition is not groundless; it is based on a subconscious understanding of formal beauty formed through human long-term evolution and social life (for example, symmetry often brings stability, diagonal lines often generate a sense of movement). Cultivating acute perceptual sensitivity is the cornerstone of art appreciation.

2.2The Emotional Dimension: Inner Resonance and Experience

Art is a vessel for emotion. After perceiving the form, we quickly enter the stage of emotional experience. The atmosphere created by the work and the emotions conveyed directly strike a chord within us. The profound light and shadow in Rembrandt's paintings evoke solemnity; Bada Shanren's remnants of mountains and rivers evoke feelings of lonely desolation; Van Gogh's swirling brushstrokes are filled with fervor and agitation.

Emotional resonance is the core power of art's impact. It is sometimes direct and empathetic, such as pity for the fate of a tragic figure; other times it is complex and indescribable, such as the mix of confusion, excitement, and freedom felt when facing an Abstract Expressionist drip painting by Jackson Pollock. The emotional dimension ensures that art appreciation is not a cold academic analysis but a warm experience of life.

2.3The Cognitive Dimension: Rational Analysis and Identification

In the grand symphony of art appreciation, if perceptual intuition is the brilliant melody that instantly captures the heart, then the cognitive dimension is the rigorous music theory that gives the piece structure, harmony, and counterpoint. It guides the appreciator beyond the initial sensory impression into a realm of rational analysis and identification. This process is not meant to kill the direct emotion brought by art; on the contrary, it is to deepen that emotion, anchoring it from a vague emotional reaction into a precise understanding illuminated by knowledge. When the viewer begins consciously to ask, "How is this painting organized?" or "What does this image represent?" they actively take up the tools of reason, beginning the dissection of the work's form and the decoding of its meaning. The appreciator meticulously analyzes the picture's composition, examining the direction of lines, the contrast of colors, the distribution of light and dark, and the treatment of space, understanding how these formal elements collectively construct visual harmony, rhythm, and tension, thereby conveying an emotional tone that may be peaceful, turbulent, joyful, or sorrowful. Simultaneously, they mobilize their cultural reservoir to identify the work's subject matter, allusions, and symbolic signs—for example, recognizing the woman holding scales as the embodiment of Lady Justice, understanding the metaphorical gentlemanly character of the "Four Gentlemen" (plum, orchid, bamboo, chrysanthemum) in traditional Chinese painting, or interpreting how the complex, dynamic forms of Baroque art served the intention of promoting Catholic glory. This work of rational identification places the work back into the network of its belonging culture, thought, and tradition, making us realize that art is never a pure visual game but a symbolic system carrying specific concepts, narratives, and values. Therefore, the cognitive dimension is the bridge connecting intuitive feeling with deep understanding; it allows the appreciator not only to know *what* but also “why”, ultimately enabling a fuller and deeper comprehension of the artwork's rich connotations and masterful ingenuity.

2.4The Dimension of Understanding: Cultural Interpretation and the Construction of Meaning

When we move beyond the dissection of form and the identification of symbols, art appreciation reaches its most profound and broad —the cultural interpretation of the work and the active construction of meaning. At this point, the appreciator is no longer satisfied with knowing "what is depicted" or "what techniques are used," but strives to explore the more fundamental questions of "why is it expressed this way" and "what does it ultimately mean?" This necessitates re-situating the artwork within the historical matrix of its birth, viewing it as a crystallization of a specific zeitgeist, social condition, cultural trend, and individual consciousness. For example, understanding the pathos and radiance of the figure in white before the firing squad in Goya's “The Third of May 1808”is inseparable from knowledge of the suffering and resistance of the Spanish people during the Napoleonic Wars; while comprehending the profound melancholy and behind the aloof and(coldly lonely) fish and birds, the remaining mountains and rivers in Bada Shanren's paintings, must be connected to the Ming loyalist sentiment of the early Qing Dynasty and the painter's personal life tragedies. This restoration of historical context is not mere background supplementation; it fundamentally determines whether we can touch upon the core propositions and emotional intensity the work initially sought to address.

Furthermore, deep understanding requires the appreciator to possess a capacity for cross-cultural empathy and a critical perspective, actively participating in the construction of meaning. Artistic works, especially

classics, are never closed or static in their meaning; rather, they maintain their vitality through the continuous dialogue and interpretation of viewers from different eras and cultures. We need not only understand the work's intention within its original context but also consider what it can say to us in the present context. A medieval religious painting, at its birth, was for educating the faithful anddemonstrating ecclesiastical power, but in today's museum, it might serve more as an aesthetic object, a historical witness, or even provoke reflection on the relationship between faith and power. The appreciator mobilizes their own philosophical literacy, social concerns, and life experiences to collide with, question, and dialogue with the work, thereby generating unique, personalized interpretations. This process transforms art appreciation from a one-way reception of knowledge into a productive creative activity, ultimately building a bridge of meaning between the great artistic heritage and the living conditions of contemporary people.

3. Methodological Tools for Art Appreciation

To systematically and deeply engage with the rational level of art appreciation, particularly supporting its cognitive and understanding dimensions, art history and critical theory have developed a series of effective methodological tools. These tools provide us with multiple perspectives and clear paths, helping to transform vague feelings into precise interpretations, thereby grasping the work's connotations more comprehensively.

Among them, the most fundamental method is “Formal Analysis”, which requires the appreciator to temporarily view the work as a self-sufficient whole, focusing on its internal formal elements and their organizational relationships. The appreciator, like an anatomist, meticulously examines the quality of lines, the contrast and harmony of colors, the distribution of light and dark, the construction of space, the focus and balance of composition, and the physical properties of materials. This method trains us to first answer the question, "How is the work organized and how does it produce its visual effect?" avoiding premature distraction by subject and narrative. Through formal analysis, we can understand why Mondrian's geometric abstraction conveys pure tranquility and order, while Jackson Pollock's drip paintings are filled with restless energy, their beauty rooted in the rhythm, harmony, and tension constituted by the formal elements themselves.

When analysis needs to go beyond form and touch upon the work's theme and deeper meaning, “Iconology”provides powerful support. Systematically expounded by scholar Erwin Panofsky, this method divides interpretation into three levels: first, pre-iconographical description, objectively recording the natural objects in the image; second, iconographical analysis, identifying conventional themes, stories, and allegories, interpreting those customary symbols (e.g., dove symbolizing the Holy Spirit, skull symbolizing death); finally, reaching the level of iconological interpretation, deeply excavating the more essential cultural, social, and zeitgeist connotations behind the work. For example, using iconology, we can not only recognize the figures in Botticelli's *Primavera* as the Three Graces or Flora, the goddess of flowers, but also interpret how this work reflects the Florentine Neoplatonic philosophy's idealized concepts of love and beauty during the Renaissance.

Furthermore, placing the artwork within its birth environment through “Contextual Analysis”is crucial. This method firmly believes that artworks are by no means isolated but products of their time's soil. It guides the appreciator to investigate the specific historical period, social structure, economic base, political events, and intellectual currents that produced the work. Marxist criticism focuses on the relationship between art and class, ideology; feminist criticism excavates female artists obscured by mainstream narratives and gender power structures within works; postcolonial criticism examines how art represents the relationship between colonizing and colonized cultures. For example, understanding Jacques-Louis David's “The Death of Marat”requires placing it within the radical context of the French Revolution, analyzing how it was shaped into a revolutionary icon carrying a clear political propaganda purpose.

Finally, “Psychoanalytic Criticism”opens the door to the unconscious dimension of art. Drawing on the theories of Freud, Jung, and others, this method attempts to explore the subconscious dynamics in artistic creation and reception. It can be used both to analyze the connection between an artist's personal psychological state and their stylistic choices and thematic selections, and to interpret the universal psychological archetypes and conflicts projected by the imagery itself. Psychoanalytic criticism provides a key key particularly for understanding art movements like Surrealism and Expressionism, which are dedicated to exploring the inner world. These methodologies are not mutually exclusive but constitute a pluralistic, complementary toolbox. Skilled appreciators often flexibly synthesize them according to the specific circumstances of the work to achieve the greatest possible understanding of art's richness and complexity.

4. The Value and Significance of Art Appreciation

Art appreciation is far more than a passive leisure activity; it is an active, profound, and transformative engagement with the creative expressions of humanity. It is a journey that begins with sensory perception and evolves into intellectual exploration and emotional resonance. The value and significance of cultivating the ability to appreciate art extend far beyond the walls of museums and concert halls, enriching individuals, strengthening communities, and preserving the very fabric of our collective culture.

4.1 The Personal Journey: From Perception to Enlightenment

At its core, art appreciation is a deeply personal endeavor that fosters cognitive and emotional development. It begins with the act of perceptive looking or listening—moving beyond merely *seeing* to actively *observing*, beyond *hearing* to truly *listening*. This initial engagement, often rooted in a state of focused "mental stillness" as discussed in Eastern aesthetics, allows the individual to absorb the formal qualities of a work: its colors, lines, textures, composition, melodies, and rhythms. This sensory experience provides

immediate, often ineffable, pleasure and emotional impact, whether it's the awe inspired by the scale of a Gothic cathedral or the serenity evoked by a Monet water lily painting.

However, the true depth of art appreciation unfolds when this initial perceptual intuition is complemented by rational deconstruction. This involves inquiring into the context, history, and technique behind the work. Who created it and why? What movement does it belong to? What symbols are employed? Understanding that Van Gogh's thick, swirling brushstrokes were a manifestation of his inner turmoil, or that Picasso's "Guernica" is a powerful political statement against the horrors of war, transforms the viewing experience. It becomes a dialogue between the viewer and the artist, across time and space. This process is not about finding a single "correct" interpretation but about constructing meaning, a concept central to Reception Theory, which posits that the viewer completes the artwork through their interpretation.

This intellectual engagement is a powerful workout for the brain. It cultivates critical thinking, challenges assumptions, and nurtures empathy. By stepping into the shoes of an artist from a different era or culture, we learn to see the world from perspectives other than our own. This fosters tolerance, understanding, and a greater appreciation for human diversity. Ultimately, art appreciation is a key component of self-discovery. It helps us to understand and articulate our own emotions, questions our place in the world, and provides a unique lens through which to examine the human condition—its joys, sorrows, conflicts, and triumphs.

4.2The Social Fabric: Building Bridges and Critical Discourse

The significance of art appreciation is not confined to the individual; it is inherently social. Art serves as a cultural record, a mirror reflecting the values, beliefs, and anxieties of the society that produced it. By appreciating art from the past, we gain an invaluable window into history that is often more visceral and immediate than textbooks. The grandeur of Roman sculptures speaks to imperial power, while the intricate illuminations of medieval manuscripts reveal a devotion to spiritual life.

In the contemporary world, art continues to be a vital forum for social commentary and critical discourse. It can challenge injustices, satirize political figures, give voice to the marginalized, and imagine new futures. Appreciating this art means engaging with these important conversations. It allows societies to reflect on themselves critically and collectively. Public art, in particular, from monuments to community murals, becomes a shared point of reference, fostering a sense of shared identity and belonging.

Furthermore, the act of appreciation itself is often a social activity. Discussing an exhibition with friends, debating the meaning of a film, or participating in a book club are all social rituals built around art appreciation. These exchanges enrich our understanding, expose us to different viewpoints, and strengthen community bonds. In this way, art appreciation becomes a glue that holds communities together, facilitating communication and mutual understanding across different backgrounds.

4.3 The Essential Role of Art Education

Given its profound benefits, the cultivation of art appreciation cannot be left to chance; it must be actively nurtured through education. Art education is not merely about teaching technical skills to create art; its more crucial role is to equip individuals with the literacy to engage with and appreciate art throughout their lives. This involves developing visual and aural acuity, historical knowledge, and interpretive skills.

Integrating art appreciation into education, particularly at the university level, is essential for developing well-rounded, empathetic, and critically engaged citizens. It moves beyond STEM-focused curricula to foster the creativity, innovative thinking, and emotional intelligence that are increasingly demanded in the modern workforce. By learning to appreciate complexity, ambiguity, and multiple perspectives, students become better problem-solvers and more effective communicators. Art education ensures that we do not produce a society of purely technical specialists who are culturally illiterate and emotionally disconnected.

In conclusion, the value of art appreciation is multidimensional and profound. It is a vital human pursuit that enriches the individual intellectually and emotionally, fostering empathy, critical thinking, and self-awareness. It strengthens the social fabric by preserving cultural heritage, stimulating important dialogue, and building community. And finally, it is an essential component of a holistic education, preparing individuals to navigate and contribute meaningfully to a complex world. Art is not a luxury or an accessory; it is a fundamental record of what it means to be human. To appreciate art is to engage in a conversation with that record, a journey that deepens our understanding of others and, ultimately, of ourselves. It is through this continual engagement that we ensure the enduring power of art to inspire, challenge, and transform across generations.

5. Contemporary Challenges and Future Prospects: Towards an Open Paradigm of Appreciation

In today's world, profoundly reshaped by globalization and digital technology, the traditional paradigm of art appreciation faces unprecedented challenges, which simultaneously give rise to brand new opportunities for its evolution towards greater openness and diversity. The primary challenge comes from contemporary art practice itself thoroughly subverting traditional aesthetic categories. Conceptual art, installation, performance, and new media art constantly question the ontological problem of "what is art?", their focus shifting from creating beautiful objects to proposing thought-provoking "concepts." Duchamp's ready-mades, Tracey Emin's unmade bed, even virtual crypto-art, force the viewer to abandon traditional expectations of permanence, skill, and beauty, and instead accept a new criterion for judgment centered on context, questions, and process.

Simultaneously, we find ourselves in an era of "image overload" with an explosion of visual information. The scrolling browsing mode of social media cultivates a habit of fast, superficial viewing that seeks

instant stimulation, which is incompatible with the sustained concentration, deep interpretation, and repeated contemplation required by art appreciation. This logic of the attention economy is eroding the patience and capacity needed for deep appreciation, potentially leading to a flattening and homogenization of aesthetic sensibility.

Facing these challenges, an open, dialogical paradigm of appreciation appears particularly urgent. This new paradigm first requires us to embrace "ambiguity" and "multiple interpretations." It no longer aims to find a single standard answer but encourages the appreciator to explore personalized paths of understanding, accepting the openness and unfinished nature of artistic meaning, viewing it as a dialogical process that can be continually participated in and enriched. Secondly, it extremely emphasizes the importance of "context." Understanding a work must be closely integrated with its creative background, the site of its display (the white cube gallery, public space, or online environment), and the socio-cultural discourse it. Finally, it advocates for a capacity for "cross-cultural translation." In a context of interwoven multiculturalism, appreciators need to abandon cultural centrism, attempt to proceed from the internal logic of the work's native culture, and understand its unique value system and modes of expression with respect and empathy, thereby truly achieving mutual learning among civilizations.

Looking forward, technology is not only a challenge but also a powerful tool for enabling deep appreciation. Virtual Reality and Augmented Reality (AR) technologies can allow one to "step into" a painting or a distant museum; online high-definition databases provide unprecedented opportunities for detailed scrutiny; artificial intelligence can even assist in stylistic analysis and tracing origins. Future art appreciation education will increasingly focus on cultivating a compound ability: the capacity to immerse oneself in feeling while also skillfully using rational tools; to respect traditional classics while also embracing experimental frontiers; to engage in personal aesthetic experiences while also participating in shared community interpretation. Ultimately, art appreciation will evolve into a lifelong practice connecting past and present, integrating technology and humanities, continuously providing humanity with an important dimension for understanding the world and the self.

Conclusion

Art appreciation, far from being a simple act of viewing or listening, is in fact a profound and captivating aesthetic journey. This paper, through an analysis of the process from perceptual intuition to rational deconstruction, reveals its essence as a dynamic, multilayered aesthetic practice.

This journey begins with a state of "mental stillness" – an aesthetic frame of mind. The appreciator must first clear away distractions and immerse themselves in the world constructed by the work with a pure heart, using their senses and intuition to capture the initial shock and pleasure derived from its form, color, melody, and narrative. This perceptual experience is the cornerstone of appreciation, the most direct and authentic presentation of artistic charm. However, stopping here means the appreciation remains superficial. True depth lies in moving towards rational deconstruction and interpretation. We need to mobilize our knowledge reserves to analyze the work's historical context, genre characteristics, stylistic techniques, and symbolic meanings, thereby understanding the artist's creative intent and emotional expression. This process, as emphasized by reception aesthetics, is an active dialogue and reconstruction of meaning between the appreciator, with their "horizon of expectations," and the text. It is through this continuous interpretation that the vitality of the artwork is sustained and enriched.

It is particularly important to note that art appreciation is not an isolated individual act; it possesses profound sociality. Individual interpretations always occur within specific socio-cultural contexts and involve exchange and collision with other appreciators and traditions, thus forming more diverse and deeper understandings. This underscores the critical value of art education—through systematic guidance, it cultivates university students' aesthetic perception, imagination, and critical thinking, enabling them to move more freely between the perceptual and the rational, completing the leap from passive reception to active creation.

In summary, art appreciation is a spiraling process: from perceptual immersion to rational contemplation, and then from rational sublimation back to a higher level of perceptual understanding. It is both an individual's inner aesthetic cultivation and a social cultural practice. Ultimately, this journey not only allows us to thoroughly understand art but also to know ourselves and the world more profoundly. It achieves emotional resonance, intellectual enlightenment, and spiritual sublimation, truly demonstrating the eternal value of art that transcends time and space.

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BIOLOGICAL SCIENCES

ROLE OF ENTODYNIMORPHA IN THE INTESTINAL MICROFLORA OF RUMINANTS

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Abstract

It has been established that rumen protozoa are strictly anaerobic and highly specialized ciliates that can only live in the rumen and similar habitats. These cilia play an important role in feed utilization and the environmental impact of ruminant livestock products. The rumen is a complex anaerobic digestive ecosystem, present in ruminants and plays an important role in the digestion and fermentation of ingested food, including starch, fiber content, etc.

Keywords: entodinimorph, infusoria, rumen ecosystem, ruminants, species

INTRODUCTION

Any of a number of ciliated protozoa belonging to the order Entodiniomorphida are harmless parasites of the rumen and intestines of cattle, horses, and other herbivores. Entodiniomorphs are common and quite numerous: there may be 10 billion or more in a single cow. The cells are irregularly shaped, and the large syncilia are spirally arranged at the anterior mouth. Several projections are found on the posterior side of the cell; the largest is thought to serve as a rudder. It is possible that entodiniomorphs maintain a commensal or symbiotic relationship with their host, aiding digestion, and certain species digest cellulose. Entodiniomorphs reproduce asexually by binary fission and also exhibit the phenomenon of sexual union.

Rumen protozoa are strictly anaerobic and highly specialized ciliates that can only live in the rumen and similar habitats. These cilia play an important role in feed utilization and the environmental impact of ruminant livestock products. The rumen is a complex anaerobic digestive ecosystem present in ruminant animals and plays a crucial role in the digestion and fermentation of ingested food, including starch, fiber content, etc. This anaerobic digestion is entirely dependent on a number of microbial communities, including ruminal bacteria, archaea, fungi, and ciliated protozoa. Among these members, ruminal cilia account for up to 50% of the microbial biomass within the rumen. Their diverse biological roles, which include predation on ruminal microbes, oxygen production within the rumen, and symbiotic relationships with prokaryotes, particularly hydrogenotrophic methanogens, have profound effects on both ruminal functions and the overall performance of the host animal. Notably, ruminal cilia play a crucial role in feed digestion and consistently demonstrate significantly higher digestibility across a variety of measurements. However, within the spectrum of digestive processes, particularly those potentially associated with global warming and originating from ruminant production, ruminal cilia are recognized and account for 9% to 37% of ruminal methane production through direct or indirect combinations with ruminal methanogens. In addition, ruminal cilia contribute to the recycling of excess nitrogen within the rumen, paralleling the limited nitrogen use efficiency observed in the host ruminant. The composition of ruminal cilia varies according to factors such as geographic distribution, diet, and between different animal species; thus, between 2 and 45 species have been identified. Interestingly, substrate preferences, host specificity, and antagonistic interactions between ciliate species give rise to four faunal types: type A (characterized by the presence of Polyplastron and Ophryoscolex), type B (characterized by Epidinium and Eudiplodinium), type K (including Elytroplastron bubali), and type O (comprising only Entodinium and isotrichids). These categories were proposed by Dehority and Imai, although previously mixed populations have also been documented.

Furthermore, the functional diversity of ruminal ciliate species makes interpretation difficult, especially in the context of ongoing microbiome studies, which often rely on morphology or marker genes. Moreover, the lack of a reliable reference database highlights the importance of unraveling the biological functions and metabolic contributions of individual ciliate species. Broadly speaking, ruminal ciliate populations are divided into starch-favoring species (e.g., Entodinium, which prefers simple sugars), cellulolytics (e.g., Epidinium, Ostracodinium, Eudiplodinium, and Ophryoscolex), and ruminant bacteria (e.g., Entodinium spp. and Diplodiniinae.) However, these classifications require validation through genomic or transcriptomic exploration, as much of the knowledge surrounding ruminal ciliates comes from indirect evidence such as defunations and in vitro monocultures.

MATERIALS AND METHODS OF THE STUDY

The effects of infusoria species have been studied extensively. Cultures in which a specific type of ruminal ciliate coexists with associated or free-living microbes using in vitro conditions are widely used.

The feasibility of studying individual ruminal ciliate species largely depends on their suitability for cultivation.

In addition to the use of appropriate washing procedures, electron microscopy (including scanning and transmission electron microscopy) supplemented

with fluorescent staining can visually confirm the physical associations between ruminal ciliates and their potential symbionts. Thus, if necessary, the use of antioxidant mixtures and stepwise freezing procedures can enhance the preservation of ruminal ciliate cultures during long-term freezing.

DISCUSSION AND RESULTS OF THE STUDY

Ciliated protozoa are present in all wild and domesticated ruminants. Rumen ciliated protozoa are acquired by young ruminants by eating food directly from adult animals or contaminated with the saliva of such animals.

Digestion of cellulose by organisms in the digestive tract of herbivorous animals occurs in the rumen by microbial digestion. This phenomenon between animals and organisms occurs through symbiosis, that is, through a common life. Rumen microorganisms are natural microbial communities found in the stomach and consist of protozoa, bacteria and fungi. The rumen, which provides a good habitat for protozoa, which are divided into two groups: flagellates and ciliates, is high in terms of biological productivity. Flagellates are abundant in both the rumen and the intestine of hosts that do not have cilia. Their effect on rumen digestion is less than that of ciliates. Due to their small size, flagellates in the rumen are more difficult to recognize than ciliates. Although their numbers are generally too low to be observed, their density (103-104) cells/ml) can only be seen when they are very high, in cases where ciliates are not found in the fauna. They are small in size and constitute a small part of the rumen biome.

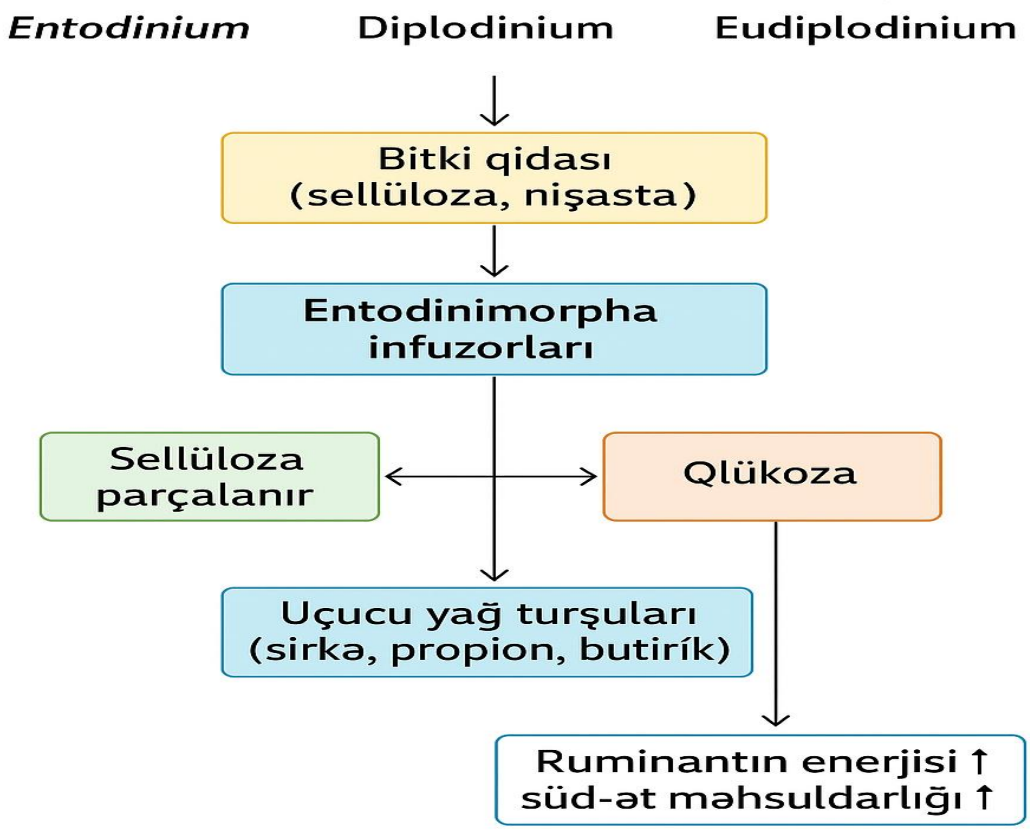
Ciliates constitute the majority of protozoa in the rumen ecosystem. These cilia are between 20 and 200 µm long, are non-pathogenic, and respire without oxygen, i.e. anaerobic. Ciliates were first observed in the stomachs of domestic ruminants by Gruby and Delafond in 1843. Based on these observations, it was assumed that they would be important for the nutrition and metabolism of the host. Various factors such as the amount of food consumed, pH, turnover rate and frequency of feeding affect the cilia in the rumen. It seems to affect its composition and concentration. Ciliates can ferment and break down many types of substrates. starch, cellulose, etc. They ferment major plant components. This fermentation produces organic acids and is also essential for the nutrition of the animal as a source of carbon and energy needed by the host. Among these cilia, Entodiniomorphid ciliates produce cellulose and hemicelluloses (Table 1).

They have enzymes that act on them. In a study by Williams and Coleman, the degradation of starch and cellulose was observed in the rumen without cilia.

In addition, it is shown that the proteolytic activity of the rumen fluid is reduced. On the other hand, the body proteins of these organisms are an important source of protein for the host.

It has been reported that extracellular proteases secreted by ciliates carry out at least part of the proteolytic activity. This suggests that ciliates help in the digestion of protein-containing foods. Since ciliates digest bacteria quickly, they keep the bacterial population under control. Ciliates

Table 1.



play an important role in the nutrition of the host animal, as they are a more important source of nitrogen than bacteria. Ciliates reproduce by dividing into two parts. They can double their number within 24 hours. Ciliates living in the rumen can only survive and reproduce in these conditions. They cannot survive when removed from their host or rumen environment. However, they are not significantly affected by the removal of fauna and may continue to survive. Furthermore, since ciliates feed on bacteria, their presence in the rumen probably helps to maintain the health of the host by preventing fermentation and associated loss of appetite.

When identifying species in rumen ciliates, the location and number of contractile vacuoles, as well as the size and shape of the skeletal plate, if present, should be considered. In addition, body shape and size, size, shape and location of the macronucleus, and the size and shape of the vestibule and cytoproct (cell anus) are morphological features that are also useful for monitoring rumen condition and the nutritional health of the animals.

Table 2. Classification of ciliated protozoa living in the rumen of ruminants

Phylum: Ciliophora Subphylum: Intramacronucleata Classis: Litostomatea Subclassis: Trichostomatia	
Ordo: Vestibuliferida	Ordo: Entodiniomorphida
Familia: Isotrichidae	Subordo: Entodiniomorphina
Dasytricha Isotricha	Familia: Ophryoscolecidae Diplodinium Enoploplastron Entodinium Epidinium Eudiplodinium Metadinium Ophryoscolex Polyplastron

The subclass Trichostomatia includes ciliates that are endosymbiotic in vertebrates.

It is divided into two orders: Vestibuliferida and Entodiniomorphida.

The ciliates of the order Vestibuliferida include several species of the family Isotrichidae.

(Table 1). In ciliates belonging to this family, the entire body is covered with cilia. Although the number of species in the family Isotrichidae is quite small, their frequency of occurrence is quite high. It is almost 100%. Dasytricha ruminantium, Isotricha prostoma, Isotricha intestinalis belong to the genus Isotrichidae and are found in all ruminants. In species of the suborder Entodinimorphina, cilia are in the form of strips or cysts. The number and population density of these underwater ciliate species make up the majority of the fauna. With the exception of Diplodinium and Entodinium, they belong to the family Ophryoscolecidae. They have skeletal plates. In determining species in rumen cilia, the location and number of contractile vacuoles should be considered, in addition to the size and shape of the skeletal plate, if present. In addition, body shape and size, macronucleus size, shape and location, and the size and shape of the vestibule and cytoproct (cell anus) are observed in the same way. Rumen cilia, rumen condition, and microscopic examination of the animal are useful in monitoring nutritional health.

Ruminal cilia are known to produce hydrogen through carbohydrate fermentation. It is noteworthy that interspecific hydrogen transfer emerged as the main reason for the increased methane production associated with ruminal cilia. Moreover, this idea led Guyader et al. to discover a strong positive correlation between the number of ruminal ciliate cells and methane production. Direct evidence for this interaction was obtained from co-culture experiments with Polyplastron multivesiculatum and Methanosarcina barkeri, which revealed significantly higher methane production accompanied by hydrogen uptake in the co-culture. Interestingly, this particular association accounted for one-third of the total methane production, whereas complete removal of ruminal cilia led to a decrease in methane production. Furthermore, it is worth noting that partial inhibition of ruminal cilia also had a mitigating effect on methane production, thus highlighting the importance of limiting ciliate-associated methanogen populations for effective methane reduction.

Although the contribution of ruminal cilia to nitrate reduction during methane reduction has been noted, the mechanisms involved remain incompletely understood. In addition, both in vitro and in vivo studies have observed increased metabolic reduction of nitrate and nitrite under faunistic conditions. This interaction highlights the role of ruminal cilia in ensuring the safe application of nitrate to reduce methane exposure. Commercial products such as Agolin and Mootral have demonstrated significant methane reduction in sheep and dairy cattle, but have limited efficacy in beef cattle. A meta-analysis of in vitro experiments showed that saponin supplementation significantly reduced total ciliate concentrations, with modest methane reduction effects. Furthermore, an analysis of sheep studies showed that methane was significantly reduced by dietary saponins, based on methane yield per dry matter intake.

Among in vivo studies reporting on ruminal cilia in saponin applications, two-thirds observed a reduction in total cilia number. A recent meta-analysis involving beef cattle and tannin supplementation supported the potential for methane reduction with a trend

toward reduced cilia number. In particular, different groups of ruminal ciliates, namely entodiniomorphs and isotrichids, exhibit different contributions to rumen methane production due to differences in their hydrogen production capabilities. Their different methanogenic associations have also been observed, as demonstrated in a study on the transfaunation of ciliate-free sheep inoculated with isotrichids. Given their role in interactions with methanogens, these interactions may differ depending on the ciliate species involved. Therefore, the mechanisms of methane inhibitors on total ruminal ciliate populations for synergistic or sequential methane reduction in complex rumen environments require further detailed investigation.

Although ruminal ciliate proteins have an amino acid composition that is superior to bacterial proteins for the host animal, their actual contribution to the host as microbial proteins is likely to be less than their numerical presence in the rumen; thus, their behavioral properties can ultimately be attributed to their overestimation of ruminal ciliate proteins, including rumen sequestration and bacterial contamination. Bacterial activity varies between ruminal ciliate families or genera. Therefore, considering both bacterial activity and ciliate cell number, Entodinium and Diplodinium spp. However, the specific effects of these ciliate groups may vary depending on factors such as age, diet, host species, and genetics. A study in monofaunated sheep showed that the presence of ruminal cilia resulted in a reduced transfer of microbial protein to the duodenum, an effect that was more pronounced in Entodinium - monofaunated sheep. Approaches such as the selection of target enzymes specific to ruminal cilia, screening of feed additives with anti-protozoal properties, and regulation of rumen transit time are also worthy of attention.

Numerous research efforts have been directed at elucidating the factors underlying variations in host feed efficiency, often quantified using residual feed intake in the context of the rumen microbiome. Thus, the low microbial and functional diversity observed in the rumen microbiome potentially allows for a more efficient use of dietary energy. The previously mentioned meta-analysis focused on the effect of defecation and established a link between ruminal cilia and higher dry matter intake, leading to lower average daily gain and consequently reduced feed conversion efficiency; a result that was particularly evident in low-quality diets.

The intriguing phenomenon of bacteria preferentially occupying specific bacterial groups, particularly key cellulolytic consortia, could potentially arise due to unbalanced dietary preferences among individual ciliate species. However, this hypothesis remains uncertain due to the limited number of predators tested to date.

Furthermore, attempts to improve the overall performance of animals through ruminal cilia-enriched vaccination, especially for entodiniomorphs, have not yet yielded significant improvements in either the pre- or post-weaning periods. Although the positive effect on diarrhea reduction has not been associated with changes in the rumen microbiome or ciliate populations, more comprehensive studies are needed to assess the advantages and disadvantages of stem ciliates, especially for young ruminants.

Furthermore, the composition of ruminal cilia could potentially influence the enrichment of bacterial groups associated with feed efficiency. Differential abundance of Proteobacteria in ciliate-associated fractions has been observed in various rumen studies, including marine ciliates. Given that these bacteria are hydrogen-utilizing, their association with ruminal cilia seems to be metabolically robust, allowing them to outperform other bacterial competitors in the faunal environment. Consequently, the reported relationship between ruminal cilia and rumen microbiota markers in the context of feed efficiency should be further investigated to facilitate their enrichment within the rumen.

CONCLUSIONS.

Infusoria belonging to the order Entodinimorpha are an important component of the intestinal microflora of ruminants, playing a key role in the breakdown of cellulose, maintaining bacterial balance, and generally meeting the energy needs of the host. As a result of their activity, ruminants are able to digest fibrous plant foods with high efficiency. Therefore, the study of representatives of this order is of great scientific and applied importance in the field of animal husbandry.

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EARTH SCIENCES

INFLUENCE OF MUONS ON HYDROLYTIC PROCESSES ON EARTH. EXPLANATION OF THE 'WATER MEMORY' MYSTERY

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Abstract

Muons produced in the atmosphere by the solar wind perform an important function on the Earth in hydrolytic processes. They increase the hydrolytic activity of water clusters, breaking them down to form free hydroxyl groups. In the absence of muons, water clusters are structured to the maximum possible size and lose hydrolytic activity. This was experimentally proven after the absorption of muons by metals was discovered. For example, while in an aluminum screen, large mature water clusters do not react with triethyl phosphite, but after the screen is removed, the muons begin to split water clusters and the reaction begins immediately and accelerates quickly. The discovered rapid splitting of water clusters by muons explains the unstable manifestation of the 'Water Memory' phenomenon. Thus, the self-organization of water molecules, as well as the chemical and biological properties of water clusters, depend on the influence of muons and the intensity of solar radiation.

Keywords: water; clusters; solar influence; muons; hydrolysis

Introduction

We recently discovered that solar radiation breaks the hydrogen bonds between water molecules, which prevents them from self-organizing and destroys water clusters. Small clusters are much more chemically reactive than large ones, since their hydroxyl groups (-OH) are not involved in the network of hydrogen bonds. For this reason, under constantly changing solar activity and distribution of solar energy due to the rotation of the Earth around its axis and around the Sun, clusters decompose and reunite, and the rate of hydrolytic processes with their participation displays diurnal, very large annual variations, and is also modulated by the 11-year cycles of solar activity [1], [2]. This was shown by regular measurements of the rate of hydrolysis of triethyl phosphite in acetonitrile for 6 years 2015-2020 which included 5 years of the second half of the 24-th solar cycle 2015-2019 and the first year 2020 of the 25-th cycle. The reaction rate difference during this period changed very dynamically and could reach 200 times. (Fig.1)

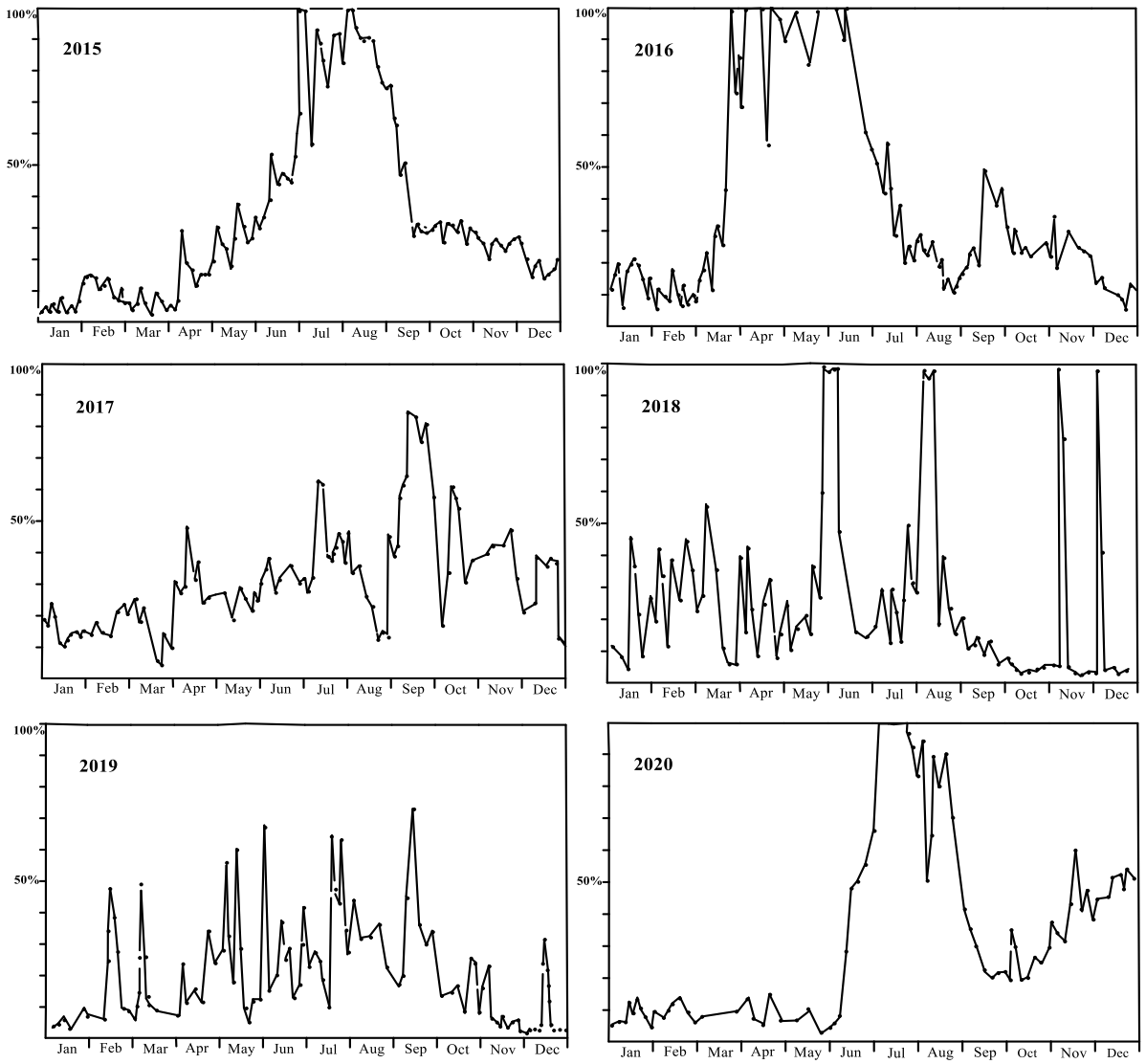

Fig. 1. Variations of the rate of hydrolysis of triethyl phosphite [$(EtO)_3P+H_2O$] in acetonitrile in 2015-2020 (conversion after 25 minutes of heating at 80°C). This period includes the second half of the 24-th solar cycle 2015-2019 and the first year 2020 of the 25-th cycle.

Such significant variations can be accounted for by the decomposition of water clusters under the influence of muons, which are constantly generated in the upper atmosphere by the solar wind. This is confirmed by the following facts. The rate of hydrolysis of triethyl phosphite in acetonitrile significantly increases after sunrise and decreases after sunset. A strong slowdown of the hydrolysis also happens during solar eclipse, when the Moon shields the solar wind, and the formation of muons is greatly weakened. This was observed in August 2017 [1]. The movement of muons in the Earth's atmosphere has also been experimentally proven by studying the structure of the Egyptian pyramids [3].

The destruction of water clusters by muons under the influence of the Sun explains another well-known mysterious phenomenon called 'Water Memory'. French scientists discovered that bulk water, when in contact with organic substances, can copy their biological properties and retain the acquired biological activity even after very strong dilution (up to 10^{120} times) [4]. This unique phenomenon has been tested many times, but is still considered scientifically unproven because it is reproduced very irregularly. For example, in July 1988, a special international commission conducted 7 verification experiments, of which the first 4 confirmed this phenomenon, and the following 3 experiments gave a negative result [5]. The reason for such instability has not yet been explained.

Our studies of water clusters (Fig. 1) showed that their size and hydrolytic activity depend not only on variations in the intensity of solar exposure. It has also been experimentally proven that bulk water, when forming clusters, is capable of copying and reproducing the size of other molecules and its own clusters [6], [7]. If the resulting clusters are also capable of acquiring biological activity, then it should disappear even after minor damage to the clusters. To experimentally study the conditions and rate of destruction of clusters, it was necessary to find a method for their effective shielding from the influence of muons and, under such conditions, to carry out the reaction of triethyl phosphite hydrolysis that we studied.

It is well known that electrons flying in space can be absorbed by metals and form an electric current in them. In radio electronics, the operation of radio tubes is based on this phenomenon. Since muons are comparable to electrons, it was logical to assume that current conductive metals would also be able to absorb muons produced by the solar wind in the Earth's atmosphere. Indeed, such elimination of the influence of muons was easily confirmed experimentally and yielded interesting and important results.

Results and discussion

We have previously found that since the muon flux is anisotropic and depends on the position of the Sun in the sky, the effect of muons on water clusters depends on the geometric shape of the reaction solution and its location in space [8]. Therefore, for the correct comparison of the results of individual experiments, each of them was carried out simultaneously in three differently directed 5-mm NMR-tubes (Vertical, North-South and East-West). After sunset, identical solutions of water in acetonitrile were left to structure overnight in the open air in three differently oriented NMR-tubes wrapped by aluminum foil. The next day after sunrise, triethyl phosphite was added to these solutions, and the tubes continued to be protected with aluminum foil throughout the reaction. At the same time, for comparison, a second similar experiment was carried out in the same place, in which, after overnight structuring of the clusters and the addition of triethyl phosphite to them, the aluminum screen was removed, and hydrolysis in oppositely directed tubes took place under the solar influence.

The results of these experiments in Figure 2 indicate that when the water clusters were shielded by aluminum before and during the reaction, they showed virtually no reaction with triethyl phosphite. After 6 hours, the yield of the hydrolysis product was only 0.5%. This means that after overnight maturation in the aluminum screen, the water clusters were structured to the largest possible size and contained no free hydroxyl groups. And in the second parallel experiment, in which after adding triethyl phosphite, the aluminum shield was removed and the mature large passive clusters were exposed to the destructive action of muons, the reaction started immediately, accelerated very rapidly, and proceeded about 100 times faster. (Fig. 2) On that day, freshly prepared reaction mixtures, without preliminary overnight maturation of water clusters in an aluminum screen, reacted at approximately the same rate.

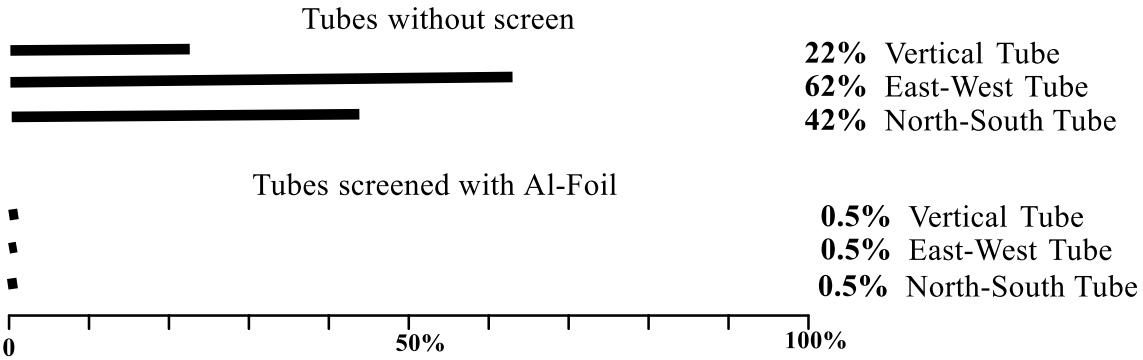

Fig. 2. Hydrolysis rates of $(EtO)_3P$ in December 2024 from 8.00 to 14.00 in multidirectional NMR-tubes unscreened and screened with Al-Foil. Before adding $(EtO)_3P$, water in CH_3CH was allowed to mature in the screened NMR-tubes for 20h overnight.

These results indicate that triethyl phosphite does not react with mature large clusters which do not contain free hydroxyl groups. This reaction begins only after muons break the hydrogen bonds between water molecules in the clusters and form hydroxyl groups, which immediately react with the triethyl phosphite present. Thus, the rate of hydrolysis is determined by the rate of decomposition of water clusters. During the daytime, under the solar influence, the splitting of clusters by muons can occur very quickly and begin suddenly. For example, in November and December 2018, a sharp acceleration of the reaction by 50 times was recorded within a few minutes. (Fig. 1) This also explains why in July 1988, when testing the 'Water Memory' phenomenon, the first four experiments confirmed it, and the following three experiments gave a negative result [5].

The unification of clusters, on the contrary, is a slow process that begins to occur after the muons influence ceases. For example, when the reaction that has already begun is shielded with aluminum, it does not stop immediately, but gradually slows down.

Methods

In the evening after sunset water (7mg) was added to acetonitrile (400mg) separately in either of three 5-mm NMR-tubes and the solutions were mixt by shacking. The NMR-tubes were wrapped in several layers of aluminum foil and placed outdoors next to each other in different directions (vertically, east-west and north-south) away from large buildings. After the water clusters had matured overnight, 25 mg of triethyl phosphite was added to each tube in the morning after sunrise (without removing the aluminum foil), and the tubes continued to be shielded throughout the reaction. The reactions were conducted at ambient temperature. At the same time, for comparison, the same experiment was carried out in the same location, but before adding triethyl phosphite, the aluminum screen was replaced with a cardboard one so that the muons could act on the reaction mixture, protected only from light.

The reaction rate was determined by measuring the integral intensities of the signals of triethyl phosphite and diethyl phosphonate in the ^{31}P-NMR spectra. Triethyl phosphite was distilled before use. Acetonitrile

was commercial and contained ≤ 0.02% water. Since bulk water can copy and reproduce clusters of different sizes [6], it is important for estimating the rate of cluster destruction by muons that the wet starting acetonitrile initially contains the largest possible clusters. Therefore, the acetonitrile used was stored in an aluminum screen to protect it from muons.

The NMR-tubes used should be from the same manufacturer. They must be checked by this reaction for identity and must not come into contact with other substances.

Conclusions

The conducted experiments and analysis of their results allow us to conclude that the constant formation of muons in the Earth's atmosphere under the influence of the Sun is a necessary condition for many hydrolytic processes involving water clusters. Muons break hydrogen bonds between water molecules, which splits water clusters and increases their hydrolytic activity. Without splitting by muons, water clusters would remain maximally large in size and would not have sufficient reactivity.

The constant destruction of water clusters by muons has another positive quality. It causes an unstable manifestation of the phenomenon called 'Memory of Water'. Bulk water, when forming clusters, is capable of copying the biological activity of other molecules. Without destruction by muons, such biologically active clusters could contribute to the emergence and spread of epidemics and pandemics. The 'Water Memory' phenomenon can only manifest itself more stably at low solar influence, when muons do not quickly destroy water clusters, for example, in winter and after sunset.

The experiments described were conducted in December and in March 2023 at 53°N, and the muon flux was completely shielded by several layers of aluminum foil. Since the muon intensity is constantly changing and can increase sharply and very strongly, more powerful shielding may be required to absorb them, especially in summer. The influence of muons on hydrolytic processes has a direct impact on all forms of life and requires detailed comprehensive study at various points on Earth at different geographic latitudes.

Competing interest

There are no conflicts to declare.

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SPATIAL ANALYSIS OF WIND FARM SUITABILITY IN KALBAJAR AND LACHIN DISTRICTS, AZERBAIJAN

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Abstract

The development of renewable energy is a strategic priority for Azerbaijan as the country seeks to diversify its energy mix and promote sustainable development. Following the recent declassification of the Kalbajar and Lachin districts, these areas offer new opportunities for utility-scale wind energy deployment. However, decades of restricted access have resulted in significant knowledge gaps regarding their technical suitability for wind farm development. This study presents the first comprehensive GIS-based spatial assessment of the wind energy potential in the Kalbajar and Lachin districts. Using open-access datasets, including Global Wind Atlas, NASA SRTM, and ESA WorldCover, an integrated multi-criteria analysis was conducted to identify areas that meet international standards regarding wind speed, topographical suitability, and land cover. The results show that 267.93 km² within these districts meet all criteria, with the most promising sites concentrated along their western and southwestern edges. This evidence-based and reproducible methodology provides a valuable reference for policymakers, investors, and planners, laying the foundation for further feasibility studies and informed decision-making. The results contribute to national renewable energy ambitions and the sustainable recovery of the newly accessible western regions of Azerbaijan.

Keywords: Renewable energy; Geographic information systems; Multi-criteria analysis; Land cover; Topographic suitability; Sustainable development.

Introduction

The global transition to renewable energy is a key strategy to combat climate change, reduce dependence on fossil fuels, and ensure long-term energy security. In 2016, 90 countries added approximately 55 GW of new wind power capacity, increasing global cumulative installations by 12.6% to approximately 486.8 GW. The share of wind energy in electricity generation has steadily increased: Denmark leads the way with around 40%; Uruguay, Portugal, and Ireland each contribute well over 20%; Spain and Cyprus are just under 20%; Germany is just under 16%; and China, the USA, and Canada each generate approximately 4%, 5.5%, and 6% of their electricity from wind power, respectively [9]. Sustained economic growth has increased energy consumption in both developed and developing countries, which can lead to rapid resource depletion, environmental damage, biodiversity loss, and exacerbation of climate change [10, 11, 12, 13]. Among the various renewable energy options, wind power stands out as a reliable and scalable technology, now recognized worldwide as an essential element of the nation's energy transition. Historically dependent on hydrocarbon resources, Azerbaijan has set ambitious targets to increase the share of renewable energy in its energy mix, in line with its "Azerbaijan 2030: National Priorities for Socioeconomic Development" and international climate commitments. Achieving these targets will require the identification and development of new renewable energy zones, particularly in regions that have only recently become available for major infrastructure projects.

The release of significant areas in western Azerbaijan between 2020 and 2023 presents new opportunities for both regional development and the expansion of the country's renewable energy sector. These newly accessible areas, such as Kalbajar and Lachin, have received little scientific research due to decades of access restrictions. Therefore, there is currently a lack of high-quality, spatially detailed assessments of their potential for renewable energy, especially for wind power. The unique landscape of these districts, with its complex topography, diverse climatic conditions, and low population density, further increases the importance of systematic site selection for sustainable development.

International literature emphasizes that the success of wind energy projects depends not only on the strength of wind resources, but also on careful consideration of terrain characteristics, environmental constraints, and technical limitations [3, 4, 5]. Geographic Information Systems (GIS) provide a powerful framework for integrating multiple datasets and applying transparent, reproducible multi-criteria analyses to site suitability mapping. This approach is particularly valuable in regions where local ground measurements are limited and rapid, evidence-based planning is essential to attracting investment and supporting national energy strategies.

Despite Azerbaijan's recognized wind potential, the developed western districts remain underexplored in terms of detailed wind resource mapping and technical suitability analysis. This gap underscores the urgent need for a robust spatial assessment to support policy objectives and enable private sector engagement in these areas.

This study addresses this challenge through a comprehensive GIS-based analysis of wind energy suitability in the Kalbajar and Lachin districts. Openly accessible, globally recognized datasets such as the Global Wind Atlas for wind speed, NASA SRTM for topography, and ESA WorldCover for land use are combined using established spatial filtering techniques. The goal is to identify and quantify the territories most suitable for wind farm development based on technical, environmental, and operational criteria. The results of this

research will provide the scientific basis for future feasibility studies, investment planning, and informed policy decisions that will shape the next phase of renewable energy development in Azerbaijan.

Materials and Methods

This study was conducted to systematically assess the wind energy potential in the recently liberated territories of Azerbaijan, with a particular focus on the Kalbajar and Lachin districts. No comprehensive wind energy studies have been conducted in these territories, liberated between 2020 and 2023, and local ground measurements remain scarce due to the recent post-conflict situation. Therefore, the analysis relied on open-access, internationally recognized datasets, including the Global Wind Atlas version 4.0, the NASA Shuttle Radar Topography Mission (SRTM) global dataset, and ESA's WorldCover 2021 land cover classification. All spatial analyses and cartographic visualizations were performed using QGIS 3.40.9, enabling transparent, reproducible, and multi-criteria site screening.

The methodological approach began with a regional comparison of all liberated districts of Azerbaijan based on the annual average wind speed from the Global Wind Atlas v4, measured at a reference altitude of 100 meters above ground [7]. This comparison was intended to identify the liberated regions with the highest technical wind energy potential and thus establish the spatial focus for more detailed suitability mapping. Among the candidate districts, Kalbajar and Lachin emerged as the most promising due to their consistently higher wind speed values. Although a limited area in southern Zangilan also exhibited relatively high wind speeds, its extent was significantly smaller compared to the adjacent high-potential areas in Kalbajar and Lachin. For this reason, subsequent phases of the site selection process focused on these two western districts.

The most important suitability criterion for wind farm development was the average annual wind speed at 100 meters above ground. Based on generally accepted standards for large-scale wind energy generation, only areas with wind speeds above 6 meters per second were considered technically feasible for wind energy generation [3,4]. Raster layers from the Global Wind Atlas were downloaded and cropped to the boundaries of the released regions using official district shapefiles. All spatial datasets were reprojected to a common coordinate reference system (WGS 84 / UTM zone 38N) to ensure spatial accuracy and enable precise area calculations. Raster layers were resampled to a cell size of 250 meters to balance computational efficiency and spatial resolution.

Topographical suitability was the next critical filtering step. Large-scale wind farm construction is typically limited to flat or gently sloping terrain to minimize planning costs and ensure operational safety. Following established guidelines, any region with a slope greater than 10 percent was considered unsuitable for wind farm development [5]. Slope data were derived from the NASA SRTM DEM at a resolution of 30 meters and processed in QGIS to generate a continuous slope grid. This grid was then reclassified into binary suitability masks, with all cells above the 10 percent slope threshold coded as unsuitable. The slope mask was overlaid with the wind speed suitability grid to further refine the pool of candidate sites. Land-cover constraints were subsequently applied to address ecological, regulatory, and practical aspects. The ESA WorldCover 2021 v200 land cover dataset, with a spatial resolution of 10 meters, was resampled to match the wind and slope grids. All pixels classified as forest, snow or ice, water, herbaceous wetland, mangroves, moss, or lichen were systematically excluded from the analysis [8]. These land cover types were masked using the QGIS raster calculator and overlay tools to ensure that only open, unforested, and unprotected areas remained as candidates for wind farm development. Mixed or ambiguous land cover pixels were remapped to the 250-meter grid according to their majority class. Urban areas did not pose a significant constraint in these districts due to the low population density and predominantly rural land use.

All raster datasets underwent quality assurance checks prior to overlay analysis, including a visual inspection of orientation, verification of cell size and projection, and cross-validation of samples with available high-resolution imagery. No spatial interpolation was applied to categorical datasets to ensure thematic accuracy throughout the workflow.

The final suitability analysis was performed by intersecting the binary wind speed, slope, and land cover masks using QGIS's raster overlay features. This produced a composite suitability raster in which each cell represents land that meets all technical, topographic, and environmental limits for wind energy use. The total area of suitable land was calculated using the Zonal Statistics tool, which aggregates the number of suitable raster cells within each district and multiplies this by the cell area. In this way, it was determined that a total of 267.93 square kilometers in the Kalbajar and Lachin districts met all suitability criteria and could be considered for future wind farm construction.

The results were visualized in the form of suitability maps showing the spatial distribution of annual average wind speed, slope, excluded land cover types, and the final composite mask. These maps illustrate the strong spatial contrasts within the region: While most of Kalbajar and Lachin are mountainous and heavily forested, their western and southwestern edges comprise large contiguous areas with sufficient wind resources, low slopes, and open land cover. These areas stand out as priority zones for detailed feasibility studies and eventual wind energy development.

The study deliberately did not consider additional criteria such as grid proximity, road access, or microclimatic variability, as these data are not yet fully available for the recently developed areas and are expected to change rapidly during reconstruction. Likewise, detailed field reviews and high-resolution environmental impact assessments are recommended as necessary follow-up actions at the project level once the priority areas have been shortlisted based on this regional assessment.

This GIS-based, multi-criteria approach provides an objective, evidence-based foundation for energy planning in the developed western districts of Azerbaijan. By using transparent methodologies and globally

recognized datasets, the analysis delivers reproducible results that can be refined as new data become available. At the same time, it closes a critical knowledge gap for regional decision-makers and investors prioritizing wind energy development in the country's newly developed areas.

Results

The GIS-based multi-criteria analysis yielded a high-resolution spatial assessment of wind energy suitability in the recently liberated territories of Azerbaijan, with a particular focus on the Kalbajar and Lachin districts. A preliminary comparison of all liberated districts based on the annual average wind speed at 100 meters altitude showed that the western edges of Kalbajar and Lachin are the most promising regions for wind energy development. These areas consistently exceeded the 6 m/s threshold, as shown in Figure 1.

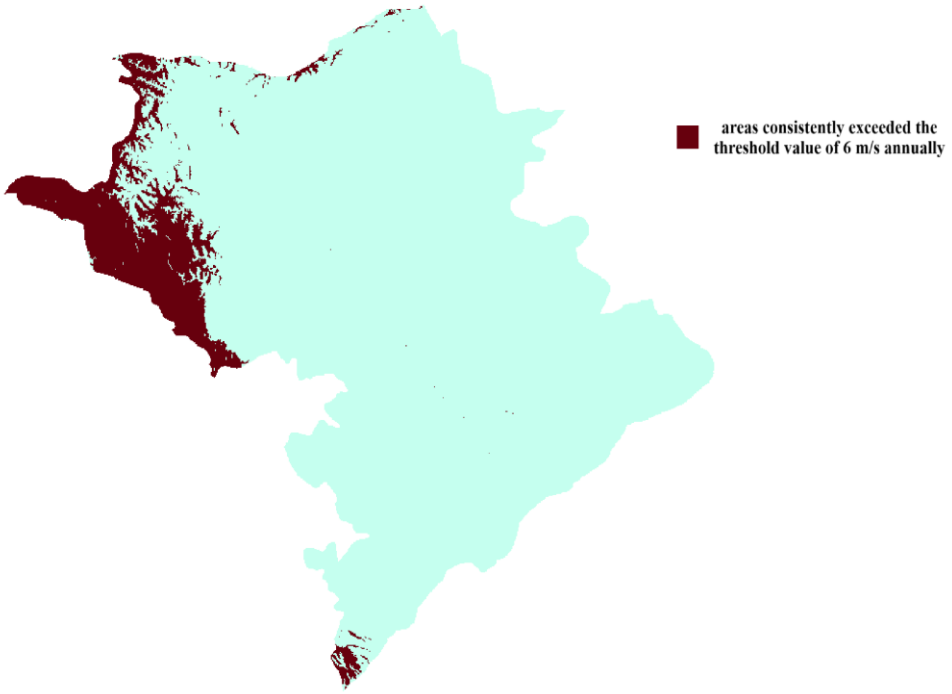

Figure 1. *Spatial distribution of areas in the liberated districts of Azerbaijan where the annual average wind speed at a height of 100 meters exceeds 6 m/s*

After the wind speed assessment, topographical suitability was assessed by excluding areas with slopes greater than 10 percent. Slope analysis derived from SRTM data further limited the suitable regions to the western and southwestern parts of both districts, where the terrain is relatively flat or gently sloping.

Land cover analysis using ESA WorldCover data resulted in the exclusion of forest, water, wetlands, snow, and other unsuitable categories. After overlaying all criteria in QGIS, the final composite suitability map (Figure 2) showed 267.93 km² of land in Kalbajar and Lachin that met all technical, topographical, and ecological criteria for wind farm construction.

Spatial visualization of the results shows that the majority of these suitable sites are concentrated in contiguous areas along the western and southwestern borders of the two districts. These areas have minimal overlap with ecologically sensitive or inaccessible land cover types, ensuring practical feasibility for future wind energy projects.

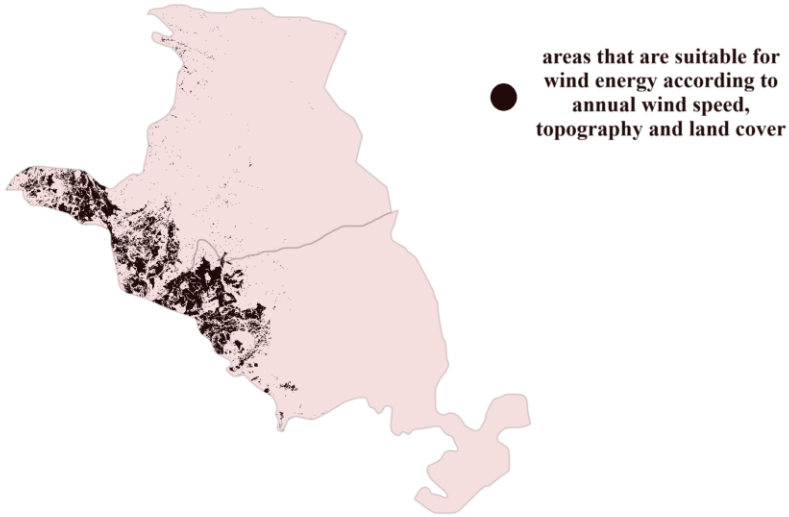

Figure 2. *Spatial distribution of land suitable for wind energy projects in the liberated western districts of Azerbaijan, based on a combined analysis of wind speed, slope gradient, and land cover constraints*

Discussion

The results confirm that the development of wind energy in the liberated territories of Azerbaijan, particularly in the Kalbajar and Lachin districts, is both technically and spatially feasible. The methodology, based on established international standards and using exclusively open-access datasets, enables a transparent and reproducible screening of wind energy potential. The dominant limiting factors were the availability of wind resources and topographical suitability, with land cover playing a significant but secondary exclusion role.

The western parts of Kalbajar and Lachin emerged as the leading areas due to their unique combination of high average wind speeds and relatively favorable terrain. The exclusion of regions with excessive slope gradients (>10%) is consistent with best practices to minimize construction and maintenance challenges and ensure economic viability [5]. The use of a wind speed threshold of 6 m/s is consistent with scientific literature and industry practice and ensures that only sites with genuine long-term generation potential are selected [3,4,7].

Comparison with recent regional studies shows a strong correlation regarding spatial suitability patterns. As in other post-war or mountainous regions, the interplay of topography and wind resources is the most important factor in selecting suitable sites for renewable energy projects. The exclusion of unsuitable land cover types, particularly forests and wetlands, helps ensure that potential wind farm sites do not conflict with ecological or conservation priorities [8].

A limitation of the present analysis is the exclusion of infrastructure-related factors such as grid connection, road access, and proximity to settlements. This is justified by the current context of rapid infrastructure development in the liberated areas and the ongoing updating of relevant spatial datasets. As more detailed local data become available and reconstruction progresses, future studies should incorporate these variables into a refined multi-criteria assessment. Furthermore, field validation of modeled wind speeds and microclimatic effects is recommended before initiating site-level feasibility studies.

Despite these limitations, this research provides an important evidence base for policymakers, investors, and planners seeking to prioritize wind energy development in the region. The GIS workflow is based exclusively on globally recognized datasets and systematic binary masking and can be easily updated and adapted as new information becomes available. This supports robust energy planning and contributes to Azerbaijan's strategic goals of increasing renewable energy capacity and accelerating the sustainable restoration of vacated land.

Conclusion

This study presents the first comprehensive, GIS-based spatial assessment of wind energy site suitability in the recently declassified Kalbajar and Lachin districts of Azerbaijan. By integrating high-resolution wind speed data from the Global Wind Atlas, topographical analyses from SRTM DEM, and land-cover mapping from ESA WorldCover, a total of 267.93 square kilometers were identified as suitable for wind farm development. This was done according to internationally recognized technical, environmental, and operational criteria.

The results highlight the unique potential of the western parts of Kalbajar and Lachin, combining strong wind resources with accessible terrain and minimal ecological or land-use conflicts. The transparent and replicable approach of this study provides a valuable

reference for further detailed feasibility studies, investment decisions, and policy planning.

Further research should incorporate dynamic infrastructure data, field-based wind measurements, and more detailed environmental and social aspects to refine site selection at the project level. Nevertheless, the results represent a significant step forward in supporting Azerbaijan's renewable energy ambitions and the sustainable transformation of its newly developed territories.

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HISTORICAL SCIENCES

THE ROLE OF SEVERAL COUNTRIES ON THE WAY OF SETTLEMENT OF THE NAGORNO-KARABAKH CONFLICT

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Abstract

The resolution of Nagorno-Karabakh conflict was supposed to create new geopolitical realities in the South Caucasus region and in the post-Soviet space as a whole.

It was important for extra-regional forces, in the event of a settlement of the problem around Nagorno-Karabakh, to use the created situation to their advantage, not allowing the victorious country to strengthen, but most importantly, to contribute to the weakening of Russia's role in post-imperial countries.

Keywords: Nagorno-Karabakh conflict, geopolitics, farsighted policy, interaction

Purpose of Research. The dominance of the OSCE Minsk Group co-chair countries' own ambitions, an attempt to disrupt the political, economic and military development of the Republic of Azerbaijan did not provide an opportunity to facilitate the peaceful settlement of the Nagorno-Karabakh conflict.

Based on the above, it becomes absolutely clear that the OSCE Minsk Group co-chairs did not want the Armenian-Azerbaijani Nagorno-Karabakh conflict to be resolved peacefully or militarily.

The resolution of the problem could lead to the natural loss of positions of the Russian Federation, the USA, and France in the South Caucasus.

But on the other hand, Türkiye's growing interest in the problem around Nagorno-Karabakh made worry the Minsk Group co-chairing countries, because they could lose their positions in the South Caucasus. The activation of Türkiye's diplomacy, rapprochement with Azerbaijan expanded Türkiye's participation in the process of resolving the conflict and establishing the territorial integrity of the Republic of Azerbaijan.

Research Methodology. The methodological and theoretical basis of this paper were articles, Internet resources touching upon the foreign policy aspects of Azerbaijan, Türkiye and other countries at the present stage, as well as a deep analysis of the author.

Scientific novelty. Nagorno-Karabakh conflict and the ways to resolve its problem studied in all aspects. Its first paper reveals in detail prospects for the settlement of the Nagorno-Karabakh conflict for leading forces in the world.

The signing of the 'Contract of the Century' (September 1994) increased the West's interest in the region and consequently intensiied its engagement in the conlict resolution giving the new momentum to the peace process via CSCE mediation [p.79].[1]

The ineffective activities of the OSCE Minsk Group co-chair countries to resolve the Nagorno-Karabakh problem led to closer alignment with the countries that faced aggressive policies.

For example, Georgia took a neutral position regarding the conflict around Nagorno-Karabakh. Therefore, official Tbilisi declared its desire to maintain friendly relations with both Armenia and Azerbaijan, and proposed to hold negotiations within the framework of the OSCE Minsk Group in Tbilisi. But the destructive position of Armenia showed itself in this direction.

After restoring its independence, Georgia faced the problem of separatism, which gave grounds for drawing analogies between Karabakh, Abkhazia and South Ossetia.

Also, many Turkish and Azerbaijani investments in the Georgian economy, for example, strengthening the position of Turkish business circles in Adjara, the spread of Islam - all this became an additional reason in the hands of the Armenian authorities to speak out against Azerbaijani-Georgian relations.

In January 2000, a meeting was held in Tbilisi with Georgian President Eduard Shevardnadze. As a result, the "Cooperation and Security Pact in the Caucasus" ("Tbilisi Pact") was signed. As a result of a farsighted policy, Azerbaijan joined the pact.

The protracted nature of peace negotiations and the deadlock created around the resolution of the Nagorno-Karabakh conflict have led to an intensive rapprochement between the countries of the Turkic world in all directions.

Today, the integration process is receiving increasing support, and the idea of unifying Turkic countries frightens Western countries.

Since 1992, a summit of the states of Turkic languages has been held; in the same year of 1992, the United Administration of Turkic Arts and Languages was formed in Almaty, and in 1998, the Parliamentary Assembly of Turkic-Speaking Countries began operating in Baku.

[1] Garibov, A. OSCE and Conflict Resolution in the Post-Soviet Area: The Case of the Armenia-Azerbaijan Nagorno-Karabakh Conflict. URL: https://d1wqtxts1xzle7.cloudfront.net/55800070/Azad_Garibov-libre.pdf

On August 22, 2012, Türkiye, Kazakhstan, Kyrgyzstan and Azerbaijan adopted a single flag, and at the end of 2014, through the efforts of the Azerbaijani diaspora, the first regional diaspora office of the Turkic Council opened in Kyiv.[2]

It is indisputable that the support of the Turkic states for the territorial integrity of Azerbaijan and the process of peaceful settlement of the Armenian-Azerbaijani.

Nagorno-Karabakh conflict by peaceful means within the framework of the norms and principles of international law, the active Turkish and Kazakh mediation mission could not help but worry many, including the co-chair countries of the OSCE Minsk Group.

Azerbaijan's ties with the Arab and Muslim world subsequently played a decisive role in the process of restoring the country's territorial integrity. The policy of the National Leader Heydar Aliyev, which meets national interests, and the continuation of this policy by President Ilham Aliyev led to the propaganda of Azerbaijan's objective position in the Armenian-Azerbaijani Nagorno-Karabakh conflict.

During the Nagorno-Karabakh conflict, the structure of the geopolitics of the South Caucasus was determined by a complex of internal and external factors, among which the strategic position and geopolitical significance of the region, the presence of territorial claims of certain states on their neighbors (Armenia and Azerbaijan) played a leading role.

The above circumstances make this region a center of intersection of strategic interests of the world's leading countries and major international organizations. Thus, among them were the USA, Russia, China, Iran, Türkiye, Israel, as well as regional organizations and associations such as NATO, OSCE, EU, etc.[3]

The problem around Nagorno-Karabakh gave everyone an idea of the interaction of regional and global powers in international mediation.

The policy of the Republic of Azerbaijan towards resolving the Nagorno-Karabakh conflict is a valuable example of the successful use of natural resources, diplomatic ties and the geopolitical position of the state in order to resolve and attract the interest of strong states to the process of resolving the conflict peacefully [c. 471].[4]

Unfortunately, in the modern political arena, international conflicts often lead to the formation of new unrecognized states that make every effort to gain independence, relying on international law and the support of the patron state [c. 28].[5]

Therefore, it is imperative to separately consider the prospects for the OSCE Minsk Group co-chair countries in the process of resolving the Nagorno-Karabakh conflict, as the details of the expectations of each of these countries are revealed.

It should be taken into account that the OSCE Minsk Group co-chair countries had their own visions for resolving the Nagorno-Karabakh conflict.

For example, Russia, if the problem was resolved, wanted to maintain its dominance in political, military and economic initiatives throughout the region.

It was important for the Russian Federation to resolve the conflict without losing its lead and without allowing the US to become more involved in the region.

The prospects for Russia in the South Caucasus were vast. In addition to the above, there was a desire to use the region's trans communications.

In general, Azerbaijan is a natural barrier for Russia against threats from the South (from the Middle East, Central Asia and the Persian Gulf). Therefore, a stable and strong Azerbaijan is extremely important for Russia, otherwise the Russian Caucasus may face unpleasant destructive influences.[6]

Analyzing these nuances, we come to the conclusion that Russia should be interested in the South Caucasus, which is part of its strategic interests and necessary living space, always remaining a zone of peace and stability. At the same time, the policies of the South Caucasus states themselves have become more predictable for Russia.

In the near future, Russia should rely on socio-cultural factors, equal and mutually beneficial foundations that eliminate previous mistakes, and direct its finances and efforts to supporting the culture and historical traditions of the ethnic groups of the South Caucasus and Russia. Such values of foreign state policy can prevent disintegration and destructive processes.[7]

But, at the same time, it was necessary to preserve its own ambitions in the South Caucasus region by oppressing the interests of other states and maintaining the status quo around Nagorno-Karabakh. The US had an important interest and its own vision of the post-conflict period.

For example, the main thing for the official White House was not only the weakening of the Russian Fed-

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eration in the region, but also the intensive use of Azerbaijan's geopolitics for greater activation of its foreign policy concepts in all former Soviet republics, thereby affirming the postulates of a multipolar world as opposed to a unipolar one.

Based on this, the end of the ideological confrontation between the USSR and the USA led to the growth of American ambitions and attempts by official Washington to resolve regional conflicts. However, due to the lack of sufficient experience in conducting policy in the post-Soviet space, the USA began to approve of Turkey as a conductor of Western European ideas in the region of the South Caucasus and Central Asia.

By building friendly relations between post-Soviet states and Turkey, the United States attempted to reduce Russia's influence and then completely eliminate the presence of the Russian factor in these states.

Throughout history, France has had problems with Muslim countries and the Nagorno-Karabakh conflict is a strong indicator of this. The prospects for the increase in Islamophobia and Azerbaijanophobia for France were quite high, given the possibilities of settling the Nagorno-Karabakh conflict within the OSCE Minsk Group.

However, the well-thought-out policy of Azerbaijan has become a catalyst for the restoration of full sovereignty over its lands. The opening of the Zangezur corridor will further contribute to the creation of a multipolar world. In this regard, the Republic of Azerbaijan will continue to exert an ever-increasing influence on events in the region and beyond its borders.

Azerbaijan also paid attention to relations with European countries. On November 14, 2006, the EU-Azerbaijan Cooperation Action Plan came into force.

The EU expressed its consent to the peaceful settlement of the Nagorno-Karabakh conflict by supporting the efforts of the OSCE Minsk Group and using the capabilities of the UN Security Council. All this contributed to strengthening the EU dialogue with states interested in the political settlement of the Nagorno-Karabakh conflict and ensuring stability in the South Caucasus.

It is clear that European countries were additionally interested in establishing stability in the regions of the South Caucasus in order to advance their economic plans and maximize the use of the energy resources of the Republic of Azerbaijan.

Europe realized that maximum rapprochement with Azerbaijan is possible only through assistance in the peaceful resolution of the conflict around Nagorno-Karabakh and the restoration of the territorial integrity of Azerbaijan.

Awareness of these facts was insufficient to establish peace in the region, since the application of double standards did not provide an opportunity for a real and objective acceleration of the peace negotiations process within the framework of the norms and principles of international law.

The Belt and Road Initiative (BRI), launched in 2013 by China's leadership to integrate the country into the Middle East and Europe, has made Azerbaijan even more important.

In the struggle for world leadership, China has strengthened its economic initiatives, which has resulted in the acceleration of economic integration of countries located along the Great Silk Road, including, naturally, Azerbaijan.

Therefore, the PRC has become one of the state's interested in resolving the conflict around Nagorno-Karabakh and establishing stability in the Caucasus in order to ensure its political interests.

Conclusion

Today, the Republic of Azerbaijan, as a result of a far-sighted policy, control of transport communications and energy resources, is becoming a state that shapes the geopolitics of the region. Depending on this, how deeply the world's power centers, including the Armenian government, will be able to assess the role and strengthening of Azerbaijan's position will depend on the nature of the processes in Eurasia.

Due to new challenges thrown at Azerbaijan by some Western countries, our state will continue the policy of developing the military sphere to fully ensure its security, and the process of the country's prosperity in all areas will also continue to further strengthen the strong status of the state of Azerbaijan in the South Caucasus region and far beyond its borders.

Predictions for future.

In the future, Azerbaijan will continue the policy of developing the military sphere to ensure its security, and the process of the country's prosperity in all spheres will also continue to further strengthen the country's strong status both in the South Caucasus region and throughout the world.

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JURISPRUDENCE

DISTRIBUTION OF THE COMMON PROPERTY vs MANAGEMENT OF THE COMMON PROPERTY (REFLECTIONS ON THE FIELDS OF A COURT ACT)

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РАСПОРЯЖЕНИЕ ОБЩИМ vs УПРАВЛЕНИЕ ОБЩИМ (РАЗМЫШЛЕНИЯ НА ПОЛЯХ ОДНОГО СУДЕБНОГО АКТА)

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Abstract

The article analyzes various approaches to the concept of managing the common property of apartment building owners in different jurisdictions. The author aims to show that managing the common property does not necessarily lead to its alienation and, consequently, the loss of the title of ownership. On the contrary, there are a number of transactions that, although they involve managing the common property, maintain the regime of common ownership. In this case, the author believes that obtaining consent to manage the common property should not be based on unanimity, but rather on the rules of majority.

Аннотация

В статье анализируются различные подходы к понятию распоряжения общим имуществом собственников помещений в многоквартирных домах в различных юрисдикциях. Автором поставлена цель показать, что распоряжение общим имуществом не обязательно влечёт его отчуждение и, как следствие, утрату титула собственника. Напротив, существует ряд сделок, совершение которых хотя и означает распоряжение общим имуществом, но сохраняет режим общей собственности. В этом случае получение согласия на распоряжение общим должно, по мнению автора, происходить не на условиях единогласия, а подчиняться правилам о большинстве.

Keywords: housing, common property of apartment building owners, management of common property, general meeting of apartment building owners, transfer of common property to use

Ключевые слова: жилое помещение, общее имущество собственников помещений многоквартирного дома, распоряжение общим имуществом, общее собрание собственников помещений многоквартирного дома, передача общего имущества в пользование

Двадцатилетний юбилей Жилищного кодекса Российской Федерации (далее по тексту - ЖК РФ) остался в научных кругах практически незамеченным. Вместе с тем, то неоднородное правовое регулирование, которое подарил российскому правопорядку данный нормативный акт, остается в фокусе внимания как участников гражданского оборота, так и судебной практики, в том числе и Верховного Суда Российской Федерации (далее по тексту также ВС РФ). Приняв зачастую взаимопротиворечащие нормы, а также нормы, плохо сочетающиеся с положениями Общей части Гражданского кодекса Российской Федерации (далее по тексту - ГК РФ), законодатель подарил правоприменителю не только широту усмотрения, но и неоднозначность используемых конструкций. Это порой позволяет диаметрально противоположно толковать содержание вроде бы одних и тех же правовых норм в течение весьма непродолжительного отрезка времени и в условиях неизменности самого толкуемого правила, что в том числе находит своё отражение и в текстах принимаемых судебных постановлений.

Одно из кассационных определений, постановленных ВС РФ, и вызвало к жизни дискуссию с уважаемым Михаилом Владимировичем Бандо, обоснованно обратившим внимание на необходимость отличать распоряжение общим от управления общим в том случае, когда речь заходит об общем имуществе многоквартирного дома. Во всяком случае, по мнению Михаила Владимировича, именно здесь стоит искать первоисточник суждений, высказанных высшей судебной инстанцией в Определении от 20 мая 2025 г. по делу № 4-КГ25-19-К1.

Необходимо сразу же отметить, что как указывает Д.А. Формакидов, в российской доктрине под правом общей собственности «понимается ... субъективное право нескольких лиц сообща ... владеть, пользоваться и распоряжаться принадлежащим им имуществом, составляющим единое целое» [2, с. 81]. При этом, как видится, одним из ключевых условий реализации правового режима имущества, находящегося в общей собственности, выступает то, что его судьба может определяться исключительно в результате согласования мнений (воли) каждого из сособственников.

Если обратиться к положениям части 4 статьи 36 ЖК РФ, то по решению собственников помещений в многоквартирном доме, принятому на общем собрании таких собственников, объекты общего имущества в многоквартирном доме могут быть переданы в пользование иным лицам. Что же подразумевал законодатель, используя конструкцию «переданы в пользование иным лицам»? Оставляя в стороне дискуссию о триаде правомочий собственника, необходимо отметить, что сама конструкция цитируемой нормы предполагает изъятие части общего у собственников на условиях достигнутого ими соглашения и передачу изъятого неким иным лицам. Фактически речь идёт о распоряжении какой-то частью общего имущества.

Здесь необходимо сделать небольшое отступление о применимости норм гражданского законодательства к жилищным отношениям, ведь положения о передаче общего в пользование иным лицам помещены законодателем в ЖК РФ, а не в ГК РФ.

В силу части 1 статьи 7 ЖК РФ нормы гражданского законодательства применяются, если жилищные отношения не урегулированы жилищным законодательством или соглашением участников, напрямую, без применения условий об аналогии закона. Таким образом, вполне корректным будет обратиться к тому, как регулирует действующее российское гражданское законодательство распоряжение общим.

Формально правило, приведенное в части 4 статьи 36 ЖК РФ, не расходится с общими положениями о распоряжении общим, сформулированными в пункте 1 статьи 246 ГК РФ и предполагающими, что в основе таких действий лежит достигнутое сособственниками соглашение. При этом соглашение по правилам пункта 1 статьи 246 ГК РФ должно рассматривается как единодушно достигнутое согласие [1, с. 71], ведь ни один из собственников не обладает всей полнотой власти над вещью по сравнению с другими участниками общей собственности.

Российский правопорядок не одинок в установлении условий о достижении собственниками соглашения при распоряжении общим имуществом. Сходное регулирование можно обнаружить и в других правовых системах, относящихся к романо-германской правовой семье. Так, в статье 173 Гражданского Кодекса Грузии прямо установлено условие о необходимости достижения соглашения между участниками общей собственности при залоге или ином обременении вещи, находящейся в общей собственности.

В ряде случаев законодатели соответствующих государств, чтобы избежать двусмысленного толкования прямо указывают, что для распоряжения общей вещью требуется не просто достигнуть соглашения, но прийти к согласию. Например, в статье 1068 Гражданского Кодекса Латвийской Республики закреплено правило, гласящее, что распоряжаться предметом общей собственности как целиком, так и определенными отдельными частями, можно только при согласии всех общих собственников.

Таким образом, определенная часть правопорядков Европы устанавливает правила о том, что общее принадлежит всем его собственникам, а значит его судьба не может определяться волей кого-то одного. Напротив, требуется достигнуть соглашения о будущем общего имущества.

При этом те же правовые системы соглашаются с наличием у собственников жилых помещений в многоквартирных домах права общей собственности на некое общее имущество. В частности, о том, что собственник жилого помещения вправе пользоваться общей собственности прямо указано в статьи 220 Гражданского Кодекса Грузии.

При этом в части 1 статьи 36 ЖК РФ содержится перечень того, что может быть отнесено к общему имуществу собственников помещений многоквартирного дома. Сходный подход можно встретить и в других юрисдикциях. К примеру, в статье 4 Закона Латвийской Республики «О квартирной собственности» в качестве объектов общей собственности упомянуты внутренние и внешние отграничивающие конструкции, обслуживающие жилой дом системы инженерных коммуникаций, а также земельный участок.

Необходимо отдельно отметить, что исследуемые правопорядки подчеркивают неразрывную правовую связь между судьбой вещи, находящейся в индивидуальной собственности, и долей в общем имуществе. Так, в статье 213 Гражданского Кодекса Грузии закреплено, что собственник жилого помещения одновременно является и участником общей собственности. В свою очередь, в статье 2 Закона Латвийской Республики «О квартирной собственности» определено, что входящая в состав квартирной собственности отдельная собственность и идеальная часть общей собственности в правовом отношении не отделяются.

Вместе с тем, раз существует некое общее имущество, поступающее в общую собственность, значит существуют и правила распоряжения таким имуществом. Но каковы они?

Если обратиться к положениям статьи 4 Закона Латвийской Республики «О квартирной собственности», то в них прямо указано на то, что положения статьи 1068 Гражданского Кодекса Латвийской Республики о необходимости получения согласия на распоряжение общим будут применяться только в той степени, насколько соответствующими положениями статьи 17 Закона Латвийской Республики «О квартирной собственности» не установлено иное. В свою очередь, в указанной статье со ссылкой на положения статьи 16 того же нормативного акта предусматривается, что вопросы о передаче находящейся в общей собственности части в пользование решаются большинством голосов собственников всех квартир. Таким образом, признавая, что отчуждение части общей собственности без одновременного отчуждения индивидуальной невозможно, законодатель тем не менее допускает возможность отдать в пользование часть общего.

Федеральным законом от 24 июля 2023 г. № 351-ФЗ (вступившим в действие с 01 октября 2023 г.) глава 16 ГК РФ была дополнена параграфом 2,

определяющим правовой режим общего имущества собственников недвижимых вещей.

В пункте 2 статьи 259.2. ГК РФ воспроизведена идея общей судьбы доли в праве общей собственности на общее имущество и индивидуальной вещи, с возникновением права на которую у лица и возникает право общей долевой собственности. При этом законодателем отдельно подчеркнуто, что такая доля не может быть выделена в натуре.

О том же, каким образом должно осуществляться распоряжение общим имуществом, законодатель деликатно умолчал, указав, впрочем, что такое решение должно приниматься принимается большинством голосов всех собственников недвижимых вещей, если иное число голосов не предусмотрено ГК РФ или иным законом. Одновременно в пункте в пункте 4 статьи 259.3. вышеуказанного кодекса определено, что пригодное для самостоятельного использования общее имущество может быть передано во владение или пользование третьим лицам. Это вполне коррелирует с положениями части 4 статьи 36 ЖК РФ, также предусматривающей возможность передачи объектов общего имущества в многоквартирном доме иным лицам.

В силу чего допустимо предположить, что законодатель, не изменив запрет на распоряжение общим имуществом иначе как по согласию всех участников общей собственности, всё же видит разницу между распоряжением-отчуждением и распоряжением-передачей в пользование иным лицам-несобственникам и не считает такое распоряжение тождественным. Следует предположить, что в данном случае речь идёт о реализации правомочия распоряжения, которое не приводит к утрате титула, а равно доступа к вещи. По сути, собственники управляют общим, отдавая его в пользование третьим лицам без отчуждения индивидуального. Но это именно распоряжение, а не что-либо иное, к примеру, не реализация механизма определения порядка пользования.

О том, что речь идёт именно о распоряжении, но совершенном в определенных условиях, косвенно высказывается и Конституционный Суд Российской Федерации (далее - КС РФ). В частности, в Определении от 10 апреля 2025 г. № 910-О КС РФ отметил, что допускается пользование общим имуществом в многоквартирном доме иными лицами, решение о чём принимается большинством не менее двух третей голосов от общего числа голосов собственников помещений в многоквартирном доме. То есть КС РФ фиксирует, что распоряжение возможно и без получения общего согласия всех участников общей собственности, но только в отношении общего имущества многоквартирного дома и только в случае, когда такое имущество передается в пользование. Кроме того, в указанном Определении КС РФ делает ссылку на положения части 3 статьи 36 ЖК РФ, согласно которым уменьшение общего имущества возможно только в результате согласия всех собственников помещения многоквартирного дома. Таким образом, высшая судебная инстанция очерчивает границы - в результате передачи общего имущества в пользование иным лицам оно точно не может уменьшиться.

Если обратиться к фабуле спора, послужившей основой для принятия ВС РФ Определения от 20 мая 2025 г. по делу № 4-КГ25-19-К1, то она вкратце такова. Два собственника жилых помещений в многоквартирном доме обратились к ряду юридических лиц с требованиями о признании незаконным размещение рекламных конструкций на крыше многоквартирного дома, в котором расположены принадлежащие заявителям квартиры. В ходе рассмотрения спора было установлено, что задолго до обращения истцов с требованиями о защите своего права на общее имущество (а именно нарушением права на беспрепятственное владение и обосновывался иск) на общем собрании собственников помещений многоквартирного дома было принято решение о предоставлении части крыши для размещения рекламной конструкции. При этом свое согласие на подобное занятие части общего имущества выразило более 75% собственников помещений многоквартирного дома.

Можно ли в рассматриваемом споре говорить о том, что имело место распоряжение общим имуществом? Как видится, ответ однозначен - да, конечно. Часть общего целого была передана лицу, не являющемуся участником общей собственности.

Первая инстанция, разрешая спор, построила свои суждения на том, что такое распоряжение возможно, коль скоро оно допускается законом при соблюдении формы достижения соглашения - две трети собственником помещений многоквартирного дома высказались за передачу части крыши в пользование иному лицу. Первоначально такую же позицию занял и суд апелляционной инстанции при проверке дела по жалобам истцов.

Однако при первом рассмотрении суд кассационной инстанции не согласился с мнением суда второй инстанции и, отменяя апелляционное определение указал, что такое использование требует получения согласия всех собственников помещений в многоквартирном доме при принятии решения о пользовании общим имуществом дома. Фактически при повторном рассмотрении спора суд предложил проверить, имеется ли распоряжение общим имуществом, в том смысле, какой изложен в пункте 1 статьи 246 ГК РФ и части 3 статьи 36 ЖК РФ.

При новом рассмотрении суд апелляционной инстанции принял иное решение, сочтя, что в данном случае речь идёт о распоряжении, на совершение которого требуется общее согласие всех участников общей собственности. С чем и согласился суд кассационной инстанции теперь уже при рассмотрении кассационной жалобы ответчика.

В свою очередь, ВС РФ, проверяя суждения судов нижестоящих инстанций, ссылается на условие распоряжения общим, установленное в пункте 1 статьи 246 ГК РФ, предусматривающее получение согласия от всех участников общей собственности. Для высшей судебной инстанции вполне очевидно, что передача общего кому-то иному есть наиболее естественное проявление правомочия распоряжения.

Однако дальше ВС РФ, ощущая, что речь идёт «о каком-то не таком распоряжении», делает пара-

доксальный вывод о том, что размещение рекламной конструкции на крыше многоквартирного дома представляет собой частный случай определения порядка пользования общим имуществом собственников помещений в многоквартирном доме. При этом судом игнорируется и то, что порядок пользования может быть определен только между самими участниками общей собственности, и то, что в результате размещения рекламной конструкции часть общего передается в обладание лицу, не являющемуся сособственником.

Почему же судом допущено такое очевидное искажение? Как видится, в судебном акте предпринята попытка отказаться от использования категории «распоряжение» в том случае, если речь не идёт об отчуждении. Фактически ВС РФ ставит знак равенства между распоряжением и отчуждением, опасаясь признать, что распоряжение не всегда приводит к утрате не то, что титула, но даже и владения общим имуществом.

Однако и здесь дьявол может скрываться в деталях. Допустимо предположить, что при установке рекламной конструкции происходит демонтаж пусть и незначительного, но всё же участка ограждения на крыше, т.е. фактически части общего имущества собственников помещений многоквартирного дома. И тогда налицо все признаки уменьшения общего имущества многоквартирного дома, которое по правилам части 3 статьи 36 ЖК РФ однозначно трактуется законодателем как распоряжение, требующее согласия всех участников общей собственности.

Но, допустим, никакого уничтожения части общего имущества для монтажа рекламной конструкции не происходит. Мало того, конструкция имеет такую форму и такое крепление, что все участники общей собственности сохраняют беспрепятственный доступ к крыше, включая и переданную в пользование иному лицу часть. То есть одновременно сохраняется и владение общим, и возможность пользоваться им, но при этом из использования этого имущества лицом, не являющимся участником общей собственности, извлекается доход в результате распоряжения. Можно ли в этом случае вести речь о том, что мы имеем дело с частным проявлением правомочия распоряжения - управлением? По всей видимости, ответ должен быть положительным.

Если предположить, что управление не означает отчуждения (терминологически предложенная автором конструкция весьма несовершенна и нуждается в доработке), то возможно разрешить коллизию о необходимости получения общего согласия при распоряжении общим. Так, в случае утраты титула в результате распоряжения, а равно в результате уменьшения объема общего имущества, даже в отношении общего имущества собственников помещений многоквартирного дома должен сохраняться принцип общего согласия. В том случае, когда речь идет о передаче части общего в пользование другому лицу, т.е. несобственнику, можно говорить о субординации воли меньшинства воле большинства, не требующей единодушия.

Подводя итоги, вполне допустимо предположить, что увеличение количества объектов, находящихся в общей долевой собственности большого числа лиц, в частности, продолжающийся рост количества многоквартирных домов, ещё не раз поставят перед исследователями вопрос о пределах воли меньшинства при определении судьбы общего имущества, а также нахождении эффективного механизма согласования разнонаправленных интересов участников общей собственности. Как видится, одним из возможных вариантов преодоления выявленной проблемы (вне изменения существующей модели правового регулирования) может быть проведение дифференциации между распоряжением-отчуждением и распоряжением-управлением. При таком подходе на долю судов выпадет установление последствий того или иного решения и действия сособственников, но это будет значительно меньшим злом, нежели установление препятствий для оборота имущества или пренебрежение правами кого-либо из участников общей собственности.

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INCLUSIVE EDUCATION AND HUMAN RIGHTS: ENSURING THE RIGHT TO EDUCATION FOR PERSONS WITH DISABILITIES IN UKRAINE AND EUROPE

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Abstract

The article analyzes the legal and institutional framework for ensuring the right to education for persons with disabilities in Ukraine within the context of European standards of inclusive education. Particular attention is given to the principles of equality, non-discrimination, and accessibility, which gain special importance in the conditions of war and the growing number of persons with disabilities. International and national legal acts, as well as the practices of EU member states (Poland, Germany, Slovakia), are examined, and gaps in the implementation of inclusive policies in Ukraine are identified. The article substantiates the prospects for harmonizing the Ukrainian education system with European practices within the framework of the country's European integration course.

Keywords: right to education; inclusive education; persons with disabilities; equality; non-discrimination; accessibility; European standards; Ukraine.

Statement of the problem. The right to education is a fundamental human right guaranteed by several international documents, including the 1948 Universal Declaration of Human Rights [1], the 1966 International Covenant on Economic, Social and Cultural Rights [2], and the 2006 UN Convention on the Rights of Persons with Disabilities [3]. In the European legal space, it is enshrined in the European Convention for the Protection of Human Rights and Fundamental Freedoms [4] and the Charter of Fundamental Rights of the European Union [5]. Of particular importance is the issue of realizing the right to education for persons with disabilities, which is not only a manifestation of social justice but also an indicator of the maturity of a democratic state governed by the rule of law.

In Ukraine, the right to education is enshrined in the Constitution [6] and detailed in special legislation, in particular in the Law "On Education" [7] and the Law "On Complete General Secondary Education" [8]. At the same time, ensuring its accessibility for persons with disabilities remains a pressing challenge, requiring the implementation of effective mechanisms for inclusive education. European experience shows that inclusion in the educational environment is a legal obligation and a tool for integrating such persons into society and ensuring their active participation in public life and the labor market.

Despite positive developments, barriers remain in Ukraine regarding infrastructure inaccessibility, a lack of specially trained teaching staff, and insufficient funding for adapted programs and assistive technologies. An additional challenge is the consequences of Russia's armed aggression against Ukraine, which has led to an increase in the number of persons with disabilities, including children, who need inclusive education services.

European countries have already accumulated considerable experience in inclusive education based on the principles of equality, non-discrimination, and universal access. A comparative analysis of legal mechanisms for ensuring the right to education for persons with disabilities in Ukraine and Europe is essential for forming national policy. It allows us to identify the strengths and weaknesses of domestic legislation, outline areas for its adaptation to European standards, and propose practical ways to implement the right to education as an integral part of human rights.

The purpose of this article is to provide a comprehensive analysis of the legal mechanisms for ensuring the right to education for persons with disabilities in Ukraine in comparison with European standards, as well as to identify practical tools for inclusive policy that can be implemented in the domestic education system, taking into account international obligations and current challenges.

Materials and methods of research. The work uses a comparative legal method to compare Ukrainian legislation with European approaches in inclusive education. Historical and legal analyses were used to trace the evolution of legal regulation of the right to education for persons with disabilities. Systemic and structural-functional methods assessed the relationship between international norms, national legislation, and educational practice. A problem-oriented approach was also used to identify key barriers and develop practical recommendations for improving inclusive policies in Ukraine.

Research findings and discussion. Effective enforcement of the right to education for persons with disabilities in Ukraine is only possible if national legislative initiatives are combined with best European practices in inclusive education based on equality, non-discrimination, and accessibility. The principle of equality means equal recognition of the right to education for all categories of citizens, regardless of their health or social status. Non-discrimination prohibits any form of restriction or prejudice against persons with disabilities in the educational environment. The principle of accessibility covers physical, informational, and digital dimensions, ensuring barrier-free learning opportunities. Today, in the context of war, when the number of people with disabilities is growing due to injuries and trauma, and the educational infrastructure is being destroyed, the importance of these principles is particularly relevant. Their implementa-

tion is also a key condition for Ukraine's European integration course, which harmonizes educational policy with European standards of human rights and inclusion.

The development of inclusive education and ensuring the right to education for persons with disabilities in Ukraine are inextricably linked to forming a multi-level regulatory framework that includes international documents of the UN, the Council of Europe, and the European Union, as well as national legislation. These acts enshrine the universal principles of equality, non-discrimination, and accessibility, which are gradually being implemented in Ukraine's domestic legal system. However, in practice, there remain gaps and problems in their implementation.

At the universal level, the fundamental act is the 1948 Universal Declaration of Human Rights, Article 26 of which proclaimed the right of every person to education as an inherent and universal right [1]. This document became the basis for developing legal approaches in education, which were later detailed in the 1966 International Covenant on Economic, Social, and Cultural Rights. Article 13 of the Covenant defined education as a universal right to be progressively ensured by the participating states, emphasizing the obligation of states to create conditions for universal access to and compulsory basic education [2].

Of particular importance for inclusive policy is the 2006 UN Convention on the Rights of Persons with Disabilities, ratified by Ukraine in 2009. Article 24 of this document provides for creating an inclusive education system at all levels and lifelong learning, emphasizing equal access without discrimination, the need to adapt curricula, and the creation of reasonable accommodations [3]. Another important earlier act was the Standard Rules on the Equalization of Opportunities for Persons with Disabilities (1993), which systematized the basic requirements for creating educational opportunities in the field of inclusion.

At the regional level, the Council of Europe has significantly contributed to developing inclusive education. The European Convention on Human Rights (1950), specifically Article 2 of Protocol No. 1, enshrines the right to education, which was subsequently specified in the European Court of Human Rights case law. The Court emphasized that this right must also be guaranteed for vulnerable groups, including persons with disabilities. In addition, the European Social Charter (revised in 1996), in Article 15, explicitly provides for the obligation of states to ensure the right of persons with disabilities to independence, social integration, and participation in public life, which includes the right to education. Several recommendations by the Committee of Ministers of the Council of Europe are also significant, particularly Recommendation No. R(92)6 on strengthening cooperation in special education for children with disabilities, which enshrined the approach to inclusion as a universal right [9].

Despite the absence of a separate education convention, the European Union has created several strategic documents that set standards for inclusive education. First and foremost, it is worth highlighting the European Disability Strategy 2010-2020 and its continuation and the EU Strategy on the Rights of Persons with Disabilities 2021-2030. These acts emphasize the removal of barriers, the creation of accessible infrastructure, the introduction of digital technologies in education, and the provision of academic mobility for students with disabilities. In addition, Article 14 of the Charter of Fundamental Rights of the European Union (2000) enshrines the right to education, and Article 21 prohibits discrimination on any grounds, including disability [4].

Ukrainian legislation is also gradually being harmonized with European standards. Article 53 of the 1996 Constitution of Ukraine guarantees the right of everyone to education, and Article 24 enshrines the principle of equality of citizens and the prohibition of discrimination [6]. The Law of Ukraine “On Education” (2017) was the first normative act in which the principle of inclusiveness was enshrined as a state priority. Article 19 explicitly provides for the right of persons with special educational needs to education and outlines mechanisms for creating an inclusive environment [7]. The Law of Ukraine “On Complete General Secondary Education” (2020) detailed the work of inclusive classes, the provision of teacher assistants, and the use of adapted programs [8]. This framework is supplemented by the Law of Ukraine “On the Rehabilitation of Persons with Disabilities in Ukraine” (2005), which defines the right to educational services as a component of social integration [10].

However, there are significant gaps compared to European standards. First, in practice, the principle of accessibility is not fully implemented: a substantial number of educational institutions are not architecturally adapted to the needs of persons with disabilities. Second, funding for inclusive education in Ukraine is fragmented, while the EU has dedicated funds and grant programs. Thirdly, digital inclusion, a key European priority, is being implemented slowly in Ukraine due to technical and human resource constraints. Fourthly, the monitoring and accountability system is still being developed. While the EU has powerful institutional mechanisms, particularly through the ombudsperson institution, this area remains underdeveloped in Ukraine.

In the context of war, the problem of inclusive education in Ukraine has become particularly acute. The number of people with disabilities has increased as a result of hostilities, and a significant part of the educational infrastructure has been destroyed or damaged. This requires the restoration of the material and technical base and the integration of modern inclusive practices adapted to the conditions of wartime and post-war development. In particular, the digitisation of education and the introduction of distance learning technologies, which allow access to education even without physical infrastructure, are of particular importance.

Ukraine's European integration course creates additional obligations to harmonize education policy with European standards. Implementing the provisions of the European Social Charter and the EU Strategy on the Rights of Persons with Disabilities 2021-2030 should form the basis for modernizing Ukrainian education legislation and practices. This will not only contribute to increasing the level of inclusiveness of education in

Ukraine, but also ensure that the national education system meets the Copenhagen criteria, which is necessary for the process of accession to the European Union.

When it comes to the practical implementation of inclusive education, it requires the coordinated action of at least four interrelated components: physical and digital accessibility of the educational environment, professional training of teaching staff, provision of assistive technologies and services, and sustainable financial mechanisms. Their synergy determines the real ability of the education system to integrate persons with disabilities into the learning process at all levels, from preschool to higher and postgraduate education.

First, it is worth talking about the accessibility of educational institutions. In the modern understanding, accessibility covers not only the architectural and spatial dimension (barrier-free entrance, elevators, ramps, sanitary rooms, Braille navigation), but also information and communication accessibility (alternative formats of materials, subtitling, sign language interpretation, web accessibility according to WCAG standards), as well as organizational procedures (reasonable adjustment of schedules, individual study plans, support). In recent years, Ukraine has made noticeable progress in forming a "barrier-free culture", but the actual condition of many buildings and digital services remains uneven. Against the backdrop of destruction caused by the war, the problem of physical accessibility is compounded by the need to combine barrier-free access with safety requirements (shelters, evacuation routes, and ensuring the accessibility of shelters).

In EU countries, architectural accessibility is institutionalized through building codes strictly enforced during the design and commissioning stages. For example, in Germany, barrier-free access is standard for public buildings, and funding programs run by federal states and municipalities cover the adaptation of existing buildings. Poland systematically implements barrier-free solutions through PFRON (State Fund for Rehabilitation of Disabled Persons) programs, which provide grants to schools and universities for architectural and digital modernization. Slovakia combines architectural requirements with regional school support programs, focusing on equal access in small communities. For Ukraine, it is relevant to combine regulatory oversight with targeted support for communities and institutions in reconstruction and typical "universal design" project solutions to speed up reconstruction.

Secondly, teacher training is worth mentioning. The quality of inclusion is determined not only by infrastructure, but above all by the competence of teachers. An inclusive school or university needs a team that includes a teacher/lecturer, a teacher/lecturer assistant, a psychologist, a speech therapist, rehabilitation specialists, tutors, and assistive technology specialists. Ukraine has introduced the institution of teaching assistants and inclusive resource centers. Still, staff shortages and uneven training of specialists remain challenging, especially in communities that host large numbers of internally displaced persons.

Germany practices a dual teacher training model: special modules on inclusion are integrated into teacher training programs, and schools have access to external mobile support teams. Poland is systematically developing postgraduate courses in inclusive competence for teachers and assistants, and universities are expanding the role of "accessibility offices" with specialists who advise teachers on adaptations. In Slovakia, the emphasis is on regional support centers that provide advice to schools and supervise individual plans. Ukrainian educational institutions should scale up short modular professional development programs (microcredentials) emphasizing practical cases, working with mixed groups, building individual educational trajectories, and using assistive technologies.

The third important factor is technology and digital inclusion. Assistive technologies from screen readers, speech-to-text and text-to-speech software, to adaptive keyboards, tactile devices, and FM systems are key to participation in education. University "accessibility offices" in EU countries provide individual selection of technologies, training in their use, and technical support. At the school level, cloud platforms with universal learning design (UDL) are widespread, allowing content to be accessed in various formats.

In recent years, Ukraine has made a significant leap in the digitization of education: remote platforms, electronic journals, and educational resources. However, content accessibility (alternative text descriptions, subtitling, keyboard navigation, etc.) often needs improvement. An important area is the implementation of web accessibility standards (WCAG 2.1/2.2) for websites and LMS, as well as the centralized procurement of software licenses for assistive solutions. It would be appropriate to borrow from Polish practice: state or industry tenders for nationwide licenses with educational packages for all levels of education.

It is also worth noting that inclusion requires predictable funding at the start-up stage and long-term support (technical maintenance of assistive devices, support services, staff training). In EU countries, this is solved through mixed models: basic funding from the state budget, targeted regional/municipal programs, and grants (including from the EU). In Poland, PFRON and the Accessibility Plus program combine investments in infrastructure with funding for support services [11]. In Germany, states and communities have funds for adapting schools and universities, and universities have accessibility centers with separate budgets. Slovakia uses regional programs with agreed minimum standards for schools.

The Ukrainian context requires a multi-channel model: protected spending on inclusion in education budgets, targeted reconstruction programs with a "universal design" component, partnerships with donors and businesses (corporate social responsibility), as well as voucher mechanisms for families (individual support packages) that can be used at any accredited institution or service.

It is also essential to ensure individualization and support for students/pupils. European practice shows that "formal" inclusion without a personal support plan often does not provide real participation. Universities and schools in Germany and Poland use individual learning support agreements that specify accommodations: extra time on exams, alternative assignment for-

mats, methodological tutoring assistance, and technological adjustments. In Ukraine, individual plan mechanisms are gradually spreading, but they require unified templates, internal regulations, and trained department/dean's office coordinators.

An essential element is independent monitoring of the quality of inclusion: indicators of accessibility, student/parent satisfaction, effectiveness of support, academic results, and graduate employment. In EU countries, the participation of persons with disabilities and their associations in policy planning and evaluation is mandatory. Ukraine can strengthen institutional feedback mechanisms through systematic surveys in institutions, the creation of accessibility councils at universities, publishing annual reports on the state of inclusion, and external accessibility audits using standardized scales.

Finally, it should be noted that Russia's full-scale aggression has created a new dimension of needs: an increase in the number of children and young people with disabilities as a result of injuries and psychological trauma, internal displacement of families, and destruction of infrastructure. The practice of implementing inclusion must consider the rehabilitation component, interagency cooperation (education – health care, social sphere), mobile and distance learning, and the accessibility of shelters and evacuation routes for people with various forms of disability. European experience in post-crisis reconstruction (in particular, the “build back better” standard) should form the basis of Ukrainian programs for reconstructing educational institutions. Every new or renovated building must be barrier-free, and every digital service must be accessible.

Conclusions. Inclusive education is a multidimensional process in which infrastructure, personnel, technology, and funding must work together as an integrated system. The European experience of Poland, Germany, and Slovakia demonstrates that success is ensured by clear accessibility standards, professional support teams in institutions, centralized funding instruments, and beneficiaries' participation in policy planning and evaluation. For Ukraine, which is at war and at the same time moving towards European integration, the key factors are: institutionalisation of accessibility offices, modernisation of infrastructure according to universal design principles, mass training of teachers in inclusive practices, digital accessibility of content, and stable funding mechanisms. This configuration of practical solutions will transform formal guarantees into absolute equality of opportunity in education.

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MEDICAL SCIENCES

NEW APPROACHES TO THE TREATMENT OF NEURODEGENERATIVE DISEASES (ALZHEIMER'S DISEASE, PARKINSON'S DISEASE)

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Abstract

Neurodegenerative diseases, including Alzheimer's disease and Parkinson's disease, are among the most serious medical and social problems of our time. Their pathogenesis is associated with progressive neuronal death, accumulation of pathological proteins, chronic inflammation and immune response dysregulation. Despite the achievements of traditional pharmacotherapy aimed at temporary symptom relief, these methods are unable to change the course of the disease. In recent decades, special attention has been paid to innovative approaches: gene and cell therapy, immunotherapy and nanomedicine. These strategies make it possible to influence the fundamental mechanisms of pathology, including gene expression, restoration of neural networks, removal of toxic protein aggregates and targeted drug delivery to the brain. Personalized medicine and the use of digital technologies create conditions for individualization of treatment, increasing its effectiveness and safety.

Thus, modern research is forming a new paradigm for the treatment of neurodegenerative diseases, in which the integration of molecular, cellular and immune technologies opens up the prospect of slowing down progression and improving the quality of life of patients.

Keywords: Alzheimer's disease, Parkinson's disease, immunotherapy, cell therapy, neurodegeneration.

Introduction: Neurodegenerative diseases in the 21st century are becoming not only a medical but also a global socio-economic challenge. Alzheimer's disease and Parkinson's disease affect millions of people every year, limiting their independence and creating a huge burden for health care systems. According to the World Health Organization, dementia is one of the leading causes of disability in old age, and the prevalence of Parkinson's disease has doubled in recent decades.

Traditional therapies, including acetylcholinesterase inhibitors, memantine, and levodopa, provide temporary relief of cognitive and motor impairments but do not address the underlying mechanisms of neurodegeneration. This raises the challenge for medicine to find new solutions that can not only control symptoms but also modify the course of the disease.

This is where innovative areas come to the fore — gene therapy, cell technologies, immunotherapy and nanomedicine. They are united by the desire to influence the molecular and cellular mechanisms of pathology, restore damaged neural networks and increase the adaptive potential of the brain. These approaches form the basis of a new paradigm of neuromedicine, in which personalization of therapy and interdisciplinary synthesis of knowledge play a key role.

Neurodegenerative diseases are among the most serious medical problems of our time. Their key feature is the progressive death of neurons and dysfunction of the central nervous system, which is manifested by cognitive, motor and behavioral disorders. Among the many known forms, Alzheimer's disease and Parkinson's disease are of particular importance, making up the main contribution to the global burden of neurodegenerative pathology [5, p. 229]. According to the World Health Organization, dementia associated with Alzheimer's disease affects more than 55 million people worldwide, and this number may double by 2050 [4, p. 639]. Parkinson's disease is less common, but its prevalence is also rapidly increasing: over the past twenty-five years, the number of patients has more than doubled [7, p. 1875].

The socioeconomic significance of these diseases is extremely high. Patient care requires significant resources: from direct medical costs (hospitalization, pharmacotherapy, rehabilitation) to indirect costs associated with loss of ability to work and increased burden on family members. In a number of countries, the total costs of patients with Alzheimer's disease exceed one percent of the gross domestic product [14, p. 5542].

Historically, therapy for Alzheimer's disease and Parkinson's disease has been based primarily on a symptomatic approach. In dementia, acetylcholinesterase inhibitors (donepezil, rivastigmine) and memantine, which affects glutamatergic transmission, are used. These drugs can temporarily improve cognitive functions, but do not affect the fundamental mechanisms of neurodegeneration [15, p. 696]. For Parkinson's disease, the "gold standard" remains levodopa, a dopamine precursor. Despite its pronounced effectiveness in relation to motor symptoms, long-term use is accompanied by complications, including dyskinesia and a decrease in the stability of the therapeutic response [2, p. 569]. Thus, existing methods can temporarily improve the quality of life of patients, but do not change the course of the pathological process itself, which stimulates the search for new treatment strategies.

Modern approaches are focused on direct impact on pathogenesis. The main directions include removal of pathological proteins (β-amyloid, tau, α-synuclein),

reduction of neuroinflammation, protection of mitochondria and reduction of oxidative stress [1, p. 229; 6, p. S263]. At the same time, methods of regeneration and restoration of neural networks are actively developing, among which the use of stem cells occupies a special place, opening up prospects for restoration of damaged areas of the brain and induction of neurogenesis [18, p. 217].

A personalized approach is also becoming key. Modern methods of molecular biology make it possible to form a genetic and biomarker profile of a patient, and the introduction of digital technologies and artificial intelligence algorithms ensures individualization of therapy selection [13, p. 639]. Particular attention is also paid to the development of new drug delivery systems. One of the most important obstacles remains the blood-brain barrier, which limits the penetration of most drugs. In this regard, nanoparticles, liposomes, and exosomes are actively being studied, which can increase the bioavailability of drugs and ensure their precise action in pathological foci of the brain [9, p. 11].

Over the past decades, the treatment paradigm for neurodegenerative diseases has changed significantly. If earlier medicine sought to find a “magic bullet,” today it is obvious that there is no simple solution. Numerous attempts to develop anti-amyloid drugs for Alzheimer’s disease have not shown the expected effectiveness in late-stage clinical trials, which has forced researchers to focus on early diagnosis and multi-target therapeutic strategies [15, p. 698]. Modern medicine views the treatment of neurodegenerative diseases by analogy with oncology: early screening, comprehensive interventions, and their personalization are necessary [12, p. 14453].

The social aspect should not be underestimated either. Patients with Alzheimer's disease gradually lose their autonomy and are completely dependent on care, while with Parkinson's disease, cognitive functions are often preserved longer, but severe motor impairments lead to disability. All this creates a significant burden not only on families, but also on the healthcare system and society as a whole. As a result, neurodegenerative diseases are considered not only a medical but also a social problem requiring an interdisciplinary approach [11, p. 650].

Today, four key areas of research can be identified, each of which has clinical potential. Gene therapy involves the delivery or editing of genes to eliminate mutations or compensate for the deficiency of neurotrophic factors [18, p. 218]. Cell therapy is based on the use of stem cells to restore neural networks [17, p. 13595]. Immunotherapy is aimed at eliminating pathological proteins and regulating inflammatory processes [12, p. 174; 16, p. 1875]. Finally, nanotechnology opens up opportunities to overcome delivery barriers and target pathological brain structures [9, p. 14453].

All of the above approaches are gradually moving from the laboratory research stage to clinical trials. The first data are accumulating, indicating the possibility of modifying the course of the disease, and not just relieving its symptoms. In the future, it is the combination of these methods in combination with a personalized approach and digital technologies that will likely determine the future of neurodegenerative disease therapy.

One of the most promising areas in recent decades is considered to be gene therapy. Unlike traditional pharmacological agents, which have a predominantly symptomatic effect, gene technologies allow for direct action on the molecular mechanisms of pathogenesis. The essence of the method is to deliver genetic material to cells that can change the expression of certain proteins, compensate for mutations, or ensure the production of therapeutically significant molecules. In neurodegenerative diseases, the key targets are pathological proteins: β-amyloid and tau in Alzheimer's disease, α-synuclein in Parkinson's disease, as well as enzymes involved in the metabolism of neurotransmitters [1, p. 229].

Of particular interest is the use of viral vectors. The most widely used are adeno-associated viruses (AAV), characterized by relative safety, stable expression, and the ability to target neurons. Clinical trials have shown that the introduction of AAV carrying genes for tyrosine hydroxylase or aromatic L-amino acid decarboxylase increases dopamine synthesis in the brain of patients with Parkinson's disease and reduces the severity of motor symptoms [2, p. 569]. For Alzheimer's disease, attempts have been made to deliver genes for neurotrophic factors such as NGF (nerve growth factor), which support the survival and function of cholinergic neurons. A number of early trials showed an improvement in cognitive indicators, although the effect remained limited [3, p. 50].

In addition to the delivery of therapeutic genes, the field of gene correction is actively developing. CRISPR-Cas9 technologies have opened up the possibility of precise editing of mutations associated with hereditary forms of neurodegenerative diseases. Thus, in familial forms of Alzheimer's disease, mutations in the APP, PSEN1 and PSEN2 genes play a key role; their correction in experimental models reduced the level of pathological β-amyloid [4, p. 173]. In the case of Parkinson's disease, attention is focused on mutations in the LRRK2 and PARK2 genes: successful experiments on cell cultures and animals have shown normalization of mitochondrial functions and a decrease in neurodegeneration [5, p. 1927]. However, the transfer of these technologies to clinical practice is associated with a number of problems related to safety, accuracy and ethical aspects.

One of the serious challenges remains the delivery of genetic material through the blood-brain barrier. Direct introduction into the brain is invasive and associated with risks, so systemic approaches are being actively developed. Research is underway on modified vectors that can penetrate the brain after intravenous administration. A promising direction is the use of exosomes - natural extracellular vesicles capable of transporting nucleic acids and targeted delivery of therapeutic molecules to pathological areas of the brain [6, p. 14452].

The key advantage of gene therapy is its long-term effect. Unlike drugs that must be administered daily, the expression of the delivered gene can persist for months or even years. However, this advantage is associated with risk: if unexpected complications develop, the reversibility of the intervention is limited. In this regard, one of the urgent tasks remains the creation of

systems with regulated expression that allow the activity of the introduced genes to be controlled [7, p. 639].

An equally important direction is the individualization of therapy. The diversity of clinical phenotypes of Alzheimer's disease and Parkinson's disease, as well as differences in the genetic background of patients, suggest that there is no universal gene drug. A promising direction is the personalization of treatment based on the genetic profile, stage of the disease and biomarkers. Therapeutic panels adapted to a specific patient are already being developed [8, p. 592].

Clinical trials of gene therapy have shown both promising results and limitations. For example, the ProSavin study in Parkinson's disease used a lentiviral vector to deliver three genes needed to synthesize dopamine. Some patients experienced sustained improvement in motor function, while others had a moderate effect [9, p. 211]. Such results show that success is largely determined by the accuracy of delivery, the stage of the disease, and individual characteristics of the body.

In Alzheimer's disease, a number of studies have focused on the delivery of apolipoprotein E (APOE) genes. The presence of the APOE4 allele is associated with an increased risk of the disease, while APOE2 has a protective effect. Attempts to modify the expression of these genes in the human brain are still in their early stages, but animal experiments have demonstrated a decrease in β-amyloid deposition with increased APOE2 expression [10, p. 696].

The future of gene therapy appears to lie in integration with other approaches. Combining gene editing and cell therapy may restore neurons and eliminate their primary defects. Additionally, it may be combined with immunotherapy, in which gene constructs stimulate the production of antibodies against pathological proteins directly in the patient’s body. Such strategies may create a more lasting and multi-level therapeutic effect.

However, one should not forget about the ethical aspects. The use of gene therapy at the brain level raises questions related to possible risks to personality, cognitive functions and even the identity of the patient. In addition, the high cost of such interventions can significantly limit their availability to the general population. In this regard, it is necessary to form a clear legal and ethical framework that will ensure the safe and fair implementation of these technologies in clinical practice [11, p. 649].

Thus, gene therapy is a revolutionary direction in the treatment of neurodegenerative diseases. It allows to influence key links of pathogenesis, compensate for genetic defects and provide long-term improvement of nervous system functions. Despite the remaining problems of delivery of genetic material, safety issues and the need for individualization of interventions, the accumulated experience demonstrates that this approach is capable of changing the paradigm of therapy of Alzheimer's disease and Parkinson's disease. Most likely, in the coming years, combined schemes will be developed that include gene technologies along with cell therapy, immunotherapy and nanomedicine. This will create the basis for personalized treatment and will slow down the progression of neurodegenerative processes [7, p. 639].

Cell therapy is gradually taking a central place in the strategy of combating neurodegenerative diseases. Unlike gene therapy, which modifies the expression of existing cells, this approach is aimed at replenishing lost neurons and restoring damaged neural networks. The central idea is that transplanted cells are capable of either replacing dead structures or having a trophic and immunomodulatory effect on surrounding tissues [1, p. 229]. For Parkinson's disease and Alzheimer's disease, this approach is of particular importance, since both pathologies are characterized by a pronounced loss of certain neuronal populations and subsequent neurotransmitter deficiency.

The most actively studied are stem cells, which are divided into embryonic, mesenchymal and induced pluripotent (iPSC). Embryonic stem cells have the greatest differentiation potential, but their use is associated with ethical restrictions and the risk of teratogenicity. Mesenchymal stem cells (MSCs), obtained from bone marrow or adipose tissue, exhibit a pronounced paracrine effect: they secrete growth factors, reduce inflammation and stimulate the survival of neurons. In a number of clinical trials, intravenous or intrathecal administration of MSCs to patients with Parkinson's disease led to an improvement in motor functions and a decrease in the expression of inflammatory markers [2, p. 569].

Induced pluripotent stem cells are of particular interest. The iPSC technology, proposed by S. Yamanaka and colleagues at the beginning of the 21st century, allows reprogramming mature somatic cells (e.g., skin fibroblasts) into a pluripotent state, after which they can be targeted to differentiate into neurons. For Parkinson's disease, the main area of research has become the generation of dopaminergic neurons capable of compensating for the dopamine deficiency in the nigrostriatal system. The first clinical cases of transplantation of such cells showed that they integrate into the human brain, form synaptic connections and provide a long-term clinical effect [3, p. 592].

In Alzheimer's disease, the focus shifts not only to neuron replacement, but also to supporting synaptic plasticity and reducing the accumulation of pathological proteins. Experimental studies have demonstrated that transplantation of progenitor cells improves memory in animal models by increasing the level of acetylcholine and secretion of neurotrophic factors such as BDNF and GDNF [4, p. 13595]. In the clinical perspective, it is expected that combined effects on cognitive and neuroinflammatory processes will achieve a more sustainable therapeutic effect.

However, cell therapy is associated with a number of serious difficulties. One of them is the problem of immune compatibility. Even when using allogeneic transplants, the use of immunosuppressive drugs is required, which limits the long-term safety of treatment. A solution may be the creation of iPSC based on the patient's own cells, which minimizes the risk of rejection. However, this approach remains expensive and requires significant time to prepare an individual cell line [5, p. 1926].

The second problem of cell therapy is related to the integration of transplanted cells into existing neural

networks. For full restoration of functions, their survival is not enough: it is necessary to form correct connections with target brain structures. Modern methods of neuroimaging and electrophysiological studies confirm that in animals transplanted dopaminergic neurons are able to restore the activity of the basal ganglia, but in humans this process is much more complex and variable [6, p. 14452].

The third major obstacle remains differentiation control. There is a risk that the introduced cells will transform into undesirable types or form tumors. To minimize such risks, preliminary selection and standardization of cell cultures is necessary, as well as the use of genetic “switches” that allow cell growth to be interrupted when complications arise [7, p. 639].

Despite the existing difficulties, clinical studies demonstrate the potential of this direction. Thus, in Japan, the first case of transplantation of iPSC-derived dopaminergic cells to a patient with Parkinson's disease was carried out. Over the course of two years, an improvement in motor functions was observed without signs of tumor growth or rejection. This experiment became important evidence of the possibility of safe use of cell therapy in practice [8, p. 592].

An interesting direction is the combination of cell therapy with bioengineering technologies. The use of biopolymer matrices and three-dimensional frameworks allows the formation of a favorable microenvironment for the engraftment and survival of cells. In the future, three-dimensional tissue bioprinting technologies can ensure the creation of “neuronal implants” capable of replenishing lost areas of the brain [9, p. 11].

In addition to the replacement effect, considerable attention is paid to the immunomodulatory properties of stem cells. Chronic inflammation plays a key role in the progression of Alzheimer's disease and Parkinson's disease. Cell therapy can reduce the level of proinflammatory cytokines and increase the production of anti-inflammatory mediators, which has a protective effect on neurons and slows down their death [10, p. 5541]. Thus, stem cells are considered not only as a tool for restoring neurons, but also as a means of preventing further neurodegeneration.

The development of cell editing technologies prior to transplantation is of particular importance. CRISPR/Cas9 systems and other methods allow the creation of cell lines resistant to pathological processes. In the case of Parkinson's disease, it is possible to modify cells to prevent the accumulation of α-synuclein, and in Alzheimer's disease, to enhance the expression of protective proteins [11, p. 650]. This approach combines the advantages of gene and cell therapy, providing a double protective effect.

Personalization of cell therapy remains an important area. The creation of iPSC line banks reflecting the genetic diversity of the population will allow transplants to be selected taking into account the individual characteristics of the patient. In combination with biomarkers that determine the stage of the disease and the level of neuroinflammation, this will ensure the most accurate selection of therapeutic strategies [5, p. 1926].

Thus, cell therapy is becoming one of the most promising tools in the treatment of neurodegenerative diseases. It combines the ability to restore lost functions, protect neurons and modulate inflammatory processes. Despite the remaining difficulties, including safety, integration and standardization issues, the accumulated clinical experience confirms the reality of its application. Most likely, in the future, it is the combination of cell technologies with gene therapy, nanomedicine and immunotherapy that will allow the creation of complex programs capable of slowing down or even stopping the progression of Alzheimer's disease and Parkinson's disease.

The immune system is now considered one of the key factors in the pathogenesis of neurodegenerative diseases. Traditionally, the brain was considered an "immune-privileged organ", but studies in recent decades have convincingly proven the active participation of immune cells in the formation of pathological processes in Alzheimer's disease (AD) and Parkinson's disease (PD). Microglia, astrocytes, T-lymphocytes and humoral links of the immune system have a significant impact on the progression of these pathologies, regulating inflammation, protein aggregation and neuronal death [1, p. 229]. In this regard, immunotherapy aimed at correcting the immune response and eliminating pathological protein aggregates is considered one of the most promising areas in the therapy of AD and PD.

Initially, the attention of researchers was focused on the amyloid hypothesis of Alzheimer's disease. According to this concept, the key pathogenetic factor is the accumulation of β-amyloid in the form of extracellular plaques, which triggers a cascade of inflammatory reactions and neurotoxicity. Therefore, one of the first immunotherapy strategies was the use of vaccines and antibodies against β-amyloid. Experiments on animal models have shown that active immunization reduces amyloid levels, improves cognitive functions and reduces inflammatory changes [2, p. 173].

However, the first clinical trials of active immunization (AN1792 vaccine) revealed serious side effects, including aseptic meningoencephalitis in some patients. This led to a transition to a passive immunotherapy strategy - the introduction of ready-made monoclonal antibodies against β-amyloid. Among such drugs, the most well-known are aducanumab, lepantumab, donanemab and gantenenumab. Despite ongoing debate about the clinical significance, the results of a number of studies have confirmed that antibodies are able to reduce the amyloid load in the brain and slow down cognitive decline in the early stages of the disease [3, p. 50].

An important area of focus has been targeting tau protein. Unlike amyloid, which is deposited extracellularly, hyperphosphorylated tau protein forms intracellular neurofibrillary tangles. Immune approaches include both active and passive immunization. Experimental data have shown that antibodies against tau protein reduce its aggregation and spread through neural networks. At the clinical level, several drugs (e.g., semoramcemab and genenumab) have demonstrated satisfactory safety, but their efficacy remains a matter of debate [4, p. S265].

In Parkinson's disease, immunotherapy is primarily aimed at α-synuclein, a protein that forms pathological aggregates (Lewy bodies) that lead to the death of

dopaminergic neurons. Passive immunotherapy using antibodies against α-synuclein (e.g., prunezumab, sinipazumab) is in clinical trials. Initial results indicate a decrease in the level of pathological protein in the cerebrospinal fluid and a slowdown in the progression of motor symptoms [5, p. 211].

In addition to monoclonal antibodies, cellular immune technologies are actively developing. In particular, modified T-lymphocytes capable of recognizing and destroying cells with pathological protein aggregates are being studied. Although this approach is still at an early stage, it opens up the prospect of creating an "immune weapon" against key pathogenetic mechanisms of neurodegeneration [6, p. 217].

An equally important area is the control of microglial activation. It has been established that excessive activation of microglia leads to chronic inflammation and the release of neurotoxic mediators. Immunotherapy in this context is aimed at switching microglia from a pro-inflammatory phenotype (M1) to an anti-inflammatory one (M2). The use of antibodies against signaling molecules that regulate microglial activation, as well as the use of low-molecular inhibitors, helps reduce inflammation and preserve neurons [7, p. 696].

Of particular interest is the interaction between the immune system and the intestinal microbiota. It is known that dysbiosis in Parkinson's disease affects the activation of immune cells and can contribute to the spread of pathology along the "gut-brain" axis. In this regard, immunomodulatory probiotics and specific bacterial metabolites are considered as a potential tool for preventing and slowing the progression of PD [8, p. 1470].

The issue of the staging of immunotherapy deserves special attention. The most significant results have been achieved in patients with early stages of diseases, when the pathological process has not yet led to massive loss of neurons. This emphasizes the need for early diagnosis and the search for reliable biomarkers that allow timely treatment. Modern research is actively conducted in the field of identifying biomarkers in cerebrospinal fluid, blood, and in the intestinal microbiota [9, p. 1469].

However, immunotherapy is associated with a number of difficulties. Firstly, there is a risk of excessive activation of the immune system, which can lead to the development of inflammatory complications. Secondly, not all antibodies have the ability to effectively overcome the blood-brain barrier, which limits their therapeutic potential. To solve this problem, new delivery technologies are being actively developed, including nanoparticles, liposomes and exosomes capable of transporting antibodies to brain structures [10, p. 217].

In addition, it remains controversial whether the removal of pathological proteins is directly related to clinical improvement. A number of studies have noted a significant reduction in amyloid load, but patients' cognitive functions continued to deteriorate. These data indicate the multicomponent nature of the pathogenesis of neurodegenerative diseases and the need for comprehensive approaches in which immunotherapy will be combined with cell therapy, gene correction, and the use of neuroprotective drugs [11, p. 650].

Despite the existing difficulties, the development of immunotherapy opens a new page in the treatment of Alzheimer's disease and Parkinson's disease. This approach allows us to influence not only the symptoms, but also the key pathogenetic mechanisms - the aggregation of pathological proteins, neuroinflammation and immune dysregulation. In the future, it is likely to use personalized schemes, including a combination of several immune drugs, adapted to the characteristics of a particular patient.

Thus, immunotherapy occupies one of the leading places among innovative areas of modern neuromedicine. Its success will largely depend on early diagnostics, precise selection of biomarkers and integration with other methods. If we manage to overcome the existing barriers, we can expect that in the coming decades, it is immunotherapeutic strategies that will become the basis for the treatment of neurodegenerative diseases.

Conclusion

Modern medicine is undergoing a period of rapid transformation, and neurodegenerative diseases - Alzheimer's disease and Parkinson's disease - are becoming one of the key areas of application of new technologies. If at the end of the 20th century the main emphasis was placed on symptomatic therapy, allowing for temporary relief of the manifestations of pathology, then in the 21st century attention is focused on the fundamental impact on pathogenesis.

Gene therapy makes it possible to correct mutations, restore the balance of protein synthesis, and even change the fate of cells, preventing their death. Cell therapy makes it possible to replenish lost neurons, maintain the functions of existing ones, and modulate inflammatory processes. Immunotherapy has proven that it is possible to influence pathological protein aggregates that have long been considered "untouchable" brain structures. Nanotechnology and delivery systems expand the capabilities of pharmacology, allowing to overcome the blood-brain barrier and minimize side effects. Personalized medicine based on genetic and biochemical profiles makes it possible to select a therapy that is maximally adapted to a specific patient.

Digitalization of medicine is becoming no less significant: machine learning and artificial intelligence are used to analyze medical images, predict disease progression, and optimize therapeutic strategies. Thus, a holistic ecosystem is being formed, where traditional pharmacology is integrated with cellular technologies, genetics, immunology, and bioinformatics.

Of course, the path to widespread adoption of these methods remains complex and fraught with risks, from immune complications to ethical issues around the use of stem cells. But the history of medicine shows that overcoming such challenges is what drives progress. Today, we are on the cusp of moving from the paradigm of "neurodegeneration is inevitable" to a model in which it can be slowed or even stopped.

In the coming decades, treatment strategies will likely be driven by combination approaches. A patient with early Alzheimer's disease could receive genetic therapy to correct predisposing factors, immunotherapy to reduce the amyloid load, and stem cell support to preserve cognitive function. Such an integrated approach

could change the prognosis for millions of people worldwide.

Thus, new therapies for Alzheimer's and Parkinson's disease are not just experimental strategies, but an emerging paradigm for the medicine of the future. Whether the 21st century will be the time of victory over neurodegenerative diseases depends on how quickly the scientific community will be able to overcome technological, clinical and social barriers.

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THE INFLUENCE OF ALIGNERS ON THE CONDITION OF ORAL ORGANS AND TISSUES

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Abstract

The study is devoted to examining the influence of aligners on the level of salivation, oral hygiene status, the occurrence of carious lesions, as well as the condition of the gingival mucosa, in comparison with orthodontic treatment using bracket systems.

Keywords: orthodontic treatment, aligners

One of the primary requirements for modern orthodontic treatment is aesthetics. Quite often, despite the obvious need for orthodontic intervention, adult patients refuse treatment precisely because of changes in the appearance of their smile [4]. This has led to the creation of aligners—transparent removable orthodontic trays that allow inconspicuous and relatively comfortable correction of dentoalveolar anomalies and deformities. In our country, aligners have appeared relatively recently. Patients show interest in this type of orthodontic care, but practitioners often approach such innovations with caution. At present, domestic literature contains little data on the impact of aligners on the condition of oral organs and tissues.

In this study, based on a group of 30 individuals aged 19 to 42 years, the effect of aligners was examined with regard to salivation rate, plaque index, the appearance of carious lesions (including white spot lesions), and the development of gingivitis. The comparison group included 28 individuals aged 17 to 38 years undergoing orthodontic treatment with fixed bracket systems.

All parameters were assessed according to the following schedule: before treatment, the day after treatment began, after 1 week, after 1 month, and subsequently at 1-month intervals during the first year of treatment; in the second year, assessments were performed every 2 months. The average treatment duration with aligners was 9–12 months, while treatment with bracket systems lasted 17–20 months.

For the evaluation of salivation, sialometry was performed according to the method of M.M. Pozharitskaya [3]. At baseline, the mean salivation rate in both groups was 0.39 ± 0.03 ml/min, corresponding to the norm and to average values reported by several authors [1, 2]. On the second day after treatment initiation, there was a sharp increase in salivation to 0.45 ± 0.034 ml/min in the aligner group and 0.43 ± 0.03 ml/min in the bracket group, which can be explained as a reflex protective reaction. The difference in favor of the aligner group is most likely due to the greater contact area of aligners with the oral mucosa and, consequently, the larger number of impulses transmitted to the brain.

After 2 weeks of treatment, salivation decreased to 0.41 ± 0.03 ml/min in both groups, although patients still subjectively reported an increased salivation rate. After 1 month, the salivation rate gradually decreased to 0.40 ± 0.03 ml/min in both groups, with no further subjective complaints of hypersalivation. By the beginning of the second month, salivation stabilized in patients treated with bracket systems and returned to baseline (0.39 ± 0.03 ml/min). In patients treated with aligners, salivation remained slightly elevated (0.40 ± 0.03 ml/min) throughout the entire treatment course, although patients no longer noticed it subjectively. This fact can apparently also be explained by the greater contact area of removable trays compared with conventional bracket systems.

To assess oral hygiene, the Turesky index (1970) was used. Its distinguishing feature is that it stains not only the vestibular but also the lingual surfaces of the teeth, and it evaluates all teeth rather than individual groups, providing a more accurate reflection of a patient's oral hygiene status. Before treatment, the average hygiene level in both groups ranged from 1.02 to 1.23.

However, after just 1 month of treatment, the Turesky index in the aligner group was 1.23 ± 0.15, while in the control group it increased to 1.85 ± 0.25. This difference is explained by the difficulty of maintaining individual oral hygiene with fixed orthodontic appliances. In patients with aligners, the main areas of plaque accumulation were around the composite attachments.

By the beginning of the third month, the index stabilized at 1.22 ± 0.18 in the aligner group. In the bracket group, it reached 2.30 ± 0.30, which is attributed to the appearance of various elastic ligatures at this stage, also contributing to plaque accumulation.

During further observation, there was a tendency for the index to increase in the bracket group over the course of a year to 2.4–2.45, while remaining stable at 1.15–1.22 in the aligner group. This further demonstrates the advantage of removable appliances for maintaining adequate oral hygiene and preserving a normal hygienic status.

One of the primary objectives of this study was to determine the influence of aligners on the development

of carious lesions. To track this, the DMF (Decayed, Missing, Filled) index was used. Observations showed an increase in the DMF index in patients treated with bracket systems (from 10.70 ± 5.11 to 11.41 ± 5.44), while patients in the aligner group remained relatively stable (from 6.83 ± 5.18 to 6.93 ± 5.24).

Since the DMF index accounts only for cavitated carious lesions, it is not informative regarding early forms of caries, which actively appear during orthodontic treatment. For this reason, the emergence of white spot lesions was tracked separately. At baseline (before treatment), 4 white spot lesions (0.47%) were found in the aligner group and 8 lesions (1%) in the comparison group.

During orthodontic treatment with aligners, 24 new white spots appeared, whereas 74 new spots were observed in patients treated with bracket systems. In the aligner group, lesions primarily appeared in the cervical region and on the approximal surfaces of teeth. In the bracket group, spots were most often located around brackets, in the cervical area, and on contact surfaces.

However, while the appearance of white spots in bracket-treated patients can be explained by difficulty maintaining oral hygiene and the presence of numerous retention points, in the case of removable aligners, it can be explained by the isolation of the enamel surface from saliva—the main source of ions necessary for remineralization.

The study examined the effect of aligners and fixed bracket systems on the development of gingivitis, based on the dynamics of the Plaque, Marginal, and Attachment (PMA) index in the Parma modification. According to the data, before treatment, the PMA index was 4.6 ± 1.0 in the aligner group and 5.5 ± 3.0 in the bracket group. This difference is explained by the greater crowding and degree of dental arch deformation in the second group.

During orthodontic treatment, starting from the first month, a negative trend in gingivitis was observed in both groups, with a clear predominance in patients treated with bracket systems. One month after treatment began, the PMA index in the aligner group was 5.8 ± 2.0, whereas in the bracket group it was 8.6 ± 4.0. By the third month, the index increased to 6.2 ± 2.0 in the aligner group and 14.1 ± 4.0 in the bracket group. This large difference can be attributed to more difficult oral hygiene maintenance and, consequently, poorer hygiene status in patients with brackets compared to the aligner group.

After 3 months of treatment, the PMA index stabilized in the aligner group, while it continued to increase in the bracket group (16.5 ± 5.0). By the end of the first year of treatment, the PMA index in the control group reached 20.7 ± 6.0 (Table 5). Thus, in the bracket group, the index increased nearly fourfold compared to baseline, whereas in the aligner group the change was minimal. This can be explained, first, by the shorter duration of treatment and, second, by the higher hygienic properties of removable appliances.

Based on these observations, several conclusions can be drawn. First, removable dental trays—aligners—are more hygienic compared to conventional bracket systems. Because they are removable, patients can maintain individual oral hygiene more easily. In addition, orthodontic treatment with aligners involves fewer retention points on tooth surfaces, resulting in lower plaque accumulation. Since dental plaque is the main factor in the development of carious lesions and gingivitis, its formation is reduced when aligners are used.

Second, although aligners are a type of removable orthodontic appliance that facilitates individual oral hygiene, the appearance of white spot lesions is still observed due to the isolation of the tooth enamel surface from the remineralizing environment—saliva. Therefore, patients in this group require additional remineralization therapy during orthodontic treatment to prevent the development of caries.

Third, since aligners are worn for 20–22 hours per day, there is a constant presence of an irritant in the oral cavity, which can contribute to the development of gingivitis. Consequently, it is recommended that patients using aligners, as well as those with conventional bracket systems, use various oral rinses to prevent gingivitis and other inflammatory conditions of the oral cavity.

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PEDAGOGICAL SCIENCES

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STUDY OF SOCIAL AND PSYCHOLOGICAL DETERMINANTS OF THE ELDERLY IN ARMENIA WITH THE PURPOSE OF ORGANIZING THEIR DIFFERENTIATED SERVICE

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Abstract

The article presents research on the socio-psychological determinants of older people and discusses measures needed to improve the social and psychological state of older people. In this article the measures necessary to improve the socio-psychological state of the elderly are considered.

The article deals with the main issues and problems of aging, such as reduction of social ties, changes in interpersonal and family relationships, loneliness, issues of household support, that is, problems that have influence and impact on social activity.

Particular attention is paid to increasing the targeting of social services for lonely elderly people.

Attention is paid to the issues of social and psychological adaptation of elderly people, which is currently relevant for society as a whole. The importance of the practical application of the research results of gerontopsychology in the development of state programs on social support, social services, ensuring active longevity of the elderly is shown.

The data of studies conducted both by the author and on her initiative are provided.

Conclusions are drawn and recommendations are made for measures necessary to improve the social and psychological state of the elderly.

Аннотация

В статье представлены исследования социально-психологических детерминант пожилых людей, рассматриваются меры, необходимые для улучшения социального и психологического состояния пожилых людей.

Делается акцент на основные вопросы и проблемы старения, такие как одиночество, сокращение социальных связей, изменения в межличностных и семейных отношениях, вопросы обеспечения жизненного быта, то есть проблемы имеющие своё влияние и воздействие на социальную активность.

Особое внимание уделяется повышению адресности социальных услуг для одиноких престарелых. Уделяется внимание вопросам социальной и психологической адаптации пожилых людей, что в настоящее время является актуальным для общества в целом.

Именно развитие и практическое применение результатов исследований геронтопсихологии должны внедряться в государственные программы социальной поддержки, социального обслуживания, обеспечения активного долголетия пожилых людей.

Приводятся данные исследований как проведённых автором, так и проведённых по его инициативе.

Делаются заключения и даются рекомендации по мерам, необходимым для улучшения социального и психологического состояния пожилых людей.

Keywords: aging, social aging, socio-psychological determinants, system of socio-psychological services, social and psychological services, problems of elderly people.

Ключевые слова: старение, социальное старение, социально-психологические детерминанты, система социально-психологического обслуживания, социальные и психологические услуги, проблемы пожилых людей.

Введение.

Активное старение, согласно определению ВОЗ, позволяет людям реализовывать свой потенциал физического, социального и психического благополучия на протяжении всей жизни и участвовать в общественной жизни и получать надлежащую защиту, поддержку и уход, когда они в этом нуждаются.

Современная демографическая ситуация показывает стремительное увеличение доли пожилых людей в общей численности населения во многих странах. В Армении в 1990 году доля пожилых людей составляла 5,6% от общей численности населения, и постоянно возрастая, в 2010 году составила 11,1%, а к 2024 году достигла почти 14%.

Наряду с результатом длительных демографических изменений, воспроизводства населения, рождаемости, смертности, сдвигов в их соотношениях, в Армении сложилась устойчивая тенденция к увеличению продолжительности жизни. Совокупность указанных демографических процессов привела к увеличению доли граждан старшего возраста в общей численности населения и, соответственно, требует повышенного внимания к решению социальных, психологических, медицинских и других проблем пожилых людей, решение которых невозможно без укрепления системы социально-психологического обслуживания, внедрения мер для обеспечения активного долголетия.

Следует учитывать, что процесс старения очень индивидуален, каждый человек стареет по своему и нуждается в разных видах психологической и социальной поддержки. Исходя из того, что старение протекает у людей по разному, меняя их характер, влияя на их физиологические возможности и социальные связи, необходимым и важным является изучение и учёт социально-психологических детерминантов пожилого человека при предоставлении ему социальных и психологических услуг. организации его социального обслуживания.

Говоря о социально - психологических детерминантах мы имеем ввиду факторы, влияющие на индивидуальные характеристики человека, на межличностные взаимоотношения, на внутриличностные установки, на общее видение и на ролевую структуру. Мы рассмотрели через призму социальных отношений такие психологические детерминанты как поведение, эмоции, чувства, ценности, мораль, модели мышления и комплексы человека, которые во многом зависят от отношения к ним его самого, его окружения и от имеющихся социальных стериотипов. Внутриличностные психологические детерминанты зависят и от прожитого человеком жизненного пути, от потери самостоятельности, т.е. зависимости от членов семьи, от пережитого травматичного опыта, что особенно присуще пожилым Армении, и др...

Мы попробовали исследовать социально-психологические детерминанты пожилого возраста с целью оценки взаимоотношений детерминант как фактора регулирования, дающего возможность: регулировать взаимоотношения пожилого человека с самим собой и с окружающими его людьми; регулировать социальные ожидания; повышения мотивации самореализации и самоактуализации, приносящих пожилому человеку счастье, удовлетворение и продливающие смысл жизни; дальнейшего повышения качества жизни.

Нами определена важность комплексного подхода в учёте физиологических, социальных и психологических детерминант и выделении ведущих из них, а также вариаций, позволяющих проявлять гибкий подход к взаимосоотношению и взаимовлиянию выявленных и детерминантов и важности для пожилого человека того или иного детерминанта с учетом возраста, ситуации, этнических и других особенностей.

Литературный обзор

Вопросам старения населения и исходящей из этого необходимости изучения социально-психологических проблем старости посвящены работы многих учёных. Это теория геронтогенеза (М.Д. Александрова) [1], теория жизненного пути (К.А. Абульханова-Славская; Л.И. Анцыферова) [2], концепция личности пожилого человека (О.В. Краснова) [3] и другие.

Проблемы и аспекты социализации пожилого человека рассмотрены в работах Кона И.С. [4], Выготского Л.С. [5] и других авторов.

В психологической литературе уделяется особое внимание типам переживания старости. Наиболее полно психологические и философские аспекты старости и старения исследованы российскими учеными Альперовичем В.Д. [6].

Старение, действительно, постепенный процесс. Человеку в старости свойственна склонность к осмыслению итогов индивидуального жизненного пути и передачи богатого социального опыта последующим поколениям. В пожилом возрасте изменяются подходы человека к оценке событий, как прошлого, так и настоящего. Человек в старости приобретает новые качества, которые позволяют ему объективно рассмотреть наиболее значимые аспекты своей жизни. Однако, вопрос тенденции изменения смысла жизни в этот возрастной период остаётся актуальным для философского и психологического анализа.

Социальное старение, как переход в систему новых ролей, пожилыми людьми переживаются по разному. С выходом на пенсию резко изменяются условия и образ жизни человека, его социальные контакты, социальный статус, его статус и роль в семье. Важно отношение самого пожилого человека к выходу на пенсию, к изменению статуса. Разница во взглядах пожилых людей на собственное старение и старение вообще логично объясняется в эпигенетической модели человеческого развития (Фрейджер Р., Erikson E.H., Erikson J.M.) [7,8].

Представляют интерес работы, в которых анализируется становление геронтологического направления социальной политики, развитие системы социальных услуг и современных видов социального обслуживания и поддержки пожилых людей, эффективности специализированных заведений (В.Д. Альперович, О.А. Воронина.) [10].

В научной литературе представлены теоретические и практические подходы к психологической

работе с пожилыми людьми, а также требования к специалистам, работающим в этой области. (Сахарова Т., Овсянникова Н.В., Седракян С.А., J. Baghdasaryan) [9, 11,12].

Методы исследования

Эмпирическую базу работы составляют результаты социологического исследования, проведенного в 2021 г. методом анкетирования пожилых людей, находящихся на социальном обслуживании в Норкском доме-интернате г. Еревана объемом 180 человек, интегрированный анализ результатов проведенного в 2024г. социологического исследования методом анкетирования пожилых людей, получающих социальные услуги на дому (158 человек), в дневных центрах социального обслуживания (116 человек), в домах-интернатах (124 человека), проживающих в семьях (120 человек), формализованное интервью 40 социальных работников, психологов и других специалистов, имеющих стаж работы в социальной сфере более 3 лет, а также анализ состояния сферы социальной защиты пожилых людей, анализ нормативно-правовой базы, мнения экспертов, интервью с пожилыми людьми. В целом показатели социально-психологических механизмов и детерминантов среди пожилых людей были изучены у 738 респондентов.

Методика исследования включала в себя методы теоретического анализа, анализ документов, метод анкетирования, метод экспертных оценок, статистические методы, беседы, интервью, авторские опросники, метод независимых характеристик, референтометрии и социометрии.

Был применён специальный методический комплекс исследовательских методик:

– анкеты оценки состояния здоровья, исследования эмоционального состояния, жизненных целей, планов, перспективы, ощущения нужности обществу, востребованности, активности, круга общения и досуга. Данная анкета была применена как многогранный, адаптированный и применённый в Армении в исследовании, проведённом при поддержке UN DESA в 2009 году;

– анкеты для изучения психологического состояния пожилых людей а) проживающих в своих домах, б) обслуживаемых на дому, в) получающих услуги в дневных центрах и г) обслуживаемых в стационарных учреждениях социального обслуживания;

– анкеты для изучения потребности пожилых людей в альтернативных формах социально-психологического обслуживания;

– анкетирование оценки ограничений в различных сферах жизни по Индексу Бартела для оценки повседневной активности жизни;

– анкеты для исследования смысловых характеристик понятий «быть одиноким» и «быть в одиночестве»;

– методика противоположных утверждений по новозеландской версии шкалы «Социотропность- независимость», адаптированной российскими учеными Муртазиной И.Р., Стрижицкой О.Ю., Петраш М.Д., включающей четыре шкалы: «Социальная неуверенность», «Зависимость от мнения окружающих», «Привязанность» и «Самодостаточность»;

– анкеты для оценки состояния тревожности и депрессии у пожилых людей;

– валидизированная шкала возрастной жизнеспособности (Resilience Scale for Adults RSA);

– шкала возрастной жизнеспособности (Resilience Scale for Adults RSA), (валидизированная), оценивающая способность преодолевать трудности, восприятие себя и своего положения в данном возрасте, экзистенциальное одиночество, настойчивость и наличие осмысленности жизни;

– шкала одиночества по адаптированному опроснику И. Муртазиной, О. Стрижицкой;

– опросник исследования по отношению к стереотипам.

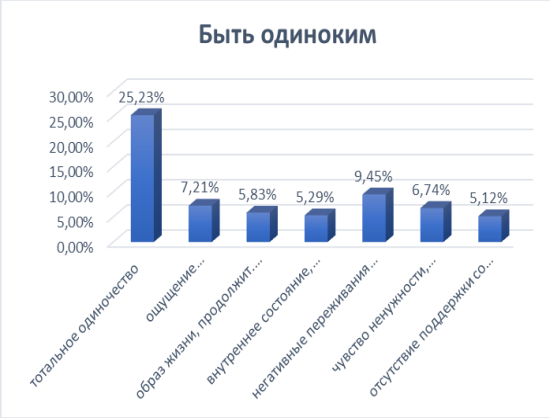
В процессе исследования были проведены беседы как с группами пожилых людей разных возрастных групп и разного социального положения и психоэмоционального состояния, так и индивидуальные беседы. Особое внимание уделялось методу референтометрии, как выявлению наиболее влиятельной, авторитетной социальной группы, чьи нормы и экспектации учитываются пожилым человеком при организации своего поведения.

Метод социометрии позволил получить информацию о реальном статусе пожилого человека в группе, психологической совместимости между членами группы.

Результаты исследования

Исследование имело целью изучить социально-психологическое состояние пожилых людей и его влияние на их активность и вовлеченность в социальные связи. Для нас было важно выявить социально-психологические детерминанты учёт которых обеспечит адресность и индивидуальность предоставления социально-психологических услуг, что послужит повышению качества жизни пожилых людей.

Учитывая, что социально-психологические услуги предоставляются в первую очередь одиноким пожилым людям, **было проведено исследование по важности смысловых характеристик понятий «быть одиноким» и «быть в одиночестве»**, полученные от респондентов ответы показали следующее.



Гистограмма 1 (основные характеристики понятия «быть одиноким»)

Гистограмма 2 (основные характеристики понятия «быть в одиночестве»)

Как видно по гистограмме 1., опрошенные пожилые люди считают, что основными характеристиками понятия «быть одиноким», с их точки зрения являются: а) тотальное одиночество человека, т. е. «быть одиноким» рассматривается респондентами как отсутствие близких, когда человек абсолютно один по жизни, данную характеристику отметили 25,23% респондентов; б) ощущение изолированности от общества упомянули 7,21% респондентов; в) образ жизни, продолжительный период - так ответили 5,83% респондентов; г) «быть одиноким» – внутреннее состояние, глубоко переживаемое человеком - мнение 5,29% респондентов; д) 9,45% респондентов в качестве характеристик понятия «быть одиноким» назвали негативные переживания (тоску, грусть, горечь); е) чувство ненужности, покинутости отметили 6,74% респондентов; ж) отсутствие поддержки со стороны друзей и близких – так ответили 5,12% респондентов.

Таким образом, определяя понятие «быть одиноким», большинство респондентов, в первую очередь, подчеркивают тотальность, устойчивость, длительность и статичность данного состояния, отмечая при этом изолированность, отчужденность, непонимание со стороны других, а также отсутствие поддержки.

По результатам наших исследований получено следующее: состояние «быть в одиночестве» это: а) временный и обратимый характер состояния – так ответили 31,34% респондентов; б) возможность человека побыть наедине с самим собой (уединение) – такого мнения придерживаются 13,26% респондентов; в) сознательный выбор человека, который отметили 11,52% респондентов; г) это время для отдыха от внешнего мира, перезагрузки, ресурсное состояние, по мнению 8,31% респондентов; д) необходимое время от времени состояние, что отметили 8,42% респондентов; е) 6,91% респондентов ответили, что «быть в одиночестве» является физическим состоянием (внешним), когда человек просто находится наедине с собой, без других, при этом человек является включенным в систему отношений.

Так, определяя понятие «быть в одиночестве», респонденты преимущественно отмечают его временный и обратимый характер, а также сознательный выбор и желание человека пребывать в данном состоянии, отмечая его пользу и необходимость время от времени для каждого человека. При этом «быть в одиночестве» предполагает включенность человека в систему межличностных отношений, что, по мнению респондентов, отсутствует в понятии «быть одиноким».

Было проведено исследование важности имеющихся контактов для пожилых, находящихся в стационарных учреждениях социального обслуживания, а также проживающих у себя дома и посещающих дневные центры социального обслуживания.

С помощью разработанной анкеты была оценена случайная выборка 73 пожилых людей (что составляет 30,5% от общего числа лиц, находящихся на попечении в учреждении круглосуточного ухода в Ереване). Оценку проводил специалист по социальной работе. Так, по результатам исследования, 79,4% респондентов имеют хорошие или удовлетворительные отношения с другими иждивенцами. У 82,3% респондентов есть близкий друг, что является достаточно высоким показателем.

Результаты исследования свидетельствуют о том, что никто из респондентов не считает себя лишним и бесполезным, 91,2% респондентов довольны собой, 82,3% респондентов не думают о смерти, 82% респондентов не обвиняют в своем нынешнем положении других людей. Вышеприведенные и все остальные ответы вполне удовлетворительны, особенно для этой возрастной группы.

Приведенные выше результаты показывают, что хотя 82,3% респондентов заявили, что не могут жить одни и самостоятельно, только 38,2% выразили желание воспользоваться услугами ухода на дому. Те, кто ответил отрицательно, указали, что хотели бы остаться в учреждении по уходу. Данное обстоятельство говорит о двух вещах: во-первых, они довольны обслуживанием заведения, уже адаптировались к жизни там, у них есть друзья и они боятся неопределенности, во-вторых, отсутствует информация об услугах, доступных для пожилых людей или их недостаточный уровень.

Выводы

Анализ проведённых исследований показал, что граждане пожилого возраста в большинстве своём достаточно социально активны и готовы к

продолжению трудовой или общественной деятельности, либо к различным формам самореализации. Ресоциализация пожилых людей ставит проблему определения опоры на внутренние, личностно-психологические факторы, с одной стороны, и на создание условий для их реализации, с другой.

Сопоставив результаты наших исследований с исследованиями, проведёнными российским ученым Муртазиной И.Р., мы отметили, что понятие «быть в одиночестве» у нас (в Армении) преобладает, что можно обьяснить значением семейных и родственных связей.

В то же время мы заметили схожесть исследований Муртазиной И.Р. и проведенных нами исследований в том, что пожилые люди, живущие в одиночестве, лишены общения и часто замыкаются в себе, что негативно сказывается на их здоровье, и это еще раз подтверждает необходимость вовлечения пожилых в активную социальную жизнь с учетом их потребностей и мотивации.

В целях создания или улучшения благоприятной и здоровой среды для пожилых людей необходимо внедрение и развитие новых моделей социально-психологического обслуживания, основанных на оценке потребности каждого человека с учетом его ведущих социально-психологических детерминантов. Необходимость внедрения новых моделей услуг, психологических, медико-социальных, гериатрических обусловлена наличием следующих обстоятельств:

a. недостаточность социальных, психологических и медицинских услуг для пожилых людей, отсутствие гериатрической помощи;

b. несовершенство системы полной и всесторонней оценки потребностей пожилых людей;

c. проблемы пожилых людей, живущих в семьях, в основном, остаются без внимания, несмотря на их разнообразие и серьезность потребностей.

Вышеуказанная проблема носит межсистемный характер и требует организации комплекса мер, включающих социальные, психологические, медицинские и другие меры, которые будут способствовать повышению качества жизни пожилых людей.

С учётом данных исследования, считаем, что становится актуальным вопрос необходимости учёта основных характеристик понятия одиночества, создания и развития службы социально-психологической помощи одиноким пожилым людям с параметрами характеристики «быть одиноким» в борьбе с одиночеством, предоставлению ему соответствующих социальных и психологических услуг.

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PHILOLOGICAL SCIENCES

THE CONCEPT OF DISCOURSE, ITS INTONATION AND FUNCTIONS IN A NEW PARADIGM IN LINGUISTICS

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Abstract

The article deals with the concept of discourse from a new paradigm point of view in linguistics. It considers discourse as a unit of language which is meant to be longer and larger than a sentence. The article also informs about some origin of the term.

It reports that the concept of "discourse", which entered linguistic circulation in the 1950s. This concept, which consists of several utterances and has a single content from a structural point of view, later led to the emergence of discourse theory, and text-discourse relations became a hot topic of discussion in linguistics. The results of discussions and research on text and discourse issues were reflected in the works of foreign (M. Hallidey, V. Dijk, N. Enkivist, T. Givon), Russian (I.R. Galperin, T.M. Nikolaeva, Z.Y. Turayeva, A. Kibrik, etc.) and Azerbaijani (K.M. Abdullayev, A.A. Abdullayev, A.Y. Mammadov, M.T. Gayibova, F.Y. Veysalli, and M.Y. Mammadov,) linguists. Recent studies show that this concept, initially considered as a social practice, has become a complex concept in modern linguistics with multicomponent, multifaceted and wide-ranging content. Recent studies on discourse research show that this concept in the process of verbal communication is a process that includes a number of components, including social context; specific situation, as well as psychological, sociological, linguistic and cultural phenomena.

Keywords: discourse, text, analysis, context, situation

Main Part

Discourse is considered to be a unit of language that is longer and larger than a sentence in linguistics.

The term includes two words in Latin: the prefix *dis*- and the verb *currere. Dis*- means “away” (beyond); *currere* means “to run”. In accordance with these meanings, discourse is often explained as “to run away”, that is, discourse covers the course of conversations. The study of discourse is the analysis of the use of spoken or written language in a social context.

The concept of “discourse” in linguistics is known to have entered linguistic circulation in the early 1950s with the publication of Z. Harris’s article [1, p. 474]. Z. Harris approaches this concept as a unit outside the sentence, that is, larger than the sentence in that article. Starting from the late 1970s and early 1980s, along with this term, the term “text” began to be widely used in linguistics. Some linguists preferred to use the term discourse, while others preferred to use the term text. Thus, the term discourse began to be used in English-language sources, and the term text in German, Russian and Azerbaijani sources (V. Dressler, 1978; Galperin, 1981, K. Abdullayev, 1999, etc.).

As is known, the sentence was considered to be the unit of the syntactic level until the early 1980s in linguistics. However, research shows that the final unit of the syntactic level is not limited to the sentence. In this regard, K. Abdullayev’s ideas are needed to be paid attention to, and they are interesting. According to this linguist, researchers approached the syntactic unit, which consists of a sentence and a union of several sentences from the same position in terms of structure. Thus, a paradoxical situation was created. According to the scientist, the shortcomings in syntactic theory gave a special impetus to the creation of such a field as text linguistics [2, p. 178]. Recent research conducted in the field of text linguistics shows that the sentence is not the final unit in the syntactic space. Thus, at the syntactic level, after the sentence, there are micro- and macrotexts, which are also constructed in accordance with the structural model of the sentence [2, p. 178]. It is known that the concept of "text" is a Latin word, meaning connection, union. In other words, this term refers to the connection of various phenomena and sentences that are their means of grammatical expression, which have internal structural connections, and the semantic unity of this connection. Thus, on the one hand, this concept is used to define an utterance consisting of a connected sequence of several sentences to express the speaker’s idea. On the other hand, the term text refers to the names of prose works (story, novel, etc.). At the same time, some linguists understand the text as a segment of speech, oral and written, of any length, forming a whole, while others view the text in close connection with the context, and still others approach the text from a broader perspective - as a syntactic unit that includes linguistic aspects (pragmatic, lexical, grammatical, stylistic, logical, etc.) [3, p. 18].

It should be noted that in linguistic sources, especially in dictionaries of linguistic terms and encyclopedias, various explanations are found regarding the explanation of the concept of “text”. O.S. Akhmanova explains the concept of “text” as a) an approximate collection of utterances presented in the form of a written text selected for analysis, a tape recorder competition, etc.; b) the entire sum, collection of a speech work

created by a collective of speakers of a specific language [4, p. 209].

Expressing his attitude to the meanings explained as text in O. Akhmanova's dictionary, A. Mammadov notes that the meanings given as an explanation of the text are quite complex and ambiguous in them [5, p. 17].

This concept is explained as the intention of the speaker or writer in spoken or written form; the verbal expression of the purpose; the form of expression of activity in language for the purpose of communication in the encyclopedia of linguistics [6, p. 293]. As for the content of the concept of discourse, here too there are different approaches. Thus, researchers explain this concept as "speech carried out in the process of communication", "the process of conversation in action", "a piece of related speech" [7, p. 40].

The term "discourse" is explained as the main concept in American-English linguistics that denotes various aspects of the text, the text spoken in a coherent conversation in another linguistic source [8, p. 220].

A.Y. Mammadov considers discourse as a phenomenon formed by the intersection of cognitive and communicative processes, and he notes the differences between text and discourse according to the following parameters: while the text can be studied in its entirety as a ready-made reality, discourse should be studied as a process of creating texts with its own specific characteristics [7, p. 41].

The research conducted shows that the difference between text and discourse is that the text is understood as a structural model consisting of a number of units and having coherence, completeness and internal structural manifestations. Text as a medium is studied and considered more as abstract formal constructions, while discourse is studied and considered from the point of view of intellectual-mental processes and in relation to extralinguistic factors.

The formation of discourse, that is, the selection of language units, the finding of coherence between them, and the formation and form of discourse in accordance with the intention of the speaker or writer, is of a subjective nature. In other words, the formation and structure of discourse depends on the speaker's intention, purpose, social and communicative situation, spatial and temporal components, the intellect of the discourse participants, their worldview, and the availability of knowledge of the content of the topic.

R. Nordquist writes that discourse studies concern the form and function of language in speech beyond small grammatical units such as phonemes and morphemes [9, p. 12].

T. van Dijk is also known as one of the discourse researchers. He connects discourse with thought, that is, he writes that discourse is related to human thought. This field of research, which he was largely responsible for developing, involves the meaning created in speech by larger linguistic units, including lexemes, syntax, and context.

A. Mammadov and M. Mammadov present discourse as a coherent piece of speech. They write: "Discourse is a coherent piece of speech. However, if it is compared with the text, that its being a coherent piece of speech does not distinguish it from the text" [10, p.22].

N. Enkvist also writes that discourse has its own characteristics: "Discourse is considered to be as part of a situation" [11, p. 369].

Discourse can sometimes reflect a word, a combination, or even a paragraph. For example, N. Enkvist's famous example: No smoking! - this piece of language is discourse when it is hung on the wall in writing. Thus, in writing, it already creates a certain situational context and is transformed into discourse.

Or "Stop!" - this is also a discourse. Alternatively, a piece of discourse can consist of hundreds of thousands of words, as in some novels.

N. Enkvist also writes that discourse is perceived as a synthesis of the text with its existing context in social life. The text acquires meaning in context. In this regard, L. Wintgenstein writes: "The context is used by the sender of the text for certain purposes, under certain conditions and in a certain sense". T. van Dijk writes: "The context includes those participating in the communication and their role, purpose, intention, general background knowledge" [12, p.32].

F. Henry and K. Tator present discourse as following: "Discourse is the social use of language to convey broad historical meanings. It is language determined by the social conditions of its use, by whom and in what circumstances it is used. Language can never be "neutral" because it connects the personal and social worlds" [13, p. 11].

Azerbaijani linguist F. Veysalli emphasizes the role of context in the use of discourse. He writes that the study of discourse is entirely context-dependent, since discourse can also encompass situational knowledge that occurs outside of speech. Often, a person cannot extrapolate meaning from a mere verbal exchange, because many semantic factors are involved in real communication [14, p. 32].

M. Bloor and T. Bloor also share this opinion. They write: "The study of discourse... can encompass issues such as context, background information, or shared knowledge between speaker and listener" [15, p. 13].

Discourse can be used to refer to specific contexts of language use, and in this sense it is similar to units such as genre or text type. For example, we can conceptualize political discourse (language used in political contexts) or media discourse (language used in the media).

In addition, some writers conceive of discourse as related to specific topics, such as ecological discourse or colonial discourse. Such labels sometimes require a specific attitude to the topic. In this regard, M. Foucault defines discourse in a more ideological sense as "practices that systematically shape the objects they speak of"... [16, p. 850].

Within the social sciences, discourse is primarily used to describe the verbal accounts of individuals. In particular, discourse is used to describe meaning for those interested in language and speech, and to analyze what people do with their speech. This approach examines the language used to describe aspects of the world and is adopted by those who use a sociological perspective.

Discourse is a collaborative activity that requires the active participation of two or more people and depends on the lives, knowledge, and communication conditions of the two or more people.

Discourse involves more than just the message between the sender and receiver of information.

It should be noted that the organization of discourse is organized with the help of language tools at all levels. These language tools are observed not only in the function of processing events within time and space, but also in the thematic development that ensures their coherence in the discourse as a whole.

Kh. Gojayeva, S. Mustafayeva highlight the role of intonation in the study of discourse.

Kh. Gojayeva writes: "The analysis of the relationship of the components of the discourse structure to the prosodic components of intonation shows that there is a structural-functional correspondence, dependence, and correlation between the content of each component of the discourse structure and the prosodic components that implement and realize the functions of intonation in the expression plan" [17, p. 22].

S. Mustafayeva analyzes discourse from the point of view of intonation and concludes that discourse is primarily related to the moment of conversation and that intonation plays an important role in its (discourse) articulation, and the syntagm is taken as the unit of this articulation [18, p. 20].

Thus, our conclusion is that discourse is a larger language unit than a sentence.

Discourse can be composed of a word, a sentence, and even a paragraph.

The formation of discourse is precisely related to the moment of speech, context, and situation.

Discourse is also considered as a verbal speech-thought activity that combines linguistic and extralinguistic components.

Communicative acts exist in discourse and they shape discourse. The study of language and linguistic phenomena at the intersection of cognition and communication is the most adequate method of investigation.

Intonation plays an important role in discourse analysis and should be understood in a broad sense. Intonation in discourse analysis is a phonological device with the help of which individual words can transform information into independent units, depending on the context and situation.

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PHYSICAL SCIENCES

THE ROLE OF QUALITATIVE ANALYSIS IN PHYSICS

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Abstract

Exploring laws is the core method in natural science learning, and qualitative analysis, by virtue of its inherent characteristics, has become a research field with special value in physics. Investigating its role in physics is of great significance for the development of the discipline. Combining specific examples, this paper systematically analyzes the role of qualitative analysis in three major fields of physics: mechanics, electromagnetism, and atomic physics. The research shows that qualitative analysis plays an irreplaceable role in the discovery of physical principles, the interpretation of experimental phenomena, the simplification of complex problems, and the construction of physical concepts.

Keywords: Qualitative Analysis; Physics; Newton's First Law; Electric Field Lines

1 Introduction

Rutherford once famously said, "Qualitativeness is insufficient quantification." This statement undoubtedly reveals the awkward position of qualitative analysis in physics. Although physics has always taken the pursuit of high-precision quantitative research as its core goal, qualitative analysis is still widely applied in various branches of physics.

In fact, qualitative analysis plays a crucial role in the initial stage of in-depth understanding of physical problems. This "initial stage"—the preliminary ideas and viewpoints formed before the launch of rigorous research—is particularly important for researchers and physics teachers: it not only helps organize preliminary cognition, clarify the positioning and expression of problems, but also provides directional guidance for exploring solutions to problems and putting forward reasonable hypotheses. At the same time, qualitative analysis can effectively simplify the complexity of physical problems when addressing them, which will be demonstrated with specific examples in the following sections.

2 The Role of Qualitative Analysis in Mechanics

Physical concepts are the reflection of the common physical attributes and essential characteristics of objective things in the human mind, and are abstract generalizations of physical phenomena. Qualitative analysis is proficient in solving such abstract physical problems, and can draw conclusions through methods such as analysis, generalization, and reasoning. Newton's First Law, for example, is formed through the analysis of objective facts, followed by further generalization and reasoning. Its content states: "Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it." Since there are no objects in reality that are completely free from external forces, this law cannot be directly verified through actual experiments.

From the discovery process of Newton's First Law, it can be seen that thought experiments (ideal experiments) played a decisive role in the birth of this law. A thought experiment, relying on the logical reasoning method of qualitative analysis and giving full play to imagination, involves idealizing objective experimental conditions and research objects at the ideological level, thereby abstracting an "idealized process experiment." In the exploration of this law, Galileo designed the ideal inclined plane experiment. Since such an experiment under pure ideal conditions cannot be realized in reality, the qualitative analysis method, which focuses on theoretical analysis, solves this problem appropriately: through in-depth qualitative logical reasoning on the essence of physics to conduct scientific abstraction, key conclusions are finally drawn. Newton's First Law, summarized based on these conclusions, has also become an important foundation for the establishment of classical mechanics.

In fact, qualitative analysis also plays an increasingly important role in the discovery of principles and laws in modern physics. For instance, Einstein designed a qualitative analysis experiment on "the relativity of simultaneity." Through the qualitative study of this experiment, he established the scientific concept of "the relativity of simultaneity," which laid a crucial foundation for the creation of the special theory of relativity.

3 The Role of Qualitative Analysis in Electromagnetism

Qualitative analysis also plays an important role in describing abstract problems in physics, and the introduction of electric field lines is a typical example. As is well-known, electric field lines are not objectively existing substances; instead, they are scientific models constructed by Faraday using qualitative analysis thinking. Several curves are drawn in the electric field space,

where the density of the curves represents the magnitude of the electric field intensity, and the tangent direction at each point on the curve is consistent with the direction of the electric field intensity at that point. Such curves that conform to the rules are defined as electric field lines. The introduction of this model successfully transforms the abstract and complex problem of electric fields into an intuitive and perceivable image, greatly reducing the difficulty of understanding and analysis.

Similarly, to describe magnetic fields (which are invisible to the naked eye) in a vivid and convenient way, Faraday once again used qualitative analysis thinking to introduce the magnetic field line model. In physics, the proposal of core concepts such as electric field lines and magnetic field lines lies in breaking through the limitation of "only focusing on the electric field or magnetic field itself," and instead emphasizing the core role of the "field" in the interaction of substances—this has completely revolutionized people's understanding of the essence of electric and magnetic fields. In addition, the introduction and description of abstract physical concepts such as solenoidal fields also rely on the support of qualitative analysis methods.

Case Study: As shown in Figure 1, a bar magnet is placed on a horizontal table. A long straight wire is fixed directly above the center of the magnet, and the wire is perpendicular to the magnet. If a current is passed through the wire, directed perpendicular to the plane of the paper inward, and F represents the pressure exerted by the magnet on the table, determine how F changes after the current is applied compared to before.

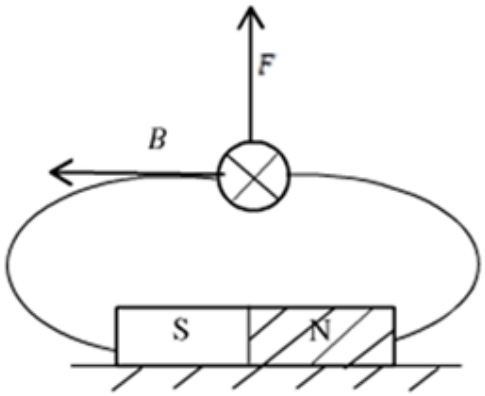

Figure 1: Bar Magnet

Analysis: Draw a magnetic field line passing through the position of the current in the figure; it can be observed that the direction of the magnetic field line at this position is horizontally to the left. According to the left-hand rule, the current in the wire will be subjected to an Ampere force in the vertically upward direction. Based on Newton's Third Law, the current will exert a reaction force on the magnet (which generates the magnetic field) that is equal in magnitude and opposite in direction—this reaction force is directed vertically downward. Since the magnet needs to balance its gravity and this reaction force in the vertical direction, it exerts greater pressure on the table. Therefore, the pressure exerted by the magnet on the table increases after the current is applied compared to before.

If we directly analyze the effect of the current's magnetic field on the bar magnet, it is difficult to draw a conclusion for this problem. However, by changing the approach—first analyzing the "effect of the magnet on the current" (which we are more familiar with), then switching the research object based on Newton's Third Law to deduce the force on the bar magnet—we can easily arrive at the answer.

When dealing with problems such as "the motion of a current-carrying conductor (or magnet) in a magnetic field under the action of Ampere force," qualitative analysis can be carried out using the equivalent analysis method. For example, a circular current can be equivalent to a small magnetic needle, and the result can be deduced through the law of interaction between magnetic poles. In addition to the equivalent analysis method, qualitative analysis in electromagnetism also commonly uses methods such as the special position method, the inference analysis method, and the research object conversion method. For instance, the part of the circuit that generates an induced electromotive force can be equivalent to a power supply; if multiple parts of the conductor in the circuit cut the magnetic field lines and are interconnected, they can be further equivalent to a series or parallel circuit of power supplies.

Furthermore, the electromagnetic induction process is often accompanied by various forms of energy conversion, which can be qualitatively analyzed from the perspective of energy. Taking the relationship between work and energy as the starting point to clarify the specific process of energy conversion is an important approach to solving energy-related problems in electromagnetic induction. When applying this approach, it is first necessary to identify the forms and types of energy involved in the conversion, and then determine which forms of energy increase and which decrease, thereby grasping the overall law of energy change.

4 The Role of Qualitative Analysis in Atomic Physics

Qualitative analysis also plays an important role in interpreting experimental phenomena related to physical laws, and the exploration process of atomic structure is a typical example. Atomic structure has long been an unknown field for human exploration; to uncover its mystery, scientists have conducted a series of studies. J.J. Thomson, who first discovered the elec-

tron, proposed an atomic model similar to a "watermelon". Later, to further explore the specific model and internal structure of the atom, physicists such as Rutherford designed the famous α-particle scattering experiment—a beam of high-speed, positively charged α-particles (with a mass much larger than that of atoms) was used to bombard a thin gold foil. Three key phenomena were observed in the experiment: most α-particles penetrated the gold foil and continued along their original direction; a small number of α-particles had their direction of motion deflected; and an extremely small number of α-particles were directly bounced back.

Through the qualitative analysis of experimental phenomena, the internal causes of the above phenomena can be gradually deduced: First, since the volume of the atomic nucleus is extremely small, there is a large amount of empty space inside the atom—thus, most α-particles can penetrate the gold foil unobstructed and continue along their original direction. Second, from the phenomenon that "a small number of α-particles have their direction of motion deflected," it can be inferred that the atomic nucleus is positively charged. Since α-particles are also positively charged, they repel each other due to like charges, generating an electric field force. When α-particles pass near the atomic nucleus, they are acted upon by this repulsive force, causing their direction of motion to change. Finally, by analyzing the phenomenon that "an extremely small number of α-particles are bounced back" in combination with the momentum theorem, it can be known that the α-particles collided head-on with the gold atomic nuclei. The result of the α-particles being bounced back also proves that their mass is much smaller than that of the gold atomic nuclei.

Based on the analytical conclusions of the experimental phenomena, Rutherford proposed the nuclear model of the atom: at the center of the atom, there is a nucleus with a very small volume; all the positive charge and almost all the mass of the atom are concentrated in the nucleus, while negatively charged electrons move in the space outside the nucleus around the nucleus.

When using qualitative analysis to discover physical principles or laws, its core advantage lies in its ability to simplify and purify problems to a degree that is difficult to achieve with real experiments, thereby exploring and revealing the inherent laws of natural things and phenomena more efficiently. In addition, interpreting physical phenomena through qualitative analysis is also an important way to put forward scientific hypotheses: on the one hand, it helps researchers deepen their understanding of real experiments, the essential attributes of research objects, and their movement laws; on the other hand, it makes the process of logical proof and refutation clearer, more intuitive, and more persuasive. Although the physical laws deduced by qualitative analysis often lack sufficient data support, throughout the development history of physics, all core conclusions obtained through qualitative analysis have stood the test of practice.

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JEL Classification: O32, O38, D85, Q42, Q55
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THEORETICAL ANALYSIS OF THE VARIATION OF REFRACTIVE INDEX WITH BAND GAP IN SEMICONDUCTOR MATERIALS USING DIFFERENT MODELS

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Abstract

This study investigates the variation of the refractive index (n) as a function of the band gap energy (Eg) in semiconductor materials using several theoretical models, including Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh. The results obtained from these models were systematically compared through tables and graphical representations to identify their consistencies and deviations. All models demonstrated a general trend of decreasing refractive index with increasing band gap, which is attributed to optical dispersion. The Herve–Vandamme model exhibited no intersection with the other models, reflecting its strong theoretical and physical foundation. In contrast, the Reddy and Kumar–Singh models showed closer agreement with experimental data, indicating their practical

Keywords: Semiconductors, Refractive index, Band gap, Optical dispersion, Moss, Ravindra, Herve–Vandamme, Reddy, Kumar–Singh

1. Introduction

The efficiency of modern optoelectronic technologies— including solar cells, photodetectors, smart windows, advanced optical sensors, and transparent conducting electrodes— is largely determined by the optical properties of the materials employed [1–3]. Among these properties, the relationship between the refractive index (n) and the band gap energy (Eg) is of particular importance, as these two parameters govern a material's ability to absorb, transmit, and reflect light [4, 5].

The refractive index (n) defines the propagation and phase velocity of electromagnetic waves within a material, directly influencing the refraction, propagation, and reflection of light. On the other hand, the band gap energy (Eg) determines whether a material can absorb photons within a specific energy range, thereby defining its sensitivity spectrum with respect to photon energy. The correlation between these two parameters is crucial not only from the perspective of fundamental semiconductor physics but also for the optimal selection of materials in optoelectronic device applications [1, 6, 7].

In this context, several theoretical and empirical models have been proposed to predict the $n{\sim}Eg$ relationship in advance. These models provide an initial framework for evaluating semiconductor materials and allow for preliminary analysis without relying on experimental data. The most frequently referenced models include: Moss [8], Ravindra [9], Herve–Vandamme [10], Reddy [11], and Kumar–Singh [12].

In the present study, the relationship between the refractive index (n) and the band gap energy (Eg) is systematically analyzed based on different theoretical models (Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh). The selected interval of $2.0 \div 3.5\ eV$ is not arbitrary; it corresponds to the band gap energies of semiconductors widely used in modern optoelectronic devices, such as CdO, ZnO, CdS, ZnSe, GaN, TiO_2, SnO_2, and In_2O_3 [13–15]. These materials are widely integrated into practical applications across the photon energy spectrum, including solar cells, transparent conducting electrodes, UV sensors, gas and biosensors, as well as optoelectronic converters.

Therefore, the theoretical comparison of these models is significant not only from a fundamental scientific standpoint but also for the technological task of selecting the most suitable model for various optical systems and application scenarios. The primary objective of this research is to investigate how the $n{\sim}Eg$ dependence changes across each model, to identify its overall trend, and to define the applicability limits of each model. This approach aims to improve the accuracy of predicting the optical properties of materials and to provide theoretical support for the interpretation of experimental results.

The research is directed toward addressing the following key problems:

- How do the existing classical models (Moss, Ravindra, Herve–Vandamme, Reddy, Kumar–Singh) vary across different Eg intervals?
- Which of these models provide more realistic predictions for real materials within specific Eg ranges?
- Under what conditions does the practical predictive capability of each model weaken?

In addition, the study evaluates the reliability of these models in targeted optical calculations carried out for technological optimization. The aim is not only to compute the $n = f(Eg)$ functions, but also to scientifically highlight their comparative advantages and limitations.

2. Methodology

In this study, the relationship between the refractive index (n) and the band gap energy (Eg) for semiconductor and oxide-based materials was analyzed using various empirical and semi-theoretical models. The analysis was carried out in the following methodological stages:

2.1. Justification of the Selected Eg Interval

For this study, the interval $of\ 2.0 \div 3.6\ eV$ was chosen. This range is characteristic of wide-bandgap semiconductors and oxides, and it corresponds both to the stable applicability domain of theoretical models and to the practical applications of optoelectronic converters [5]. The materials that fall within the selected interval include:

- **III–V compounds:** AlAs (2.16 eV), GaP (2.26 eV), AlP (2.45 eV), GaN (3.40 eV)
- **II–VI compounds:** CdO (2.3–2.5 eV), CdS (2.42 eV), ZnTe (2.26 eV), ZnSe (2.70 eV)
- **Oxides and chalcogenides:** TiO_2 (3.00–3.20 eV), CuI (3.10 eV), In_2O_3 (3.20 eV), ZnO (3.37 eV), SnO_2 (3.60 eV)

The values of $Eg\ and\ n$ were determined under the same temperature conditions ($T \approx 300\ K$), identical crystal phases, and consistent measurement methods, and were obtained from reliable scientific sources [15, 16]. When multiple values under identical conditions were available, the median (central tendency) was used to ensure statistical stability.

Thus, the selection of this interval is justified both in terms of testing theoretical models and for their practical significance.

2.2. Calculation Procedure for Each Model

Model	Əsas düstur	Parametrlər
Moss (1950)	$n^4 E_g = K$	$K = 95$
Ravindra (1979)	$n = a + bEg$	$a = 4{,}084$ $b = -0.62$
Herve–Vandamme (1995)	$n = \sqrt{1 + (\frac{A}{E_g + B})^2}$	$A = 13{,}6$ $B = 3{,}47$
Reddy	$n = \sqrt{\frac{C}{E_g + D}}$	$C = 12{,}417$ $D = 0{,}365$
Kumar-Singh	$n = K \cdot E_g^m$	$K = 3{,}3668$ $m = -0.32234$

Here, the constants A, B, C, D, K, m, and others were taken as reported by the original authors of the respective models and applied to experimental data for validation. By using the functional expressions, the values of n were calculated within the interval of $2.0 \div 3.6\ eV$. [8, 10, 17–19].

2.3. Solution Algorithms and Tools Used

All calculations were performed using Microsoft Excel. In Excel, the functional formulas were arranged in columns, enabling the automatic calculation of n for any given Eg. Tables and graphs were dynamically constructed, which simplified the comparison between models. The obtained theoretical $n{\sim}Eg$ results were compared with the static refractive index values reported in the literature, and the consistency trends were visually analyzed through graphs. This approach allows users to replicate the computational framework and apply the models to different materials.

Alternatively, these models can also be easily coded in programming environments such as MATLAB or Python. However, in this study, the objective was to demonstrate the implementation of the methods in a simple and widely accessible environment.

Theoretical Background

The refractive index (n) is an important optical parameter that defines the propagation characteristics of electromagnetic waves as they pass through a material. In semiconductor materials, an inverse proportionality is typically observed between *n* and the band gap energy (Eg). This interdependence is analyzed using a number of empirical and semi-empirical models. The accuracy and reliability of these models vary depending on the type of material under consideration. The main features of these models and the corresponding computational results are presented below.

3.1. Moss Model (1950)

The Moss model is one of the earliest and most widely used empirical approaches expressing the inverse proportional relationship between the refractive index and the band gap energy. First proposed by T. S. Moss in 1950, this model attempted to establish a quantitative correlation between the optical and electronic properties of semiconductors [8]. It is formulated by the following simple expression:

$$n^4 E_g = const$$

Where:

n — refractive index of the material, Eg — band gap energy (eV), $const$ — an approximately constant value, independent of the material.

Moss suggested a constant value of about $95\ eV$; however, subsequent studies reported a wider range of $170 \div 300\ eV$. This inconsistency is a major limitation of the model and indicates that the constant may depend on the crystal structure, measurement method, and temperature [16, 17].

The main idea of the model is that materials with a wide band gap (e.g., ZnO, GaN, SnO_2) tend to be less polarizable and therefore possess a lower refractive index. Conversely, narrow-bandgap semiconductors (e.g., PbS, CdO) are optically denser and exhibit a higher n. This inverse relationship demonstrates the intrinsic link between electronic structure and optical response.

The application of the Moss model in the analyzed studies indicates that this model provides reasonable agreement only within a limited band gap range and for classical semiconductor systems. For example:

- Tripathy (2015) systematically analyzed the application of the model to different materials and obtained consistency with constants in the range of $170 \div 268\ eV$ [5].
- Reddy et al. (2006) demonstrated that the model lacks accuracy for low-band-gap materials and proposed a modified expression [18].
- Based on their results, Kumar and Singh (2012) reported that the Moss model shows less agreement with experimental data compared to power-law type theoretical approaches [19].

Nevertheless, the Moss model is still widely employed as a fundamental approach in the initial stage of $n{\sim}Eg$ analysis and serves as a baseline for the development of more complex models.

To demonstrate the application of this model, the refractive index (n) was calculated for five different Eg values:

$$n = \left(\frac{K}{E_g}\right)^{1/4}$$

If the Moss constant is taken as K = 95 eV:

(CdO): for $Eg = 2.5\ eV$

$$n = \left(\frac{95}{2{,}5}\right)^{1/4} \approx 2{,}48$$

(ZnO): for $E_g = 3{,}3\ eV$

$$n = \left(\frac{95}{3{,}3}\right)^{1/4} \approx 2{,}32$$

(ZnSe): for Eg ≈ 2.7 eV

$$n = \left(\frac{95}{2{,}7}\right)^{1/4} \approx 2{,}44$$

TiO_2: for Eg ≈ 3.2 eV

$$n = \left(\frac{95}{3{,}2}\right)^{1/4} \approx 2{,}33$$

In_2O_3: for Eg ≈ 2.9 eV

$$n = \left(\frac{95}{2{,}9}\right)^{1/4} \approx 2{,}39$$

These results show that, according to the Moss model, the refractive index (n) decreases as the band gap energy (Eg) increases. The structural simplicity of the model makes it practical and quick to apply compared to more complex approaches. At the same time, due to its ability to provide approximate agreement over a wide range, it is widely used in the optical analysis of similar semiconductor and oxide materials.

3.2. Ravindra Model (1979)

Following the Moss model, in order to provide a more realistic representation of the relationship between the refractive index and the band gap energy in semiconductors, Ravindra and Srivastava (1979) proposed a model based on a simple linear dependence [17]:

$$n = a - bEg$$

Where: n — refractive index, Eg — band gap energy (eV), a, b — empirical constants (for the Ravindra model: $a \approx 4.084, b \approx 0.62$).

This approach is based on the principle that the refractive index decreases linearly as Eg increases. The main advantage of the model lies in its computational simplicity and its better agreement with experimental data, especially for materials within the medium band gap range $(2 \div 3\ eV)$.

Compared to the Moss model, the Ravindra model can be applied to a broader class of materials and demonstrates higher accuracy particularly for II–VI and III–V semiconductors. Tripathy (2015) tested this model on a range of materials and reported high consistency for semiconductors such as CdS, ZnSe, and InP [5]. Similarly, Reddy et al. (2006) compared the Ravindra model with other nonlinear models and confirmed that within the $2 \div 3\ eV$ range, the linear trend aligns well with both theoretical predictions and experimental observations.

However, the drawback of the model is that for materials with very large band gaps (e.g., GaN, SnO_2, β-Ga_2O_3), the linear decrease may lead to negative values of n, which is physically unacceptable. Therefore, the applicability of the Ravindra model is considered reliable only within a limited band gap range.

Using this model, calculations can be performed to observe how *n* varies for different band gap energies Eg.

CdO for $Eg = 2{,}5eV$: $n = 4{,}084 - 0{,}62 \cdot 2{,}5 = 4{,}084 - 1{,}55 \approx 2{,}53$

ZnO for $Eg = 3{,}3eV$: $n = 4{,}084 - 0{,}62 \cdot 3{,}3 = 4{,}084 - 2{,}046 = 2{,}03$

ZnSe for $Eg = 2{,}7eV$: $n = 4{,}084 - 0{,}62 \cdot 2{,}7 = 4{,}084 - 1{,}674 = 2{,}41$

TiO_2 for Eg ≈ 3.2 eV: $n = 4{,}084 - 0{,}62 \cdot 3{,}2 = 4{,}084 - 1{,}984 = 2{,}10$

In_2O_3 for Eg ≈ 2,9 eV: $n = 4{,}084 - 0.62 \cdot 2{,}9 = 4{,}084 - 1{,}798 = 2{,}29$

As a result, although the Ravindra model is useful in providing a simple and remarkably practical relationship between the refractive index and the band gap energy, it exhibits theoretical inconsistencies at extreme Eg values and must be complemented by more sophisticated models.

3.3. Herve–Vandamme Model (1995)

Proposed by Herve and Vandamme in 1994–1995 [10, 16], this model explains the relationship between the refractive index and the band gap energy based on the theory of electromagnetic wave propagation in solids. It is primarily theoretically justified for wide-band-gap semiconductors and is expressed by the following empirical relation:

$$n(E_g) = \sqrt{1 + \frac{A}{E_g + B}}$$

Where: n — refractive index; Eg — band gap energy (eV); $A \approx 13.6\ eV$ — a constant close to the ionization energy of the hydrogen atom; $B \approx 3.47\ eV$ — an empirical correction constant.

The main idea of the model is that optical conductivity and the real part of the dielectric function are related to the band gap energy and atomic-level transitions of high-frequency photons. The fact that A is $13.6\ eV$ indicates that the model is linked to the ground-state energy of the hydrogen atom in quantum mechanics, while B serves as a correction factor depending on the crystal structure and binding energies.

The primary advantage of the Herve–Vandamme model is its high accuracy for wide-band-gap semiconductors (e.g., ZnO, GaN, TiO_2). It shows broad agreement with experimental data, particularly within the $2.5 \div 4.0\ eV$ range.

However, the model also has certain limitations. For narrow-band-gap semiconductors (e.g., PbS, InSb), their accuracy is low. In systems with high carrier concentrations and a strong Burstein–Moss effect, the constants need to be re-optimized [15].

Tripathy (2015) tested this model across a wide range of semiconductors and demonstrated that the Herve–Vandamme relation provides higher accuracy compared to the Moss and Ravindra models, especially for oxides and III–V semiconductors. Reddy et al. (2006) also emphasized that the model works well for wide-band-gap II–VI compounds [18].

The strength of this model lies in the fact that the relationship between the refractive index (n) and the band gap (Eg) is explained not only empirically but also because of physical principles of electron–photon interactions.

CdO $for\ Eg \approx\ 2{,}5eV$:

$$n = \sqrt{1 + \frac{13{,}6}{2{,}5 + 3{,}47}} \approx \sqrt{1 + 2{,}13} \approx 1{,}76$$

ZnO for $Eg \approx\ 3{,}3eV$:

$$n = \sqrt{1 + \frac{13{,}6}{3{,}3 + 3{,}47}} \approx \sqrt{1 + 1{,}88} \approx 1{,}70$$

TiO_2 for $Eg \approx\ 3{,}2eV$:

$$n = \sqrt{1 + \frac{13{,}6}{3{,}2 + 3{,}47}} \approx \sqrt{1 + 2{,}039} = \sqrt{3{,}039} \approx 1{,}74$$

$İn_2O_3$ for $Eg \approx\ 2{,}9eV$:

$$n = \sqrt{1 + \frac{13{,}6}{2{,}9 + 3{,}47}} \approx \sqrt{1 + 2{,}135} = \sqrt{3{,}135} \approx 1{,}77$$

(ZnSe) for Eg ≈ 2.7 eV

$$n = \sqrt{1 + \frac{13{,}6}{2{,}7 + 3{,}47}} \approx \sqrt{1 + 2{,}204} = \sqrt{3{,}204} \approx 1{,}79$$

These results indicate that the model can be applied to wide-band-gap oxide semiconductors such as CdO, ZnO, TiO_2, and In_2O_3. By providing a more realistic and physically grounded variation of the refractive index, the Herve–Vandamme model can play an important role in modeling the optical properties of materials with large band gaps.

3.4. Reddy Model (1992, 1995)

The models proposed by Reddy and co-workers emerged as modifications of the Moss model and aimed to more accurately represent the relationship between the refractive index (n) and the band gap energy (Eg).

The first model, proposed by Reddy and Anjaneyulu in 1992, is expressed in a form like the Moss relation and is constructed on a simple empirical basis. Later, in 1995, Reddy and Nazeer Ahammed modified this expression by introducing a second constant, which improved the agreement for materials with lower band gap energies.

$$\mathrm{n} = \sqrt{\frac{\mathrm{C}}{\mathrm{E_g} - \mathrm{D}}}$$

where: $n -$ refractive index,

Eg- band gap energy (eV),

C and D — empirical constants; for Reddy et al. [1] üçün C≈12,417, D≈0,365.

This expression resembles the square-root form of the Moss model; however, the inclusion of the constant D prevents the occurrence of near-zero or negative arguments at low band gap energies and ensures better agreement with experimental values.

One of the main advantages of the Reddy model is its high accuracy for a wide range of II–VI and III–V semiconductors with band gaps in the range of $1.5 \div 3.5\ eV$ [18]. Owing to its simple structure, it is computationally as convenient as the Moss and Ravindra models. For low-band-gap materials (CdO, PbS, CdSe), it provides more accurate results compared to the Moss model.

Along with these advantages, the Reddy model also has certain drawbacks. As $Eg \rightarrow C$ (very narrow-band-gap materials), the model may yield unrealistically high n values, which are physically unacceptable. For wide-band-gap oxides (e.g., ZnO, Ga_2O_3), its accuracy may deteriorate unless the parameters are re-optimized.

Tripathy (2015) applied this model to various semiconductors and found a higher correlation coefficient in the range of $2.0 \div 3.3\ eV$ compared to the Moss model. Reddy et al. (2006) [18] also emphasized that, in most cases, the difference between experimental and theoretical n values is less than ± 0.05, as shown in tabulated results.

CdO $for\ Eg \approx 2{,}5eV$:

$$n = \sqrt{\frac{12{,}417}{\mathrm{E_g} - 0{,}365}}$$

ZnO $for\ Eg \approx 3{,}3eV$:

$$n = \sqrt{\frac{12{,}417}{\mathrm{E_g} - 0{,}365}}$$

$ZnSe\ for\ Eg \approx 2{,}7eV$:

$$n = \sqrt{\frac{12{,}417}{\mathrm{E_g} - 0{,}365}}$$

$TiO_2\ for\ Eg \approx 3{,}2\ eV$:

$$n = \sqrt{\frac{12{,}417}{\mathrm{E_g} - 0{,}365}}$$

$In_2O_3\ for\ Eg \approx 2{,}9\ eV$:

$$n = \sqrt{\frac{12{,}417}{\mathrm{E_g} - 0{,}365}}$$

The refractive index (n) values obtained through this model provide useful analytical opportunities both for comparison with other theoretical models and for evaluating experimental agreement.

3.5. Kumar–Singh Model (2012)

Proposed by Kumar and Singh in 2012 [19], this model establishes an empirical power-law type dependence between the refractive index and the band gap energy. Unlike the rigid forms of the earlier Moss and Ravindra models, this approach allows for flexible adjustment to experimental data by optimizing two parameters.

The model is expressed by the following general relation:

$$n = K \cdot E_g^m$$

where: n — static refractive index, Eg — band gap energy (eV), K — scaling factor, m - exponent (power index), which varies depending on the class and structure of the material.

The power-law approach describes a monotonic decrease of the refractive index with increasing Eg. The coefficients $K\ and\ m$ are optimized through regression analysis of experimental data. This provides greater flexibility in the modeling process and allows for the selection of specific parameters for different groups of semiconductors.

The advantages of the Kumar–Singh model include the possibility of determining suitable parameters for different band gap ranges. It can be applied to a broader spectrum of materials compared to other models. Due to parameter optimization, it provides high correlation with experimental data.

As for its limitations, the parameters are not universal - $K\ and\ m$ must be re-determined for each new material group. Its physical meaning is not as explicit as that of fixed models (e.g., Moss, Herve–Vandamme); rather, it has a more empirical fitting character.

Tripathy (2015) [5] applied this model to oxides and II–VI semiconductors and obtained high R^2 (correlation) values in the range of $2.0 \div 3.5\ eV$ compared to other models. Kumar and Singh (2012) [19] used the least-squares method to calculate the optimal values of $K\ and\ m$ presenting results for a wide class of materials.

The accuracy of each model depends on the type of material, the band gap range, and the experimental conditions. In this study, the chosen $2.0 \div 3.5\ eV$ range covers semiconductors such as ZnO, TiO_2, In_2O_3, ZnSe, CdS, and GaN, which enables a direct comparison of the models' outcomes within the same window.

RESULTS AND DISCUSSION

In this study, the dependence of the refractive index (n) on the band gap energy (Eg) for semiconductor materials was comparatively analyzed based on five different theoretical models— Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh. The variations observed in the results across different models arise from the diversity of the theoretical principles and methodological approaches underlying each model.

Table 1 presents the calculated static refractive index (n) values corresponding to different band gap energies (Eg) using the Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh models. These values were systematically arranged to facilitate a comparative analysis of the $n{\sim}Eg$ dependence among the models.

Table 1. Theoretical dependence between the band gap energy (*Eg*) and the static refractive index (*n*) according to different models. Calculations were carried out using the Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh models.

Eg (eV)	Moss modeli	Ravindra modeli	Herve-Vandamme modeli	Reddy modeli	Kumar - Singh
2,00	2,63	2,84	3,52	2,76	2,69
2,10	2,59	2,78	3,47	2,68	2,65
2,20	2,56	2,72	3,43	2,60	2,61
2,30	2,54	2,66	3,39	2,53	2,57
2,40	2,51	2,60	3,34	2,47	2,54
2,50	2,48	2,53	3,31	2,41	2,51
2,60	2,46	2,47	3,27	2,36	2,48
2,70	2,44	2,41	3,23	2,31	2,45
2,80	2,41	2,35	3,19	2,26	2,42
2,90	2,39	2,29	3,16	2,21	2,39
3,00	2,37	2,22	3,13	2,17	2,36
3,10	2,35	2,16	3,09	2,13	2,34
3,20	2,33	2,10	3,06	2,09	2,32
3,30	2,32	2,04	3,03	2,06	2,29
3,40	2,30	1,98	3,00	2,02	2,27
3,50	2,28	1,91	2,97	1,99	2,25
3,60	2,27	1,85	2,94	1,96	2,23

Based on the $Eg\ and\ n$ values presented in Table 1, Figure 1 illustrates the variation of the refractive index with the band gap energy for each theoretical model. The graphs provide a comparative representation of how the different models evaluate this dependence and clearly highlight the trends, agreements, and divergences among the models.

It is evident from the figure that there is a negative correlation between the refractive index and the band gap energy. In other words, as Eg increases, the refractive index decreases across all models, which is consistent with the general optical behavior reported in the literature [8, 20, 21].

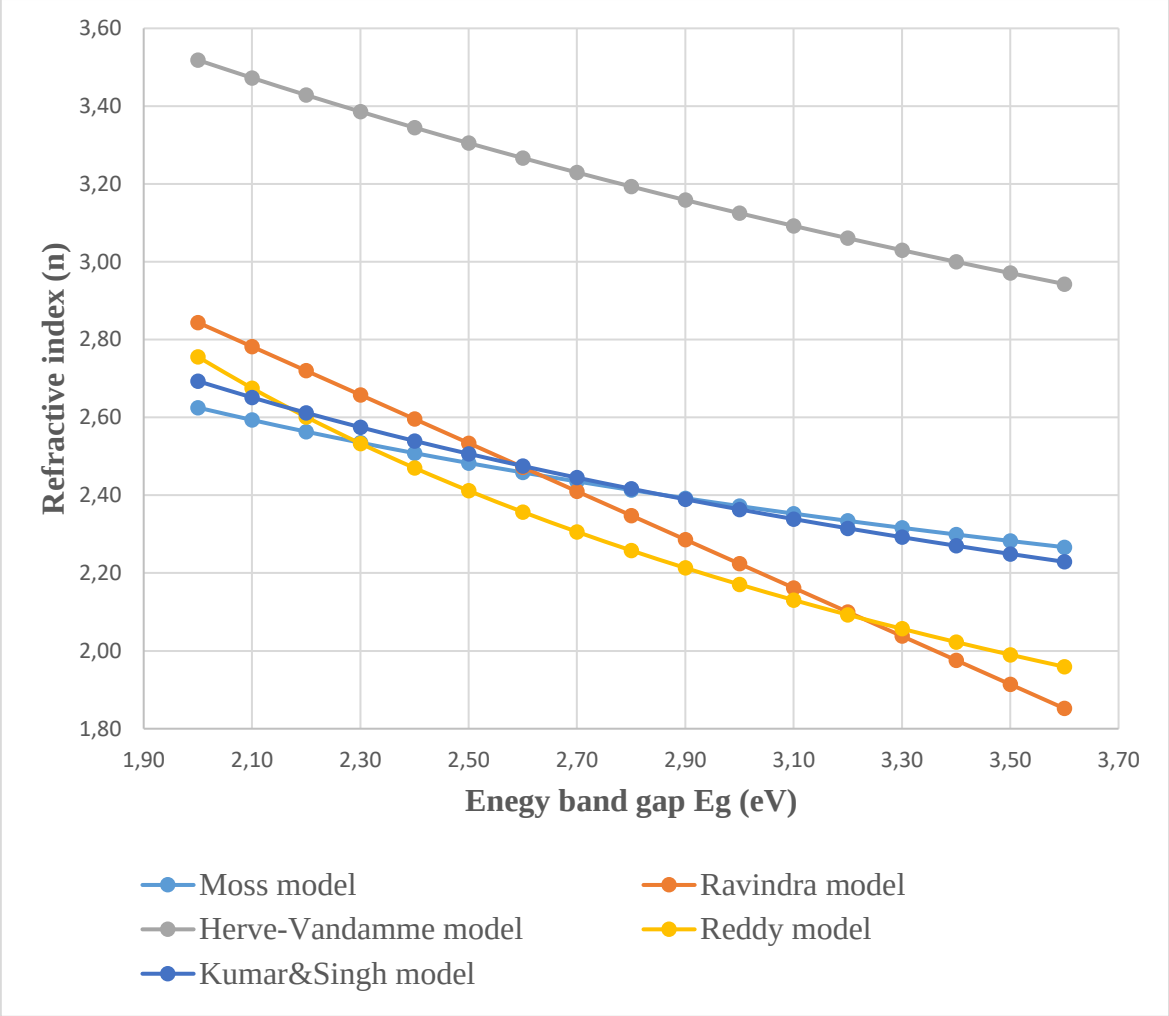

Figure 1. Graphical representation of the dependence of the refractive index (n) on the band gap energy (Eg) according to different theoretical models (Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh). The graph demonstrates the inter-model differences and the nonlinear nature of the $n(Eg)$ relationship.

The Herve–Vandamme model differs fundamentally from the others. The n values obtained from this model are not only the highest but also show no intersection points with the other models. The main reason why different models predict the relationship between refractive index and band gap energy differently lies in their varying physical foundations. For example, some models (Moss, Ravindra) are based on empirical observations and provide simple mathematical relations, whereas others (Herve–Vandamme, Kumar–Singh) employ more complex physical concepts, such as electron–photon interactions, optical response functions, and high-frequency dielectric constants.

Therefore, the outcomes predicted by different models may significantly diverge. In particular, the parabolic dependence observed in the Herve–Vandamme model exhibits a distinct trend without intersecting the other models. This stems from the model's consideration of both polarizability and the quantum-mechanical approach to light–matter interaction. While such models have stronger theoretical justification over a wider energy range, they may not always fully align with experimental results.

Thus, inter-model differences are a direct consequence of their theoretical foundations—namely, which physical effects are included or excluded—and this factor must always be taken into account when analyzing the results. Because the Herve–Vandamme model incorporates polarization effects and frequency dependence more extensively, its outcomes stand apart from those of the other models [10].

The Moss model, based on classical quantum mechanics, explains the $Eg{\sim}n$ relationship in a straightforward way and provides intermediate values of the refractive index compared to other models. While it shows good accuracy at low Eg, it becomes less reliable at higher Eg values.

In the Ravindra model, a sharp decrease in the refractive index is observed as Eg increases. However, at high Eg values, this may lead to unrealistic n predictions. For example, in the range of $3.5 \div 3.6\ eV$, the predicted n falls to $\sim 1.85 \div 1.90$, which does not agree with experimental data [20].

The Reddy model presents an empirical relation between Eg *and* n, and in some cases yields results closer to experimental observations. Its accuracy is particularly higher in the range of $2.2 \div 3.2\ eV$ [21].

The Kumar–Singh model shows a relatively stable variation of n compared to the other models, with weaker changes in refractive index. This indicates that

the model has been optimized for certain classes of materials [22].

Table 2 presents the band gap energies (*Eg*) and refractive index (*n*) values of various semiconductor materials as predicted by the five different theoretical models (Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh). For materials with identical *Eg* values, the predicted *n* values are compared, and the behaviors and inconsistencies of the models are analyzed. Based on this data, graphs were constructed to visually evaluate the trends of the models.

	Eg (eV)	Moss modeli	Ravindra modeli	Herve-Vandamme modeli	Reddy modeli	Kumar - Singh
AlAs	2,16	2,58	2,74	3,45	2,63	2,63
ZnTe	2,20	2,56	2,72	3,43	2,60	2,61
CdS	2,42	2,50	2,58	3,34	2,46	2,53
AİP	2,45	2,50	2,57	3,32	2,44	2,52
CdO	2,50	2,48	2,53	3,31	2,41	2,51
ZnSe	2,70	2,44	2,41	3,23	2,31	2,45
GaP	2,80	2,41	2,35	3,19	2,26	2,42
TiO2	3,00	2,37	2,22	3,13	2,17	2,36
CuI	3,10	2,35	2,16	3,09	2,13	2,34
In_2O_3	3,20	2,33	2,10	3,06	2,09	2,32
ZnO	3,37	2,30	1,99	3,01	2,03	2,28
GaN	3,40	2,30	1,98	3,00	2,02	2,27
SnO2	3,60	2,27	1,85	2,94	1,96	2,23

Based on the theoretical calculations presented in Table 2, the $Eg{\sim}n$ dependence according to the different models is illustrated in Figure 2. Through this graph, the effect of variations in the band gap energy on the refractive index of semiconductor materials can be visually compared for each model. The differences among the models as well as the overall trends can be observed more clearly in this representation.

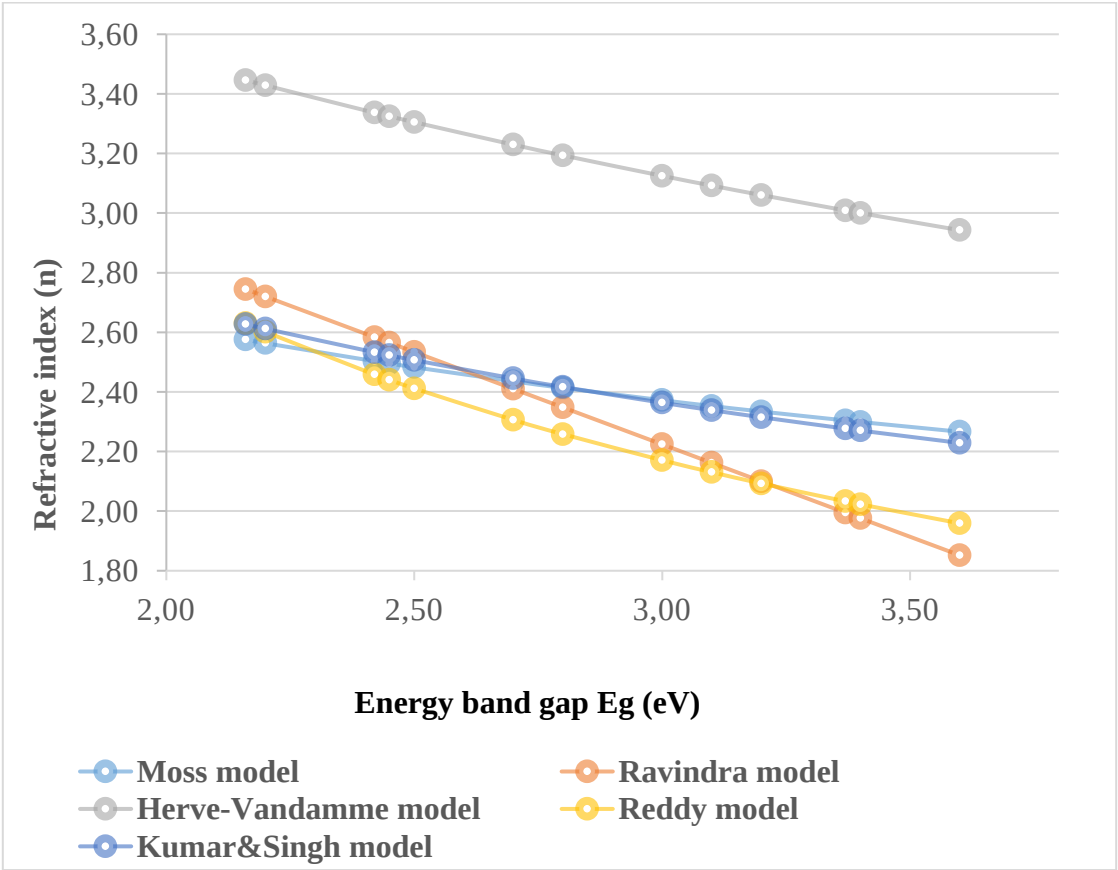

Figure 2. Dependence of the refractive index (n) on the band gap energy (Eg) constructed according to different theoretical models (Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh). As seen from the graph, n exhibits a decreasing trend with increasing Eg for all models. The Herve–Vandamme model, in contrast to the others, is characterized by higher n values and distinct behavior, which is attributed to its different approach based on the optical dielectric constant.

For materials such as CdO, ZnO, ZnTe, SnO_2, and GaN, the n values obtained from the Herve–Vandamme model were higher than the actual experimental indicators. The Reddy and Kumar–Singh models, on the other hand, often show closer agreement with experimental data. For example, the experimental refractive index of ZnO is approximately $2.0 \div 2.1$, which is in close agreement with the Reddy (2.03) and Kumar–Singh (2.28) models. The Moss model provides acceptable results particularly for relatively narrow-band-gap materials such as GaP and CdS.

These results demonstrate that since the applicability and accuracy of each model differ, no single model can be universally applied to all semiconductors. The choice of model should be made according to the band gap energy and structural properties of the material under investigation.

Conclusion

In this study, the relationship between the refractive index (n) and the band gap energy (Eg) was comparatively analyzed based on five different theoretical models— Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh. For Eg values in the range of $2.3 \div 3.3\ eV$, the refractive index values were calculated for each model and compared.

The results show that the refractive index decreases inversely with the band gap energy across all models, a trend explained by optical dispersion. Comparative analysis revealed that the Herve–Vandamme model, due to its theoretical and physical foundation, systematically diverges from the others and does not intersect with them in the graphical representation. The Reddy and Kumar–Singh models demonstrated closer agreement with experimental data, especially in the medium and wide band gap ranges, making them more suitable for practical applications.

The analysis confirms that each model provides more accurate results within specific *Eg* intervals; therefore, the optimal choice of model for a given material should be made based on its optical parameters and band gap characteristics. Since the accuracy of results in optical structure design and simulation depends on the selected model, the differences among models emphasize the importance of choosing the most appropriate one.

These theoretical evaluations are consistent with results reported in other studies indexed in Scopus and Web of Science and can be effectively used in analyzing the optical properties of materials such as $CdO, ZnO, SnO_2, ZnSe, TiO_2, and\ In_2O_3$. Future research combining these models with DFT and experimental data could provide more precise assessments and broaden the scope of conclusions in optoelectronic applications.

Abstrakt

This study analyzes the relationship between the refractive index (n) and the energy band gap (Eg) using Moss, Ravindra, Herve–Vandamme, Reddy, and Kumar–Singh models. Results were compared through tables and graphs. All models show an inverse relation between Eg and n, attributed to optical dispersion. Herve–Vandamme deviates due to its theoretical basis, while Reddy and Kumar–Singh agree better with experimental data, especially for medium and wide Eg ranges.

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SOCIAL SCIENCES

UDC 343.9
LBC 67.52

CONCERNING PRIVATE INVESTIGATIVE METHODS AND DETECTIVES' INTERACTIONS WITH INTERNATIONAL LAW ENFORCEMENT AGENCIES

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Abstract

The proposal aims to enhance the effectiveness of ways to combat crimes committed in the fields of information technology, money-laundering, and terrorist crimes. Law enforcement authorities can identify the 'professional' money launderer, along with their beneficiaries and networks, in advance thanks to the author-detective's uncovering of new functions of the private investigator. An analysis is conducted on the author's practical cases that involve the collaboration between detectives and international law enforcement agencies. The proposal aims to improve the effectiveness of private investigative methods to fight crimes related to information technology, money laundering, and terrorist activities.

Keywords: international crime, joint (international) private investigations

One of the main challenges in investigating and proving the criminal activities of established criminal networks is the timely detection of the signs of an imminent or continuing offense. Most such investigations require significant time and human resources to be mobilised by state investigative agencies. At the same time, the illegal activities of a criminal group may be manifested from different countries, that is, they can be transnational in nature. Due to the imperfections of international legal assistance and the lack of effective prompt assistance, most investigations stall before they even begin.

However, even if an investigation is successfully initiated, the subsequent gathering of evidence and documents remains a difficult process, due, for example, to the difficulties the competent authorities face in obtaining procedurally relevant information in the case. Those suspected of preparing to commit serious offences carefully disguise their identity and conceal their whereabouts from foreign law enforcement agencies and courts. The investigation process is slowed down by objective difficulties in obtaining time-sensitive information about the beneficial owners of companies registered in the name of bi-nationals or under invalid/lost documents.

Procedures for investigating crimes of an international character have their own unique features and ambiguities. These include the regulated nature of legal assistance, peculiarities in obtaining business-related information about the suspect, and the impossibility of urgent identification of participants in illegal transactions and activities. Another problem is the use of electronic means and proxy servers by criminals when they conduct illegal transactions on specialised darknet platforms. As a result, the competent authorities often close cases without even identifying the first intermediaries associated with the illegal activities of professional criminal groups.

The nature of private investigations reveals the most unexpected sides to the detective's work. This often happens when the object of investigation is a single ordinary client trying to place an order for money related to various illegal activities that the client, while being an intermediary in the 'Money Mule[8] – Beneficiary' scheme, is not even aware of. For example, this situation may occur with funds received by the 'patron' from drug trafficking, fraud, and even acts of terrorism.

8 'Money mules' are people who provide services to the beneficiaries of criminal schemes to transfer criminally derived funds.

Example 1. War Crimes Prevention

In 2014, a detective accidentally found an online recruitment advertisement for former members of special paramilitary units to participate in a military conflict in a European country. The press had previously reported on the participation of foreign mercenaries of British PMCs in military operations in Eastern Europe. However, the Foreign Office of that country consistently denied the participation of foreigners in spec ops.

As per Article 359 of the Criminal Code of the Russian Federation (Criminal Code of the Russian Federation of 13 June 1996, 2022), these acts are treated as penal, so the detective informed the law enforcement agencies on the grounds of instituting criminal proceedings.

While law enforcement agencies were conducting their own checks, the detective proactively continued gathering evidence of illegal mobilisation and discovered that the British PMC recruitment scheme involved Spanish nationals who had completed a year's course at the UK MoD Military Academy.

The mercenaries were paid by the criminal group organiser at the rate of 3,000 euros per month. In some cases, the mercenaries were unaware of the true nature of the criminal activity they were involved in, because initially, the employer promised the applicants employment in a foreign private security company without giving further details.

As a result of the investigation, the detective was able to gather evidence indicating that 'private security' services were provided by a UK-registered security company.

Source: Detective A. E. Krioni, Russian Federation

The detection of cross-border criminal schemes, including in the area of cybercrime, are most effective when law enforcement agencies and private investigators cooperate.

At the first stage of the investigation, the detective uses traditional methods and techniques of searching and collecting evidence such as personal identification, encrypted (legend) interviews, collection and analysis of documents, test purchases, and infiltration into different levels of the hierarchy of a professional criminal organisation. The detective collects all available information, including email correspondence, IP addresses, payment details, payment card and bank account numbers, specimens of signatures and stamps, telephone numbers, names of operating systems installed on computers, and so on. Access to this information at the early stages of an investigation provides the greatest opportunity to identify the organisers and coordinators of a criminal scheme.

Example 2. Prevention of an IT/computer-related crime

In early 2015, the detective received an email from a foreign customer asking for advice about the possibility and terms of providing computer-related investigative services. Subsequently, it became clear to the detective from the correspondence that the client intended to gain unauthorised access to the information resources and information systems of a national bank in a western European country.

The circumstances that became known to the detective were treated as 'illegal access to computer information' as per Article 272 and as 'causing property damage by deceit or abuse of trust' as per Article 165 of the Criminal Code of the Russian Federation (Criminal Code of the Russian Federation of 13 June 1996, 2022). Therefore, on the day when the signs of an imminent crime were detected, the detective notified the law enforcement agencies in writing on the grounds for instituting criminal proceedings[9].

However, the detective did not finish his investigation but continued his work proactively, trying to temporise as long as possible. While negotiations were ongoing and the terms of the contract were being discussed, the detective was determining the client's identity as well as the beneficiaries' identities of the company he worked for. Finally, it was time to arrange a meeting between the detective and the 'money mule', where the latter was required to hand over an advance payment of 300,000 (three hundred thousand) euros in cash to the detective. At this point, the detective knew that there would be no interactions with law enforcement agencies, so he contacted the Interpol representative office in the country of the imminent crime and, following the instructions provided, handed over a 15-page report to the Interpol representative office in Moscow.

Ten days later, the detective notified the perpetrator of his refusal to fulfil his assignment, reasoning that he had the right to withdraw from the investigation at any stage until he received the advance payment.

Source: Detective A. E. Krioni, Russian Federation

In the course of a private investigation, detectives are greatly assisted by their colleagues from the countries where the suspects plan to commit the offence. Detectives engage foreign colleagues solely on a 'trust' basis, warning of the possible transfer of collected evidence and testimonies to the state investigative services and courts. Additionally, it should be taken into account that professional criminals use various encryption mechanisms and hold correspondence in foreign languages. In such cases, the detective needs extensive knowledge in the field of forensics, cryptography, financial analysis, and foreign languages.

In order to suppress the activities of criminal organisations and their networks, detectives try to collect as much evidence, characterising the financial, economic, and social aspects of their work, as possible.

9 In accordance with paragraph 1 of Article 7 of the Law of the Russian Federation 'On Private Detective and Security Activity in the Russian Federation', private detectives are prohibited from concealing any of the facts of imminent or committed crimes that have become known to them from law enforcement agencies.

Understanding of these aspects enables the state law enforcement officers to quickly recreate the picture of the criminal group's activities and to reach those community members who can provide direct and substantial assistance to the investigative services without wasting time in the second stage.

Example 3. Investigation of a terrorist-related incident

Russian cities were attacked by telephone terrorists starting on 10 September 2017, for approximately one month. Tens of thousands of people were evacuated because of phone reports of alleged mine planting in public buildings. Shopping centres, railway stations, and other public institutions were affected due to such phone calls. According to the Ministry of Internal Affairs of the Russian Federation, about 150 thousand people overall were evacuated from more than 480 buildings countrywide. For example, in Moscow alone, Kievsky, Yaroslavsky, and Kazansky railway stations, Metropolis shopping centre, Head Department of the Ministry of Internal Affairs, Sechenov Moscow State Medical University, Plekhanov Russian Economic University, and electronics market in Mitino were evacuated over the course of three days.

The FSB opened a criminal investigation for all these facts under Article 207 of the Criminal Code of the Russian Federation (false report of terrorism) (Criminal Code of the Russian Federation of 13 June 1996, 2022). The main assumption of the investigators was a planned attack using IP-telephone services. Having taken the investigative committee's assumption as the basis for the proactive investigation, the private detectives prepared methodological recommendations for searching and identifying anonymous callers, which were taken into account by the Centre for Combating Extremism in its practical activities. (See the letter of the Centre for Combating Extremism, 'On Consideration of the Report by A. E. Krioni', dated 5 December 2017, No. 3/177717072252) (Cabinet of Private Detective Alexander Krioni, 2023).

Source: Detective A. E. Krioni, Russian Federation

The general scheme of proactive private investigation of crimes of an international character is provided in Figure 1.

Step 1. The detective monitors news via the Internet and carries out private business activities—investigations, verbal and written counselling, and electronic correspondence with clients and potential business partners. If the detective finds grounds for opening a criminal case, he/she shall (in accordance with the law) inform the law enforcement agencies and either stop 'monitoring' or continue the 'operational game', depending on the nature of offense. In the second case, the detective secretly takes all possible measures to find the identities of the suspects, identifies the beneficiaries of the illegal transaction, and collects any other case-relevant information.

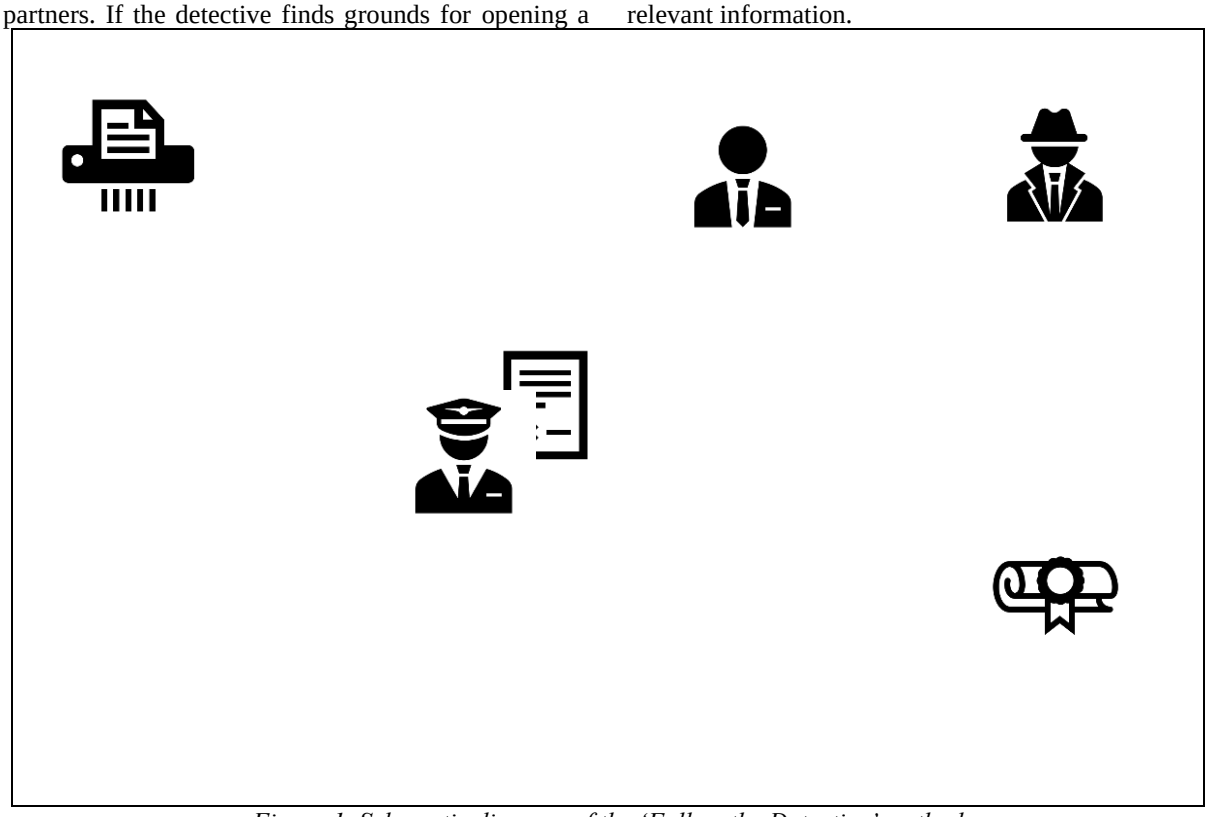

Figure 1. Schematic diagram of the 'Follow the Detective' method

Step 2. If, after two weeks of proactive private investigation, the national law enforcement agencies do not respond, take no action, or refuse to classify the evidence collected by the detective as a criminal offence, but the detective still believes that the threat of an unlawful act persists, the detective shall notify the Interpol bureau in the country of the imminent crime about the evidence discovered in writing.

The 'Follow the Detective' method allows the detective to obtain the information on the perpetrator, as well as the infrastructure used by professional money-launderers, in advance, and, in the long term, to gain control over transactions involving the disposal of criminal assets, which in theory should lead to significant financial and organisational losses to the organised crime. The criminal organisation's financial loss will result in an inability to fulfil its obligations to criminal clients and will render its further activities impossible.

Given the difficult process of recording the offence and subsequent collection of evidence, the need to use multiple sources of information, and the high resource intensity of such cases, it is recommended that national law enforcement agencies amend the early stages of the investigation methodology by adding the step of asking a detective to provide his/her own information about the signs of the detected crime.

The creation of a unified transnational database maintained by the detective communities in conjunction with the interested international law enforcement agencies would be particularly effective in such a case. In order to identify abnormal and questionable activities that may indicate organised crime, law enforcement agencies can use intelligence and analytical data that are proactively collected by detectives.

Conclusion

To coordinate the work of detectives, it is advisable to establish a specialised public–private partnership with the Interpol NCB with a main headquarters and representative offices in the participating countries. For example, the information retrieval system for exchanging significant evidence, which is being created at the initiative of the detective community, contains information on all private investigations and enquiries in the Russian Federation with a search depth since 1998.

The participation of detectives in international crime-fighting cooperation, as well as providing Interpol with direct access to the databases of private investigators, will contribute to the timely detection and suppression of certain types of criminal offences.

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TECHNICAL SCIENCES

APPLICATION OF FUZZY SUGENO MODEL TO CONSTRUCTING A DIGITAL TWIN OF A WASTEWATER TREATMENT BIOREACTOR

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ПРИМЕНЕНИЕ НЕЧЕТКОЙ МОДЕЛИ SUGENO ДЛЯ ПОСТРОЕНИЯ ЦИФРОВОГО ДВОЙНИКА БИОРЕАКТОРА ОЧИСТКИ СТОЧНЫХ ВОД

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Abstract

This article discusses the application of Sugeno-type fuzzy logic for constructing a digital twin of a bioreactor used in municipal wastewater treatment processes. A fuzzy model was implemented based on six input variables that represent key operational parameters of the bioreactor, using the Sugeno inference system. The model was developed in the MATLAB Fuzzy Logic Designer environment, employing product (prod) for "And" operations, minimum (min) for implication, maximum (max) for aggregation, and weighted average for defuzzification. The proposed system generates three output signals that reflect the behavior of the bioreactor under various operational conditions. The results demonstrate high accuracy and adaptability of the model in predicting system responses, making it an effective tool for developing digital twins in environmental and engineering applications. The fuzzy inference system was developed using MATLAB's Fuzzy Logic Designer, employing the Sugeno model structure due to its suitability for dynamic systems and real-time applications. Logical operations within the model were implemented using the product method for conjunctions, minimum for implication, maximum for aggregation, and weighted average for defuzzification. These settings ensure precise rule evaluation and output calculation.

The simulation results show that the constructed fuzzy model provides accurate and robust predictions of the bioreactor's output behavior, even in the presence of nonlinearities and uncertainties inherent in biological wastewater treatment processes. The system exhibits strong generalization capabilities and can be easily adapted for other types of reactors or environmental systems. The research confirms the effectiveness of soft computing approaches in the digital transformation of wastewater treatment infrastructure and underscores the potential of fuzzy logic as a core component in the design of intelligent digital twins for environmental engineering applications.

Аннотация

В данной работе разработана система нечеткого вывода с использованием среды Fuzzy Logic Designer MATLAB, при этом была выбрана структура модели типа Sugeno. Благодаря данной модели возможно моделирования динамических систем в реальном времени. Логические операции в модели реализованы с использованием метода произведения (prod) для логической связки "И", минимума (min) для импликации, максимума (max) для агрегации и взвешенного среднего (wtaver) для дефаззификации. Эти параметры обеспечивают точную оценку правил и вычисление выходных значений. Результаты моделирования показывают, что построенная нечеткая модель обеспечивает точные и устойчивые прогнозы поведения выходных параметров биореактора, даже при наличии неточности и неопределённостей, которые характерны для процессов биологической очистки сточных вод. Система показывает высокие способности к обобщению и может быть легко адаптирована для других типов реакторов или экологических систем. Исследование подтверждает эффективность методов мягких вычислений в цифровой трансформации инфраструктуры очистки сточных вод и подчёркивает потенциал нечеткой логики как ключевого элемента при разработке интеллектуальных цифровых двойников для задач экологической инженерии.

Keywords: Fuzzy Logic, Sugeno model, bioreactor, wastewater treatment.
Ключевые слова: Нечеткая логика, биореактор, Sugeno модель, очистка сточных вод.

ВВЕДЕНИЕ

Современные технологии очистки сточных вод требуют высокой степени точности и интеллектуального управления, особенно при работе с биореакторами, где протекают сложные биохимические и физико-химические процессы. Одним из перспективных направлений в этой области является построение цифровых двойников. Цифровой двойник это виртуальная модель, которая способна отражать систояние физической уставноки в реальном времени. Цифровой двойник способен прогно-

зировать поведение системы и оптимизировать технологические параметры. Применение цифровых двойников с элементами искусственного интеллекта в очистительных сооружениях способствует не только оптимизации процессов, но и снижению эксплуатационных расходов, повышению надёжности управления и достижению экологических нормативов. В связи с этим, традиционные методы моделирования на основе точных математических уравнений часто оказываются недостаточно гибкими и устойчивыми.

В данной работе мягкие вычислительные методы, такие как нечеткая логика, нейронные сети и генетические алгоритмы, находят широкое применение. Особенно надо отметить нечеткая логика типа Sugeno. Sugeno обладает высокой вычислительной эффективностью и способностью интегрироваться в системы реального времени. Благодаря возможности использовать экспертные знания в виде логических правил, такие модели обеспечивают высокую интерпретируемость и адаптивность. Целью данного исследования является разработка нечеткой модели типа Sugeno на основе ключевых параметров функционирования биореактора и её применение для построения цифрового двойника, способного предсказывать поведение системы при различных условиях эксплуатации. В работе описывается архитектура модели, методы логического вывода, настройки дефаззификации, а также приведены результаты симуляции и анализ точности построенного двойника.

Цель

Целью данной статьи является разработка и реализация нечеткой модели типа Sugeno для построения цифрового двойника биореактора, который применяется в процессе очистки сточных вод. Данный цифровой двойник построен с целью повышения точности прогнозирования выходных параметров системы, при этом улучшая управления технологическим процессом и адаптивностью модели к изменяющимся условиям эксплуатации. Дополнительно ставится задача верификации модели на основе симуляционных данных и оценки её эффективности при различных сценариях работы биореактора.

Начальные условия

В данном исследовании в качестве объекта моделирования рассматривается аэробный биореактор, который предназначен для очистки городских сточных вод. Модель разрабатывается на основе набора экспериментальных и/или симуляционных данных, отражающих функционирование установки в различных режимах работы. Для построения нечеткой модели типа Sugeno были выбраны шесть входных параметров, которые характеризуют ключевые условия и процессы внутри биореактора. К входным параметрам относятся: расход приточной воды, возвратный поток ила, скорость оттока отходов, концентрация субстракта, концентрация кислорода в резервуаре реактора, концентрации биомассы. В качестве выходных параметров модели выбраны показатели, отражающие эффективность очистки и техническое состояние системы, такие как: степень удаления органических загрязнений, концентрация остаточного аммония, микробиологическая активность (или биомасса активного ила). Модель строятся на основе ниже перечисленного дифференциального уравнения. Это уравнени соответствуют модели очистки сточных вод с участием гетеротрофных микроорганизмов и активного ила и применяются в рамках концепции Activated Sludge Model (ASM) или её модификаций.

Изменение концентрации органического субстрата S_S описыватеся следующим уравнением:

$$\frac{dS_S}{dt} = \frac{q_F}{V}(S_{SF} - S_S) - \frac{\mu_H}{Y_H}\left(\frac{S_S}{K_S + S_S}\right)\left(\frac{S_O}{K_{OH} + S_O}\right)X_H + (1 - f_P)b_H X_H \quad (1)$$

Это уравнение описывает, как изменяется концентрация растворимого органического вещества в биореакторе с течением времени. Первое слагаемое означает приток субстракта с загрязненной сточной воды. Второе слагаемое описывает биологическое потребление субстракта гетерофными бактериями. Третье слагаемое отражает поступление субстрата обратно в жидкость в результате разложеня мертвой биомассы. Функционирование аэробного биореактора представляет собой сложный нелинейный процесс, включающий массообмен, биохимические реакции, микробный рост и гидродинамику. Взаимосвязь этих процессов описана выше представленной системой дифференциальных уравнений. На основе этого уравненния можно выделить, что чем выше концентрация X_H тем интенсивнее утилизация субстрата S_S. При этом нужно отметить, что этот процесс ограничивается доступностью кислорода S_O. При S_O снижении утилизация замедляется. Следовательно, рост биомассы напрямую связан с доступным субстратом, но также опосредован через кислород. Растворенный кислород неоюходим для аэробного дыхания и также он принимает участие в процессе окисления субстрата. Увеличение X_H и S_S приводит к ускорение биопроцесса, а это означачет к ускоренному потреблению кислорода. При этом если уровень S_O опускается ниже критичного значения, то активность биомассы падает. Следовательно, можно отметить что между кислородом и биомассой существует обратная связь. То есть кислород активирует рост , но при этом сам потребляется в этом процессе. Представленное уравнение интегрируют ключевые биохимические и физические процессы, при этом обеспечивая точное математическое описание работы аэробного биореактора. Данное уравнение позволяет моделировать динамику очистки, выявлять узкие места (например, нехватку кислорода), управлять процессом путём изменения параметров (аэрация, рециркуляция).

Методы

Модель цифрового двойника для биореактора очистки сточных вод реализуется с использованием среды Fuzzy Logic Designer MATLAB, при этом ло-

гические операции в системе построены с применением метода произведения (prod) для конъюнкции, минимума (min) для импликации, максимума (max) для агрегации и взвешенного среднего (wtaver) для дефаззификации. Общее количество нечетких правил определено на основе анализа взаимосвязей между входами и выходами и с учетом экспертных знаний о функционировании биореактора. В данной работе использовалась 15 000 строк из ANFIS или симулятор на базе дифференциальных уравнений.

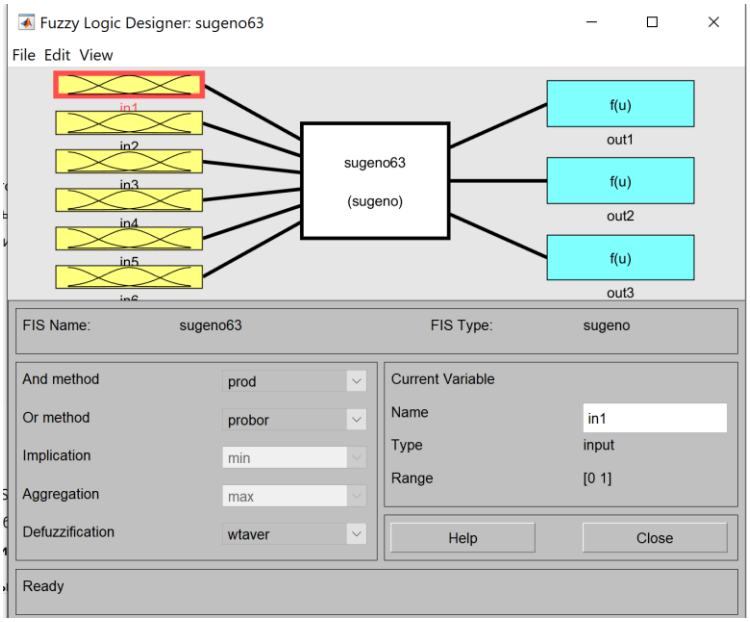

Рисунок1. Структура нечеткой модели Sugeno для цифрового двойника биореактора

На рисунке 1 показана архитектура нечеткой модели типа Sugeno, которая реализованна в среде Fuzzy Logic Designer MATLAB. Данная модель предназначена для построения цифрового двойника биореактора, применяемого в системах очистки сточных вод. Входными переменными модели являются шесть параметров, отражающих ключевые технологические и физико-химические характеристики процесса. Каждая входная переменная проходит через этап фаззификации, где значения переводятся в соответствующие нечеткие множества на основе предварительно заданных функций принадлежности. После этого активируются нечеткие правила, сформированные на основе знаний об объекте и экспертной логики. В процессе агрегации и импликации используется метод prod (произведение), а для обобщения выходных воздействий — метод max (максимум). Вывод модели осуществляется по типу Sugeno, которое означает, что выход каждого правила представлен линейной функцией входов либо константой. На этапе дефаззификации применяется метод взвешенного среднего (wtaver), что позволяет получить точное числовое значение на выходе. Модель формирует три выходных параметра, которые отражают поведение биореактора в реальных условиях эксплуатации. Эти выходы могут включать, например, степень удаления загрязняющих веществ, концентрацию остаточного аммония и активность биомассы. Данная модель обеспечивает высокую точность, адаптивность и интерпретируемость, что делает её эффективным компонентом при построении цифрового двойника в области водоочистки.

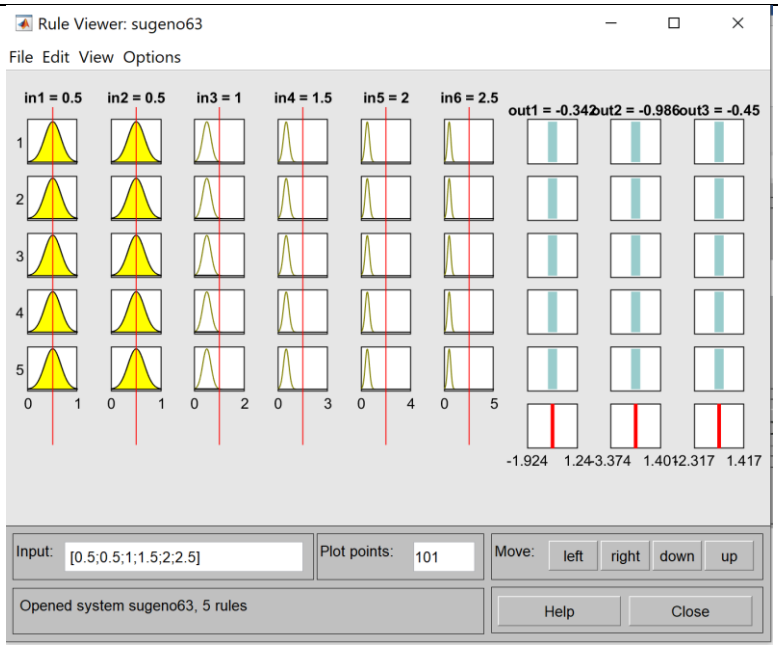

Рисунок 2. Правило (Rule Viewer) в модели Sugeno: визуализация логического вывода для шести входов и трёх выходов

На данном рисунке 2 показан интерфейс окна Rule Viewer среды MATLAB Fuzzy Logic Designer, который отображает работу нечеткой модели Sugeno в режиме визуализации вывода. Этот инструмент позволяет оценить, как текущие значения входных параметров влияют на активность нечетких правил и на формирование выходных сигналов модели. Горизонтальные строки (1–5) представляют пять активных нечетких правил, построенных на основе экспертных знаний о функционировании биореактора. Каждое правило связывает определённые комбинации входных значений с соответствующими выходами. Вертикальные столбцы обозначают (in1–in6) — это входные переменные, каждая из которых имеет три функции принадлежности. Жёлтые области указывают на степень активации соответствующего нечеткого множества при заданных входных значениях. Эти значения указаны в нижнем текстовом поле ввода (Input: [0.5 0.5 1 1.5 2 2.5]) и представляют конкретный набор условий эксплуатации биореактора. Правые три столбца **(out1, out2, out3)** представляют выходы модели, которые полученны на основе сработавших правил:

- out1 = -0.342
- out2 = -0.986
- out3 = -0.45

Эти значения интерпретируются как предсказания по целевым показателям, например, эффективности очистки, концентрации загрязнений или активности микробиоты. Красные вертикальные линии в графиках функций принадлежности показывают текущие значения входов, а их пересечение с нечеткими множествами определяет степень активации каждого правила. Чем выше уровень перекрытия (интенсивность жёлтого цвета), тем выше вклад соответствующего правила в итоговое значение выхода. На правой стороне отображается итоговая агрегация всех правил и дефаззифицированное значение по каждому из выходов. Этот рисунок 2 иллюстрирует, как модель Sugeno адаптируется к изменениям во входных данных и мгновенно пересчитывает прогнозируемые выходные параметры. Такой подход особенно важен при создании цифрового двойника, так как позволяет отслеживать поведение биореактора в режиме реального времени и принимать обоснованные управленческие решения на основе выходных данных модели. Следовательно, Rule Viewer подтверждает логическую целостность модели, демонстрируя прозрачность процесса вывода и высокую интерпретируемость полученных результатов.

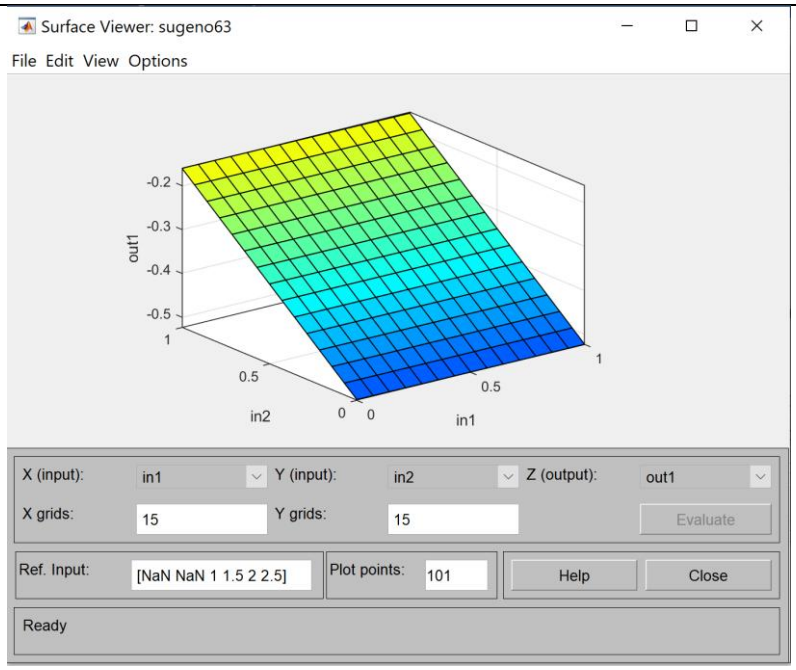

Рисунок 3. Поверхность вывода (Surface Viewer) модели Sugeno: визуализация зависимости выходного параметра out1 от входных переменных in1 и in2.

На рисунке 3 показана трёхмерная поверхность, которая созданна с помощью инструмента Surface Viewer в среде MATLAB Fuzzy Logic Designer, отражающая поведение нечеткой модели типа Sugeno. Данная визуализация служит для анализа того, как изменения двух выбранных входных параметров — in1 и in2 — влияют на значение одного из выходов системы — out 1. Ось X (in1) - первый вход модели, варьируется от 0 до 1. Ось Y (in2) - второй вход модели, также варьируется от 0 до 1. Ось Z (out1) - первый выход модели, рассчитываемый системой Sugeno на основе значений in1 и in2 при фиксированных значениях остальных входных переменных На рисутке 3 чётко прослеживается линейная и гладкая зависимость выхода out1 от двух входов. Снижение значений по оси Z по мере роста in1 и in2 указывает на то, что при увеличении этих двух параметров происходит снижение выходного сигнала. Surface Viewer позволяет визуально проверить адекватность логики, заложенной в правила модели. Гладкая поверхность без резких скачков подтверждает устойчивость и согласованность нечеткой модели Sugeno. Такая форма зависимости удобна для инженерного анализа и может быть использована как инструмент поддержки принятия решений при эксплуатации биореактора, а также при калибровке системы управления. В рамках построения цифрового двойника биореактора данная визуализация играет ключевую роль, так как демонстрирует, как изменения технологических параметров в реальной системе будут влиять на прогнозируемый отклик. Это позволяет инженерам и операторам заблаговременно оценивать последствия изменений и управлять процессом в проактивном режиме.

Для количественной оценки точности разработанной нечеткой модели Sugeno был использован показатель среднеквадратичной ошибки (RMSE, Root Mean Square Error), значение которой составило 0.06. Это значение указывает на высокую точность модели при аппроксимации выходных данных биореактора. Для моделирования биологических и экологических процессов, где допустимыми считаются ошибки в диапазоне 0.1–0.2, полученный результат RMSE = 0.06 свидетельствует о высокой согласованности между предсказанными моделью и фактическими значениями. Низкое значение RMSE демонстрирует хорошее соответствие между моделью и реальным (или симуляционным) поведением системы, минимальное влияние шумов и нелинейностей на точность прогнозов, эффективность выбранной архитектуры модели и применённых правил нечеткой логики. Следовательно, значение RMSE = 0.06 подтверждает высокую надёжность и пригодность модели Sugeno для построения цифрового двойника биореактора и её потенциальное применение в системах мониторинга и управления очистными сооружениями.

Выводы

В ходе исследования была разработана и реализована нечеткая модель типа Sugeno, которая применяется для построения цифрового двойника биореактора, используемого в системах очистки сточных вод. Модель основана на шести ключевых входных параметрах, которые отражают технологические и физико-химические характеристики процесса, и формирует три выходных сигнала, представляющих важнейшие показатели эффективности работы биореактора. Применение инструментов MATLAB Fuzzy Logic Designer позволило визуализировать работу нечеткой системы, отладки правил вывода, степени принадлежности и окончательных результатов дефаззификации. Анализ результатов, полученных с использованием Rule Viewer и Surface Viewer, подтвердил адекватность логики модели, согласованность поведения си-

стемы, а также высокую интерпретируемость и гибкость при изменении входных условий. Разработанная модель продемонстрировала хорошие показатели точности и устойчивости при прогнозировании отклика биореактора даже в условиях неопределённости и нелинейности, что характерно для реальных биологических процессов. Таким образом, предложенный подход может эффективно использоваться при создании цифровых двойников в водоочистных установках и в других инженерных задачах, где важны адаптивность, прозрачность и способность к обобщению.

В дальнейшем изучение модель может быть дополнена элементами адаптивного обучения, интеграцией с нейросетевыми компонентами и включена в состав интеллектуальных систем управления для реального времени, что откроет новые возможности для автоматизации и оптимизации биотехнологических процессов.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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MODELING AND CONTROL OF WASTEWATER TREATMENT EFFICIENCY WITH MAMDANI FUZZY INFERENCE SYSTEM

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МОДЕЛИРОВАНИЕ И УПРАВЛЕНИЕ ЭФФЕКТИВНОСТЬЮ ОЧИСТКИ СТОЧНЫХ ВОД С ИСПОЛЬЗОВАНИЕМ СИСТЕМЫ НЕЧЕТКОГО ВЫВОДА МАМДАНИ

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Abstract

Efficient wastewater treatment is essential for sustainable environmental management, yet conventional mathematical models often fail to capture the nonlinear and uncertain dynamics of biological processes. This study develops a Mamdani-type Fuzzy Inference System (FIS) to model and control wastewater treatment efficiency using operational data. Nearly 15,000 data samples, obtained from a mathematical process model, were analyzed to identify the main variables influencing treatment performance. The fuzzy logic framework incorporates linguistic rules and membership functions, enabling the system to manage uncertainty and approximate expert decision-making in real time. Simulation results demonstrate that the Mamdani FIS achieves accurate predictions of treatment efficiency and provides robust control of critical process parameters under fluctuating conditions. The model enhances dissolved oxygen regulation, improves pollutant removal, and stabilizes bioreactor operation, ultimately leading to higher energy efficiency and better effluent quality. Overall, the findings highlight the effectiveness of Mamdani fuzzy logic as a decision-support tool for intelligent and adaptive wastewater treatment management.

Аннотация

Эффективная очистка сточных вод является важнейщим фактором устойчивого экологического управления, при этом традиционные математические модели часто не способны отражать нелинейную и неопределённую динамику биологических процессов. В данном исследовании разработана система нечеткой логики типа Мамдани (FIS) для моделирования и управления эффективностью очистки сточных вод на основе эксплуатационных данных. Были прообработаны около 15 000 образцов данных, которые получены из математической модели процесса, с целью выявления основных переменных, которые влияют на эффективность очистки. Рамки нечеткой логики включают лингвистические правила и функции принадлежности, что позволяет системе управлять неопределенностью и приближать принятие решений эксперта в режиме реального времени. Результаты моделирования показывают, что FIS типа Мамдани обеспечивает точное прогнозирование эффективности очистки и надёжное управление критическими параметрами процесса при изменяющихся условиях. Модель улучшает регулирование растворённого кислорода, повышает удаление загрязняющих веществ и стабилизирует работу биореактора, что в конечном итоге способствует повышению энергоэффективности и улучшению качества сброса. Результаты подчеркивают эффективность нечеткой логики Мамдани в качестве инструмента поддержки принятия решений для интеллектуального и адаптивного управления очисткой сточных вод.

Keywords: Mamdani model, wastewater treatment, dissolved oxygen regulation, Fuzzy logic.

Ключевые слова: Мамдани модель, очистка сточных вод, регулирование растворенного кислорода, Нечеткая логика.

ВВЕДЕНИЕ

Очистка сточных вод является одной из важнейщих задач современного экологического и ресурсного управления. Повышение эффективности очистки позволяет снизить воздействие на окружающую среду, а также способствует рациональному использованию энергии и ресурсов. Традиционные математические модели, которые используются для описания биологических процессов в биореакторах, часто сталкиваются с ограничениями при работе с нелинейными, динамическими и неопределёнными процессами, что снижает точность прогнозирования и управления.

В настоящее время подходы на основе нечеткой логики привлекают внимание исследователей благодаря своей способности моделировать сложные системы, где традиционные методы оказываются недостаточными и неточными. Системы нечеткой логики способны учитывать экспертные знания и неопределённость данных, которые обеспечивют гибкое и адаптивное управление процессами в реальном времени. Особенно важным является регулирование растворённого кислорода, поскольку этот параметр напрямую влияет на активность микробной флоры и эффективность удаления загрязняющих веществ.

Данное исследование направлено на разработку и применение системы нечеткой логики типа Мамдани для моделирования и управления эффективностью очистки сточных вод. Использование обширного набора эксплуатационных данных дает возможность выявить ключевые параметры, которые влияют на качество очистки, и реализовать интеллектуальную стратегию управления биореактором. Результаты работы показывают возможности повышения стабильности работы, энергоэффективности и качества сброса сточных вод при применении подхода на основе нечеткой логики. Применение нечеткой логики дает возможность создавать адаптивные стратегии управления, которые способны быстро реагировать на колебания параметров процесса и поддерживать оптимальные условия работы биореактора. Данное исследование демонстрирует практическую применимость Mamdani FIS для повышения эффективности очистки сточных вод и служит основой для дальнейшего внедрения интеллектуальных систем управления в отрасли водоочистки.

Цель

Целью данной работы является разработка и реализация нечеткой модели на основе Мамдани для построения цифрового двойника биореактора, используемый в процессе очистки сточных вод. Исследование направлено на оптимизацию регулирования важнейщих параметров процесса, включая растворённый кислород, с целью повышения стабильности работы биореактора, эффективности удаления загрязняющих веществ и энергоэффективности процесса. Данный цифровой двойник построен с целью повышения точности прогнозирования выходных параметров системы, при этом улучшая управления технологическим процессом и адаптивностью модели к изменяющимся условиям эксплуатации.

Начальные условия

В данной работе в качестве объекта моделирования рассматривается аэробный биореактор, используемый для очистки сточных вод. Модель разрабатывается на основе набора симуляционных данных, которые отражают функционирование установки в различных режимах работы. Для построения нечеткой модели Mamdani были определены шесть входных параметров, которые характеризуют важнеищие условия и процессы внутри биореактора. К выбранным входным параметрам относятся: расход приточной воды, возвратный поток ила, скорость оттока отходов, концентрация субстракта, концентрация кислорода в резервуаре реактора, концентрации биомассы. В качестве выходных параметров модели рассматриваются такие показатели которые отражают эффективность очистки и техническое состояние системы. К ним относятся степень удаления органических загрязнений, концентрация остаточного аммония, микробиологическая активность (или биомасса активного ила). Модель строятся на основе одного из ниже представленноого дифференциального уравнения.

$$\frac{dX_H}{dt} = \frac{q_F}{V}X_{HF} - \frac{q_{tz}}{V}X_H + \frac{(q_F+q_R)}{(q_F+q_R)}X_H - \frac{\mu_H}{Y_H}\left(\frac{S_S}{K_S+S_S}\right)\left(\frac{S_O}{K_{OH}+S_O}\right)X_H(1-f_P)^{b_H}X_H \quad (1)$$

Ниже представленая таблица с основынми параметрами, которые описывают процесс биологической очистки.

Таблица 1. Основные параметры модели.

Параметр	Обозначение	Единицы	Значение
Концентрация органического субстрата (БПК)	S_S	мг/л	4.4
Концентрация растворённого кислорода, мг/л	S_o	мг/л	3.0
Концентрация гетеротрофной биомассы, мг/л	X_H	мг/л	5
Скорость потока	q_F	м³/сут	50
Скорость потока рециркуляции	q_R	м³/сут	50
Скорость оттока отходов	q_W	м³/сут	4.8
Объем резервуара аэрации	V	м³	12.5
Максимальная скорость биомассы	μ_H	1/сут	3.733
Коэффициент насыщения субстрата	K_S	мг/л	20
Коэффициент насыщения субстрата	K_{OH}	мг/л	0.2
Коэффициент производительности	$У_H$		0.6
Скорость гетеротрофного разложения	b_H	л/сут	0.4
Концентрация насыщения кислрода	S_{osat}	мг/л	10

Это уравнение (1) представляет динамику концентрации кислорода необходимый для аэробного окисления органический веществ. Первое слагаемое в уравнения отражает приток кислорода с входной водой, второе слагаемое означает вынос кислорода с выходящей жидкостью. Третье слагаемое показывает потребление кислорода при росте биомассы. Последнее слагаемое отражает процесс аэрации, то есть перенос кислорода из воздуха в жидкость. Работа биореактора очистки сточных вод является сложным объектом, который состоит из биохимических реакций и гидродинамики. На основе выше представленного дифференциального уравнения осуществляется взаимосвязь между параметрами. На основе уравнения можно выделить, что чем выше концентрация X_H тем интенсивнее

утилизация субстрата S_S. Таким образом , рост биомассы напрямую связан с доступным субстратом, но также опосредован через кислород. Для аэробного дыхания необходим растворенный кислород. Увеличение X_H и S_S приводит к ускорение биопроцесса, а это означает к ускоренному потреблению кислорода. Следовательно, отмечается связь между кислородом и биомассой существует обратная связь. То есть кислород активирует рост, но при этом сам потребляется в этом процессе. Представленное уравнение показывает биохимические процессы, при этом обеспечивая точное математическое описание работы биореактора.

Методы

С помощью среды Fuzzy Logic Designer MATLAB строится модель цифрового двойника для биореактора очистки сточных вод. В данном случае применяется структура биза правил Mamdani FIS. Основываясь на анализ взаимосвязей между входами и выходами и с учетом экспертных знаний о деятельности биореактора определено общее количество нечетких правил.

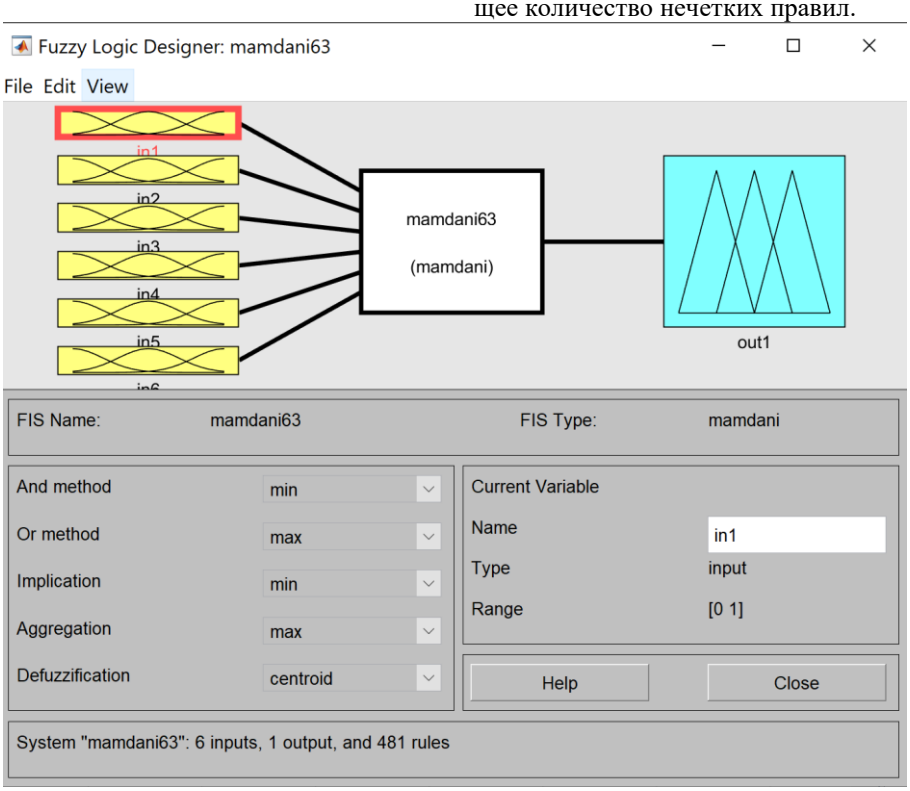

Рисунок 1. Структура нечеткой модели Мамдани для цифрового двойника биореактора

На рисунке 1 представлена архитектура нечеткой модели Мамдани, где показана зависимость dX_H/dt от двух ключевых входных переменных системы. Рисунок указывает на сложность динамики процесса и подчёркивает, что традиционные линейные модели были бы недостаточными для описания поведения системы. Использование нечеткой логики Мамдани позволяет гибко учитывать такие нелинейные взаимодействия. Данной работе применяется около 15000 данных из ANFIS. Шесть параметров являются входными переменными модели, которые характеризуют важнейшие технологические характеристики процесса. Каждая входная переменная проходит через этап фаззификации, где значения переводятся в соответствующие нечеткие множества на основе предварительно заданных функций принадлежности. В завершение активируются нечеткие правила, которые формируются основываясь на знаниях об объекте и экспертной логики. Данная модель обеспечивает высокую точность, адаптивность и интерпретируемость, что делает её эффективным компонентом при построении цифрового двойника в области водоочистки.

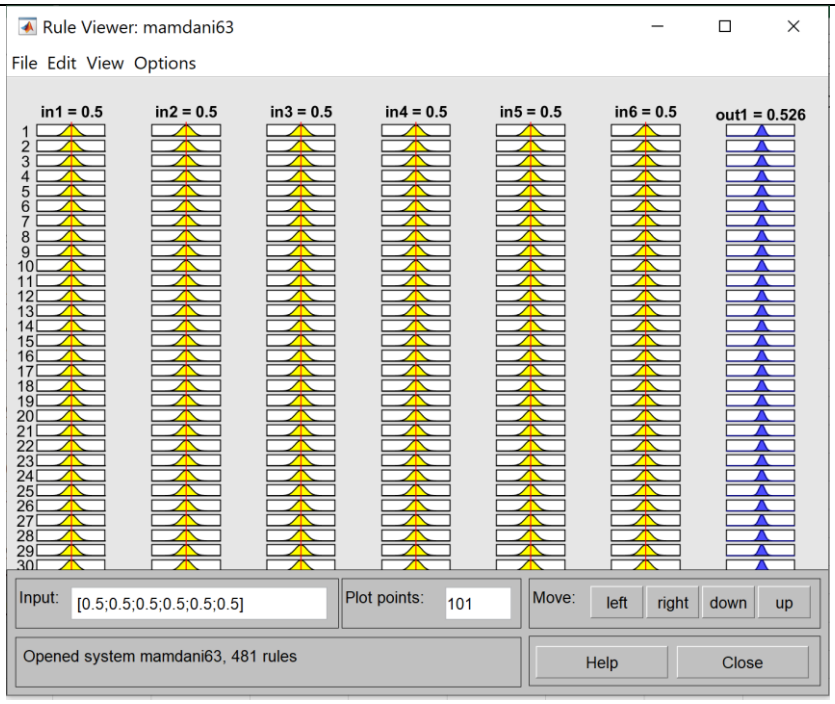

Рисунок 2. Правило (Rule Viewer) в модели Mamdani

На рисунке 2 представлен интерфейс визуализации правил Mamdani Fuzzy Inference System (FIS) с 481 правилом для моделирования процесса очистки сточных вод. На рисунке представлены шесть входных переменных (in1–in6), каждая из которых имеет начальное значение 0,5, и выходная переменная (out1), значение которой составляет 0,526. С помощью интерфейса возможно визуально оценить влияние каждого входного параметра на выход системы и служит инструментом анализа и отладки нечеткой модели Mamdani, обеспечивая понимание логики принятия решений в условиях неопределенности.

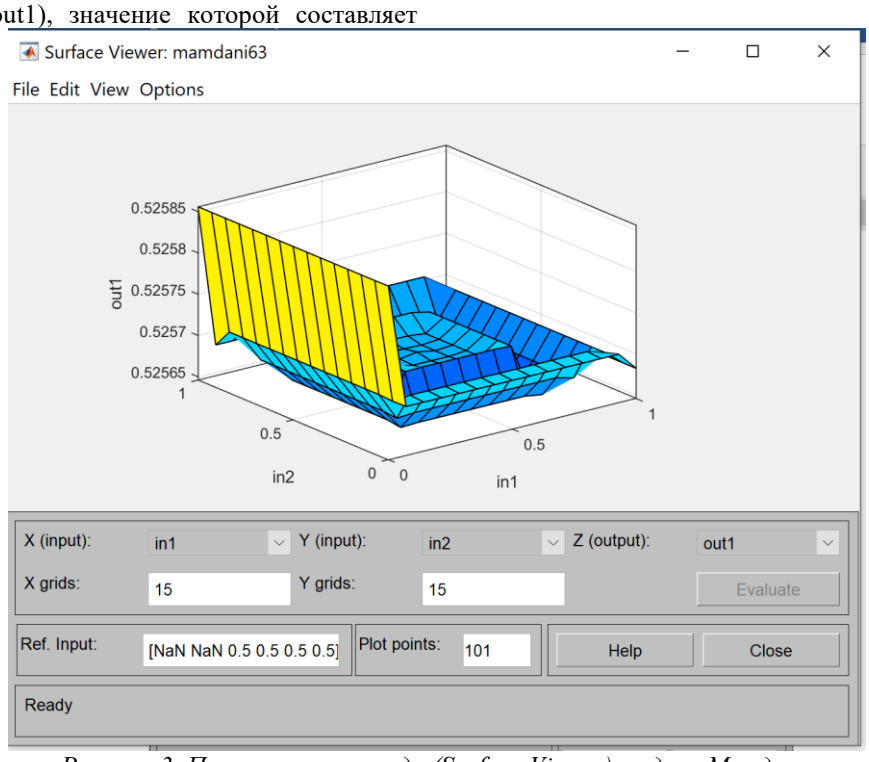

Рисунок 3. Поверхность вывода (Surface Viewer) модели Мамдани

На рисунке 3 показана трёхмерная поверхность, которая созданна с помощью инструмента Surface Viewer в среде MATLAB Fuzzy Logic Designer, отражающая поведение нечеткой модели типа Мамдани. Данная визуализация показывает зависимость между двумя выбранными входными параметрами — in1 и in2 — влияют на значение одного из выходов системы — out 1. Ось X (in1) - первый вход модели, варьируется от 0 до 1. Ось Y (in2) - второй вход модели, также варьируется от 0 до 1. Ось Z (out1) – варьируется от 0.52565 до 0.52585. Главную визуализацию обеспечивает сетка. Линии

сетки четко выделяют изменение выходной величины при изменении входов. По рисунку 3 можно выделить. Что поверхность плоская что указывает на низкую чувствительность выходной переменной к изменением входов в указанном диапазоне. Небольшие колебания свидетельствует об минимальном изменение входного значения при комбинированном влияние входов. Также можно выдулить. Что слегка возвышен краевые значения графика. Что свидетельствует о незначительном нелинейном эффекте на выходе. Для количественной оценки точности разработанной нечеткой модели Мамдани был использован показатель среднеквадратичной ошибки (RMSE, Root Mean Square Error), значение которой составило 0.466. Значение RMSE (Root Mean Square Error), равное 0.466, характеризует среднеквадратичное отклонение предсказанных моделью значений от фактических данных. Это свидетельствует, что в среднем ошибки предсказаний составляют около 0.466 единиц измерения рассматриваемого параметра. RMSE является одной из наиболее часто используемых метрик для оценки точности моделей, поскольку она чувствительна к крупным ошибкам: большие расхождения между предсказанным и фактическим значением вносят больший вклад в итоговую оценку. Таким образом, полученное значение демонстрирует удовлетворительную степень соответствия модели реальным данным, позволяя использовать её для прогнозирования и анализа процесса с учетом существующей погрешности.

Выводы

Разработка и реализация нечеткой модели Мамдани применяется для построения цифрового двойника биореактора, используемого в системах очистки сточных вод. Модель основана на шести ключевых входных параметрах, которые отражают технологические и физико-химические характеристики процесса, и формирует три выходных сигнала, представляющих важнейшие показатели эффективности работы биореактора. Использование инструментов MATLAB Fuzzy Logic Designer дает возможность визуализировать работу нечеткой системы, отладки правил вывода, степени принадлежности и окончательных результатов дефаззификации. Данный результат подтверждает, что модель адекватно описывает процесс и может использоваться для предсказания выхода системы в заданных пределах. Анализ результатов подтверждает корректность логической структуры модели, согласованность динамических характеристик системы, а также высокую интерпретируемость и адаптивность при варьировании входных параметров. Построенная модель демонстрирует устойчивость и точность в прогнозировании функционирование биоректора, даже в определенных условиях нелинейности и неопределенности. Результаты свидетельствует об эффективности и надежности примененнго инструмента для построения цифровго двойника для биореактора.

В перспективе дальнейшее развитие модели может включать внедрение механизмов адаптивного обучения, интеграцию с нейросетевыми компонентами, а также её использование в составе интеллектуальных систем управления в режиме реального времени.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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THE EFFECT OF SEVERE SMOG POLLUTION ON TURBULENCE

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Abstract

This study examines the complex interaction between anthropogenic air pollution and atmospheric turbulence. Particular attention is given to the critical role of turbulence in dispersing harmful substances within the atmospheric boundary layer. It is shown that pollutants such as soot not only deteriorate air quality but also suppress turbulent transport, thereby creating a positive feedback loop. This process leads to atmospheric stabilization and the accumulation of hazardous concentrations of fine particulate matter with diameters smaller than 2.5 μm, ultimately forming persistent smog. Conversely, reducing soot emissions can enhance turbulence and improve ventilation. The study summarizes field observations and modeling results that demonstrate the influence of the turbulent barrier effect and meteorological factors on pollutant transport. The findings provide a foundation for developing effective strategies to improve air quality and protect public health.

Keywords: air pollution, turbulence, soot, feedback, smog

Atmospheric pollution intensifies the greenhouse effect, contributes to the formation of acid rain, reduces air quality, and leads to the accumulation of toxic substances in soil and water, resulting in ecosystem degradation and biodiversity loss. Human interaction with the environment has long been the subject of research, as anthropogenic activities significantly affect both biotic and abiotic components of ecosystems. Pollution is defined as the release of harmful substances into the environment in concentrations exceeding natural levels, which leads to the degradation of air, water, and soil, as well as to climate change. Since the Industrial Revolution, mass production and the increase in emissions have become key drivers of environmental deterioration and a major threat to public health [1].

CO_2 emissions and soot exert opposite effects on turbulence and the height of the planetary boundary layer. With increasing CO_2 concentrations and decreasing aerosol emissions, the number of severe air pollution episodes is expected to decline, further confirming the health benefits of reducing black carbon emissions [2].

Theoretical models of the atmosphere have traditionally relied on radiative transfer and the characteristics of the underlying surface, where solar heating and anthropogenic emissions serve as primary energy sources. However, at the local scale, a significant factor is the kinetic energy of motor vehicles, which generates turbulence and influences the vertical distribution of pollutants in the lower troposphere. The authors of [3] developed a parameterization of vertical pollutant transport induced by traffic-related turbulence, drawing an analogy with subgrid approaches for industrial plume dispersion. Turbulence is a key factor contributing to ground-level pollution, while also being affected by it. Within the boundary layer—the lowest part of the atmosphere—turbulence mixes pollutants and can facilitate their removal (far-left panel).

At high concentrations of absorbing aerosols, such as soot, heating of the upper boundary layer stabilizes the air, reduces turbulence, and promotes the accumulation of pollutants closer to the surface (middle panel). Pollution studies have also revealed a weaker turbulence-enhancing effect associated with surface warming caused by greenhouse gases such as CO_2 (far-right panel). Under weak wind conditions, intermittent turbulence frequently develops in the atmospheric boundary layer, substantially limiting the vertical diffusion of pollutants and contributing to the formation of dense haze. Turbulence can vanish at specific altitudes, leading to the formation of a barrier layer that prevents the vertical transport of contaminants. Based on turbulence data across five layers and concentrations of fine particulate matter with diameters smaller than 2.5 μm at two levels, it has been demonstrated that the vertical turbulence barrier is directly linked to the accumulation and vertical distribution of particles [4–5].

Atmospheric turbulence and the properties of the planetary boundary layer play a crucial role in modulating near-surface concentrations of fine particulate matter ($PM_{2.5}$); however, the mechanisms of their influence remain insufficiently understood. Using meteorological observations, $PM_{2.5}$ data, turbulence measurements, and high-resolution sounding, a regional transport episode was analyzed. During the growth stage, northerly winds (2–4 m/s) carried a polluted air mass, which was accompanied by an increase in $PM_{2.5}$ concentrations. During the pollution period, a decline in turbulent kinetic energy and heat fluxes correlated with rising $PM_{2.5}$ levels, with the nature of this relationship varying across different stages of the event: a negative correlation was observed during the initial and maintenance stages, while a positive correlation was found in the growth stage.

The absence of a pronounced inversion below 500 m and vertically uniform northerly winds facilitated the transboundary transport of pollutants, whereas wind

shear limited their downward transport to the surface [6]. Turbulent diffusion is often considered a desirable phenomenon in many contexts, yet it also presents significant challenges, particularly in the domain of air pollution. Air pollution, a widely recognized and condemned problem, deteriorates air quality and poses serious long-term health risks. Turbulent flows, characterized by chaotic and random fluid motions, give rise to turbulent diffusion—a process that serves as a transport mechanism for dispersing pollutants in the atmosphere. Advances in research have deepened the understanding of turbulent diffusion and its broad applications, as new methods are continuously being employed to expand both the scope of studies and practical applications [7].

Turbulence poses not only potential hazards but also economic costs for aviation, accelerating aircraft wear and increasing fuel consumption as pilots attempt to avoid it. The intensification of chaotic atmospheric motions has stimulated efforts to develop methods for forecasting and mitigating its effects. Among promising approaches is the use of lidar systems for three-dimensional mapping of the air surrounding an aircraft, similar to point cloud technology employed in autonomous vehicles. A 2023 study proposed a “dual-wavelength” system capable of detecting light and moderate turbulence up to 7–10 km ahead. However, at higher altitudes, such devices remain too bulky, heavy, and energy-intensive for use on commercial aircraft.

Flying through vortices, eddies, and updrafts with minimal disturbances requires not only precise engineering but also a profound understanding of hydrodynamics, as air, like water, obeys the laws of fluid motion. The chaotic nature of turbulence makes flow behavior highly sensitive to even small perturbations, whether caused by wind deflection near a building or the jet stream of another aircraft. Surface air pollution remains a serious threat to human health, causing millions of premature deaths each year. One of the major pollutants is soot, generated from coal combustion and vehicle exhaust.

In study [8], researchers employed a combination of global climate models, specialized modeling experiments, and previous findings on the relationship between soot emissions and turbulence in the lower atmosphere. It was shown that high concentrations of soot contribute to a reduction in turbulence. Under low-turbulence conditions, the atmosphere becomes more stable, leading to the accumulation of pollutants near the surface and resulting in intense pollution episodes, typical of the winter season. Dark soot particles absorb solar radiation, locally heating the air, enhancing stagnation, reducing the efficiency of vertical pollutant dispersion, and increasing the frequency of such events.

The anticipated reduction in soot emissions in the future may enhance turbulence and mitigate the adverse effects of aerosol pollution on human health. However, the magnitude and patterns of future emissions remain uncertain, particularly in Asia, and the number of people affected by changes in turbulence depends on specific pollution dispersion scenarios. Despite ongoing efforts to reduce emissions, air pollution continues to cause millions of deaths annually, and the effectiveness of mitigation measures will depend not only on emission levels but also on demographic and socio-economic factors.

Conclusions. The study demonstrates that atmospheric turbulence plays a critical role in the formation and dispersion of pollutants; however, its characteristics are strongly influenced by aerosol concentrations and meteorological conditions.

1. High concentrations of soot and fine particulate matter lead to a reduction in turbulent kinetic energy and the formation of barrier layers, promoting the accumulation of pollutants in the near-surface atmosphere and the development of persistent smog.
2. Conversely, the reduction of aerosol emissions enhances turbulence and increases ventilation efficiency, highlighting the importance of emission reduction measures for improving air quality.
3. Human activities exert a dual effect: on one hand, pollutant emissions contribute to air stagnation, while on the other, mechanical and thermal turbulence generated by transportation and human movement can facilitate local dispersion of contaminants.
4. The obtained data can be used to improve predictive air quality models and to develop effective environmental policy strategies aimed at mitigating the adverse health impacts of aerosol pollutants.

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