SCIENTIFIC RESEARCH OF THE SCO COUNTRIES: SYNERGY AND INTEGRATION

上合组织国家的科学研究：协同和一体化

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这些会议文集结合了会议的材料 – 研究论文和科学工作者的论文报告。 它考察了职业化人格的技术和社会学问题。一些文章涉及人格职业化研究问题的理论和方法论方法和原则。
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These Conference Proceedings combine materials of the conference – research papers and thesis reports of scientific workers. They examine technical, juridical and sociological aspects of research issues. Some articles deal with theoretical and methodological approaches and principles of research questions of personality professionalization.

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丧偶后的生活：社会和心理方面
LIVING IN WIDOWHOOD: SOCIAL AND PSYCHOLOGICAL ASPECTS

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注释。本文介绍了作者在与丧偶客户合作方面的经验。文章探讨了丧偶的社会心理层面，并为支持丧偶人士提供了建议。作者还从心理学角度解释了人们对丧偶经历的一些传统误解。

关键词：丧偶，心理治疗工作，丧偶支持，人格的个体心理特征，“六个月综合症”。

Annotation. *This article presents the author's experience working with clients experiencing widowhood. It addresses the socio-psychological aspects of widowhood and provides recommendations for supporting widowed individuals. The author also provides a psychological explanation for traditional misconceptions about the experience of widowhood.*

Keywords: *widowhood, psychotherapeutic work, widowhood support, individual psychological characteristics of personality, "six-month syndrome".*

The issue of widowhood is a significant one in crisis psychology, requiring therapeutic solutions. Its relevance increases especially during periods of military conflict.

In our work we would like to address some of the socio-psychological aspects of living as a widower and offer recommendations for supporting this social category of citizens.

The results of our study are based on work with widowed women, but the data obtained can also be used in work with widowed men. Men who are widowed experience similar experiences. The client's age is also irrelevant in this case. The characteristics we've identified are typical for widowhood at any age.

Experience has shown that widowed people are reluctant to seek help from a psychologist. This is because, regardless of the quality of their marriage, every widow considers theirs unique and special. They don't want to let a third party into their relationship illusion or receive any recommendations or advice. It's better for

them to talk through their experiences with someone who is experiencing the same emotional state. In this situation, a widow's best contact is with a fellow widow. In therapeutic work, the psychologist places great emphasis on discussing the client's memories and associated emotions and feelings.

Therefore, when organizing psychotherapy, group sessions are recommended. Experiencing shared emotions unites these women and produces better therapeutic results than simply working with a psychologist. A significant number of widows withdraw into themselves, believing they must cope with their grief on their own. The fear is the same: an unwillingness to let anyone into their world of experiences and illusions.

The next challenge is accepting one's new status. This is especially acute in the case of sudden widowhood. At this stage, it can be very difficult for a woman to psychologically comprehend and apply the concept of "widow" to herself. Moreover, it is during this period that she is constantly reminded of her changed status. For example, when completing a large number of documents. These circumstances often become an additional traumatic fact.

A widow desperately needs help, and even though she knows others are willing to help, she may find it especially difficult to ask for anything. Therefore, widow support should include a range of actions to ensure the widow's needs are met. When offering to help a widow, you should be specific about how you can help, avoiding phrases like, "If you need anything, call me."

It is quite difficult for a widow to talk about her problems with others, but if she does begin to talk about her experiences, she is often immediately advised to seek professional medical or psychological help. Most people, even close ones, subconsciously fear dealing with strong emotions and try to avoid discussing their experiences. The topic of conversation is often changed under the pretext that the widow needs to be distracted from her thoughts. As a result, an emotional void forms around the widow, and a feeling of loneliness in a crowd develops.

While the reaction to a husband's death depends on the individual's psychological characteristics and life priorities, most widows tend to mobilize internal resources and become stronger, especially if they have children.

During the period of awareness of widowhood, many women exhibit strange and inconsistent behavior. During this period, support from friends, family, and other widows is crucial. When interacting with other widows, they don't try to teach a woman anything, but rather provide her with the opportunity to openly express her grief in appropriate company, and she learns to live with other lonely people.

In the early days of widowhood, a woman may act actively and rationally, which creates the impression that she is coping well with grief (strictly adheres to ethical and social norms of behavior, accepts condolences, conducts a memorial

service, etc.). In reality, these are simply actions honed to the point of automatism. This phenomenon can be explained by the protective function of the psyche. Typically, a woman later has only vague memories of this period. If the death of her husband was sudden, the widow, by inertia, acts as if programmed. In her mind, she is still a wife and maintains the traditions that existed in their family.

A widow should be involved in organizing her husband's funeral. Being involved in this process helps her avoid becoming paralyzed.

The most difficult stage of acceptance comes after the funeral. The widow has endured all the social norms, and everyone around her believes the worst is over. She's now faced with a new reality. It's only now that she begins to comprehend what happened.

Emotions overwhelm a woman and spill out. This is especially common among widows who had previously "held themselves well." It's no coincidence that Slavic funeral traditions included mourners whose lamentations would draw the widow's tears, thus giving her the opportunity to express her emotions publicly and share them with everyone present.

The problem is that the widow hides these emotions, believing this is unnatural. The mourning period begins in its most severe form. The biggest mistake is advising the woman to occupy herself with something else, changing the subject when talking to the widow, or complimenting her on her appearance. During this period, the widow needs to acknowledge her loss and mourn together. It is not recommended to discourage the widow from processing her grief. Many widows prefer to talk about their husbands. But people avoid talking about death. Widows are hurt by others' attempts to avoid the topic.

A widow's social circle changes dramatically. Many married couples, previously close to her, distance themselves. There are several reasons for this. The married couple subconsciously feels a false sense of guilt about their marital happiness and avoids spending time with the widow. Widows themselves are less eager to rejoin the same groups they once frequented with their husbands. The woman begins to socialize with similarly lonely friends or simply remains alone. The widow is more inclined to accept informal invitations. Furthermore, there are cases where wives from friendly couples begin to see the widowed woman as a rival and shield their family from contact with her.

Every widowed woman wonders how long she will experience grief and when the pain will subside.

Experience shows that in this situation, there are no clear boundaries or time limits. Psychologists note that the first year of widowhood is easier to cope with than the second. They explain this by the fact that the first year is about adapting to the new status, while in the second year, the widow realizes that this is forever.

Widowhood is a way of life that must be accepted and learned to live with. The pain of loss subsides, but it never goes away completely.

There's no point in setting any deadlines. They might pass, and the widow might realize she hasn't gotten any better and feel even worse.

J. Ginsburg identifies the "half-year syndrome"—a condition in which it seems as if things have gotten better, but after a while, the same feelings return [1, 16]. "Six-month syndrome" is a conditional term, as it first appears around this time, but it can also occur at other times, for example, several years later. "Six-month syndrome" can be triggered by events that cause the widow to return to her previous experiences of loss.

A widow's life is marked by constant ups and downs in her mood, and she is prone to anger and resentment.

A widow rebuilds her identity and realizes that she will now have to cope with all of life's problems alone. It's important to accept this fact and learn to live with it. She will have to deal with men's everyday problems, go to the theater, go on vacation, and so on alone. This is a new social role and a new way of life. Mastering this lifestyle requires overcoming a number of psychological barriers, ingrained stereotypes, and attitudes. Once a woman once again feels self-sufficient, she can say she has overcome the grief and is ready for a new, productive phase of her life.

Thus, in this article we have examined some of the socio-psychological aspects of living through widowhood, presented recommendations to others on supporting widowed persons based on the psychological characteristics of living and accepting a new social status, and scientifically substantiated the everyday perception of widowed persons.

This topic is relevant for any society and requires further, more in-depth study.

References

1. Ginzburg J.D. Widow to widow: [sensitive practical ideas on how to start living anew] [translated from English by Y.V. Timkova]. Moscow, 2006. 288 p.

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有自伤行为的青春期女孩的心理特征
PSYCHOLOGICAL CHARACTERISTICS OF ADOLESCENT GIRLS WITH SELF-INJURIOUS BEHAVIOR

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注释。本文对青少年自伤行为（SIB）进行了全面分析。文章探讨了这种行为的心理、社会和生物学成因，并强调其作为一种功能失调的应对机制，在应对青春期特有的压力和身份认同危机方面所起的作用。文章着重分析了SIB与埃里克森心理社会发展理论之间的关系，以及家庭因素（例如父母的敌意、过度保护或情感冷漠）的关键作用。文章特别关注非自杀性自伤（NSSI），包括其形式、功能（情绪调节、沟通、自我惩罚）以及与自杀行为的区别。文章分析了有SIB的青少年的心理特征，包括负面的自我概念、情绪失调和身体排斥。作者得出结论，自伤行为是严重的社会心理适应不良的标志，但通过及时识别和提供心理援助，随着青少年发展出更成熟的应对策略，自伤行为可以得到缓解。

关键词：自残行为（SHB）、青少年、非自杀性自残（NSSH）、身份危机、情绪失调、应对策略、家庭因素、自我概念。

Annotation. *This article provides a comprehensive analysis of self-injurious behavior (SIB) in adolescence. It examines the psychological, social, and biological causes of this behavior, emphasizing its role as a dysfunctional coping mechanism for the stress and identity crisis characteristic of puberty. The paper emphasizes the relationship between SIB and Erikson's theory of psychosocial development, as well as the key role of family factors such as parental hostility, overprotection, or emotional coldness. Particular attention is paid to non-suicidal self-injury (NSSI), its forms, functions (emotion regulation, communication, self-punishment), and differences from suicidal behavior. The psychological characteristics of adolescents with SIB are analyzed, including a negative self-*

concept, emotional dysregulation, and body rejection. The authors conclude that SPP is a marker of deep socio-psychological maladjustment, but with timely identification and provision of psychological assistance, it can be reduced as the adolescent develops more mature coping strategies.

Keywords: *self-harming behavior (SHB), adolescence, non-suicidal self-harm (NSSH), identity crisis, emotional dysregulation, coping strategies, family factors, self-concept.*

Self-harming behavior in adolescence is a complex and multifaceted phenomenon, rooted in a host of psychological, social, cultural, and biological causes. On the one hand, a tendency toward self-harm may be an outward manifestation of serious psychopathological disorders requiring professional intervention. On the other hand, in some cases, self-harming behavior conceals psychological problems and crises that naturally accompany the process of maturation and personality development in adolescents.

Adolescence is a period of dramatic change and transformation, affecting all levels of human functioning. New mechanisms of self-regulation and self-control are formed, and the perception of one's own personal boundaries, self-identification, and overall worldview shift. Gaining an identity, defining one's place in the world, and understanding the range of available social roles are key developmental tasks at this age [2].

Self-harming behavior in this context can be interpreted as a dysfunctional way of coping with stress that accompanies extensive internal work on self-determination and mastering new life roles.

Adolescence, according to E. Erikson's theory of psychosocial development, is characterized by an identity crisis, during which the previous childhood self-perception is destroyed, giving way to a qualitatively new experience of oneself.

This crisis is often accompanied by a state of "confused identity," in which the adolescent loses internal integrity and integration. If the crisis unfolds unfavorably, confused identity can develop into "diffuse identity"—a state of profound disorientation in the value-semantic and social spheres [9].

During this period, not only the adolescent's self-perception but also their perception of how others perceive them undergoes radical changes. Sensitivity to the judgments of others heightens, and self-criticism increases. The process of self-definition itself is often uneven and erratic, characterized by extremes—from the experience of endless possibilities and grandiose plans to a sense of meaninglessness and despair. A tendency toward deviant and self-destructive behavior can be part of this unstable developmental dynamic.

According to Erikson, adolescence is associated with a "psychosocial moratorium"—a time of tentatively assuming various social roles and experimenting

with identities without fully accepting the associated obligations. One of the risks of this period is the possibility of marginalization—a withdrawal from the active search for one's place in society and the adoption of an asocial or antisocial identity [9]. Self-harming behavior can be an expression of insufficient personal maturity and self-regulation skills, as well as a consequence of experiencing rejection and social unacceptance.

During adolescence, the likelihood of various forms of anti-vital behavior increases significantly: suicide and suicide attempts, non-suicidal self-harm, peer violence, bullying, and bullying [8]. These behavioral manifestations may conceal both relatively normative difficulties of adolescence—lack of self-confidence, communication difficulties, increased impulsivity—and deeper problems—the consequences of violence and abuse, dysfunctional family relationships, and social isolation.

Adolescents with repetitive self-harming behavior are at high risk for social maladjustment and the development of persistent emotional-volitional and behavioral disorders [8].

At the same time, with timely identification of the psychological problems underlying self-harm and the provision of professional assistance, such behavior patterns can be softened and reduced as the adolescent acquires more mature and adaptive ways of coping with stress and internal tension.

Adolescence is a time of turbulent change, both physical and psychological. During this period, young people face numerous challenges and difficulties as they try to find their place in the world and understand who they are. It's no surprise that during such a challenging time, borderline states often arise, teetering on the edge of normality and pathology. It can sometimes be very difficult to distinguish the temporary age-related characteristics common to most adolescents from the first warning signs of emerging mental disorders [7].

One such controversial phenomenon is self-harming behavior. Unfortunately, modern approaches to parenting often fail to provide young people with the necessary tools and skills to constructively address life's challenges and overcome difficulties.

Instead of learning to face challenges head-on and find effective solutions, teenagers often try to avoid difficult situations. This avoidance strategy gradually leads to personal degradation, hinders the development of vital competencies, and deprives them of the opportunity to gain valuable experience.

Family factors, particularly parental hostility, play a significant role in the development of a tendency toward self-harm. If a teenager grows up in an atmosphere of rejection, criticism, and emotional abandonment from those closest to them, this inevitably has a devastating impact on their psyche. Paradoxically, excessive directiveness and overprotectiveness from parents often have the

opposite effect, also contributing to the development of self-harming behavior [10].

The overall emotional background of family relationships is crucial here. If parental directives stem from genuine love and care, if they are rooted in a warm and trusting relationship, then even strict control will be perceived by the teenager quite differently—as a sign of concern and empathy. However, if parental instructions and prohibitions are masked by hostility and detachment, they will be perceived as a rude invasion of personal space, an attempt to suppress the child's will and individuality.

The mother's role and her ability to provide the teenager with sufficient autonomy and independence are particularly important here. A combination of emotional closeness and acceptance with a reasonable amount of freedom is the gold standard to strive for.

Significant risk factors for auto-aggressive behavior are also non-constructive semantic systems, identity disorders and distortions of the worldview, which lead to general maladaptation and create the preconditions for self-destruction [5].

At its core, adolescent self-harm is a result of their socio-psychological maladjustment, which arises from conflicts and dysfunction in their immediate environment, primarily within the family. The main causes and triggers for this behavior include the following [5]:

1. The loss of a loved one, whether it's the breakup of a romantic relationship or the death of a family member. Deep grief and the sense of irreparable loss can result in self-harm as a way to numb the unbearable emotional pain.
2. Chronic fatigue due to colossal academic and other workloads that are inappropriate for their age. At some point, a teenager simply can't cope with the grueling pace and overwhelming demands.
3. Painful blows to pride, humiliation of human dignity, especially in public. A teenager's fragile self-esteem is very vulnerable, and any dismissive or offensive behavior is perceived extremely harshly.
4. Alcohol and drug use, which chemically affect the brain and distort perception of reality, lead to many teenagers losing control of their behavior under the influence of psychoactive substances.
5. Imitating those who have already committed suicide or self-harm, especially if they are public figures or simply authority figures among teenagers. Immature minds are particularly susceptible to such influences.
6. Affective outbursts, uncontrollable bouts of rage, despair, and horror. In a state of intense emotional arousal, the teenager has little awareness of their actions.
7. Deep-rooted inferiority complexes, chronic self-doubt, feelings of worthlessness and uselessness. Sometimes it seems that by humiliating and punishing one-

self, one can atone for the perceived guilt of one's own imperfections.

Non-suicidal self-harm is a complex and multifaceted phenomenon that is of growing concern to mental health professionals. This behavior is characterized by intentional self-inflicted physical injuries without the intent to end one's life. The most common forms of self-harm include cutting, burning, hitting, scratching, hair pulling, and other actions intended to cause pain or harm.

Non-suicidal self-harm is rooted in various factors, with interpersonal issues being a prominent factor. Conflicts with parents, friends, or partners, feelings of rejection, loneliness, or misunderstanding can drive a person to inflict physical pain on themselves as a way to cope with emotional distress.

Negative emotions such as anger, anxiety, sadness, guilt, or shame also play a significant role in the development of self-harming behavior. People experiencing strong and difficult-to-tolerate emotions sometimes resort to self-harm to distract themselves from their emotional pain and achieve short-term relief. Obsessive thoughts of self-harm can constantly haunt a person, prompting them to injure themselves again and again.

It is important to note that the category of non-suicidal self-harm does not include socially acceptable and culturally conditioned practices such as tattoos or piercings. These forms of body modification typically have aesthetic or symbolic purposes and are not associated with the intent to harm oneself. Self-harm also does not include common habits such as nail biting or skin picking, which, while they may cause minor damage, are not intentional. Self-harming behavior should be distinguished from the symptoms of certain mental disorders, such as autism or intellectual disability, in which self-harm may be a manifestation of developmental differences or sensory needs [10].

Adolescence is a period of heightened risk for non-suicidal self-harm. At this age, young people often experience intense emotions, identity conflicts, and difficulties in interpersonal relationships. Self-harm can become a way for them to regulate their emotional state when other coping strategies are unavailable or ineffective.

Some teenagers resort to self-harm to attract the attention of others and gain their support or care. Displaying wounds or scars can be a cry for help and an attempt to communicate in a situation where verbal expression is difficult.

Self-harming behavior in adolescents is sometimes associated with a desire to boost self-esteem by overcoming pain or gaining control over one's body. However, more often, it becomes a source of shame and self-abasement, further exacerbating an already fragile sense of self-worth. Many adolescents carefully conceal the traces of self-harm, fearing condemnation or punishment from adults [15].

Self-harm encompasses a wide range of actions, varying in form, severity, and psychological significance. Overt and easily recognizable acts of self-harm

include cutting, burning, and hitting, which leave visible wounds or scars on the body. Cutting is one of the most common forms, in which a person uses sharp objects (blades, knives, shards of glass) to inflict cuts on the skin. Burns can be caused by hot objects, lighters, or caustic substances. Banging one's fists, head, or other body parts against hard surfaces is another method of self-harm, aimed at causing pain and bruising or abrasions. However, there are also more subtle, less obvious forms, such as scratching the skin, pulling out hair, preventing wound healing, or inserting foreign objects under the skin. These actions can go unnoticed for a long time, making it difficult to provide timely assistance. In severe cases, self-harm results in serious injuries requiring medical intervention: deep cuts to tendons or arteries, extensive burns, bone fractures and other life-threatening consequences [8].

Self-harming behavior can manifest itself in various forms and have various causes and consequences. Some of the most common methods of self-harm include hitting various parts of the body, as well as damaging the skin, such as scratches and cuts. These injuries are typically inflicted parallel to each other, spaced one to two centimeters apart, most commonly on the skin of the thighs and arms. Self-harming behaviors include burns of varying severity, as well as intentional obstruction of the normal healing of wounds and cuts [15].

The connection between the skin, bodily sensations, and the perception of the self was noted by Sigmund Freud [6]. This idea was further developed by the French psychoanalyst Didier Anzieu in his concept of the skin-ego [1]. According to this concept, the skin is considered a boundary separating a person's inner world from the outer world and plays a key role in maintaining the integrity and stability of the ego system.

Research shows that approximately 10% of adolescents resort to self-harm during particularly difficult and stressful periods of their lives. Among girls, the most common forms of self-harm are cutting and scratching, while boys are more likely to use firearms [11].

American psychologists propose to distinguish several main types of self-harming behavior [17]:

1. Self-harm associated with neurotic disorders. This behavior is often a consequence of anxiety, depression, obsessive thoughts, and other neurotic symptoms.
2. Self-harm in psychopathic conditions. In this case, the tendency to self-harm may be due to traits such as impulsiveness, emotional coldness, and an inability to consider the consequences of one's actions.
3. Self-harm in underlying pathologies such as borderline personality disorder, schizophrenia, and bipolar disorder. In these illnesses, self-harm is often a way to cope with overwhelming emotions, internal pain, and feelings of emptiness.
4. Ritual self-harm is a form of self-harm influenced by cultural and religious

factors. For example, some initiation rites, purification rituals, or atonement rituals may include elements of self-harm.

5. Domestic, or household, forms of self-harm. These include self-harm that people inflict on themselves in everyday life, such as scratching, nail biting, and hair pulling.

Menninger theorized that acts of self-harm could be a manifestation of suicidal ideation or a desire to punish oneself while still preserving one's life. This idea was further developed by Armando Favazza and his colleagues, who emphasized the social significance of various types of self-harm [4].

Self-harming behavior can be divided into two main categories [3]. The first category includes actions motivated by a person's religious views and beliefs. The second category encompasses stereotypical, repetitive patterns of self-harm, which are often associated with certain mental disorders.

When considering self-harm in a socio-cultural context, we can distinguish such varieties as rituals of transition into adulthood, accepted in some communities, as well as self-harm committed under the influence of modern subcultural tendencies and trends.

Self-harm is divided into three groups based on the degree of negative impact on the body. Significant self-harm is a rare but serious and spontaneous act that requires medical intervention. Standard self-harm is a systematic act without any apparent ideological motive, often associated with certain mental disorders. Superficial self-harm is minor damage to the skin, such as scratches or shallow cuts.

Compulsive self-harm is typically committed to relieve psychological stress and anxiety [1]. A person may experience an overwhelming desire to inflict pain on themselves in order to temporarily relieve distressing emotions and experiences.

When studying self-injurious behavior in children with intellectual disabilities, researchers identify five main types of such behavior [3]. Extreme self-injurious behavior is characterized by the infliction of serious injuries and can pose a threat to the child's life. Stereotyped behavior manifests itself in the monotonous repetition of the same self-injurious actions. Self-injury accompanied by arousal occurs against a background of increased emotional and motor activity. Self-injury with multiple topography affects different parts of the child's body. There is also self-injurious behavior in which the child injures themselves in a single area of the body.

Mental health professionals regularly encounter self-harming behavior in their patients. The nature and causes of such actions can vary significantly depending on the underlying mental disorder the individual suffers from. Therefore, effective assistance for people prone to self-harm requires a comprehensive approach tailored to the individual circumstances of each case.

Non-suicidal self-injury (NSSI) remains a complex and controversial phenomenon, raising numerous questions among researchers and practitioners. Although NSSI is often associated with mental disorders, research shows that a significant proportion of individuals who engage in self-injury lack obvious signs of psychopathology [17]. This observation challenges traditional understandings of the nature and causes of NSSI, necessitating a deeper understanding of the psychological and social factors underlying this behavior.

Adolescence is a particularly vulnerable period for the development of self-destructive tendencies. During this time, young people face numerous stressors and challenges related to physical changes, identity development, social pressures, and family conflicts. For some adolescents experiencing difficulties with emotion regulation, NSSI can become a maladaptive coping strategy, allowing them to reduce the intensity of negative experiences or punish themselves for perceived shortcomings [12]. However, although NSSI may provide temporary relief, in the long term it only exacerbates emotional problems and hinders the development of healthy coping mechanisms.

A significant factor mediating the link between emotional dysregulation and NSSI is a person's relationship to their own body. Research shows that individuals who self-harm tend to devalue and reject their bodies, viewing them as objects for expressing internal distress [16]. This detachment from the body may be the result of traumatic experiences, attachment disorders, or the internalization of negative social attitudes. As a result, the physical pain of self-harm is perceived as a deserved punishment or a way to feel something in a state of emotional numbness.

Defining NSSI as intentional injury to bodily tissue without suicidal intent highlights a key difference between this behavior and suicide attempts. While suicide aims to end life, NSSI serves to regulate overwhelming emotions and is typically not associated with a desire to die. Nevertheless, NSSI is a significant risk factor for subsequent suicidal thoughts and actions, especially in the absence of timely assistance and support.

Family factors play a significant role in the development of self-harm in adolescents. Some studies indicate an increased risk of NSSI in middle-born children from disadvantaged families [3], although this finding remains controversial and requires further study.

A negative family environment characterized by conflict, violence, neglect, or excessive demands creates the basis for emotional disturbances and self-destructive behavior in children. A lack of secure attachment, empathy, and emotional regulation skills in the family hinders the development of adaptive coping strategies in adolescents.

An analysis of the psychological characteristics of adolescents with NSSI reveals a significant link between self-concept and a tendency toward self-destruc-

tive behavior. Young people who engage in self-harm often exhibit a negative self-image, lack of self-confidence, heightened anxiety, emotional immaturity, and sensitivity to criticism [14]. They tend to devalue their achievements, exaggerate their shortcomings, and experience a profound sense of inadequacy. This negative self-concept fuels self-punishing behavior and hinders the search for constructive solutions to problems.

Adolescent girls with NSSI represent a particularly vulnerable group, characterized by negative self-esteem, high levels of self-criticism, and a tendency to experience rejection [13, 18, 19]. They are characterized by intense feelings of self-hatred, significantly exceeding those of their peers who do not engage in self-harm. This self-hatred is often rooted in traumatic experiences, dysfunctional family relationships, and the internalization of gender stereotypes that place inflated demands on girls' appearance, success, and social acceptance.

Thus, recognizing the role of emotional dysregulation, negative body image, and self-concept in the development of self-harming behavior opens up opportunities for the development of effective preventive and therapeutic interventions.

References

1. Anzio, D.I-skin [Text] / D. Anzieu. - Izhevsk: ERGO, 2021. – 302 p.

2. Bratus, B.S. Personality anomalies [Text] / B.S. Bratus. – M.: AST, 2019. – 301 p.

3. Gorbatov, S.V. Features of the self-concept of adolescent girls with non-suicidal self-harmful behavior [Text] / S.V. Gorbatova, E.N. Arbuzova, A.V. Shaboltas, V.V. Gorbacheva // Suicidology. - 2020. - No. 1 (38). - P. 53-69.

4. Polskaya, N.A. Phenomenology and functions of self-harming behavior in normal and impaired mental development: Abstract of a Doctor of Psychology dissertation. [Text] / N.A. Polskaya. - M., 2019. - 432 p.

5. Weinhold B. Liberation from codependency. [Text] / B. Weinhold, J. Weinhold - M.: Class, 2006 – 255 p.

6. Freud, Z. Introduction to Psychoanalysis [Text] / Z. Freud. – M.: Azbuka, 2024. – 448 p.

7. Khukhlaeva, O.V. How to Maintain a Teenager's Psychological Health? [Text] / O.V. Khukhlaeva. – M.: "September", 2023. – 176 p.

8. Shorokhova, O.A Life's Traps of Dependence and Codependency [Text] / O.A. Shorokhova. - St. Petersburg: Rech, 2022. - 136 p.

9. Erickson, E. Childhood and Society [Text] / E. Erikson. – St. Petersburg: Piter, 2021. – 366 p.

10.American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. [Text] - Arlington, VA, American Psychiatric Association. – 2023. – Vol.13. - R. 803–806.

11.Carroll, J. Family experiences of self-mutilating patients. [Text] / J. Carroll // The American journal of psychiatry. – 2019. - Vol.137 (7). – P. 852–853.

12.Chapman, ALSolving the puzzle of deliberate self-harm: The experiential avoidance model. [Text] / AL Chapman // Behavior research and therapy. – 2018. - Vol.44 (3). – P. 371-394.

13.Glassman, L.H.Child maltreatment, non-suicidal self-injury, and the mediating role of self-criticism. [Text] / LH Glassman // Behavior research and therapy. – 2017. - Vol.45 (10). – P. 2483-2490.

14.Hooley, J.M.Pain perception and nonsuicidal self-injury: a laboratory investigation. [Text] / JM Hooley // Personality Disorders: Theory, Research, and Treatment. – 2020. - Vol.1 (3). – P. 170-179.

15.Klonsky, EDThe functions of deliberate self-injury: A review of the evidence. [Text] / ED Klonsky // Clinical Psychology Review. – 2018. - Vol.27. – P. 226-239.

16.Muehlenkamp, J.J. Body regard as a moderator of the relation between emotion dysregulation and nonsuicidal self-injury. [Text] / JJ Muehlenkamp // Suicide and LifeThreatening Behavior. – 2018. - Vol.43 (5). – P. 479-493.

17.Nock, M.K. Disorders of impulse-control and self-harm. [Text] / MK Nock - New York, NY: Oxford University Press, 2019. – 529 p.

18.Nock, M.K. Prevalence of and risk factors for suicide attempts versus suicide gestures: Analysis of the National Comorbidity Survey. [Text] / MK Nock // Journal of Abnormal Psychology. – 2021. - Vol.115 (3). – P. 616-623.

19.Whitlock, B.K. Heritable bovine fetal abnormalities. [Text] / BK Whitlock // Theriogenology. – 2020. – Vol.70. – P. 535–549.

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老龄化的心理情感生态学：当代挑战与环境压力因素
PSYCHO-EMOTIONAL ECOLOGY OF AGING: CONTEMPORARY CHALLENGES AND ENVIRONMENTAL STRESSORS

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摘要：本文探讨了在快速的社会文化、技术和城市转型背景下，影响老年人心理情感生态的当代问题。心理情感生态的概念被定义为一个由外部环境、社会和信息因素构成的系统，这些因素共同塑造着老年人的情绪健康、认知平衡和主观舒适度（1,5）。本文基于对国际老年学、心理学和社会学研究的分析，探讨了不断变化的感官环境、日常生活美学、沟通数字化、社会关系碎片化以及传统价值体系的衰落如何影响老年人的情绪调节、身份认同的延续性和心理韧性（2,5,6）。本文特别关注老年人的情感记忆与年轻一代所处的快速变化的信息和视觉环境之间的不匹配。这种不匹配会导致认知失调、情绪耗竭和持续的疏离感，进而损害心理稳定性（5,7）。本文认为，融合环境心理学、感官人类学和老年学的生态老龄化方法能够帮助我们从多维度理解老年人面临的挑战。结论部分提出了一系列旨在为老年人创造情感支持环境、加强代际沟通以及减轻其心理情感压力的理论和实践措施（1,2）。

关键词：老年人，心理情感生态学，情感健康，环境心理学，老龄化，感官环境，认知失调，代际沟通。

Abstract. *The article examines contemporary problems affecting the psycho-emotional ecology of elderly people in the context of rapid sociocultural, technological and urban transformations. The notion of psycho-emotional ecology is conceptualized as a system of external environmental, social and informational factors shaping the emotional well-being, cognitive balance and subjective comfort of individuals of advanced age (1,5). Based on the analysis of international gerontological, psychological and sociological studies, the article explores how changing sensory environments, aesthetics of everyday life, digitalization of communication, fragmentation of social ties and the decline of traditional value frameworks influence emotional regulation, identity continuity and resilience among older adults (2,5,6). Special attention is paid to the mismatch between the emotional memory of the elderly and the rapidly shifting informational and*

visual environment inhabited by younger generations. This mismatch produces cognitive dissonance, emotional exhaustion, and a persistent sense of alienation, which in turn undermines psychological stability (5,7). The paper argues that the ecological approach to aging, incorporating environmental psychology, sensory anthropology, and gerontology, allows for a multidimensional understanding of the challenges experienced by older people. The conclusion proposes a set of theoretical and practical measures aimed at creating emotionally supportive environments, enhancing intergenerational communication, and reducing psycho-emotional stressors for elderly populations (1,2).

Keywords: *elderly people, psycho-emotional ecology, emotional well-being, environmental psychology, aging, sensory environment, cognitive dissonance, intergenerational communication.*

Introduction

The twenty-first century is marked by unprecedented speed of social, technological, and cultural transformation (5,6). These changes create new formats of communication, alter urban spaces, modify aesthetic norms, and shape new value systems—primarily through digital platforms (1,2). While younger generations adapt to such changes naturally due to neuroplasticity, high cognitive flexibility, and socialization in digital culture (5,6), older adults experience these shifts differently. Aging is associated with physiological, cognitive, and emotional changes which inevitably modify the perception of novelty, the ability to process large volumes of information, and the capacity for rapid adaptation (5). Therefore, the emotional life of elderly individuals becomes especially sensitive to the ecology of their environment: the quality of visual and auditory stimuli, the rhythm of social interactions, the content of information flows, and the structure of interpersonal communication (1,2,5).

This sensitivity raises an important scientific question: How do contemporary environments influence the psycho-emotional well-being of elderly people? In the age of digital acceleration, attention fragmentation, declining sensory quality, and socially mediated norms of "youth-centeredness," this question becomes central for psychology, gerontology, anthropology, sociology, and public health (5,6,7).

The term *psycho-emotional ecology*, used here as a central conceptual tool, refers not to environmental ecology in the classical sense but to the ecology of experiences—the composition, intensity, and quality of stimuli influencing emotional stability (1,5). In this paper, psycho-emotional ecology is understood as a dynamic system of relationships between an individual and their multi-layered environment: sensory, aesthetic, social, informational, and communicative (1,2,5,6).

The article examines:

1. The transformation of sensory and aesthetic environments and their effects on elderly emotional well-being (1,2).
2. The role of digitalization and information overload in shaping emotional fatigue (5,6,7).
3. Intergenerational gaps created by differing cultural codes and communication styles (5,6).
4. Emotional memory as a stabilizing mechanism and source of vulnerability (5,7).
5. Strategies for strengthening psycho-emotional resilience in elderly individuals (5,6).

The relevance of this topic is emphasized by demographic trends: the global population is aging, longevity is increasing, and the proportion of people aged over 65 continues to grow (6). According to the World Health Organization, emotional well-being in older age is a key determinant of healthy aging (6). Yet emotional well-being cannot be considered in isolation from the environment. The ecology of feelings - their rhythm, quality, and intensity - turns into a decisive factor for the mental health of the elderly (1,2,5).

The article does not aim to provide quantitative data but offers a theoretical and analytical framework combining interdisciplinary scientific developments with conceptual synthesis (5,6). This approach makes it possible to reveal the complexity of the problem and outline promising directions for further research.

Materials and Methods

This work is conceptual and theoretical. Its methodology is based on an interdisciplinary synthesis of:

- Gerontology, with emphasis on psychosocial models of aging (5,6,7)
- Environmental psychology, focused on the influence of physical and informational environments (1,5,6)
- Cultural anthropology, including sensory anthropology and the study of aesthetic environments (1,2)
- Sociology of aging, exploring changing social roles and intergenerational dynamics (5,6)
- Cognitive psychology, particularly research on emotional memory, cognitive load, and attention in older adults (5,7)

The research was conducted through:

1. Content analysis of studies published between 2015 and 2024 on environmental stressors, emotional aging, and digital communication (5,6).
2. Comparative analysis of different scholarly approaches to aging and emotional well-being (1,2,5).
3. Theoretical modeling of psycho-emotional ecology as a multidimensional construct (1,5).

Primary sources included works by international organizations (WHO, UN DESA) (6), academic research on aging (5,7), studies on digital cultures (5), and anthropological literature on sensory environments (1,2).

Results

1. Sensory and aesthetic degradation of everyday environments Contemporary visual and auditory environments have become noisier, brighter, more fragmented, and less harmonious (1,2,5). Urban landscapes prioritize functionality over aesthetic integrity; commercial design often values aggressive attention-grabbing strategies over emotional comfort (1,2). Advertisements, digital screens, transportation noise, and rapid shifts of visual stimuli generate a constant background of irritation (5,6).

For elderly individuals, this sensory overload is problematic because:

- Emotional regulation becomes more vulnerable with age (5,7).
- The threshold of sensory tolerance decreases (5).
- Harmonious environments play a stronger stabilizing role (1,2).
- Visual and auditory noise increases anxiety and fatigue (5,6).

The decline of aesthetic consistency in public spaces creates a sense of emotional discomfort and "loss of home," as the environment stops reflecting familiar cultural codes (1,2,5).

2. Digitalization as a source of emotional overload

Digital environments reshape communication, but not always in ways beneficial to the elderly (5,6). Social networks impose:

- rapid switching between content types (5)
- constant exposure to emotionally charged stimuli (5,7)
- normative pressure to "stay updated" (6)
- new rules of social visibility and self-presentation (6)

Older adults often perceive digital communication as:

- overly fast (5,7)
- emotionally superficial (5)
- lacking depth (5,6)
- filled with chaotic information (5,7)

This leads to emotional exhaustion and feelings of exclusion (5,6). The digital world appears foreign, and emotional connection is undermined by the lack of stable, direct communication (5,7).

3. Emotional memory and identity continuity

Emotional memory becomes especially important with age (5,7). It organizes experiences and provides continuity of identity. Yet rapid cultural changes disrupt this continuity (5,6).

When the present differs drastically from emotionally significant past experiences:

- the emotional system loses stability (5)
- internal conflict emerges (5,7)
- a sense of disorientation arises (6)

The elderly may feel that their emotional "language" is no longer recognized, understood, or valued (5,7).

4. Intergenerational cognitive and emotional gaps

Younger generations live in an environment shaped by:

- speed (5)
- novelty (6)
- multitasking (5)
- aesthetic fragmentation (2,5)
- short-lived emotional content (5,6)

Older people live in an emotional framework shaped by:

- stability (5,7)
- continuity (5)
- deep personal relationships (3,5)
- meaningful communication (3,5)

The collision between these frameworks generates:

- cognitive dissonance (5,7)
- miscommunication (5,6)
- emotional distancing (5,7)
- loss of intergenerational solidarity (3,5)

Many elderly individuals interpret rapid social changes as a threat to identity or devaluation of accumulated life experience (5,6,7).

5. Emotional alienation and loss of "place attachment"

Environmental psychology shows that attachment to place is crucial for emotional well-being (2,5). When the environment changes rapidly—visually, socially, or symbolically—older adults may experience:

- alienation
- loss of belonging
- increased anxiety
- emotional withdrawal

This phenomenon becomes one of the core problems of psycho-emotional ecology (1, 6).

Discussion

1. Why the elderly are especially vulnerable

Aging changes the emotional system. Studies show:

- increasing reliance on familiar stimuli (5, 6)
- decreased tolerance to chaotic sensory input (2)
- preference for emotional stability (6)
- reduced capacity for rapid cognitive adaptation (5, 7)

Thus, the modern environment a combination of digital acceleration, aesthetic fragmentation, and social instability—directly contradicts the emotional needs of elderly people (1, 5).

2. The role of social narratives

Contemporary culture increasingly promotes:

- youthfulness as an ideal (5, 6)
- flexibility as a social norm (6)
- constant novelty as a sign of relevance (5)

These narratives marginalize the lived experiences of older adults and produce structural emotional inequality (1, 6).

3. Why psycho-emotional ecology matters

The ecological model assumes that emotional well-being depends not only on internal resilience but also on:

- the quality of sensory environments (2, 5)
- emotional culture of society (1, 3)
- design of public spaces (1, 5)
- communication practices (5, 6)
- informational hygiene (5, 7)

Thus, emotional comfort becomes a socio-ecological issue, not purely a psychological one (1, 2, 5).

Conclusion

The ecology of elderly people's psycho-emotional sphere is a complex interdisciplinary problem shaped by sensory, social, informational and cultural environments (1, 2, 5, 6). Rapid societal changes destabilize emotional memory, undermine identity continuity, and create environments in which the emotional needs of older adults remain unmet (1, 5, 6).

The key solutions include:

1. Designing emotionally supportive environments
- calm sensory landscapes (2, 5)
- aesthetic consistency in public spaces (1, 5)
- accessible, clear, emotionally safe communication environments (5, 6)

2. Rebuilding intergenerational dialogue
- shared cultural codes (1, 3)
- respectful communication (5, 6)
- recognition of emotional differences (1, 5)

3. Supporting emotional memory
- creating spaces preserving cultural continuity (1, 6)
- including older adults in community life (2, 5)

4. Reducing informational overload
- clear interfaces (5, 7)

- emotionally neutral digital environments (6, 7)
- less intrusive communication formats (5, 6)

The ecological approach allows us to understand aging as a dialogue between an individual and the world — a dialogue that can either support emotional resilience or undermine it (1, 5, 6, 7). Modern society must consider the emotional needs of older adults not as marginal, but as central to building humane, psychologically stable and socially cohesive environments (1, 2, 5).

References

1. Kadyrova, V. Kh. (2012). Psychological features of the emotional sphere of elderly people. Concept, (7), 46–50.

2. Malykhin, F. T. (2011). Quality of life determined by the state of health of persons of advanced and senile age: A literature review. Qualitative Clinical Practice, (1), 11–18.

3. Narutto, S. V. (2017). Family as a constitutional value. Actual Problems of Russian Law, 5(78), 21–30.

4. Tkach, T. V. (2017). Neuropsychology and neuro-law: Prospects of interdisciplinary studies. Criminal Executive System: Yesterday, Today, Tomorrow, 1, 130–143.

5. Park, D. C., & Reuter-Lorenz, P. (2009). The adaptive brain: Aging and neurocognitive scaffolding. Annual Review of Psychology, 60, 173–196.

6. Carstensen, L. L. (2006). The influence of a sense of time on human development. Science, 312(5782), 1913–1915.

7. Fiske, A., Wetherell, J. L., & Gatz, M. (2009). Depression in older adults. Annual Review of Clinical Psychology, 5, 363–389.

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摘要：本文以萨马拉州新库伊比雪夫斯克中心市立医院（一家公立医疗机构）为例，探讨了在综合性城市医院建立心脏病学培训班的经验。该心脏病学培训班主要面向两个方面：一是循环系统疾病患者，二是循环系统疾病领域的医务人员。

关键词：循环系统疾病，心脏病学培训班，综合性城市医院。

Abstract. *This article examines the experience of establishing a cardiology school at a consolidated city hospital, using the Novokuibyshevsk Central City Hospital, a state-funded healthcare institution in the Samara Region, as an example. The cardiology school operates in two main areas: for patients with circulatory diseases and for medical personnel working with circulatory diseases.*

Keywords: *circulatory diseases, cardiology school, consolidated city hospital.*

The main structural unit of the city hospital's cardiology service for providing primary specialized medical care to patients with circulatory diseases (CD) is the cardiology office, headed by a cardiologist.

As part of improving the organization of outpatient medical care for patients with CD, the City Hospital's Cardiology School (SCS) was established within the cardiology office, working with other departments of the medical organization (the

Department of Medical Prevention and the Software Department) to functionally improve the organization of medical care for patients with CD.

The City Hospital's Cardiology School operates in two main areas:

1. A school for patients with circulatory diseases (CSD), which addresses the needs of adult patients in areas of prevention, diagnosis, treatment, and rehabilitation.

2. A school for medical personnel on CSD issues related to organizational, clinical, expert, and other issues related to providing medical care to patients with CSD.

The development of this second area of the Cardiology School's activities is no coincidence, given the significant prevalence of this pathology, the lack of resources for the cardiology service, and the significant volume of new information on various aspects of CSD.

Both areas of the City Hospital's Cardiology School are supported not only by developed organizational measures but also by appropriate information software.

1. The CSD Patient School is a preventative-focused organizational technology necessary for raising patient awareness of CSD issues to improve the effectiveness of treatment and preventive measures and enhance quality of life. The development of a school for patients with cardiovascular diseases involves a number of medical and organizational measures:

1. Formation of the target audience (ensured by referrals to the School by a cardiologist, a local general practitioner, or other specialist physicians). The target audience includes the following categories: a group of patients with circulatory diseases; a group of patients with risk factors for developing circulatory diseases in small groups (up to 10 people); individual patients during online classes.

2. Training facilities and resources (determined by the specific topic and format of the class). These include: an outpatient department of a city hospital; a room equipped for the target audience with office equipment; demonstration educational materials (audio, video files, presentations); an information platform for distance learning.

3. School lecturers (receive pedagogical and psychological training in effective communication with patients). They may include: healthcare workers (doctor, nurse) from the preventive medical department; a cardiologist; a local general practitioner; an endocrinologist; Neurologist; other specialists.

4. Schedule of classes (determined by the target group and the format of the class). A training plan is developed; with group classes, classes are held 1-2 times a week at a convenient time; the training cycle consists of 4-6 classes lasting up to 60 minutes; individual online training is possible.

5. Development of a training program (conducted taking into account the target audience and the format of the classes). This ensures: availability of informational

material; active learning (answering questions, teaching practical skills, familiarization with reference material, etc.); maintaining a favorable emotional environment; clear, unambiguous presentation of material; avoiding patient fatigue from information.

6. Ensuring effective work. For a medical organization, this means saving resources and reaching a wider range of patients; for patients, this means acquiring new knowledge and skills from medical staff and patients themselves, as well as receiving psychological support from both medical staff and patients themselves.

An important aspect of the CVS patient school's activities is developing its target audience, which is ensured by referrals to the school by cardiologists, general practitioners, and other specialist physicians. Patients with specific medical conditions as well as those with risk factors for developing cardiovascular disease can be referred. The schedule for conducting classes is largely determined by the target group itself, as well as the format of the class—in-person group classes or individual classes, with consideration given to distance learning technologies and the use of an information program.

The school's lecturers, drawn from among the city hospital's medical staff, have the appropriate pedagogical and psychological skills to communicate with patients during training. The schedule for conducting classes is determined by both the target group and the format. In-person training typically consists of a series of classes, according to a pre-planned schedule agreed upon with patients, at a time convenient for them, with the expectation that they will not miss a class.

The curriculum for the training course is also developed taking into account the target audience and the format of the classes. Classes are structured to include informational content and active forms within the hourly schedule. The creation of a school for patients with circulatory diseases ensures effectiveness both for the medical organization by conserving resources and for patients by acquiring new knowledge in a psychologically comfortable environment.

The curriculum for the School for Patients with Circulatory Diseases includes topics related to risk factors for these diseases, including arterial hypertension, hypercholesterolemia and dyslipidemia, nutrition, bad habits, physical activity, psychoemotional factors, and specific medical conditions.

Training at the school reduces patient anxiety, helps them better tolerate pain and stress, accelerates recovery, and reduces the duration of treatment. This training helps plan preventive, diagnostic, and therapeutic measures in outpatient and inpatient settings, reduce wait times for medical care, etc.

Classes at the circulatory system patient school are recorded in the "Journal of Medical and Preventive Institution Activities for Medical Prevention." Accordingly, a "Patient Receipt for Outpatient Medical Care" is completed for

each participant, and information about the class is also recorded in the “Medical Record of a Patient Receiving Outpatient Medical Care” form.

Recent experience has shown that many patients prefer distance learning with individualized instruction over in-person classes at the patient school. To support these classes and expand the capabilities of the circulatory system patient school, a computer program, “Cybervascular Diseases School Management Program,” was developed. This software product, developed by the city hospital, allows patients to create a personal account in the circulatory system patient school and take advantage of individualized learning opportunities.

Thanks to a built-in information platform for distance learning, the program offers the same capabilities as in-person participation in a school for patients with circulatory diseases. This includes familiarization with the school’s programs, a question-and-answer mode, monitoring of blood pressure and cholesterol levels, questionnaire testing, and receiving personalized medical recommendations for treatment and preventive measures, including those using a neural network.

The program for managing the school for patients with circulatory diseases allows access to the electronic registry of the city hospital’s outpatient department, allowing for scheduling doctor’s appointments.

2. School of Medical Personnel for Diseases of the Circulatory System. In accordance with federal regulatory requirements, the city hospital plans and directs medical personnel for advanced training, including through continuing medical education programs and professional retraining at medical educational institutions.

However, the existing personnel training system needs to be refined to better meet the requirements of practical work, taking into account specific factors. Given the growing volume of medical information, the advent of new technologies, and the relatively infrequent professional development of specialists, knowledge quickly becomes outdated.

To improve the quality of continuous medical training for staff on circulatory diseases, we have established a School of Medical Personnel on Circulatory Diseases within the City Hospital’s School of Cardiology.

The development of a school of medical personnel on circulatory diseases involves a number of medical and organizational activities:

1) The formation of a contingent of medical personnel to be trained (target audience) is ensured by referral to the School by a cardiologist (head of the hospital’s cardiology service), as well as by request from employees interested in gaining knowledge. These contingents include doctors of various specialties, nursing staff of various specialties, and junior medical staff. Classes are held in small groups (up to 3-5 people); individual lessons (online mode) are also possible.

2) The training facilities and resources (determined by the specific topic and format of the lesson). These include: an outpatient department of a city hospital; an inpatient department of a city hospital; a room equipped for the target audience with office equipment; demonstration training materials (audio, video files, presentations); standard operating procedures; simulation mannequins and phantoms for practicing practical skills, including cardiopulmonary resuscitation, invasive interventions, and nursing procedures; an information platform for distance learning.

3) Formation of a training contingent (leading, experienced specialists from various fields). The contingent includes: a healthcare organizer, a cardiologist, a clinical pharmacologist, a resuscitator, a surgeon, an epidemiologist, a psychologist, a lawyer, and a head nurse.

4) Schedule of classes (determined by the target group and the format of the class). A training plan is developed; with group classes, classes are held 1-2 times a week; the training cycle consists of 4-6 classes lasting up to 45 minutes; individual training is primarily used online.

5) Development of a training program (conducted taking into account the target audience and the format of the classes). This ensures: availability of informational material; active forms of learning (answering questions, teaching practical skills, familiarization with reference material, etc.); maintaining a favorable emotional environment; use of distance technologies.

6) Ensuring the effectiveness of the work is determined by resource conservation; wide coverage of contingents of healthcare workers; acquisition of new knowledge and competencies.

The formation of a contingent of medical personnel to be trained (the target audience) is ensured by referrals to the School by both cardiologists (heads of the hospital's cardiology service) and by training city hospital employees interested in gaining knowledge on current issues related to circulatory diseases. Trainees can include not only physicians of various specialties, but also nursing staff of various specialties, junior medical personnel, and other personnel.

The School's training resources and training methods are determined by the specific topic and format of the lesson. These can be conducted in person, but are primarily conducted using a distance learning platform. The training contingent is comprised of the most experienced leading specialists in various fields related to circulatory diseases (clinical, organizational, expert, legal, psychological, nursing, and other aspects).

The schedule of lessons and the development of programs are determined based on the target group and the format of the lesson. The effectiveness of the School is determined by resource conservation, significant outreach to healthcare professionals, and the acquisition of new knowledge and competencies. The city

hospital has developed and implemented a specially designed computer program, "Program for Managing a School of Medical Professionals on Circulatory Diseases," which consists of the following elements: 1) registering medical professionals for training; 2) monitoring results through testing; 3) notifying medical professionals about the availability of new materials; 4) creating an individualized training plan for doctors and nurses of various specialties. Using a neural network, the program provides the ability to create an individualized educational trajectory for specific medical professionals on circulatory diseases.

"The Program for Managing a School of Medical Professionals on Circulatory Diseases" includes an information platform for training various categories of medical professionals. Medical professionals, including doctors, mid-level and junior medical personnel, undergo training according to a schedule. Contingents of trainees can also be formed upon their request, as well as to familiarize themselves with new regulations, the results of internal audits and audits by higher-level organizations, and to analyze the performance of the hospital's cardiology service.

The program's remote platform is loaded with materials related to circulatory diseases, such as "Algorithms for Emergency Medical Care for Cardiovascular Diseases," "Clinical Guidelines," "Drug Safety," "Standard Operating Procedures for Circulatory Diseases," "Standards and Procedures for Providing Medical Care," "Patient Care and Nursing Procedures," and others.

Training materials are presented in a variety of files: audio, video, images, presentations, and text. A training course is launched for healthcare professionals with the option to enroll specific groups of students, and testing is conducted to monitor their progress.

The remote platform provides extensive reporting capabilities on various aspects of the educational process, including assignments, materials, users, tests, etc. The implementation of automated processes, such as reminders to students of upcoming events, automatic test checking, and report generation, significantly optimizes the organizational and economic costs associated with in-person training.

Thus, the newly created school of cardiology services at the United City Hospital operates in two main areas: for patients with circulatory diseases and for medical personnel dealing with circulatory diseases.

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生态民族植物学–医学材料：巴德赫兹植物群中用于土库曼斯坦纳德医学的药用植物

ECO-ETHNO-BOTANY-MEDICAL MATERIALS MEDICINAL PLANTS OF THE BADHYZ FLORA USED IN TURKMEN NARD MEDICINE

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摘要：巴德赫兹高地位于土库曼斯坦东南边缘，拥有独特的植被覆盖。目前，这里记录到约1100种高等植物，其中696种分布在巴德赫兹自然保护区内。巴德赫兹高地约有75种特有植物，其中至少60种分布在土库曼斯坦境内，超过一半位于保护区内。

目前，巴德赫兹植物区系中600多种药用植物被用于民间医学，治疗各种疾病。

关键词：自然资源，巴德赫兹，特有种，土库曼斯坦民间医学，煎剂，浸剂。

Abstract. *The Badhyz upland with its characteristic vegetation cover occupies the southeastern edge of Turkmenistan. Currently, about 1,100 species of higher plants are recorded here, 696 of which occur in the boundaries of the Badhyz Nature Reserve. Approximately 75 endemic species grow on the Badhyz upland, at least 60 of them are on the territory belonging to Turkmenistan and more than half are in the reserve.*

At present over 600 species of medicinal plants of the Badhyz flora are used in folk medicine for the treatment of various diseases.

Keywords: *natural resources, Badhyz, endemic species, Turkmen folk medicine, decoctions, infusions.*

Relevance. The Badhyz upland with its unique vegetation cover lies in the southeastern part of Turkmenistan. Currently, about 1,100 species of higher plants are known here, 696 of which occur in the nature reserve. Around 75 endemic species are found in Badhyz, with at least 60 within Turkmenistan's borders and more than half are in the reserve [1; 2]. Presently, more than 600 medicinal plant species

from the Badhyz flora are used in folk medicine to treat various diseases. The total area of the Badhyz State Nature Reserve located in the extreme southeast of Turkmenistan and the northwestern part of the Badhyz upland, is 144,000 hectares.

Objective. To study the bioecological characteristics and medico-ethnobotanical aspects of certain medicinal plants, according to the generally accepted methodology, determine their natural reserves in the Badhyz State Nature Reserve and adjacent territories.

Materials and Methods. During field expeditions organized in the Badhyz State Nature Reserve and adjacent territories in 2020–2025, the bioecological characteristics of several medicinal plants were studied and their natural resources were assessed according to the standard methodology [4]. Information on their use in folk medicine was obtained through oral sociological surveys of the local population. Below is information about medicinal plants studied by the authors based on their own observations.

Results.

Arum jacquemontii Blume – a perennial herbaceous plant of the Araceae family, 30–50 cm tall. It blooms and bears fruit in April–June. It grows at an altitude of 600-1200 m above sea level. The plant is found on the northern slope of the Gyazgedik ridge. Arum Jacmonta is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, arum Zhakmont is used for kidney stones, high acidity, colic, liver and bile diseases, hemorrhoids. In addition, an ointment made from tuber powder and chicken fat is rubbed on pain points for rheumatism.

Ornithogalum arianum Lipsky ex Vved. – a perennial herb of the Iridaceae family, 10–25 cm tall. It blooms and bears fruit in April-June. It grows at an altitude of 250-1200 m above sea level. The plant is found in Serhetabad, Childukhtar. The Aryan bird shrub is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, Aryan bird berry is used for joint pain, osteochondrosis, sciatica, gout, as a wound healing agent, for abscesses, bruises, sprains, headaches, warts, boils, flu, accompanied by cough. Its bulbs are used for colds and heart failure; its leaves are used for diseases of the digestive tract.

Halopeplis pygmaea (Pall.) Bunge ex Ung.-Sternb. – an annual herb of the Chenopodiaceae family, 10–20 cm tall. It blooms and bears fruit in July and October. It grows at an altitude of 50-150 m above sea level. The plant is found in Yerolanduz. Low-growing cowberry is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, decoctions and water-alcohol infusions of the green part of the undergrowth are used in the treatment and prevention of diseases of the cardiovascular and nervous systems. In addition, the plant is used to improve the functioning of the heart and increase vascular permeability.

Asparagus persicus Baker – a perennial herb of the Asparagaceae family, 50-100 tall. It blooms and bears fruit in April and July. It grows at an altitude of 400-1200 m above sea level. The plant is found in Yerolanduz, Nardivanli, Giazgedik. Persian asparagus is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, decoctions of Persian asparagus root are used for bladder inflammation, difficulty urinating, rheumatism and cardiovascular diseases [2].

The highest gulyavnik (Sisymbrium altissimum L.) - is an annual herbaceous plant of the Cruciferous family (Brassicaceae), 30-80 cm tall. It blooms and bears fruit in April-June. It grows at an altitude of 400-800 m above sea level. The plant is found in Serhetabad, Ellibir, Kepel, Pynhancheshma. The highest gulyavnik is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, the herb of the highest gulyavnik is used as an anti-scurvy, hemostatic, antipyretic, and wound healing agent. The seeds of the plant are used for inflammation, asthma, as an expectorant, stimulant, restorative, irritant.

The thick–leaved bedbug (Lepidium crassifolium Waldst. et Kit.) - is a perennial herbaceous plant of the Cruciferous family with a height of 20-30 (40) cm. It blooms and bears fruit in April-July. It grows at an altitude of 400-800 m above sea level. The plant is found in Serhetabad, Childuhtar, Akarcheshma, Pynhancheshma, Nardivanli, Kepel, Kyzyljar. The thick-leaved bedbug is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, decoctions of the thick-leaved bedbug herb are used for sexual impotence and infertility.

The common springfoil (Zygophyllum fabago L.) - is a perennial herbaceous plant of the Springfoil family (Zygophyllaceae), 40-80 cm tall. It blooms in April-June, bears fruit in May-August. It grows at an altitude of 400-1200 m above sea level. The plant is found in Serhetabad, Serhetchi village, Akarcheshma, Pynkhancheshma, Kerlek, Nardivanli, Pulkhatun, Giazgedik. The common springfoil is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, cloven-leaf is used for diseases of the bladder, rheumatism, skin diseases, as an anthelmintic. In addition, decoctions of the roots are used for carbuncles (boils). In traditional medicine, the effectiveness of the plant in the treatment of boils, boils, dermatoses, and chronic eczema has been revealed [2].

Whole–leaved multicolored (Haplophyllum versicolor Fisch. et Mey.) - is a perennial herbaceous plant of the Rutaceae family, 10-20 cm tall. It blooms in April-May, bears fruit in June-July. It grows at an altitude of 400-800 m above sea level. The plant is found in Akarcheshma. Whole-leaved multicolored is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, decoctions of whole-leaved multicolored herb are used for malignant neoplasms of the esophagus.

Ferula szoviciana D.C. - is a perennial herbaceous plant of the Celery family (Apiaceae), 60-80 cm tall. Blooms in April — May, bears fruit in June — July, monocarpic. It grows at an altitude of 400-800 m above sea level. The plant is found in Pulhatun, Zulfigara. Ferula Sovicea is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, the resin of the roots of pherula Sovicha is used for cataracts and bronchitis. In addition, the resin is used for gastrointestinal diseases and asthma.

Smyrnium cordifolium Boiss. (S. androssovii Korov.) - is a perennial herbaceous plant of the celery family with a height of 30-50 cm. It blooms in April and bears fruit in May. It grows at an altitude of 400-800 m above sea level. The plant is found near the Kushka River and the village of Serhetchi, on the Gyazgedik ridge. This is the only habitat of the species in all of Central Asia. It is endemic to Badhyz [1]. Smyrnia cordial is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve. It was listed in the Red Book of Turkmenistan (2024) [3].

In Turkmen folk medicine, herbs and decoctions and infusions of myrrh fruits are used for skin diseases, inflammatory processes, rheumatism, and joint injuries [2].

Monoecious stepping stone (Bryonia monoica Aitch. et Hemsl.) - is a perennial herbaceous plant of the Cucurbitaceae family with a top length of 2-4 m. It blooms and bears fruit in April-June. It grows at an altitude of 400-800 m above sea level. The plant is found in Yarylangala. In April 2024, for the first time, we found and accounted for new habitats of the species in the Nardivanli and Damdam gorges [1]. The monoecious step is one of the rare herbaceous plants. Natural

reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve. It was listed in the Red Book of Turkmenistan (2024) [3].

In Turkmen folk medicine, decoctions, infusions, and syrups of the root of the monoecious herb are used for chronic gout, rheumatism, neuralgia, and joint injuries. The herb is used as a hemostatic agent for uterine bleeding, analgesic, laxative and anthelmintic; fruits are used for rheumatism, fainting, hemorrhoids, headache.

Yarrow of Kerman (Achillea kermanica Gand.) - is a perennial herbaceous plant of the Asteraceae family, 12-25 (30) cm tall. Blooms and bears fruit in April-July. It grows at an altitude of 400-800 m above sea level. The plant is found in Akarcheshma [1]. Yarrow of Kerman is one of the rare herbaceous plants. Natural reserves are insignificant for medicinal purposes. It is recommended to introduce it into the culture. It is protected in the Badhyz State Nature Reserve.

In Turkmen folk medicine, decoctions and infusions of yarrow herb are used for gastrointestinal diseases, tuberculosis, hemorrhoids, malaria, as a hemostatic agent.

Conclusion.

1. Smyrnium cordifolium and Bryonia monoica are included in the Red Data Book of Turkmenistan (2024). It is necessary to monitor the status of their natural populations, study their bioecology both in nature and in cultivation, and search for new habitats.

2. Scientific data on new habitats of Bryonia monoica are reported for the first time. They can be used in future editions of "Flora of Turkmenistan", "Determinant of Plants of Turkmenistan", "Determinant of Plants of Central Asia" and "Red Book of Turkmenistan".

3. Medicinal plants growing in the Badhyz State Nature Reserve and adjacent territories can serve as environmentally pure raw materials for preparing medicines used in the treatment of kidney and urinary tract, heart and vascular, gastrointestinal, liver, gallbladder, skin, and rheumatic diseases. They also have potential applications in modern medicine—particularly in cardiology, urology, dermatology, gastroenterology, oncology, ophthalmology, and pulmonology.

List of references

1. Akmuradov A., Rahmanov O. Kh., Shayymov B. K. Synopsis of Endemic Species of the Flora of Turkmenistan: Results of Work 2007–2017. Kazan: Buk, 2018. – 142 p.

2. Berdimuhamedov, G. M. Medicinal Plants of Turkmenistan. Vol. XVII. Ashgabat: Turkmen State Publishing Service, 2024. – 416 p.

3. The Red Data Book of Turkmenistan. Vol. 1: Plants. 4th revised and expanded edition. Ashgabat: Turkmen State Publishing Service, 2024. – 296 p.

4. Maslyakov V. Yu., Khanumidi E. I., Sorokopudova O. A., et al. Assessment of Medicinal Plant Resources: Experience and Research Approaches. Moscow: FGBNU VILAR, 2024. – 126 p.

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高水平手球运动员年度训练周期比赛期运动心脏功能的形态计量学和血液动力学参数

MORPHOMETRIC AND HEMODYNAMIC PARAMETERS OF THE FUNCTIONING OF THE SPORTS HEART IN THE COMPETITIVE PERIOD OF THE ANNUAL TRAINING CYCLE OF HIGH-QUALIFICATION HANDBALL PLAYERS

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摘要：本文研究了精英手球运动员（俄罗斯超级联赛参赛选手）在年度训练周期比赛期间对不同类型运动负荷的心血管适应情况。研究分析了心脏功能的形态学和血流动力学参数，以及它们与选定的体格测量数据的相关性。在运动员静息状态下，分别于心动周期的不同阶段检测了心脏功能的形态学和血流动力学参数。重点关注反映心脏在长期手球训练中有效耐受不同类型运动负荷能力的参数。

关键词：适应，心肌，二尖瓣血流，心肌重塑，体育活动，精英运动员，各种类型的体育活动，训练阶段。

Abstract. *This article examines the cardiovascular adaptation of elite handball players (participants in the Russian Championship Super League) to various types of workload during the competitive period of the annual training cycle. Morphometric and hemodynamic parameters of cardiac function are examined and analyzed, as well as their correlation with selected anthropometric data. Morphometric and hemodynamic parameters of cardiac function are examined in different phases of the cardiac cycle, while the athletes are at rest. Attention is paid to parameters reflecting the heart's ability to effectively tolerate various types of workload during long-term handball training.*

Keywords*: adaptation, myocardium, transmitral blood flow, myocardial remodeling, physical activity, elite athletes, various types of physical activity, training phase.*

Introduction

Progress in athletic performance is associated with increased volume and intensity of training and competitive loads. It is important to be aware of the signs of overtraining and fatigue in athletes. The latter are accompanied by a disruption of the adaptation process to physical activity of various types [1]. Endurance training leads to autonomic remodeling of the heart rhythm in favor of the cardioprotective properties of the vagus nerve, which affects a decrease in the heart rate with a heart rate of less than 60 beats per minute (bradycardia), and an increase in the influence of the parasympathetic effect on the work of the heart [19]. In our opinion, an important component in determining the level of readiness of athletes for volumetric and intense loads is a comprehensive assessment of the functioning parameters of various body systems, in particular, the cardiovascular system, with a combination of methods that informatively complement each other. Therefore, there is a need to focus not only on heart rate variability indicators, but also, additionally, on the study of morphometric and hemodynamic parameters of the functioning of the heart muscle. According to the opinion of L.A. According to Bokeria (2009), the prognostic significance of heart rate variability increases in combination with other research methods, including ECHO-CG, where special attention is paid to the ejection fraction. We adhere to the opinion of L.A. Bokeria [2], since marker values of overstrain according to ECHO-CG can be diagnosed as a decrease in the ejection fraction and stroke volume, the determination of which requires dynamic monitoring [1]. Therefore, this publication considers the morphometric and hemodynamic indices of myocardial function, taking into account the phases of the cardiac cycle in athletes of team sports (handball), with the aim of determining marker morphometric and hemodynamic systolic-diastolic parameters of the heart with a decrease in heart rate at rest to bradycardia (with a heart rate below 60 beats / min), or with a tendency to develop bradycardia with a decrease in the heart rate below 65 beats / min [16, 17]. Future studies plan to evaluate heart rate variability parameters and conduct a correlation analysis with echocardiography data during the competitive period of the annual training cycle.

The aim of the study is to examine and compare morphometric and hemodynamic parameters of the heart during the competitive period of the annual training cycle of a highly qualified men's handball team competing in the Russian Championship Super League.

Mathematical Statistical Methods. Statistical data processing was performed using the STATISTIKA 8.0 statistical analysis package. Reliability was

calculated using the Kruskal-Wallis ANOVA test. Data are presented as X ± SE. Correlation analysis was conducted to identify relationships between the studied parameters. The reliability of the calculated parameters was assessed at a 5% significance level.

Methodology and Study Organization:

The study involved 19 highly skilled athletes competing for the main team, a regular participant in the Russian Handball Championship Super League (EG – experimental group). The subjects ranged in age from 18 to 32 years. The average age of the handball players was 24.7 ± 5.6 years. The average length of their sports experience ranged from 10 to 20 years. All athletes participating in the experiment were licensed to engage in professional sports in accordance with Russian Federation law.

Several physical development indicators (anthropometric data for athletes in both groups) were studied: body mass index (BMI – kg/m²) and body surface area (BSA, m²) [9]. Morphometric and hemodynamic parameters of the heart were assessed using echocardiography (ECHO-CG) as part of the medical support of the Super League team. The Mindray Z60 diagnostic ultrasound equipment was used. The following parameters of left ventricular (LV) remodeling were measured: left ventricular myocardial mass (LVMM), g; LVM index (LVMI), g/m2, ejection fraction (EF%), stroke volume (SV, ml). Normal LV geometry was considered to be a relative wall thickness (RWT) < 0.42 with normal parameters of LVM less than 115 g/m2 in men and less than 95 g/m2 for women [6,8,9,18].

An additional parameter proposed for assessing LV remodeling is the sphericity index (SI), which has a standard value of 0.6 conventional units [7]. According to the classification of V.S. Alexandrov and A.P. Makhnov (2002), the standard value of the sphericity index is in the range of 0.6-0.7 conventional units. Data within the range of 0.71-1.0 c.u. indicate a moderate increase in IS [11].

To assess the hemodynamic parameters of diastolic and systolic function, the following parameters of transmitral and transaortic blood flow were used: maximum early diastolic filling velocity (Peak E), m/s; maximum filling velocity in atrial systole (Peak A), m/s; the ratio of peaks E and A (E/A) c.u.; LV isovolumic relaxation time (IVRT) in milliseconds (ms); isovolumic contraction time (IVCT); early diastolic filling deceleration time (DT), transmitral diastolic flow ejection time (ET mitr.), transaortic systolic flow ejection time (ET aortic); diastasis time (ms). The parameters indicated in the work correspond to the phases of the cardiac cycle: systole, early and late diastole [12,14]. These parameters were measured at rest at the specified heart rate parameters.

Discussion

The results of the study of individual anthropometric data (BMI and body surface area) and myocardial morphometric parameters in athletes during the fall

and spring phases of the competitive period are presented in Table 1. According to the calculated data, no statistically significant differences were found between athletes at different stages of the competitive period ($p < 0.05$). According to the previously presented values, the myocardial parameters in the athletes tested at different stages of the elite competitive period are related to normal LV geometry, and no significant differences were found between the beginning and end of the competitive period.

Table 1

Physical development parameters and myocardial morphometric parameters (X ± SE)

№	Indicators	Groups of athletes examined	
		EG autumn 2024(n=19)	EG spring 2025 (n=19)
1.	BMI	25,4±2,6	25,6±2,4
2	Body surface area, m²	2,27±0,18	2,27±0,17
3	LVM, g	202,97±41,72	210,3±34,96
4	LVM, g/m²	89,75±15,77	92,42±12,17
5	LV TCS	0,35±0,03	0,35±0,03
6	IS	0,65±0,07	0,65±0,67

Note: * indicates a significant difference from the control group ($p < 0.05$)

Athletes with functional changes characteristic of the athlete's heart can achieve a high level of athletic fitness while maintaining normal LV geometry, assessed in accordance with recommendations for the quantitative assessment of cardiac structure and function (Table 1) [18]. This is confirmed by the results of our previous studies and the results of other studies with a large sample of athletes in various sports [4].

The data in Table 1 show that LVMI and TBW are within the parameters of normal LV geometry. The assessment was performed taking into account body surface area and body mass index [9]. A moderate increase in TBW during the competitive period (taking into account the standard LVMI and TBW values), in our opinion, may be adaptive to various types of stress and form one of the components of the athlete's heart, if we focus on the standard value of 0.6 conventional units, according to research [7]. However, according to research by V.S. Alexandrov and A.P. Makhnov (2002), the IS parameters are within the normal range. Table 1 shows a slight increase in LVM and LVMMI during the annual competitive period, indicating an adaptive nature of myocardial changes during various types of stress. However, the above parameters are within the normal LV geometry range, as recommended by [18].

Table 2

Hemodynamic parameters of the heart in team sports athletes (handball) during the annual competitive period (Xmean ± SE)

№	Indicators	Groups of athletes examined	
		EG autumn 2024(n=19)	EG spring 2025 (n=19)
1.	HR (beats/min) at rest	57,9±3,6	56,6±3,7
2.	E/A (units)	2,43±0,51	2,32±0,30
3.	IVRT (ms)	88,4±11,3	91,5±9,6
4.	ET mitral (ms)	766,4±149,7	789,3±138,6
5.	ET aortic (ms)	300,1±36,6	308,6±41,1
6.	IVCT (ms)	80,9±12,2	82,1±10,1
7.	DT (ms)	147,2±12,1	142,0±11,7
8.	Diastasis (ms)	373,8±140,1	422,7±158,2
9.	EF (%)	64,9±5,6	65,7±5,1
10.	SV (ml)	96±21,2	101,9±18,7

Note: * indicates a significant difference from the control group ($p<0.05$)

The study results presented in Table 2 demonstrate that HR with a heart rate below 60 bpm (bradycardia) or a tendency toward bradycardia (HR below 65 bpm) can be considered a hemodynamic marker of an athletic heart with a "supernormal" transmitral blood flow configuration (E/A ratio greater than 2 c.u.) and normal LV geometry [6,12]. The contribution of the atrial component to diastolic function increases with increasing resting heart rate [10]. In our previous studies, we determined the correlation coefficient (-0.72) between mitral ejection time (ET) and resting heart rate [15]. The obtained data on the ratio of the maximum early diastolic filling velocity (m/s) (Peak E) and the maximum filling velocity in atrial systole (m/s) (Peak A), i.e. E/A, more than 2.0 conventional units, are consistent with the data of A. Yu. Tatarinova (2013), where it is noted that this is typical for individuals involved in sports [13]. In our opinion, an important point that attracts attention is the determination of the time parameters of the diastolic component (early and late diastole) of the cardiac cycle, since, taking into account the results of studies [14], it is in the diastolic component that the systolic capabilities of the heart are laid down, realized through the physiological Frank-Starling law. Correlation relationships of individual indicators of morphometric and hemodynamic parameters of the heart are of interest. Thus, stroke volume (SV) has a positive correlation with LVM (0.72) and LVMMI (0.67). A negative correlation with LV TCO (-0.70) is also observed. Among the hemodynamic parameters of diastolic function, mitral ejection time (MET mitr.) is of particular interest, as this indicator has a close negative correlation with resting heart rate. Accordingly, one of the late diastolic parameters [12], namely, diastasis time, has a strong positive correlation (0.91) with mitral ejection time (MET mitr.), which is reflected in a

decrease in resting heart rate. This may be one of the main temporal components of the diastolic portion of the cardiac cycle in bradycardia. In our opinion, this can be considered an indicator reflecting the level of readiness to withstand training and competitive loads of various types and a high level of training.

Conclusion

1. The dynamics of morphometric and hemodynamic parameters of cardiac function in highly skilled athletes during the competitive period must be included in the medical and biological monitoring of Super League teams;
2. Based on an analysis of scientific and methodological literature and the data from our survey, monitoring of overstrain for individual hemodynamic parameters of cardiac function can be carried out, including using echocardiography;
3. Early and late diastole parameters can be used as markers in assessing the readiness of highly skilled athletes in team sports to tolerate various types of stress;
4. Regular comprehensive assessment of morphometric and hemodynamic parameters of cardiac function will enable timely prevention of possible pathological changes in the myocardium.

References

1. V. A. Badtieva, V. I. Pavlov, A. S. Sharkin, M. N. Khokhlova, A. V. Pachina, V. D. Vybornov Overtraining syndrome as a functional disorder of the cardiovascular system caused by physical activity // Russian Journal of Cardiology. – 2018. – 23 (6). – P. 180-190 (1)

2. Bokeria L. A., Bokeria O. L., Volkovskaya I. V. Heart rate variability: methods of measurement, interpretation, clinical use // Annals of Arrhythmology. – 2009 – No. 4. – P. 21-32 (2)

3. Butova O. A. Adaptation to physical activity: anaerobic metabolism of muscle tissue / O. V. Butova, S. V. Masalov // Bulletin of N.I. Lobachevsky University of Nizhny Novgorod. – 2011. – No. 1. – P. 123-128. (3)

4. Bykov E.V. Possibilities of using superficial reflexology in correcting the vegetative status of swimmers / E.V. Bykov, V.V. Erlich, A.V. Chipyshev // Bulletin of SUSU. – 2007.- - No. 16. – P. 77-79. (4)

5. Vasiliev A.P. "Athlete's Heart" / A.P. Vasiliev, N.N. Streltsova // Medical Council. – 2018. – No. 12. – P. 185-188. (5)

6. Gavrilova E.A. Remodeling of an athlete's heart depending on the focus of the training process / E.A. Gavrilova, G. M. Zagorodny // "Applied Sports Science" - 2019 - No. 1 (9). – P. 48–57. (6)

7. Gorbenko A. V. Athlete's Heart: Norm or Pathology / A. V. Gorbenko, Yu. P. Skirdenko, N. A. Nikolaev [et al.] // Blood Circulation Pathology and Cardiac Surgery. – 2020. – Vol. 24. – No. 2. – P. 16–25. (7)

8. Doroshenko D. A. Transthoracic Echocardiography in Adults: Guidelines / compiled by D. A. Doroshenko, M. A. Benevskaya, N. N. Vetsheva // Series "Best Practices in Radiation and Instrumental Diagnostics". – Issue. 54. – M.: State Budgetary Healthcare Institution "Research and Clinical Center for Diagnostics and Technology, Department of Health of the City of Moscow", 2020. – 40 p. (8)

9. Ibragimova I.N. Comparative assessment of left ventricular hypertrophy in patients with arterial hypertension and comorbid pathology using echocardiography and electrocardiography at the outpatient stage / I.N. Ibragimova, E.V. Egorova, A.B. Tileuberdieva [et al.] // Clinical medicine and pharmacology. – 2022. - No. 5 (244). – P. 76-82. (9)

10. Kovalenko V.N. Physiology of the heart (physiology, changes in pathological conditions) / V.N. Kovalenko, N.I. Yabluchansky // Bulletin of the Kharkiv National University. – 2003. – No. 597. – P. 1-14. (10)

11. Patent No. 2182456 Russian Federation, IPC A 61 B 5/02. Method for assessing the functional state of the left ventricular myocardium by determining the cardiac muscle dysfunction index: No. 2000104724/14: declared 27.12.2001: published 20.05.2002 / Aleksandrov V. S., Makhnov A. P.; applicant I. I. Mechnikov St. Petersburg Medical Academy. - 11 p.: ill. – Text: direct (11)

12. Rybakova M. K. Practical guide to ultrasound diagnostics. Echocardiography / M. K. Rybakova, M. N. Alekhine, V.V. Mitkov. - M .: Vidar Publishing House, 2008. – 512 p., with ill. (12)

13. Tatarinova A.Yu. Tissue Dopplerography in Assessing Left Ventricular Myocardial Diastolic Function in Athletes / A.Yu. Tatarinova, A.V. Smolensky, A.V. Mikhailova // Bulletin of New Medical Technologies – 2013 – Vol. 20. – No. 4. – Pp. 57-61. (13)

14. Chernozemova A.V. Diastolic Function and Myocardial Remodeling in Patients After Coronary Artery Bypass Grafting: Guidelines / A.V. Chernozemov, I.A. Khlopina, E.N. Shatsova. - Arkhangelsk: Northern State Medical University (SSMU), 2009. - 32 p. (14)

15. Shakhnovich P.G. Diastolic myocardial dysfunction: an echocardiographic phenomenon or a type of heart failure? / P.G. Shakhnovich, A.I. Zakharova, D.V. Cherkashin [et al.] // Bulletin of the Russian Military Medical Academy. - 2015. - 3 (51). - P. 54-57. (15)

16. Sherstyuk S.A. Adaptation capabilities of the physiologically normal heart of young men to aerobic and anaerobic loads: diss. ... Cand. Biol. Sciences 1.5.5. - Tomsk, 2022. - 181 p. (16)

17. Sherstyuk S.A. "Supernormal" diastolic function of the left ventricle - a functional indicator of an athlete's heart / S.A. Sherstyuk, A.Yu. Aseeva, V.I. Andreev [et al.] // Human. Sport. Medicine. – 2022. – Vol. 22. – No. 1. – P. 56-62. (17)

18.Sherstyuk S.A. Hemodynamic characteristics of athletes' performance taking into account vegetative regulation / S.A. Sherstyuk, L.V. Kapilevich, A.A. Sherstyuk // Theory and practice of physical education. – 2021. – No. 4 (922). – P. 55-58. (18)

19.Shlyk N.I., Gavrilova E.A. Bradycardia and heart rate variability in athletes // Human. Sport. Medicine. – 2023. – Vol. 23, No. S1. – P. 59-69 (19)

20.Roberto M Lang Recommendations for chamber quantification / Roberto M Lang, Michelle Bierig, Richard B Devereux [et al] // Eur J Echocardiogr/ - 2006. Vol. 7(2). – P. 79-108. -DOI: 10.1016/j.euje.2005.12.014. (20)

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医疗机构中的手部卫生：将该理念应用于预防医院感染的有效措施
HAND HYGIENE IN MEDICAL ORGANIZATIONS: IMPLEMENTATION OF THE CONCEPT AS AN EFFECTIVE MEASURE FOR HAI PREVENTION

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摘要：本文介绍了旨在论证医疗机构中手部卫生是预防医疗相关感染（HCAI）最有效措施的研究结果。该研究是在实施《国家医疗相关感染预防概念》（俄罗斯联邦首席国家卫生医师于2011年11月6日批准）框架下进行的。研究发现，医疗相关感染是俄罗斯现代医疗保健面临的紧迫问题。HCAI的主要原因是医疗机构感染控制措施不完善以及抗菌药物的过度使用。本研究采用了内容分析、文献综述、排序、假设演绎法、概括和形式化等方法。本研究使用的材料包括发表在国际文献数据库（Scopus、PubMed）中的文章、俄罗斯联邦官方文件以及与医疗服务相关的感染的国际文件（立法、规划、公约等）。系统文献分析表明，预防医疗相关感染（HCAI）的主要措施之一是手卫生。研究发现，通过实施多模式方法可以最大限度地提高HCAI的预防效果。基于现有科学研究，本研究确定了医护人员必须进行手卫生的5个关键点。结论认为，HCAI的预防应采取多模式方法，成功实施HCAI预防需要医院层面的文化转变，并且需要国家层面的协调，以应对HCAI带来的严重威胁。

关键词：医疗相关感染，手卫生，预防，房间清洁，感染预防理念。

Abstract. *The article presents the results of a study aimed at substantiating hand hygiene in medical organizations as the most effective measure for preventing HCAI in the framework of the implementation of the National Concept for the Prevention of Infections Associated with Medical Care (approved by the Chief State Sanitary Doctor of the Russian Federation on November 6, 2011). It was found that healthcare-associated infections (HCAIs) are an urgent problem of modern Russian healthcare. The main causes of HCAI are insufficiently effective infection control methods in medical organizations and the overuse of antimicrobials. In the course of the study, such methods as content analysis, literature review, ranking,*

hypothetical-deductive method, generalization, formalization were used. The materials used were articles published in international bibliographic and abstract databases (Scopus, PubMed); official documents of the Russian Federation, as well as international documents (legislative acts, programs, conventions, etc.) on infections related to the provision of medical care. The performed systematic literature analysis suggests that one of the main measures to prevent HCAI is hand hygiene. It was found that the maximum result in the prevention of HCAI can be achieved through the implementation of a multimodal approach. Based on available scientific research, 5 key points have been identified when hand hygiene is mandatory for healthcare professionals. It was concluded that HCAI prevention should be multimodal, with successful implementation of HCAI prevention requiring cultural shifts at the hospital level, and coordination at the national level is needed to address the serious threat posed by HCAI.

Keywords: *healthcare-associated infections, hand hygiene, prevention, room cleaning, infection prevention concept.*

Background

Healthcare-associated infections (HAIs) are infections acquired by a patient during treatment in a healthcare facility, such as a hospital, or from a healthcare worker, such as a physician or nurse. Healthcare-associated infections can enter the body through portals such as the bloodstream, lungs, skin, urinary tract, or gastrointestinal tract, causing serious illness. These infections are difficult to treat and can persist in the body for long periods. In the worst cases, these infections can be fatal [1, 2].

The main causes of HAIs are inadequate infection control practices in healthcare facilities and the overuse of antimicrobials. Long-term reduction in HAIs depends on the implementation of multimodal preventive strategies that require behavioral and cultural changes. Key components of such strategies include identifying carriers of multidrug-resistant organisms, eliminating environmental reservoirs, preventing cross-transmission, and evidence-based antimicrobial use. These measures must be implemented within a framework of individual responsibility, strong administrative support, and access to up-to-date national and local surveillance data [3].

The treatment of HAIs is exacerbated by rising levels of antimicrobial resistance. Healthcare workers and contaminated hospital environments are increasingly becoming a source of transmission and persistence of multidrug-resistant organisms, as well as other pathogens such as Clostridium difficile. This necessitates focusing on a range of HAI prevention measures.

The aim of this study is to substantiate hand hygiene in healthcare organizations as the most effective measure for HAI prevention within the framework of

the National Concept for the Prevention of Healthcare-Associated Infections (approved by the Chief State Sanitary Doctor of the Russian Federation on November 6, 2011).

Materials and Methods

To achieve this goal, methods such as content analysis, literature review, ranking, hypothetical-deductive reasoning, synthesis, and formalization were used.

The materials used included articles published in international bibliographic and abstract databases (Scopus, PubMed); official documents of the Russian Federation; and international documents (legislation, programs, conventions, etc.) on healthcare-associated infections. Twenty domestic and international sources were cited.

Results

The key components of HAI prevention were identified as including:

1. Antimicrobial stewardship to reduce antimicrobial overuse and ensure evidence-based use of antimicrobials;

2. Infection prevention strategies to control multidrug-resistant organisms—particularly methicillin-resistant Staphylococcus aureus and vancomycin-resistant Enterococcus spp. (VRE) and, more recently, multidrug-resistant gram-negative bacteria;

3. Cleaning and disinfection of hospitals;

4. Development of prescribing guidelines and treatment standards [4, 5, 6].

The main preventive measures recommended for patients to avoid infection are:

- Mandatory hand washing by the patient or the use of liquid or gel hand sanitizers.
- Hand washing by healthcare workers before performing procedures or the use of liquid and/or gel hand sanitizers;
- Taking antibiotics only as prescribed by a doctor;
- Taking antibiotics strictly as directed by a doctor, and completing the course as prescribed;
- When taking antibiotics or painkillers, it is necessary to protect the gastrointestinal tract from side effects;
- Knowledge of patient rights [7, 8].

Available research suggests that Clostridium difficile is one of the most common pathogens causing HAI, with an annual incidence of 3.65 cases per 10,000 hospital days and a 30-day mortality rate of 6–7%. Clostridium difficile has increased in prevalence in recent decades. Between 1999 and 2013, a hypervirulent strain of C. difficile (ribotype 027), which causes high morbidity among the elderly, became endemic in hospitals in North America and the United Kingdom. Factors contributing to its emergence included poor antibiotic prescribing practices,

particularly fluoroquinolones, and inadequate environmental and hand hygiene; these deficiencies are also common in modern Russian healthcare [9, 10, 11]. Complicating the epidemiology is the fact that, according to expert estimates and available research data, up to one-third of new cases of Clostridium difficile infections occur in the community; only 35% of hospital-acquired Clostridium difficile infections were linked to other hospital cases when studied using whole-genome sequencing [12, 13].

Available research data indicate that viable spores of HAI pathogens are isolated from 49% of surfaces surrounding patients in healthcare facilities, including frequently touched areas such as call buttons and bed rails, reflecting the ability of pathogens to resist desiccation and survive on hard surfaces. Furthermore, other factors, including spore aerosolization after toilet flushing and the isolation of asymptomatic carriers, further contribute to environmental contamination in healthcare facilities [14, 15]. Patients hospitalized in spaces previously occupied by patients with C. difficile are at increased risk of acquiring HAIs, despite proper cleaning. Asymptomatic carriers of viable C. difficile spores have been found to contaminate 29% of surrounding surfaces. It is currently unclear whether standard bleach cleaning and contact precautions should be followed in such cases or whether a specific, specialized approach is required [16].

It has now been established that C. difficile spores, the primary causative agent of HAIs, are resistant to standard hospital disinfection methods, including alcohol-based hand rubs and common disinfectants (quaternary ammonium compounds). To minimize pathogen transmission, patient care packages should include contact precautions, the use of dedicated patient equipment, regular bleach cleaning, and hand hygiene with soap and water [17].

A systematic literature review suggests that hand hygiene is a key intervention for preventing HAIs. Furthermore, maximum results in HAI prevention can be achieved through a multimodal approach.

Hand hygiene is a fundamental principle of quality healthcare. While interventions are often multimodal, and direct cause-and-effect relationships are difficult to prove, there is epidemiological evidence supporting the role of hand hygiene in reducing HAIs.

For example, between 2002 and 2013, hospital-acquired S. aureus bacteremia (SAB) (MRSA and MSSA) decreased by 63%, and similar reductions have been demonstrated in many countries worldwide. This decline in HAIs occurred in parallel with national initiatives, leading to the widespread implementation of successful hand hygiene programs. Proper hand hygiene is a core principle in HAI prevention packages and remains a key indicator of hospital safety and quality systems [18].

Infection with HAI pathogens occurs in hospital settings through cross-transmission, so hand and environmental hygiene are key prevention strategies. Healthcare workers, patients, and visitors should be educated about the importance of strict hand hygiene, especially after using the toilet.

Based on available scientific research, five key moments have been identified when healthcare workers must perform hand hygiene [19, 20].

1. Before contact with the patient. Hand hygiene is performed to protect the patient from pathogen colonization and, in some cases, from exogenous infection and harmful microbes carried on the hands. Situations covered by this section include: shaking hands; assisting the patient with self-care; providing assistance and other non-invasive therapeutic procedures: applying an oxygen mask, massage, etc.; performing a non-invasive physical examination: measuring pulse, blood pressure, auscultation of the chest, recording an ECG, etc.

2. Before clean/aseptic procedures. Hand hygiene is performed to protect the patient from contamination by harmful microbes, including their own microbes entering their body. Situations included in this item: brushing a patient's teeth, administering eye drops, performing a digital vaginal or rectal examination, examining the mouth, nose, or ear with or without instruments, inserting a suppository/pessary, aspirating the mucous membrane; dressing a wound with or without an instrument, applying ointment to a vesicle, injections/punctures; inserting an invasive medical device (nasal cannula, nasogastric tube, endotracheal tube, urinary tube, catheter, drainage); preparing food, medications, pharmaceutical products, or sterile materials.

3. Contact with biological fluids. Hand hygiene is performed to protect the healthcare worker from colonizing or contaminating the patient with harmful microbes and to protect the healthcare environment from the spread of microbes. Situations included in this item: contact with the mucous membrane and intact skin; performing an injection or puncture; Insertion of an invasive medical device (vascular access, catheter, tube, drain, etc.); Removal of an invasive medical device; Removal of any protective material (napkin, bandage, gauze, sanitary pad, etc.); Handling a sample containing organic matter; After cleaning excrement and any other biological fluids; After cleaning any contaminated surfaces and material (dirty bed linen, dentures, instruments, urinals, bedpans, toilets, etc.).

4. After contact with the patient. Hand hygiene is performed to protect healthcare workers from infection with pathogenic microbes and to protect the healthcare facility environment from the spread of microbes. Situations included in this section: After shaking hands, stroking a child's forehead; After assisting a patient with self-care; After providing assistance and other non-invasive treatment; After performing a non-invasive examination: measuring pulse, blood pressure, auscultating the chest, recording an ECG, etc.

5. After contact with objects surrounding the patient. Hand hygiene is performed to protect healthcare workers from colonization with pathogens that may be present on surfaces/objects around the patient, as well as to protect the healthcare facility environment from the spread of pathogens. Situations covered by this section include: after physical contact with the patient and their surroundings; after providing medical care, for example, after setting up equipment; after contact with surfaces or other objects, such as the bed, bedside tables, etc.

When considering hand hygiene, wearing gloves deserves special attention. The use of gloves does not replace the need for thorough hand hygiene. Hand hygiene should be performed in all the above-mentioned situations and in other situations, regardless of the indications for glove use. After each use, gloves should be discarded and hands washed. Gloves should only be worn when indicated according to established standards; otherwise, they become a major risk for microbial transmission.

Conclusion

Successful implementation of HAI prevention requires a cultural shift at the hospital level, and national coordination is essential to address the serious threat posed by HAI. HAI prevention should be multimodal, with hand hygiene being the most effective measure.

References

1. Edwards VR. Preventing and managing healthcare-associated infections: linking collective leadership, good management, good data, expertise, and culture change. J Hosp Infect 2016; 94: 30– 31.

2. Pakyz AL, Moczygemba LR, VanderWielen LM, Edmond MB, Stevens MP, Kuzel AJ. Facilitators and barriers to implementing antimicrobial stewardship strategies: results from a qualitative study. Am J Infect Control 2014; 42:257–263.

3. Grayson ML, Macesic N, Huang GK, Bond K, Fletcher J, Gilbert GL et al. Use of an innovative personality-mindset profiling tool to guide culture-change strategies among different healthcare worker groups. PLoS One 2015; 10: e0140509.

4. Entesari-Tatafi D, Orford N, Bailey MJ, Chonghaile MN, Lamb-Jenkins J, Athan E. Effectiveness of a care bundle to reduce central line-associated bloodstream infections. Med J Aust 2015; 202: 247– 250.

5. Mitchell BG, Ware C, McGregor A, Brown S, Wells A. ASID (HICSIG)/AICA position statement: preventing catheter-associated urinary tract infections in patients. Healthcare Infection 2011; 16: 45– 52.

6. Bode LG, Kluytmans JA, Wertheim HF, Bogaers D, Vandenbroucke-Grauls CM, Roosendaal R et al. Preventing surgical-site infections in nasal carriers of Staphylococcus aureus. N Engl J Med 2010; 362: 9– 17.

7. Perl TM, Cullen JJ, Wenzel RP, Zimmerman MB, Pfaller MA, Sheppard D et al. Intranasal mupirocin to prevent postoperative Staphylococcus aureus infections. N Engl J Med 2002; 346: 1871– 1877.

8. Harris AD, Pineles L, Belton B, Johnson JK, Shardell M, Loeb M et al. Universal glove and gown use and acquisition of antibiotic-resistant bacteria in the ICU: a randomized trial. JAMA 2013; 310: 1571– 1580.

9. Abad C, Fearday A, Safdar N. Adverse effects of isolation in hospitalised patients: a systematic review. J Hosp Infect 2010; 76: 97– 102.

10. Freedberg DE, Salmasian H, Cohen B, Abrams JA, Larson EL. Receipt of antibiotics in hospitalized patients and risk for Clostridium difficile infection in subsequent patients who occupy the same bed. JAMA Intern Med 2016; 176: 1801– 1808.

11. Abreu AC, Tavares RR, Borges A, Mergulhão F, Simões M. Current and emergent strategies for disinfection of hospital environments. J Antimicrob Chemother 2013; 68: 2718– 2732.

12. Rubin ZA, Murthy RK. Outbreaks associated with duodenoscopes: new challenges and controversies. Curr Opin Infect Dis 2016; 29: 407– 414.

13. Otter JA, Burgess P, Davies F, Mookerjee S, Singleton J, Gilchrist M et al. Counting the cost of an outbreak of carbapenemase-producing Enterobacteriaceae: an economic evaluation from a hospital perspective. Clin Microbiol Infect 2016; 23: 188– 96.

14. Leffler DA, Lamont JT. Clostridium difficile infection. N Engl J Med 2015; 372: 1539– 48.

15. Eyre DW, Cule ML, Wilson DJ, Griffiths D, Vaughan A, O'Connor L et al. Diverse sources of C. difficile infection identified on whole-genome sequencing. N Engl J Med 2013; 369: 1195– 205.

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8-11岁多生牙患者面部特征参数分析
CHARACTERISTICS OF PROFILE PARAMETERS OF PATIENTS WITH SUPERNUMERARY TEETH AGED 8-11 YEARS

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摘要：本研究旨在分析8-11岁上颌前牙区多生牙（多生牙症）患者的面部轮廓参数，并考虑安氏咬合类型，以优化诊断和正畸治疗方案的制定。材料与方法：本研究分析了40例8-11岁多生牙患者（20名男孩和20名女孩）的全景X线片（OPG）和侧位头颅X线片（TRG），并根据安氏分类将其分为3组。方法：根据A.D.Viazis方案进行面部轮廓的人体测量分析（鼻唇角、唇颏位置、软组织厚度）；评估多生牙的位置及其对切牙位置的影响；进行统计数据处理（均值±标准差、学生t检验、Pearson相关系数）。结果：各组间面部轮廓参数存在显著差异。安氏I类错颌畸形以直型面型（65%）和中等鼻唇角（95-110°）为主。II类错颌畸形以下颌后缩（70%）、鼻唇角增大（>110°）和上唇短小为特征。III类错颌畸形以下颌前突（60%）

、鼻唇角减小（<95°）和下唇前移（p < 0.05）为特征。研究发现，多生牙的数量与切牙后缩程度（r = 0.58）以及牙弓狭窄程度（r = 0.61）之间存在相关性。结论：多生牙的存在显著影响面部轮廓参数，且变化的性质取决于初始咬合类型。关键指标包括：鼻唇角的变化、嘴唇相对于美学平面的位置以及面部下三分之一的形状。所开发的诊断算法，包括头影测量和人体测量分析，能够以85%的准确率预测轮廓变化，并优化正畸治疗方案。研究创新点：首次全面评估了青春期前儿童多生牙的存在、咬合类型和软组织轮廓参数之间的关系，这凸显了早期采取跨学科治疗方法的必要性。

关键词：多生牙、牙齿过多症、轮廓测量、安氏咬合、头影测量、正畸治疗、儿童。

Abstract. *The aim of the study was to characterize the profilometric parameters in patients aged 8-11 years with supernumerary teeth (hyperdontia) in the anterior region of the upper jaw, taking into account the type of Angle's occlusion to optimize diagnosis and orthodontic treatment planning.* ***Materials and methods.*** *The study analyzed orthopantomograms (OPG) and lateral cephalometric radiographs (TRG) of 40 patients (20 boys and 20 girls) aged 8-11 years with supernumerary teeth, divided into 3 groups according to Angle's classes. Methods used: anthropometric analysis of the facial profile according to the A.D. Viazis scheme (nasolabial angle, position of lips and chin, soft tissue thickness); assessment of the position of supernumerary teeth and their impact on the position of incisors; statistical data processing (M ± m, Student's t-test, Pearson correlation coefficient).* ***Results.*** *Significant differences in profilometric parameters between the groups were revealed. In Angle's Class I, straight profiles (65%) and average nasolabial angle values (95-110°) prevailed. In Class II, a retrognathic profile (70%), an increased nasolabial angle (>110°), and a shortened upper lip were noted. Class III was characterized by a prognathic profile (60%), a decreased nasolabial angle (<95°), and an anterior position of the lower lip (p < 0.05). A correlation was established between the number of supernumerary teeth and the degree of incisor retrusion (r = 0.58), as well as the narrowing of the dental arches (r = 0.61).* ***Conclusions.*** *The presence of supernumerary teeth significantly affects the parameters of the facial profile, and the nature of the changes depends on the initial type of occlusion. Critical markers are: changes in the nasolabial angle, the position of the lips relative to the aesthetic plane, and the shape of the lower third of the face. The developed diagnostic algorithm, including cephalometric and anthropometric analysis, makes it possible to predict profile changes with an accuracy of 85% and optimize the orthodontic treatment plan. Novelty of the study: For the first time, the relationship between the presence of supernumerary teeth, the type of occlusion, and the parameters of the soft tissue profile in prepubertal children has been comprehensively assessed, which determines the need for an early interdisciplinary approach.*

Keywords: *supernumerary teeth, hyperdontia, profilometry, Angle's occlusion, cephalometry, orthodontic treatment, children.*

Introduction

The problem of supernumerary teeth (hyperdontia) is a pressing issue in modern orthodontic practice, particularly in childhood [3, 5, 13]. According to various authors, the prevalence of hyperdontia in children ranges from 0.5% to 3.8%, with supernumerary teeth most often located in the anterior maxilla [1, 7, 10]. Their presence leads to serious dental anomalies: crowding, diastema, retention of permanent teeth, dental malalignment, and malocclusion [2, 4, 9].

The influence of supernumerary teeth on the development of the facial profile is particularly significant during the period of active jaw growth in children aged 8-11 years [6, 8, 14]. At this age, the bite changes, and the presence of an additional tooth can exacerbate existing orthodontic problems or be the primary cause of their development. Despite this, the relationship between hyperdontia, occlusion type, and soft tissue profile parameters is insufficiently addressed in the available literature, necessitating appropriate research.

The aim of the study was to characterize profilometric parameters in patients with supernumerary teeth aged 8 to 11 years, taking into account the Angle occlusion type.

Study Materials and Methods

The study analyzed the lateral orthodontic and transoral radiographic images (TRG) of 40 patients (20 boys and 20 girls) aged 8 to 11 years diagnosed with hyperdontia. All patients were receiving comprehensive orthodontic treatment at a dental clinic.

Participants were divided into three groups according to Angle's classification:

Group I: Patients with Class I molar occlusion and the presence of supernumerary teeth (n=14).

Group II: Patients with Class II molar occlusion and the presence of supernumerary teeth (n=16).

Group III: Patients with Class III molar occlusion and the presence of supernumerary teeth (n=10).

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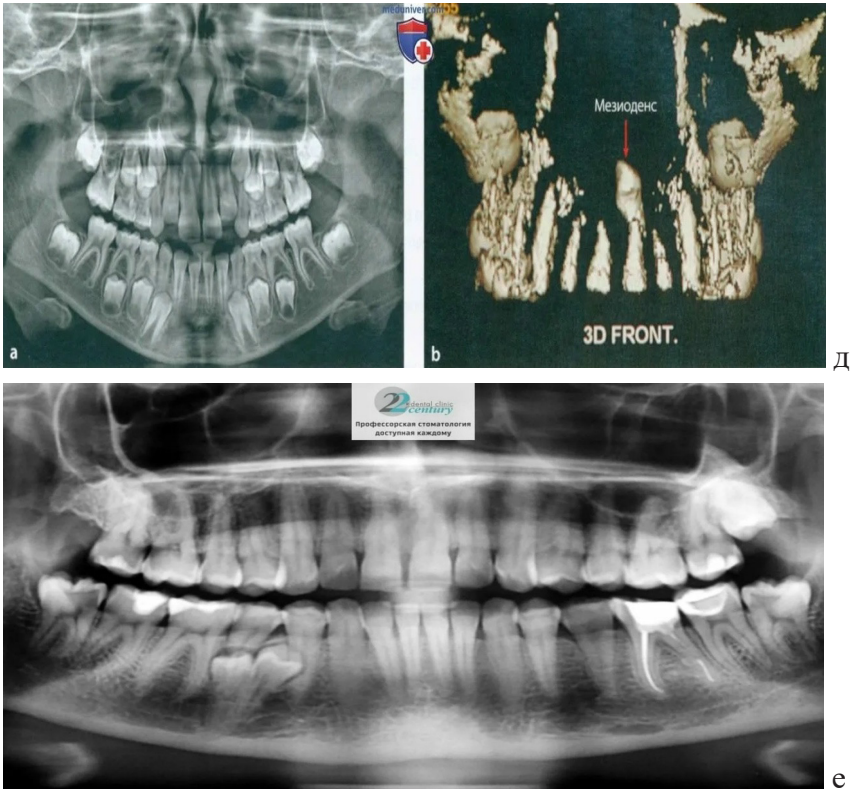
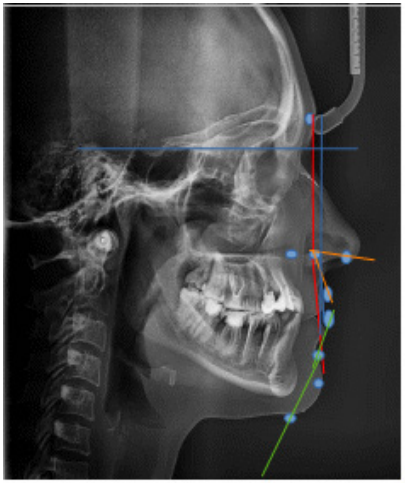


Figure 1. *Variants of supernumerary teeth arrangement.*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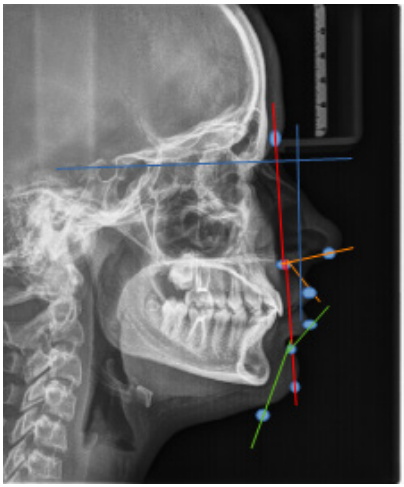
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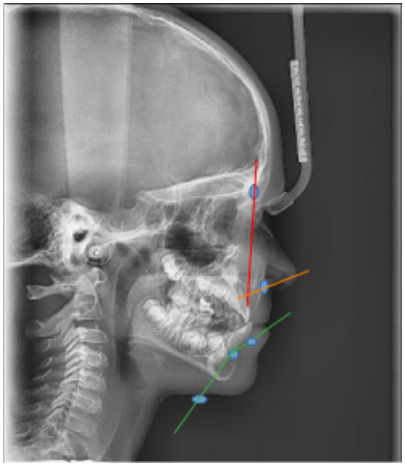
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Figure 2. *Teleradiographs of patients (groups A – I), B – II, and C – III*

The research methods included:

Anthropometric analysis of the facial profile according to the A.D. Viazis scheme (1991): assessment of profile shape (angle gl-sn-pg), nasolabial angle (Ls-sn-cm), lip position relative to the vertical (snV), chin position (vV-snV), and soft tissue thickness indices.

Cephalometric analysis of the transrectal radiographs (TRG): assessment of the position of supernumerary teeth, their influence on the inclination and position of the incisors, and analysis of dental arch parameters.

Statistical data processing was performed using Statistica 10.0. Mean values (M) and standard errors (m) were calculated, and the significance of differences was determined using Student's t-test at $p < 0.05$. The Pearson correlation coefficient (r) was used to assess correlations.

Table 1

Characteristics of profile parameters of patients with supercomplete teeth aged 8-11 years depending on the angle occlusion class

Profile parameter	Angle's Class I (n=14)	Angle's Class II (n=16)	Angle's Class III (n=10)
Predominant profile shape	Straight (65%)	Retrogenic (70%)	Prognathic (60%)
Lower facial shape	Normo- / Progenic	Retrogenic	Prognathic
Nasolabial angle (Ls-sn-cm)	Average values (95-110°)	Enlarged (>110°)	Decreased (<95°)
Position of the lips relative to the vertical (snV)	Average position	Anterior position of the upper lip, often shortened	Posterior upper lip, anterior lower lip
Position of the chin (vV-snV)	Average	Average	Front
Influence of a supernumerary tooth on the incisors	Diastema, slight crowding	Worsening retrusion of the upper incisors	Promotes protrusion of the upper incisors
Primary morphological type of deformity	Dental arch narrowing	Increased profile concavity, narrowing of the arch	Disguise of the mesial bite by protrusion of the upper incisors, increasing the sagittal gap.
Correlation with the number of supernumerary teeth	Moderate (r ~ 0.5-0.6) with dental arch narrowing	Moderate (r ~ 0.5-0.6) with a degree of incisor retrusion	Moderate (r ~ 0.5-0.6) with protrusion of the incisors and narrowing of the arch

Results and Discussion

Data analysis revealed significant differences in profilometric parameters between the groups.

In Group I (Angle's Class I), straight profiles predominated (65%), with a normo- or progenic lower third. The nasolabial angle was within the average range (95-110°). The position of the lips and chin relative to the aesthetic plane was average. The presence of a supernumerary tooth most often manifested as a diastema or slight crowding without a significant impact on the profile.

In Group II (Angle's Class II), a retrogenic profile was observed in 70% of cases. The nasolabial angle was increased (>110°), and the upper lip was shortened and positioned posteriorly relative to the snV vertical. The presence of a supernu-

merary tooth exacerbated the retrusion of the upper incisors, which increased the tendency toward a concave profile.

In Group III (Angle's Class III), 60% of patients had a prognathic profile. The nasolabial angle was reduced (<95°), and the lower lip occupied an anterior position. In this situation, a supernumerary tooth often contributed to protrusion of the upper incisors, which in some cases could partially mask the mesial bite but also led to an increase in the sagittal gap.

Statistical analysis confirmed a moderate positive correlation between the number of supernumerary teeth and the degree of upper incisor retrusion ($r = 0.58$), as well as the narrowing of the dental arches ($r = 0.61$). Patients with multiple hyperdontia had the most pronounced profile changes.

Conclusions

The presence of supernumerary teeth in the anterior maxilla in children aged 8-11 years has a significant impact on facial profile parameters.

The nature and severity of profile changes are closely related to the initial Angle's occlusion type. In Class II, hyperdontia exacerbates retrognathic features, while in Class III, it can partially compensate for prognathism due to incisor protrusion.

Critical markers requiring attention during diagnosis include: deviation of the nasolabial angle from the norm, changes in the anterior-posterior position of the lips, and the shape of the lower third of the face.

Using a comprehensive diagnostic algorithm, including cephalometric and anthropometric analysis, allows for a high accuracy (85%) in predicting changes in the soft tissue profile and developing a personalized orthodontic treatment plan, including the timely removal of supernumerary teeth and subsequent appliance treatment.

References

1. Abramova N.E., Petrosov Yu.A. Prevalence and localization of supernumerary teeth in children // Pediatric Dentistry and Prevention. – 2020. – Vol. 19. No. 4. – Pp. 15-19.

2. Vinogradova T.S. Analysis of complications in the treatment of impacted teeth associated with hyperdontia // Orthodontics. - 2019. - No. 2 (70). - Pp. 22-25.

3. Grigoriev S.S., Mirzabekova O.V. Modern aspects of diagnostics and tactics of managing patients with supernumerary teeth // Institute of Dentistry. - 2021. - No. 4 (53). - Pp. 60-63.

4. Zhukova E.A., Komarova E.S. The influence of supernumerary teeth on the formation of the dentoalveolar system in children // Problems of Dentistry. – 2022. – Vol. 18. - No. 1. – Pp. 78-83.

5. Persin LS Orthodontics. Diagnostics and Treatment of Dentoalveolar Anomalies. - Moscow: MIA, 2018. - 640 p.

6. Slabkovskaya AB The Impact of Dentoalveolar Anomalies and Orthodontic Treatment on the Condition of Oral Soft Tissues // Orthodontics. - 2018. - No. 2 (66). - Pp. 38-41.

7. Fadeev RA, Chibisova MA Diagnostics of Supernumerary Teeth Using Cone Beam Computed Tomography // Dentist. - 2020. - No. 11. - Pp. 45-49.

8. Khoroshilkina F.Ya. Orthodontics. - M.: Medicine, 2006. - 544 p.

9. Alkhatib R., Al-Nimri K. Supernumerary teeth: a review of the literature and a survey of 152 cases // Int J Paediatr Dent. – 2022. – Vol.32(2). – P. 244-254.

10. Garvey M.T., Barry H.J., Blake M. Supernumerary teeth--an overview of classification, diagnosis and management // J Can Dent Assoc. - 1999. - Vol.65(11). - P.612-6.

11. Liu J.F. Characteristics of premaxillary supernumerary teeth: a survey of 112 cases // ASDC J Dent Child. - 1995. - Vol.62(4). - P.262-5.

12. Rajab L.D., Hamdan M.A. Supernumerary teeth: review of the literature and a survey of 152 cases // Int J Paediatr Dent. - 2002. - Vol.12(4). - P.244-54.

13. ORAL HYGIENE IN CHILDREN WITH DOWN SYNDROME AND PARENTAL KNOWLEDGE ABOUT PRESERVING CHILDREN'S DENTAL HEALTH Pestryakova I.Yu., Ivanov A.S., Kiselnikova L.P., Kraevskaya N.S., Leontyeva E.Yu., Babko E.G., Kapitsa A.A. Chief Physician of the South of Russia. 2020. No. 3 (73). pp. 21-24.

14. THIRTY-FIVE-YEAR EXPERIENCE OF THE CENTER FOR CARE OF CHILDREN WITH CONGENITAL FACIAL PATHOLOGY IN THE VOLGOGRAD REGION Fomenko I.V., Kasatkina A.L., Filimonova E.V., Kraevskaya N.S., Shishkina V.I. In: Congenital and Hereditary Pathology of the Head, Face, and Neck in Children: Current Issues in Comprehensive Treatment. Proceedings of the V All-Russian Scientific and Practical Conference. 2016. P. 319.

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预测作为一种旨在减少慢性阻塞性肺病致残率的手段
FORECASTING AS A FUNCTION AIMED AT REDUCING DISABILITY DUE TO CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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摘要：本文预测了达吉斯坦共和国成年人群中慢性阻塞性肺疾病导致的原发性、复发性和累积性残疾率至2029年的变化趋势。

关键词：预测，原发性、复发性和总体残疾，残疾程度，慢性阻塞性肺疾病，年龄组，残疾严重程度。

Abstract. *This article presents projected values for primary, recurrent, and cumulative disability rates in the adult population due to chronic obstructive pulmonary disease in the Republic of Dagestan through 2029.*

Keywords: *forecasting, primary, recurrent, and overall disability, level, chronic obstructive pulmonary disease, age groups, disability severity.*

Forecasting is a critical management function. Management methods, whose role is currently of paramount importance, are based on forecasts. Forecasts for key health indicators, such as disability rates, serve as the basis for developing strategic frameworks and target programs aimed at preventing and reducing morbidity and disability in individuals with this condition [1, 2, 3].

Objective: To calculate projected values for primary, recurrent, and overall disability rates in the adult population due to chronic obstructive pulmonary disease in the Republic of Dagestan through 2029.

Materials and Methods: The accumulated database of indicators of primary, recurrent, and overall disability in the adult population due to chronic obstructive pulmonary disease in the Republic of Dagestan for 2018-2024 was used.

Methods: Dynamic series of primary, recurrent, and overall disability were generated, and projected values were determined using extrapolation and approximation of the dynamic series based on linear regression equations.

Results and Research: Using the statistical database of indicators of primary, recurrent, and overall disability in the adult population due to chronic obstructive pulmonary disease in the Republic of Dagestan for 2018-2024 accumulated during the study, projected values for the indicators for the near future were calculated using modern information technologies.

Table 1

Projected values of primary disability rates for the adult population of the Republic of Dagestan due to chronic obstructive pulmonary disease, taking into account age categories, for 2025–2029 (cases per 10,000 of the corresponding population, %)

Indicators	Years						growth/decrease rate
	2024	2025	2026	2027	2028	2029	
VPI aged 18 and older	0,24	0,34	0,34	0,35	0,36	0,36	+50,0
working age	0,23	0,226	0,218	0,210	0,202	0,194	-15,6
older than working age	0,27	0,20	0,19	0,18	0,17	0,16	-40,7

Table 2

Projected values of primary disability rates in the adult population due to chronic obstructive pulmonary disease, taking into account the disability group for 2025–2029 (cases per 10,000 of the corresponding population, %)

Disability groups	Years						growth/decrease rate (%)
	2024	2025	2026	2027	2028	2029	
II	0,05	0,028	0,024	0,020	0,016	0,012	-76,0
III	0,19	0,172	0,166	0,160	0,154	0,148	-22,1

As can be seen, the primary disability rate will grow at an accelerated rate. By 2029, the intensive disability rate is expected to reach 0.36, a growth rate of +50% compared to the 2024 figure. At the same time, the intensive rate among individuals of working age is projected to decrease from 0.23 to 0.194, with a decline rate of -15.6%. Among individuals older than working age, a more rapid decline is expected, from 0.27 to 0.16 (a decline rate of -40.7%) (Table 1).

As can be seen from Table 2, the primary disability rate for Group II has a more pronounced downward trend, from 0.05% to 0.012% by 2029, with a decline rate of -76.0%. The level of primary disability of group III by 2029 will be 0.148%, a decrease of -22.1% compared to 2024.

Table 3

Characteristics of projected indicators of levels of recurrent disability of the adult population of the Republic of Dagestan due to chronic obstructive pulmonary disease, taking into account the disability group for 2025–2029 (cases per 10 thousand adult population, %)

Disability groups	Years						growth/decrease rate (%)
	2024	2025	2026	2027	2028	2029	
Personal disability groups aged 18 and older	0,78	1,03	1,01	0,99	0,97	0,95	+21,7
I	0,020	0,024	0,022	0,020	0,018	0,016	-20,0
II	0,27	0,302	0,301	0,300	0,299	0,298	+10,4
III	0,49	0,68	0,66	0,64	0,62	0,60	+22,4

The rate of recurrent disability among those repeatedly recognized as disabled at the age of 18 years and older due to COPD is expected to increase from 0.78% in 2024 to 0.95% in 2029 (a growth rate of +21.7%). A study of projected values of recurrent disability due to COPD among the adult population, taking into account the severity of disability, revealed that the rate of group I is expected to decrease from 0.020% to 0.016% (a decrease rate of -20.0%) and an increase in the level of group II disability is projected from 0.27% to 0.298% (a growth rate of +10.4%). The rate of recurrent disability of group III is projected to increase more intensively from 0.49% in 2024 to 0.60 in 2029 (the growth rate will be +22.4%) (Table 3).

Таблица 4.

Characteristics of projected values of indicators of general disability levels among the adult population due to chronic obstructive pulmonary disease for 202–2029 (cases per 10 thousand population, %)

Indicators	Years						growth/ decrease rate (%)
	2024	2025	2026	2027	2028	2029	
General Disability Level	1,0	1,16	1,12	1,08	1,04	1,0	0
Disability Level Group I	0,02	0,018	0,014	0,010	0,006	0,002	-90,0
Disability Level Group II	0,32	0,328	0,324	0,320	0,316	0,312	-2,5
Disability Level Group III	0,68	0,90	0,88	0,86	0,84	0,82	+20,6
Over the working age	0,93	1,35	1,39	1,43	0,47	1,51	+62,4

The overall disability rate by 2025 is projected to increase to 1.16% (growth rate of +16.0%), followed by a decrease to 1.0% by 2029 and remain at the 2024 level. The overall disability rate of group I is projected to decrease from 0.02 in 2024 to 0.002 by 2029 (decrease rate of -90.0%). The disability rate of group II is also expected to decrease from 0.32 to 0.312% (decrease rate of -2.5%). At the same time, the overall disability rate of group III is projected to increase from 0.68% to 0.82% (growth rate of +20.6%). The overall disability rate among persons older than working age is projected to increase rapidly from 0.93% to 1.51% (growth rate of +62.4%) (Table 4).

Conclusion. Thus, the identified trends in disability development will be aimed at reducing the incidence and disability of the population due to chronic obstructive pulmonary disease by improving the effectiveness of prevention, early diagnosis, treatment, and rehabilitation of this category of patients and individuals with disabilities.

References

1. Bagdasaryan, D.G. Methodological materials "Planning and forecasting in the activities of healthcare organizations." Pyatigorsk, 2020 – 309 p.

2. Kasiev, N.K., Kanatbekova, G.K. Planning and forecasting in the healthcare system. // Bulletin of science and practice, 2020 – Vol. 6, No. 5. – Pp. 195-202.

3. I.M. Son, A.V. Polikarpov, G.A. Alexandrova [et al.] Methodological recommendations for algorithms for calculating indicators of the national project "Healthcare." M.: EPD CRIOIH MH RF, – 2020, – 108 pp.

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现代年轻人对全球创新技术发展的态度和看法，在拓展他们视野的同时，不仅对他们的饮食习惯产生了不利影响，还助长了被动吸烟等非传染性疾病的高发，对儿童的生长发育造成负面影响。

THE MODERN ATTITUDE AND VIEWS OF YOUNG PEOPLE TOWARDS THE DEVELOPMENT OF GLOBAL INNOVATIVE TECHNOLOGIES, WHICH, ALONG WITH EXPANDING THEIR HORIZONS, HAVE A HARMFUL EFFECT NOT ONLY ON THEIR EATING BEHAVIOR BUT ALSO CONTRIBUTE TO THE HIGH DEVELOPMENT OF NON-COMMUNICABLE DISEASES SUCH AS PASSIVE SMOKING, WHICH HAS A NEGATIVE IMPACT ON THE GROWTH AND DEVELOPMENT OF THE CHILD'S BODY

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摘要：被动吸烟会影响学龄儿童的饮食习惯和进食行为，进而影响其体重超标，而体重超标是肥胖的危险因素。过量摄入碳水化合物会导致代谢紊乱，并增加胰腺胰岛素的分泌。细胞对胰岛素（一种负责葡萄糖分解的关键激素）的敏感性降低。当胰岛素过量时，葡萄糖更容易转化为脂肪。皮下脂肪组织的分布与男性原发性肥胖的心理生理和代谢特征密切相关。此外，肥胖本身也会降低组织对胰岛素的敏感性，从而导致2型糖尿病的发生。

关键词：心理情绪障碍，进食障碍，被动吸烟，学龄儿童，人体测量指标，健康生活方式。

Abstract. *The dietary habits and eating behaviors of schoolchildren exposed to passive smoking influence the development of excess body weight, which is a risk factor for obesity. Excessive carbohydrate intake leads to metabolic disturbances and increased insulin production by the pancreas. Cellular sensitivity to the*

crucial hormone insulin, responsible for glucose breakdown, is reduced. When exposed to excess insulin, glucose is easily converted into fat. The distribution of adipose tissue in subcutaneous depots is associated with psychophysiological and metabolic characteristics underlying the development of primary obesity in men. Furthermore, obesity reduces tissue sensitivity to insulin itself, leading to the development of type 2 diabetes.

***Keywords**: psycho-emotional disorder, eating disorder, passive smoking, schoolchildren, anthropometric indicators, healthy lifestyles.*

Doctors believe that the root cause of smoking is often internal problems [1-4]. It's crucial to prevent a smoker's body from switching to another addiction. After all, nicotine withdrawal can lead to cravings for overeating and alcohol, along with the development of dangerous non-communicable diseases such as psycho-emotional disorders, hypercholesterolemia, eating disorders, and obesity [5,6]. The diet and eating habits of schoolchildren exposed to secondhand smoke influence the development of excess body weight, which is a risk factor for obesity. Excessive carbohydrate intake leads to metabolic disorders and increased insulin production by the pancreas. Cellular sensitivity to the crucial hormone insulin, responsible for glucose breakdown, decreases [7]. When exposed to excess insulin, glucose is easily converted into fat. The distribution of adipose tissue in subcutaneous depots is associated with psychophysiological and metabolic factors underlying the development of primary obesity in men [8-10]. Obesity reduces tissue sensitivity to insulin itself. This leads to the development of type 2 diabetes. Smoking cessation, in addition to withdrawal symptoms, is usually accompanied by weight gain [11]. People who quit smoking develop symptoms associated with nicotine withdrawal: increased irritability, depressed mood, anxiety, stress, deteriorating relationships with friends and family, difficulty concentrating, increased hunger and binge eating, insomnia, decreased physical activity, and cravings for tobacco [12,13]. Weight gain with age occurs in both smokers and non-smokers, but is more pronounced among moderate smokers. This is presumably due to the accelerated metabolism caused by nicotine. As excess weight increases, smokers resume smoking, influenced by their appearance as a factor in psycho-emotional stress. For many smokers, especially women, fear of weight gain is the primary motivator for continuing smoking. Social media, internet clubs, and leisure activities such as cafes, bars, and mini-restaurants are significant factors in schoolchildren's eating disorders and smoking addiction [14-17]. These activities often involve young people sitting in comfortable chairs and sofas, watching sports on TV, and using computers, tablets, and phones. All of this is accompanied by copious amounts of smoke from lit cigarettes, hookahs, and e-cigarettes. Reduced physical activity directly leads to overeating, hormonal imbalances, and obesity,

which negatively impacts schoolchildren's anthropometric measurements [18,19]. Social media platforms should take responsibility for reducing the negative effects of body image. These platforms often promote body ideals, diets, or plastic surgery, which undermines users' body positivity and healthy lifestyles [20]. Seeing this, young men and women tend to think in this direction and try to create an ideal image of themselves, which leads to high levels of anxiety and stress, leading to unhealthy habits [21-24]. Families have a great influence on their children's eating behavior, body image, and health. Parents can help reduce the risk of eating behavior disorders, EBD in children by talking to their children in an open, constructive, supportive and understanding manner about healthy eating habits, body image, self-esteem and emotional health [25,26-29]. Parents should teach their children healthy eating habits, introduce them to foods from different food groups, explain the importance of healthy eating and set a positive example of healthy eating. Parents should teach their children not to restrict foods, not to diet, not to label foods as "good" or "bad," and not to create feelings of guilt or shame about eating [30-33]. Family meals are a great opportunity for children to learn healthy eating habits, to communicate with family members, and to create a positive food environment [34]. Parents should teach their children to love, accept, respect, and care for their bodies, not to pressure them about their body shape and weight, to make positive, encouraging, and supportive comments about their appearance, and to value their inner qualities and abilities [35,36]. Parents who have a positive attitude about their bodies, have self-esteem, live a healthy lifestyle, and manage body image concerns can help children develop a positive attitude about their bodies, increase their self-esteem, and resist body image issues. EBD, sometimes can be related to emotional problems, including stress, anxiety, depression, loneliness, anger or trauma [37]. Parents should meet their children's emotional needs, provide them with support, listen to their problems, create a safe environment for them to express their emotions and teach them stress management skills. Family feeding programs are designed to help parents prepare healthy foods with their children, create a positive environment during meals, solve problems related to nutrition, strengthen communication between family members and form a healthy lifestyle [38-40]. Family feeding programs, healthy eating in children. The schools should provide education about healthy eating, body image, mental health, the harms of smoking, protection from the negative effects of social media, and social skills. This education can help students understand the importance of healthy eating, body image pressures, the dangers of obesity, the importance of emotional health, and the role of social skills. Education should be interactive, fun, age-appropriate, and culturally sensitive. It can help develop healthy eating habits, develop positive body image, increase self-esteem, maintain emotional health, and reduce the risk of obesity. The food environment has a significant impact on people's eating

behaviors [41].. The food environment includes the physical, economic, social, and cultural factors that facilitate or hinder people's food choices. Limited access to healthy foods, their high cost, lack of accessibility, poor quality, or the availability, cheapness, attractiveness, and increased advertising of unhealthy foods can lead people to choose unhealthy foods, fail to develop healthy eating habits, and increase the risk of obesity [42,43].

Purpose of work. On the basis of a questionnaire conducted among schoolchildren, as well as an anonymous study of their outpatient cards in district polyclinics at the place of their residence, to conduct among schoolchildren and their parents social and prophylactic explanatory work on measures to eliminate such non-infectious diseases as disorders of eating behavior, passive smoking, psycho-emotional failure and obesity.

Materials and methods. By examining anthropometric indicators, it is possible to estimate the physical development of children and its compliance with age norms. This is especially important in childhood. Identified deviations may be risk factors or symptoms of certain diseases. They decided to determine the measurements of height, weight and volume of the chest by dividing schoolchildren into two groups - exposed and not exposed to passive smoking. The work was carried out as part of the study of the impact of family passive smoking on the health and performance of children. We developed a questionnaire containing 7 blocks of questions on various social and hygienic aspects of passive smoking. The questionnaire contained two parts, one part was filled out by students, and the other by their parents. The work was carried out in 5 city secondary schools (Yasamal, Narimanov and Sabunchin districts). It was also decided to compare the anthropometric measurements of children, whose cards were examined by us in district clinics for the presence of their diseases under anonymous conditions during the year. Only completely filled out questionnaires were included in the development. 6000 questionnaires were distributed to all students. Of them, 2,363 were completely filled in, and the answers of 3,895 parents - 1,885 fathers and 2,010 mothers - were included. Each of the 2363 questionnaires represented the 1st student. Depending on the intensity of smoking, all families were divided into 2 groups: 818 families (tobacco dependent) and 1545 families (tobacco dependent, i.e. control group). According to the intensity of passive smoking, the tobacco-addicted group of families was divided into: 1st group – 204 families, tobacco addiction is weak, less than 5 cigarettes/day; 2nd group – 252 families, moderate tobacco addiction – from 5-15 cigarettes/day, and 3rd group – 362 families, parental smoking, heavy tobacco addiction, more than 15 cigarettes/day. Measurements were carried out separately among boys and girls. Observations were carried out in the most anthropometrically significant age groups of schoolchildren. Each anthropo-

metric indicator - weight, height and volume of the chest was analyzed separately and, if necessary, compared with others.

Results and discussion. According to the data in Fig. 1, the first anthropometric studies on the effects of passive smoking on children yielded very interesting results. First, let's look at the growth rates of schoolchildren. Across all age groups, the height of boys in Group 1, according to the reliable value of the Van der Waerden criterion ($x = 6.13$; $p < 0.01$), is higher than that of boys in Group 2. It should also be noted that schoolchildren in Group 1 are much more likely to have various nosological forms of somatic and infectious-parasitic diseases than schoolchildren in Group 2, and it is possible that their combined effects contribute to an even greater growth retardation. Overall, the height of boys in Group 1 was 2.7-9.7 cm shorter than that of boys in Group 2. The reliability of the data was confirmed by the Van der Waerden test ($x=7.16$; $p<0.01$). The Van der Waerden test was also reliable when comparing similar data sets for chest circumference ($x=5.63$; $p<0.01$). Thus, in Group 1, the chest circumference among boys was 2.0-3.6 cm shorter than that of similar boys in Group 2. The impact of passive smoking on children's physical development occurs across all age groups, with no discernible differences. Therefore, we calculated the weighted arithmetic means for all observed groups, excluding age differences. At first glance, the differences in anthropometric indicators between schoolchildren exposed to passive smoking and those without it are not that significant. For example, height is shorter, on average, among boys by 4.39±0.26 cm. We have already noted that height is a systemic indicator of the normal functioning of the body and its dynamic, consistent development. Therefore, even a slight growth retardation, which is facilitated by passive smoking, indicates poor body function. On average, boys weigh 2.52±0.19 kg more. This is confirmed by the fact that excess weight, albeit slight, is observed in tobacco-dependent schoolchildren. This is due to a chain of interrelated phenomena: passive smoking reduces physical activity, children lead a sedentary lifestyle, and their body weight increases. Moreover, excess weight itself is an independent risk factor that adversely affects children's health. Increased body weight also leads to a parallel increase in chest circumference - it is greater in boys by 2.53±0.16 cm. The effectiveness of family feeding programs depends on educating, supporting, engaging parents in the programs, and building healthy relationships with their children. Creating a healthy food environment requires changing local food industries, trade policies, food safety standards, and food culture. Expanding treatment options involves increasing the number of psychologists, psychiatrists, nutritionists, social workers, and other health professionals, specializing in EBD, and ensuring that treatment services are accessible, high-quality, and affordable.

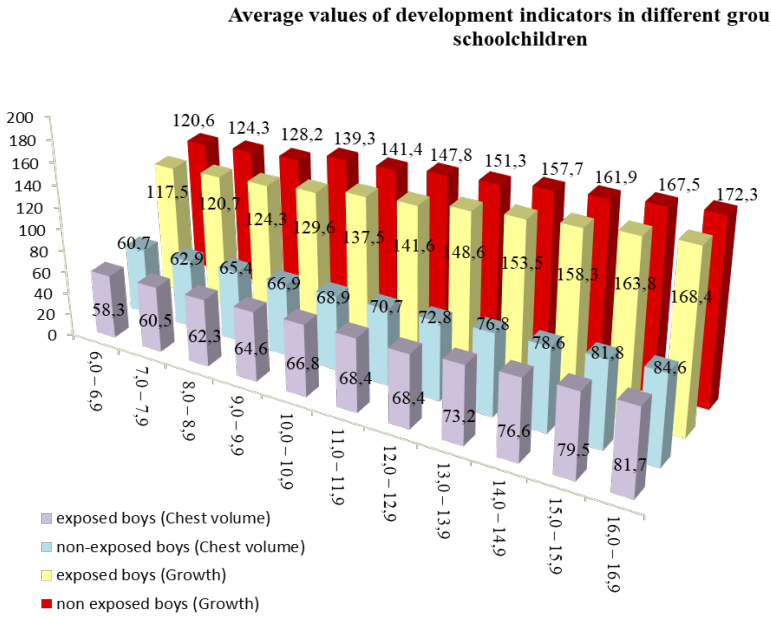

Figure 1. *Exposure to passive smoking by age among boys*

Conclusion. Scientific data indicates that the prevalence of attention deficit hyperactivity disorder and autism is currently increasing among children and adolescents. It has been recognized that children and adolescents, along with adults, should be included in preventative mental health programs. Children, adolescents, and young adults should not only be informed about risk factors but also actively participate in shaping their own health and the health of those around them. Young people can also be notified to limit the time they spend on social media, take breaks from social media, and spend more time on social activities in real life. Conscious use of social media can help protect young people from the negative effects of social media and protect their psychological health. Meeting children's emotional needs can help them cope with stress, regulate their emotions, maintain their psychological health, and reduce their risk of developing EBD. Schools should provide an important environment for the prevention of EBD. Programs implemented in schools for the prevention of EBD should focus on educating adolescents about healthy eating, body image, self-esteem, emotional health, and social skills, developing healthy eating habits, creating a positive attitude towards body image, developing stress coping skills, protecting them from the negative effects of social media, and reducing the risk of EBD.

Literature

1. Babaev P.N. The relationship between seeking medical care and susceptibility to psychosomatic diseases of schoolchildren with the factor of passive smoking Svpn. 2020.OmskNo.2 (107) p 75-81.

2. Eisenberg M.J., Grandi S.M., Gervais A. et al. Bupropion for smoking cessation in patients hospitalized with acute myocardial infarction: a randomized, placebo-controlled trial. J Am Coll Cardiol. 2013;61:524-32. doi:10.1016/j.jacc.2012.08.1030.

3. Korotkova A.A. Teaching Oral Hygiene to Schoolchildren / A.A. Korotkova, A.S. Pyrkina // Science. Heritage. University: Collection of Materials of the 56th International Scientific Student Conference. Dedicated to the Year of Cultural Heritage of the Peoples of the Russian Federation, the Year of Outstanding Fellow Countrymen in the Chuvash Republic (Cheboksary, April 8–15, 2022). – Cheboksary: Chuvash State University named after I.N. Ulyanov, 2022. – P. 396–401.

4. Chursina O.A., Konstantinova O.D., Sennikova Zh.V., Demina L.M., Loginova E.A. The Impact of Active and Passive Smoking on the Course of Pregnancy and Childbirth. Russian Bulletin of Obstetrician-Gynecologist. 2019;19(4):-52.

5. Aleksandrov A.A., Rozanov V.B., Dadaeva V.A., Kotova M.B., Ivanova E.I., Drapkina O.M. Association of smoking status and smoking intensity with general and abdominal obesity in a sample of middle-aged men. Cardiovascular Therapy and Prevention. 2020; 19(3): 2446. https: //doi.org/10.15829/1728-8800-2020-2446

6. Tsareva N. M. Relevance of anti-tobacco propaganda among children and adolescents / Tsareva N. M., Tsareva Yu. A. // Actual problems of children's life safety and ways to solve them: collection of materials of the All-Russian scientific and practical conference with international participation / under the general editorship: N. V. Timushkina, D. V. Vorobyov. - Balashov, 2017. - Pp. 443-448.

7. Babayev P.N. Characteristics of tobacco smoking in families of Baku and assessment of the effectiveness of measures to protect children from the effects of passive smoking. / Azerbaijan Medical Journal / Department of Public Health and Health Organization / Azerbaijan Medical University / 2013 / pp. 68-73.

8. Shestakova M.V., Chazova I.E., Shestakova E.A. Russian multicenter screening study to detect undiagnosed type 2 diabetes mellitus in patients with cardiovascular pathology. Diabetes mellitus. 2016;19(1):24–29. DOI: 10.14341/DM7765.

9. Makhov M.A. Comorbidity of alcohol and nicotine addiction. Narcology. 2014; 6: 91–101.

10.Keles M., Avsar U., Avsar Z. et al. Effect of kidney transplantation on smoking habits of kidney donors. Transplantation Proceedings 2015; 47 (5): 1302-1305

11.P.N. Babayev, S.F. Mirgadi / The prevalence of passive smoking among school-age children has a detrimental effect on their health and development / Modern achievements of Azerbaijani medicine / No. 2.2024 / pp. 152-157

12.Babina K.S. Index evaluation of the effectiveness of various means and methods of individual oral hygiene: Abstract of Cand. Sci. (Medicine) dissertation: 14.01.14 /K.S.Babina –M.,2014.–24 p.

13.Davydova, L.A. Formation of psychoneurological disorders in children born premature with very low and extremely low body weight / L.A. Davydova, N.N. Zavadenko // Consilium Medicum. Pediatrics. - 2018. - No. 1. - P. 111-116.

14.Skoblina N.A. Chapter 3. Physical development and health status of children: methods for assessing physical development // Skoblina N.A., Milushkina O.Yu., Setko N.P. et al. Physical development of children: fundamental and applied aspects. Moscow: Union of Hygienists, 2018. pp. 59-68.

15.Babayev P.N., Musayev R.G./Passive smoking as a social and public ailment among schoolchildren in Baku./journal. Modern achievements of Azerbaijani medicine. Azerbaijan Medical University. No. 1, 2024, pp. 244-248.

16.Almirall J., Serra-Prat M., Bolibar I. Passive smoking at home is a risk factor for community-acquired pneumonia in older adults: a population-based case-control study // Community Acquired Infection. - 2015. - Vol. 2. - P.32-37.

17.Anifandis G., Bounartzi T., Messini C., Dafopoulos K., Sotiriou S., Messinis I.E. The impact of cigarette smoking and alcohol consumption on sperm parameters and sperm DNA fragmentation (SDF) measured by Halosperm. Arch. Gynecol. Obstet. 2014;290:777–782.

18.Kuprina I.V., Kiseleva E.A., Grishkyan T.M., Grishkyan A.M., Kiseleva K.S., Kiselev D.S. The influence of parental smoking on the incidence of caries in primary teeth in children. — Clinical dentistry. — 2020; 3 (95): 132—135. DOI: 10.37988/1811-153X_2020_3_132.

19.O. N. Titova, V. D. Kulikov, O. A. Sukhovskaya. Passive smoking and respiratory diseases // Medical Alliance. - 2016. - P. 73-77.

20.Kalyagin A.N. School for Overcoming Tobacco Addiction / A.N. Kalyagin, E.A. Shvetsova// Fundamentals of Life Safety. - M., 2017. - No. 2. - P. 22-24.

21.Lotti F., Corona G., Vitale P., Maseroli E., Rossi M., Fino M.G., Maggi M. Current smoking is associated with lower seminal vesicles and ejaculate volume, despite higher testosterone levels, in male subjects of infertile couples. Hum. Reprod. 2015;30:590–602.

22.How tobacco smoke causes disease: the biology and behavioral basis for smoking–attributable disease : a report of the Surgeon General. – Rockville, MD:Dept. of Health and Human Services, Public Health Service, Office of Surgeon General, 2010. P. 704.

23.Babaev P.N., Mamedov R.M. The impact of passive smoking on the dental health of schoolchildren / journal Modern Dentistry / Azerbaijan Medical University. 2011 pp. 14-16

24.Aleksandrov A.A., Rozanov V.B., Dadaeva V.A., Kotova M.B., Ivanova E.I., Drapkina O.M. Association of smoking status and smoking intensity with general and abdominal obesity in a sample of middle-aged men. Cardiovascular Therapy and Prevention. 2020; 19(3): 2446. https: //doi.org/10.15829/1728-8800-2020-2446

25.Novoselova E.N. The fight against smoking as a factor in the formation of a healthy lifestyle. Bulletin of Moscow University. Series 18. Sociology and political science. 2019; 25(4): 309–324. https://doi.org/10.24290/1029-3736-2019-25-4-309-324

26.H.J. Sabbagh, M. Hassan Ahmed Hassan, N. P. T. Innes, H. M. Elkodary, J. Little, P. A. Mossey. Passive Smoking in the Etiology of Non-Syndromic Orofacial Clefts: A Systematic Review and Meta-Analysis // PLoS One. — 2015.

27.Kulikov V. A. Passive smoking and its consequences. Bulletin of Pharmacy. 2017. pp. 98-102.

28.Babaev P.N., Musaev R.G., Mirgadi S.F./Decreased immunity of schoolchildren due to the influence of passive smoking/Journal of Allergology and Clinical Immunology./Azerb. med. univ./vol.12; No. 1, pp.51-56. 2024.

29.Bryun E.A., Buzik O.Zh., Kutyshev O.T., Lykov V.I. Prevention and treatment of tobacco addiction. Methodological recommendations of the Moscow Department of Health No. 29, parts 1 and 2, 2016: 60 p.

30.Galiakberova, I. L. Problems and prospects of using the neuropsychological approach in a population study of population viability / I. L. Galiakberova, E. A. Mysnikova // World of Science. - 2017. - No. 4 (5). - P. 6.

31.Giovino G.A., Mirza S.A., Samet J.M. et al. GATS Collaborative Group. Tobacco use in 3 billion individuals from 16 countries: an analysis of nationally representative cross-sectional householdsurveys.Lancet.2012;380:668-79. doi:10.1016/S0140-6736(12)61085-pmid:22901888.

32.World Health Organization. Cancer fact sheet [cited by Feb 01, 2019]. Available from: http://www.who.int/media - centre/factsheets/fs297/en/.

33.Hartmann-Boyce J., Chepkin S.C., Ye W. et al. Nicotine replacement therapy versus control for smoking cessation. Cochrane Database Syst Rev. 2018;5:CD000146. doi:10.1002/14651858. CD000146.pub5.

34.Suissa K., Larivière J., Eisenberg M.J. et al. Efficacy and Safety of Smoking Cessation Interventions in Patients With Cardiovascular Disease: A Network Meta-Analysis of Randomized Controlled Trials. Circ Cardiovasc Qual Outcomes. 2017; 10:e002458. doi:10.1161/CIRCOUTCOMES.115.002458.

35.Koegelenberg C.F., Noor F., Bateman E.D. et al. Efficacy of varenicline combined with nicotine replacement therapy vs varenicline alone for smoking

cessation: a randomized clinical trial. JAMA. 2014;312:155-61. doi:10.1001/jama.2014.7195.

36.Nadezhdin A.V., Tetenova E.Yu. Nicotine addiction: diagnosis and treatment. Medicine, 2016; No. 3: pp. 164-189.

37.Ibragimova E.E., Yakubova E.F., Yakubova Z.A. Assessment of the impact of smoking on visceral organs and regulatory functions of the body. Population Health and Environment. 2018; 3 (300): 51–54/doi.org/10.35627/2219-5238/2018-300-3-51-54.

38.Kozlov V.A., Golenkov A.V., Sapozhnikov S.P. Formation of harmful minor impurities during simultaneous alcohol consumption and tobacco smoking. Narcology. 2014;3:74-80.

39.Babayev P.N., Nagieva R.K. Passive smoking as a risk factor for ophthalmological morbidity in schoolchildren and its social and hygienic characteristics./Azerb. ophthalmological journal/ Azerbaijani medical university/ 2020/3 (34) pp. 28-37.

40.Bushueva T.V., Borovik T.E., Zvonkova N.G., et al. The role of nutrition in providing vitamin D // Practical Medicine. 2017; 106(5): 14–18.

41.Martinchik A.N., Baturin A.K., Keshabyants E.E., Peskova E.V. Retrospective assessment of anthropometric indicators of Russian children in 1994-2012 according to the new WHO standards // Pediatrics. Zhurn. im. G.N. Speransky. 2015. Vol. 94, No. 1. P. 156-160.

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精氨酸酶抑制剂L-正缬氨酸在改良的离体节段性小肠缺血模型中的抗缺血活性
ANTI-ISCHEMIC ACTIVITY OF THE ARGINASE INHIBITOR L-NORVALINE IN A MODIFIED MODEL OF ISOLATED SEGMENTAL SMALL INTESTINAL ISCHEMIA

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摘要：小肠缺血是多种病理状况（尤其是闭塞性病变）的重要致病因素。研发具有显著抗缺血作用的药物是药物治疗领域最重要的任务。在药物活性研究中，建立一个能够高度可靠地重现病理过程的合适模型至关重要。本研究在改良的急性肠系膜缺血模型中考察了L-正缬氨酸的作用，发现其在恢复呼吸链酶活性方面比在未阻断侧支循环的模型中更为显著。

关键词：缺血，再灌注，小肠，L-正缬氨酸。

Abstract. *Ischemia of the small intestine is an important pathogenetic factor in many pathological conditions, primarily occlusive lesions. The development of drugs with a pronounced anti-ischemic effect is the most important task in pharmacotherapy. The presence of an adequate model reproducing the pathological process with a high degree of reliability is mandatory in the study of drug activity. When studying the effect of L-norvaline on a modified model of acute mesenteric ischemia, we found its greater significance in restoring the activity of respiratory chain enzymes than in the model without eliminating collateral blood flow.*

Keywords*: ischemia, reperfusion, small intestine, L-norvalin.*

Ischemia of the small intestine is an important pathogenetic factor in many pathological conditions, primarily occlusive lesions. One of the main problems in the treatment of mesenteric ischemia is the lack of well-developed approaches to personalized pharmacocorrection. The arginase inhibitor L-norvaline seems to be a promising drug for the correction of ischemic disorders, but the mechanisms of anti-ischemic action have not been fully identified [3]. Earlier, we noted a marked difference in the nature of ischemic and reperfusion disorders of the tissues of the small intestine and pancreas, which can serve as a starting point for the formation of differences in approaches to pharmacotherapy of these pathological conditions [1]. In the course of previous studies [5], a change in the activity of respiratory chain enzymes was found, however, in some animals, the presence of collateral vessels passing along the small intestine was noted, on which segmental ischemia and reperfusion were modeled, which led to a change in data in areas with collateral blood flow.

The aim of the study was to determine the effect of the arginase inhibitor L-norvaline on the activity of respiratory chain enzymes in segmental mesenteric ischemia in its optimized model.

Materials and methods

The study was performed on 12 male white Wistar rats weighing 250 ± 25 g.

The arginase inhibitor L-norvaline was administered intraperitoneally at a dose of 15 mg/kg 30 minutes before the simulation of ischemic and reperfusion injury.

The NADH activity level was measured by biofluorescence using laser Doppler flowmetry using the LASMA-D software and hardware complex.

The simulation of an episode of deep 30-minute ischemia followed by reperfusion was approached as carefully as possible due to the marked variability in the anatomy of this segment of the small intestine and the presence of collateral extending along the wall of the small intestine or sinking into it. Segmental mesenteric ischemia was reproduced by occlusion of 3 segmental and two collateral arteries, additionally, in order to eliminate collateral blood flow, occlusion of two arteries passing along the intestinal wall was performed, the effectiveness of occlusion was checked by laser Doppler flowmetry based on the absence of blood flow in the microcirculatory bed [4].

All manipulations were performed intraperitoneally under general anesthesia with xylazine at a dose of 6 mg/kg and zoletil 100 at a dose of 50 mg/kg.

Results and its discussion

In order to determine the possibility of correcting ischemic and reperfusion effects on the activity of respiratory chain enzymes, we recorded NADH biofluorescence with a blue-spectrum laser in the wavelength range from 350 to 560 nm in the model, as well as against the background of L-norvaline correction.

In the course of the work, the following indicators were obtained

In the intact group, NADH activity was at the level of 45.72±3.12 units.

An episode of deep 30-minute ischemia resulted in a decrease in NADH activity to 31.84±2.25units.

Restoration of blood flow in the small intestine segment lasting 30 minutes resulted in a slight increase in biofluorescence to the level of 34.76±3.12 units.

Intraperitoneal administration of L-norvaline at a dose of 15 mg/kg resulted in a decrease in biofluorescence to a level of 38.63±4.3 units, against the background of a prolonged 30-minute episode of ischemic exposure simulation. This indicator is 1.18 times higher than in the ischemia group. The resumption of blood flow in the basins of the occluded arteries against the background of the administration of L-norvaline led to an increase in the biofluorescence level to 42.10±3.78units.

A similar reaction of respiratory chain enzymes to the administration of L-norvaline partially explains the effect of this drug on the volume of necrotic tissues in the segmental mesenteric thrombosis model [3].

The presence of a restoration of NADH activity is a characteristic feature in the reperfusion group and an increase in the biofluorescence level to 42.10±3.78units can be explained by an increase in the blood flow rate in the microcirculatory bed of the small intestine [2].

An interesting fact is the increase in nitric oxide production against the background of arginase blockade, thus arginase becomes one of the most attractive targets for the pharmacological correction of various pathological conditions, given its involvement in the pathogenesis of a large number of diseases based on a decrease in nitric oxide production. In this regard, one of the likely points of realization of the protective effect of L-norvaline may lie in the pharmacological modeling of the effects of the second or delayed window of ischemic preconditioning.

Conclusion

Thus, ischemia leads to a decrease in the activity of respiratory coenzymes, however, the restoration of blood flow in segmental arteries followed by reperfusion does not significantly affect the change in the activity of respiratory chain coenzymes by the 30th minute of reperfusion. Administration of L-norvaline at a dose of 15 mg/ kg 30 minutes before the simulation has a more pronounced effect than in the variant without occlusion of the collateral arteries running along the wall of the small intestine. This may indirectly indicate the mechanisms of the protective effect similar to those of direct and distant ischemic preconditioning, since it is known that the protective effect of these phenomena decreases in areas with collateral blood flow.

References

1. Alekhin S. A., Bezhina E. N., Firsova T. I., Nazarenko D. P. The nature of ischemic and reperfusion injuries of the tissues of the small intestine and pancreas as the basis for differences in approaches to pharmacological correction // Innova. – 2022. – Vol. 2, № 27. – P. 6-10.

2. Bezhina E. N., Alekhin S. A., Artyushkova E. B.«u соавт.». Effect of L-norvaline on the small intestinal wall blood perfusion in a model acute segmental mesenteric thrombosis // Archivos Venezolanos de Farmacologia y Terapeutica. – 2020. – Vol. 39, № 5. – P. 556-560.

3. Alekhin S. A., Bezhina E. N., Nazarenko D. P., Druzhikin L. V. First discovered positive effect of L-norvaline on the volume of small intestine tissues necrosis in a model of segmental mesenteric thrombosis in rats // Research Result in Pharmacology. – 2023. – Vol. 2, № 9. – P. 17-19.

4. Alekhin S. A., Kolmykov D. I., Bezhina E. N. Response of abdominal organs microcirculation to the recombinant erythropoietin action in ischemia and reperfusion // International Conference "Scientific research of the SCO countries: synergy and integration", Beijing, China 2019. – 2019. – Vol. 2. – P. 115-119.

5. Bezhina E. N., Alekhin S. A., Druzhikin L. V. The effect of the arginase inhibitor L-norvaline on NADH activity in small intestine ischemia // Genetic technologies for biology and medicine: proceedings of the International Scientific and practical conference, Belgorod (Russia), Dezhou (China), November 2024 / edited by M.V.- Pokrovsky. – P. 8-10.

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维加-哈雷号探测器的防陨石保护：如何实现
ANTI-METEORITE PROTECTION OF THE VEGA-HALLEY SPACECRAFT: HOW IT WAS DONE

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摘要：本文简要回顾了维加号探测器防陨石屏蔽模型的构建历史。显然，基于两层或三层空间分离屏蔽层的防陨石屏蔽方案最早由R. Z. Sagdeev提出。本文阐述了计算实验在研究目标与撞击体高速相互作用过程中的作用。V. F. Minin及其应用物理研究所团队与V. E. Fortov及其化学物理研究所团队的积极合作，促进了防陨石屏蔽物理机制的成功开发和理解。该研究建立了维加号探测器防护罩与微陨石相互作用时的物理模型，并确定了复杂的防护参数，包括第一层屏蔽层中剥落元素的动态特性及其对第二层屏蔽层的冲击。此外，本文还评估了撞击后产生的等离子体射流参数以及撞击物在不同角度下对屏蔽层法线的相组成。最后，本文介绍了美国同行对该建模项目的意见。

关键词：航天器保护，计算实验，Vega项目。

Abstract. *This paper briefly reviews the history of modeling the anti-meteorite shielding for the Vega spacecraft. Apparently, anti-meteorite shielding based on two and three spatially separated shields was first proposed in the works of R. Z. Sagdeev. The role of a computational experiment in studying high-speed interaction processes between the target and the impactor is demonstrated. The successful development and understanding of the physics of anti-meteorite shielding was facilitated by the active collaboration between V. F. Minin and the team from the Institute of Applied Physics and V. E. Fortov and his team from the Institute of Chemical Physics. The research allowed us to develop a physical model for the destruction of the Vega spacecraft's protective shields upon interaction*

with micrometeorites and determine complex protection parameters, including the dynamic characteristics of spall elements in the first shield and their impact on the second shield. We also assessed the parameters of the resulting plasma jets and the phase composition of the destruction products upon impact at various angles to the shield normal. The opinion of American colleagues on this project regarding modeling is presented.

***Keywords**: spacecraft protection, computational experiment, Vega project.*

Introduction. The Vega space project was developed under the leadership of Academician R. Z. Sagdeev (Deputy Chairman - R. Pella, F. Szabo) at the Space Research Institute of the USSR Academy of Sciences with the participation of colleagues from Austria, Bulgaria, Hungary, the GDR, Poland, Czechoslovakia, France, and the FRG. This space mission combined the flyby of Venus and the flyby of Halley's Comet by two identical spacecraft, Vega 1 and Vega 2, in 1984. To protect against hypervelocity impacts from microparticles, the concept of two (in some cases, three) shields, spaced at a certain distance from each other, was used [1]. The operating principle of such shielding was qualitatively substantiated in [2]. In [1, 2], it was assumed that the outer layer of the shield acted as an evaporator for the dust particle, and as a result of a microexplosion, a microcrater would form in it, with fragments at large angles to the original direction of the particle's motion flying in different directions. The second shield was intended to dampen the energy of particles that penetrated the first shield.

It should be noted that these studies are important from historical, scientific, and human perspectives, as this relates not only to issues of research priority. Knowledge and citation of "ancient" publications also demonstrates significant respect for the contributions of colleagues in the relevant field, as well as a fair assessment of results from a modern perspective and a culture of human interaction in science. The purpose of the following brief account of the history of the development of meteorite shielding for spacecraft is to convey an impression of the cohort of "great" scientists of those years and a glimpse of that creative time. Scott Fitzgerald, in the words of his character in "The Great Gatsby," said: "We try to swim forward, fighting the current, but it keeps sweeping our little boats back into the past."

Collaboration. In the early 1980s, V.E. Fortov joined the project on behalf of the Institute of Chemical Physics of the Russian Academy of Sciences. At that time, he traveled extensively throughout the country and the world delivering his lectures on the semi-empirical equation of state of matter under extreme conditions. In the late 1970s and early 1980s, he met Vladilen Fedorovich Minin (Fig. 1, iiii), the founder and director general of the Institute of Applied Physics (IAP, Novosibirsk). Alan Turing once said, "Sometimes it's the people no one imagines

who do what no one imagines." The difficult beginning of the IAP's founding under V.F. Minin's leadership was determined by the spectacular demonstrations of his laboratory's achievements in the summer of 1964, where his talent was recognized by the outstanding physicist, academician, and then President of the USSR Academy of Sciences, M.V. Keldysh (Fig. 1, i). One of M.V. Keldysh's exceptional traits, extremely important for a scientist and high-level manager, was his ability to evaluate and understand the achievements and results of others, including in fields not particularly close to his own. V. F. Minin, who was already known as "the encyclopedic man" in the then-under-construction Novosibirsk Academic City, possessed this trait. Throughout his life, he carried a love of science (as defined by L. Feuerbach)—a love of truth, which is why honesty is the fundamental virtue of a scientist.

V.E. Fortov requested that the Institute of Applied Physics be involved in a project to protect spacecraft from dust particles. Figure 1. ii. V.E. Fortov, E.I. Shemyakin, and V.F. Minin at the All-Union Conference on the Problems of Cumulation and High-Velocity Impacts at the Institute of Applied Physics. There were not many willing to take on this topic, since there was no understanding of the physics of impacts with such energies and velocities. It should be noted that for the correct interpretation of computational experiments, it is necessary to have a deep understanding of the hydrodynamics of explosive flows [3], and to be able to conduct complex modeling with real parameters of matter under extreme pressures and temperatures. V.F. Minin possessed precisely this knowledge and the corresponding experience. Since 1977, the Institute of Applied Physics (IAP) has operated a 24-hour computing complex consisting of two BESM-6 computers, linked by disk memory and connected via high-speed channels to minicomputers with analog and digital displays of the Gamma series (also developed at IAP entirely using Soviet components—subsequently, all television centers in the USSR were equipped with them) and other service devices. Taking into account the institute's achievements, in 1980, an industry-specific research center for the mathematical modeling of non-stationary processes in continuous media was established within the IAP Computer Center. It was deservedly considered one of the best in the USSR in terms of both hardware, software, and personnel. Only by leveraging IAP's experience in full-scale modeling, including experimental models, of high-speed impact processes and the corresponding scientific potential was it possible not only to thoroughly investigate the interaction of hypervelocity dust particles with multilayer screens and the plasma formation process, but also to optimize its characteristics. It should be noted that IAP researchers rarely published many of their results in the open press at that time.

Computational Experiment. However, a computational experiment, when applied to the real world, can sometimes lead to self-deception, although it is often

useful and remains the only "tool" for knowledge. We must remember and take into account that some idealization always occurs when constructing a model, and according to the rules of formal logic, we operate with these idealized objects, explaining everything that can be explained based on them. According to V.F. Minin, a computational experiment should be capable of being conducted by a physicist or designer, not just a developer of the corresponding codes or a programmer. As F. Klein aptly put it, the "subtle poison" of mathematical education is that the absolutized model no longer describes reality and becomes distant from it.

Based on many years of research at the Institute of Applied Physics under the direction of V.F. Minin, along with various numerical methods enabling parallelization of processes, a new general technology for computational experiments was developed at that time [5]. In general, the concept of a "computational experiment" (CE) is broader than the methodology of simple modeling. The main difference is that a CE allows one to answer the question: "What will happen if...?" [5]. At the Institute of Applied Physics, a software and hardware system meeting the requirements of a mass-scale CE was tested on a system of two BESM-6 computers, and then implemented using two 64-processor computers based on the PS-2000 and a Gamma series graphics station. Details of the algorithm and capabilities of the computing complex of that time can be found in [5].

Results. As a result of intensive research, a physical model of the destruction of the Vega spacecraft's protective shields under the impact of micrometeorites was developed. The successful solution of this problem was largely facilitated by the active collaboration of V.F. Minin and the IAP team with V.E. Fortov and his colleagues (seconded at Fortov's request from the OIKhF and LPI, who spent their time at the IAP) from the Physics Institute, headed by Academician A.M. Prokhorov. The conducted series of VE allowed us to develop a physical model of the destruction of the Vega protective screens under the impact of micrometeorites and to determine the complex parameters of the antimeteorite protection - the size of craters, penetration and parameters of through holes in the protective screens from the mass and density of meteorite particles, to determine the sizes and speeds of spall elements in the first screen and to estimate their impact on the second protective screen, the distance between the screens, to calculate the parameters of plasma jets and the phase composition of the destruction products both during impacts along the normal and at an angle (Fig. 1, iii). The modeling results allowed us to develop specific recommendations for the design of the antimeteorite protection of Vega-type spacecraft. Some of the results were later published in a detailed article [6]. It should be noted that at that time the list of authors was indicated not by contribution to the development, but in alphabetical order. V.E. Fortov also published a couple of papers on high-speed impactor-obstacle interactions at that time, particularly in journals like "JETP Letters," but they failed to generate any

significant interest—their citations today do not exceed 1-2. Some publications mention that V.E. Fortov proposed anti-meteorite protection for spacecraft using two- and three-layer shields, ignoring earlier publications by R. Sagdeev and others. But as V.I. Arnold pointed out, "if any concept has a personal name, it is not the name of its discoverer" [7].

In 1988, V.F. Minin and five IAP employees were awarded the USSR State Prize for their work on the development of computing equipment and DE technology in the field of continuum mechanics. V.E. Fortov was brought in from the Academy of Sciences to serve as the driving force. And their "contribution" to the created hardware and software complex was the equation of state of matter under extreme conditions. It's worth noting that Vladilen Fedorovich, despite the Ministry's opposition, defended his staff and didn't give up some of the Ministry's positions (by right of "might," they wanted two for themselves), even though this came at a high cost...

Later, American colleagues noted that [8] *"A strength of the Soviet program was the close collaboration between researchers from the Institute of Applied Physics in Novosibirsk, who possess the expertise in two-dimensional and three-dimensional hydrocodes necessary for these calculations, and researchers from the Institute of Chemical Physics in Chernogolovka, who apply these capabilities in equation-of-state experiments." And in the same analytical review, the Americans noted the high level of the created complex [8]: "An American scientist visiting the Institute of Applied Physics in Novosibirsk in 1990 was shown the state of the art in parallel computing for solving large hydrodynamic problems. This demonstration utilized Soviet computers (manufactured with Soviet-made electronic microcircuits) to achieve high-speed computing without the need for a supercomputer, with a computing time equivalent to a Cray supercomputer."*

The days after... Aristotle noted that "being fair in thought does not necessarily mean being fair in deed." Collaboration with Fortov, undoubtedly an energetic and talented organizer, within the Vega program, unfortunately, also had negative consequences. The lure of IAP employees with promises of "mountains of gold," training of Fortov's group members, and promises of positions, apartments, and "other benefits" were among the activities. Several dissertations were defended. But when the need for former IPF employees dried up, V.E. Fortov stopped answering phone calls and letters, and these former employees were forced to return to Novosibirsk "with nothing," ending their lives in "warm" company and playing the accordion.

Figure 1. *i) V.F. Minin demonstrating an experiment on the high-energy atmospheric effect to M.V. Keldysh, President of the USSR Academy of Sciences, 1964, ii) V.F. Minin, E.I. Shemyakin, and V.E. Fortov (from right to left) at the All-Union Conference on the Problems of Cumulation and High-Speed Impacts at the Institute of Applied Physics, iii) modeling the impact of a micrometeorite on the two-layer protection of the Vega spacecraft: impact velocity 30 km/s, colors – solid – blue, liquid – red, plasma – green. Respectively, at times of 9, 29, 59, and 92 ns after the impact. iiii) – a) title page of the preprint by V.E. Fortov. With a dedication to V.F. Minin, b) simulation of a nylon ball impacting a steel barrier: initial stage and barrier destruction, IAP, 1978, c) simulation of a nuclear explosion on a meteor's surface, d) simulation of a meteorite falling into the ocean. IAP, 1986.*

Nevertheless, a little later, at the IAP's branch center for advanced physics, at the request of V.F. Fortov, Minin and his colleagues conducted a series of advanced physics experiments in other areas of physics, often referred to as "applied physics." Although we are more receptive to L. Pasteur's assertion that "there are no 'applied sciences,' only applications of science." Thus, to understand the physics of these processes, comprehensive studies were conducted on pulsed sources of low-temperature plasma and light. A series of studies on the interaction of aluminum impactors with a conical cavity for the explosive initiation of D-D reactions, conducted for the first time at the Institute of Applied Physics (IAP), revealed and explained the formation of high-speed cumulative jets within a target, including the detection of the effects of Mach acceleration of the central part of a "thick" impactor during its interaction with the target. A later joint experiment with the Institute of Chemical Physics (OIPhF) confirmed the modeling results. Regimes of irregular collisions of conically converging shock waves in the regime of irregular (Mach) reflection of shock waves were studied in detail, in particular, for obtaining extremely high temperatures and pressures. The dependence of the main characteristics of a Mach wave on the intensity and angle of incidence of a conical shock wave was established. This made it possible to excite a shock wave in metal with an amplitude comparable to the pressures in the near zone of a nuclear explosion. High-pressure explosive generators based on the formation of a double Mach reflection regime were also investigated. The discrepancy between the critical angle for weak shock waves in gases and aluminum and copper was explained. The formation of tsunamis during the fall of meteorites to the earth and a number of other areas were studied (Fig. 1, iiii). Several USSR patents were received. But these and other studies were mostly completed only with the publication of preprints of the International Albert Einstein Physics Institute; the joint articles promised by V.E. Fortov never saw the light of day. In his monograph [9], as well as in the lecture dedicated to the awarding of the Einstein Gold Medal to him (Intense shock waves and extreme state of matter. International Albert Einstein Gold Medal Lecture), V.E. Fortov presents the result of a simulation of conical shock waves (Fig. 3.27, on the right from [9]). However, he does not cite [10] the authors of the simulation. However, this is a completely different story.

References

1. Whipple F. L. In: Physics and Medicine of Upper Atmosphere/Ed. White, Benson; Albuquerque: Univ. New Mexico Press, 1952.

2. R. Z. Sagdeev, S. 1. Anisimov, A. A. Galeev, V. D. Shapiro, V. I. Shevchenko. Dust hazard near Harlley comet in case of the Vega project. AdV. Space Res. V.2(12), 1983. P.133—143.

3. I.V.Minin, O.V.Minin. The breakup of gas bubbles by a shock wave: brief historical background. Eur. Phys. J. H. 49, 5 (2024).

4. Minin V. F., Musatov V. V., Seleznev A. I., Frumin V. L. Modification of the "large particles" method for solving two-dimensional non-stationary problems of continuum mechanics // Mechanics of fast processes. Novosibirsk, Issue 73. 1985. 78-85.

5. V. F. Minin, I. V. Minin, O. V. Minin. Calculation Experiment Technology, In: Cmputational Fluid Dynamics, IntechOpen, Rijeka, 2011. P.1-28. DOI https://doi.org/10.5772/22497

6. Agureikin V. A., Anisimov S. I., Bushman A. V., Kanel G. I., Kartin V. T. T., Konstantinov A. B., Kryukov B. P., Minin V. F., Razorenov S. V., Sagdeev R. Z., Sugak S. G., Fortov B. E. Thermophysical and gasdynamic problems of anti-meteorite protection of the VEGA spacecraft. TVT, v. 22 (5), 1984, pp. 964–983.

7. Arnold V. I. On the teaching of mathematics, UMN, v. 53 (1), 1998, pp. 229–234.

8. W.M. Isbell, C. E. Anderson, J. R. Asay, S. J. Bless, D. E. Grady, J. Sternberg. Petentation mechanocs research in the former Soviet Union. FASAC Technical Assessment Report. PB93-146488, 1992

9. V.E.Fortov. Extreme States of Matter. High Energy Density Physics (2nd edition, Springer, Berlin-Heidelberg, 2011)

10.S. E. Shipilov, V. P. Yakubov. History of technical protection. 60 years in science: to the jubilee of Prof. V. F. Minin. IOP Conf. Ser.: Mater. Sci. Eng. 2018. V.363. P. 012033.

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振动条件下各向异性板的最优设计
OPTIMAL DESIGN OF ANISOTROPIC PLATE UNDER VIBRATION CONDITIONS

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摘要。最优设计理论旨在解决需要确定结构运行条件、结构材料内部属性以及在选定结构特性下取最大值或最小值的形状和尺寸的问题。最优设计涉及选择模型、控制函数以及定义在状态函数和控制函数上的泛函，以及待优化的指标和约束系统。本文研究了由空间纤维复合材料构成的结构。该空间系统的结构单元包括杆、板和壳。每个单元都具有简化的（等效）刚度：膜刚度、弯曲刚度、扭转刚度和混合刚度。该结构承受静载荷、分布载荷和集中载荷。

本文的初始数据包括：复合材料板、整体尺寸和声载荷。复合材料板被替换为强度和动力学参数等效的均质各向异性变刚度板。优化过程分三个阶段进行。第一阶段，选择目标函数，指定控制函数并施加约束条件。第二阶段，确定纤维复合材料的约化圆柱刚度和圆柱刚度的控制函数。第三阶段，建立并求解各向异性板振动的微分方程，并检验约束条件。

除了均质边界条件外，还考虑了非均质边界条件。最终得到了正交各向异性板位移振动的微分方程。

关键词：目标函数，优化设计，空间纤维复合材料，正交各向异性板，应力，应变。

Abstract. *Optimal design theory addresses problems that require determining the operating conditions of structures, the internal properties of structural materials, and the shapes and dimensions that assume maximum or minimum values for a selected structural characteristic. Optimal design involves selecting models, control functions, and functionals defined on state functions and control functions, as well as the indicator to be optimized and the constraint system. This paper examines structures formed from spatial-fiber composites. The structural elements of the spatial system are rods, plates, and shells. Each individual element*

is characterized by reduced (equivalent) stiffnesses: membrane, bending, torsional, and mixed. The structure is subject to static, distributed, and concentrated loads.

In this article, the initial data are: composite plate, overall dimensions, and acoustic load. The composite plate is replaced by a homogeneous, anisotropic plate with variable stiffness equivalent in strength and dynamic parameters. The optimization process is performed in three stages. In the first, the objective function is selected, the control function is specified, and constraints are imposed. In the second, the reduced cylindrical stiffness for the fiber composite material and the control function for the cylindrical stiffness are determined. In the third, a differential equation for the oscillations of the anisotropic plate is formulated and solved. The constraints are then checked.

Along with homogeneous boundary conditions, inhomogeneous boundary conditions are considered. A differential equation for the oscillations of an orthotropic plate in displacements is obtained.

Keywords: *objective function, optimal design, spatial fiber composites, orthotropic plate, stresses, strains.*

Introduction. Optimal design theory [1] addresses problems in which it is necessary to determine the operating conditions of structures, the internal properties of the structural material, and the shapes and dimensions that assume the maximum or minimum values of the selected structural characteristic. Using optimal design theory [1], a wide variety of problems can be solved. This is due to the fact that the equations describing the loading and deformation of a structure, as well as the requirements for its mechanical characteristics, differ significantly when considering different types of structures (beams, plates, shells) and the properties of the materials from which they are made. The type of equations is also affected by the applied loads (static or dynamic, planar or spatial, etc.) and the methods of fixing the structure. The accuracy of the model and initial data influences the formulation of the problems.

Research Objective. When solving optimal design problems, select a control function model and a system of constraints imposed on the control variables, state functions, and the functionals under consideration. Also, obtain a differential equation for oscillations in displacements.

Research Material and Methods. The study utilized theoretical research methods based on mathematical modeling [2].

Research Object and Methods.

This paper examines structures formed from spatial-fiber composites. The structural elements of the spatial system are rods, plates, and shells. Each individual element is characterized by reduced (equivalent) stiffnesses: membrane,

bending, torsional, and mixed. The structure is subject to static, distributed, and concentrated loads.

In this article, the initial data are: the composite plate, its overall dimensions, and the acoustic load. The composite plate is replaced with a homogeneous, anisotropic plate with variable stiffness and equivalent strength and dynamic parameters. The optimization process is performed in three stages.

Research results and discussion.

In the first stage, the target function [3] is selected, the control function is defined, and constraints are imposed. The minimum plate weight is adopted as the target function. –

P_{min} = *(a, b, h, Y)*. The weight function depends on the geometric characteristics and structure of the material. Weight (kN) is calculated using the formula:

$$P = V_M \gamma_M + V_в \gamma_в, \quad (1)$$

where $V_м$, $V_в$, $\gamma_м$, $\gamma_в$ –объем (мм^3), Specific gravity (kN/mm^3) of the matrix and fiber, respectively.

Fiber volume (mm^3) is:

$$V_в = n\pi r_в^2 a = n\pi \frac{d_в^2}{4} a, \quad (2)$$

where n is the number of fibers; $r_в$, $d_в$ – radius and diameter of the fiber (mm); a is the fiber length (mm). The matrix volume (mm^3) is:

$$V_M = V_0 - V_в = abh - n\pi \frac{d_в^2}{4} a, \quad (3)$$

where V_0 – Total plate volume (mm3). The specific gravity of the matrix (kN/mm^3) and fiber is determined by the formulas:

$$\gamma_м = \rho_м g, \quad \gamma_в = \rho_в g \quad (4)$$

The optimization problem is to find a control function that minimizes weight and satisfies constraints.

The control function is the reduced cylindrical stiffness. –

$D_{упр} = D_o f(x, y)$, included in the differential equation of oscillations and controlling the oscillation frequency.

The constraints are:

1. Fatigue strength condition;
2. Elimination of resonant frequency;
3. Overall dimensions of the plate.

In the second stage, the reduced cylindrical stiffness for the fiber-reinforced composite material is determined. $D_o = (E_i, v_i, h)$ and the control function for cylindrical stiffness – $f(x, y) = f\left(\frac{M_x}{M_x^{max}}, \frac{M_y}{M_y^{max}}\right)$. To determine the reduced cylindrical stiffness, an element is isolated from the plate. The cylindrical bending of the isolated element is considered, and its equilibrium condition is formulated by

analogy with an isotropic plate, from which the reduced cylindrical stiffness is obtained. The control function allows one to transition from a complex system to a homogeneous one, provided that they are equivalent in strength and dynamic parameters. To determine the control function $F_{упр} = f(x,$ y), We need to calculate the bending moments. To do this, we consider the problem of a rigidly clamped (pivot-supported) uniformly loaded rectangular plate.

In the third stage, a differential equation for the vibrations of the anisotropic plate is developed and solved. Then, the constraints are checked.

1) Fatigue strength condition:

$$\sigma_{max} \leq [\sigma], \tag{5}$$

where σ_{max} – the calculated value of stress at the point where the greatest stresses occur, [σ] is the permissible stress. The value of which is determined by the formula:

$$[\sigma] = \frac{\sigma_{-1}}{n}. \tag{6}$$

Here, σ-1 is the fatigue limit, and n is the safety factor.

The calculated stress value (MPa) is calculated using the formula:

$$\sigma_{max} = \frac{6M_{max}}{h^2}, \tag{7}$$

M_{max} is the maximum bending moment (kN*mm), h is the plate thickness (mm).

2) Elimination of the resonant frequency:

$$W \neq W_0 \tag{8}$$

The natural frequency W0 must not coincide with the forced (specified) frequency.

3) The plate's overall dimensions must not exceed the specified ones; otherwise, the mass and, consequently, the cost will be exceeded.

If the constraints are met, the optimization process ends; if they are not met, we return to the second stage.

Results.

Let us consider the fundamental equations of elasticity theory for an anisotropic [4], in particular, an orthotropic body, subjected to forces that cause material deformation. We place the body in a Cartesian coordinate system [4]. The displacements experienced by each point M within the body are written as:

$u_x = u_x(x, y, z)$,

$$u_y = u_y(x, y, z), \tag{9}$$

$u_z = u_z(x, y, z)$.

The deformed state of a solid body in the vicinity of point M is characterized by six components of deformations, which are associated with displacements u_x, u_y, u_z:

$$e_x = \frac{du_x}{dx}, e_{yz} = \frac{du_y}{dz} + \frac{du_z}{dy},$$
$$e_y = \frac{du_y}{dy}, e_{zx} = \frac{du_z}{dx} + \frac{du_x}{dz}, \quad (10)$$
$$e_z = \frac{du_z}{dz}, e_{xy} = \frac{du_x}{dy} + \frac{du_y}{dx}.$$

For a body in equilibrium, the differential equations of equilibrium in coordinates *X, Y, Z* have the form:

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xy}}{\partial z} + P_x = 0$$
$$\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} + P_y = 0 \quad (11)$$
$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \sigma_z}{\partial z} + P_z = 0,$$

where P_x, P_y, P_z – volumetric force in projections on the Cartesian coordinate axes, acting on a unit volume. Substituting the inertial terms into the right-hand sides of equations (11) $\frac{\partial^2 u_x}{\partial t^2}, \rho \frac{\partial^2 u_y}{\partial t^2}, \rho \frac{\partial^2 u_z}{\partial t^2}$, where ρ is the density of the material, t is time, we obtain the differential equations of motion of a continuous medium in a Cartesian coordinate system *x, y, z.*

For small deformations, the generalized Hooke's law is considered valid [5]. For a homogeneous elastic body, it can be written as follows:

$$e_x = a_{11}\sigma_x + a_{12}\sigma_y + a_{13}\sigma_z + a_{14}\tau_{yz} + a_{15}\tau_{xz} + a_{16}\tau_{xy},$$
$$e_y = a_{12}\sigma_x + a_{22}\sigma_y + \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots + a_{26}\tau_{xy}, \quad (12)$$
$$e_{xy} = a_{16}\sigma_x + a_{26}\sigma_y + \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots + a_{66}\tau_{xy}.$$

By integrating each of the equilibrium equations (11) in the absence of volumetric forces over z in the range from *z = - l/2h to z = l/2h* and then multiplying the first two equations of system (11) and integrating the result over z in the same range, we obtain five differential equations of equilibrium of the plate, written with respect to eight internal forces $M_x, M_y, H, T_x, T_y, S, N_x, N_y$:

$$\frac{\partial T_x}{\partial x} + \frac{\partial S}{\partial y} = -X_2, \quad (13)$$
$$\frac{\partial T_y}{\partial y} + \frac{\partial S}{\partial x} = -Y_2, \quad (14)$$
$$\frac{\partial N_x}{\partial x} + \frac{\partial N_y}{\partial y} = -Z_2, \quad (15)$$
$$\frac{\partial M_x}{\partial x} + \frac{\partial H}{\partial y} = N_x - hX_1, \quad (16)$$

$$\frac{\partial M_y}{\partial y} + \frac{\partial H}{\partial x} = N_y - hY_1. \tag{17}$$

In deriving equations (13)–(17), surface conditions were also used.

As is known [6], homogeneous boundary conditions in the case of a three-dimensional problem of thick plate theory under conditions of some idealization of the edge fixing of a given structural element (in particular, hinged support or rigid fixing [7]), which is actually implemented in practice, are conventionally formed as follows:

a) Free edge:

$$\sigma_x = 0, \tau_{xz} = 0, \tau_{xy} = 0. \tag{18}$$

b) Articulated edge:

$$\sigma_x = 0, \tau_{xy} = 0, u_z = 0. \tag{19}$$

or

$$\sigma_x = 0, u_y = 0, u_z = 0.$$

c) Rigidly sealed edge:

$$u_x = 0, u_y = 0, u_z = 0, \tag{20}$$

$$u_x = 0, \tau_{xy} = 0, u_z = 0.$$

Along with homogeneous boundary conditions, there may also be non-homogeneous boundary conditions. As an example, let's consider three variants of non-homogeneous boundary conditions [8]:

a) Loaded edge:

$$T_x = T_x^*, M_x = M_x^*, N_x = N_x^*, S = S^*, H = H^*, \tag{13}$$

where $T_x^* \ldots\ldots, H^*$ - forces applied to the edge in question; in a particular case, some of them may be equal to zero.

b) A hinged edge loaded with forces and moments[8]:

$$T_x = T_x^*, M_x = M_x^*, w = 0, S = S^*, H = H^* \tag{21}$$

c) Displaced edge:

$$u + a_{55}K_1^+(z_0)\varphi + a_{45}K_2^+(z_0)\psi + \frac{z_0^2}{2h}(a_{55}X_2 + a_{45}Y_2) = \frac{u^+ + u^-}{2}$$

$$v + a_{44}K_2^+(z_0)\psi + a_{45}K_1^+(z_0)\varphi + \frac{z_0^2}{2h}(a_{45}X_2 + a_{44}Y_2) = \frac{v^+ + v^-}{2},$$

$$w = w^*, \tag{22}$$

$$-\frac{\partial w}{\partial x} + a_{55}\frac{K_1(z_0)}{2z_0}\varphi + a_{45}\frac{K_2(z_0)}{2z_0}\psi + (a_{55}X_1 + a_{45}Y_1) = \frac{u^+ + u^-}{2z_0},$$

$$-\frac{\partial w}{\partial y}+\ a_{44}\frac{K_2^-(z_0)}{2z_0}\varphi+(a_{45}X_1+\ a_{44}Y_1)=\frac{v^+\ +\ v^-}{2z_0},$$

where w^* - given normal edge displacement, u^+, u^-, v^+, v^- given tangential displacements of the edge, corresponding $z = \pm z_0$.

Let's consider the differential equation for the vibrations of an orthotropic plate.

Let's isolate the static side of a plate of variable thickness made of an orthotropic material, subject to a static load normal to the midplane.

Let's isolate an element from the plate with dimensions *dx, dy*, and thickness *h*. The linear forces and moments are related to the stresses by the following relationships:

- transverse forces and shear stresses:

$$Q_x=\int_{-h/2}^{h/2}\tau_{zx}dx, Q_y=\ \int_{-h/2}^{h/2}\tau_{zy}\,dz. \tag{23}$$

- bending moments and normal stresses:

$$M_x=\ \int_{-h/2}^{h/2}\sigma_x z dz, M_y=\int_{-h/2}^{h/2}\sigma_y\,z dz. \tag{24}$$

- torques:

$$M_{xy}=M_{yx}=\ \int_{-h/2}^{h/2}\tau_{xy}\,z dz=\int_{-h/2}^{h/2}\tau_{yz}z dz. \tag{25}$$

The equilibrium equations for a rigid plate to which a load q is applied, acting perpendicular to the mid-surface, are written:

$$\frac{\partial Q_x}{\partial x}+\frac{\partial Q_y}{\partial y}+q=0 \tag{26}$$

$$\frac{\partial M_{xy}}{\partial x}-\frac{\partial M_y}{\partial y}+Q_y=0, \tag{27}$$

$$\frac{\partial M_{xy}}{\partial y}+\frac{\partial M_x}{\partial x}-Q_y=0. \tag{28}$$

Excluding Q_x, Q_y and taking into account that $M_{xy} = M_{yx,}$ we get one equation:

$$\frac{\partial^2 M_x}{\partial x^2}+\frac{\partial^2 M_y}{\partial y^2}-2\frac{\partial^2 M_{xy}}{\partial x\partial y}+\frac{\rho h\partial^2 w}{\partial t^2}=-q \tag{29}$$

Let us express the internal forces in an orthotropic plate through displacements and elastic constants:

$$M_x=\ -D_1\left(\frac{\partial^2 w}{\partial x^2}+\mu_2\frac{\partial^2 w}{\partial y^2}\right), \tag{30}$$

$$M_y=-D_2\left(\frac{\partial^2 w}{\partial y^2}+\mu_1\frac{\partial^2 w}{\partial x^2}\right), \tag{31}$$

$$M_{xy}=-\frac{Gh^3}{12}\frac{\partial^2 w}{\partial x\partial y}, \tag{32}$$

$$Q_x = -\frac{\partial}{\partial x}\left(D_1\frac{\partial^2 w}{\partial x^2} + D_3\frac{\partial^2 w}{\partial y^2}\right), \quad (33)$$

$$Q_y = -\frac{\partial}{\partial y}\left(D_3\frac{\partial^2 w}{\partial x^2} + D_2\frac{\partial^2 w}{\partial y^2}\right). \quad (34)$$

For an orthotropic plate, taking into account dependencies (30) – (34), we obtain a differential equation for oscillations in displacements:

$$D_1\frac{\partial^4 w}{\partial x^4} + 2D_3\frac{\partial^4 w}{\partial x^2 \partial y^2} + D_2\frac{\partial^4 w}{\partial y^4} + \frac{\rho h\partial^2 w}{\partial t^2} = q, \quad (35)$$

where D_1 and D_2 – bending rigidity in the principal directions; D_3 – torsional rigidity; these values are determined by the formulas:

$$D_1 = \frac{E_1 h^3}{12(1-\mu_1\mu_2)},\ D_2 = \frac{E_2 h^3}{12(1-\mu_1\mu_2)},\quad D_3 = \frac{Gh^3}{12}. \quad (36)$$

Conclusion. This article examines structures made of spatial-fiber composites. When solving a specific problem, the composite plate is replaced with a homogeneous anisotropic plate with variable stiffness. The optimization process is performed in three stages. Expressions for determining the forces arising in the plate are written. The objective and control functions are selected. A differential equation for oscillations in displacements is obtained.

References

1. Zinoviev P.A., Smerdov A.A. Optimal Design of Composite Materials: Part II. Moscow: Bauman Moscow State Technical University Press, 2006. 103 p.

2. Zvonarev S.V. Fundamentals of Mathematical Modeling. Yekaterinburg: UrFU Press, 2019. 116 p.

3. Pevneva A.G., Kalinkina M.E. Optimization Methods. St. Petersburg: ITMO University, 2020. 64 p.

4. Novozhilov, V.V. Theory of Elasticity. Leningrad: Sudpromgiz, 1985. 370 p.

5. Lekhnitsky, S.G. Theory of Elasticity of an Anisotropic Body. Moscow: Gostekhizdat, 1977. 415 p.

6. Goldenweiser, A.L. Theory of Elastic Thin Shells. Moscow: Nauka, 2016. 512 p.

7. Wasidzu, K. Variational Methods in the Theory of Elasticity and Plasticity. Moscow: Nauka, 2018. 556 p.

8. Kanovich, M.Z., Trofimov, N.N. Resistance of Composite Materials. Moscow: Mir, 2014. 504 p.

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人为污染背景下城市绿地环境安全：现状评估及优化途径
ENVIRONMENTAL SAFETY OF URBAN GREEN SPACES IN THE CONTEXT OF ANTHROPOGENIC POLLUTION: ASSESSMENT OF THE STATE AND WAYS OF OPTIMIZATION

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摘要：本文探讨了在人为活动强烈影响下，保障城市绿地环境安全所面临的挑战。文章分析了主要污染源及其对植物生理状态和绿地生态系统功能的影响，并论证了利用生物监测和植物指示方法评估乔木和灌木可持续性的有效性。文章提出了优化城市绿地结构和组成、提升其环境保护功能的综合措施。研究表明，合理管理城市生态系统有助于减少人为负荷，改善城市环境质量。

关键词：环境安全，城市绿地，人为污染，生物监测，植物指示，城市生态系统，环境保护功能。

Annotation. *This article examines the challenges of ensuring the environmental safety of urban green spaces (UGS) under conditions of intense anthropogenic impact. An analysis of the main sources of pollution and their impact on the physiological state of plants and the ecosystem functions of green spaces is provided. Biomonitoring and phytoindication methods for assessing the sustainability of trees and shrubs are substantiated. Comprehensive measures are proposed to optimize the structure and composition of UGS to enhance their environmental protection properties. It is shown that rational management of urban ecosystems helps reduce anthropogenic loads and improve the quality of the urban environment.*

Keywords: *environmental safety, urban green spaces, man-made pollution, biomonitoring, phytoindication, urban ecosystems, environmental protection functions.*

Introduction

Intensive urbanization and increasing anthropogenic load necessitate strengthening the role of urban green spaces as a key element of environmental infrastructure. In large cities, urban green spaces serve a multifunctional role:

- absorb pollutants from the atmosphere (dust, SO_2, NOx, volatile organic compounds);
- regulate the microclimate (reduce temperature, increase humidity);
- reduce noise impact;
- support biodiversity;
- perform recreational and aesthetic functions.

However, the plants themselves are subject to complex negative impacts:

- emissions from vehicles and industrial enterprises;
- soil salinization anti-icing reagents;
- soil compaction as a result of anthropogenic load;
- lack of moisture and nutrients.

The relevance of the study is determined by:

- increasing man-made pressure on urban ecosystems;
- the need to maintain and increase the viability of the GZN;
- the need to develop scientifically based methods for monitoring and managing green spaces;
- the importance of integrating the State Land Survey into sustainable urban development strategies.

The purpose of the work— analysis of environmental problems of urban green spaces in conditions of man-made pollution and justification of measures to improve their sustainability and functionality.

Research objectives:

1. To assess the current state of the public health system in major cities of the Russian Federation.
2. To analyze the main sources and mechanisms of anthropogenic impact on vegetation.
3. Consider biomonitoring methods and phyto indications for diagnosing plant conditions.
4. Identify the criteria for selecting resistant species woody shrub plants.
5. To propose systemic solutions for optimizing the structure and content of the GZN.

Object of study— urban green spaces as elements of urban ecosystems. The subject of this study is mechanisms for ensuring their environmental safety under anthropogenic impacts.

The methodological base includes: systems analysis, phytoindication methods, biochemical analysis of plant tissues, geoinformation technologies, statistical methods of data processing.

The current state of urban green spaces

In large Russian cities, the per capita green space area often fails to meet standards (at least 16 m²/person according to SanPiN). For example, in Moscow this figure is approximately 20 m²/person, in St. Petersburg – 12 m²/person, and in a number of industrial centers – less than 8 m²/person [1].

Main problems:

- degradation of forest stands - a reduction in the proportion of healthy trees to 40–50% in the central regions;
- soil pollution - excess of maximum permissible concentrations of heavy metals (Pb, Cd, Zn) 2–5 times near highways;
- soil compaction - disruption of aeration and water regime of root systems;
- damage by pests and diseases - an increase in the number of bark beetles, aphids, fungal infections on weakened plants;
- lack of care - irregular pruning, lack of fertilizing and watering.

According to research, in areas with high traffic loads:

- photosynthetic activity of leaves decreases by 30–40%;
- the share is increasing chlorotic and necrotic tissues up to 25–35%;
- the lifespan of trees is reduced by 1.5–2 times compared to suburban forests [2].

Sources and mechanisms of anthropogenic impact

Key factors of negative impact:

- atmospheric pollution - CO emissions, NOx, SO_2, polycyclic aromatic hydrocarbons (PAHs), and fine particulate matter (PM10, PM2.5). These substances disrupt gas exchange, inhibit photosynthetic enzymes, and cause necrosis.
- Soil salinization - the introduction of sodium and calcium chlorides in winter leads to osmotic stress, root death, and leaf chlorosis.
- heavy metals – accumulation Pb, Cd, Ni in leaves and bark, which disrupts the metabolism and reproductive functions of plants.
- noise and light pollution are uncomfortable conditions for symbiotic organisms (soil bacteria, mycorrhiza).
- mechanical impact - soil compaction, damage to trunks and roots during construction work.

Plant adaptation mechanisms include:

- thickening of the cuticle and epidermis;
- increased synthesis of antioxidants (ascorbic acid, flavonoids);
- activation of detoxification enzymes (catalase, peroxidase);
- changes in leaf morphology (decrease in area, increase in thickness).

However, with prolonged exposure to stress factors, compensatory mechanisms are depleted, which leads to the drying out and death of plants.

Methods for assessing the state of the gastrointestinal tract

For diagnostics the following are used:

- Phytoindication—assessment of visual signs of stress (chlorosis, necrosis, leaf asymmetry, premature leaf fall). For example, silver birch (Betulapendula) serves as an indicator of SO2 pollution [3].
- biochemical analysis - determination of chlorophyll content, proline, malondialdehyde (a marker of oxidative stress).
- anatomical studies - study of the structure of the mesophyll, stomatal apparatus, conducting tissues.
- Geographic information systems (GIS) – mapping of risk zones taking into account wind rose, building density, and traffic load.
- Remote sensing - analysis of spectral indices (NDVI, SAVI) to assess photosynthetic activity over large areas [4].

Comprehensive monitoring allows:

- identify areas of degradation at early stages;
- predict the dynamics of the state of plantings;
- justify rehabilitation measures.

Criteria for selecting resistant plant species

When selecting the range, consider:

- gas resistance - the ability to tolerate high concentrations of SO2, NOx (for example, balsam poplar (Populus balsamifera), Norway maple (Acerplatanoides)).
- Salt tolerance - tolerance to chloride salinity (rough elm (Ulmusglabra), common rowan (Sorbusaucuparia)).
- resistance to soil compaction - species with a deep and branched root system (pedunculate oak (Quercus robur), small-leaved linden (Tiliacordata)).
- growth rate and longevity - a balance between rapid crown formation and lifespan.
- Ornamental value and biodiversity - inclusion of species that attract birds and insects.

It is recommended to form mixed plantings with alternating trees and shrubs, which increases the resistance of phytocenoses to pathogens and pests.

Ways to optimize environmental safety of the State Healthcare Institution

1. Improving the regulatory framework:

- updating regional landscaping regulations taking into account climatic and technological features;
- introduction of mandatory requirements for the composition and structure of the State Land Registry in urban planning regulations.

2. Technological solutions:

- the use of soil conditioners (zeolites, biochar) to reduce soil toxicity;

- use of drip irrigation and hydrogels to save water;
- the introduction of "green roofs" and vertical gardens to increase the photosynthetic surface area.

3. Agrotechnical measures:
- regular fertilizing with complex fertilizers containing microelements;
- mulching tree trunk circles to retain moisture and aeration;
- sanitary and formative pruning;
- biological protection against pests (entomophages, biological preparations).

4. Digitalization of management:
- creation of digital passports of plantings with data on species composition, age, and condition;
- integration of GIS systems for planting planning and monitoring;
- usage IoT sensors for monitoring soil moisture and air parameters.

5. Public participation:
- volunteer programs for plant care;
- environmental education of the population about the role of the State Health Inspectorate;
- involving residents in landscaping planning (participatory design).

6. Scientific research:
- selection and introduction of resistant varieties adapted to local pollution conditions;
- development biomarkers of stress resistance for early detection of weakened plants;
- study of symbiotic interactions (mycorrhiza, rhizosphere bacteria) to increase the viability of plantings [5].

7. Spatial planning:
- creation of "green corridors" to connect individual areas and ensure the migration of organisms;
- zoning of territories taking into account wind roses and emission sources (industrial zones, highways);
- formation of buffer strips from gas-resistant species along highways and enterprises [6].

8. Monitoring and adaptation:
- regular assessment of the condition of plantings (once every 3–5 years) with adjustment of the assortment;
- implementation of early warning systems for pest and disease outbreaks;
- development of response scenarios for extreme events (droughts, hurricanes, chemical accidents).

Conclusions

1. Urban green spaces perform critical environmental protection functions, but their condition remains unsatisfactory in the face of anthropogenic pollution. In areas of high anthropogenic load, up to 50% of trees show signs of decline, and soil heavy metal levels exceed the maximum permissible concentration by 2–5 times.

2. The main risk factors are atmospheric pollution (SO2, NOx, PM), soil salinization, heavy metal accumulation, and mechanical stress. These stressors disrupt plant physiological processes, reducing their viability and ecosystem effectiveness.

3. To diagnose the state of the GZN, it is advisable to use a combination of methods: phytoindication, biochemical analysis, GIS mapping, and remote sensing. This allows for the early detection of degradation sites and the prediction of change dynamics.

4. Increasing the sustainability of plantings requires:

- selection gas and salt-resistant species (poplar, elm, rowan, linden);
- implementation of agrotechnical measures (fertilizing, mulching, biosecurity);
- use of digital tools (digital passports, IoT sensors, GIS);
- improving the regulatory framework and public involvement.

5. Promising areas include:

- development of "green infrastructure" (roofs, vertical gardens);
- use of soil conditioners and hydrogels;
- integration of the State Environmental Protection Agency into urban climate adaptation strategies.

6. Comprehensive implementation of the proposed measures will allow:

- increase the proportion of healthy trees to 70–80%;
- reduce the concentration of pollutants in the ground layer by 20–30%;
- increase bio diversity urban ecosystems;
- improve the microclimate and quality of life of city residents.

Thus, ensuring environmental safety of the GZN requires a systematic approach that combines scientific, technological, managerial and social solutions.

References

1. SanPiN 2.1.2.2645 10 "Sanitary and epidemiological requirements for living conditions in residential buildings and premises" (with amendments and additions).

2. State report "On the state and protection of the environment of the Russian Federation in 2023". - M.: Ministry of Natural Resources of Russia, 2024. - 482 p.

3. Nikolaevsky, V.S. Plant ecology: textbook. - M.: Education, 2021 .-- 320 p. ISBN 978 5 09 078945 6.

4. Lukina, N.V., Smirnova, I.E. Bioindication of the state of urban ecosystems: methods and criteria. - Ekaterinburg: Ural Branch of the Russian Academy of Sciences, 2022. - 184 p. ISBN 978 5 7691 3012 5.

5. FAO. Urban Forestry: A Toolkit for Local Governments. - Rome: Food and Agriculture Organization, 2023. - 148 p. ISBN 978 92 5 134567 1.

6. United Nations Economic Commission for Europe. Handbook on Green Infrastructure in Cities. — New York; Geneva: UN, 2022. — 96 p. ISBN 978 92 1 117234 8.

7. GOST R 58875-2020 "Green Standards. Green Roofs. Terms and Definitions, Classification, Technical and Environmental Requirements."

8. Petrov, V.N., Ivanova, L.M. Urban ecology and urban greening: monograph. - St. Petersburg: St. Petersburg State University Publishing House, 2021. - 248 p. ISBN 978 5 288 06123 7.

9. CABI. Invasive Species Compendium. — Wallingford: CAB International, 2023. — Electronic resource. URL: https://www.cabi.org/isc/ (accessed: 15.11.2025).

10.Methodological recommendations for assessing the viability of urban trees (approved by order of the Ministry of Construction of Russia dated 25.12.2022 No. 1011/pr).

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用于全面解决数学问题的集成式 Telegram 机器人：从架构到实现
INTEGRATED TELEGRAM BOT FOR COMPREHENSIVE MATHEMATICAL PROBLEM SOLVING: FROM ARCHITECTURE TO IMPLEMENTATION

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摘要：在种类繁多的在线应用中，能够提供俄语界面并采用集成方法全面解决数学问题的免费服务数量有限，这仍然是一个亟待解决的问题。本研究旨在创建一个多功能的 Telegram 机器人，该机器人能够自动解决各种数学问题，并提高用户计算的便捷性。该机器人使用 JavaScript 和 Python 编程语言以及用于符号和数值计算、生成图形表示和通过 WebSocket 组织组件间交互的专用库实现。研究实现了求解方程、计算导数和积分、绘制图形、执行矩阵运算以及统计数据分析等功能。研究特别关注用户界面的易用性、对自然表达式输入的支持以及保存查询和结果历史记录的功能。试点研究验证了所提出方法的有效性及其在基于即时通讯平台的智能教育服务开发中的潜力。所开发的Telegram机器人有望成为学生、工程师和研究人员学习和自学的热门工具，从而促进数字教育技术的发展。

关键词：Telegram机器人，自动化，数学计算，LaTeX，WebSocket，符号计算，教育技术，Python，JavaScript，用户界面，聊天机器人，人工智能。

Abstract. *Among the wide variety of online applications, the limited number of free services with Russian-language interfaces capable of using an integrated approach to comprehensively solving mathematical problems remains a pressing issue. The goal of this study is to create a multifunctional Telegram bot capable of automating the solution of a wide range of mathematical problems and increasing the accessibility of computations for users. The bot was implemented using JavaScript and Python programming languages, as well as specialized libraries for symbolic and numerical computations, generating graphical representations, and organizing interactions between components via WebSocket. The study implemented functions for solving equations, calculating derivatives and integrals,*

plotting graphs, performing matrix operations, and statistical data analysis. Particular attention was paid to the user interface's usability, support for entering expressions in natural form, and the ability to save query and result history. The pilot study demonstrated the effectiveness of the proposed approach and its potential for the further development of intelligent educational services based on messenger platforms. The developed Telegram bot could become a sought-after tool for supporting learning and self-education for students, engineers, and researchers, contributing to the development of digital educational technologies.

Keywords: *Telegram bot, automation, mathematical computations, LaTeX, WebSocket, symbolic computations, educational technologies, Python, JavaScript, user interface, chatbot, artificial intelligence.*

Introduction

Today, a wide range of applications and web resources are available for automating the solution of a wide range of mathematical problems of varying complexity. However, the limited number of services capable of using an integrated approach to comprehensively solve them remains a pressing issue. An analysis of existing online mathematical applications revealed that many of these platforms offer advanced features only for a fee or do not support a Russian-language interface. The creation of a Telegram bot capable of solving a wide range of mathematical problems is a relevant and promising area in educational technology. Such a tool could become a personal assistant for students, engineers, researchers, and anyone else who uses calculations in their work. It will enable students to quickly obtain results, save time searching for and using disparate online services and software packages, and improve the efficiency of the solution. A. I. Abramova, in her article "Using a Telegram Bot in the Educational Process at a University" [1], notes that this approach offers significant advantages and facilitates student learning. A similar opinion is expressed in the article by B. S. Goryachkin, D. A. Galichy, V. S. Tsapiya, V. V. Burashnikov, and T. Yu. Krutov, "The Effectiveness of Using Chatbots in the Educational Process" [2].

The authors emphasize that with proper bot development, including adding the features students need, defining the bot's communication style, and ensuring the use of only proven services and libraries, it is possible to create an effective and useful assistant for students.

The functionality of the proposed application includes solving algebraic equations, calculating derivatives and integrals, plotting function graphs, performing matrix operations, solving linear algebra problems, and performing statistical data analysis [3, 4, 5]. An important aspect is the ability to process mathematical expressions entered by the user in natural form, which significantly simplifies interaction with the bot.

Developing an intuitive and user-friendly interface is one of the key aspects. The bot should provide the user with clear instructions for use, offer various options and parameters for solving problems, and display calculation results in a structured format. It is also important to provide the ability to save a history of queries and results, allowing users to return to previous calculations for comparison. The development of such an application contributes to the development of educational and scientific tools, providing a convenient and effective way to solve mathematical problems.

Research Objective

The aim of the research is to develop a multifunctional Telegram bot for automating the solution of a wide range of mathematical problems.

Research Objectives

- Analyze and select Node.js and Python libraries for implementing a Telegram bot.
- Implement basic mathematical functions, including solving equations, calculating derivatives and integrals.
- Develop a user-friendly interface with explanatory messages.
- Provide output of solutions in LaTeX format and integration of Python libraries for image generation.
- Organize interaction between components via WebSocket.
- Research Materials and Methods

The Telegram bot is implemented using JavaScript and Python, which is necessary to integrate tools for symbolic computations, generating graphical representations, and ensuring user interaction [6,7]. The main logic of the bot is implemented on the Node.js platform, where the following libraries were installed and used via the npm package manager: Node.js Telegram Bot API, path, fs, Nerdamer, Algebrite, and Math.js [8,9]. The Node.js Telegram Bot API library handles request processing and interaction with the Telegram API. path and fs are used for working with the file system, and Nerdamer, Algebrite, and Math.js are used to perform symbolic and numerical mathematical calculations of varying complexity [10, 11].

The Python libraries Matplotlib, SymPy, and re are used to generate images with solutions in LaTeX format. Matplotlib and SymPy provide the construction and visualization of mathematical expressions, while the re library is used to process and validate input data using regular expressions.

Interaction between the components implemented in JavaScript and Python is organized using WebSocket technology. To achieve this, the Python script responsible for image generation utilized the asyncio and websockets libraries, while the Node.js library used the ws library [12].

The component's operation algorithm is implemented as follows: after receiving a command from the user and performing the corresponding calculations on the Node.js side, the task data and the resulting output are transmitted to the Python server via WebSocket. The Python script converts this data into an image, which is saved on the server. Once the image generation process is complete, the Python server sends a file readiness notification, and the Node.js script forwards the resulting image to the user via Telegram, automating the process and visually displaying the calculation results, significantly improving the usability of the software being developed.

Interaction with the Telegram bot is implemented through an intuitive interface, allowing users to select one of the following key functionality: solving algebraic equations of degrees I–III, calculating derivatives of functions, definite and indefinite integrals, simplifying algebraic expressions, plotting graphs, performing matrix operations, as well as solving linear algebra problems and statistical data analysis. Each of these tasks requires step-by-step input of initial data, followed by the generation of results in text and graphical formats. This approach ensures the service's wide accessibility for users of varying skill levels and promotes the efficiency of mathematical calculations.

Research results and discussion

We'll show a fragment of part of the code with a description.

Solving cubic equations

```
function thirdDegree(a, b, c, d) {
   if (isNaN(+a) || isNaN(+b) || isNaN(+c) || isNaN(+d)) {
      return «Неправильный ввод данных»;
   } else {
      const p = (3 * a * c - b ** 2) / 3 * a ** 2;
      const q = (2 * b ** 3 - 9 * a * b * c + 27 * a ** 2 * d) / 27 * a ** 3;
      const Q = (p / 3) ** 3 + (q / 2) ** 2;
      const alpha = math.cbrt(math.sum(-q / 2, math.sqrt(Q)));
      const beta = math.cbrt(math.subtract(-q / 2, math.sqrt(Q)));
      const y1 = math.sum(alpha, beta);
       const y2 = math.sum(math.divide(math.multiply(-1, y1), 2), math.multiply(math.sqrt(3), math.multiply(math.divide(math.subtract(alpha, beta), 2), math.complex(0, 1))));
         const y3 = math.subtract(math.divide(math.multiply(-1, y1), 2), math.multiply(math.sqrt(3), math.multiply(math.divide(math.subtract(alpha, beta), 2), math.complex(0, 1))));
      let x1, x2, x3;
      if (Q < 0) {
         x1 = y1.re - b / (3 * a);
```

```
            x2 = y2.re - b / (3 * a);
            x3 = y3.re - b / (3 * a);
        } else if (Q.toFixed(5) == 0) {
            x1 = y1 - b / (3 * a);
            x2 = y2.re - b / (3 * a);
            x3 = y3.re - b / (3 * a);
        } else {
            x1 = y1 - b / (3 * a);
            x2 = math.subtract(y2, math.divide(b, math.multiply(3, a))).toString();
            x3 = math.subtract(y3, math.divide(b, math.multiply(3, a))).toString();
        }
        const answer = [x1, x2, x3];
        for (let i = 0; i < answer.length; i++) {
            if (typeof answer[i] === "string") {
                const number = answer[i].slice(0, answer[i].length - 1);
                    if (number.includes(".") && number.split(".").pop().length >=
5 && (number.split(".").pop().includes("99999") || number.split(".").pop().in-
cludes("00000"))) {
                    answer[i] = math.round(+number) + "i";
                }
            } else {
                const stringRoot = String(answer[i]);
                const fixedStringRoot = String(answer[i].toFixed(5));
                    if (stringRoot.includes(".") && stringRoot.split(".").pop().length
>= 5 && (fixedStringRoot.split(".").pop().includes("99999") || fixedStringRoot.
split(".").pop().includes("00000"))) {
                    answer[i] = math.round(answer[i]);
                }
            }
        }
        return answer;
    }
}
```

The thirdDegree function implements an algorithm for calculating all the roots of a cubic equation. The input parameters—the equation coefficients—are checked for correctness: if at least one of them is not a number, the function reports an invalid input. The main part of the algorithm is based on Cardano's method, which allows one to analytically find the roots of a cubic equation. First, the parameters expressing the equation in depressed form are calculated, as well as the discriminant, which determines the type of roots (real or complex). Its sign is

checked, and based on this, the roots of the equation are calculated (by performing a back substitution). If the value has a negative sign, then all three roots are real, meaning it is sufficient to take only the real part of the variables (in this case, the imaginary part will be zero). If it is zero, then we are dealing with repeating real roots. It is important to note that, due to an error, it may not be exactly zero, but a number extremely close to it. Therefore, in the condition, only the integer part of the number and the first five decimal places are checked for compliance with zero. If the value is greater than zero, the result is one real root and two conjugate complex roots. For this reason, functions from the Math.js library are used to calculate their values. Finally, all that remains is to round off numbers with a large number of 0s or 9s in their decimal notation.

To solve quadratic equations, the *secondDegree* function was written using the discriminant formula.

```
function secondDegree(a, b, c) {
   if (isNaN(+a) || isNaN(+b) || isNaN(+c)) {
      return «Неправильный ввод данных»;
} else {
const d = b ** 2 - 4 * a * c;
      if (d > 0) {
         if (Math.sqrt(d) % 1 === 0) {
             return [`${(-b - Math.sqrt(d)) / 2 * a}`, `${(-b + Math.sqrt(d)) / 2 *
a}`];
         } else {
               return [Algebrite.run(`(${-b} - sqrt(${d}))/2*${a}`), Algebrite.
run(`(${-b} + sqrt(${d}))/2*${a}`)];
         }
      } else if (d === 0) {
         const x = -b / 2 * a;
         return [x];
      } else {
         if (Math.sqrt(d) % 1 === 0) {
             return [`${(-b - Math.sqrt(-d)) / 2 * a}i`, `${(-b + Math.sqrt(-d)) / 2
* a}i`];
         } else {
             return [Algebrite.run(`(${-b} - sqrt(${-d}))/2*${a}*i`), Algebrite.
run(`(${-b} + sqrt(${-d}))/2*${a}*i`)];
         }
      }
   }
```

The feasibility of extracting the root of the discriminant is also tested. In cases where root extraction is impossible, the expression simplification function from the Algebrite library is used.

The developed bot operates on a personal server; its identifier is @Universal-MathBot. The obtained results confirm the effectiveness of the proposed approach and demonstrate the potential for further development of intelligent educational services based on messenger platforms.

Conclusion

This study resulted in the implementation of the software architecture of a multifunctional bot designed to automate the solution of a wide range of mathematical problems. The developed bot combines modern symbolic and numerical computation algorithms, an intuitive interface, and the ability to visualize solutions in LaTeX format. The integration of Node.js and Python technologies, as well as the use of WebSockets for cross-language interaction, ensure the flexibility and extensibility of the software product.

Perhaps the bot's functionality will be expanded by implementing machine learning modules for recognizing handwritten formulas and intelligently analyzing user errors. Particular attention will be paid to ensuring data security and system scalability to support a large number of concurrent users. Furthermore, integration with external educational platforms and the creation of an API for third-party developers are planned, enabling the bot to be used in various educational and research projects. Thus, the implemented Telegram bot could become an effective tool for supporting learning and self-education in mathematics, contributing to the development of digital educational technologies.

References

1. Abramova A.I. Using a Telegram Bot in the Educational Process of a University // Science Bulletin No. 1 (46), Vol. 3. pp. 150–153. 2022. ISSN 2712-8849 // Electronic resource: https://www.vesnik-nauki.rf/article/5148 (date of access: 11/14/2025).

2. Goryachkin B.S., Galichy D.A., Tsapiy V.S., Burashnikov V.V., Krutov T.Yu. Efficiency of Using Chatbots in the Educational Process // E-Scio. 2021. No. 4 (55). URL: https://cyberleninka.ru/article/n/effektivnost-ispolzovaniya-chat-botov-v-obrazovatelnom-protsesse (date of access: 14.11.2025).

3. Urayev D. A. Classification and methods for creating chatbot applications // International scientific review. 2019. No. LXIV. URL: https://cyberleninka.ru/article/n/klassifikatsiya-i-metody-sozdaniya-chat-bot-prilozheniy (date of access: 14.11.2025).

4. S. A. Shilova, A. A. Kryuchkova Lingvodidactic potential of chatbots // Foreign languages in the context of intercultural communication. 2021. No. XIII.

URL: https://cyberleninka.ru/article/n/lingvodidakticheskiy-potentsial-chat-botov (Accessed: 14.11.2025).

5. Trashkova S. M. Information technologies in education: theoretical and legal aspects // Modern educational technologies in the global educational space. 2016. No. 3. URL: https://cyberleninka.ru/article/n/informatsionnye-tehnologii-v-obrazovanii-teoretiko-pravovye-aspekty (date of access: 14.11.2025).

6. Fedotov V. A. Development of an information system for a wholesale warehouse using the Python programming language // Forum of young scientists. 2021. No. 2 (54). URL: https://cyberleninka.ru/article/n/razrabotka-informatsionnoy-sistemy-dlya-optovogo-sklada-na-yazyke-programmirovaniya-python (accessed: 14.11.2025).

7. Baidybekov A. A., Gilvanov R. G., Molodkin I. A. Modern frameworks for developing web applications // Intelligent technologies in transport. 2020. No. 4 (24). URL: https://cyberleninka.ru/article/n/sovremennye-freymvorki-dlya-razrabotki-web-prilozheniy (date of access: 14.11.2025).

8. Vinokurova D. V. Selecting the optimal programming language for generating mathematical problems // Bulletin of NSU. Series: Information Technologies. 2024. No. 3. URL: https://cyberleninka.ru/article/n/vybor-optimalnogo-yazyka-programmirovaniya-dlya-generatsii-matematicheskih-zadach (date of access: 14.11.2025).

9. Akishin B.A. Features of solving mathematical problems in the Python environment // DM. 2019. No. 49. URL: https://cyberleninka.ru/article/n/osobennosti-resheniya-matematicheskih-zadach-v-srede-python (date of access: 14.11.2025).

10. Testov V.A., Popkov R.A. Research teaching of mathematics and computer algebra systems // Bulletin of Syktyvkar University. Series 1. Mathematics. Mechanics. Computer Science. 2024. No. 4 (53). URL: https://cyberleninka.ru/article/n/issledovatelskoe-obuchenie-matematike-i-sistemy-kompyuternoy-algebry (date of access: 14.11.2025)

11. Valinurova A.A., Balabanova N.V., Matsenkov I.A. Algorithm for developing a Telegram bot - a productive assistant for modern business // Modern science-intensive technologies. Regional supplement. 2023. No. 2 (74). URL: https://cyberleninka.ru/article/n/algoritm-razrabotki-telegram-bota-produktivnogo-pomoschnika-sovremennogo-biznesa (Accessed: 14.11.2025).

12. K.G. Lykova, T.A. Shchuchka, N.A. Gnezdilova The use of stochastic approaches in computational modeling of professional tasks in the training of future personnel in the field of physical education and sports // Theory and Practice of Physical Culture. 2025. №4. URL: https://cyberleninka.ru/article/n/the-use-of-stochastic-approaches-in-computational-modeling-of-professional-tasks-in-the-training-of-future-personnel-in-the-field (дата обращения: 14.11.2025).

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几何代数在管道磁场快速分析中的应用：多边形测试结果
GEOMETRIC ALGEBRA IN EXPRESS ANALYSIS OF PIPELINE MAGNETIC FIELDS: RESULTS OF POLYGON TESTING

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摘要：本文探讨了几何代数方法在管道检测中快速分析磁数据的应用。本研究的主要目标是快速识别管道沿线的关键结构参考点——焊接接头。所提出的方法基于磁场的多矢量表示，并利用几何不变量来识别局部空间变化。在专业测试场地进行的现场试验验证了该方法的可行性，使用标准计算工具即可可靠地检测焊接接头，准确率约为76%至82%。该方法对磁场背景和外部因素的变化具有鲁棒性，因此有望应用于开发用于管道快速诊断的移动系统。

关键词：管道磁诊断；残余磁场；几何代数；多矢量分析；焊接接头；结构识别；快速检测；移动诊断系统。

Abstract. *This article examines the application of geometric algebra approaches for rapid analysis of magnetic data during pipeline inspections. The main objective of the work is the prompt identification of welded joints as key structural reference points along the pipeline route. The proposed method is based on a multivector representation of the magnetic field and the use of geometric invariants to identify local spatial variations. Field tests conducted at a specialized testing site confirmed the feasibility of reliable detection of weld joints with an accuracy of about 76–82% using standard computing tools. The method is robust to variations in the magnetic background and external factors, which opens up the possibility of its use in the development of mobile systems for rapid pipeline diagnostics.*

Keywords: *pipeline magnetic diagnostics; residual magnetic field; geometric algebra; multivector analysis; weld joints; structural identification; rapid inspection; mobile diagnostic systems.*

Introduction

The residual magnetic field of pipelines carries information about the distribution of mechanical stresses related to the specific properties of the metal [5], [9]. Welded joints, technological zones, and areas of mechanical impact on the

metal introduce additional regions of mechanical stress, which are reflected in the magnetic field. During field inspections, one of the key tasks is the reliable identification of weld joints on the pipeline before excavation works are carried out.

This task is effectively solved by in-line inspection tools (smart pigs) during internal pipeline examinations. However, this process is complex and time-consuming, and the inspection results become available only after extensive post-processing of the collected data.

In contrast to large-scale in-line inspection systems, mobile diagnostic solutions can provide:

- operation under challenging environmental conditions,
- resistance to magnetic field noise and inhomogeneities,
- rapid on-site data analysis [7], [8],
- independence from complex machine learning models and mathematical algorithms [10].

The proposed approach is based on **Geometric Algebra (GA)**, which makes it possible to analyze the magnetic field as a *geometric structure* rather than as a set of independent components [1], [2], [4].

Methodological Foundations. Representation of the Magnetic Field Three orthogonal components of the magnetic field (Bx, By, Bz) are measured with a spatial sampling interval of 10 cm along the pipeline route.

The goal was to apply a processing approach that differs from traditional vector-based methods. It was decided to explore the potential of the **GA-based approach** [1], [3], which allows representing the field as a **multivector**, thereby enabling:

- preservation of the spatial properties of the magnetic field,
- tracking of geometric transformations within the magnetic field,
- enhancement of stable structural features associated with weld joints.

To achieve this, a computational model of an **integral indicator L(x)** was developed. The algorithm for calculating L(x) includes the following sequence of steps:

1. Collection of magnetic field components
2. Preprocessing: stabilization, drift, and background removal
3. Formation of the multivector representation in GA [2]
4. Extraction of local geometric invariants
5. Aggregation – computation of the integral indicator L(x)

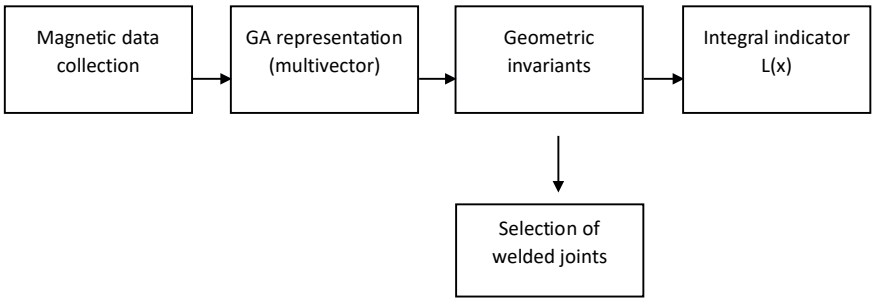

Figure 1. *Scheme of data analysis stages*

Mathematical Foundations of the Approach and Computational Methods

The core of the proposed approach is the **spatial representation of the pipeline's magnetic field** and the subsequent analysis of its **geometric structures** using the apparatus of **Geometric Algebra (GA)**. This framework makes it possible to describe and evaluate variations in multidimensional physical fields while preserving their spatial relationships.

1. Representation of the Magnetic Field

The measured magnetic field is represented as a vector quantity:

$B(x) = \{B_x(x), B_y(x), B_z(x)\}$, where B_x, B_y, B_z are the orthogonal components of the residual magnetic field.

In the classical approach, the components and derivatives of each signal are analyzed separately. In contrast, we represent the field as a **multivector** in space [1], [3]:

$\mathcal{B}(x) = B_x e_1 + B_y e_2 + B_z e_3$, where e_1, e_2, e_3 form an orthonormal basis.

This representation allows consideration not only of the magnitude and direction of the field but also of its **rotational** and **divergent** characteristics—crucial for identifying structural variations in the metal.

2. Geometric Transformations

The key analytical concept for magnetic data is the **local evaluation of structural variations** in the field.

Within the GA framework, the following components and transformations are computed:

- **Scalar component** — corresponds to the overall field intensity,
- **Vector component** — describes spatial directions of variation,
- **Bivector component** — reflects local rotational properties of the magnetic field.

The generalized formulation is expressed as:

$\Phi(x) = f(\mathcal{B}(x), \nabla\mathcal{B}(x))$, where $f(\cdot)$ is a functional operator estimating local geometric features.

3. Formation of the Structural Indicator

The resulting observation function is defined as:

$$L(x) = g(\Phi(x)),$$

where $g(\cdot)$ is an integrative functional that aggregates geometric features into a single indicator.

To ensure **geometric and scale invariance**, normalization is performed as follows:

$$\tilde{L}(x) = \frac{L(x) - \min(L)}{\max(L) - \min(L)}.$$

Significant magnetic field variations, typically caused by weld joints, manifest as local extrema of $L(x)$:

$$\text{A weld joint is identified when } L(x) > T,$$

where T is an adaptive threshold determined from the statistical characteristics of the profile.

In essence, the method performs the following:

- **Geometric decomposition** of the magnetic field,
- **Identification of spatially stable signatures** of stress–strain zones,
- **Integration of multicomponent characteristics** into a single structural indicator.

The proposed approach exhibits the following properties:

- Invariance to the global magnetic background [4], [6];
- Sensitivity to structural changes within the metal;
- Robustness against noise and local disturbances [4], [6].

Implementation and Polygon Testing

Testing and validation were carried out at a **specialized test site** approximately 300 meters long, under controlled conditions with **known weld joint positions**.

Data acquisition was performed using a **magnetometer** based on **Xtrinisic MAG3110 sensors**. The inspection was conducted from the ground surface, with the operator moving the magnetometer along the pipeline axis. The recording speed did not exceed **1 m/s**, which ensured the most uniform possible motion and accounted for the physical limitations of the equipment.

Results

After processing the recorded magnetic field data using the developed **Geometric Algebra–based method**, the resulting **integral indicator L(x)** exhibited distinct **local maxima** corresponding to the areas of welded joints.

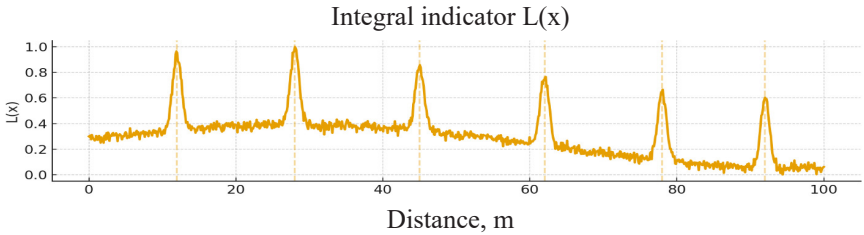

Figure 2. *Integral indicator L(x)*

Дополнительно продемонстрирован график изменения магнитного поля вблизи стыков при сохранении общего фона с распределением по осям.

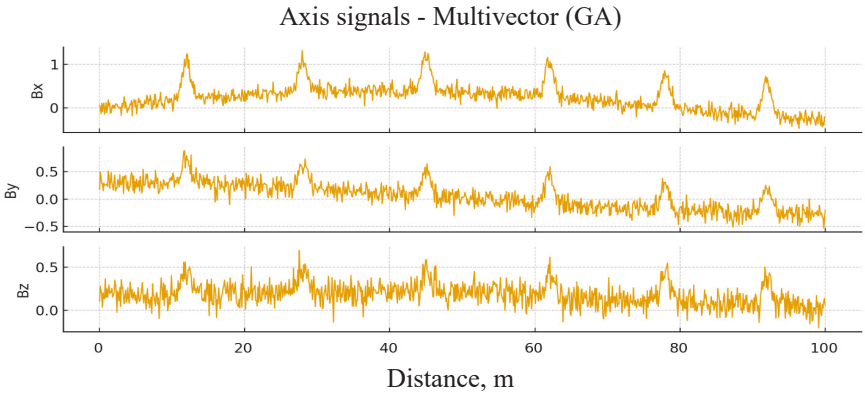

Figure 3. *Raw components Bx, By, Bz*

Based on the results of the polygon testing, the following table was compiled:

Parameter	**Value**	**Note**
Length of the test section	300 m	Specialized testing polygon
Number of weld joints on the section	30 pcs	Various magnetic background conditions
Data type	Residual magnetic field (μT)	Portable recording system
Sampling rate	10 cm per point	Walking mode acquisition
Weld joint detection accuracy	76–82%	Depending on segment conditions
Mean location error	0.5–1.2 m	Along the pipeline route
False alarm rate	5–12% of signals per 100 m	Depending on the area

Conclusion

Testing of the proposed approach for collecting and analyzing magnetic data at the test polygon demonstrated the feasibility of using a **Geometric Algebra (GA)–based data analysis method**. The key advantages of this approach are its **mobility** and **low implementation complexity**.

However, to achieve high-quality analysis results, it is necessary to account for several additional parameters — including the pipeline diameter, the distance of the magnetometer from the pipe axis, the size of the data analysis window, and the step size of data displacement.

One of the main directions for further development of this approach is the **reduction of false detections**.

Findings

The developed GA-based method for analyzing magnetic field data has demonstrated:

- **Stability and reliability** in processing data obtained under conditions close to real inspection scenarios;
- **High efficiency** in identifying magnetic field anomalies associated with weld joints and potential defects;
- **Ease of use** for rapid on-site data processing through software adapted for mobile devices.

This approach provides a foundation for **express pipeline diagnostics** using mobile data analysis systems and can be extended to the **preliminary identification of zones with local mechanical changes**.

The use of **Geometric Algebra** eliminates dependence on empirically tuned filters and does not require neural network training, which is critically important for **real-time diagnostics** and **industrial applicability** [3], [4], [8].

References

1. Hestenes D. Primer on Geometric Algebra: for Introductory Mathematics and Physics. 2005. pp. III–V (definition of geometric product), IX–XIV (rotors/rotations).

2. Hestenes D., Sobczyk G. Clifford Algebra to Geometric Calculus: A Unified Language for Mathematics and Physics. Dordrecht: Reidel/Kluwer (Springer), 1984. Ch. 1–3 (GA fundamentals), Ch. 6–7 (linear/multilinear mappings). DOI: 10.1007/978-94-009-6292-7.

3. Dorst L., Fontijne D., Mann S. Geometric Algebra for Computer Science (Revised Edition). Morgan Kaufmann/Elsevier, 2010. Ch. 2–4 (multivectors, rotors), Ch. 10–11 (computational aspects).

4. Wang R., Wang K., Cao W., Wang X. Geometric Algebra in Signal and Image Processing: A Survey. IEEE Access, 2019. Sec. I–II (theory), Sec. III (GA-based algorithms). DOI: 10.1109/ACCESS.2019.2948615.

5. Riesgo G. et al. Villari Effect at Low Strain in Magnetoactive Materials. Materials, 2020, 13(11):2472. Sec. 1–2. DOI: 10.3390/ma13112472.

6. Zhao S., Gao J., Chen J., Pan L. Residual Magnetic Field Testing System with TMR Arrays for Crack Inspection in Ferromagnetic Pipes. Sensors, 2024, 24(11):3259. Sec. 2 (Theoretical Analysis), Sec. 3 (Experiments). DOI: 10.3390/s24113259.

7. Ma Q. et al. A Review on Pipeline In-Line Inspection Technologies. Sensors, 2025, 25(15):4873. Sec. 2.1 (Electromagnetic Inspection). DOI: 10.3390/s25154873.

8. ASNT (Moore D.G., ed.). Nondestructive Testing Handbook, 3rd ed., Vol. 8: Magnetic Testing. Columbus, OH: ASNT, 2008. Ch. 1–3 (physics of the method), MFL sections (magnetic circuits, sensing elements).

9. Blitz J. Electrical and Magnetic Methods of Nondestructive Testing. London/Boca Raton: Chapman & Hall / CRC Press, 1991. Ch. 5–7 (magnetic methods, residual fields), 238 pp. DOI: 10.1201/9781003062905.

10. Review of Magnetic Flux Leakage NDT. Overview of principles, 3D dipole model, influence of defect size and liftoff.

11. EP 2737242 B1 (EPO). Non-contact Magnetic Tomography Method (MTM) for Pipeline Inspection. European Patent, issued 06.09.2017. [0035]–[0036].

12. US 5,614,825 A (Google Patents). Magnetic Flux Leakage Inspection Apparatus Systems with Independently Suspended Magnetic Sensor Blocks. Issued 25.03.1997. Abstract; Description (col. 1–2).

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基于云的机器人运动规划仿真
CLOUD-BASED SIMULATION OF ROBOT MOTION PLANNING

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摘要：随着现代社会的发展，机器人技术日新月异，仿真环境在机器人运动和行为的预测试与试验以及对最优解的探索中变得至关重要，并且其重要性与日俱增。在真实环境中测试机器人面临着时间和成本方面的诸多挑战。因此，机器人运动规划能够帮助众多科学家和研究人员以更安全、更清晰、更高效的方式测试他们的算法。本文提出了一种利用云计算技术进行机器人运动规划仿真的新方法。机器人运动规划在机器人领域扮演着至关重要的角色，它使机器人能够在各种环境中高效地控制和执行任务。利用云计算，所提出的仿真框架在可扩展性、资源利用率和可用性方面具有显著优势。本文首先概述了云计算在机器人运动规划和仿真任务中的潜在应用。随后，文章介绍了基于云的仿真框架的架构和组成部分，并重点阐述了其相对于传统方法的优势。总而言之，本文为将云技术集成到机器人领域提供了宝贵的见解，为更高效、可扩展的仿真解决方案铺平了道路。

关键词：机器人技术，集成，基于云的仿真，机器人运动。

Abstract. *In line with the demands of the modern era, the development of robotics technologies, the importance of simulation environments for pre-testing and trialing robot movements and behaviors, and the search for optimal solutions are all of great significance and are increasing as time goes on. Testing robots in a real-world environment presents numerous challenges in terms of time and cost. Therefore, robot motion planning allows many scientists and researchers to test their algorithms in a safer, clearer, and more efficient manner. The paper presents a new approach to the simulation of robot motion planning using cloud computing technologies. Robot motion planning plays a crucial role in robotics and enables robots to efficiently control and perform tasks in various environments. Using cloud computing, the proposed simulation framework offers significant advantages in terms of scalability, resource utilization, and availability. The paper begins with an overview of the potential applications of cloud computing in robot motion planning and simulation tasks. It then presents the architecture and components of*

a cloud-based simulation framework, highlighting its advantages over traditional methods. Overall, this paper provides valuable insights into the integration of cloud technologies into robotics, paving the way for more efficient and scalable simulation solutions.

Keywords: *robotics, integration, cloud-based simulation, robot movement.*

Motion planning for robots plays a crucial role in the field of robotics, as it involves determining a reliable sequence of robot movements that allows the robot to move from an initial position to a target position in a specific environment while avoiding obstacles. This process is essential for various applications such as industrial automation, autonomous vehicles, and space exploration. Efficient motion planning algorithms not only ensure the robot's safety but also optimize its trajectory to enhance its performance and efficiency.

Cloud computing has revolutionized the execution of computational tasks by providing on-demand access to a shared pool of configurable computing resources over the internet. This technology brings scalability, flexibility, and cost-effectiveness to various industries by offloading the computational load from local machines to remote servers. In the context of robot motion planning, cloud computing opens up vast possibilities for simulating complex scenarios that require significant computational resources and storage capacity.

Cloud-based simulation offers a number of advantages in the field of robot motion planning research. By using resources available in the cloud, researchers can access high-performance computing clusters to run simulations that are impractical on local machines. This capability allows for the evaluation of various motion planning algorithms, the testing of robot behaviors in different environments, and the more efficient analysis of large databases. Additionally, cloud-based simulation facilitates collaboration among researchers by providing a centralized platform for sharing simulation results and comparing experimental data [3, s.886].

The integration of cloud computing with robot motion planning research is a significant advancement in the field of robotics. The application of cloud-based simulation not only accelerates the development of innovative motion planning methods but also strengthens collaboration and knowledge sharing within the research community. As cloud technology continues to evolve, the potential to enhance robot motion planning capabilities through scalable, distributed, and cost-effective simulation approaches becomes increasingly promising.

1. Enhanced Computational Power. One of the key advantages of cloud-based simulations in robot motion planning is the ability to offload computationally intensive tasks to remote servers. This allows robots to execute complex motion planning algorithms that would be impossible on limited on-board hardware.

2. Real-time data exchange and collaboration. Cloud computing facilitates real-time data exchange and collaboration among multiple robots and operators.

This capability is particularly useful in scenarios where robots need to share sensor data and coordinate their movements dynamically.

3. Measurable Storage and Retrieval of Motion Plans. Cloud storage solutions offer scalable options for storing and retrieving motion plans, allowing robots to access a vast repository of pre-calculated paths and strategies.

In path-planning algorithms like A, the cost function f(n) is crucial for determining the optimal path. The cost function is typically defined as the sum of two components:*

$$f(n) = g(n) + h(n) \quad (1)$$

Here:

g(n) - is the cost from the starting node to the current node,

h(n) - is a heuristic estimate of the value of the current node,

n - is considered the target node.

For the Euclidean distance heuristic, h(n) can be calculated as follows:

$$h(n) = \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \quad (2)$$

The integration of cloud computing in robot motion planning brings numerous innovations and prospects, increasing computational power, facilitating real-time data exchange, and providing scalable storage solutions. By leveraging cloud-based resources and technologies, the field of robotics can achieve new heights in efficiency, collaboration, and adaptability [6, s.12].

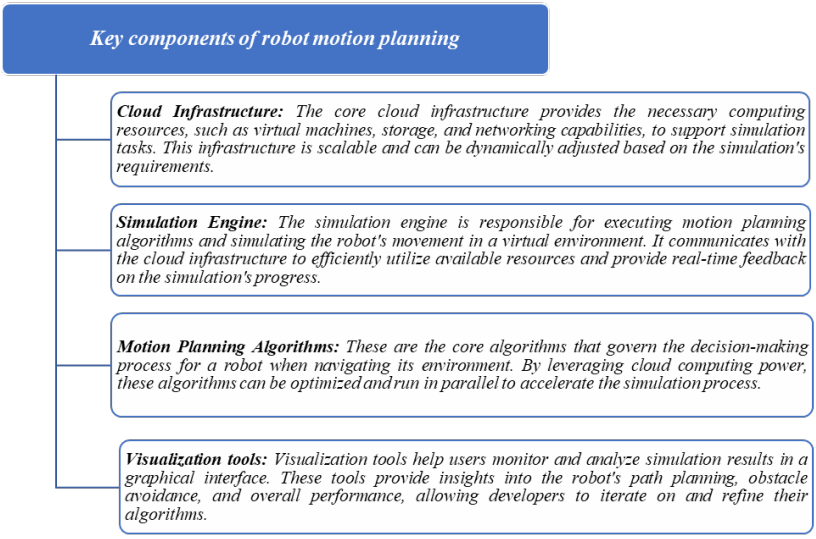

Figure 1. *Key components of robot motion planning.*
Source: *Author's own work based on internet resources.*

As we have noted, cloud-based simulation frameworks have revolutionized the field of robot motion planning by providing scalable, efficient, and cost-effective solutions for simulating complex environments and behaviors. These frameworks leverage cloud computing resources to offload the computational burden of motion planning tasks by running simulations in a distributed manner across multiple virtual machines. This allows researchers and developers to focus on designing and testing motion planning algorithms without being limited by the constraints of local hardware resources. [2, s.81].

Motion planning for robots has always been an important research area in robotics, affecting how robots move through their environment and interact with objects. Traditional methods for motion planning, which typically involve local computing resources, can be limited by processing power, data processing capabilities, and real-time response requirements. However, with the rise of cloud computing, cloud-based simulation for robot motion planning has emerged as a transformative solution, enabling more efficient and scalable systems.

Cloud computing provides computing power with the ability to store large volumes of data and offers scalable services that extend the capabilities of robotics beyond traditional methods. In robotics, this encompasses everything from processing power for algorithms to memory for large databases. For motion planning, cloud computing offers a number of advantages, such as parallel processing capabilities and real-time data access, which significantly enhance the overall performance of robots in complex and dynamic environments.

Through cloud-based systems, robots no longer need to rely solely on their onboard processors. Instead, they can offload complex tasks to cloud platforms that are better equipped to handle them. This approach allows robots to access vast data repositories and intensive computational algorithms, simplifying the planning and execution of movement strategies. The integration of cloud technologies into motion planning has led to improvements in both the speed and accuracy of robots' decision-making processes.

One of the key advantages of using cloud-based simulations for robot motion planning is scalability. Cloud platforms can distribute computational workloads across multiple servers, enabling parallel processing. This significantly reduces the time required for the computations of the two main components of robot motion planning: path optimization and collision avoidance. In dynamic environments where real-time adjustments are necessary, this computational advantage can mean the difference between success and failure in task execution.

Another key advantage is the efficiency of cloud-based simulations. Traditional motion planning systems require expensive hardware to perform on-premise processing tasks. On the other hand, cloud computing allows users to scale resources as needed, paying only for what they use. This makes high-performance

motion planning accessible to a wider range of users, from academic researchers to commercial enterprises. [5, s.349].

Additionally, cloud-based platforms offer advanced collaboration capabilities. Many robots can use shared cloud resources to share data in real time and learn from each other's experiences. For example, when a robot encounters a particular obstacle or environment, it can upload the data to the cloud, which allows other robots to use this information to improve their motion planning. This collective intelligence makes robots more adaptable to complex, unpredictable environments.

Despite numerous advantages, there are also challenges to be addressed in cloud-based robot motion planning. One of the most common concerns is latency. When robots use the cloud for data processing, any delay in data transfer can negatively impact their decision-making process, especially in real-time applications. This problem can be alleviated with advanced network solutions, such as edge computing, which places some computational resources closer to the robot.

Security is another major concern in cloud-based robotics. Data transmission between the robot and the cloud poses risks of interception and cyberattacks. Ensuring data confidentiality and integrity requires robust encryption protocols and strict access control measures to protect sensitive information such as robot trajectories and environmental maps.

Furthermore, cloud-based motion planning requires a reliable internet connection. In environments with poor network availability, such as remote or hazardous locations, the robot's ability to rely on cloud resources may be limited. Hybrid approaches that combine both local processing and cloud resources can address these issues by ensuring the robot retains essential functionality if its connection to the cloud is lost.

Cloud-based simulation of robot motion planning presents a promising way to increase the efficiency, scalability, and accuracy of robot systems. By leveraging the power of cloud computing, robots can access vast resources and process data more efficiently, leading to better decision-making in complex environments. While challenges such as latency, security, and network reliability persist, continuous advancements in cloud technologies and networking solutions will likely make cloud-based motion planning a cornerstone of future robotics development [7, s.91].

The architecture of a typical cloud-based simulation framework for robot motion planning consists of several key components that work together to provide a robust and scalable environment for conducting simulations.

Cloud-based simulation frameworks have emerged as a powerful tool for advancing research and development in robot motion planning. Researchers and developers can push the boundaries of what is possible in the simulation and

optimization of robot motion planning algorithms by leveraging the scalability, cost-effectiveness, accessibility, and performance advantages of cloud computing.

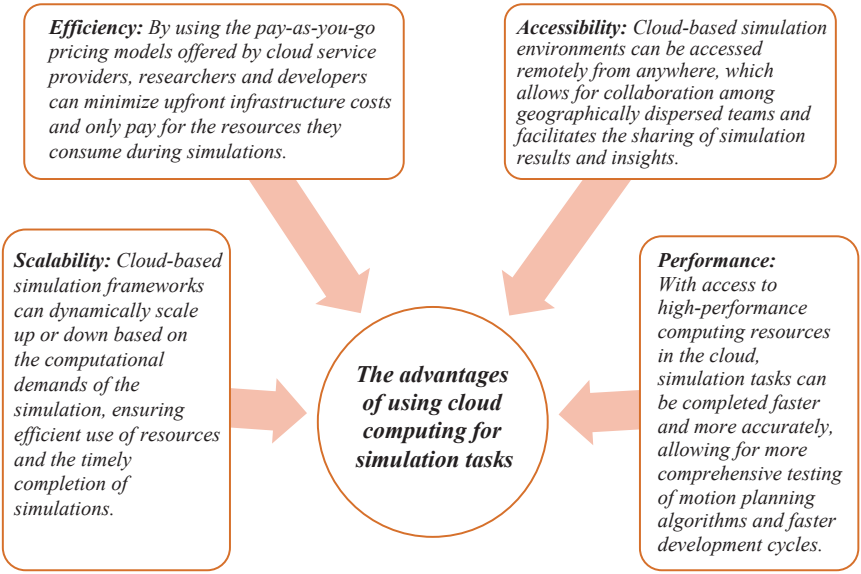

Figure 2. *Advantages of using cloud computing for simulation tasks*
Source: Author's own work based on internet resources.

The implementation and testing of robot motion planning in a cloud-based simulation environment holds great promise for the advancement of robotics and automation. By leveraging computing resources and the flexibility of cloud computing, researchers can develop and test complex motion planning algorithms that enhance the autonomy and navigation capabilities of robots in various environments. Overall, cloud-based simulation presents an attractive opportunity to accelerate innovation and experimentation in robotics, paving the way for smarter and more adaptable robotic systems [1, s.29].

Cloud-based simulation enables faster iteration of algorithm design and testing, allowing researchers to explore a wider range of scenarios and optimize performance parameters more efficiently. This rapid prototyping capability can significantly shorten the development cycle for new motion planning methods and facilitate the integration of advanced algorithms into real-world robotic systems. Furthermore, the scale of cloud-based simulation allows researchers to analyze and evaluate the performance of motion planning algorithms on a large scale. By simulating complex environments with multiple robots and dynamic obstacles,

researchers can evaluate the scalability and robustness of their algorithms across various scenarios. This capability is crucial for validating the effectiveness of motion planning techniques in real-world applications where robots must navigate dynamic environments with unexpected obstacles.

Several key areas can be identified for potential improvements and optimizations for a cloud-based simulation framework. First, strengthening the integration of simulation tools with cloud computing platforms can facilitate the deployment and management of simulation environments. By automating the setup and configuration of simulations in the cloud, researchers can focus more on developing algorithms and conducting experiments, rather than on managing the infrastructure.

Secondly, optimizing the performance and resource utilization of cloud-based simulations can increase the efficiency and cost-effectiveness of conducting large-scale experiments. By applying techniques such as load balancing, task scheduling, and resource provisioning, researchers can ensure the efficient use of computational resources and prevent bottlenecks during the simulation workflow [4, s.77].

Looking ahead to future research directions, cloud-based simulation holds significant promise for advancing the field of robotics in various applications. One potential avenue is the integration of machine learning and artificial intelligence techniques into cloud-based motion planning frameworks. By leveraging cloud resources for training and applying machine learning models, researchers can develop adaptive and intelligent motion planning algorithms that can learn from experience and improve over time. Furthermore, combining cloud-based simulation with real-time sensor data processing can enable robots to make more informed and dynamic decisions in complex environments. By combining sensor data from cameras, lidar, and other sources with cloud-based simulation, robots can enhance their perception and decision-making capabilities, leading to more robust and reliable motion planning strategies.

In conclusion, cloud-based simulation of robot motion planning presents a transformative approach to enhancing the capabilities and efficiency of robotics research. By leveraging the cloud's computing power and scalability, researchers can accelerate the development of advanced motion planning algorithms, analyze performance at scale, and explore new frontiers in adaptive and intelligent robotic systems. As this field continues to evolve, the synergy between cloud computing and robotics holds great potential to transform how robots interact with and navigate complex environments.

References

1. Fox, D., Burgard, W., & Thrun, S. (1998). The dynamic window approach to collision avoidance. IEEE Robotics & Automation Magazine, 4(1), 23-33.

2. Goulette, F. (2017). Distributed Robot Motion Planning in Cloud-Based Simulations. Proceedings of the 2nd International Conference on Cloud Computing and Internet of Things (CCIOT 2017).

3. Karaman, S., & Frazzoli, E. (2011). Sampling-based algorithms for optimal motion planning. The International Journal of Robotics Research, 30(7), 846-894.

4. Li, W., & Zhang, C. (2019). Cloud-Based Robotics: From Distributed Robotics to Cloud Robotics. Springer.

5. Malik, A., Kumar, A., & Jha, S. Cloud-based Robot Motion Planning Using Genetic Algorithms. Procedia Computer Science, 154, 2019, pp. 347-354

6. Pandey, P., & Reddy, P. V. Cloud-Based Multi-Robot Motion Planning Using Deep Reinforcement Learning. Journal of Cloud Computing: Advances, Systems, and Applications, 2021, pp. 1-15

7. Russell, S. J., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.

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基于众筹项目文本描述的科技创业公司神经评分模型
NEURAL SCORING MODEL FOR TECHNOLOGY STARTUPS FROM TEXT DESCRIPTIONS OF CROWDFUNDING PROJECTS

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摘要：众筹平台会产生大量科技创业项目提案，这使得人工筛选有潜力的项目既费时费力又带有主观性。本文利用包含约21.5万个项目（每个项目都有一个二元成功标签）的开源Kickstarter-NLP数据集，研究了如何根据项目的简短文本描述对其进行评分。在固定的训练集-验证集-测试集划分下，我们比较了四种模型：基于TF-IDF特征训练的逻辑回归和线性SVM、双向LSTM网络（BiLSTM）以及作为冻结文本编码器并在其上叠加浅层MLP分类器的DistilBERT Transformer。模型性能通过准确率、F1值、ROC曲线下面积（AUC）和Brier评分进行评估。DistilBERT + MLP配置在测试集上取得了最佳结果（准确率≈0.695，F1值≈0.70，ROC曲线下面积≈0.76），优于可解释的TF-IDF基线模型和BiLSTM模型，同时保持了相当的概率校准精度。研究结果表明，该架构可作为众筹平台上高科技商业项目筛选决策支持系统的核心。

关键词：众筹，科技创业公司，数字平台，文本分类，机器学习，神经网络，Transformer模型，项目评分，概率校准。

Abstract. *Crowdfunding platforms generate a large stream of technology startup proposals, which makes manual screening of promising projects labor-intensive and subjective. This paper investigates the problem of scoring projects from their short textual descriptions using the open Kickstarter-NLP dataset comprising about 215,000 campaigns with a binary success label. On a fixed train–validation–test split, four models are compared: logistic regression and linear SVM trained on TF–IDF features, a bidirectional LSTM network (BiLSTM), and a DistilBERT transformer used as a frozen text encoder with a shallow MLP classifier on top. Model performance is evaluated using Accuracy, F1, ROC–AUC and Brier score. The DistilBERT + MLP configuration achieves the best results on*

the test set (Accuracy ≈ 0.695, F1 ≈ 0.70, ROC–AUC ≈ 0.76), outperforming the interpretable TF–IDF baseline and the BiLSTM while maintaining comparable probability calibration. The results indicate that this architecture can serve as the core of a decision-support system for selecting high-tech business projects on crowdfunding platforms.

Keywords: *crowdfunding, technology startups, digital platforms, text classification, machine learning, neural networks, transformers, project scoring, probability calibration.*

The rapid growth of digital crowdfunding platforms has led to a situation in which thousands of technology projects compete each year for the attention of a distributed crowd of backers. Platforms such as Kickstarter enable entrepreneurs to present their ideas, test market demand and obtain initial funding without relying on traditional venture capital institutions. For the platform itself, for accelerators, and for partner investors, an early identification of promising projects within this stream of applications becomes a key task. Under limited expert resources, manual reading of every description is difficult to scale, and it is natural to turn to machine learning (ML) and natural language processing (NLP) techniques to support automated scoring of applications based on their textual content.

Empirical studies in the economics and sociology of crowdfunding have demonstrated that campaign success depends not only on project characteristics and the founders' social capital but also on how the project is described to potential backers [1–3]. Writing style, clarity of the product vision, level of specificity and the transparency of the value proposition have been shown to be statistically significant factors. Against this background, a growing body of work applies text analysis and ML methods to predict crowdfunding outcomes and identify linguistic features that drive investor behaviour [1, 3, 5].

In parallel, NLP has undergone a methodological shift from classical models with manually engineered features to deep neural architectures. Recurrent networks with LSTM units and bidirectional processing became a standard tool for modelling sequences and long-range dependencies, and were subsequently surpassed by transformer architectures, which offer advantages in quality and scalability [6]. Pre-trained language models such as BERT and its lighter variants, including DistilBERT, have effectively become de facto standards for a wide range of text classification tasks [7, 8]. In this context, it is both relevant and practically important to examine how much benefit transformer-based architectures provide for the specific task of scoring startup-like projects from short text blurbs on real crowdfunding data, and how their probabilistic outputs can be used in decision support.

The empirical analysis in this paper is based on the open Kickstarter-NLP dataset, which contains a snapshot of Kickstarter campaigns launched in 2017 [4]. The platform covers a wide spectrum of categories (board games, design and art projects, technology products, etc.), so the term “startup” is used here in a broad sense to denote initiatives that aim to develop a new product or service in the form of a crowdfunding campaign. The study employs the curated df_text_eng subset, which includes only two fields: the short textual description blurb and the binary target state with values “successful” or “failed”. After filtering out records with empty descriptions, missing labels or irrelevant states, the working sample comprises 215,510 observations. The class distribution is almost symmetric, with the proportion of successful campaigns slightly exceeding the proportion of failed ones, which avoids strong imbalance and simplifies interpretation of performance metrics.

To ensure a fair comparison of models, the dataset is randomly split into three disjoint parts: approximately 70 % of observations for training, 15 % for validation and 15 % for testing. The validation subset is used for hyperparameter tuning and early stopping of neural networks, while the test subset is reserved exclusively for final evaluation and model comparison. Project descriptions in the dataset are relatively short, which limits the amount of information contained in each textual instance and makes the task a natural stress test: models must extract a maximum of predictive signal from compact blurbs.

The first family of models consists of classical ML algorithms on sparse vector representations of text. The corpus is transformed into TF–IDF features over a vocabulary of the most frequent tokens and n-grams. Preliminary experiments show that augmenting unigrams with bigrams yields a consistent, albeit moderate, improvement over a purely unigram-based representation, and the final configuration therefore uses 1–2-gram features. Logistic regression with L2 regularization and a linear support vector machine (SVM) are trained on these features, providing an industry-relevant baseline for subsequent comparison with neural architectures.

The next model family is represented by a bidirectional LSTM (BiLSTM) network. Texts are converted into sequences of token indices with a fixed maximum sequence length and vocabulary size. Tokens are mapped to trainable embeddings of moderate dimensionality, the sequences are processed by a bidirectional LSTM layer, and the aggregated representation is passed to a dense output layer with a sigmoid activation. The network is trained using binary cross-entropy and the Adam optimizer; early stopping based on validation F1-score is used to reduce overfitting.

The strongest architecture in the study is based on DistilBERT, used in a feature-extraction regime. A pre-trained DistilBERT model, trained on large-scale English corpora, generates contextualized sentence embeddings for each project

description [7, 8]. For every blurb, a single vector representation is extracted and fed into a compact multilayer perceptron (MLP) classifier with one hidden non-linear layer and a sigmoid output neuron for binary prediction. In this set-up, the computationally intensive language modelling component remains frozen, while only the lightweight classifier head is trained, which reduces computational cost and stabilizes training.

Model comparison relies on several complementary metrics. Accuracy measures the proportion of correctly classified campaigns and is intuitively understandable for business stakeholders. The F1-score, computed for the positive class "successful project", balances precision and recall and reflects the ability of a model to identify promising projects without overwhelming experts with excessive false positives. ROC–AUC serves as a threshold-independent indicator of discriminative power, quantifying how well a model separates successful and failed campaigns along the scoring scale. In addition, the Brier score is computed as the mean squared error of probabilistic predictions; it is sensitive to calibration quality and is widely used when assessing probabilistic models in applied domains [9, 10].

The aggregate results on the test set are summarized in Figure 1. Logistic regression on TF–IDF features achieves accuracy of about 0.678, F1-score of about 0.681 and ROC–AUC of roughly 0.745. The linear SVM yields slightly lower accuracy (≈0.659) and F1 (≈0.660); ROC–AUC is not reported for SVM in this study due to implementation specifics. The BiLSTM model provides a small but stable gain over the linear baselines, with accuracy around 0.683, F1 around 0.686 and ROC–AUC around 0.750. The DistilBERT + MLP model attains the highest performance, with accuracy around 0.695, F1 around 0.702 and ROC–AUC around 0.764, indicating a noticeable improvement both in ranking quality and balanced classification quality compared to simpler approaches.

	model	accuracy	precision	recall	f1	roc_auc
0	Logistic Regression (TF-IDF)	0.678400	0.679300	0.682200	0.680700	0.745000
1	Linear SVM (TF-IDF)	0.658700	0.661100	0.658500	0.659800	nan
2	BiLSTM	0.683100	0.683700	0.687300	0.685500	0.750500
3	DistilBERT + MLP	0.694900	0.689400	0.714900	0.701900	0.764000

Figure 1. *Test-set performance of logistic regression, linear SVM, BiLSTM and DistilBERT + MLP (Accuracy, F1, ROC–AUC, Brier Score)*

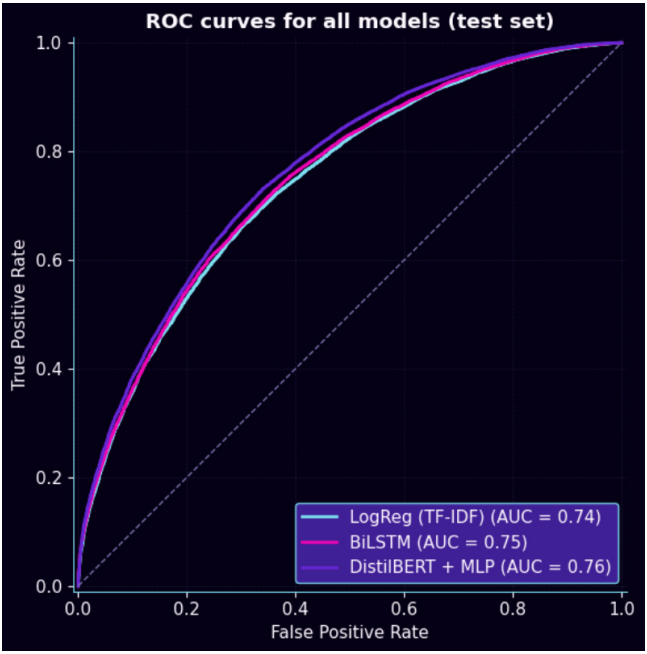

Figure 2. *ROC curves for logistic regression, BiLSTM and DistilBERT+MLP on the test set*

The graphical analysis of the ROC curves (Figure 2) supports the numerical findings: the curves for logistic regression and BiLSTM lie well above the diagonal of random guessing, while DistilBERT + MLP achieves higher true positive rates across the entire range of false positive rates, with a particularly noticeable advantage in the low-FPR region that is critical for application-screening tasks.

Importantly, the superiority of the transformer-based architecture is not an artefact of a particular random split. For the pair DistilBERT + MLP versus logistic regression, a bootstrap analysis of the ROC–AUC difference is performed with a 95 % confidence interval. For DistilBERT + MLP, the test-set metrics are as follows: Accuracy = 0.695 (95 % CI: 0.690–0.700), F1 = 0.702 (95 % CI: 0.697–0.708), ROC–AUC = 0.764 (95 % CI: 0.760–0.769). The mean AUC improvement ΔAUC = AUC(DistilBERT) – AUC(LogReg) is approximately 0.019, and the corresponding 95 % confidence interval [≈0.014; ≈0.023] lies entirely above zero. Together with the relatively narrow confidence intervals for all metrics, which are expected given the test-set size of several tens of thousands of observations, this supports the conclusion that DistilBERT + MLP provides a statistically significant gain in discriminative performance.

Probability calibration warrants separate attention. Prior work has shown that modern neural networks tend to produce over-confident probability estimates [9]. In this study, the calibration of logistic regression, BiLSTM and DistilBERT + MLP is assessed using reliability diagrams and Brier scores; the three calibration curves are presented in Figure 3. Logistic regression exhibits near-ideal calibration: the empirical curve lies close to the diagonal, and the Brier score is about 0.2045. The BiLSTM model achieves a similar Brier score (≈0.2027), but displays a tendency to over-confidence at high predicted probabilities (above ≈0.9). DistilBERT + MLP attains the lowest Brier score (≈0.1975) and the curve closest to the diagonal, which indicates the best alignment between predicted probabilities and empirical success frequencies among the three models.

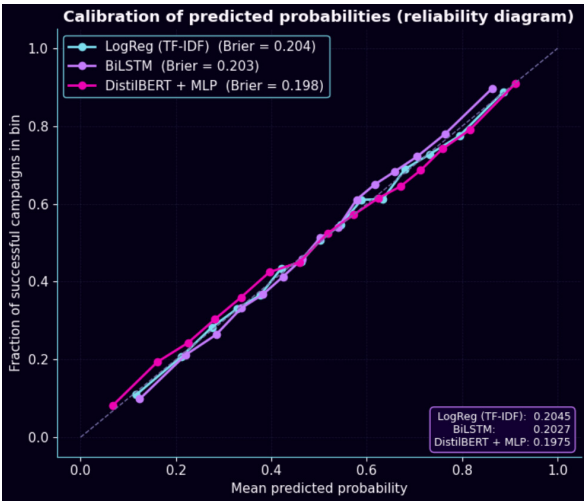

Figure 3. *Calibration curves and Brier scores for logistic regression, BiLSTM and DistilBERT + MLP*

From a platform's perspective, the choice of decision threshold is as important as the average level of predictive performance. To illustrate this aspect, a simple utility function is introduced that assigns a positive payoff to correctly accepted successful projects and penalties to missed successful projects and unnecessary expert reviews of failed ones. The numeric coefficients are chosen heuristically to reflect plausible preferences of a platform and serve as an example; in a production system they would need to be tuned on business data. For a range of probability thresholds t, the expected utility per campaign is computed and plotted (Figure 4), which allows one to select a trade-off between the coverage of potentially successful projects and the number of applications passed to human experts. For Distil-

BERT + MLP, the optimal threshold is substantially lower than the conventional 0.5 and is located around t ≈ 0.03, with a maximum expected utility of about 0.45. This behaviour reflects the nature of the task: under a large inflow of projects, it can be economically rational to pass a relatively wide funnel of applications to manual review if the share of truly successful campaigns in this subset is sufficiently higher than in the overall stream.

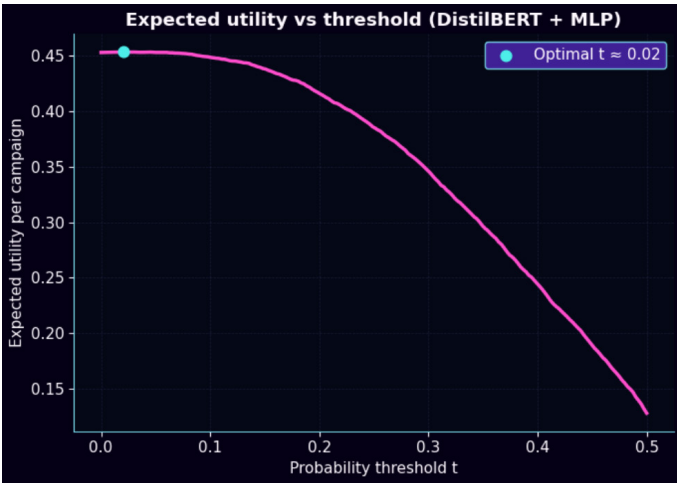

Figure 4. *Dependence of the expected utility U(t) on the selection threshold t for the DistilBERT + MLP model*

Model interpretability remains an important concern for business users. In this regard, the logistic regression baseline has a clear advantage: its coefficients on TF–IDF features can be directly interpreted as contributions of n-grams to the predicted success probability. In the experiments, lists of n-grams with the largest positive and negative weights were constructed. Among positively associated phrases are expressions referring to concrete, well-packaged products (“tabletop miniatures”, “board game”, “art book”), mentions of limited editions and special releases, and formulations signalling confidence and thorough preparation. Negatively associated phrases include generic terms such as “app”, “website”, “marketing” as well as constructions that give the impression of an unstructured request for support. This pattern is consistent with qualitative observations: campaigns that present a clearly formulated product with an obvious value proposition tend to elicit a stronger positive response than abstract ideas or underdeveloped projects.

To gain insight into how the transformer model organizes the space of projects, DistilBERT embeddings for the test set were visualized using t-SNE followed by

k-means clustering. Dimensionality was reduced to two and the resulting two-dimensional projections were plotted (Figure 5). In the left panel, points are coloured by the true label (successful vs failed campaigns), revealing partial but incomplete class separation and regions with a higher concentration of successful projects. In the right panel, the same embeddings are coloured by five k-means clusters, making compact thematic groups visible (for example, board games, technology gadgets, art projects), with success rates differing across regions of the embedding space. This behaviour indicates that the transformer captures meaningful semantic distinctions between project types and leverages them when predicting campaign outcomes.

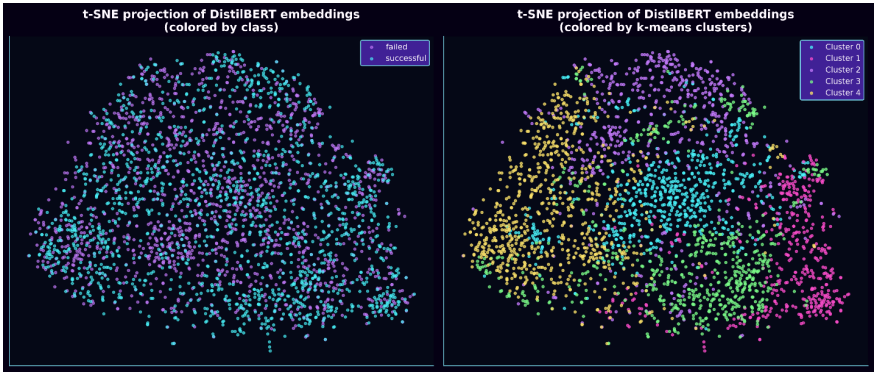

Figure 5. *t-SNE projections of DistilBERT embeddings for the test set: on the left, points are colored by the true class (failed / successful); on the right, by clusters identified by the k-means algorithm.*

An additional contribution of the study is the comparison of model complexity and practical deployability on a real platform. Logistic regression on TF–IDF features has minimal resource requirements: both training and inference are straightforward on CPUs and the resulting model is highly interpretable. BiLSTM already benefits from GPU acceleration to speed up training and delivers a moderate quality gain while remaining relatively compact. DistilBERT + MLP is the computationally heaviest setup, yet in the feature-extraction regime with a frozen transformer it remains feasible for offline scoring of large batches of applications or for asynchronous processing in a queue. In a realistic system, a hybrid design appears attractive, where a lightweight model is used for initial filtering and a transformer-based scorer is applied to a shortlist of projects.

The findings have both methodological and applied implications. On the one hand, the results confirm that even simple linear models on TF–IDF features can capture a substantial portion of the signal present in short startup descriptions and

may serve as a minimal viable tool for decision support. On the other hand, transformer architectures provide a statistically significant improvement in predictive performance and, crucially, better probability calibration, which is essential when subsequent economic decisions are based on model outputs [8–10]. Utility-based threshold analysis helps move from abstract metric values towards answering the practical question of which threshold and which share of applications are optimal for a specific platform, given the cost of manual review and the desired proportion of successful projects in the portfolio.

Naturally, the study has several limitations. First, it relies on a dataset that reflects a single time snapshot of the Kickstarter platform (2017), so the results may be partly influenced by temporal effects and the topical composition of projects at that time [4]. Second, only the textual component of applications is modelled; structured metadata such as funding goals, campaign duration, geography and social activity are not used, even though prior work demonstrates their importance for success prediction [1–3]. Third, DistilBERT is employed in a feature-extraction mode without full fine-tuning, which simplifies the experimental setup and reduces overfitting risk but does not exploit the full potential of transformer models. Finally, the utility function is intentionally simplified and does not account for campaign dynamics or portfolio-level effects.

Promising directions for further research include combining textual information with structured project and context features, applying more advanced interpretability techniques (for example, gradient-based explanations for transformers), and developing interactive tools for platform managers in which the scoring model is integrated into application dashboards and risk visualizations. From a business perspective, controlled experiments (A/B-tests) that embed the scoring model into real moderation workflows and evaluate its impact on conversion and portfolio quality would be particularly informative.

Taken together, the results demonstrate that modern NLP methods can act not just as an auxiliary technology but as a core analytical component of decision support systems in the creation of high-technology businesses. Neural scoring models based on text descriptions enable platforms and accelerators to select promising startups more consistently and at scale, reducing expert workload and increasing the share of successful projects in their portfolios.

References

1. Mollick E. The Dynamics of Crowdfunding: An Exploratory Study // Journal of Business Venturing. 2014. Vol. 29, No. 1. P. 1–16.

2. Crosetto P., Regner T. Crowdfunding: Determinants of Success and Funding Dynamics. Working Paper, 2014.

3. Lysin S. Predicting the Success of Crowdfunding Campaigns on Kickstarter. Master Thesis. University of Twente, 2024.

4. Ktzioumis T. Kickstarter-NLP: Sentiment and Word Usage – GitHub repository. URL: https://github.com/ktzioumis/Kickstarter-NLP.

5. Ktzioumis T. Sentiment Analysis and Word Usage for Kickstarter Blurbs. Medium, 2019.

6. Vaswani A., Shazeer N., Parmar N. et al. Attention Is All You Need // Advances in Neural Information Processing Systems. 2017.

7. Devlin J., Chang M.-W., Lee K., Toutanova K. BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding // NAACL-HLT. 2019. P. 4171–4186.

8. Sanh V., Debut L., Chaumond J., Wolf T. DistilBERT, a Distilled Version of BERT: Smaller, Faster, Cheaper and Lighter // arXiv preprint arXiv:1910.01108. 2019.

9. Guo C., Pleiss G., Sun Y., Weinberger K.Q. On Calibration of Modern Neural Networks // Proceedings of the 34th International Conference on Machine Learning. 2017. Vol. 70. P. 1321–1330.

10. Brier G.W. Verification of Forecasts Expressed in Terms of Probability // Monthly Weather Review. 1950. Vol. 78, No. 1. P. 1–3.

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调查行动中的数字技术
DIGITAL TECHNOLOGIES IN THE COURSE OF INVESTIGATIVE ACTIONS

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摘要：本文探讨了对执法实践（包括侦查行动）各个方面产生重大影响的最新数字技术。将数字技术引入侦查过程可以加快侦查速度，提高侦查效率，提升证据质量，并增强侦查的透明度。本文研究了数字技术在侦查实践中应用的关键领域、其意义和发展前景。

关键词：数字技术，侦查行动，侦查，犯罪，虚拟现实，网络空间，生物识别技术，国际合作。

Abstract. *The article deals with the latest digital technologies which have significantly influenced on various aspects of law enforcement practice including investigative actions. The introduction of digital technologies into investigative processes allows to accelerate and increase their effectiveness, improve the quality of evidence and increase the transparency of investigations. In the article, we have studied the key areas of the digital technologies application in investigative practice, their significance and prospects for development.*

Keywords: *digital technologies, investigative actions, investigations, crime, virtual reality, cyberspace, biometric technologies, international cooperation.*

Evidence digitalization

One of the most obvious aspects of the introduction of digital technologies into investigative actions is the evidence digitalization. Whereas in the past investigative actions were carried out by means of physical media (paper documents, photographs, physical evidence), nowadays many proofs exist in digital form (electronic correspondence, data from surveillance cameras, call recordings). An

application of a digital protocol instead of the paper media makes it possible to speed up the documentation process and improve the data accuracy.[1]

Video recordings in the course of investigative actions

Video recording of investigative actions has become an integral part of modern criminal investigations. According to V.P. Ivanov, video recording of interrogations and inspection of crime scenes facilitate better recording of all the details and prevent the possibility of data falsification and controversial situations in further court proceedings.[2]

In some countries, video recording has already become a mandatory part of the proceedings. This method contributes to the creation of a transparent criminal justice system, and also protects the rights of both suspects and law enforcement officers by eliminating the possibility of unfounded accusations.

Data analysis using artificial intelligence

Artificial intelligence (AI) and machine learning has gained much importance in modern investigative processes. Large amounts of data arising in the course of investigation (phone calls, bank transactions, Internet activity) can be effectively analyzed by means of AI. Machine learning technologies allow investigators to find hidden connections and patterns in criminal activity that could have been missed during manual analysis, and help them in solving complex cases.

In addition, AI is used to create forecasts based on available data. AI can be useful in determining the likelihood that a crime will be committed in a certain place or a suspect may escape from the investigation.

Remote participation in investigative actions

Digital technologies have made it possible to introduce new forms of participation in investigative actions. For example, conducting interrogations and court sessions via videoconference saves time and resources and ensures the safety of participants.[3] This was especially true in the context of the COVID-19 pandemic, when physical meetings were difficult.

Moreover, remote technologies can be applied for international cooperation. For example, countries can share information and coordinate their actions in transnational criminal cases, which speeds up the investigation process and reduces the likelihood that criminals will be able to escape justice.

[1] Loshkarev A.V., Mikhailina E.B. Current trends in the introduction of digital technologies in the justice system of the Russian Federation // Economic and legal issues. 2022. №. 3 (165). p. 25.

[2] Ivanov V.P. The use of video recordings in criminal proceedings: Theory and practice. — St. Petersburg: Pravo. Publishing House, 2018. p. 75.

[3] Oreshko V.E. Possibilities of using digital technologies in the production of investigative actions // Pravo. Theory and practice of social development. 2023. №. 4. p.163.

Virtual (VR) and Augmented (AR) reality in crime reconstruction

The use of virtual and augmented reality technologies opens up new opportunities for crime reconstruction. Using these technologies, it is possible to recreate the crime scene digitally, which allows investigators and the court to better understand the sequence of events, the location of evidence and other circumstances of the case.[4]

By the way, VR can be used to train investigators by giving them opportunity to undergo training at virtual crime scenes. Thus, the introduction of this technology contributes to improving investigations and the level of professional training of employees, as well.

Cybersecurity and protection of digital evidence

One of the key challenges when using digital technologies in investigative actions is ensuring cybersecurity and protection of the received data. Digital evidence, such as emails, CCTV footage, or social media data, can be easily altered or destroyed if measures to properly protect them are not taken into account. This necessitates the introduction of special methods to prevent cyber threats and protect information.

At the moment, according to Shakhnazarov B.A., one of the main promising methods to solve the problem is the blockchain technologies application in the modern system of intellectual property protection in order to prevent unauthorized access and alteration.[5] Blockchain allows to record every action using digital data (for example, access, copying, transfer), which alows to trace any changes easily. Thus, the blockchain can guarantee the immutability of digital evidence from the moment it is received until it is presented in the court.

Biometric technologies in investigative actions

The use of biometric technologies such as facial recognition, fingerprints, voice and DNA greatly simplify the process of identifying suspects, victims and witnesses. For example, L. Konakova speaks about a rapid way to find a person on video recordings from surveillance cameras by means of facial recognition technologies FindFace SDK. This system is extremely important in promptly detention of a suspect. So in 2017, in Qingdao (China), using this system the police detained 25 wanted criminals, and in Russia, at the World Cup, 180 violators including the thief of the sponsor's cup were effortlessly caught[6].

[4] Investigative Committee Website. Information technology in the Investigative Committee: advantages and risks. // 2024.

[5] Shakhnazarov B.A. Complex interrelation of blockchain technology and intellectual property objects in cross-border private law relations // Right. Journal of the Higher School of Economics. 2019. No. 5. p. 123.

[6] Konakova L.Y. Foreign experience in the development of facial recognition technology in ensuring public safety // Law and Management. No. 1. 2023. p.179.

Besides, biometric technologies are actively used to prevent document forgery and ensure the reliability of the evidence presented. Contemporary software allows to compare suspects' data with extensive databases and speed up the investigation and minimize identification errors.

Legal aspects of the use of digital technologies in investigative practice

One of the most important issues related to the introduction of digital technologies is their legal regulation. Most countries have legislation governing the collection, storage and use of digital technologies during investigative actions to ensure their legality and the protection of the rights of participants.[7] So, in Russia, since 2019, a law has been in force that allows the use of video recordings as evidence in court.

Furthermore, it is important to have an international cooperation in the use of digital technologies in investigative actions. Cybercrime-related crimes are often transnational in nature, which requires the harmonization of legislative norms and working methods in different countries.

Conclusion

The use of digital technologies in investigative practice has already played a key role in ensuring the effectiveness of investigations. Technologies make it possible to speed up the process of collecting and analyzing evidence, improve their reliability and protection. However, it is necessary to take into account the emerging challenges: legal regulation, personal data protection and cybersecurity remain urgent issues that require constant attention and improvement.

References

1. Ivanov V.P. The use of video recordings in criminal proceedings: Theory and practice. — St. Petersburg: Pravo. Publishing House, 2018. p. 75.

2. Konakova L.Yu. Foreign experience in the development of facial recognition technology in ensuring public safety // Law and Management. No. 1. 2023. p.178-182. file:///C:/Users/user/Downloads/zarubezhnyy-opyt-razvitiya-tehnologii-raspoznavaniya-lits-v-obespechenii-obschestvennoy

3. Loshkarev A.V., Mikhailina E.B. Current trends in the introduction of digital technologies in the justice system of the Russian Federation // Economic and legal issues. 2022. No. 3 (165). pp. 21-27. https://www.law-journal.ru/files/pdf/202203/202203_21.pdf

4. Oreshko V.E. Possibilities of using digital technologies in the production of investigative actions // Theory and practice of social development. 2023.

[7] Investigative Committee Website. Information technology in the Investigative Committee: advantages and risks. // 2024.

No. 4 (23). pp. 160-165. https://sciup.org/vozmozhnosti-ispolzovanija-cifrovyh-tehnologij-pri-proizvodstve-sledstvennyh-149142595

5. Investigative Committee website. 2024. https://www.tadviser.ru/index.php/article:Informationtechnology_InvestigativeCommitte

6. Shakhnazarov B.A. Complex interrelation of blockchain technology and intellectual property objects in cross-border private law relations // Right. Journal of the Higher School of Economics. 2019. No. 5, pp. 121-147.

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现代世界的替代能源和核工业的发展
ALTERNATIVE ENERGY SOURCES AND THE EVOLUTION OF THE NUCLEAR INDUSTRY IN THE MODERN WORLD

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摘要：本文重点探讨了替代能源以及“和平原子能”的积极利用，这与各国能源依赖程度以及全球核工业的发展密切相关。全球核工业的总体发展与高风险核设施的运行密切相关，这些设施有时会引发人为事故，造成负面的环境后果，直接关系到环境安全。

关键词：核工业，替代能源，能源依赖，事故，环境安全。

Abstract. *In the article, the authors focused on alternative energy sources, as well as the active use of a «peaceful atom», which is interesting in connection with the energy resistance of various states and the evolution of the global nuclear industry. The general planetary evolution of the nuclear industry is associated with the operation of high-risk nuclear facilities, which sometimes cause man-made emergencies with negative environmental consequences, which directly concerns environmental safety.*

Keywords: *nuclear industry, alternative energy sources, energy dependence, emergency, environmental safety.*

The interest in alternative energy sources and the evolution of the nuclear industry in the modern world today is determined, firstly, by the fact that it is impossible to stop the spread of the «peaceful atom», since humanity is constantly increasing energy consumption, and the use of other energy carriers (coal, oil, gas) becomes unprofitable due to the intensive use of natural energy sources, which today are almost completely exhausted by humanity.

Secondly, in the event of an emergency at a high-risk nuclear facility, a change in the radiation background is observed which has economic and environmental

consequences that can lead to significant and irreversible consequences, having a devastating effect on the biosphere and sociosphere. Therefore, the organization of material and technical support for nuclear facilities at the stage of their operation, the improvement of quality control tools for technological processes (multi-parameter control of multilayer structures) optimization of software tools for monitoring the distribution of energy removal in reactors at a modern nuclear power plant are becoming a priority. At the same time, it is important to pay special attention to the development of radiation-protective composite materials, theoretical, practical aspects of route optimization of dose loads in a system with radioactive objects, in relation to different stages of the life cycle of a nuclear power plant.

And, thirdly, the need to take into account the ongoing global, regional multidirectional transformations that are directly related to the development of the nuclear industry by humans, the development and justification of a computational model for analyzing the safety of a deep burial point for liquid radioactive waste during operation of equipment for the deformed state of destruction mechanisms in the event of an emergency and elimination of the consequences of a radiation accident at a high-risk nuclear facility.

The global processes taking place on the planet recently relate to the search for alternative energy sources for humanity and the further evolution of the global nuclear industry, which directly concerns hydrodynamics, heat exchange, a biogeochemical barrier in groundwater contaminated with radiation at nuclear fuel cycle enterprises, in the event of an emergency at a high-risk nuclear facility, emergency response and timely elimination of the consequences of a radiation accident are assumed.

At the same time, it is important to pay special attention to optimizing the operating modes of modern nuclear complexes that operate on renewable energy sources. International practice today testifies to the fact that global trends and the development of a “peaceful atom” prove the desire of modern states (Kazakhstan, Armenia), to actively develop the nuclear industry, since it is planned to build new nuclear power plants, the basis of which will be the prolongation of the service life of existing nuclear facilities of increased danger.

High growth rates of energy consumption in these countries imply an increase in imports of electricity and gas which is unprofitable therefore this issue was actively discussed at a national referendum, as young people are interested in the dynamic development of nuclear energy. In modern Kazakhstan, there is experience in the operation of nuclear facilities, the use of modern technologies and the necessary scientific base, which will ensure the economic independence of the country in the process of diversification of the energy sector, as well as create new jobs, which is a strategic priority in the near future.

In recent years, Kazakhstan has been widely considering a project to modernize and extend the life of the Armenian nuclear power plant, which is not only a technical prospect, but also the result of cooperation with Rosatom, the IAEA, and other partners to replace the power unit, taking into account economic efficiency, safety, the nature and characteristics of the national energy system, prospects for the development of geographical environmental safety systems [1].

In the Republic of Belarus, which does not yet fully have its own fuel and energy resources, purposeful work is actively continuing to reduce risks to economic stability and energy dependence (import of gas, electricity). The Department of Energy estimates that electricity consumption will increase to around 44 billion kWh by the end of 2025, with a target of 47 billion expected by 2030 [2]. In the context of geopolitical instability, constant fluctuations in world energy prices, the Republic of Belarus has achieved serious success and reduced its energy dependence, constantly developing alternative energy sources. Therefore, the fundamental directions today are the construction of the Belarusian nuclear power plant and an increase in the share of renewable energy sources, as well as the transition to local fuels [3]. In the modern world, the nuclear industry is in great demand in all countries, although, as practice shows, the number of natural and man-made disasters does not decrease, which is associated with economic, environmental safety and the evolution of the global nuclear energy market [4, p. 154].

World practice confirms that emergencies at high-risk nuclear facilities are characterized by physical, chemical-biological effects, radiation pollution that affect nature and human health, which is directly related to the culture of economic safety and its strategic importance for nuclear energy [5, p. 188]. Therefore, in the system mode, specialists carry out an examination that establishes the correspondence (inconsistencies) of economic activity, like any other activity of a modern person, which must correspond to the previously set parameters.

The determining factor necessary for the implementation of measures to ensure the safety of nuclear facilities, is the audit, development and testing of the procedure for temporary storage of used radioactive waste of nuclear power plants, which are specific measures aimed at developing the method of scanning contact potentiometry, results of use when monitoring equipment at the station, as well as identification, prevention of violations of environmental legislation necessary to prevent environmental disasters and accidents at nuclear power plants.

It should be noted that the fundamental principle that ensures the safety of initiating the global nuclear industry is layered protection, focused on a system of barriers to the spread of radioactive substances, ionizing radiation, organizational and technical measures to protect the population and personnel of the station, which involves the creation of successive levels of protection against probable personnel errors, equipment failures at modern nuclear facilities.

The emergency situation as the most destructive spatio-temporal change affects all spheres of social life (economic, political, social, spiritual) has specific features and its own special characteristics. Emergencies have a duration in real time necessary to identify sources, consequences and the most effective implementation of measures to minimize damage from nuclear facilities.

In this regard, the priority, as a rule, is to ensure engineering safety systems at a nuclear power plant, which is a system implementation of effective layered protection (emergency shutdown of the reactor, heat removal from the reactor core, retention of radioactive substances within the specified boundaries of the plant structures).

Recall that in the event of an emergency, it is important to clearly implement the planned activities (structuring, aggregation, search for patterns, informing), which actualizes the modeling of algorithmization of management decisions in eliminating the consequences of a radiation accident, a culture of economic and environmental safety, its strategic importance for national nuclear energy, as well as when moving to a new technological platform for nuclear energy [6, p. 3].

Particular attention is required to develop a method for predicting and preventing abnormal growth of vibrations in the equipment of the primary circuit of a nuclear power plant, taking into account the peculiarities of radiation and thermal resistance of steels with a high nickel content, in relation to the operating conditions of high-temperature reactor shells of high-risk nuclear facilities and the prospects for the development of world nuclear energy in the near future [7, p. 174].

The originality of the author's idea within the declared topic is determined by the following.

Firstly, the fact that, in the event of a negative environmental impact of an object of economic activity and the occurrence of an emergency situation at a nuclear facility of increased danger during the elimination of the consequences of a radiation accident, as a rule, dramatic changes of a global nature occur, which lead to very significant, often irreversible changes in the natural environment, having a devastating effect on human health and the territory where the nuclear facility of increased danger is close.

Secondly, in connection with the above, it is necessary to take into account the ongoing global and regional geopolitical transformations related to environmental safety, especially in the event of an emergency at a modern nuclear power plant during the elimination of the consequences of a radiation accident.

The world practice of recent decades confirms the fact that technogenic accidents occur quite often on our planet, as well as emergencies characterized by physical, chemical-biological effects and radiation pollution on nature and humans, which is directly related to environmental safety, situational modeling in the operating conditions of a nuclear power plant.

Environmental safety is a special state of protection of the natural environment and personal health, as well as from the possible destructive impact of a person and society on the natural and economic system in the event of man-made emergencies. The evolution of technogenic civilization indicates that in human society, problems inevitably arise related to the impact of personality and society on the biosphere, which actualizes issues related to environmental safety. It is, environmental safety that today requires close attention of the public, specialists and systematic implementation of environmental audits, which means that the implementation of a professionally directed documented process of verification of the information received, clarifying the criteria and existing triggers established in the process of environmental protection activities.

In this regard, an environmental impact assessment is also carried out establishing the compliance (inconsistencies) of economic activity, as well as any other activity of a modern person, which should correspond to the previously set environmental parameters.

It is as a result of environmental expertise that the permissible norms are determined during the implementation of the facility to prevent possible adverse effects of human activities on the environment, which does not exclude the occurrence of an emergency, as well as the socio-economic consequences of the operation of a nuclear power plant, and therefore, as a rule, control measures are systematically carried out.

The determining factor necessary for the implementation of measures to ensure environmental safety is environmental control (audit results), which are specific measures aimed at identifying and suppressing violations of environmental protection legislation necessary to timely prevent environmental disasters and man-made accidents. When carrying out environmental control by economic and other entities on the basis of standards (regulatory documents), it is planned to conduct an environmental review of a specific natural and economic system for more effective environmental protection.

In the modern context, the use of remote and local monitoring is of the greatest interest, which is due to modern approaches to information processing in the process of eliminating the consequences of a radiation accident, which in the future makes it possible to combine these methods within a single measuring task, making it possible to comprehensively solve the emerging problems of operating high-risk nuclear facilities.

At the same time, an important element of environmental control and technical safety of nuclear power plants is monitoring and modeling, as well as timely implementation of emergency measures outside the territory of a nuclear power plant, implementation of plans for protecting the population in the aftermath

of man-made accidents. Consequently, the main principle ensuring the safety of modern high-risk nuclear facilities is layered protection, focused on a system of barriers to the spread of radioactive substances, ionizing radiation, as well as the implementation of organizational and technical measures to protect the population and plant personnel, which implies the creation of successive levels of protection against probable personnel errors and failures of the equipment used at the facility.

It is important to initiate international cooperation in the modern world against the background of the evolution of the nuclear industry and search, use of alternative energy sources, actively create databases on natural disasters, radiation accidents, man-made disasters occurring in the modern world, use neural network, statistical, logical-probabilistic methods developed on the basis of statistics of natural and man-made disasters, to probe the territories of the environment polluted by humans, to algorithmize the modeling databases using geographic information, Internet technologies to optimize compensation for environmental damage caused in the event of an emergency at a high-risk nuclear facility.

In modern conditions, it is important for specialists working in the nuclear industry to update the timely comprehensive work of a specialized scientific institution for comprehensive monitoring of high-risk facilities, which will expand the range of parameters in real time, and carry out a better long-term study of the state of the environment (geo-economics, gynecological monitoring), paying special attention to the use of high-temperature superconducting materials, timely detection of electromagnetic damage to synchronous generators based on the analysis of failures of the external magnetic field, develop a fail-safe control algorithm that increases the efficiency of the operating mode of a high-risk nuclear facility. Today it is necessary to develop a forecast of the safe operation of high-risk nuclear facilities and modern designs based on integrated control using artificial intelligence.

Timely measures taken to ensure environmental safety at high-risk nuclear facilities should concern the integrated operation of nuclear power plants (nuclear waste, active spent fuel, reprocessing, uranium hexafluoride production, etc.). In addition, specialists need to take into account the fact that in the event of an emergency at a nuclear power plant, it is situational modeling that becomes especially relevant in a situation of possible destructive effects of radiation on the facility (human, material losses, economic, environmental damage). At the same time, to optimize the operating mode and systematically carry out timely comprehensive monitoring of nuclear facilities, apply mathematical, situational modeling, carry out quantitative and qualitative markers to characterize nuclear events and develop ways to eliminate emergency situations, which is important for the evolution of the global nuclear industry [9].

As a result, the software and hardware complex for monitoring the fire safety of nuclear power plants, large-scale modeling, planning of operation modes of an autonomous power system based on a nuclear power source, as well as optimizing the strength of composite structures, nanomodified light-absorbing coatings with improved properties when using an integration platform, as well as an integrated approach to updating solutions for deep burial of liquid radioactive waste, makes it possible to implement algorithms for automation of organizational control of fire and explosion safety of facilities of fuel and energy complex of nuclear power plant.

In the modern world, special attention is required to situational modeling necessary for the most efficient implementation of emergency rescue operations, the organization of financing of material and technical services in the event of a radiation accident at a nuclear facility, which is necessary to ensure safety at high-risk facilities, emergency response in eliminating the consequences of a radiation accident in the event of its occurrence at a nuclear power plant [10, p. 106]. Apparently, in the near future it is necessary to specify the criteria for the method of assessing the characteristics of the radiation background of the surface atmosphere near a nuclear power plant, to determine the relationship between the properties of a high-temperature gas-cooled water-cooled water-cooled power reactor and the state of the environment to ensure environmental safety in the evolution of the nuclear industry, as well as to develop alternative energy sources.

References

1. Binenko, V.I., Donchenko, V.K., Rastoskuev, V.V. Risks and environmental safety of natural and economic systems. – St. Petersburg: St. Petersburg State University, NICEB RAS, 2019. – 352 p.

2. Belarusian energy: status and trends [Electronic resource]. – Access mode https://dzen.ru/a/Z2Vqtjr1MkR0dmYl?ysclid=m9yn9642jj509082127. 26.04.2025.

3. Shishko, E. L., Shumskaya, V. V. Energy independence of the Republic of Belarus and the development of alternative energy sources // Humanitarian scientific research. – 2025. – №1 [Electronic resource]. URL: https://human.snauka.ru/2025/05/55568 (access date: 25.08.2025).

4. Osetskaya, M. M., Ukraintsev, V. F. Current trends in the global nuclear energy market / M. M. Osetskaya, V. F. Ukraintsev // Spatial economy. – 2018. – №1. – P. 154–169.

5. 电厂安全的理论问题 *Theoretical aspects of safety of nuclear power plants Sokolova Anastasia Andreevna, Sokolova Svetlana Nikolaevna / Proceedings of*

the International Conference «Scientific research of the SCO countries: synergy and integration». – Reports in English. – 2023. – P. 188–194.

6. Adamov, E. O., Lopatkin, A. V., Muravyov, E. V., Rachkov, V. I., Khomyakov, Yu. S. National Strategy for the Development of Nuclear Energy: Two Approaches to a New Technological Platform for Nuclear Energy/N. O. Adamov, A. V. Lopatkin, E. V. Muravyov, V. I. Rachkov, Yu S. Khomyakov // Izvestia RAS. Energy. – 2019. – №1. – P. 3–14.

7. Sokolova, A. A., Sokolova, S. N. High-risk nuclear facilities and prospects for world nuclear energy / Collection of scientific articles based on the results of the International Scientific Forum SCIENTIFIC DIALOGUE: THEORY AND PRACTICE (Moscow, May 8, 2025). / Rest. ed. D.R. Khismatullin. – Moscow: Infinity Publishing House, 2025. – P. 174–179.

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SPD 项目中的 BBC 检测器：概念、技术和目标概述
THE BBC DETECTOR IN THE SPD PROJECT: AN OVERVIEW OF CONCEPTS, TECHNOLOGIES, AND OBJECTIVES

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摘要：本文探讨了束流-束流计数器（BBC）子系统在NICA对撞机SPD实验中的作用和实现。BBC作为关键探测器，用于确定事件起始时间T0、基于时间的顶点重建、最小偏置和基于类别的触发，以及在线监测亮度和本底条件。借鉴现代对撞机实验的经验，本文提出了SPD实验的目标要求，并就技术选择提出了建议。总而言之，BBC应满足以下要求：

• 每个“臂”的时间分辨率为50-80 ps，每个通道为100-150 ps，从而沿束流轴的顶点精度达到σ_z ≈ 1-2 cm。

• 在指定的η-φ分段内具有高效率和均匀响应，每个通道的速率可达数MHz，并且具有抗堆积效应的鲁棒性。 • 抗辐射能力和长期稳定性，可重复的时间对准（<20-30 ps），以及受控的系统误差（旋转、T 形走位）。

Abstract. *This article discusses the role and implementation of the Beam–Beam Counters (BBC) subsystem in the SPD experiment at the NICA collider as a key detector for determining the event start time T0, time-based vertex reconstruction, formation of minimum-bias and class-based triggers, as well as for online monitoring of luminosity and background conditions. Drawing on the experience of modern collider experiments, target requirements for SPD conditions are formulated and recommendations on technology choices are provided. In summary, the BBC should provide:*

• Time resolution at the level of 50–80 ps per “arm” and 100–150 ps per channel, yielding vertex precision along the beam axis of σ_z ≈ 1–2 cm.

• High efficiency and uniform response within the specified η–φ segmentation, at rates up to several MHz per channel and with robustness against pile-up.

• Radiation hardness and long-term stability, reproducible time alignment (<20–30 ps), and controlled systematics (slewing, T-walk).

Introduction

For SPD [0], we recommend using a global coordinate system: the z axis is directed along the nominal beam direction, the y axis is vertical, and the x axis is perpendicular to them and points toward the center of the collider ring. The origin coincides with the nominal center of the setup. We often refer to this point as the interaction point (IP), although the actual beam overlap region has a Gaussian profile along the z axis with σ_z of about 30 cm at zero crossing angle [4].

In terms of time structure, in the p–p mode the bunch crossings are assumed to occur every 76 ns.

The detector comprises a cylindrical (barrel) part and two endcap sections. A pair of zero-degree calorimeters (ZDC) should be installed sufficiently far from the interaction point to be located within the beamline equipment area. The detector layout in the full configuration with the main dimensions is shown in Fig. 1.

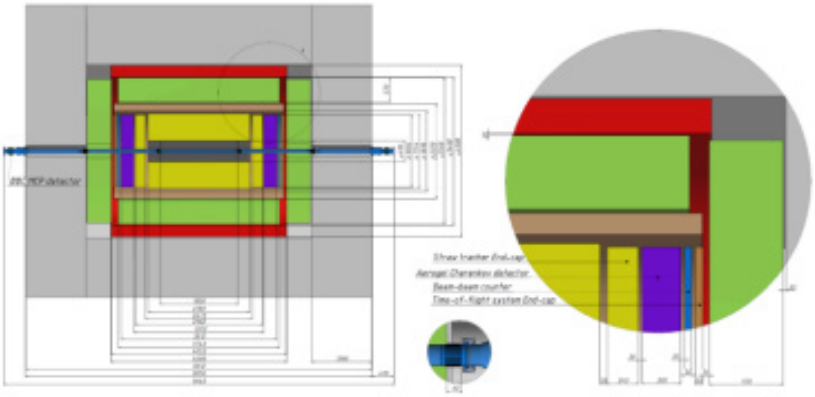

Figure 1. *Schematic side view in section of the SPD detector with dimensions given in millimeters.*

The main parameters of the SPD detector are also given.

	Stage I	Stage II
Maximum luminosity, 10^{32} cm^{-2} s^{-2}	up to 0.1	1
Interaction rate, MHz	up to 0.4	4
Magnetic field at IP, T	up to 1.0	1.0
Maximum stored magnetic field energy, MJ	21	21
Track momentum resolution $\frac{\delta p}{p}$ at 1 GeV/c, %	~1.7	~1.0
Photon energy resolution, %		$5/\sqrt{E} \oplus 1$
$D^0 \to K\pi$ vertex spatial resolution, μm		60 for MAPS 80 for DSSD
PID capabilities	dE/dx, RS	dE/dx, ECal, RS, TOF, FARICH
Number of channels, 10^3	177	280 for MAPS SVD $+ 6.2\times10^9$ pixels 608 for DSSD SVD
Raw data flow, GB/s	up to 1	up to 20
Total weight, t	1249*	1253
Power consumption**, kW	75	109 for MAPS SVD 89 for DSSD SVD

Having completed an overview of the general geometry and central subsystems of the SPD setup, we now turn to the BBB system. These beam-to-beam forward counters produce an intersection time stamp, the first minimum-bayas trigger, and a coarse vertex z-coordinate, as well as a bunch of monitoring conditions. The low polar angle placement at endcaps and the high speed make the BBB a key element of event synchronization and selection. Fig. 2

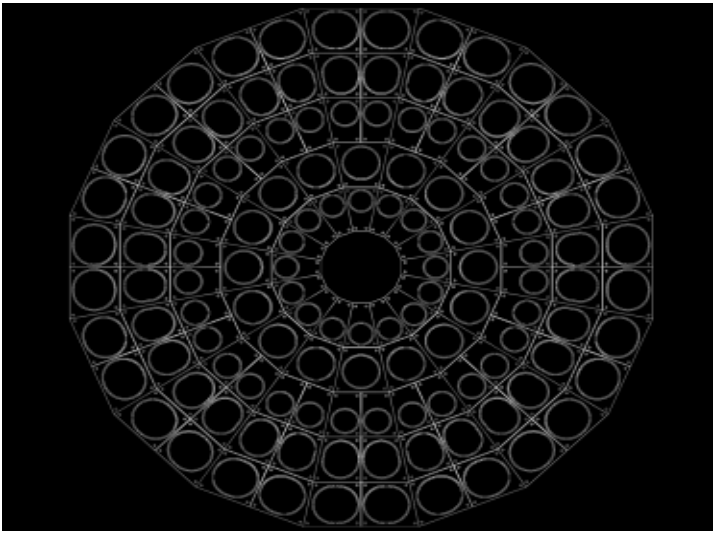

Figure 1. *A model of one ring of the BBC detector made using the GEANT4 software package.*

It is planned to install two Beam–Beam Counters (BBC) in front of the TOF system, in the endcap modules of the SPD setup, at a distance of approximately ±1.7 m from the detector center (see Fig. 10.4). The concept includes two regions—inner and outer—both based on plastic scintillators. In the inner region, highly segmented scintillators are used with direct optical coupling to silicon photomultipliers (SiPMs). The outer region is made of scintillating tiles, where the signal is read out by SiPMs via a wavelength shifter (WLS).

The inner part covers the polar-angle range of 30–60 mrad and is divided into 4 layers, each split into 32 azimuthal sectors. The outer part spans 60–500 mrad and consists of 13 concentric layers with 16 azimuthal sectors in each (see Fig. 10.4). The final granularity will be refined during optimization for the full range of collision energies at SPD.

Key BBC tasks:

1) local polarimetry at SPD based on measuring azimuthal asymmetries in inclusive charged-particle production in collisions of transversely polarized proton beams; 2) beam collision monitoring;

3) contributing to precise determination of the interaction time t0 for events where other detectors are not applicable (e.g., in elastic scattering);

4) event-plane determination for studies of global polarization and flow in ion–ion collisions.

Functions and requirements for the BBC in SPD

In modern collider experiments, BBCs perform several key functions. First and foremost, they provide the T0 source and precision timing: they establish the "time zero" for synchronizing the trigger and subdetectors, define the start time for time-of-flight measurements, and estimate online the longitudinal coordinate of the interaction vertex from the difference in signal arrival times from the two end stations; such solutions have been implemented, for example, in ALICE (T0/V0) and STAR (VPD) [1–2,6]. Next, BBCs provide minimum-bias triggering and fast rejections via coincidence logic and time/amplitude thresholds, enabling efficient recording of unbiased pp/AA events; analogous functions are standard for forward counters such as ALICE VZERO, ATLAS MBTS, and systems at RHIC [1–2,6]. The time difference between the left and right stations is used for prompt determination of the vertex z-coordinate to reject events outside the acceptance and as a seed for offline reconstruction, as demonstrated in ALICE VZERO/T0 and STAR VPD [1–2,6]. Another essential task is luminosity monitoring: BBCs measure relative luminosity bunch-by-bunch, are cross-calibrated using van der Meer scans, and are tied to an absolute scale; mature implementations are shown in ATLAS

LUCID-2, CMS BRIL/BCM1F, and ALICE VZERO on the vdM methodological basis [2–4,7–8]. Finally, BBCs help suppress collider backgrounds by vetoing single-beam and machine-related components (beam–gas, halo, afterglow) using timing and coincidence logic; corresponding approaches are used in ALICE VZERO and in CVD-diamond beam-monitoring systems in ATLAS/CMS/LHCb [2,4,9].

BBC/analogue implementations in other experiments and comparison

A brief overview shows that fast forward detectors based on quartz Cherenkov radiation and/or diamonds/scintillators have become the de facto standard for T0, time-based vertex reconstruction, MB triggering, and online luminometry.

PHENIX BBC (RHIC)

• Technology and geometry: an array of quartz Cherenkov radiators (fused silica) with fine-mesh PMTs, one array at each end of the detector, $|\eta| \approx 3–4$. The optics minimize light path and scattering; timing is read out with fast CFD/LE thresholds.

• Achieved performance: single channel typically 50–70 ps; event T0 of 30–40 ps with several hits per side; vertex $\sigma(z)$ on the order of 1 cm.

• Roles: provided the MB trigger and a local polarimeter (ϕ asymmetries), and was used for luminosity calibrations (Vernier scans).

• Operating conditions: high rates in p+p and d+Au, robustness to pile-up thanks to segmentation and the fast Cherenkov response; moderate doses and integrated currents under RHIC conditions.

STAR VPD/TOF start (RHIC)

• Technology: two arrays of forward fast detectors for T0 and the z-vertex. In the pVPD/VPD versions, compact radiators (lead glass or quartz/scintillator in different iterations) with fine-mesh PMTs were used; geometry at large $|\eta|$ for early time-of-flight.

• Performance: single channel about 80–120 ps; after averaging over multiple hits, T0 ~ 20–40 ps; z resolution ≈ 1 cm.

• Roles: provided the start for the main TOF and stable online monitoring. • Conditions: a wide range of counting rates from heavy ions to p+p; requirements for stable inter-channel calibration and slewing correction.

The following LHC experiments will be presented

ALICE T0 and V0 (LHC)

• T0: quartz radiators with MCP-PMTs (Run 1/2) and an upgrade in Run 3 with improved electronics; optimized for minimal jitter and short light paths. • V0: fast scintillators with WLS fibers and PMTs for the MB trigger, centrality/multiplicity determination, and background suppression.

• Performance: T0 — single channels 30–50 ps; event T0 ~ 10–25 ps (depending on the system and operating mode). V0 — times on the order of 200–300 ps, but with very high efficiency and rate capability.

• Conditions: LHC bunch-crossing frequencies and high pile-up; significant radiation doses. T0 employs regular laser calibrations and temperature stabilization.

ATLAS LUCID (LHC)

• Technology: Cherenkov counters with quartz radiators, designed primarily for luminometry (online/offline); segmentation around the beam, fast counting electronics. • Performance: per-channel timing typically hundreds of picoseconds (sufficient for background rejection); the detector is optimized for counting linearity at very high rates and radiation hardness rather than ultimate time resolution.

• Conditions: extreme rates (25 ns bunch spacing) and large doses; stability and absolute luminosity calibration are key requirements.

Table 2

Comparison of detectors.

Experiment/detector	Active environment	Photosensor	Coverage by η	Resolution, channel	T0/vertex (event)	Role in the trigger
PHENIX BBC	fused quartz (Cherenkov)	fine-precision photomultiplier	~ 3–4	50–70 ps	T0 ~ 30–40 ps; σ(z) ~ 1 sm	MB, vertex, luminometry/polarimetry
STAR VPD	fast radiator (lead glass/quartz), Cherenkov/scintillation	fine-precision photomultiplier	> 4	80–120 ps	T0 ~ 20–40 pc; σ(z) ~ 1 smm=	TOF start, vertex
ALICE T0	Quartz (Cherenkov)	MCP-PMT	asymmetric forward	30–50ps	10–25 ps	T0, pile-up veto
ALICE V0	scintillator	photomultiplier	forward	200–300 ps	—	MB, centrality, background
ATLAS LUCID	quartzn (Cherenkov)	photomultiplier	~ 5	~0.3–1 ns	~0.5–1 ns	protection/background
CMS BCM1F	Diamond (sCVD) прямой	account/FE	—	~0.5–1ns		protection/background

Based on the comparison in the BBC experiment, we will use a fast scintillator and the same SiPM/PMT, which provide ~60–120 ps per channel. The ring geometry used and reasonable segmentation along the η axis reduce the pile-up per channel and improve time averaging. In PHENIX/STAR, arrays on both sides provide a stable z-vertex; for SPD, 16–32 sectors per side and ≥1 ring along the η axis are practical. Minimizing optical path spread (short radiators, no long light guides) is critical for <50 ps (ALICE T0 experiment).

Calibration and stability are required for regular slewing/T-walk corrections (by ToT/amplitude), interchannel synchronization at tens of picoseconds, laser pulses for drift monitoring, temperature control, and HV (common experience for all systems). Also for SiPM - thermal stabilization and dynamic threshold adjustment; for MCP-PMT - integral charge control (ALD coatings increase service life).

In comparison:

– With PHENIX BBC: similar functions (T0, vertex, MB, luminometry), similar geometries and speeds; lessons on local polarimetry and threshold/gain stability are directly applicable.

– With ALICE T0: best practices for jitter minimization, laser calibration, and MCP-PMT operation over a long campaign at lower radiation loads than at the LHC, with a good margin for SPD.

– With STAR VPD: simple mechanics and proven interchannel alignment and TOF-start methods; suitable for choosing scintillators/PMTs or a hybrid scheme.

Technological design BBC.

Geometrically, the BBC consists of two symmetric stations[0] installed on both sides of the interaction point at distances of ±Z along the beam axis, downstream of the inner tracker elements and the beam pipe. The radial coverage is chosen based on the available space and the required pseudorapidity reach; typically the main contribution comes from particles with |η| of order 3–4. Each station is assembled from modules that provide full azimuthal coverage (e.g., dozens of sectors) and, if needed, one or two rings in radius. The design emphasizes minimizing material in the aperture, suppressing parasitic reflections, and shielding against background light.

The active elements of the modules include plate radiators about 5–10 mm thick with matte-finished and blackened side faces, optically coupled to the photocathode. As photosensors, multi-channel MCP-PMTs with small electron transit-time spread (on the order of 20–40 ps per photoelectron) or fast thin-window PMTs are used; MCP-PMT versions with ALD coatings provide extended lifetime under high integrated charge. Segmented anodes (multiple channels per module) reduce pile-up effects and enable local time averaging.

The front-end electronics provide stable high-voltage bias with current monitoring and temperature compensation, low-noise preamplification, and signal discrimination with time-walk compensation. For precise timing, constant-fraction discriminators (CFD) or leading-edge threshold schemes with time-over-threshold (ToT) and subsequent slewing correction are employed. Digitization is implemented either with high-resolution TDCs with binning on the order of tens of picoseconds, or by waveform sampling with fast digitizers; in parallel with time, amplitude parameters are measured for calibration corrections. At the module level, local primitives are formed—hit times, multiplicity, and the side-averaged time with outlier rejection.

The BBC trigger logic is based on coincidences between the two sides within a narrow time window centered on the expected T0, with configurable multiplicity/energy thresholds to suppress beam–gas background and random coincidences. For online luminometry, separate counters of single-arm and double-arm coincidences with flexible time windows are provided. The interface to the global trigger system transmits flags and metadata (time, multiplicity), and the T0 timestamp is recorded in the DAQ for subsequent reconstruction.

Timing calibration is performed with regular light pulses (laser/LED) and using physics events with high multiplicity. For each channel, tables of time offsets and time-versus-amplitude dependencies are maintained, enabling effective slewing correction. The system includes online quality monitoring: the stability of times, counting rates, coincidence fraction, and the distribution of reconstructed z_(\mathrmvtx) are tracked; automatic alerts are generated when parameters drift. The thermal conditions of the modules and electronics are monitored and logged in the detector control system.

The expected performance meets the goals of fast detection: single-channel time resolution of about 50–70 ps when using quartz and MCP-PMTs; event T0 after averaging over multiple hits of about 15–30 ps; longitudinal vertex resolution σ(z_(\mathrmvtx)) of about 1 cm. The minimum-bias trigger efficiency for non-diffractive events across the operating energy range exceeds 99%. The detector is designed to operate at high counting rates—tens to hundreds of kHz per segment and megahertz-scale totals per side—without timing degradation, and the materials and photosensors used provide the required radiation hardness.

Mechanical integration involves mounting the modules on a rigid, temperature-stabilized support with precise positioning relative to the beam axis and service access for replacing heatsinks and photodetectors. Stabilized high-voltage and low-voltage signals, clock signals, and beam structure markers are supplied, along with fiber optics for light calibration if necessary. Proper grounding and shielding are implemented to ensure electromagnetic compatibility with picosecond timing.

Reliability measures include light and current load limits, MCP-PMT degradation monitoring for integral charge and gain with rapid threshold readjustment, as well as built-in channel self-diagnostics and redundancy for critical components. Specific geometric parameters (installation coordinates, number of segments), selected photodetector and electronics types, and target radiation hardness standards are subject to refinement based on the results of prototyping and beam testing and will be included in the final TDR.

Literature

1. SPD Collaboration, Technical Design Report of the Spin Physics Detector at NICA, Natural Science Review 1 1 (2024)

2. ALICE Collaboration, The ALICE experiment at the CERN LHC, JINST 3 (2008) S08002. — Description of the T0/V0 subsystems and their roles in triggering/timing. [2] ALICE Collaboration, Performance of the ALICE VZERO system, JINST 8 (2013) P10016. — MB trigger, timing, z-vertex, backgrounds, and luminosity monitoring.

3. ATLAS Collaboration, LUCID-2: a new detector for luminosity measurement at ATLAS, JINST 13 (2018) P07017. — Relative/absolute luminosity, operation.

4. CMS BRIL Collaboration, The CMS Beam Radiation Instrumentation and Luminosity Project, JINST 13 (2018) P10034. — BCM1F/PLT, online luminosity and beam conditions.

5. PHENIX Collaboration, PHENIX detector overview, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Volume 499, Issues 2–3, 1 March 2003, Pages 469–479 — The role of Beam–Beam Counters in RHIC timing/trigger.

6. STAR Collaboration, STAR detector overview, Nuclear Instruments and Methods in Physics Research A 499 (2003) 624–632 — Using BBC/VPD for MB triggering and z-vertex estimation.

7. S. van der Meer, Calibration of the effective beam height in the ISR, CERN-ISR-PO/68-31 (1968). — Basic method of vdM scans for absolute luminosity.

8. ATLAS Collaboration, Luminosity determination in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector in 2011, Eur.Phys.J.C71:1630, 2011 — Application of vdM and transfer to the absolute scale.

9. Ch. Ilgner (Senior Member, IEEE), M. Domke M. Lieng, M. Nedos, J. Sauerbrey, S. Schleich, B. Spaan, K. Warda, and J. Wishahi, The Beam Conditions Monitor of the LHCb Experiment, TNS-00807-2009, submitted to the IEEE Transactions on Nuclear Science—Background/Beam Condition Monitoring and veto timing.

10.A. V. Tishevsky, The spd beam-beam counter scintillation detector prototype tests with fers-5200 front-end readout system

11.Alla Maevskaya, Start and trigger detector T0 of the ALICE experiment, Conference: XXI International Baldin Seminar on High Energy Physics Problems

12.V. Tishevsky(Dubna, JINR), F.A. Dubinin(Moscow Phys. Eng. Inst.) Yu. V. Gurchin(Dubna, JINR) A.Yu. Isupov(Dubna, JINR), V.P. Ladygin(Dubna, JINR), Prototype of Scintillation Detector for Extended Version of BBC Subsystem in SPD Detector ,Phys.Part.Nucl.Lett. 22 (2025) 5, 1184-1186

13.SPD Experiment at NICA Collider:Status and Outlooks Victor T. Kim Petersburg Nuclear Physics Institute, Gatchina NRC "Kurchatov Institute" for the SPD Collaboration.

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为零浪费生产周期设计建筑物和结构
DESIGNING BUILDINGS AND STRUCTURES FOR A ZERO-WASTE PRODUCTION CYCLE

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摘要：本文探讨了在彼尔姆边疆区中部地区的牛舍中应用零废弃物技术和生物反应器的可能性。文章分析了沼气装置的运行原理和组成，以及其作为替代能源的用途。

关键词：零废弃物产生，闭环，循环利用，能源效率，沼气装置，沼气，生物肥料。

Abstract*. The article discusses the possibility of applying waste-free technology and bioreactors in a cow barn in the central region of the Perm Krai. The operating principle and composition of biogas plants are considered, as well as their use as a source of alternative energy.*

Keywords*: zero waste production, closed loop, recycling, energy efficiency, biogas plants, biogas, biofertilizer.*

One of the main problems in the agricultural sector today is the issue of waste processing and production waste. It's still more cost-effective to discard agricultural waste rather than recycle it. Of the 150 million tons of waste produced annually by livestock and poultry farming, only a few percent are processed. In total, agriculture produces 250 million tons of waste annually [1].

For small farms, this question is very pressing. Strict environmental and economic interests of society and the national economy dictate the desire to reduce waste thru the development of waste-free technologies [2].

It is well-known that the processes of nature's ecosystems, involving the formation and decomposition of living matter, are balanced. Thus, the waste products of some organisms serve as a habitat for others, which indicates a cycle of matter

that is virtually closed. Nature itself suggested the idea of "waste-free technologies" to humanity.

When studying the issues of waste-free technology development, special attention should be paid to considering the main provisions of the waste-free production concept. A number of interconnected principles form the basis for achieving solutions to the problems of developing and implementing waste-free production in practice thru the realization of new organizational, technical, technological, economic, and psychological directions for production development.

Waste-free construction allows for the comprehensive use of resources, minimizes the negative anthropogenic impact on nature, reduces waste volumes, and lowers disposal costs. This direction is of strategic importance for sustainable development and environmental conservation.

Within the framework of the work carried out, the rationality of using waste-free technology and bioreactors in a cow barn in the central region of the Perm Krai was considered.

Buildings that support zero-waste production are designed based on circular economy principles, where waste from one process becomes raw material for another, and all resources used are comprehensively recycled.

Key principles for designing buildings for waste-free production [3]:

• **Adaptability to a closed-loop system**: The building should be designed with logistics and technological chains in mind, where waste from one workshop can be safely and efficiently transported for use in another.

• **Flexibility and Modularity**: It is necessary to provide for the possibility of reconfiguring production lines and facilities to adapt to changing technologies and raw materials.

• **Built-in recycling systems**: The building must be equipped with integrated systems for the collection, processing, and reuse of all types of waste, including solid, liquid, and gaseous.

• **Energy Efficiency**: Designing buildings with maximum energy efficiency, the use of renewable energy sources, and heat recovery, which reduces the overall burden on resources and the environment.

• **Logistics Solutions**: Well-thought-out solutions for internal and external logistics minimize transportation costs and environmental impact by optimizing routes and reducing vehicle mileage.

Compliance with regulatory requirements: Buildings must comply with strict environmental and sanitary standards.

Buildings for a zero-waste dairy farm represent a comprehensive closed-loop livestock complex where all waste is processed into valuable resources (fertilizers, biogas, cattle bedding) instead of simply being disposed of.

Key technological and design solutions for achieving a zero-waste cycle in a cow shed include [4]:

• **Efficient manure removal systems**: Mechanized (scraper, chain) or hydraulic systems are used to quickly remove manure from animal housing areas, minimizing pollution and the loss of valuable raw materials.

• **Manure Fractionation Systems**: Liquid and solid manure fractions are separated using special equipment (separators) for further specialized processing.

• **Biogas plants**: liquid manure and other organic waste are directed to digesters where anaerobic digestion takes place. This process produces biogas, which can be used as an energy source (for heating, electricity generation), and high-quality organic fertilizer (digestate).

• **Compost/Solid Fertilizer Production**: The solid fraction of manure is composted or processed into animal bedding (if technology and hygiene levels allow) or into granulated organic fertilizer for sale.

• **Integrated Use**: Obtaining energy and fertilizers from waste allows for a closed-loop system where nutrients are returned to the soil for growing fodder crops, and energy is used to meet the farm's needs, thereby reducing external costs and environmental impact.

• **Rational land use**: Having a sufficient amount of agricultural land is necessary for the safe and effective application of the resulting organic fertilizers in accordance with agronomic standards, to avoid soil nitrogen saturation and water body pollution.

A biogas plant functions as a waste disposal system (for manure and other waste, such as from slaughterhouses, etc.), processing it and producing energy: from 1 m3 of biogas (the product of anaerobic (without air) decomposition of organic matter of various origins, consisting of 50–70% methane (CH4) and 30–50% carbon dioxide (CO2)), a generator can produce up to 2 kW of electricity [5]. Additionally, this technology allows for the production of higher-quality fertilizer than composting does – one ton of such fertilizer replaces 100 tons of manure.

Let's consider the operating principle of the installation using the example of a vertical bioreactor, the NVS 250:

• Manure is first separated into liquid and solid fractions, most often using a separator.

• The solid fraction is loaded into the bioreactor.

• Thermophilic bacteria are activated inside the reactor, for which optimal conditions are created, including aeration (air supply).

• The process is controlled by automation that monitors the temperature, humidity, and material mass.

• Upon completion of the process, sterile bedding with a specified moisture level is unloaded, ready for use in stalls.

Biogas plants allow for accelerated material disinfection. The bio-drying and bio-stabilization processes take place inside the bioreactor. Oxygen (air) supplied by a blower supports the aerobic process of biological decomposition of organic matter present in cow manure. The process is exothermic; the resulting heat is used to disinfect the manure and evaporate water. The manure is held at a temperature of 65°C for at least 60 minutes, which ensures its pasteurization.

The installation can be located inside the cow barn, at a minimum temperature of +5 degrees Celsius. The manure will be transported by an inclined conveyor to a shredder-homogenizer, where the necessary consistency will be achieved by mixing with water, and then by a fecal pump to the fermentor.

Building a biogas plant makes sense when it will draw 500 kW of power or when manure must be processed mandatorily. To obtain fertilizer, there are technologies for manure separation and processing in a bioreactor. The result is a dry mass that can be used as bedding or packed into containers.

Conclusion.

During the work, a waste disposal option was studied, the production of biogas, and its use as an alternative energy source for heating the cowshed. The operating principle of a biogas plant for producing bedding for cattle is considered.

Another result of biogas plant operation is the production of biofertilizers. Ordinary manure, distillery waste, or other waste cannot be effectively used as fertilizer for 3-5 years. However, when using a biogas plant, organic waste ferments, and the fermented mass can be immediately used as a highly effective biofertilizer. Unlike mineral fertilizers, biofertilizers do not accumulate in the soil and enrich it with beneficial microorganisms, increasing yields by up to 30%.

The construction of a biogas plant is relevant not only for newly established farms but also for older ones. After all, old lagoons are often overflowing, and repairing them requires significant funds. For a farm, a biogas plant, whether homemade or purchased, will ultimately bring benefits. The main advantage is biogas, which is no different in properties from natural gas. Such installations provide a good boost toward ecology, as the recycled biomass causes no harm to the soil.

Bibliography

1. Dashkovsky I.A. Leaky Ecology // Journal "Agrotechnics and Technologies". 2018 No. 12, pp. 47-48.

2. The Sustainable Development Goals Report 2020 // UN [Electronic resource] — Access mode: https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020_Russian.pdf.

3. "Principles of Developing Low-Waste and Waste-Free Technologies," by V. M. Sutyagin, V. G. Bondaletov, and O. S. Kukurina. — 2nd ed., revised and expanded — Tomsk: Tomsk Polytechnic University Publishing House, 2009, p.7.

4. "Main Directions of Waste-Free and Low-Waste Technologies," authors: N. I. Boyko, V. A. Odaryuk, A. V. Safonov. — Journal "Technologies for Civil Safety", 2015.

5. Resource-saving and waste-free technologies for animal husbandry, November 9, 2023. [Electronic resource] — Access mode: https://blog.rostselmash.com/ zhivotnovodstvo/resursosberegayushchie-i-bezotkhodnye-tekhnologii-dlya-zhivotnovodstva.

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高加索矿泉水区马舒克林场林分中的气溶胶含量
AEROSOL CONTENT IN FOREST STANDS OF THE MASHUK FORESTRY IN THE CAUCASIAN MINERAL WATERS REGION

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摘要：本研究对高加索矿泉疗养区别什陶戈尔斯基林业区马舒克林区人工林中生长的红栎（Quercus rubra L.）、欧洲栎（Quercus robur L.）和克里米亚松（Pinus pallasiana Lamb.）三种树种进行了微气候研究，以确定其潜在危害人体的细颗粒物（粒径小于5 μm）浓度。该区域设有疗养步道和气候疗法场所。研究结果表明，不同林分林冠下的细颗粒物浓度存在统计学上的显著差异，但总体而言，其浓度均未超过最大允许浓度（MAC）水平。

关键词：林分生态学，细颗粒物，别什陶戈尔斯基林业区马舒克林区，高加索矿泉疗养区。

Abstract. *Microclimatic studies were conducted to determine the concentration of fine aerosols (particles less than 5 μm in size) potentially hazardous to humans in artificial middle-aged stands of red oak (Quercus rubra L.), pedunculate oak (Quercus robur L.), and Crimean pine (Pinus pallasiana Lamb.) growing in the Mashuk district forestry of the Beshtaugorsky forestry district in the Caucasian Mineral Waters resort region, where therapeutic terrain cure paths and climatotherapy sites are located. The data obtained indicate statistically significant differences in aerosol concentrations under the canopy of different stands, which generally did not exceed the MAC level.*

Keywords*: forest stand ecology, fine aerosol, Mashuk district forestry of the Beshtaugorsky forestry district, Caucasian Mineral Waters.*

The relevance of the study is determined by the strict legislative requirements established in Russia for the ecological state of natural therapeutic factors (therapeutic climate) at resorts [1, 2]. At the federal resort of Pyatigorsk, located in the Caucasian Mineral Waters region, resort climatotherapy facilities - therapeutic terrain cure paths and climatotherapy sites - are located under the canopy of recreationally important forest plantations on the territory of the Mashuk district forestry of the Beshtaugorsky forestry [3, 4]. The ecological potential of subcanopy ground-level atmospheric aerosol, which is an important indicator of the therapeutic significance of the climate [5], is largely determined by the types of forest plantations. This problem has not been sufficiently studied for the Caucasian Mineral Waters resort region [6]. The aim of this study was to assess the fine aerosol content under the canopy of various forest stands in the Mashuk district forestry of the Beshtaugorsky forestry in the Caucasian Mineral Waters resort region.

Materials and methods. The average height of the stand was determined using a Blume-Leiss altimeter, and the average diameter was measured using a measuring tape. Reference literature was used to determine the forest stand taxation parameters (Tretyakov, Gorsky, Samoylovich, 1952; Handbook of Forest Taxation Standards for the North Caucasus, 1995) [7]. Temperature (°C), relative air humidity (%), and wind speed (m/s) under the tree canopy in the surface layer of the atmosphere were measured using a Meteoscope-M BVEK.431110.04 RE (number 32014-11 in the State Register of Measurement Instruments of the Russian Federation). Aerosol concentrations were determined using an OEAS-P optical-electronic aerosol counter (OEAS-P) from the L. Ya. Karpov Scientific Research Institute of Physical Chemistry, Moscow (registered as 23507-02 in the Russian Federation State Register of Instruments of Measurements). Experimental data were processed using variation statistics methods (Dospekhov, 2011) [8].

Main Part. The studies were conducted on permanent sample plots (PSP) in artificial middle-aged plantations of red oak (Quercus rubra L.), pedunculate oak (Quercus robur L.), Crimean pine (Pinus pallasiana Lamb.) on the territory of the Mashuk district forestry of the Beshtaugorsky forestry of the Caucasian Mineral Waters region (Slepykh V.V., Povolotskaya N.P., Slepikh I.V., 2023; Slepikh, Zubko, 2017; O Slepykh, A Zubko, V Slepykh, M Zubko, 2019) [9, 10, 11]. A series of studies were conducted at the PPP to determine forest stand taxation parameters, phytocenotic descriptions of the stands, and microclimatic measurements under their canopy. The results are presented in Table 1.

The studied stands are highly productive in terms of growing stock (English oak - 360 m^3/ha; Crimean pine - 524 m^3/ha; red oak - 685 m^3/ha), with quality classes II, I, and Ib, respectively, which is rare for the region. The significant density of red oak and Crimean pine stands is due to the deliberately high number of seedlings per unit area during the production of experimental forest plantations from introduced species.

Oak forest type: fresh pedunculate oak grove (FPO). Oak stand habitat type: D2.

Pine forest type: fresh pedunculate pine (FPO). Pine habitat type: C_2 C [12].

The studied stands are located in stands located within the same block. The stand with red oak directly borders the pedunculate oak stand, which is adjacent to the Crimean pine stand. Recreational use of the studied area is insignificant. No trails or signs of forest litter damage were observed.

In October 2023, the main measurements of microclimate parameters and fine aerosol concentrations in the ground layer of air were conducted at the FPO (Table 2). Meteorological conditions during the measurement period at all the PPPs were comparable, with the exception of a slightly lower air temperature in the pine forest (12.7°C).

Table 2 presents data on the total number of all fine aerosol particles <5 μm in size, which penetrate deep into the alveoli of the lungs and therefore have physiological and therefore sanitary and hygienic significance [5]. The proportion of particles >5 μm in size, according to the study results, is less than 1 percent of the total number of aerosol particles and therefore has no significant ecological or physiological significance. The result of statistical processing of the obtained measurements in order to determine the significance of the difference (Student's t-test) (Dospekhov, 2011) [8] showed a reliable, at a 0.1% significance level, excess of the level of total concentration of aerosol particles in the ground layer of the atmosphere of the Crimean pine stand (28.07 particles/cm3) by 1.6 times over the concentration indicator (17.71 particles/cm^3) in the pedunculate oak stand (Table 3). The level of total concentration of aerosol particles in the pine forest exceeded the total aerosol values in the red oak stand (14.60 particles/cm3) by 1.9 times.

Table 1

Taxation characteristics of forest stands of red oak, pedunculate oak and Crimean pine of the Mashuk district forestry of the Beshtaugorsky forestry of the Caucasian Mineral Waters region

№ PSP	Location	Predominant species, composition of the forest stand	Age, years	Average height, m	Average diameter, cm	Bonitet	Completeness	Number of trees, pcs/ha	Sum of cross-sectional area, m^2/ha	Wood stock, m^3/ha
1	Quarter 2, Section 14	Red oak, 10 Dkr, units Yao, Brsh, Dch, Vz	48	27	22	I б	1,7	1271	45,6	685
2	Quarter 2, Section 8	English oak, 9Дч1Яо	71	20	24	II	1,0	-	32,5	360
3	Quarter 2, Section 9	Crimean pine, 9Sk, 1Yao, Klp, Klo, Lpk, G, Brsh.	50	19,5	30	I	1,5	747/1372	52,1/58,4	480/524

Note: the numerator is the main species, the denominator is the planting

Table 2

Microclimate indicators and aerosol concentrations in the ground air layer of forest plantations of the Mashuk district forestry of the Beshtaugorsky forestry of the Caucasian Mineral Waters region

In the ground air under the canopy of plants										
Plant species, PSP coordinates	Measurement period	Height above sea level, m	Air temperature, °C	Relative air humidity,%	Wind speed, m/s	Fine aerosol particles/cm^3	Standard deviation	Error	Coefficient of variation	Proportion of particles >5 μm, % of total quantity
Red oak. N44.08720° E43.06705°	October 30, 2023 3:48 pm - 1:49 pm		19,4	55,7	0,0	14,60	1,4195	0,3098	0,097	0,046

English oak. Coordinates N44.08743° E43.06823°	October 30, 2023 3:57 pm - 4:30 pm		18,9	55,6	0,0	17,71	1,474	0,491	0,083	0,063
Crimean pine. Coordinates N 44.08717° E 43.06956°	October 27, 2023 3:49 pm - 4:22 pm	591	12,7	54,4	1,0	28,07	1,926	0,642	0,069	0,104

Table 3

The significance of the difference in the total concentrations of aerosol particles in one cm3 of the ground layer of the atmosphere of forest plantations of the Mashuk district of the Beshtaugorsky district of the Caucasian Mineral Waters region

PSP	**The average number of all aerosol particles in one cm³ of surface air**	**The criterion of significance of the difference (t) between the average number of aerosol particles on the PSP of Crimean pine and English oak**	**The criterion of significance of the difference (t) between the average number of aerosol particles on the PSP of pedunculate oak and red oak**	**The criterion of significance of the difference (t) between the average number of aerosol particles on the PSP of Crimean pine and red oak**
1. Red oak	14,60	$t=12,821>t_{0,001}=5,41$	$t=5,357<t_{0,001}=5,41$; $t=5,357>t_{0,01}=3,50$	$t=18,892>t_{0,001}=5,96$
2. English oak	17,71			
3. Crimean pine	28,07			

The significance test (t) for the difference between the average number of aerosol particles in adjacent canopy plots of pedunculate oak and red oak is insignificant at a 0.1% significance level, but significant at a 1% significance level (Table 3).

A priori, there is reason to assume that the minimal aerosol concentration under the canopy of red oak, compared to pedunculate oak, is due to the larger leaf blade, which ensures better deposition of aerosol particles on its surface. According to some reports, the leaf surface area of red oak is 2.06 times larger than that of pedunculate oak (Prokofev-F.M.-MBOU-KSOSh-3-Kingisepp-Leningradskaya-obl.docx).

According to the study results, the ability of the crown of Crimean pine to deposit fine aerosol is statistically significantly lower than that of oak forests. However, since the microclimate and aerosol measurements in the Crimean pine stand were conducted on different days (October 27, 2023, and October 30, 2023, in the oak stands), it can be assumed that turpentine emissions, as well as transboundary aerosol transport, were involved on the day of the pine stand measurements.

Conclusion: The conducted studies of the microclimate and aerosol content in the ground-level atmosphere of the stands of the Mashuk district forestry of the Beshtaugorsky forestry in the Caucasian Mineral Waters resort region revealed the following.

The lowest concentration of aerosol particles (14.60 particles/cm3 of air) was found under the canopy of the red oak stand, which is apparently due to the large size of its leaf blades, which ensures significant canopy density. Aerosol concentrations in the common oak stand (17.71 particles/cm3) are statistically significantly higher than those in the red oak stand at a 1% significance level.

The highest concentration of aerosol particles (28.07 particles/cm3) was observed in the Crimean pine stand, possibly due to the morphological features of the assimilation apparatus of this coniferous tree species, the release of volatile organic compounds (VOCs) into the atmosphere, primarily terpenes, which are detectable organoleptically. This may also include turpentine emissions and the influence of transboundary aerosol penetration during the pine stand measurements.

Research in this area is ongoing.

References

1. Federal Law "On Natural Healing Resources, Health Resorts and Spas" dated 23.02.1995 N 26-FZ (latest revision) https://www.consultant.ru/document/cons_ doc_LAW_6001/ Date of access 03.10.2023. Federal Law "On Natural Healing Resources, Health Resorts, and Spas" dated February 23, 1995 N 26-FZ (latest revision) ttps://www.consultant.ru/document/cons_doc_LAW_6001/ Accessed October 3, 2023.

2. RF Government Resolution of May 27, 2024 N 681 "On the Preparation and Issuance of Special Medical Reports" together with the "Rules for the Preparation and Issuance of Special Medical Reports" (regarding the therapeutic climate)/RF Government Resolution of May 27, 2024 N 681 "On the Preparation and Issuance of Special Medical Reports" (together with the "Rules for the Preparation and Issuance of Special Medical Reports", "Rules for Calculating the Amount of Fee for the Preparation and Issuance of Special Medical Reports") //https://www.consultant.ru/document/cons_doc_LAW_477266/ Date of access: 11.11.2025

3. Natural aeroionophytotherapy on terrain cure routes as a factor in increasing the adaptive capabilities of the body / I. I. Gaidamaka, F. M. Khapaeva, S. A. Pachin [et al.] // Theory and practice of physical education. - 2019. - No. 6. - P. 47-49. - EDN JZKGME

4. Slepikh V.V., Povolotskaya N.P., Slepikh I.V. The influence of forest taxation indicators on the ionization of the ground atmosphere in mountain resorts // Proceedings of the VI Caucasus International Environmental Forum "Integrated Study of Mountain Ecosystems" October 20-21, 2023. Pp. 339-346.

5. Methodology for assessing the landscape and climatic potential of resorts and health resorts: Methodological recommendations of the MR FMBA of Russia 13-2021 / N. P. Povolotskaya, V. V. Slepikh, L. I. Zherlitsina [et al.]; Federal State Budgetary Institution "North Caucasus Federal Scientific and Clinical Center of the Federal Medical and Biological Agency" (FSBI SKFNCC FMBA of Russia). – Essentuki: North Caucasus Federal Scientific and Clinical Center of the Federal Medical and Biological Agency (FSBI SKFNCC FMBA of Russia), 2021. – 39 p. – EDN YSZXXO.

6. Problems and strategic proposals for the rational use of natural medicinal resources of the Caucasian mineral waters in resort and recreational practice / N. V. Efimenko, N. P. Povolotskaya, S. R. Danilov [et al.] // Resort medicine. – 2020. – No. 3. – Pp. 17-29. – EDN VOTWRJ.

7. Tretyakov I. V., Gorsky P. V., Samoylovich G. G. Taxator's Handbook. Tables for forest taxation. Edited by N. V. Tretyakov. M.-L.: Goslesbumizdat, 1952, 853 p.

8. Dospekhov, B. A. Methodology of field experiment: (with the basics of statistical processing of research results): textbook for students of higher agricultural educational institutions in agronomic specialties / B. A. Dospekhov; B. A. Dospekhov. - 6th ed., reprinted from the 5th ed. 1985 - Moscow: Alliance; 2011. ISBN 978-5-903034-96-3 (in translation).

9. Slepikh Viktor Vasilyevich, Povolotskaya Nina Pavlovna, Slepikh Olga Viktorovna, Zubko Anna Viktorovna Ecological potential and bioclimate of oak groves of the resort region of the Caucasian Mineral Waters // Spa medicine. 2024. No. 2. URL: https://cyberleninka.ru/article/n/ekologicheskiy-potentsial-

i-bioklimat-dubrav-kurortnogo-regiona-kavkazskie-mineralnye-vody (date of access: 13.11.2025).

10.Slepikh, V. V. Protective properties and recreational potential of oak groves of the Caucasian Mineral Waters / V. V. Slepikh, N. P. Povolotskaya, O. V. Slepikh // Resort medicine. – 2017. – No. 4. – Pp. 10-16. – EDN XQYGEP.

11.O. Slepykh, A. Zubko, V. Slepykh, M. Zubko. Problems of natural restoration of forest and green spaces of the resort Caucasian Mineral Waters region. To cite this article: 2019 IOP Conf. Ser.: Earth Environ. Sci. 316 012068 (Scopus), doi: 10.1088/1755-1315/316/1/012068.

12.Project for the organization and development of forestry of the Beshtaugorsky forestry enterprise of the Stavropol forestry administration of the Federal Forestry Service of Russia. Volume III. Taxation description of the Mashuk forestry, Voronezh, 1997. 259 p.

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2008-2021年春季迁徙期间，肯特-奇科伊高地东部边缘的贝氏天鹅（CYGNUS BEWICKII YARRELL, 1830）和豆雁（ANSER FABALIS (LATHAM, 1787)）的迁徙地点

MIGRATION SITES OF THE BEWICK'S SWAN CYGNUS BEWICKII YARRELL, 1830 AND THE BEAN GOOSE ANSER FABALIS (LATHAM, 1787) DURING THE SPRING MIGRATION PERIOD OF 2008–2021 ON THE EASTERN OUTSKIRTS OF THE KHENTII-CHIKOI HIGHLANDS

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摘要：本文介绍了2008年至2021年春季迁徙期间，肯特-奇科伊高地东部边缘地区大天鹅（Cygnus bewickii Yarrell）和豆雁（Anser fabalis (Latham, 1787)）的迁徙特征和动态。在此之前，该地区未曾记录到大天鹅，豆雁的数量也远低于此。这些物种的出现体现了鸟类在迁徙路线变化时期的适应能力。

关键词：大天鹅，大天鹅，迁徙，肯特-奇科伊高地。

Abstract. *This article provides information on the nature and dynamics of migration of Bewick's swan (Cygnus bewickii Yarrell) and bean goose (Anser fabalis (Latham, 1787)) during the spring migration period of 2008-2021 on the eastern outskirts of the Khentii-Chikoi Highlands. Before this period, Bewick's swan had not been recorded here, and bean goose numbers were much lower. The presence of these species here serves as an example of how birds adapt during periods of changing migration routes.*

Keywords: *Bewick's swan, whooper swan, migrations, Khentii-Chikoi Highlands.*

Although changes in the migration routes of Bewick's swan and bean swan, particularly those of the eastern groups, have long been documented, many details of long-distance migrations remain unclear, particularly the presence of temporary resting places en route to nesting sites. Observations were conducted on the eastern outskirts of the Khentii-Chikoi Highlands, at stopover sites for migratory birds, within the Altano-Kyra intermountain basin, and at Shivichi and Altano

lakes. During migration, the number of birds on water bodies, as well as first and last sightings, were recorded.

According to our observations, during spring migrations from 2008 to 2021, in the vicinity of the Khentii-Chikoi Highlands and within the Altano-Kyra intermountain basin, An ever-increasing number of large water birds, the bean goose and the little swan, began to be observed (the little swan had previously been practically not observed here, and the number of bean goose was much lower) (Figure 1, 2).

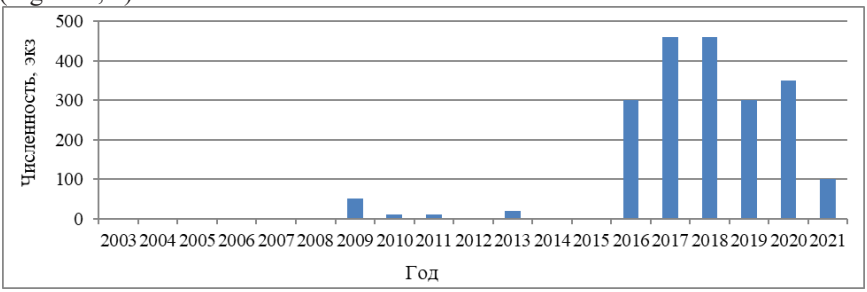

Figure 1. *Number of Bewick's swans on the lakes of the Altano-Kyra basin during the spring migration period 2003-2021.*

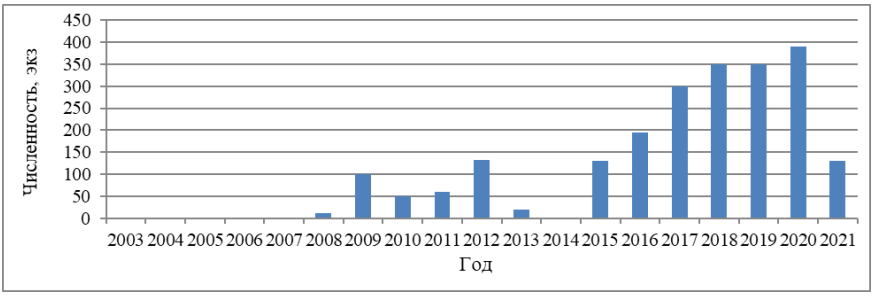

Figure 2. *Bean Geese Abundance on Lakes of the Altano-Kyra Depression During Spring Migration Periods 2003-2021*

Birds stopped at the largest lakes in the steppe basin – Shivichinsky Lake (averaging 60 hectares) and Altan Lake (Bolshoye Lake, approximately 100 hectares, and Maloye Lake, approximately 30 hectares).

The Bewick's Swan was first observed in 2009 in a flock of approximately 50 individuals, while the Bean Geese were observed in 2008 in a flock of just over 10. Until 2016, the maximum numbers of both species during migration ranged from up to two dozen for the Bewick's Swan to around 130 for the Bewick's Bean Geese. Since 2016, a sharp increase in numbers has been observed for both

species; Around 300 Bewick's swans and around 200 Bean swans were recorded at any one time. Subsequently, until 2020, the numbers of both species increased, reaching a maximum of around 500 Bewick's swans and up to 400 Bean swans. By 2021, the numbers of both species began to decline, remaining around one hundred individuals for both species.

The timing of both species' migrations is roughly the same: the first sightings of the Bean swan were recorded in the first ten days of April; the peak of migration was usually observed from mid- to late April, and the last sightings were recorded before the first ten days of May. For Bewick's swan, the beginning of migration was usually observed in the second ten days of April; the peak of numbers occurred in late April - early May; the last sightings were recorded before the first ten days of May, in isolated cases before the end of May.

In the south of Eastern Transbaikalia, specifically through Dauria, global migration routes for waterfowl and semi-aquatic birds, such as the Central Asian-Indian and East Asian-Australian routes, pass. Here, the migratory flow of birds narrows and concentrates, passing through the Torey Lakes and a large number of small reservoirs, up to 1,500 in number (over 50 m in diameter). These are crucial habitats for birds of Eastern Transbaikalia, both during migration periods and during nesting [1].

However, by 2009, most of the reservoirs in the Torey Basin had dried up, including the largest, the Torey Lakes. Similar processes were observed in the neighboring territory of the Khentii-Chikoi Highlands during the dry season (1995-2017), which almost coincided with that in Dauria. As a result of climatic and hydrological fluctuations in the area, the drying up of small bodies of water and streams, depletion of vegetation, an increase in forest and steppe fires, changes in fauna, etc. have been recorded.

However, there are qualitative differences in the characteristics of the water bodies of Dauria and the Khentii-Chikoi Highlands, used by birds during both migration and nesting periods. Lakes in the intermountain basins of Transbaikalia, including those in the Amur River basin, are typically covered with permafrost, as these lakes were formed as a result of prolonged glacial processes, and during periods of climate warming, thawing of the permafrost layer beneath the lakes is typical [2, 3]. Thus, the lakes are practically full even during dry periods, which attracts birds.

Migrations of these species are noted primarily in the spring, when the birds fly from wintering grounds to nesting sites. Two subspecies of bean goose commonly migrate through the south of eastern Transbaikalia: the Siberian taiga bean goose (A. f. middendorffii) and the eastern tundra bean goose (A. f. serrirostris). Both subspecies likely share migration routes and wintering grounds in China.

According to the Northern Eurasia Anseriformes Working Group, following expeditionary research on the coast of the Sea of Okhotsk (Magadan Oblast), the Koryaksky State Nature Reserve (Kamchatka Krai), and Kresta Bay (Chukotka Autonomous Okrug) in 2022, "telemetry data confirm the hypothesis of a westward shift in the range of the eastern tundra bean goose (Anser fabalis serrirostris); traced routes showed that the birds are using wintering grounds in China." "The hypothesis of a westward expansion of Asian populations of Bewick's swan (*Cygnus bewickii*) has also been confirmed (all tagged birds also use Chinese wintering grounds)" [4].

As can be seen from Figures 3 and 4 (according to the Northern Eurasian Anseriformes Working Group), the migration routes of both the Bewick's swan and the Bewick's swan pass through the eastern outskirts of the Khentii-Chikoi Plateau.

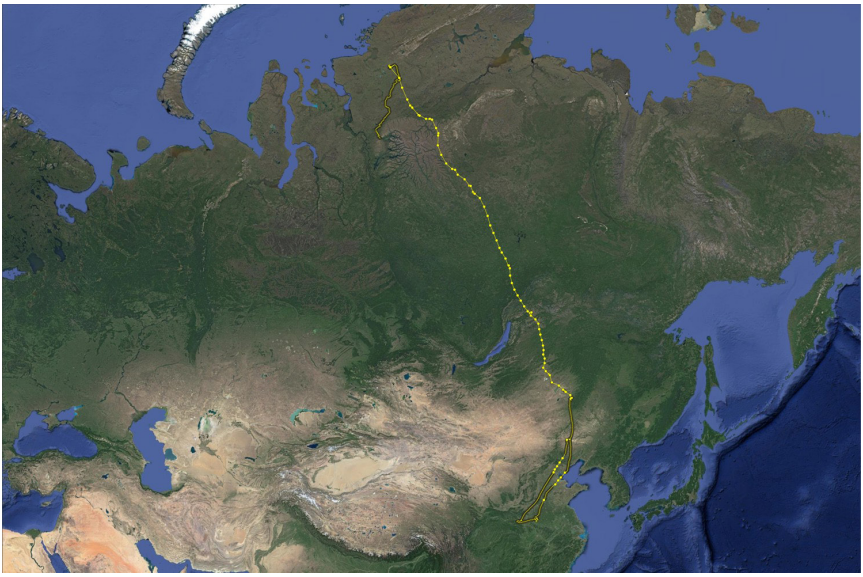

Figure 3. *Migration route of bean geese tagged at the mouth of the Tareya River*

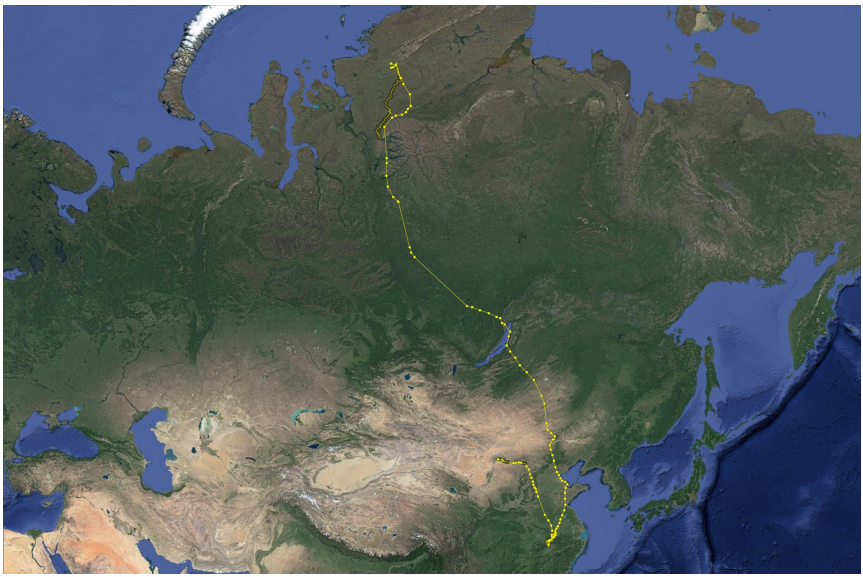

Figure 4. *Migration route of a Bewick's swan tagged at the mouth of the Tareya River*

Thus, the shift in migration routes occurred both globally and locally, exemplifying the adaptation of migratory aquatic bird species to changing conditions under the influence of hydroclimatic changes during periods of mass migration.

References

1. Goroshko, O.A. The Torey Depression. The Small Encyclopedia of Transbaikalia: Natural Heritage / Ed. R.F. Geniatulin. – Novosibirsk: Nauka, 2009. – 698 p.

2. Report on the research work on project IX.137.1.1 "Biodiversity of natural and natural-technogenic ecosystems of Transbaikalia (Central Asia) as an indicator of regional climate change dynamics." – 2020. – pp. 11-23.

3. Konishchev, V.N. Permafrost Response to Climate Warming // Vestn. Moscow University. Series 5. Geography. – 2009. – No. 4. – P. 10-20.

4. Working Group on Anseriformes of Northern Eurasia [Electronic resource]: Aerial survey of the coast of the Sea of Okhotsk, the territory of the Koryak Nature Reserve and Kresta Bay. URL: https://www.casarca.ru (date of access: 10.11.2025).

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体外脑组织电活动的3D打印传感器
3D PRINTED SENSOR OF ELECTRICAL ACTIVITY OF BRAIN TISSUE IN VITRO

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摘要：本文研究了3D光敏聚合物打印技术在制备大鼠海马切片细胞外神经元电活动平面传感器中的应用。研究发现，通过调节曝光时间和传感器通道的几何形状，可以调整电极的工作区域大小，从而能够记录场兴奋性突触后电位。在模拟病理过程的过程中，记录了切片中的癫痫样电活动。

关键词：神经元电活动，细胞外记录，微电极传感器，3D打印。

Abstract. *The application of 3D photopolymer printing method for the fabrication of planar sensors of extracellular neuronal electrical activity of rat hippocampal slices is studied in this work. It was obtained that by adjusting the exposure time and the geometry of the sensor channels, the size of the working area of electrodes can be adjusted to the extent which allows the registration of field excitatory postsynaptic potentials. Epileptiform electrical activity in the slice has been recorded during modeling of a pathological process.*

Keywords: *neuronal electrical activity, extracellular recording, microelectrode sensors, 3D printing.*

Experimental models *in vitro* are essential for studying brain functioning mechanisms. Such models, including cultured neural tissue cells and brain slices, have several advantages over *in vivo* approach. *In vitro* experiments provide more precise control of experimental conditions (temperature, pH, composition of extracellular medium), reduce variability of parameters compared to *in vivo* work, and exclude the influence of systemic processes.

The brain is an organ with a very complex structure, and the use of brain slices *in vitro* simplifies the study of the organization and functioning of certain interneuronal connections. Such objects are used to model various pathological conditions, ischemia, trauma [1], neurodegenerative diseases [2], epilepsy [3], and to perform

high-throughput screening of pharmacological drugs under development. At present, new *in vitro* models, such as three-dimensional brain organoids, are being developed with promising applications in the field of neuroregenerative medicine.

Electrophysiological experiments with brain tissue *in vitro* are often performed with slices of the hippocampus, a region involved in learning and memory. The hippocampus has a layered organization, and cross-sections preserve the structure of major synaptic connections, such as mossy fibers and Schaefer collaterals. This makes it convenient to study synaptic transmission and synaptic plasticity. The arrangement of neurons in dense, clearly distinguishable layers allows for effective recording of electrical activity. This can be done using intracellular techniques or extracellular electrodes with precise visual positioning.

A fundamental aspect of experimental studies involving the recording of neuronal electrical activity in brain slices *in vitro* is the necessity of employing specialized equipment and methodologies to ensure the maintenance of conditions that support the vital functions of neural tissue cells outside the organism, as well as stimulation, amplification, and recording of the neuronal electrical activity. The Department of Biophysics at the Belarusian State University, in collaboration with the Institute of Physiology of the National Academy of Sciences of Belarus, has developed a system of automated equipment for conducting electrophysiological experiments with rat hippocampal slices. This system is utilized in the curriculum of the Department of Biophysics, and is used to conduct experiments with extracellular recording of neuronal electrical activity and synaptic transmission processes.

The developed system uses specialized metal microelectrodes to stimulate and record electrical activity. At the same time, 3D printing methods are increasingly used for the development of various biomedical devices. The aim of this work was to study the possibilities of using the method of photopolymer 3D-printing for the fabrication of a planar sensor of extracellular electrical activity of rat hippocampal slice neurons in a perfusion recording chamber and to demonstrate the possibility to record a modeled pathological process (epileptiform electrical activity).

Materials and methods

The microelectrode sensor is designed as a three-dimensional model in STL format for 3D-printing. The sensor's microelectrodes consist of channels embedded in the substrate. At the center of the substrate, the channels extend to the surface, forming the working area of electrodes. In recording mode, the sensor channels are filled with a conductive solution. The diameter of the microelectrode's working area is approximately 100 μm, and the distance between the microelectrode centers is about 250 μm. The other side of the channels extends beyond the recording chamber to connect the amplifier of the electrical activity recording system via interface electrodes. The sensors were made using Elegoo Mars 4 3D printer (Elegoo, PRC) and modified e-Resin PLA Clear photopolymer (ESUN,

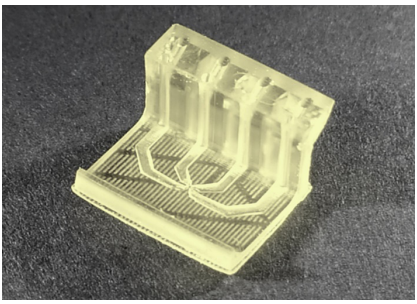
PRC). The sensor has a connector for installation in a micro-manipulator holder and connection to an amplifier.

The electrical activity of neurons in rat hippocampal slices was recorded using an amplifier of the recording system with transverse hippocampal slices from 3-4-week-old rats, according to ethical standards for the handling of experimental animals. The sensor was placed in the perfusion channel of the temperature-stabilized perfusion recording chamber through which a carbogen-saturated solution of artificial cerebrospinal fluid was pumped. The hippocampal slices were placed on the surface of the sensor. Stimulation of Schaffer collaterals was performed using a TM33B01 tungsten needle electrode (WPI Inc, USA). Epileptiform electrical activity was induced by application of 10 μM of inhibitory receptors antagonist bicuculline.

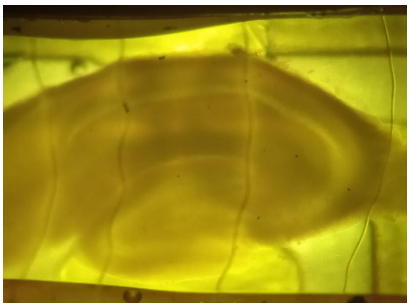
Results and its discussion

A set of samples of different variants of the microelectrode sensor was printed with different printing parameters. It was obtained that by adjusting the exposure time and channel geometry, modifying the composition of the photopolymer, the size of the working area of the electrodes of the order of 100 μm can be achieved. The printed version of the sensor is shown in Figure 1*a*, and the slice placed on the sensor int the recording chamber is shown on Figure 1*b*.

Figure 1*c* shows a graph of time dependence of the amplitude of the recorded signal (field excitatory postsynaptic potential) when an electrode of the sensor was positioned under the *stratum radiatum* layer of the CA1 region of the hippocampus, and stimulating current pulses were applied to Schaffer collaterals.



a



b

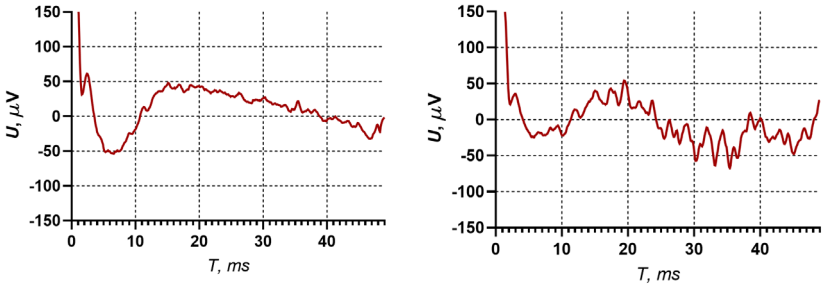


Figure 1. *Sensor of electrical activity (a). Hippocampal slice positioned on the sensor (b). Recorded field excitatory postsynaptic potential (c). Recorded epileptiform activity (d).*

Figure 1*d* shows a graph of field excitatory postsynaptic potential when 10 μM of bicuculline was added to the perfusing solution. In this case, the recorded signal has repeating ripples resembling epileptiform activity due to blockade of inhibitory synapses.

The amplitude of the signals recorded with the sensor is lower than the typical signal amplitude obtained using metal needle microelectrodes. This is due to the fact that the needle microelectrode is positioned in the depth of the slice, while the electrodes of the planar sensor are positioned near the surface of the slice, where there are fewer viable cells.

Thus, the use of 3D printing methods opens up opportunities for refining the design and rapid prototyping of microelectrode sensors for capturing extracellular electrical activity of neurons. Using 3D printing methods, it is possible to integrate microfluidic elements into the recording chamber for precise control of fluid flows near the cut surface or to integrate electrical activity sensors directly into the recording chamber structure. Our study showed that the printing requirements for the channels of the presented sensor are near the limits of the capabilities of modern consumer-grade photopolymer printers, and further refinement of the printing technique is necessary to improve printing accuracy.

Another factor that must be taken into account when using with 3D-printed parts in biomedical experiments is the biocompatibility of the photopolymer. Photopolymers for 3D printing contain photoinitiators, photoabsorbers, monomers/oligiomers and other additives. Unreacted monomers and other compounds may leach from the printed detail to extracellular solution and have toxic effects on cells. There are special photopolymer compositions for medical applications, but the complete absence of adverse effects is not guaranteed even for them [4]. In this

regard, post-processing procedures can be applied to the printed parts in order to improve biocompatibility, such as extraction in solvents [5], protective coating [6], additional exposure [7]. Another promising approach in this direction is the development of intrinsically biocompatible «bio-based» photopolymers [8]. They can be based not only on plant-derived monomers, but even on plant-derived photoinitiators [9], which are usually the most harmful components of a photopolymer.

Although the use of photopolymer structures in acute *in vitro* experiments in conditions of continuous perfusion of an extracellular solution makes the negative impact of photopolymer components on cells less likely than with chronic implantation, the development and testing of photopolymer compositions with high biocompatibility remains an important scientific challenge.

References

1. Li Q., Han X., Wang J. Organotypic Hippocampal Slices as Models for Stroke and Traumatic Brain Injury // Mol Neurobiol. – 2016. – Vol. 53, № 6. – P. 4226–4237. https://doi.org/10.1007/s12035-015-9362-4.

2. Croft C.L. et al. Organotypic brain slice cultures to model neurodegenerative proteinopathies // Mol Neurodegener. – 2019. – Vol. 14, № 1. – P. 45. https://doi.org/10.1186/s13024-019-0346-0.

3. Jones R.S.G. et al. Human brain slices for epilepsy research: Pitfalls, solutions and future challenges // J Neurosci Methods. – 2016. – Vol. 260. – P. 221–232. https://doi.org/10.1016/j.jneumeth.2015.09.021.

4. Alifui-Segbaya F. et al. Biocompatibility of Photopolymers in 3D Printing // 3D Printing and Additive Manufacturing. – 2017. – Vol. 4, № 4. – P. 185–191. https://doi.org/10.1089/3dp.2017.0064.

5. Ngan C.G.Y. et al. Optimising the biocompatibility of 3D printed photopolymer constructs in vitro and in vivo // Biomed. Mater. – 2019. – Vol. 14, № 3. – P. 035007. https://doi.org/10.1088/1748-605X/ab09c4.

6. Kreß S. et al. 3D Printing of Cell Culture Devices: Assessment and Prevention of the Cytotoxicity of Photopolymers for Stereolithography // Materials. – 2020. – Vol. 13, № 13. – P. 3011. https://doi.org/10.3390/ma13133011.

7. Guttridge C. et al. Biocompatible 3D printing resins for medical applications: A review of marketed intended use, biocompatibility certification, and post-processing guidance // Annals of 3D Printed Medicine. – 2022. – Vol. 5. – P. 100044. https://doi.org/10.1016/j.stlm.2021.100044.

8. Zhou H. et al. High-performance, high biobased content, self-repairable, and recyclable biobased photopolymers for UV-curing 3D printing // Industrial

Crops and Products. – 2025. – Vol. 224. – P. 120299. https://doi.org/10.1016/j.indcrop.2024.120299.

9. Chen H. et al. Photopolymerization using bio-sourced photoinitiators // Polym. Chem. – 2023. – Vol. 14, № 31. – P. 3543–3568. https://doi.org/10.1039/D3PY00651D.

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学龄前早期反应迟缓儿童对视觉刺激的感知
PERCEPTION OF VISUAL STIMULI BY SLOW CHILDREN OF EARLY PRESCHOOL AGE

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摘要：物体感知的主要方面——形状、大小和颜色——在儿童的生长发育过程中逐渐形成。早期经验的积累对感知技能的发展至关重要。发育正常的儿童能够区分视觉图像，但患有智力障碍或注意力缺陷障碍的儿童由于注意力不稳定，在信息处理方面面临困难。一项针对60名3-4岁儿童的研究表明，他们更难根据颜色而非大小选择物体。反应较慢的儿童完成任务所需的时间更长，尤其是在嘈杂的环境中。这凸显了在幼儿园教育过程中考虑个体差异以提高教育效率的重要性。

关键词：学前儿童，视觉感知，不同颜色的几何图形，不同大小的几何图形，声学背景，“反应较慢”的儿童，错误选择，选择时间。

Abstract. *The main aspects of object perception — shape, size, and color — are formed in children during their growth and development. Gaining experience at an early age plays a key role in developing perceptual skills. Children with normal development are able to distinguish between visual images, but those with mental disabilities or attention deficit disorder face difficulties processing information due to unstable concentration. A study involving 60 children aged 3-4 years showed that it is more difficult for them to choose objects by color than by size. Children with slow reactions spend more time completing tasks, especially in noisy environments, which emphasizes the importance of taking into account individual characteristics to improve the effectiveness of educational processes in kindergartens.*

Keywords*: early preschool children, visual perception, geometric shapes of different colors, geometric shapes of different sizes, acoustic background, “slow” children, erroneous choice, time of choice.*

Introduction. There are “slow” children with a slow pace of action, which does not affect their cognitive abilities, but makes it difficult to switch between actions and form skills. Their slowness is noticeable from infancy, especially in kindergarten, where they dress slowly, eat and complete tasks (Lukyanov, Ner-

ovnykh, 2023). The problem may be related to the slow process of myelination of nerve fibers, which ends by the age of 6-7, as well as early stress, anxiety, low motivation, and deprivation (Kolosova, Stefanova, 2016; Znamenskaya, Martynyuk, Schweikina, 2019). It is impossible to accelerate the maturation of higher nervous activity, and "slow" children will differ from their peers, which can lead to stress and anxiety. The transition to kindergarten creates additional stress factors that contribute to chronic anxiety disorder and decreased attention (Murray, Farrington, et al., 2009; Escobar, Trianes, et al., 2010). The desire to catch up with others can lead to self-doubt and acquired anxiety. Research shows that prolonged stress in preschool age can indicate poor academic performance in elementary school, especially in children with an anxious temperament. Hearing and vision are important channels of learning, and the neural mechanisms of sensory processing in healthy children and patients with ADHD are actively being investigated (Bonetti, Haumann et al., 2018).

The purpose of the present study. An analysis of the literature has shown that the success of the educational process in a normally developing child and children with developmental delay of various etiologies directly correlates with the perception, processing and memorization of new information. However, we did not find any studies related to the analysis of learning in "slow" and anxious children. This fact determined the relevance of this work and the task was set to conduct a comparative analysis of the identification of various visual stimuli by children aged 3-4 years with varying degrees of anxiety and speed of response to signals against the background of the noise of children's polyphony.

Materials and methods. This work continues the research that began in 2020 on children's detection of geometric shapes on the touchscreen (Struzhkin, Kuznetsova, Godynskaya, 2020; Kuznetsova, Struzhkin, Golubeva, 2024). The 2022-2024 study involved 60 3-4-year-old children with normal eyesight and hearing from St. Petersburg, with the written permission of their parents and in accordance with the Protocol of the Ethical Committee of the Pavlov Institute of Physiology of the Russian Academy of Sciences. The classes were conducted on a touchscreen monitor with an illumination of 475 lux. The stimuli were shapes of identical size but different color, or identical color but different size. The children's task was to identify and move the target stimulus to a designated area. In the first part of the study, blocks of images of triangles of different colors and sizes were presented, followed by blocks of circles, triangles, and squares of the same size, but different in color. The children were looking for incentives through trial and error without prior training. The search time was not limited, at the end of the task, a laughing smiley face and a beep appeared, and at the end of the lesson, the children received a toy. Two months later, the study was repeated with the same children and stimuli against the background of the noise of children's polyphony

through headphones. The signal characteristics are shown in Fig. 1. The pitch frequency was 363.5 Hz. The noise level corresponded to the average level of spoken language in this kindergarten group during children's free play (45 dB).

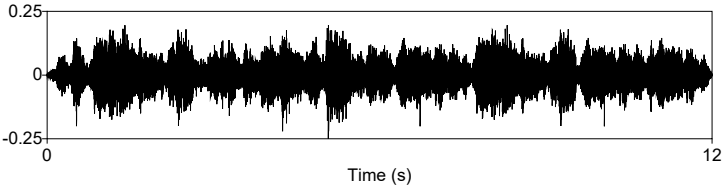

Figure 1. *An oscillogram of the noise of "children's" polyphony. Notation: horizontally – time (seconds), vertically – conventional units of signal amplitude. Duration - 12 seconds.*

The frequency of erroneous choices and the latent response period, defined as the time from the presentation of a stimulus to its tactile contact with the child's finger, were evaluated. Two-factor analysis of variance was used for statistical analysis (2-way ANOVA).

Results. All the children willingly participated in the study. However, the majority (52%) sat down quickly, performed tasks with joy, and actively sought incentives, which led to their being called "normal". 40% of the children (24 people) showed indecision, completing tasks slowly and waiting for support from the experimenter; they were called "slow". Five children (8%) did not leave the group at all. The study confirmed that children made more mistakes when choosing color stimuli of the same size ($p < 0.001$) compared to single-color stimuli of different sizes, spending more time ($p < 0.001$). Figure 2 shows a visualization of the data obtained, which illustrates the difference in the number of errors and the time spent choosing different types of stimuli.

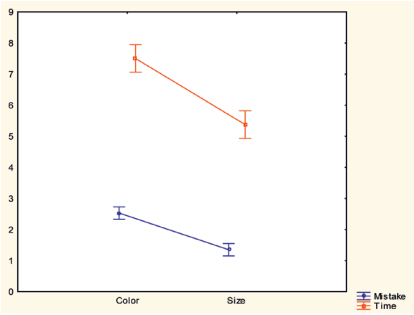

Figure 2. *Comparison of the overall success and search time of children aged 3-4 years when detecting colored stimuli of the same size and stimuli of different sizes, but the same color in a normal situation (without noise). Notation: horizontally – completing the task with the "color" stimulus and completing the task with the "size" stimulus, vertically – the number of errors (units) and the search time seconds. The results of the first part of the study in silence showed interesting patterns in the behavior of children. Participants made more mistakes (p <0.0000000) when choosing colored geometric shapes of the same size than monochrome ones based on size. Also, the time to find the correct color stimulus was significantly longer (p <0.0000000).*

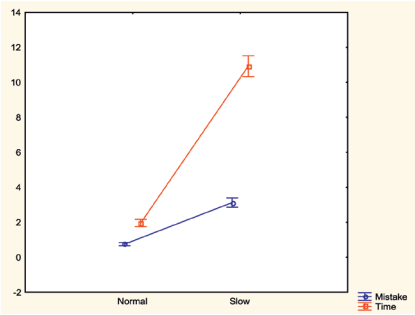

Figure 3. *Comparative characteristics the number of mistakes made and visual-spatial indicators of informative signs of "slow" and "normal" children aged 3-4 years. Notation: horizontally – the performance of the task by normal children is "normal" and the performance of the task by slow children is "Deviation", vertically – the number of errors (units).*

An analysis of the success of the task revealed that the group of "slow" children differs significantly from the main group in key indicators. Their visual-spatial indicators (VSI) were four times higher than those of other children (p <0.000000). This group made more mistakes (p <0.000000), which underlines the importance of taking into account individual characteristics when developing educational programs. Fig.3.

The introduction of noise interference – children's polyphony – significantly increased the VSI of color stimuli (p <0.001) in the entire group. In the slow

group, this indicator was significantly higher, especially when looking for colored stimuli against a background of noise. There was no significant difference in the number of stimuli of the same color but of different sizes ($p < 0.04$), but it was lower than when stimuli of the same size were detected ($p < 0.001$).

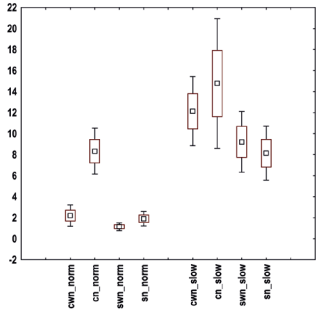

Figure 4. *Comparison of visual-spatial indicators of visual stimuli in two groups of children in a normal situation and against the background of acoustic noise of children's polyphony.*

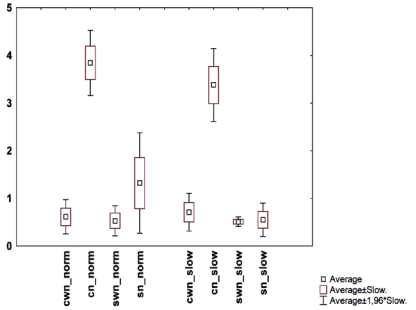

Figure 5. *Comparison of the number of erroneous choices of visual stimuli in two groups of children in a normal situation and against the background of acoustic noise of children's polyphony.*

Notation: on the ordinate axis, time in seconds, on the abscissa axis: left part of the graph – color without noise norm (cwn_norm) – Visual spatial indicators (VSI) of colored stimuli without noise in normal children; color noise norm (cn_norm) – VSI of colored stimuli against noise in normal children; size without noise norm (swn_norm) – VSI of single-color stimuli of different sizes without noise in normal children; size noise norm (sn_norm) - VSI of monochrome stimuli of different sizes against the background of noise in normal children. A similar designation is shown on the right side of the graph for slow children: color without noise slow (cwn_slow) – the VSI of color stimuli without noise in slow children; color noise slow (cn_slow) – VSI of colored stimuli against the background of noise in slow children; size without noise slow (swn_slow) – VSI of single–color stimuli of different sizes without noise in slow children; size noise slow (sn_slow) - VSI of single-color stimuli of different sizes against the background of noise in slow children. The symbols in **Fig. 5** are identical to **Fig. 4.**

Similarly, when analyzing children's mistakes, the number of erroneous choices increased against the background of noise compared to the usual situation ($p < 0.001$). Interestingly, in the children of the second group, noise interference dramatically increased the number of erroneous choices of color stimuli, affecting

stimuli of different sizes to a lesser extent, although there were more errors when searching for them against the background of noise than without it.

Discussion. Studies from 2021-2024 confirmed that children aged 3-4 years are worse at recognizing color stimuli of the same size compared to monochrome stimuli of different sizes due to the earlier development of visual perception systems (PapMacrides, Miliou, Angeli, 2022; Trifunović et al., 2024; Rodriguez et al., 2024) regarding frontal structures and the second signaling system (Jones et al. 2019; Pylypiuk, 2022; Richmond, et al., 2022; Shangguan et al., 2022; Farsi, Pirian, 2023). Errors in "slow" children are associated with more complex recognition of video images compared to real stimuli (Anderson, Kuroshima, Fujita, 2017; Brecht, Ostojic, et al., 2018) in combination with insufficient concentration of attention, slow myelination of nerve fibers (Kolosova, Stefanova, 2016; Znamenskaya, Martynyuk, Shveikina, 2019; Adaskina, Voronkova, Siradzheva, 2024; Meinert E. K. et al., 2020) and the negative effects of acoustic noise (Mealings, 2022; Mishchenkov et al., 2023; Andreeva, 2024). Difficulties with color stimuli, especially in "slow" and anxious children, may indicate mental retardation (ASD) due to immaturity of the brain, lack of attention, and poor behavior control (Marakushina, Pavozkova, Polyashova, 2019; Mubarakzyanova et al., 2024; Farsi, Pirian, 2023; Ghodrati, Nejad, Sharifian, Nejati, 2021; Nejati, Derakhshan, Mohtasham, 2023; Richmond, Kirk, Gaunson et al., 2022), as well as educational neglect. There are age-related features in the recognition of visual (Cherenkova, Sokolova, 2016) and auditory stimuli (Kornev, Lyublinskaya, Stolyarova, 2012; Osokina, Chernyshev, Chernysheva, 2011; Romanov, Goncharov, 2020). The choice of color stimuli is complicated by the need for spatial alignment of figures. The noise of "children's speech" affects the performance of complex tasks with colored stimuli in children, which may indicate habituation and a decrease in the threshold of noise exposure to nervous activity. Matching stimuli requires attention to the characteristics of objects rather than their relationships, which manifests itself as a "video deficit effect" (Xu, Tomonaga, Adachi, 2024).

Conclusion. The study, which confirmed the data obtained from 2021 to 2024, revealed a significant negative impact of noise interference (children's polyphony) on "slow" children in comparison with normal learning conditions. It has been established that background children's polyphony slows down the performance of educational tasks and critically affects the solution of complex tasks. The importance of taking into account the individual characteristics of children, including the characteristics of GNI and temperament, in the organization of the educational process is emphasized. The results of the study can be used to develop recommendations for optimizing the educational environment for preschool children, taking into account the peculiarities of their perception and information processing. This

can help improve children's academic performance and confidence in their abilities, which is important for their further education and socialization.

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References

1. Adaskina A. A., Voronkova I. V., Siradzheva Sh. Sh. (2024). The relationship between anxiety and learning success in 4th grade students. Bulletin of practical Psychology of Education, 21(4), 165-175. (In Russian).

2. Andreeva S. V. (2024). Understanding speech in children with autism spectrum disorders. Special education, 2(74), 63-89. (In Russian).

3. Znamenskaya T. K., Martynyuk V. Yu., Shveikina V. B. (2019). Morpho functional features of the development of the brain and circulatory system in ontogenesis. International Neurological Journal, 6(108), 17-29. (In Russian).

4. Kolosova N. G., Stefanova N. A. (2016). Neurotrophic provision of the brain in ontogenesis and in the development of neurodegenerative diseases. Moscow University Biological Sciences Bulletin, 4, 72-82. (In Russian).

5. Kornev A. N., Lyublinskaya V. V., Stolyarova E. I. (2012). Selective auditory attention in preschool children. Experimental Psychology, 5(4), 18-31. (In Russian).

6. Kuznetsova T. G., Struzhkin M. L., Golubeva I. Yu. (2024). Features of recognizing images of shapes of different colors and sizes by children aged 3-4 years using a noise background. Psychological-Educational Studies, 16(1), 111-120. (In Russian).

7. Luk'yanov O. V., Nerovnykh M. S. (2023). Socio-demographic filters for the development of higher mental functions in preschoolers. Siberian journal of psychology, 89, 65-85. (In Russian).

8. Marakushina I. G., Pavozkova O. E., Polyashova N. V. (2019). Dynamics of working capacity and noise immunity of attention in primary school children in the learning process. Problems of modern pedagogical education, 62(3), 193–294. (In Russian).

9. Meinert E. K. (2020). Changing the time of simple human reactions under the influence of low-frequency acoustic noises [thesis].Tomsk. URL: https://vital.lib.tsu.ru/vital/access/manager/Repository/vital:12076 (In Russian).

10. Mishchenkov R. S. (2023). The effect of loud sounds on human tactile-motor response and detection response [thesis]. Tomsk. URL: https://vital.lib.tsu.ru/vital/access/manager/Repository/vital:17776 (In Russian).

11. Mubarakzyanova Z. R., Sadovaya V. V. (2024). Prevention and psychocorrection of anxiety as a factor influencing the academic performance of primary school children. IX St. Andrew's Readings: modern concepts and technologies of creative self-development of personality: collection of articles by participants of the All-Russian Scientific and Practical Conference with international participation (pp.305-309). Kazan. (In Russian).

12. Osokina E. S., Chernyshev B. V., Chernysheva E. G. (2011). The relationship of selective auditory attention with individual characteristics. Psychology. Journal of the Higher School of Economics, 8(3), 121-129. (In Russian).

13. Struzhkin M. L., Kuznetsova T. G., Godynskaya N. V. (2020). Development and testing of a technique for recognizing visual stimuli using digital technologies in preschool children. Vestnik of North-Eastern Federal University "Pedagogy. Psychology. Philosophy" Series. 4(20), 65-68. (In Russian).

14. Romanov S. G., Goncharov O. A. (2020). Age-related features of categorical perception of focal and non-focal colors in the central and peripheral visual fields. Psychological Studies, 13(74). (In Russian). https://doi.org/10.54359/ps.v13i74.165

15. Cherenkova L.V., Sokolova L. V. (2016). Features of invariant visual image recognition in preschool children with typical and atypical development. Human Physiology, 42(3), 74-81. (In Russian). https://doi.org/10.7868/S0131164616010069

16. Anderson J. R., Kuroshima H., Fujita K. (2017). Observational learning in capuchin monkeys: a video deficit effect. Quarterly Journal of Experimental Psychology, 70, 1254–1262. https://doi.org/10.1080/17470218.2016.1178312

17. Bonetti L., Haumann N. T., Brattico E., Kliuchko M., Vuust P., Särkämö T., Näätänen R. (2018). Auditory sensory memory and working memory skills: Association between frontal MMN and performance scores. Brain Research, 1700, 86–98. https://doi.org/ 10.1016/j.brainless.2018.06.034

18. Brecht K. F., Ostojić L., Legg E. W., Clayton N. S. (2018). Difficulties when using video playback to investigate social cognition in California scrub-jays (Aphelocoma californica). PeerJ, 6, e4451. https://doi.org/10.7717/peerj.4451

19. Escobar M., Trianes M. V., Fernández-Baena F. J., Miranda Páez J. (2010). Relaciones entre aceptación sociométrica escolar e inadaptación socioemocional,

estrés cotidiano y afrontamiento. Revista Latinoamericana de Psicología, 42(3), 469–479.

20.Farsi A., Pirian F. The Effect of Perceptual-Motor Training and Mindfulness on Performance and Working Memory in Children with Attention Deficit Hyperactivity Disorder. Sport Psychology Studies. 2023. https://doi.org//10.22089/spsyj.2020.8905.1961

21.Ghodrati S., Nejad M. S. A., Sharifian M., Nejati V. (2021). Inhibitory control training in preschool children with typical development: an RCT study. Early Child Development and Care, 191(13), 1-10. https://doi.org//10.1080/03004430.2019.1691544

22.Jones P. R., Landin A., McLean M. Z. et al. (2019). Efficient visual information sampling develops late in childhood. Journal of Experimental Psychology: General, 148(7), 1138-1152. https://doi.org//10.1037/xge0000629

23.Mealings K. (2022). Classroom acoustics and cognition: a review of the effects of noise and reverberation on primary school children's attention and memory. Building Acoustics, 29(3). 401–431. https://doi.org/10.1177/1351010X221104892

24.Murray J., Farrington D. P., Sekol I., Olsen R. F. (2009). Effects of parental imprisonment on child antisocial behaviour and mental health: a systematic review. Campbell Systematic Reviews, John Wiley & Sons, 5(1), 1-105. https://doi.org// 10.4073/csr.2009.4

25.Nejati V., Derakhshan Z., Mohtasham A. (2023). The effect of comprehensive working memory training on executive functions and behavioral symptoms in children with attention deficit-hyperactivity disorder (ADHD). Asian Journal of Psychiatry, 81. https://doi.org//10.1016/j.ajp.2023.103469

26.Macrides E., Miliou O., Angeli C. (2022). Programming in early childhood education: A systematic review. International Journal of Child-Computer Interaction, 32(C). https://doi.org// 10.1016/j.ijcci.2021.100396

27.Pylypiuk K. M. (2022). Prevention and correction of pedagogical neglect based on research materials of German universities. Scientific Bulletin of Mukachevo State University. Series: Pedagogy and Psychology, 8(1), 78-85. https://doi.org// 10.52534/msu-pp.8(1).2022.78-85

28.Richmond S., Kirk H., Gaunson T. et al. (2022). Digital cognitive training in children with attention-deficit/ hyperactivity disorder: a study protocol of a randomized controlled trial. BMJ Open, 12. https://doi.org//10.1136/bmjopen-2021-055385

29.Rodríguez Deliz C. L., Lee G. M., Bushnell B. N., Majaj N. J., Movshon J. A., Kiorpes L. (2024). Development of radial frequency pattern perception in macaque monkeys. Journal of vision, 24(6). https://doi.org//10.1167/jov.24.6.6

30.Xiaoyun Shangguan, Jianfen Wu, Yunpeng Wu, Chen Chen. (2022). Design and Evaluation of a School-based Sustained Attention Training Program with

Parental Involvement for Preschoolers in Rural China. Early Education and Development, 35(2), 188-203. https://doi.org//10.1080/10409289.2022.2126265

31.Trifunović A. et al. (2024). Education of children on the recognition of geometric shapes using new technologies. Education Science and Management, 2(1), 1-9. https://doi.org//10.56578/esm020101

32.Xu S., Tomonaga M., Adachi I. (2024). Chimpanzees utilize video as reference in a spatiotemporally distant search for hidden food. Royal Society Open Science, 11(9). https://doi.org//10.1098/rsos.240440

DOI 10.34660/INF.2025.43.86.033

哈萨克斯坦共和国哈萨克白头牛、奥列科尔牛和卡尔梅克牛肉类生产性能的畜牧业评估

LIVESTOCK ASSESSMENT OF MEAT PRODUCTIVITY IN KAZAKH WHITE-HEADED, AULIEKOL AND KALMYK BREEDS IN THE REPUBLIC OF KAZAKHSTAN

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摘要：本研究对哈萨克斯坦科斯塔奈州农场条件下哈萨克白头牛、奥列科尔牛和卡尔梅克牛三个品种的后备公牛的肉用性能指标进行了比较评价。研究选取了60头10至18月龄的幼牛（每个品种20头）。研究考察了活重动态、绝对增重、相对增重、日均增重以及生长系数。结果表明，奥列科尔牛的最终活重（504公斤）和日均增重均显著优于其他品种（哈萨克白头牛为481公斤，卡尔梅克牛为461公斤）。研究还发现了不同品种的生长模式：奥列科尔牛表现出持续的快速生长期，哈萨克白头牛断奶适应性更好，而卡尔梅克牛的绝对增重则呈现周期性高峰。考虑到不同品种的遗传潜力，本研究结果对哈萨克斯坦的肉牛育种计划和育种策略优化具有实际意义。

关键词：肉牛养殖，哈萨克斯坦，哈萨克白头牛，奥利科尔牛，卡尔梅克牛，活重，日增重，育肥性能。

Abstract. *The study presents a comparative evaluation of meat productivity indicators in replacement bulls of Kazakh White-Headed, Auliekol, and Kalmyk breeds under farm conditions in the Kostanay region of Kazakhstan. The research involved 60 young animals (20 from each breed) aged from 10 to 18 months. The study examined live weight dynamics, absolute, relative, and average daily gains, as well as animal growth coefficients. Bulls of the Auliekol breed demonstrated significantly superior final live weight (504 kg vs. 481 kg in Kazakh White-Headed and 461 kg in Kalmyk) and average daily gain indicators. Breed-specific growth patterns were identified: Auliekol cattle showed prolonged*

intensive growth, Kazakh White-Headed exhibited better adaptation to weaning, and Kalmyk displayed periodic peaks in absolute gain. The results have practical value for breeding programs and optimization of beef cattle breeding strategies in Kazakhstan, considering the genetic potential of different breeds.

Keywords: *beef cattle breeding, Kazakhstan, Kazakh White-Headed breed, Auliekol breed, Kalmyk breed, live weight, average daily gain, fattening performance.*

Beef cattle breeding holds a strategically important position in the structure of the agro-industrial complex of the Republic of Kazakhstan, serving as one of the priority areas for livestock development. The availability of extensive natural and climatic resources, including significant areas of pastureland, creates prerequisites for sustainable industry growth, which could also position Kazakhstan as a key player in the international beef market while ensuring stable supply of domestic meat products to the population [10].

It is important not only to increase beef production volumes but also to introduce qualitative improvements into the beef cattle breeding sector, achieved through enhanced feeding systems, implementation of more efficient animal husbandry technologies, and utilization of highly productive specialized beef breeds [9, 8, 7, 2].

Kazakhstan possesses numerous genetic resources represented by beef cattle. Among them, domestic breeds such as Kazakh White-Headed, Auliekol, and Kalmyk can be distinguished.

Created in the 1930s-1940s by crossing local Kazakh and Kalmyk cattle with Hereford bulls, the Kazakh White-Headed breed was officially recognized in 1950. This unique breed combines the adaptability of local breeds with the excellent meat qualities of Herefords, demonstrating high slaughter yield and exceptional adaptation to harsh climatic conditions [3, 5].

Characteristic features of the breed include a red-white coat with typical white markings on the head, chest, and limbs, as well as pronounced seasonal dimorphism of the hair coat. According to 2022 data, the population numbers about 500 thousand head, of which 200 thousand are breeding stock, with the highest concentration observed in the East Kazakhstan Region [3].

Kalmyk cattle formed under extreme conditions of a sharply continental climate with year-round pasture maintenance, which determined the development of exceptional endurance in the breed. Long-term natural selection in conditions of harsh winters with ice and deep snow cover, supplemented by targeted breeding, contributed to the consolidation of unique adaptive characteristics [4].

The animals are distinguished by a harmonious medium-sized build with a predominance of red color and characteristic white markings. An important mor-

phophysiological feature is the seasonal development of a dense hair coat ensuring effective thermoregulation in winter. According to 2022 data, the total population of purebred Kalmyk cattle in Kazakhstan is 23 thousand head, including 15 thousand cows, with the main breeding zone in the western regions of the country. For preserving and improving valuable genetic qualities of the breed, purebred breeding using modern selection methods seems the most promising direction [3].

The Auliekol breed, created through complex crossing of Kazakh White-Headed, Charolais, and Aberdeen-Angus breeds, is distinguished by high adaptability to the sharply continental climate. The animals demonstrate good early maturity (average daily gain 1.2-1.8 kg) and productivity: live weight of bulls reaches 800-900 kg, cows - 450-500 kg, slaughter yield - 60-65% [6].

The breed possesses pronounced meat productivity with characteristic marbling. However, 12-15% of difficult calvings are noted due to large fetus size (calf weight 40-50 kg). As of 2023, the population was 70 thousand, including 33 thousand cows, with the main breeding area in the Kostanay Region [8, 1].

The aim of this research was to assess lifetime indicators of meat productivity in replacement bulls of specialized beef breeds under farm conditions in the Republic of Kazakhstan.

In accordance with the aim, the following objectives were set:

- study the live weight dynamics of experimental bulls;
- calculate absolute and relative indicators of live weight gain;
- analyze age-related dynamics of average daily gains;
- determine animal growth coefficients.

Materials and methods

The experimental part of the work was conducted on the basis of breeding enterprises “Krymskoye” LLP and “Moskalevsky” LLP (Kostanay Region, Kazakhstan). The research objects were purebred bulls of Kazakh White-Headed, Auliekol, and Kalmyk breeds.

For the experiment, three groups of bulls (20 heads each) were formed considering breed affiliation. Calving took place in January-March, and cows with calves during the stall period were kept in pens with lightweight premises equipped with exercise yards and a water heating system in drinkers.

After weaning, the bulls were transferred to a sectioned premises allowing for group housing. Adjacent were exercise yards where feeding and watering of animals also took place. During the cold season, water was heated using automatic or group drinkers. Intensive rearing was conducted up to 15 months of age with stall housing and group accounting of feed consumption. The diet was formulated based on high-quality feeds of own production, including: roughage (hay) - 20-25%, succulent feeds (haylage/silage) - 20-25%, and concentrated feeds - 50% (of total nutritional value).

Feeding was standardized in accordance with current zootechnical standards (Kalashnikov A.P., Fisinin V.I. et al., 2003), aiming to achieve by the end of fattening a live weight corresponding to the "elite-record" class, with an average daily gain of at least 1000 g.

Feed intake accounting was carried out by the control feeding method with recording of the given feed volume and uneaten residues over two consecutive days (according to the methodology of GNU SibNIPTIZh SO Russian Agricultural Academy). Growth dynamics were assessed by individual weighing of animals: at birth, at weaning, and monthly until reaching 15 months of age.

Based on the obtained data, the following indicators were calculated: absolute live weight gain, average daily gain, relative gain, and growth coefficient (multiplicity of mass increase). For statistical analysis of the obtained results, methods of variation statistics were used applying Microsoft Excel 2010 package. Reliability of differences between groups was determined using Student's t-test.

Results

Against the backdrop of growing demand for beef, the task of increasing the population of beef cattle breeds becomes particularly important. Determining the most adapted and productive breeds for a specific region requires a systematic assessment of their meat qualities during life, among which key criteria are weight growth indicators.

Experimental data reflecting the dynamics of live weight change of bulls during the research are presented in Table 1.

Table 1

Dynamics of live weight of bulls of different breeds, kg

Age of animals, months	Breed			Differences between groups (D)		
	I Group Kazakh White-Headed (n=20) M±m	II Group Auliekol (n=20) M±m	III Group Kalmyk (n=20) M±m	D (I-II)	D (II-III)	D (I-III)
	M±m	M±m	M±m			
10	240 ± 3,2	250±2,4	235±1,8	10*	15***	5
11	279 ± 3,6	288±3,6	267±3,0	9	21***	12*
12	311 ± 3,8	327±2,6	294±2,2	16**	33***	17***
13	341 ±3,8	360±2,6	323±2,4	19***	37***	18***
14	370 ± 4,3	395±2,9	354±2,6	25***	41***	16**
15	400 ± 4,9	428±7,3	382±3,0	28**	46***	18**
16	429 ± 4,9	454±5,9	408±4,1	25**	46***	21**
17	456 ± 5,1	479±6,2	435±3,2	23*	44***	21**
18	481 ± 5,1	504±6,2	461±4,0	23*	43***	20**

*Note: here and hereafter * – p≤0.05; ** – p≤0.01; *** – p≤0.001*

The conducted analysis of live weight dynamics of bulls in terms of age revealed that by 10 months of age this indicator reached 235-250 kg. The highest productive characteristics were demonstrated by animals of the Auliekol breed (Group II). Throughout almost the entire observation period, they significantly surpassed their peers of the Kazakh White-Headed breed (Group I) in live weight by an average of 19.7 kg, and representatives of the Kalmyk breed (Group III) - by 36.2 kg. The difference between indicators of Groups I and III was 16.4 kg.

The maximum intergroup differentiation in the studied trait was noted at the age of 15-16 months. By the final stage of the research (18 months), the following live weight indicators were established: in bulls of Group I - 481 kg, Group II - 504 kg, Group III - 461 kg. Thus, Auliekol bulls showed the highest results, exceeding the indicators of the Kazakh White-Headed breed by 23.0 kg (4.8%), and the Kalmyk breed - by 43.0 kg (9.3%).

The obtained data allow classifying the studied groups by growth type: bulls of the Kazakh White-Headed breed (Group I) belong to the medium-maturing type, Kalmyk breed (Group III) - to the early-maturing type. Features of growth processes in animals of Group II, characterized by a prolonged growth period, are probably due to the genetic influence of the Charolais breed, which is characterized by an extended period of intensive muscle growth. Relatively low live weight indicators in bulls of Group III are consistent with the breed characteristics of Kalmyk cattle, which have a genetic predisposition to smaller sizes.

Statistical analysis revealed significant ($p<0.05$) interbreed differences in average daily live weight gain indicators in the studied animal groups (Figure 1). Throughout the entire experimental period, maximum average daily gains were recorded in bulls of Kazakh White-Headed and Auliekol breeds (Groups I and II), reaching 1300 g, which significantly exceeded similar indicators in Kalmyk (Group III - 1067 g) breed.

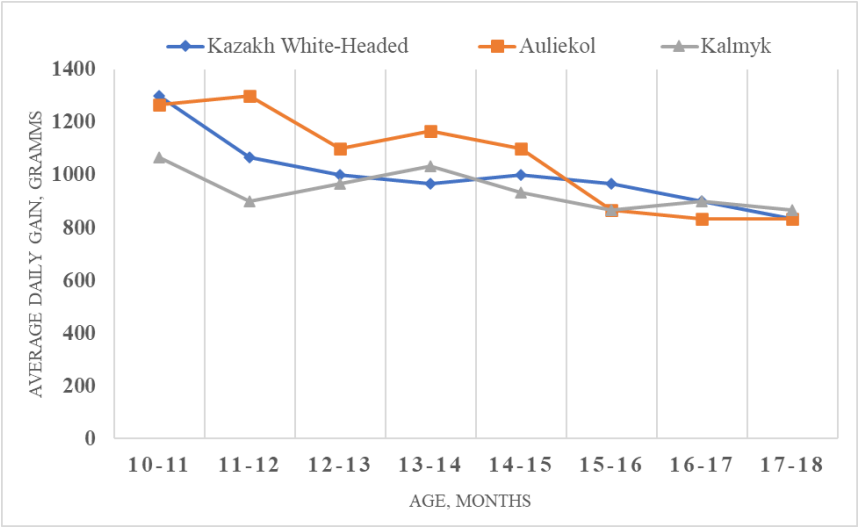

Figure 1. *Changes in average daily gain of young animals of the studied breeds*

The highest growth intensity in all studied groups was observed in the age period from 10 to 15 months, when average daily gains varied in the range of 1000-1300 g. Comparative analysis showed that in this indicator, bulls of Group II significantly surpassed animals of Group I by 5.4% (54 g) and Group III by 12.3% (116 g).

Considering the standardized housing and feeding conditions of all experimental groups, the identified differences in productivity can be explained by the genetic characteristics of the studied breeds. The highest average daily gain indicators in Auliekol bulls indicate a more pronounced genetic potential for meat productivity of this breed compared to other studied groups.

The results of the study of absolute live weight gain revealed significant ($p<0.05$) interbreed differences in the studied animal groups (Figure 2). Although no clear linear dependence was found, data analysis allows identifying a certain periodicity and rhythm of growth processes in animals of different genotypes.

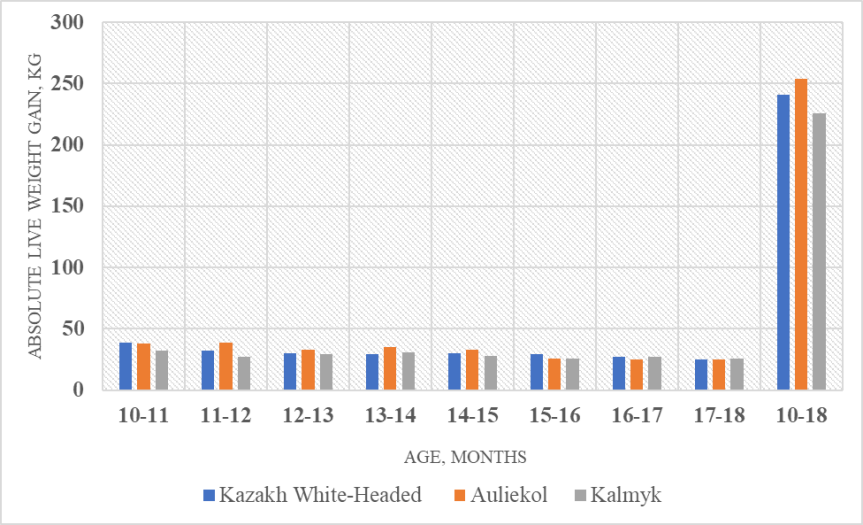

Figure 2. *Absolute gain of intensively reared bulls*

Bulls of Group I (Kazakh White-Headed breed) demonstrated good adaptation to weaning, which manifested in stable growth indicators in the first month of the post-weaning period. Maximum values of absolute gain in this group were recorded at the age of 10-11 months - 39 kg, which exceeded the indicators of Group II (38 kg) and Group III (32 kg). In the subsequent period (16-17 months), animals of Group I maintained leading positions in this indicator.

Of particular interest is the dynamics of absolute gain in bulls of Group III (Kalmyk breed), which in certain age periods demonstrated superiority over other groups. Animals of Group II (Auliekol breed) in the initial research period (first month after weaning) showed average values of absolute gain with subsequent decrease at 10-11 months of age. However, starting from 11 months, this group showed stabilization of growth processes with sharp acceleration in the period of 12-15 months. In the final phase of the experiment (15-18 months), a characteristic rhythm of changes in absolute gain was observed with alternating periods of increase and decrease in indicators while maintaining them at a high level.

The average values of absolute gain for the period from 10 to 18 months were: in Group II - 254 kg, Group I - 241 kg, Group III - 226 kg. Statistical analysis confirmed the reliability ($p<0.01$) of differences between groups: the advantage of Group II over Group I was 13.0 kg (5.4%), over Group III - 28.0 kg (12.4%). The obtained data indicate pronounced genotypic conditioning of growth characteristics of the studied cattle breeds.

Conclusion

The conducted research revealed significant differences in the growth characteristics of the studied cattle breeds. The Auliekol breed demonstrated statistically significant superiority in live weight over the Kazakh White-Headed and Kalmyk breeds at most age stages, except for 11 months of age, when differences with the Kazakh White-Headed breed did not reach the level of significance. In turn, the Kazakh White-Headed breed in most cases surpassed the Kalmyk breed, except for the age of 10 months.

Analysis of average daily gains confirmed the higher genetic potential for meat productivity of Auliekol bulls. At the same time, the Kazakh White-Headed breed showed better adaptation to weaning, which was reflected in stable growth indicators in the post-weaning period. Kalmyk bulls showed interesting dynamics of absolute gain with periodic superiority over other groups.

The obtained data on the age-related dynamics of live weight and weight growth indicators of replacement bulls of specialized beef breeds under Kazakhstan conditions are of significant practical value for improving breeding and selection work and developing beef cattle breeding in the region. The research results can be used to optimize breeding programs considering breed characteristics of animals.

References

1. Brel-Kiseleva, I. M., Aitzhanova, I. N., & Tegza, I. M. (2021). Status and Further Improvement of Beef Cattle Breeding in the Kostanay Region. In Materials of the IV International Scientific and Practical Conference Dedicated to the Memory of Doctor of Agricultural Sciences, Professor Bakhytzhan Muslimovich Muslimov (p. 19). Kostanay: A. Baitursynov Kostanay Regional University. (In Russian).

2. Grigoriev, M. F., Popova, A. V., & Chernogradskaya, N. M. [et al.]. (2022). Influence of Feed Additives on the Meat Productivity of Cattle. Meat Industry, (6), 36-38. https://doi.org/10.37861/2618-8252-2022-06-36-38 EDN HYTLJG. (In Russian).

*3. Khamzina, A. K. [et al.]. (2024). History, Current State, and Genetic Characteristics of Local Cattle Breeds in the Republic of Kazakhstan. Vavilov Journal of Genetics and Breeding, *28*(4), 416-423. (In Russian).*

4. Nasambayev, E., Akhmetalieva, A. B., & Nugmanova, A. E. [et al.]. (2023). Breeding and Productive Qualities of the Kalmyk Cattle Breed in Western Kazakhstan. Science and Education, (1-2)(70), 198-207. https://doi.org/10.52578/2305-9397-2023-1-2-198-206 EDN AAGUXR. (In Russian).

5. Nasambayev, E. G. [et al.]. (2024). Evaluation of Bulls Based on Their Own Productivity as an Advanced Approach to Improving Production Characteristics

*of Beef Cattle. Animal Husbandry and Fodder Production, *107*(3), 25-35. (In Russian).*

6. Nasambayev, E. G., Nametov, A. M., & Shamsheden, A. S. [et al.]. (2023). Program for Improving Selection and Breeding Work with the Auliekol Breed [Electronic resource]. Ural: Zhangir Khan West Kazakhstan Agrarian and Technical University. (In Russian).

7. Nikolaeva, N. Yu. (2021). Ways to Improve the Meat Productivity of Cattle: Foreign Experience. In Status and Prospects for Increasing the Production of High-Quality Agricultural Products: Materials of the XI International Scientific and Practical Conference (pp. 82-85). Novosibirsk: Novosibirsk State Agrarian University Publishing Center "Zolotoy Kolos". EDN BXZMLZ. (In Russian).

8. Shekhovtsev, G. S., Prokhorov, I. P., & Pikul, A. N. (2021). Lifetime Assessment of the Meat Productivity of Aberdeen-Angus Bulls under Different Housing Systems. Bulletin of Agrarian Science, (3)(90), 94-100. https://doi.org/10.17238/issn2587-666X.2021.3.94 EDN NVLLSN. (In Russian).

9. Vlasova, I. V., Vostroilov, A. V., & Pelevina, G. A. (2021). Meat Productivity of Limousin Cattle Considering Age Characteristics. In Theory and Practice of Innovative Technologies in the Agro-Industrial Complex: Materials of the National Scientific and Practical Conference (pp. 34-37). Voronezh: Voronezh State Agrarian University. EDN GBHALN. (In Russian).

*10. Yesengaliyeva, S. M. [et al.]. (2021). Current State and Development Trends of Livestock Farming in the Republic of Kazakhstan. Economy: Strategy and Practice, *16*(2), 134-144. (In Russian).*

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烘焙肉类和蔬菜膳食烹饪产品的开发
DEVELOPMENT OF BAKED DIETARY MEAT-AND-VEGETABLE CULINARY PRODUCTS

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摘要：本文致力于开发具有功能特性的新一代肉菜类产品。文章阐述了烹饪产品的风味和香气特性与配方成分之间的依赖关系，并建立了影响半成品结构和特性的规律。研究目标：探讨配方成分和热处理方法对肉菜类半成品和成品烹饪产品的结构和特性的影响。

关键词：热处理，肉菜类半成品，特性，品质。

Annotation*. This article is devoted to the development of a new generation of meat-and-vegetable products with functional characteristics. The dependence of the flavor and aroma properties of culinary products on the recipe components is demonstrated. Patterns influencing the structure and properties of semi-finished products are established. Research objective: to study the influence of recipe components and heat treatment methods on the structure and properties of meat-and-vegetable semi-finished products and finished culinary products.*

Keywords: *heat treatment, meat-and-vegetable semi-finished products, properties, quality.*

Introduction

Children's health is not only the foundation of a prosperous society but also a pressing issue at both national and global levels. In a constantly changing environment, including political, environmental, social, and economic factors affecting children during their growth and development, ensuring the well-being of the younger generation has become a priority for healthcare and the state [1-3].

Poor nutrition, irregular eating habits, fast food, drinks, and sweets with artificial flavors and colorings lead to the development of a number of non-communicable diseases, metabolic disorders, obesity, and depression. Therefore, preventative, functional, and dietary nutrition are recommended for dietary adjustments. Providing the country's population with healthy nutrition is of great national importance, therefore the function of its organization is assigned by the order of the Government of the Russian Federation dated 31.12.2009 to state and municipal bodies and institutions of the Russian Federation, "Fundamentals of state policy in the field of healthy nutrition of the population of the Russian Federation for the period up to 2025", the Doctrine of food security of the Russian Federation (2025) the goals of state policy in the field of healthy nutrition are declared to be the preservation and strengthening of public health, the prevention of diseases associated with poor nutrition of children and adults [4].

Meat products balanced in essential nutrients can be produced by incorporating vegetables, cereals, flour, bread, dry fiber, and sauces into the recipe [5-11]. Various methods for incorporating by-products into meat product recipes have also been proposed, including in their natural state, coarsely ground, or as a paste. Some by-products contain high levels of connective tissue, which increases their strength and requires modification [12].

The use of seafood in minced meat recipes also holds promise. For example, sea cucumber has been used in sausage mince [13, 14], extracts from sea cucumbers from the Far Eastern seas have been used as additives [15], and the use of a complex of marine-based biologically active ingredients in the biotechnology of dry-cured meat products has been noted [16].

However, research in this area is ongoing. Scientists and technologists are experimenting with animal and plant-based raw materials to optimize the nutritional and biological value of innovative products, their flavor profile, and the desired consistency.

The goal of introducing plant-based ingredients into the recipe is to enhance the product's balance, achieve high nutritional and biological value, and improve the organoleptic characteristics of poultry cutlet products. Research

Subjects and Methods

Dietary product recipes were developed based on formalized requirements. Vegetables and fruits, which clearly combine high biological properties with minimal caloric value, are essential sources of biologically active substances in balanced product recipes. They contain nutrients essential for the human body's physiological needs: carbohydrates, dietary fiber, vitamins, macro- and microelements.

The selected plant ingredients included red carrots, onions, garlic, zucchini, spirulina, ground even pepper, pine nut shell powder, bread, wheat bran, and a dry powdered functional mixture of cereals and legumes. Vegetable oil, poultry fat,

milk, sour cream sauce, salt, paprika, and a vegetable breading mixture were also included in the recipes.

Study subjects: dietary poultry meatballs (semi-finished and cooked products). Research methods: generally accepted methods for determining the nutritional and energy value of raw materials and semi-finished products, and organoleptic studies of the consumer properties of food products.

Results and discussion

When developing the production technology and recipes for dietary poultry products, we focused on both traditionally prepared semi-finished products made from cutlet mixtures—cutlets, meatballs, schnitzel, meatballs, meatballs, zrazy, dietary steamed cutlets, rolls, etc.—which enable the creation of products with a balanced composition, as well as innovative products incorporating raw materials of plant and animal origin.

The developed recipe for the dish "Dietary Poultry Meatballs" is shown in Table 1.

Table 1

Recipe for the dish "Dietary Poultry Meatballs"

Name of raw materials	Consumption of raw materials and semi-finished products			
	sample 1		sample 2	
	Gross, g	Net, g	Gross, g	Net, g
Chicken fillet	63	61	57,2	55,5
Wheat bread	13	13		
Carrots (fresh)	5	4		
Zucchini (fresh)	4	3	16,6	15,1
Fresh onion			5,3	4,5
Fresh garlic			0,7	0,5
Spirulina	0,01	0,01		
3.2% fat milk	10	10		
Poultry fat	2	2	7,0	7,0
Bran breading	4	4		
Dry functional mixture			10	10
(cereal and legume flour)	0,02	0,02		
Paprika (coloring)			0,01	0,01
Black pepper			0,2	0,2
Pine nut shell powder	0,3	0,3	1,0	1,0
Salt			5,0	5,0
Vegetable breading mixture	3	3		
Vegetable oil	20	20		
Sour cream sauce	-	100	-	100

The technology for preparing semi-finished and ready-to-eat foods includes the initial processing of raw materials, chopping, mixing with food additives, portioning, breading, heat treatment of the semi-finished product, and then serving or storing.

Poultry meat is cut into pieces and minced along with the internal fat. Chopped sautéed carrots, zucchini, bread soaked in milk, spirulina, and salt are added to the cutlet mixture. The mixture is mixed and formed into balls, 3-4 balls per serving. The meatballs are breaded in bran mixed with paprika, fried, placed in a shallow dish in 1-2 layers, covered with sour cream sauce to which 10-20 g of water has been added, and simmered for 8-10 minutes. Meatballs can be cooked in a combi-oven at 180°C for 20 minutes. The meatballs are served with a side dish and the sauce in which they were stewed.

Ready-to-eat diet meatballs must meet the quality indicators listed in Table 2.

Table 2

Quality Indicators for Diet Meatballs

Indicators	Characteristics of Quality Indicators
Appearance	Smooth, round balls
Consistency	Juicy, smooth, and moderately dense
Color	Light pink with a golden-brown crust and white sour cream sauce
Taste	Poultry, mild, sweet and sour
Aroma	Distinctive aroma of poultry and sour cream

The developed dietary poultry meatballs demonstrated high organoleptic quality indicators, meeting consumer preferences. Since these products are recommended for dietary nutrition, they are served at a serving temperature of 65 to 70°C.

The shelf life of finished products (dishes or culinary items) is no more than 24 hours from the end of the production process.

Conclusions

A literature review and patent search enabled us to identify the optimal range of the most effective plant-based ingredients to enrich this product with essential nutrients that meet the body's physiological needs.

The use of fresh vegetables along with cereal and legume flours allowed us to create the desired structure of the semi-finished and finished culinary products.

The cooking temperature for the culinary products is gentle (180°C for 20 minutes in a combi steamer), allowing us to recommend the developed meatballs for dietary nutrition.

References

1. Akhmadkhodzhaeva MM. Morbidity in preschool children. Economy and Society. 2024;2-1(117):895-900.

2. Zhdanova LA, Shishova AV, Boboshko IE. School medicine: possibilities for implementing primary prevention. Bulletin of the Ivanovo Medical Academy. 2021;26(3):5-10. DOI: 10.52246/1606-8157_2021_26_3_5

3. Physical development of children and adolescents of the Russian Federation. Collection of materials (issue VI). Ed. by Baranov AA, Kuchma VR. Moscow: PediatrЪ, 2013.

4. Vasyukova AT, Mirakov IR, Portnov NM, Makhmadaliev E.Sh. (2019) Design of recipes for meat-vegetable culinary products // Food industry. 2019. No. 9. Pp. 29-33.

5. Bayumi, A. Development of technology for low-calorie minced meat semi-finished products using plant raw materials (tiger nuts and quinoa): author's abstract. diss... cand. tech. sciences: 05.18.04 / Bayumi Ahmel Adel Ahmed Sayed. - M. - 2021. - 21 p /

6. Basova, M.S. Prospects for the use of legume protein in semi-finished meat products / M.S. Basova // Modern science-intensive technologies. - 2010. - No. 3. - Pp. 23-27.

7. Bazhenova, B.A. Biologically active additive for meat products / B.A. Bazhenova, M.B. Danilov, Yu.Yu. Zabalueva, T.M. Badmaeva, G.N. Ayusheeva // All about meat. - 2016. - No. 3. - P. 14-18.

8. Broshko, D.V. Possibility of using powder from rocky cloudberry berry pomace in recipes for minced meat semi-finished products / D.V. Broshko, N.A. Velichko, E.A. Rygalova // Bulletin of KrasSAU. - 2020. - No. 2. - P. 177-182.

9. Vasyukova, A.T. Development of technology and recipes for minced meat products with dietary supplements. / A.T. Vasyukova, M.G. Makarov, R.A. Edwards, E.Sh. Makhmadaliev, M.E. Brazhnikov // Bulletin of the Voronezh State University of Engineering Technologies. - 2020. - Vol. 82. - Pp. 124-128.

10. Vasyukova, A.T. Products with herbal additives for healthy eating / A.T. Vasyukova, A.A. Slavyansky, M.F. Khairulin, A.E. Alekseev, E.Sh. Makhmadaliev // Food industry. - 2019. - No. 12. - Pp. 72-75.

11. Voronkova, Yu.V. Domestically produced beet dietary fibers in the technology of functional meat products: author's abstract. Diss. Cand. Tech. Sciences: 05.18.04 / Voronkova Yulia Viktorovna. - Voronezh, 2014. - 19 p.

12. Gerasimov AV Development of technology for meat products enriched with plant antioxidants. Diss. Cand. Tech. Sciences, specialty 05.18.04, Ulan-Ude, East Siberian State University of Technology and Management, 2021. - 149 p.

13.Burakova, EV Cucumaria as a source of physiological fibers and biologically active substances in the production of cooked sausages / EV Burakova // Scientific conference with international participation "Development of the food and processing industry of Russia: personnel and science". - Part 3. - Electronic collection. - M .: MGUPP. - 2017. - pp. 10-15.

14.Afanasyeva, AE Justification for obtaining the dietary supplement "Akmar" from sea cucumber / A.E. Afanasyeva, G.N. Timchishina, T.N. Slutskaya // Izvestiya TINRO. - 2003. - Vol. 133. - Pp. 318-324.

15.Burakova, E.V. Use of extracts from holothurians of the Far Eastern seas in the technology of culinary products / E.V. Burakova, T.N. Slutskaya // Innovative development of the fishing industry in the context of ensuring food security of the Russian Federation: Proc. I Nat. correspondence scientific and technical. conf. - Vladivostok: Dalrybvtuz. - 2017.

16.Kalenik, T.K. Justification and use of a complex of biologically active ingredients of marine genesis in the biotechnology of raw smoked meat products / T.K. Kalenik, V.A. Nevzorova, L.A. Tekutyeva, O.M. Son, E.V. Motkina // News of universities. Food technology. - 2009. - No. 5-6 (311-312). - P. 34-36.

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