# Practice Oriented Science:
# UAE – RUSSIA – INDIA

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*Materials of International University Scientific Forum*

# Practice Oriented Science: UAE – RUSSIA – INDIA

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# IMPLEMENTATION OF PEDAGOGICAL METHODS OF EDUCATION K.D. USHINSKY FROM THE STANDPOINT OF A.A. UKHTOMSKY

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***Abstract.*** *In our country, the methods of pedagogical education K.D. Ushinsky for many decades are effective and in demand. At the same time, from the point of view of modern pedagogical science, the physiological mechanisms for implementing the methods of K.D. Ushinsky have not been studied enough. We have given an analysis of the physiological mechanisms of the legacy of his pedagogical methods of education from the point of view of the doctrine of the dominant academician A.A. Ukhtomsky. Using the examples of his own research, the positive influence of the dominant academician A.A. Ukhtomsky per person.*

***Keywords:*** *pedagogical methods K.D. Ushinsky, dominant A.A. Ukhtomsky, physiological mechanisms.*

**Relevance.** For many decades, we have been engaged not only in medical, but to a large extent in pedagogical activity, which gives us reason to call pedagogy an art, and not just a science of upbringing and education of a person. We believe that any practical activity of a person, striving to satisfy his/her highest spiritual and moral needs, is already an art. In the context of the foregoing, pedagogy will

undoubtedly be not only the first, but also the highest of the arts, because it constantly purposefully strives to improve the very nature of man - his/her soul and body.

In this regard, we again and again turn to the richest and inexhaustible pedagogical heritage of K.D. Ushinsky and understanding his work from the standpoint of medicine and neurophysiology. So, in particular, in 1861, he noted "...neither politics, nor medicine, nor pedagogy can be called sciences in ... the strict sense, but only arts ... Science only studies what exists or has existed, and art seeks to create something that does not exist yet …" [26].

Based on the extensive philosophical and pedagogical heritage of K.D. Ushinsky, one should always remember his statement that "Pedagogy is not a science, but an art - the most extensive, complex, highest and most necessary of all the arts. The art of education is based on science." There we can follow and appreciate his statement, which is still relevant today: "As an art complex and extensive, it relies on many different sciences; as an art, in addition to knowledge, it requires ability and inclination, and as an art, it strives for an ideal that is eternally attainable and never completely unattainable: the ideal of a perfect person.

Based on this postulate of our outstanding teacher and thinker, one of the innovators of pedagogical upbringing and education K.D. Ushinsky, we determine for ourselves that, most likely, in the near future, i.e., in the foreseeable future, we will not be able to achieve the ideal in pedagogy if we do not use the achievements and real possibilities of the modern art of healing in the process of comprehensive being.

That is why it seems important to us, based on the unique pedagogical heritage of K.D. Ushinsky, to consider the key possibilities of using the dominant A.A. Ukhtomsky in education.

In our country, the founder of Russian scientific pedagogy is Konstantin Dmitrievich Ushinsky (February 19 (March 3), 1824 - December 22 (January 3), 1871). It was he/she who created in Russia a new and original pedagogical system for educating children [4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 17, 31]. K.D. Ushinsky rightly was, is and will be a "teacher of Russian teachers" [2], who subtly understood the peculiarities of raising a child. For many decades, millions of children were taught and brought up according to his books [20, 21].

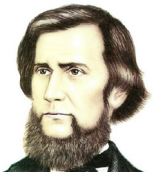

***Figure 1.*** *Konstantin Dmitrievich Ushinsky.*

Pedagogical research in recent decades has shown the importance and necessity of studying the neuronal mechanisms of learning and upbringing in modern educational systems [16, 18, 22, 32]. In other words, we are talking about the formation and development of a new integrative scientific area of pedagogical education - neuropedagogy, the development of which, in which we are deeply con-

vinced, allows more effective training of students, including those of liberal arts universities [1, 3, 16].

The methodology of neuropedagogy is based on the provisions according to which the formation of higher mental functions of a child depends on a number of cumulative factors, including the timely maturation of certain areas of the brain, on the nature of the physiological activity of sensory systems, and on the formation of intersensory connections. We believe that this is the basic foundation for the systemogenesis of mental activity, in particular learning skills (for example, writing, reading and counting). We can agree with researchers who single out neuropedagogical competencies as a separate area of pedagogical training programs and consider neuropedagogy as a science about the theory and technologies of teaching and education [13, 15]. At the same time, it is obvious that, from a methodological point of view, neuropedagogy remains a little-studied area of higher education pedagogy, and it would be interesting from a scientific point of view to use the accumulated practical experience of K.D. Ushinsky and integrate it into the modern theory and practice of education.

K.D. Ushinsky, considering the issue of the connection between the theory and practice of education, wrote: "The activity of a person as a person always proceeds from the source of conscious will, from the mind; but in the realm of reason, a fact in itself is nothing, and only the ideal side of the fact, the thought that follows from it and is supported by it, is important. The connection of facts in their ideal form, the ideal side of practice, will be theory in such a practical matter as education" [27]. It is quite natural that pedagogical theory and practice are interconnected and interact not as forces external to each other, but as mutually penetrating each other, closely intertwined aspects of a single human activity.

On the pages of modern pedagogical literature on the school, a lot of attention is paid to the number of subjects studied by schoolchildren, dividing them into "necessary" and "not necessary" for life, requiring not only time to master them, but also emotional and psychological stress to keep in memory information relevant to the subject. In the general structure of teaching K.D. Ushinsky attached exceptional importance to the memory of students. He wrote: "Studying the process of memory, we will see how shamelessly our upbringing still treats it, how it throws all sorts of rubbish there and rejoices if out of a hundred information thrown there, one somehow survives; while the educator, in fact, should not give the pupil any information, the preservation of which he cannot count on. We believe that in the age of the most powerful scientific and technological progress, the modern school should give students only the stock of knowledge that will be useful to them in practical activities. In our opinion, as a perspective-minded teacher K.D. Ushinsky is right many times when he points out: "Every educational institution now complains about a multitude of subjects of study - and indeed, there

are too many of them, if we take into account their pedagogical processing and teaching method: but they are too few, if we look at the constantly growing mass of human information. ... Opportunities to give a person with ordinary abilities and give firmly ten times more information than the most talented now receives, spending the precious power of memory on acquiring thousands of knowledge, which they will then forget without a trace. Not knowing how to deal with a person's memory, we console ourselves with the thought that the matter of education is only to develop the mind, and not to fill it with information; but psychology denounces the lie of this consolation, showing that the mind itself is nothing but a well-organized system of knowledge.

We bring up for discussion the question that often children are given tasks that are not only beyond their strength, but can also cause various disorders of the brain. K.D. Ushinsky, taking care of the issues of education, considered the rule of respect for the memory of students. He emphasized: "This also applies to the rule not to give children lessons that are beyond their strength, because such lessons that the child cannot overcome tear the memory, just as excessive bodily efforts can tear the bodily organism. If a child could not learn his lesson several times, despite his sincere efforts, then he develops uncertainty in his abilities, and this uncertainty has an extremely weakening effect on memory.

Pedagogical achievements of K.D. Ushinsky are enormous, their useful results are time-tested and, as we believe, are based on the subconscious application of the principles and properties of the doctrine of the dominant, which, as a scientific concept, was proposed by the Russian Scientist Academician Aleksey Alekseyevich Ukhtomsky [23, 24].

In this paper, we analyzed the mechanisms of successful pedagogical experience of K.D. Ushinsky from the point of view of the physiological functioning of the dominant academician A.A. Ukhtomsky (June 13, 1875 - August 31, 1942).

***Figure 2.*** *Alexey Alekseyevich Ukhtomsky.*

We emphasize that in modern scientific studies of various spheres of human life, the dominant A.A. Ukhtomsky has found wide distribution and application [19, 25, 30].

**Purpose**: from the standpoint of the physiological teachings of academician A.A. Ukhtomsky about the dominant to consider the possibilities of implementing the pedagogical methods of education K.D. Ushinsky.

**Organization and research methods.**

In this report, we give a brief analysis of the creative heritage of the outstanding domestic teacher

K.D. Ushinsky from the point of view of neurophysiological mechanisms of the doctrine of the dominant academician A.A. Ukhtomsky. We emphasize that K.D. Ushinsky in the fundamental work "Man as a subject of education. Experience of Pedagogical Anthropology" defined new approaches that reveal the relationship of pedagogical knowledge with other sciences, pointed out the role and place of pedagogy in the general system of scientific ideas about nature, society and man. In particular, he believed: "If pedagogy wants to educate a person in all respects, then she must first recognize him in all respects too" [28, 29]. It was K.D. Ushinsky was the first to analyze and summarize the data of anthropological sciences from a pedagogical point of view, which later formed the basis of scientific pedagogical knowledge.

At the beginning of the 20th century, the outstanding Russian physiologist, prince, academician Alexei Alekseevich Ukhtomsky introduced the concept of dominant into scientific use and outlined three stages of its functioning. The first stage is *stimulation*. The emergence of a dominant is due to the presence of either external or internal (physiological) stimuli. The second stage is the *formation of a conditioned reflex*. This stage is characterized by the formation of a conditioned reflex, when the dominant singles out the most significant group for it from a huge number of incoming excitations. According to the teachings of academician I.P. Pavlov, at this stage, the formation of a conditioned reflex occurs, i.e. out of countless active external stimuli, the dominant "chooses" only those that excite it. The third stage - *objectification*, is characterized by the creation of a strong connection between the dominant and the stimulus, as a result of which the latter, i.e. stimulus reinforces it. At present, a fourth stage has been added to this classification - the stage of resolution, i.e. dominance implementation.

The research complied with the ethical standards of biomedical ethics committees, developed in accordance with the Declaration of Helsinki adopted by the WMA. The principles of voluntariness, the rights and freedoms of the individual, guaranteed by Articles 21 and 22 of the Constitution of the Russian Federation, are observed.

**Results of the study and their discussion.**

We believe that from a physiological point of view, not only the concept of the dominant, as such, but the one proposed by A.A. Ukhtomsky the principle of "Dominants on the face of another". "I think, for my part," he wrote, "that one of the most difficult, at first glance, perhaps, and unattainable in its pure form, the dominants that we will have to cultivate in ourselves, is to be able to approach the people we meet opportunities without abstraction, to the extent possible to be able to hear each person, to take him/her in all his concreteness, regardless of his theories, prejudices and biases. From that moment, when the face of another is revealed, the person himself/herself deserves for the first time to be spoken of as a person" [24].

The dominant is a functional association of nerve centers, consisting of a relatively mobile cortical component and more rigid subcortical, vegetative and humoral components.

The dominant ensures the release of the nervous system from side activities in order to achieve the most important goals for the body at the moment. The dominant can be formed in any part of the central nervous system, at any of its levels, i.e. it reflects the general property of nervous processes. As proof of this statement, we present the results of our voluntary chronobiological study (at 8, 12, 16 and 20 hours of the day and week) of the moment of muscle strength in the hands (MMSH) in 11 girls who are students of the Institute of Physical Culture of the Tyumen State University. All of them in the morning during a practical lesson from 8.30 to 8.45 received a positive verbal suggestion about the possibility of increasing their MMSH against the background of the musical accompaniment of the Turkish Rondo. Let us note the positive effect of Ukhtomsky's dominant suggestion, which is expressed in the fact that all girls showed a significant ($p<0.05$) increase in hand muscle strength, which was practically maintained for a week (Table 1), especially at 4 p.m.

***Table 1***

*Chronobiological indicators of the moment of force of the muscles of the hand in female students of the Institute of Physical Culture of the Tyumen State University in a state of physiological rest (I) and after combined positive suggestion and music (II) during the day and week (M±m)*

| Day of the week | Examination time | | | |
|---|---|---|---|---|
| | **At 8 o'clock** | **At 12 o'clock** | **At 16 o'clock** | **At 20 o'clock** |
| Monday | I. 24,53±1,12<br>II. 28,77±1,15<br>Growth 4,24 | I. 24,89±1,14<br>II. 28,92±1,16<br>Growth 4,03 | I. 27,18±1,15<br>II. 31,89±1,18<br>Growth 4,71 | I. 24,48±1,10<br>II. 28,65±1,15<br>Growth 4,17 |
| Wednesday | I. 25,01±1,14<br>II. 28,73±1,15<br>Growth 3,72 | I. 25,23±1,15<br>II. 28,94±1,14<br>Growth 3,71 | I. 27,46±1,13<br>II. 31,77±1,16<br>Growth 4,31 | I. 24,92±1,15<br>II. 28,46±1,14<br>Growth 3,54 |
| Friday | I. 25,12±1,13<br>II. 29,06±1,17<br>Growth 3,94 | I. 25,21±1,15<br>II. 29,23±1,16<br>Growth 4,18 | I. 27,29±1,14<br>II. 32,14±1,18<br>Growth 4,85 | I. 24,94±1,15<br>II. 28,87±1,16<br>Growth 3,93 |
| Averages | I. 24,88±1,19<br>II. 28,25±1,15 | I. 25,15±1,16<br>II. 29,03±1,18 | I. 27,31±1,17<br>II. 31,93±1,20 | I. 24,78±1,18<br>II. 28,66±1,18 |

Thus, after a positive suggestion was made about the possibility of increasing the MSMK in combination with the use of musical accompaniment "Turkish Rondo", the MMSH indicator significantly ($p<0.05$) increased. It can be assumed with a certain degree of certainty that due to the joint positive impact of the word as a dominant according to A.A. Ukhtomsky, against the background of music,

the brain is programmed for the possibility of increasing the functional ability of muscle tissue. At the same time, the combined effect of the dominant is more stable over time, as evidenced by the stable results of the MMSH during the week of the survey. It is possible to make a philosophical, physiologically sound statement, backed up by this study, that "...no muscle will move if there is no dominant."

The results of our studies fully confirm those formulated by Academician A.A. Ukhtomsky, the main features of the dominant focus are increased excitability, persistence of excitation, the ability to sum up excitation - to retain and continue excitation once begun, and even when the initial stimulus is no longer active.

Academician A.A. Ukhtomsky attributed the dominant not only to physiology and psychology; but considered it a universal human principle: "The dominant is the principle of the centers, to which both conditioned reflexes, and association processes, and integral images in which the environment is perceived, but also the reflexes of the brain stem and spinal cord are equally obeyed." Moreover: "... the dominant is not a theory or even a hypothesis, but a principle of wide application presented from experience, an empirical law, like the law of gravitation, which, perhaps, is uninteresting in itself, but which is annoying enough to make it impossible ignore him" [23].

Thus, not only our thoughts and ideas can act as dominants, but also beliefs that are activated with a certain already fixed stimulus and determine our perception.

**Conclusions**.

Methods of pedagogical education K.D. Ushinsky are effective and popular in our time. After analyzing the physiological mechanisms of pedagogical work K.D. Ushinsky, we believe that his works are based on the doctrine of the dominant academician A.A. Ukhtomsky, although he was not familiar with the doctrine of the dominant. We have shown that in the works of K.D. Ushinsky contains invaluable scientific material, confirming and describing in detail many physiological mechanisms of functioning and formation of the dominant academician A.A. Ukhtomsky.

Our study showed that the symbiosis of the work of the teacher K.D. Ushinsky and physiologist A.A. Ukhtomsky complement each other, as if they penetrate each other. A joint analysis of these works allows us to obtain completely new mechanisms for the functioning of the dominant and significantly expands the scientific and practical scope of the creative pedagogical heritage of K.D. Ushinsky. Academician A.A. Ukhtomsky about the dominant requires wider use in the analysis of human pedagogical activity.

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# MYOFASCIAL PAIN IN ATHLETES

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***Abstract.*** *The article deals with the problem of the occurrence of myofascial pain in the shoulder joint during sports. A specific case of myofascial pain in the shoulder joint is considered. The nature of pain and the duration of rehabilitation are described. The specific methods used to restore the function of the posterior surface of the shoulder are shown. The analysis of foreign and domestic literature concerning the clinical manifestations of myofascial pain and treatment methods was carried out. Target. To study the causes and clinical manifestations of myofascial pain in the shoulder joints and consider possible ways to eliminate them.*

***Material and research methods.*** *The authors give a brief review of the literature, reflecting the appearance of myofascial pain in the shoulder joint during sports. On a specific example, an athlete actively involved in weightlifting is presented, who complains of the appearance of a sharp pain in the shoulder joint during the competitive movement "Clean and Jerk. Myopressure was used to relieve myofascial pain. Results. To eliminate myofascial pain in the shoulder joints, the authors recommend myopressure sessions over problematic segments in the posterior surface of the shoulder (supraspinatus muscle, round muscles of the shoulder).*

***Keywords:*** *sport, myofascial pain, myopressure.*

**Relevance.** In modern sports, associated with physical activity of great duration and intensity, pain is a frequent companion of the training process [2,

3, 4, 5, 15]. Shoulder pain is common among athletes involved in many sports. Power sports, due to their characteristics, are characterized by a special factor influencing the shoulder joints. Athletes who have a large range of weighted movements performed by the upper shoulder girdle often complain of pain in the anterior surface of the shoulder joint. We noted such an important clinical sign: pains localized in the anterior surface of the shoulder, as a rule, are reflected from the posterior surface of the shoulder. Movements during which pain is felt, in most cases, refer to rotational, extreme reverse leads and "pressing" movements of the projectile behind the head. For all movements in which pain is noted, the muscles of the back of the shoulder are responsible. It can therefore be assumed that the problem of pain is localized in one of the damaged muscles of the posterior surface of the shoulder (supraspinatus, infraspinatus, round muscles of the back, latissimus dorsi) and is reflected in the form of pain in the anterior surface of the shoulder joint.

We believe that this type of pain is a problem that has not been fully studied in the theory and practice of sports. Myofascial pain syndrome is a common disease of the musculoskeletal system with a complex and poorly understood origin. Currently, the diagnosis and, consequently, the methods of treatment of these pain syndromes remain insufficiently studied [1, 6, 10, 18]. All this was an incentive to study the anatomical and clinical manifestations of myofascial pain syndrome in modern sports.

**Results and discussion.**

Safiullina A.A. et al. [3] gives not only a description of the treatment of patients with myofascial syndrome, but also notes its insufficiency: «All work with such patients comes down to pharmacological treatment.» The authors cite sufficiently substantiated shortcomings of the pharmacological therapy of myofascial pain, including frequent side effects, high cost, and insufficient effectiveness.

We tend to believe that today myopressure is not only an effective, but also an affordable method for the treatment and prevention of myofascial pain. We consider it important to highlight the stages in the rehabilitation of patients with myofascial pain. **The first stage** is reduced to the diagnosis of the function of the segments of the posterior surface of the shoulder. This stage is necessary for an objective understanding of the state of the muscles at the sites of damage, their function and, most importantly, the difference from healthy muscle segments. **The second stage** is the direct work on the damaged muscle fiber, including the number of sessions and the degree (strength) of the necessary impact.

We note an important aspect of working with the upper shoulder girdle and shoulder joints. In clinical practice, tests have been developed to assess each of the tendons by bringing the shoulder into certain positions and applying force to the arm [17]. Almost at the same time, it is noted [16] that in practice it is impossible

to assess individual muscle-tendon units in the rotator cuff of the shoulder due to its structure. The tendons of the rotator cuff fuse into a single muscle structure, and when one muscle-tendon unit is innervated, the remaining parts have similar activation.

The impossibility of evaluating individual muscle-tendon structures is emphasized by [8], who used electromyography of the supraspinatus muscle, during which eight to nine adjacent muscles also showed activity. The studies of these authors confirm our hypothesis that it is necessary to take into account the complex innervation of muscle structures, thereby taking into account the entire volume of the muscles of the back surface of the shoulder in the diagnosis and release. This means that if there is a problem with the supraspinatus muscle of the shoulder, which is responsible for lifting the shoulder up - to the side, the infraspinatus, or small round muscle of the shoulder, can also be spasmed.

Considering the problem of myofascial pain, it is necessary to highlight the topic of the state of the so-called trigger points and trigger zones. So, in particular, it is pointed out [7] to the existing relationship between the "frozen shoulder" and trigger points in the infraspinatus, round and supraspinatus muscles of the scapulae.

There are a number of studies that study the state of trigger points and myofascial pain in athletes specializing in various sports, such as tennis, swimming [12, 13, 14]. Thus, [12, 13] cite the fact of the relationship between hypersensitivity under pressure in muscle segments and triggers in athletes with shoulder impingement and note that trigger points reproduce clinical pain symptoms.

Subscapular myofascial release and proprioceptive neuromuscular facilitation with conventional treatments have shown significant improvement in shoulder external rotation [11]. Dommerholt et. al. [9] reported that the release of trigger points, especially in the subscapularis muscle, in patients with frozen shoulder syndrome, reduces pain and improves range of motion in the shoulder joint.

Thus, the above studies indicate the undoubted relevance of the topic of trigger point release, point to problems with the back surface of the shoulder, supraspinatus and infraspinatus muscles of the scapula, large and small round muscles of the back.

In power sports, the main problem of pain syndromes in the shoulder joints is the impact of weights on the back of the shoulder. During the performance of competitive movements in power sports, the back surface of the shoulder, acting as a stabilizer, is subject to a large load. Weightlifting movements (Clean and Jerk, standing press, barbell snatch, overhead squat, etc.), most of the movements from functional all-around (butterfly pull-ups, bar exits, rings exits, dumbbell snatch, dumbbell lunges overhead lunges, overhead lunges, etc.) also put a lot of stress on the stabilizer muscles of the shoulder joint, respectively, putting these muscle segments at risk of injury.

Consider the specific example of the clinic and treatment of myofascial pain syndrome. R-v, 23 years old, complains of pain in the anterior surface of the shoulder during the competitive movement «Clean and Jerk». In the last phase of the movement, when fixing the bar above his head, he notes the appearance of intense pain in the anterior surface of the shoulder with the inability to fix the bar. The pain had a sharp and strong character, appearing after 65-70% of the maximum in this movement. The pain did not appear during daily movements, during movements without load. The degree of mobility in the shoulder joint is not reduced. During the first rehabilitation session, we decided to act on the back surface of the shoulder, which acts as one of the main localizations of pain in the shoulder joints. On palpation of the supraspinatus muscle of the scapula, round muscles of the back, the athlete felt severe local pain. Thus, we confirmed the hypothesis that pain syndromes in the anterior surface of the shoulder are myofascial in nature, taking into account the absence of damage to the articular surfaces and ligamentous apparatus. Work on the back surface of the shoulder took a total of 6 sessions, lasting 1 hour 30 minutes. During three rehabilitation sessions, relaxation was achieved in muscle groups that have a greater pain syndrome (supraspinatus scapula, round muscles of the back). After the third session, local tension and a feeling of «stiffness» in the target muscle groups decreased, however, at the same time, according to the athlete, the pain syndrome in these segments increased. On palpation of these muscle groups, the pain became more intense. At the same time, it was noticed that when practicing the “push” in the training program, a feeling of instability appeared after three sessions of myopressure. Tissue inflammation persisted for 5 to 6 days after the session, as evidenced by pain during palpation of the muscle segments. The next, fourth session, was characterized by less pain when exposed to the supraspinatus muscle of the scapula along the entire diameter of the muscle fiber, however, the pain syndrome continued to persist in the infraspinatus muscle of the scapula, trapezius muscle and round muscles of the back. As myopressure was applied, pain decreased in local muscle segments both during pressure and during pain-inducing motor actions. The rhomboid muscles of the back, the infraspinatus scapula were characterized by muscle cords and trigger zones. This phenomenon is a spasm of contractile muscle tissue, which manifests itself as a seal in the muscle segment, starting from the beginning and extending to the point of attachment of the muscle. On palpation, a dense band of muscle fiber is determined. Along with the pain syndromes described above, on palpation of the muscle cords, there are also reflected pains that appear in the synergist muscles. We can characterize muscle bands as hypertonicity of the muscle fiber. With the pressure of the muscle cords of the infraspinatus scapula and the round muscles of the shoulder, the pain was localized in the anterior surface of the shoulder, while it was similar to the pain experienced by the athlete during the push of the barbell.

At the request, the athlete described the pain as a strong pulling in the area of the anterior deltoid muscle and the acromioclavicular joint.

Thus, we assumed that the pain during the push of the bar was initially irradiated from the back of the shoulder. The round muscles of the back (small, large) had a more pronounced pain syndrome than the infraspinatus, supraspinatus, trapezius muscles. During the impact on the round muscle, the pain was also felt on the anterior surface of the shoulder, and according to the sensations of the athlete, it was more pronounced than with the pressure of the infraspinatus and supraspinatus muscles.

The inability to fix the bar was a manifestation of the lack of proper activation of the infraspinatus and supraspinatus muscles of the scapula. The infraspinatus and round muscles of the scapula are located close to each other, on the basis of this, irradiation is determined, and similar pain patterns.

**Conclusions:**

1. Myopressure can be considered an effective and affordable method of influencing myofascial pain in the back of the shoulder. This method is characterized as a deep massage of individual problematic muscle segments. Pain in the anterior surface of the shoulder is reflected and localized in the muscle segments of the posterior surface of the shoulder (supraspinatus, infraspinatus, round muscles of the shoulder and posterior deltoid muscle).
2. When working with problematic muscle segments in the back of the shoulder, we noted the fact of an improvement in muscle sensation and stability in the joint during movement after myopressure sessions, which helps to improve microcirculation in problematic muscles.
3. High-quality myopressure sessions over problematic segments in the posterior surface of the shoulder (supraspinatus muscle, round muscles of the shoulder) contribute not only to the elimination of pain, but also to the elimination of instability of the anterior surface of the shoulder.

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# HISTOMORPHOLOGICAL ROLE OF EXPRESSION OF CONNEXINS 40, 37, 43, 45 IN AN EMBRYONIC AND ADULT KIDNEY IN AN EXPERIMENT

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***Abstract.*** *The kidneys are very complex organs that play a crucial role in human histopathology. The functionality of the kidneys reflects such vital processes as fluid filtration and regulation of vasomotor tone. There is more and more experimental evidence that slit junctions are the main histological determinants of the kidneys. It has been demonstrated that their expression or activity of channels can vary depending on physiological and pathological situations in different parts of the kidneys. Given that some studies have focused on the role of connexins in kidney physiology. mRNA transcripts of about half of the Cx family are expressed in human and rodent kidneys, including Cx26, Cx30.3, Cx31, Cx32, Cx37, Cx40, Cx43, Cx45 and Cx46 [8, 19]. However, Cx mRNA and protein expression do not always correlate, implying that mRNA data should be routinely verified at the protein level. Unfortunately, several currently used Cx antibodies display limitations and have generated conflicting data about Cx expression and localization depending on the experimental settings. Although most studies have focused on the contribution of vascular Cx proteins to renal hemodynamics, accumulating evidence suggests an essential physiological role for these proteins in tubular epithelial function. Nowdays, there is a wide variety*

*of judgments regarding the specific expression of some forms of connexins (Cx) in the renin apparatus of the embryonic and adult kidney. Establishing the exact intrarenal localization of Cx 40, 37, 43, 45 is a prerequisite for understanding their functional role in normal renal organogenesis, as well as in maintaining fluid homeostasis and controlling renin secretion. At 8–10 weeks of embryonic development, the expression of various Cx is observed in the epithelium of blood vessels and renal tubules, as well as in the region of the renal renin apparatus, but with different patterns of expression and intensity over time. During embryogenesis, the expression of Cx 40 is higher than that of Cx 43, 37, and 45. In the postnatal period, the expression of Cx 40 decreases, while the expression of others increases. Cx 40 is involved in the formation of the renin apparatus in the developing kidney, while Cx 37, Cx 43, and Cx 45 are involved in signaling important for postnatal maintenance of kidney function and blood pressure control. Experimental studies in the adult kidney demonstrate that arterial endothelial cells express Cx 40 and Cx 37 and, to a lesser extent, Cx 43, while smooth muscle cells express Cx 45. The cells of the renin apparatus are characterized by the expression of Cx 37, Cx 40, Cx 43 and Cx 45, with the highest content of Cx 40, especially in juxtaglomerular cells. Adequate and coordinated work of Cx is crucial for the regulation of renal hemodynamics and renin secretion. The use of specific connexin-mimetic peptides may lead to the development of more effective methods for controlling renin secretion of the tubular epithelium of the kidney.*

***Keywords:*** *connexins 40, 37, 43, 45, kidney, renin apparatus, renin secretion.*

The ability of the kidneys to maintain fluid homeostasis and regulate blood pressure is mediated by tubuloglomerular feedback and renin synthesis. Renin-producing cells of the juxtaglomerular apparatus (JGA) continue the layer of smooth muscle cells in the walls of afferent arterioles at the entrance to the glomerular capillary network. The physiological control of renin release is determined by several variables: sympathetic innervation activity, delivery of sodium chloride to the macula densa, and renal perfusion pressure. The function of the renin apparatus of the kidneys is provided by the coordinated activity of juxtaglomerular cells, macula densa cells and extraglomerular mesangium. Despite the fact that the molecular mechanisms of intercellular interactions that control renin release are not well understood, it is known that connexin proteins (Cx) play a leading role in these processes [1]. Assembled as a hexameric connexon, they form a transmembrane hemichannel for paracrine signal transduction, or dock with connexons on neighboring cells, creating a gap junction for transduction of metabolic and electrical signals [2]. In total, eight different transmembrane isoforms of connexins have been found in the kidneys, however, Cx 37, Cx 40, Cx 43, and Cx 45 play a key role in the transmission and synchronization of signals of the renin appara-

tus. Their deficiency or dysfunction leads to dysregulation of renin secretion and renal hemodynamics [ 3]. Data from international scientific literature confirm the important role of gap junctions and hemichannels as factors in normal kidney organogenesis. In this regard, the exact intrarenal localization of these Cx isoforms in the embryonic and adult kidney is of particular interest.

The predominant connexin isotype in JGA cells in mice is Cx40. Cx40 immunoreactivity has been found in renin-producing cells, endothelial cells of pre- and intraglomerular vessels, mesangial cells, and medullary ray epithelium [3,4]. Its role has been studied in several models of transgenic mice: with global deficiency, with point mutation, with selective deletion of Cx40 in renin-producing cells. In all cases, damage to Cx40 led to a loss of control over renin secretion, and, as a consequence, the development of hypertension. At the same time, ectopic localization of renin-producing cells in the adult kidney was noted [5,6,7]. Chronic stimulation of renin synthesis (long-term salt deprivation, treatment with angiotensin-converting enzyme (ACE) inhibitors) increases the number of renin-producing cells due to the proximal recruitment of cells in the walls of afferent arterioles. This phenomenon is accompanied by a repeated increase in the expression of Cx 40 while maintaining normal expression of Cx 37,43 and 45. Conversely, the absence of Cx 40 leads to ectopic juxtaglomerular renin expression and abolishes recruitment in adult kidneys [4]. Thus, assessment of the physiological effects of the Cx40 mutation suggests that Cx40 is vital for the regulation of renin release and BP control. The nature of the signaling molecules crossing these gap junctions has not yet been fully understood. It has been established that such mediators are cAMP, calcium ions (Ca 2+), ATP. However, the nature of the functioning of intercellular signaling mechanisms still needs further research. It is logical to assume the development of concomitant diseases in other organs expressing the same isotypes of connexins as in the kidneys if Cx dysfunction is found in them. In confirmation of this, mutations of Cx40, characteristic of endothelial cells, were identified in patients with cardiovascular diseases [5,8]. The use of strategies such as specific connexin-mimetic peptides may lead to the development of more effective approaches to control renin secretion [9,10,11]. It has been experimentally proven that, in addition to Cx 40, the endothelium of afferent arterioles, interlobular arteries, glomerular and peritubular capillaries expresses Cx 37. Cx 37 immunoreactivity was also found in association with renin-producing cells. The experiment showed that in the vessels of Cx 40-/- mice, a reduced expression of Cx 37 was found compared to the control group. It is assumed that both Cx are interdependent and can form heterotypic channels Cx 37-Cx 40 [12].

Studies using normotensive wild type and Cx 37 deficient (CX 37 -/-) mice confirmed that knockout mice were less hypertensive than their counterparts when infused with angiotensin II (Ang II). Further refinement using a renin-dependent

model of hypertension confirmed that Cx37-/- mice rapidly regain normal blood pressure despite elevated plasma renin levels. In contrast, mice remained hypertensive in a renin-independent model of hypertension, suggesting that the loss of Cx37 most likely affects the expression of proteins involved in the Ang II pathway, in particular the Ang II type II receptor (AT2R) [13]. In addition, epithelial localization of Cx37 was found along the nephron segments. Ultrastructural immunostaining for Cx 37 was limited to basolateral interdigitations and folds of proximal and distal epithelial cells, incl. in macula densa. Stimulation of the renin system with ACE inhibitors in combination with a low salt diet significantly increases Cx37 expression. At the same time, Cx37-/- mice have higher fluid intake and lower urinary osmolality [14]. Thus, it can be assumed that Cx 37 is involved in the functional adaptation of tubular transport to changes in salt load. However, there are conflicting data in the literature regarding the localization of Cx37. In other studies, Cx37 expression in the tubular epithelium was not detected, Cx37 mRNA was found only in cells coexpressing CD31 mRNA, which indicated their endothelial affiliation [3]. While Cx 37 is overexpressed in the renal cortex, Cx 43 is less expressed. Cx43 is localized in the endothelium of the renal, lobar, arcuate and interlobular arteries, afferent and efferent arterioles, mesangial cells and the epithelium of the collecting ducts. Juxtaglomerular epithelioid cells express less Cx 37 and Cx 43 than Cx 40. Many studies have focused on the possible role of Cx 43 in the regulation of JGA. It was assumed that Cx 43 enhances renin secretion: substitution of Cx 43 for Cx 32 in transgenic mice reduced renin expression and prevented renin-dependent hypertension [15]. However, later it was shown that a specific Cx43 blocking peptide (GAP26) reduces the glomerular filtration rate without changing renin activity [16]. In addition, endothelial-specific deletion of Cx43 did not affect renin secretion and blood pressure, unlike mice deficient in Cx40. Thus, the question of the role of Cx43 in renin secretion and blood pressure control is still being discussed in the world scientific literature. In addition, Cx43 has recently been identified as a novel renal failure mediator involved in key stages of inflammation and fibrosis. Cx43-mediated ATP release is the initial trigger for early damage to tubular adhesive and tight junctions. Its inhibition, including after the onset of the disease, can attenuate this damage and preserve renal function. Therefore, Cx 43 may represent a new target for the treatment of tubulointerstitial fibrosis in CKD [17]. Cx45 immunoreactivity has been found in smooth muscle cells of preglomerular arteries and arterioles and in mesangial cells. In vessels, Cx45 is associated with α-SMA (α-Smooth muscle actin) mRNA, and in glomeruli it is associated with PDGFRß (Platelet-derived growth factor receptor ß) mRNA. In addition, there are data on the expression of Cx45 mRNA by interstitial fibroblast cells [18]. Information about the expression of Cx45 by renin-secreting cells is contradictory. Initially, it was found that the appearance

of renin-producing cells in embryogenesis corresponded to the expression of Cx 40 and, to a lesser extent, Cx 45. In the adult kidney, JGA cells expressed Cx 40, Cx 37 and Cx 43, but not Cx 45. On this basis, it was assumed that fetal, but not adult renin-producing cells express Cx45. In addition, it was shown that Cx45 immunoreactivity was absent in all renin-expressing cells of mice fed a low-salt diet in combination with an ACE inhibitor, but remained visible in vascular smooth muscle cells (VSMC) and intraglomerular cells [4]. At the same time, other studies state that renin-secreting cells of afferent and efferent arterioles, as well as intra- and extraglomerular mesangial cells, are Cx45-positive and are involved in the mechanism of tubulo-glomerular feedback mediating vascular reactivity [18, 19]. It was noted that plasma renin content and blood pressure were significantly higher in Cx 45fl/fl:Nestin-Cre mice, which have reduced Cx 45 expression. Ca2+. Basolateral ATP released from the macula densa initiates the propagation of the calcium wave in JGA cells, which controls renal blood flow and glomerular filtration rate. The increase in Ca 2+ implements two mechanisms: inhibition of renin release from juxtaglomerular cells and reduction of VSMC in afferent arterioles. It is known that the calcium wave of tubulo-glomerular feedback can be eliminated by gap junction blockers. The distribution of Ca2+ with the participation of connexins occurs through intercellular gap junctions, or through the release of an extracellular mediator, such as ATP [20]. Interestingly, in the kidney, some cell types are characterized by the expression of two different isoforms of Cx, for example, Cx 37/40 in endothelial cells, Cx 40/45 in mesangial cells. This fact probably demonstrates the existence of heterotypical gap junctions. Thus, despite the huge amount of information, the role of Cx in JGA and their interchangeability still needs to be clarified. Understanding of renin signaling and connexin expression in the kidney during embryonic development also remains limited. Establishing the localization and distribution of various JGA components during embryogenesis is a prerequisite for understanding their functional role in both embryonic and adult kidneys.

The formation of glomeruli in humans begins at the 8th week of development, when S-shaped bodies cover the blood vessels. The initial signs of JGA formation in these immature bodies, in the form of a close association between the macula densa, the afferent arteriole, and the nearby mesenchyme, giving rise to the extraglomerular mesangium, are already observed at the earliest stages of development. At 8–10 weeks of kidney development, the expression of various Cx is observed in all blood vessels and renal tubules, as well as in the JGA region, but with different patterns of expression and intensity over time. Thus, the expression of Cx40 during the development of JGA is moderately strong in the afferent arteriole, including in cells expressing renin, and in the distal tubules. Then, in the late fetal and postnatal periods, it gradually decreased [21]. It is likely that co-expression of

Cx40 with renin is required for proper formation of JGA cells, as well as for the reversible metaplastic conversion of vascular smooth muscle to renin-producing cells in the adult kidney. The existence of two different forms of juxtaglomerular cells is proposed: an immature form that exists during fetal development and a mature form that undergoes controlled metaplastic transformation. Expression of Cx 37 begins to be noted in the JGA region, which primarily corresponds to the macula densa and afferent arteriole from the 10th week of embryogenesis. In the postnatal period, the expression of Cx 37 increases to moderate. Expression of Cx43 is similarly weak in the afferent arteriole and in the macula densa, starting from the early stages and up to 38 weeks, and then in the late prenatal and especially in the postnatal period, it increases to moderate and strong. Expression of Cx45 is weak throughout the fetal period in the walls of arteries and arterioles, including renin-expressing cells, and moderate in the distal and proximal tubules, increases postnatally. The existence of two distinct forms of juxtaglomerular cells is also supported by the pattern of Cx45 expression: co-expression of Cx45 with renin occurs in fetal renin-producing cells, whereas in mature kidneys, Cx45 and renin expression appear to be mutually exclusive. Cx45 is mainly localized in arteriolar smooth muscle cells in both fetal and adult kidneys [22]. There is evidence that Cx play a triggering role in the development of pathological conditions such as renal fibrosis or diabetic nephropathy [23].

Therefore, based on the literature data, we can conclude the following. During embryogenesis, the expression of Cx 40 is higher than the expression of Cx 43, 37 and 45. In the postnatal period, the expression of Cx 40 decreases, while the expression of others increases. Co-expression of renin and connexins by the end of the fetal period is stronger with Cx 40 and 43, and less extensive and strong for Cx 37 and 45. Based on this, it is assumed that Cx 40 is primarily involved in the formation of JGA in developing kidneys, while Cx 37 , Cx 43 and Cx 45 may be involved in JGA signaling important for postnatal maintenance of kidney function and blood pressure control. Experimental studies in the adult kidney demonstrate that arterial endothelial cells express Cx 40 and Cx 37 and, to a lesser extent, Cx 43, while smooth muscle cells express Cx 45. JGA cells are characterized by the expression of Cx 37, Cx 40, Cx 43, and Cx 45, with the most high content of Cx 40, especially in juxtaglomerular renin-producing epitheioid cells. Adequate and coordinated work of connexins is crucial for the regulation of renal hemodynamics and renin secretion.

**Conflict of interest.** The authors have no conflict of interests to declare.

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# THE COMPOSITION OF THE COLLAGEN SCAFFOLD OF THE REGENERATE ISCHEMIC SKIN DEFECT IN MICE ON THE 23RD DAY AFTER TRANSPLANTATION OF THE DERMAL EQUIVALENT WITH HETEROFIBROBLASTS

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***Abstract.*** *The search for ways to improve the results of medical care for patients with trophic ulcers of the lower extremities continues to be one of the tasks of modern medicine [2]. The aim of the work was to evaluate the morphological structure and fibrous framework of newly formed scars after transplantation into an experimental wound of a dermal equivalent with heterofibroblasts. The study was performed on 18 adult white C57/B1 mice under the age of 6-7 months, which were kept in the vivarium of the Medical Academy named after S.I. Georgievsky. Animals were divided equally into control and experimental groups. It was revealed that on the 23rd day after the modeling of the wound in both groups there is a scar, in which the quantitative and qualitative composition of collagen fibers is different. In the experimental group, the composition of the scar is dominated by collagen fibers, from type I collagen, morphological signs of the formation of the papillary and reticular layers appear, which makes it look like intact skin. The basement membrane of the epidermis is more mature due to the presence of non-fibrillar type IV collagen.*

***Keywords:*** *skin defect, dermal equivalent, fibroblasts, collagen fibers.*

Treatment of chronic wounds has baffled physicians since ancient times. Physicians of Ancient Egypt, China, India, Greece, medieval Europe were looking for their own ways in solving this problem; it has not lost its relevance even today [1]. The search for ways to improve the results of medical care for patients with trophic ulcers of the lower extremities continues to be one of the tasks of modern medicine [2]. Ulcers never occur spontaneously, they are preceded by a rather long process of development of serious pathologies in the body, such as impaired venous circulation [3]. A new stage in bioengineering technologies in the treatment of long-term non-healing skin defects was the creation and use of a "living skin equivalent", which is a collagen gel containing allo- or autofibroblasts [4]. Dermal equivalents are classified into dermal, epidermal, and dual equivalents and are currently used to treat deep burns and chronic ulcers [5]. The influence of such bioengineered constructs on the formation of the fibrous component of the regenerate of ischemic skin defects remains little studied, which determined the purpose of this work: to evaluate the morphological structure and qualitative composition of the fibrous skeleton of newly formed scars after transplantation into an experimental primary ischemic surgical wound of a dermal equivalent with dermal heterofibroblasts.

**Material and methods.** The study was performed on 18 adult white C57/B1 mice under the age of 6-7 months, which were kept in the vivarium of the Medical Academy named after S.I. Georgievsky. Animals were divided equally into a control group and an experimental group. The experiments were carried out following all the principles of humanity contained in the directive of the European Community (86/609/EC) and in accordance with the "Rules for the performance of work involving experimental animals". In all groups, an operation to simulate a skin wound in the scapular region was performed after intraperitoneal injection of a 2.5% solution of Avertin 0.3-0.4 ml. The skin was excised in the form of a circle with a diameter of 12 mm, a silicone ring with an outer diameter of 12 mm was fixed to the edges of the wound with fascial interrupted sutures with atraumatic suture material "Polypropylene" 5-0 to exclude the possibility of epithelialization of the wound and closing it with mobile skin in the back region.

Fibroblasts were isolated from the excised skin of mice in the control group in a sterile box with a laminar air flow [6]. Third passage cells with the CD44+CD90+CD105+CD73+CD45+CD31-CD34-CD45- phenotype were used to form the dermal equivalent. The dermal equivalent was prepared on the basis of type 1 collagen from rat tails [7]. The finished tissue engineering construct was transplanted into the ischemic skin wound of experimental mice.

On the 23rd day after the operation, the resulting scar was excised intraoperatively in mice of all groups and fixed with 10% buffered formalin for morphological examination. The material was embedded in paraffin and stained with hema-

toxylin and eosin. The presence of collagen fibers consisting of collagen types I, II and III was determined by immunohistochemistry. The primary antibodies were polyclonal antibodies with collagen I (ab 34710), II (ab 34712), III (ab 7778), and IV types (ab 135802) from Abcam (USA) at a dilution of 1:100. Secondary antibodies conjugated with horseradish peroxidase were applied to sections and incubated in a humid chamber for 30 minutes. To visualize the cells in which the binding of antibodies to antigens occurred, 1–3 drops of 3,3-diaminobenzidine (DAB Substrate Chromogen) Gene Tex Inc (USA) were applied to each section. To adequately represent the structure of the tissue and cell nuclei, the sections were counterstained with Mayer's hematoxylin for 3 minutes. A control study was conducted to exclude pseudo-positive and pseudo-negative results.

Morphological examination of histological preparations was performed using an OLIMPUS CX-31 light-optical microscope with an OLIMPUS Z5050Z digital camera. The thickness of the epidermis, the number of microvessels in sections, the area of collagen fibers and microvessels in the dermis of scars were measured using the ImageJ program. Statistical processing of digital data was carried out using licensed software Microsoft Office Excell and Statistica 10.0.

**Results of the study and their discussion.** In mice of the control group, on the 23rd day after the operation to create a model wound, a delicate white scar with clear boundaries formed. The silicone ring fell off on the 12th day after the operation, simultaneously with complete epithelialization wounds. On sections of the scar, the epidermis is represented by an incompletely formed stratified squamous, partially keratinized epithelium, consisting of 4 poorly developed layers, characteristic of thin skin. The granular layer is present only in some areas, the stratum corneum is very thin. The basement membrane of the epidermis is not clearly visible and does not contain type IV collagen fibers. The dermis of the scar is a granulation tissue, does not form papillae protruding into the epidermis, and the border between the epidermis and the dermis is even. Granulation tissue at this age begins the process of fibrosis, characteristic of the third stage of the wound process, is not divided into papillary and reticular layers, and consists mainly of thick bundles of collagen fibers without a clear orientation in relation to the basement membrane. Granulation tissue is formed mainly by collagen fibers, the collagen protein of which belongs to type I. Such fibers are assembled into voluminous spiral bundles of collagen fibers. These bundles also contain type II collagen fibers. Type III collagen fibers forming the thin reticulum are thinner and few in number. The ratio of collagen fibers from collagen types I, II and III is 15:8:3. Bookmarks of skin derivatives: glands and hairs are absent.

In mice of the experimental group, after transplantation into the wound of a dermal equivalent with heterofibroblasts, epidermal cells also form four layers characteristic of thin skin: basal, spiny, granular, and horny. All layers are fully

developed, with the exception of the stratum corneum, which is very thin and consists of 1-2 rows of flattened keratinocytes. The basement membrane of the epidermis contains collagen fibers of type IV collagen. On the periphery of the wound there are bookmarks of skin derivatives - hairs. Under the epidermis in the biopsy specimens lies a mature fibrous granulation tissue of the third stage of the wound process. The most voluminous associations of collagen fibers lie in the subepidermal region. In the deep layers of the biopsy of the dermis of the scar, the arrangement of collagen fibers is less dense. Immunohistochemical staining revealed that the ratio of collagen fibers from collagen types I, II and III per unit area of the cut was statistically significantly higher and amounted to 25:2:1. At the same time, the number of coarse collagen fibers from type II collagen is significantly reduced.

**Conclusions**. Transplantation into a model experimental ischemic wound in mice of a tissue-engineered structure - a dermal equivalent with dermal heterofibroblasts significantly accelerates wound healing, changes the quantitative and qualitative composition of the collagen fibers of the fibrous component of the formed scar compared to the control group. The scar is rich in type I collagen fibers and shows signs of papillary and reticular formation, making it similar to intact skin. The basement membrane of the epidermis after transplantation of the dermal equivalent with dermal heterofibroblasts is functionally more mature due to the presence of non-fibrillar type IV collagen.

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# PILOT ASSESSMENT OF LOW DOSES EFFICACY OF UPADACITINIB IN MODERATE TO SEVERE ATOPIC DERMATITIS

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***Abstract.*** *Atopic dermatitis is a wide spread immune inflammatory skin disease difficult to treat. Many variants of immunosuppressive treatments are effective but with a large portion of nonresponsivenes or side effects. We assessed the clinical efficacy of low doses of upadacitinib (7.5 and 15 mg/day) to choose the best dose to combine with methotrexate for a new combination therapy with high efficacy and minimum side effects. This pilot investigation demonstrated 15 mg of upadacitinib as the best dose for future combination therapy for patients with severe atopic dermatitis.*

***Keywords:*** *atopic dermatitis, upadacitinib, methotrexate, combination therapy.*

## Introduction

Atopic dermatitis (AD) is a chronic inflammatory skin disease that affects a large portion of the global population. In AD the skin barrier function is compromised, allowing for the entry of irritants and allergens. This can trigger a predisposed immune response, leading to inflammation and itching. The current standard of care for moderate to severe AD includes topical corticosteroids, calcineurin inhibitors, and systemic immunosuppressants.[1] However, these treatments are often associated with low effectiveness and side effects, making it important to explore alternative therapeutic options.

In recent years, there has been growing interest in the use of combination therapy for atopic dermatitis, which involves the use of two or more drugs in combination to achieve improved clinical outcomes. One such combination is the use of upadacitinib, a Janus kinase (JAK) inhibitor and methotrexate, an immunosuppressive agent both in low doses.

Upadacitinib is a medication that was investigated for its potential use in the treatment of atopic dermatitis, a chronic inflammatory skin condition. The mechanism of action of upadacitinib in atopic dermatitis is similar to its mechanism in other inflammatory diseases.

Upadacitinib works by selectively inhibiting the activity of Janus kinase (JAK) enzymes, which play a role in the inflammatory response. JAK enzymes are involved in the signaling pathways of cytokines, which are proteins that play a role in the immune system's response to infection and inflammation.[2]

In atopic dermatitis, the cytokines that are primarily involved in the inflammatory response include interleukin-4 (IL-4), interleukin-13 (IL-13), and interleukin-31 (IL-31). These cytokines contribute to inflammation, itching, and skin damage.[2,4] By inhibiting the activity of JAK enzymes, upadacitinib reduces the activity of these cytokines, leading to a reduction in inflammation, itching, and skin damage associated with atopic dermatitis.

In clinical trials, upadacitinib has shown promise in improving the signs and symptoms of atopic dermatitis, including skin lesions, itching, and sleep disturbance. The approval of upadacitinib (Rinvoq) for moderate-to-severe AD in patients ages 12 and older, comes on the heels of findings from three pivotal phase 3 studies involving more than 2,500 adults and children 12 years of age and older with moderate-to-severe AD. Across the three studies, upadacitinib — both 15 mg and 30 mg once daily monotherapy — met all primary and secondary endpoints at week 16, with some patients achieving higher levels of skin clearance based on the Eczema Area and Severity Index 90 (EASI-90) and EASI-100. In one trial, 167 patients were randomized to once daily oral upadacitinib 7.5 mg, 15 mg, or 30 mg or placebo. All doses of upadacitinib demonstrated considerably higher percentage improvements from baseline in EASI scores compared to placebo at 16 weeks with a clear dose-response relationship (39%, 62%, and 74% vs 23%, respectively). In this trial, there were no dose-limiting safety events. Serious AEs were infrequent, occurring in 4.8%, 2.4%, and 0% of upadacitinib groups vs 2.5% for placebo.

Methotrexate is a widely used immunosuppressant that is also known to be effective in the treatment of AD patients. Methotrexate can be taken orally or by injection, and the dose is typically adjusted according to the patient's response and side effects.[3] Children and young people with severe atopic dermatitis had a more rapid treatment response with ciclosporin, but more sustained disease control with methotrexate in the TREAT study, reported investigators at the annual meeting of the International Society of Atopic Dermatitis (ISAD) in 2022. This study found about half of the patients had inadequate control of their disease. This may partially be due to underuse of systemic biologics in eligible patients. There remains an unmet need for additional education on current and new systemic biologics that

could allow patients to achieve better AD control, improved QoL, and greater overall treatment satisfaction.

**Objective**

The objective of this study is to evaluate the safety and efficacy of using a lower dose of upadacitinib (15 mg or 7.5 mg once daily) in the treatment of moderate to severe atopic dermatitis. The study aims to assess whether this lower dose of upadacitinib combined in future with methotrexate will be effective in improving the signs and symptoms of atopic dermatitis while minimizing the risk of side effects.

**Material and methods**

Patients aged 18 years or older with diagnosis of moderate to severe atopic dermatitis who had inadequate response to topical treatments or were intolerant to systemic treatments with Investigators Global Assessment (IGA) score of >3 and body surface area (BSA) involvement of >10%.

Exclusion criteria: patients with a history of hypersensitivity to upadacitinib or any of its excipients or with a history of active or latent tuberculosis, among others.

The 10 atopic dermatitis patients were assigned to two treatment groups monotherapy: group A (5 patients) received upadactinib 15mg once daily and group B (5 patients) received upadactinib 7.5 mg once daily. Both groups received the drug for 10 days and assessed with SCORAD and DLQI .

Assessment of efficacy: The primary endpoint was the proportion of patients who achieved the SCORAD response at first week. The SCORAD assesses the extent and severity of eczema lesions on four body regions (head and neck, upper limbs, trunk, and lower limbs), with a higher score indicating more severe disease. The secondary endpoints included improvement in pruritus (itching) measured by the Peak Pruritus Numerical Rating Scale (PP-NRS), and change in the Dermatology Life Quality Index (DLQI)

Assessment of safety: weather there are any serious adverse events, or laboratory tests changes.

Ethical considerations: The study was conducted in accordance with the Declaration of Helsinki and the International Council for Harmonisation guidelines. The study protocol was approved by an institutional review board, and all participants provided written informed consent.

**Results**

The results of the clinical trial evaluating the efficacy and safety of the treatment of moderate to severe atopic dermatitis (AD) showed that treatment with upadactinib resulted in significant improvement in the signs and symptoms of atopic dermatitis. Ten patients were assigned to receive upadacitinib 15 mg or

7,5 mg to complete 10 days and the study showed the proportion of patients who achieve 65% reduction of SCORAD (SCORAD 65) in the group A (15mg) of upadactinib and those who achieve 45% reduction (SCORAD 45) in group B (7.5mg) of upadactinib The DLQI also showed the best results in group A (15 mg/day).

**Safety**: The study also found that upadacitinib with 7.5 mg, or 15 mg was generally well-tolerated, with a safety profile consistent with previous studies of the drug in other indications.

**Conclusion**

In conclusion, The JAK-STAT signaling pathway regulates the immune system by simultaneously targeting several inflammatory cytokines, making it an ideal candidate for therapeutic intervention in a variety of inflammatory conditions, including AD disease. Upadacitinib is a selective inhibitor of Janus kinase (JAK) that has been approved for the treatment of moderate to severe atopic dermatitis. In our clinical trial, low-dose upadacitinib 15 mg compared to 7.5 mg has shown significant efficacy in improving the signs and symptoms of atopic dermatitis, including itching, redness, and skin lesions. The low dose of 15 mg is the best dose to combine with MTX that may provide a more effective and well-tolerated combined treatment option for patients with moderate to severe AD. Further studies are needed to confirm.

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# DEFINING THE CONCEPT OF PULSE CONDITIONS.

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***Annotation****: The article is devoted to the objectification of pulse diagnostics, methods of extraction and analysis of pulse parameters and pulse signal processing, to explain morphological changes in various pulse wave forms, based on optical methods and the use of wearable devices working with photoplethysmography to solve these problems.*

***Keywords:*** *blood, blood cells, photoplethysmography, pulse wave, blood velocity, pulse parameters, pulse wave shapes.*

## INTRODUCTION

Wearable pulse wave detection devices (with a single-probe pressure sensor) are more and more applied for health monitoring. The pulse signal contains very rich cardiovascular physiological and pathological information. According to the pulse diagnosis theory of Traditional Chinese Medicine (TCM), using the pulse signal can not only detect whether the subject is abnormal but also predict the pathological condition. Therefore, it is of great research significance to make an objective description of pulse signals.

In the study of the objectification of pulse diagnosis, pulse signal processing is a crucial step in obtaining the diagnosis result of Chinese medicine, including pulse signal segmentation and feature extraction and pulse signal pattern recognition and classification.

Accurate segmentation and feature extraction of pulse signals are very important for the objectification of pulse diagnosis.

From the earliest days, metaphors and descriptive languages have been used to describe the characteristics of various pulse conditions in China treatises. For example, a «Fu Mai» ("floating pulse") is presented as being like wood floating on water, a «Kou Mai» ("hollow pulse") is described as the feeling of pressing a scallion stalk, and a «Ge Mai» ("drumskin pulse") is described as resembling the beating of a drum. These descriptions are incomplete and conceptually unclear, without specific data references.

Given the obscurity and incomprehensibility of pulse terminology, visual aids have been sought to define pulse conditions since ancient times. The earliest published book that uses drawings to illustrate the characteristics of pulse conditions is «Chabing Zhinan» ("A Guide to Disease Examination"), «Tuzhu Maijue Bianzhen» ("Pulse Discrimination by Figure") published in the "Ming dynasty" and «Renyuan Maiying Guizhi Tushuo» ("Condensed Pulse illustration") published in the Western Jin dynasty, also used drawings to illustrate the distinct characteristics of pulse conditions.

Drawings in these ancient books were simply dots and lines or a combination of pictograms in one circular area.

**Examples of using figures and parameters to define pulse conditions.**

According to the «Shuyu Gongzuo»: Yuanze Yu Fangfa (Terminology Work: Principles and Methods),[2] non-verbal representations can illustrate and exemplify a concept. They should not replace a definition but complement it. Non-verbal representations include visual representations, such as figures, and mathematical expressions.

Modern science and technology provide tools for visual representation and quantification of pulse conditions that can help present precise definition of pulses.

In the 1950s, Chinese scholar Zhu Yan introduced a lever-type pulse descriptor to research TCM pulse conditions.[4] Since then, most studies have focused on pulse measuring devices and analysis methods of pulse, and have formed a unified understanding on the typical pulse figures of common pulses such as the slippery pulse and the string-like pulse.

**The slippery and string-like pulses.**

A pulse waveform graph records the trajectories of vascular pulsation of the radial artery at the wrist and contains data regarding the cardiac ejection and the process which the pulse wave travels along the vascular system.[3]

Different physiological and pathological states produce pulse conditions with different waveforms. The typical pulse waveform graphs of the slippery pulse and string-like pulse which consensus has been reached are presented in **Figure 1.**

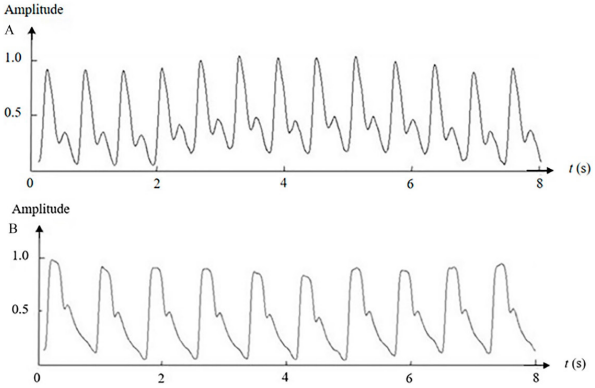


***Figure 1.*** *The pulse waveforms visualizing the characteristics of pulse conditions through a two-dimension representation with X-axis and Y-axis representing time and amplitude, respectively:* ***(A)*** *A slippery pulse with obvious double-peak waveform and a narrow percussion wave;* ***(B)*** *A string-like pulse with a broad and high percussion wave*

The pulse waveforms only support a qualitative understanding of pulse conditions, thus quantitative analysis of the waveforms is needed to obtain pulse parameters.

**Methods for extraction and analysis of pulse parameters.**

Zhou Xuehai, a physician in the late Qing dynasty, wrote that [5] "location, rate, shape, and force must be clarified to understand all pulse conditions."

This classical quotation means that the identification of pulse conditions is mainly made through four aspects: location, rate, shape, and force. Pulse parameters should be extracted to reflect the four aspects of pulse conditions using different analytical methods. Of the four aspects, the pulse shape can be quantified by the time domain analysis method and the hemodynamic method.[6-8]

We, therefore, used these approaches to extract the parameters of the string-like pulse and the slippery pulse.

***The time domain method*** [9] is an intuitive method that mainly quantifies the characteristics of the pulse wave form in a single cardiac cycle (**Figure 2**).

The pulse wave form parameters, including *h2/h1*, *h3/h1*, *h4/h1*, *h5/h1*, *As/Ad*, *t1/t*, *t1/t4*, and *t5/t4*, can reflect the morphology of different waveforms, and have different physiological significances (**Table 1**).

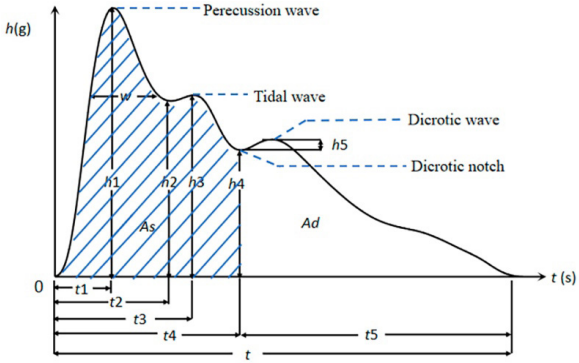


***Figure 2.*** *The pulse waveform graph in a single cardiac cycle with X-axis and Y-axis representing time and amplitude, respectively.*

***h1:*** *the height of percussion wave;* ***h2:*** *the height of canyon between percussion wave and tidal wave;* ***h3:*** *the height of tidal wave;* ***h4:*** *the height of dicrotic notch;* ***h5:*** *the height of dicrotic wave;* ***t1:*** *the time distance between the start point of pulse chart and percussion wave;* ***t4:*** *the time distance between the start point of pulse chart and dicrotic notch;* ***t5:*** *the time distance between dicrotic notch and the endpoint of pulse waveform;* ***t:*** *the time distance between the start point and the endpoint;* ***w:*** *the width of percussion wave in its 1/3 height position*

The pulse wave form parameters, including *h2/h1*, *h3/h1*, *h4/h1*, *h5/h1*, *As/Ad*, *t1/t*, *t1/t4*, and *t5/t4*, can reflect the morphology of different waveforms, and have different physiological significances (**Table 1**).

***Table 1***

*Physiological significance of pulse parameters*

| Parametr | Physiological significance |
|---|---|
| *h2*/*h*1 | Reflects the compliance and peripheral resistance of vascular wall |
| *h3*/*h*1 | Reflects the compliance and peripheral resistance of vascular wall |
| *h4*/*h*1 | Reflects peripheral resistance |
| *h5*/*h*1 | Reflects aortic compliance or aortic valve function |
| *As*/*A*d | Reflects to cardiac output |
| *t*1/*t* | Reflects the ejection function of the heart |
| *t*1/*t*4 | Reflects the rapid ejection of the heart |
| *t*5/*t*4 | Reflects to the heart rate |
| *w*/*t* | Reflects the duration of elevated aortic pressure |

The purpose of pulse analysis in the ***hemodynamic method*** is to analyze the factors influencing pulse waveforms. According to the hemodynamic principle, pulse waves can be decomposed into forward and reflected components. The

pulse wave recorded in the radial artery is the synthesis of forward and reflected traveling waves. [9-11]

Therefore, the pulse wave velocity (**PWV**) and the reflection coefficient ($\mathbf{R_f}$), which represent properties of transmission and reflection of the pulse wave, respectively, are parameters that can be used to explain morphological changes of the different pulse waveforms. The formation graphs of a string-like pulse and a slippery pulse wave-forms are presented in **Figures 3 and 4.** [11]

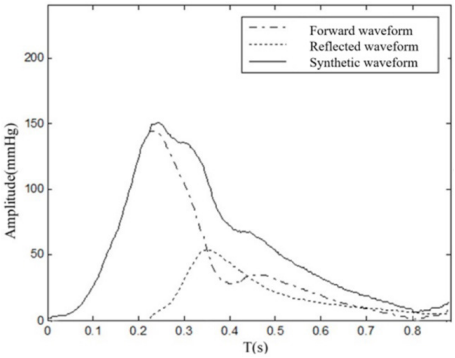


***Figure 3.*** *The formation graph of a string-like pulse waveform.*[11]

For example, in older individuals, arterial stiffening causes increased pulse wave velocity. Thus, the early return of the reflected wave affects the systolic than the diastolic part of the wave, augmenting the percussion wave with a secondary rise in late systole after an early systolic peak that creates the waveform of a string-like pulse.

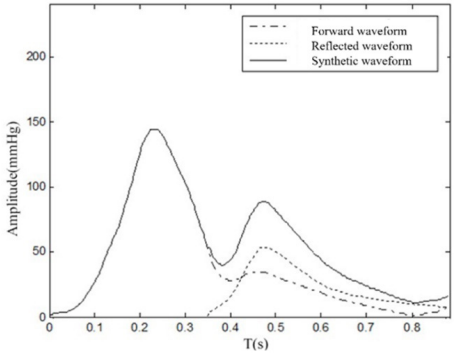


***Figure 4.*** *The formation graph of a slippery pulse waveform.*[11]

For example, in youth, good arterial compliance causes decreased pulse wave velocity. Thus, the reflected wave affects the diastolic rather than the systolic part of the wave, causing secondary fluctuations in diastole, and forming the double-peak wave of a slippery pulse.

**Figures 3 and 4** show that **PWV** and $\mathbf{R_f}$ are the factors affecting the formation of pulse waveforms, which help interpret the waveform differences between a slippery pulse and a string-like pulse. Using the hemodynamic method for extracting physiological information from TCM pulse conditions,[12] we obtained the values of **PWV** and $\mathbf{R_f}$ of the slippery pulses and the string-like pulses.

**Complementing definitions of the two pulses.**

To carry out the calculations, we used the time-domain and hemodynamic methods to analyze 247 samples of slippery pulse and 622 samples of string-like pulse, and calculated the time-domain parameters (*h2/h1*, *h3/h1*, *h4/h1*, *h5/h1*, *As/Ad*, *t1/t*, *t1/t4*, *t5/t4*, and *w/t*), **PWV** and $\mathbf{R_f}$ of these pulses. SPSS 25.0 (IBM Corp, Armonk, NY) was used to analyze the pulse parameters.

The Mann-Whitney U test for non-parametric method was applied to compare pulse parameters that are not normally distributed, and distributions of pulse parameters are described by median, the highest and lowest quar tile, as ***M*** ($\mathbf{Q_L}$, $\mathbf{Q_H}$). The results are presented in **Tables 2-4**.

***Table 2***

*Comparison of time-domain parameters of the two groups of the pulses M ($Q_L$, $Q_H$)*

| Group | n | *h2/h1* | *h3/h1* | *h4/h1* | *h5/h1* | *As/Ad* |
|---|---|---|---|---|---|---|
| Slippery pulse | 247 | 0.631(0.564, 0.735) | 0.503(0.414, 0.592) | 0.323(0.257, 0.375) | 0.413(0.354, 0.464) | 1.935(1.618, 2.352) |
| String-like pulse | 622 | 0.955(0.889, 0.982)* | 0.836(0.774, 0.881)* | 0.485(0.425, 0.549)* | 0.458(0.392, 0.511)* | 2.094(1.782, 2.526)* |

*represents a significant difference compared with a slippery pulse, P<0,001

***Table 3***

*Comparison of time-domain parameters of the two groups of the pulses M ($Q_L$, $Q_H$)*

| Group | n | *t1/t* | *t1/t4* | *t5/t4* | *w/t* |
|---|---|---|---|---|---|
| Slippery pulse | 247 | 0.138(0.120, 0.155) | 0.343(0.318, 0.368) | 1.297(1.238, 1.353) | 0.170(0.147, 0.196) |
| String-like pulse | 622 | 0.146(0.125, 0.177)* | 0.359(0.312, 0.431) | 1.193(1.129, 1.249)* | 0.259(0.238, 0.280)* |

*represents a significant difference compared with a slippery pulse, P<0,001

***Table 4***

*Comparison of PWV and $R_f$ of the two groups of the pulses M ($Q_L$, $Q_H$)*

| Group | n | PWV | $R_f$ |
|---|---|---|---|
| Slippery pulse | 247 | 8.502 (6.919, 12.920) | 0.736 (0.653, 0.813) |
| String-like pulse | 622 | 11.646 (10.091, 13.147)* | 0.811 (0.742, 0.886)* |

*represents a significant difference compared with a slippery pulse, P<0,001

In these experimental pulse samples, the values of time-domain parameters *h2/h1*, *h3/h1*, *h4/h1*, *h5/h1*, *t1/t*, *t1/t4* and *w/t* in the string-like pulses were higher than those in the slippery pulses (P<0.001), and the *t5/t4* value was lower than that in the slippery pulses (P<0.001). The **PWV** and $\mathbf{R_f}$ of string-like pulses were higher than those of slippery pulses (P<0.001). These differences between the two groups of pulses were statistically significant.

The experimental results show that pulse parameters can distinguish the waveforms of slippery pulses and string-like pulses.

The hemodynamic principle indicates that arterial stiffening and peripheral resistance can be reflected from the waveform of pulse, and arterial stiffening and peripheral resistance can be characterized by **PWV** and $\mathbf{R_f}$.

Our study shows that the string-like pulse with higher **PWV** and $\mathbf{R_f}$ indicates high arterial tension, and corresponds to the description that "a string-like pulse is like the musical strings, and stiff under the force of the fingers".[13]

The slippery pulse with a lower **PWV** and $\mathbf{R_f}$ represents good arterial compliance, and corresponds to the description [14] "a slippery pulse arrives and departs smoothly. Its form is like pearls rolling on a plate."

Therefore, the time-domain parameters, **PWV**, and $\mathbf{R_f}$ of the pulse conditions can quantify the waveform differences of string-like pulse and slippery pulse from the aspects of morphology and formation mechanism of waveforms. As exemplified in the above examples, these parameters are used to complement the definition of two types of pulses.

## CONCLUSIONS AND FURTHER SUGGESTIONS

First, pulse measuring device with a single-probe pressure sensor is most commonly used in clinical settings to obtain pulse information and display the dynamic pulse waveforms of a patient's radial artery. Researchers have made progress in obtaining objective pulse conditions through extraction and analysis of pulse parameters. [9,14]

However, the information received from a device using a single-zone pressure sensor is far from exhaustive, reflecting four aspects of the pulse state. Therefore, new measuring devices based on photoplethysmograms were later developed, which, as expected, would collect much more complete information reflecting the "location, frequency, shape, strength" of pulse conditions.

Second, the positioning mode of current pulse measuring devices produced by some companies still relies on manual positioning. The sensor must be manually moved to the position of the radial artery and pressure needs to be manually adjusted to obtain an optimal pulse waveform. These manual operations result in unreliable data, affecting the accurate acquisition of pulse waveforms and parameters. Thus, automatic positioning and pressurization techniques are important issues to be resolved in the future.

The traditional approach to pulse diagnosis (TCM) relies on the sensitive palpation of a physician's fingers, through which the physician obtains 3D pulse information. New sensors and digital signal processing technology should be applied in pulse measuring devices to obtain 3D waveforms of pulse conditions.

Using 3D pulse waveforms could maximize the simulation of the pulse diagnosis process and obtain more reliable pulse information.

The development of sensor technology, artificial intelligence and big data may support the informatization and digitization of pulse diagnosis, ultimately ensuring that the theoretical system of pulse diagnosis can be improved for future generations.

In conclusion, standardized methods on digitalization and quantification of pulse conditions based on AI can provide objective data for subjective definition of pulses, thus improving the disease diagnosis and treatment, as well as teaching and training.

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# THE POPULATION OF SHOREBIRDS AND WATERFOWL IN THE WATER AREA OF LAKE BAIKAL IN THE AUTUMN PERIOD UNDER VERY HARSH WEATHER CONDITIONS

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***Annotation.*** *As a result of special work in the middle and second half of September 2022 materials on the species composition and features of the passage of coastal birds in the water area of Lake Baikal were obtained. This season was characterized by very harsh conditions: low temperatures, early snowfall, constant storm winds. This is due to a sharp increase in air flows of the north-west direction (North Atlantic). In this regard, on the lake Baikal has recorded well-marked migrations of birds, previously very rarely observed in its waters: Heuglin's Gull, Kittiwake and Vegae Gull. For the first time in a long period of research, the flight of a Great Skua was noted. The collected data emphasize the great influence of weather conditions in the Arctic on migration processes. A special study of these processes and the peculiarities of their development in various climatic situations is necessary*

***Keywords:*** *Lake Baikal, birds, weather, autumn migrations, species composition.*

## Introduction

Despite long-term studies of Lake Baikal (XYII-XXI centuries), the fauna of its birds is still insufficiently studied. This is primarily due to modern trends towards an increase in the species richness and diversity of birds as a result of strong and rapid climate warming [7, 12-13, 17]. In addition, pointing to the high abundance and diverse species composition of birds of this large zoogeographic region, many authors use estuaries and deltas of rivers flowing into Lake Baikal, and sometimes its entire basin, as the basis of research [4, 8-10, 17, 22-23]. They are characterized by an increased diversity of bird habitats, and, consequently, their rich fauna. In essence, such descriptions cover all habitats of coastal birds of the Lake Baikal basin. At the same time, Lake Baikal itself is distinguished by a very narrow range of favorable conditions for birds [12, 28].

The exceptions are large colonies of Great Cormorant *Phalacrocorax carbo* and gull birds, mainly the Mongolian gull *Larus (vegae) mongolicus*. They form nesting colonies on islands in the Strait of the Small Sea, Chivyrkuysky, and, from part, Barguzin bays and in of the Selenga River delta. These areas of Lake Baikal are developed almost exclusively by ichthyophage birds, capable of actively foraging in the water column, as well as omnivorous species that collect food, both on the surface of the water and on land. All species of large gulls are mainly scavengers, which is confirmed by a sharp increase in their numbers in the post-war years, as the industrial development of the region progressed. In addition, a high number here is characteristic of a very specialized group of birds foraging in the air – swifts. The Common Swift *Apus apus* reaches the greatest abundance on rocky islands and in the vicinity of rocky cliffs and large rocky outcrops. Waterfowl and near-water birds are also found in such areas, but they reach high numbers only during periods of mass migrations in the autumn period.

It is the autumn period that is the least studied time of the year in the waters of Lake Baikal. Climatic conditions have a great influence on the migration process of birds at this time. The weather in autumn on Lake Baikal is highly unstable and the number of days with stormy winds increases sharply. In some years, autumn comes very early, which is usually associated with large masses of cold air breaking into Eastern Siberia from the northwest (North Atlantic). In such years, the number of northern bird species, atypical for the region, increases sharply, which was previously noted by some authors [3]. In particular, in such years, there is a well-marked flight of the Kittiwake *Rissa tridactyla*, a species usually found here only by flight. In the last decade, a well-marked flight of the Vegae Gull *Larus vegae* has been noted here. However, it is likely that it was not previously distinguished from the Larus argentatus *Larus argentatus*, which, according to modern materials, is not characteristic of the region and is replaced here by other closely related species [17, 29]. Last season, for the first time in a long period of study, on the lake Baikal is marked by two Great Skua *Stercorarius skua*. In this regard, a detailed overview of the bird species found during such periods on the lake Baikal and finding out the features of their distribution is still an urgent task.

**Material and methods**

As a result of field work, from September 8 to 22, 2022, a survey of the coasts of Middle and Northern Baikal, as well as partially Southern Baikal, was conducted using the NIS "Professor A.A. Treskov". Physical and geographical features of the lake Baikal allows dividing its water area and adjacent territories into three climatic districts: South Baikal, Middle Baikal and North Baikal. They differ in the severity of climatic conditions – it increases markedly from south to north (the coefficient of continentality of the climate according to Cenker increases from 62 to 64) [1]. At the same time, the division of lake Baikal is divided into three

sections (Southern, Middle and Northern), made by N.G. Scriabine [28], does not coincide with the boundaries of climatic districts. Therefore, our similar names of different sections of the lake Baikal does not reflect its previous division and provides ornithological characteristics of the corresponding climatic districts.

The coastal line was fully surveyed from the Launch with exits to the shore during overnight stays and ship sediments in strong storm winds. At that time, small bird species (Passeriformes, Charadriiformes, Coraciiformes, Upupiformes, etc. groups) were taken into account, which cannot be counted and determined from a Launch even with binoculars. However, most of these species do not belong to coastal birds or they are found here only during periods of migration. Coastal birds were recorded using 12-fold binoculars throughout the entire period of the vessel's passage along the coast.

Coastal birds found on Lake Baikal master areas of its water area with depths up to 10 m during foraging periods. At the same time, the dump of its depths is very sharp and the zone of coastal shallow waters is very small. It is only about 7.0% of the total area of this huge lake, i.e. the area that birds can effectively master during the feeding period is very limited, which forces them to constantly stay at the edge of the shore [12, 15, 28]. Away from the shore, birds are found only during flights and rest. However, during periods of migration, when birds cross Lake Baikal, they can occur in any part of it, often in very large flocks. However, the number of such meetings is small.

The maximum detection distance of birds found far from the coast is about 2.5 km and further it is difficult to determine them even with the use of telescopes. The average distance of their detection varies widely and ranges in different species from 30 m (Kittiwake and Great Skua) to 1.5 km (Whooper Swan *Cygnus cygnus*). Therefore, examining the coastal strip of 2 km (from one side 500 m for a detailed inspection of the shore, and from the other 1500 m of the lake water area Baikal), we actually take into account all coastal birds, conducting an absolute accounting of them. Bird encounters at a greater distance are rare even during periods of migration [12, 15].

At the initial stage of the work, birds were counted from the settlement Listvyanka to the Sandy Bay and then through Lake Baikal to the Proval Bay, of the Selenga River delta and the Posolsk Bay. Then from the settlement Listvyanka to the northern tip of the island Olkhon and then the transition to the Ushkany Islands and the Chivyrkuy Bay. From Chivyrkuysky Bay, during a strong storm, a passage was made across Baikal to the Zavorotnoiy Spit and further along the north-western coast to the city of Severobaikalsk. From Severobaikalsk, a transition was made to the opposite eastern coast to the Hakusa Bay and Frolikha Bay, and from there to Severobaikalsk. The next transition included the course from the city of Severobaikalsk to the village of Baikalskoye and further from

cape to cape to the northern tip of the island Olkhon. Then the passage along the east coast of Olkhon and from the Olkhon Gate Strait in the middle of Lake Baikal to the port Listvyanka. During periods of severe storms, the vessel was defended in places with the absence of strong waves. Since the autumn period on the lake Baikal is characterized by frequent repetition of stormy weather, about half of the total period of the survey of the shores of the lake Baikal falls on sediments as a result of unfavorable weather conditions for work.

Calculation of the population density of birds for various parts of the lake Baikal was conducted using a generally accepted methodology [26]. The average speed of the vessel, taking into account the constant stormy weather, is assumed to be 16.0 km/h. The average detection distance of birds in various parts of the lake Baikal is obtained on the basis of determining the geometric mean of the total number of bird sightings for each section of the Baikal coastline. The total length of the accounting routes in September 2022 was 1914 km.

As a result of the work, a general ornithological characteristic of the lake Baikal water area was obtained in the middle and second half of September 2022, characterized by a sharp cold snap. At that time, snow fell, covering the mountain peaks of the second line of ridges surrounding the lake. During our work, we have noted several species of birds, the meetings of which are of undoubted interest to ornithologists and the general ornithofaunistic characteristics of Lake Baikal. The species composition of birds and the order of their description are given according to the latest reports of Russia, Siberia and the Basin Lake Baikal [4, 5, 7-10, 12, 17, 27].

**Results**

A detailed survey of the shores of the lake Baikal made it possible to find out the species composition of birds and the density of their population in the autumn period during the mass autumn migration.

A fairly clear and accurate description of the habitats of coastal birds of the lake Baikal is given in several publications [12, 28]. There are two groups of stations characteristic only for the water area of this lake. **The first group of stations is the open deep–water part of Lake Baikal.** This group of stations covers a part of the lake with depths above 10 m. Its area is about 93.0% of its entire water area, but this part of the lake is practically irrelevant in the life of coastal birds [12, 28]. Some bird species are only occasionally found here, but the reasons for their pearance outside the migration period are not always clear and are still unknown. **The second group of stations includes the coastal shallow waters of Lake Baikal, with an adjacent strip of shore.** In this group of stations, there are three fairly well-differing habitats (stations) of coastal birds: a) the coastal open water area of Lake Baikal is a strip of shallow waters (depth less than 10.0 m), encircling, only occasionally interrupted, the deep-water areas of the lake; b)

shallow, closed and protected lips and bays, including only internal parts of lips and bays, closed from the influence of wind and waves; c) sections of the coast with rocky, precipitous shores - clamps, rocky scree and cliffs, steeply descending to the water shores [12, 28].

Based on the accounting work carried out, the species composition of birds characteristic of the Baikal water area in mid-September, in conditions of severe cold snap and snowfall, was revealed.

**Great Cormorant (*Phalacrocorax carbo*)**. The general type of distribution does not differ from the summer period. The maximum number was recorded in the areas of mass nesting (the Strait of the Small Sea, the Chivyrkuy Bay and of the Selenga River delta), but the number, compared with the breeding period, is much lower. Between these areas of mass nesting occurs along the shoreline of Lake Baikal almost everywhere, but is more often marked by single individuals and pairs. Small groups of up to 10-12 and very rarely 20 birds are rarely observed. However, a very large accumulation of a large cormorant was noted by us in the Posolsk Bay opposite the Posolsk Monastery – 2500 birds. In the mouths of the channels flowing into the Posolsk Bay, there are resting flocks of 30 to 500 birds, but usually there are flocks of 100-200 birds. Most likely, these are flocks of flying Great Cormorants, whose autumn migrations begin very early (end of July) and stop for rest [18-21]. The population density of the species in various parts of Lake Baikal ranged from 0.8 to 85.6 ind./km$^2$. The total number of the species during this period is at least 9400 birds, but most likely at this time in the waters of the lake Baikal holds from 10,500 to 11,000 birds of this species.

**Grey Heron *Ardea cinerea*.** The usual, but not numerous species of the shores of Lake Baikal. During the period of work, we registered 21 birds of this species (0.1 und./km$^2$). All meetings were typical for Southern Baikal, mainly in the Goloustnaya River delta.

**Whooper Swan *Cygnus cygnus***. The usual flying species of the lake. Baikal, but sometimes the flight can be very intense. Along the karga delta of the Selenga River, 35 birds of this species have been registered in Sora. In addition, one individual of this bird has been recorded in Frolikha Bay. The total population density at that time in the Baikal water area was about 0.04 ind./km$^2$.

**Ruddy Shelduck *Tadorna ferruginea*** is a common, but not numerous species of the shores of Lake Baikal. Single, most likely immature males and pairs with broods are much more common. The autumn flight takes place very early – at the end of July, the first half of August. However, sometimes (extremely rarely) birds are noted that have stopped migrating and occur before November, and in some cases remain for a “cold” wintering (the source and upper course of the Angara River). The reasons for this have not been established, but, most likely, these are sick, weakened birds and wounded. In a small bay near the village of Listvyanka

on September 8, 2022, we met one non-flying brood of this species. Consequently, it was a repeat very late brood, which, just like in other waterfowl, can also occur in this early breeding bird.

**Gadwall *Anas strepera***. The usual species of the shores of Lake Baikal on the inland waters of deltas and estuaries of rivers. We have registered only one flight flock of ducks of this species – 15 birds (0.08 ind./km$^2$).

**Pintail *Anas acuta***. It is a common species during periods of migration, but it is noted in deltas and estuaries of large rivers. On the western coast of Lake Baikal, we have registered only 4 birds (0.03 ind./km$^2$) of this species.

**Goldeneye *Bucephala clangula***. It is a common species during the periods of flight and summer molting migrations. It is distributed extremely unevenly. We have registered 1326 birds of this species. A large flock of 300 birds was found in the area of the Big Spit on Northern Baikal and a flock of 700 birds in the Chivyrkuy Bay (at the entrance) (0.4 ind./km$^2$).

**White-winged Scoter *Melanitta deglandi***. On the Middle Baikal, a little north of the village of Bolshye Koty, one flock of this species of 10 birds (0.05 ind./ km$^2$) was noted.

**Smew *Mergus albellus***. A small species occurring in solitary individuals. During the period of work, 4 birds were observed (0.03 ind./km2).

**Red-breasted Merganser *Mergus serrator*** is found everywhere in small bays and mouth of the river. Flying flocks of this species are also noted. Separately broods have not yet taken wing, but they are isolated. At the same time, already flying broods that have not formed flying flocks in small numbers are found everywhere. On northern Baikal, its abundance is sharply decreasing. The total number of the species in the second half of September reaches 500 birds (in different parts of the lake Baikal population density ranges from 0.4 to 5.2 ind./ km$^2$).

**Goosander *Mergus merganser*.** Not numerous, but a fairly common species during periods of migration. It occurs in small flocks and solitary individuals. Sometimes it can form flocks of up to several dozen birds. The total number of the species at this time is about 60 birds (from 0.04 to 0.7 ind./ km$^2$).

**Goshawk *Accipiter gentilis***. A rare species of the shores of Lake Baikal. We marked it twice in September. North of the Goloustnaya River delta, on September 11, 2022, one bird of this species was observed in flight and on September 21, another bird was noted in flight in the area of Severobaikalsk.

**Common Buzzard *Buteo buteo***. A rare species of the shores of Lake Baikal - one bird was met on September 9, 2022 in the area of Bolshaya Kadilnaya Padi.

**Golden Eeagle *Aquila chrysaetos***. In the Sandy Bay on September 11, 2022, one bird was marked on the rock. In the Strait of the Small Sea on September 14 , 2022 near the island of Ogoy marked one Golden Eagle in flight.

**White-tailed Sea Eagle *Haliaeetus albicilla***. In the area of the Goloustnaya River delta along the edge facing the lake Baikal, 5 individuals of this species have been registered. In the of the Selenga River delta along the edge of the Posolsk Bay, 3 birds of this species (singly) were registered in flight.

**Peregrine Falcon *Falco peregrinus***. One bird was met on September 8, 2022 in the evening in the village of Bolshye Koty.

**Great Skua *Stercorarius skua***. A new species for lake Baikal. Previously, no one has been registered. Its appearance here is undoubtedly connected with the expansion of its area in the tundra zone and along the sea islands of the northern seas to the east [27]. Two birds were recorded in large flocks of Kittewake in Uzura Bay (east side of Olkhon Island) on September 23, 2022.

**Parasitic Skua *Stercorarius parasiticus***. During the transition from Aya Bay to the Olkhon Gate on September 13, 2022, one bird was noted in Baikal.

**Heuglin's Gull *Larus heuglini***. A rare flying species, mainly of Southern Baikal. In September 2022, we registered 99 birds of this species (from 0.002 to 2.2 ind./km$^2$ in different parts of Lake Baikal). Almost all birds have been recorded on Southern Baikal in small groups and small flocks, and only 4 individuals on Middle Baikal.

**Vegae Gull *Larus vegae***. One of the most numerous flying species of gulls in the second half of September. During the period of work, 3720 birds were registered. The greatest abundance is characteristic of Southern and Middle Baikal, and to the north the abundance of the species is sharply decreasing (population density from 13.7 to 20.0 ind./km$^2$).

**Mongolian Gull *Larus (vegae) mongolicus*** is relatively not numerous in the second half of September. There are no concentrations of birds within the colonies. It occurs in solitary birds, pairs and small groups everywhere, but its abundance decreases to the north. Small flocks are observed in the port of the settlement Listvyanka – up to 100-150 birds. The total number obtained by us as a result of special accounting work at that time was 449 birds. The population density of the species in the North-Baikal climatic District ranged from 0.03 to 0.6 ind./km$^2$, the Middle- Baikal climatic District from 1.03 to 2.1 ind./km$^2$ and in the South-Baikal climatic District from 2.6 to 2.9 ind./km$^2$. The number of species in the last decade, according to a number of researchers and our according to observations, it decreases [24, 25].

**Common Gull *Larus canus*** is one of the smallest species of the Baikal coasts during the autumn migration. Obviously, most of the birds have already left the shores of Lake Baikal by this time. Large flocks of this species are usually observed here in the second half of August. It does not form flocks in September and occurs in single birds, less often in pairs and small groups. The total population is very low – up to 50 individuals and only in the southern and middle part of Lake Baikal (population density from 0.04 to 0.2 ind./ km$^2$).

**Kittiwake *Rissa tridactyla*** is usually a very small northern flying species. However, in the second half of September 2022, it was a very numerous species on Lake Baikal. It was found in very large and medium-sized flocks (from 20 to 3000 birds). Single meetings and couples are very rare. The total population density varied greatly in different parts of the lake Baikal: from 8.3 in the South-Baikal Climatic District to 14.3 ind./km$^2$ in the Posolsk Bay, along the western coast of Lake Baikal (from Aya Bay to Olkhon Gate) 0.8-32.0 ind./km$^2$, Zavorotnaya-Ayaya-Frolikha bays (North-Baikal Climatic District) – from 0.09 to 0.6 ind./km$^2$ and the eastern side of Olkhon Island 137.6 ind./km$^2$. The largest concentrations of birds of this species were observed on the eastern side of the island Olkhon in the Bay of Uzura – more than 3000 birds. The total number during the migration period was about 4,600 birds.

**Daurian Jackdaw *Corvus dauuricus*.** A fairly common species of Eastern Siberia. However, on lake Baikal, it is constantly found only on the western side of the island Olkhon in the sandy beach area near the village of Khuzhir. We have noted here on September 14, 2022 6 birds of this species.

**Eastern Carrion Crow *Corvus (corone) orientalis*** is a relatively small species on the Baikal coast. It occurs everywhere, but is more common along the southeastern coast of Lake Baikal near settlements along the East Siberian Railway. It is quite common on the side branch of this highway – Slyudyanka – port Baikal and the village of Listvyanka. However, in September, its number is decreasing everywhere. Obviously, this is due to a sharp reduction in the number of tourists, and, consequently, the available feed. During the period of work in 2022, we registered 15 birds of this species (population density 0.06-0.2 ind./km$^2$).

**Raven *Corvus corax***. A small number of Baikal coasts in the autumn period. We have registered 4 birds on the Southern and Middle Baikal.

**Discussion.** Our observations show that the premature onset of severe cold weather coming from the north-west direction (North Atlantic air mass transfer) led to an increase in the intensity of flight of all species of northern gulls. This is especially pronounced in the Kittiwake, which is usually marked here by single specimens. The number of Heuglin's Gull and the Vegae Gull has clearly increased. Meetings of other species do not differ much from previous years [8, 11, 14]. Obviously, it is the weather conditions (drift by strong winds) that determines the appearance of a new species, which has never been observed on the before lake Baikal is a Great Skua.

It should be noted that the late autumn migrations of birds in the water area of Lake Baikal have not yet been fully studied. Very harsh climatic conditions during this period make it difficult to study birds at this time. Almost all the information received about birds at this time refers to the delta and estuarine areas of the lake

Baikal, where you can find more comfortable living conditions. And only in recent years, special surveys of the water area of the lake Baikal allowed to close this gap in the study of birds of the region to a certain extent.

In the middle and second half of September 2022, in very harsh weather conditions in the Baikal water area, we registered 26 bird species, of which one (the Great Skua) is new to the region. Of these species, four are included in the Red Book of Russia (rare species of predatory and waterfowl) and one in the Red Book of the Irkutsk region (Ruddy Schelduck is a regionally rare species).

**Conclusion.** The obtained materials show well that Lake Baikal, as a specific deep-water mountain reservoir, without the various stations surrounding it, is unsuitable for the habitat of most species of coastal birds. The main reason for this is the significant depths in the main area of the lake, inaccessible to most species. The productivity of Lake Baikal is very high, which is emphasized by hydrobiological samples collected over its entire area [6]. At the same time, these feeds are inaccessible or very difficult to access for most bird species. During periods of migration, the number of some flying species on the lake Baikal may increase dramatically for a short time. This is especially true for typical northern species, the appearance of which here is largely determined by specific weather conditions that form over a very large area when bad weather is on a wide front. The latter requires a special in-depth analysis of the current situation in years with abnormal conditions for bird migrations.

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# MICROCRYSTALLINE PERACETIC CELLULOSE FROM HEMP

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***Abstract.*** *Hemp of industrial hemp by "Surskaya" brand (mass fraction of components: cellulose 71.2%, lignin 5.35%, extractives 9.32%, ash 1.75%) was delignified with an aqueous solution of acetic acid, hydrogen peroxide and a catalyst - sulfuric acid at a temperature of 85°C. The influence of the concentration of sulfuric acid (1-3%) and the duration of the process (3-5 hours) on the yield and properties of technical cellulose has been studied. At yields of 42 - 50%, the degree of polymerization of cellulose approaches the limit value of 110 ... 120. According to this indicator and other properties (water-holding capacity more than 30%, iodine number more than 10 mg/g), the product meets the specifications for microcrystalline cellulose.*

***Keywords:*** *cellulose, microcrystalline cellulose, hemp, delignification, hydrogen peroxide, peracetic acid.*

During decortication of technical hemp stalks (mechanical, chemical or biological treatment of hemp straw, in which pectin substances are destroyed), trust is obtained, which is mechanically divided into hemp and bonfire on crushing and scutching machines. The share of hemp in the bast layer of a hemp stem averages 20...25%, reaching 35...40% in some industrial varieties. It consists of fibers up to 2.5 m long. The chemical composition of hemp (table 1) has a number of features. Unlike wheat straw and hemp fire, hemp contains much more cellulose and less lignin, which makes it possible to reduce the consumption of reagents for its delignification (cooking). Both products, hemp and bonfire, can serve as raw materials for the production of pulp and paper and cardboard products, but their processing technologies are different.

The authors studied the possibility of obtaining microcrystalline cellulose by single-stage hemp delignification with hydrogen peroxide and peracetic acid [2].

***Table 1.***

*Chemical composition of plant materials [1, 2]*

| Vegetable raw materials | Mass fractions of components in raw materials, % | | | |
|---|---|---|---|---|
| | cellulose | lignin | extractives | ash |
| Wheat straw | 46,6 | 22,0 | 1,22 | 5,37 |
| Hemp fire | 41,2 | 23,4 | 4,64 | 1,10 |
| Hemp hemp | 71,2 | 5,35 | 0,32 | 1,75 |

The raw material for the study was hemp from technical hemp of the Surskaya brand of industrial production, its chemical composition is shown in Table 1.

The hemp fibers were ground in a dry disk mill. For experiments, we used the fraction that passed through a sieve with a hole diameter of 8 mm.

The prepared hemp was delignified with the reaction mixture "acetic acid - hydrogen peroxide - sulfuric acid catalyst - water". During cooking, acetic acid is oxidized to peracetic acid, which in turn oxidizes lignin. Constant delignification conditions: the initial concentration of hydrogen peroxide in the cooking solution is 6 g-mol/dm$^3$, acetic acid - also 6 g-mol/dm$^3$; liquid module 4.5; isothermal cooking temperature 85$^o$C.

Variable cooking factors (in parentheses - the intervals of their variation):

$X_1$ - concentration of sulfuric acid in the cooking solution, % (1 - 3);

$X_2$ - cooking time, hour. (3 - 5).

The values of these factors varied according to a three-level second-order experiment plan on cube elements [3] (Table 2).

The results of the experiments were characterized by the following output parameters:

$Y_1$ – cellulose yield, %;

$Y_2$ is the degree of cellulose polymerization;

$Y_3$ – water-retaining capacity of cellulose, %;

$Y_4$ is the iodine number of cellulose, mg J$^2$/g.

The results of the experiments are shown in Table 2, their statistical characteristics - in Table 3. Mathematical processing of the results was performed using the Statgraphics Centurion XVI software package [3].

***Table 2.***

*Conditions and results of experiments*

| Mode number | Variable factors | | Output parameters | | | |
|---|---|---|---|---|---|---|
| | $X_1$, % | $X_2$, hour. | $Y_1$, % | $Y_2$ | $Y_3$ % | $Y_4$, мг/г |
| 1 | 1 | 3 | 70,3 | 333 | 130 | 13,0 |
| 2 | 2 | 3 | 64,3 | 219 | 136 | 15,8 |
| 3 | 3 | 3 | 61,7 | 137 | 210 | 16,6 |
| 4 | 1 | 4 | 69,7 | 252 | 215 | 14,6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 2 | 4 | 64,0 | 175 | 138 | 17,5 |
| 6 | 2 | 4 | 62,0 | 192 | 192 | 17,7 |
| 7 | 3 | 4 | 49,7 | 114 | 164 | 17,5 |
| 8 | 1 | 5 | 65,7 | 168 | 240 | 17,4 |
| 9 | 2 | 5 | 46,7 | 223 | 211 | 19,4 |
| 10 | 3 | 5 | 42,0 | 120 | 214 | 16,0 |

***Table 3.***

*Statistical characteristics of the experimental results*

| **Characteristics** | **Output parameters** | | | |
|---|---|---|---|---|
| | **$Y_1$** | **$Y_2$** | **$Y_3$** | **$Y_4$** |
| | **characteristic values** | | | |
| Average value | 59,61 | 193,3 | 185,0 | 16,55 |
| Minimum | 42,0 | 114,0 | 130,0 | 13,0 |
| Maximum | 70,3 | 333,0 | 240,0 | 19,4 |
| The coefficient of variation, % | 16,6 | 34.6 | 21,5 | 10,9 |
| Standard deviation | 9,88 | 66,9 | 39,7 | 1,80 |

The dependence of each of the output parameters on the variable factors was approximated by polynomial second-order regression equations of the general form

$$\acute{Y} = b_0 + b_1X_1 + b_2X_2 + b_{12}X_1X_2 . + b_{11}X_1^2 + b_{22}X_2^2.$$

Regression coefficients that are statistically significant at a confidence level of at least 95% are shown in Table 4.

***Table 4.***

*Coefficients and statistical characteristics of regression equations*

| **Coefficients $b_{ij}$ and statistical characteristics** | **Output parameters** | | | |
|---|---|---|---|---|
| | **$Y_1$** | **$Y_2$** | **$Y_3$** | **$Y_4$** |
| | **values of coefficients and characteristics** | | | |
| $b_0$ | 31,04 | 735,3 | 56,6 | –8,57 |
| $b_1$ | 1,92 | –211,7 | - | 12,73 |
| $b_2$ | 25,25 | –103,7 | 31,5 | 5,18 |
| $b_{12}$ | –3,08 | 37,0 | - | –1,25 |
| $b_{11}$ | 1,11 | - | - | –1,72 |
| $b_{22}$ | –3,08 | - | - | - |
| Determination coefficient, % | 94,2 | 87,0 | 41,9 | 92,7 |
| Standard forecast error for Ý | 3,57 | 29,5 | 34,3 | 0,73 |

Regression equations were used to plot the results as 3D response surfaces.

The cellulose yield decreases with an increase in both technological factors $X_1$ and $X_2$ (Fig. 1), which is consistent with a priori information about delignification processes.

The degree of polymerization of cellulose in the initial period of the process also decreases almost symbatically with the yield (Fig. 2, the left part of the response surface), but at yields less than 50%, the degree of polymerization ceases to depend on the cooking time (the right part of the response surface in Fig. 2), which indicates about reaching the "limiting" degree of polymerization 120 ... 160.

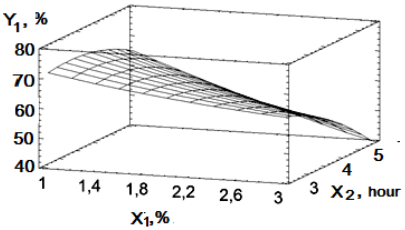


***Figure 1.*** *Dependence of pulp yield on cooking factors*

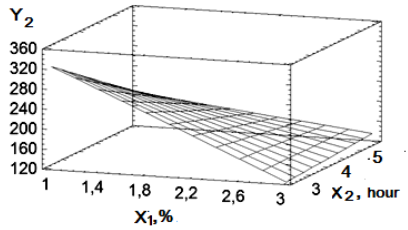


***Figure 2.*** *Dependence of the degree of cellulose polymerization on variable factors*

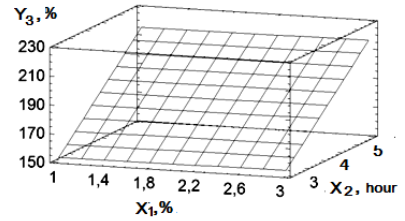


***Figure 3.*** *Dependence of the water-retaining capacity of cellulose $Y_3$ on vari-*

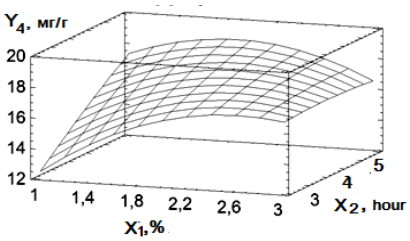


***Figure 4.*** *Dependence of the sorption capacity (iodine number) $Y_4$ of cellulose on variable factors*

The Y3 index (cellulose water-retaining capacity), when used for its determination by the generally accepted Jaime method, is poorly reproduced, in particular, a high prediction error indicates this (see Table 4). For this reason, when discussing the response surface shown in Fig. 3, we can only state a trend towards an increase in this indicator as the duration of cooking increases and the yield and degree of polymerization of cellulose decrease.

The sorption capacity of cellulose increases with an increase in the concentration of sulfuric acid and the duration of cooking only at low values of these factors (left part of the response surface in Fig. 4). This observation is in good agreement with the nature of the change in the degree of polymerization of cellulose (see Fig. 2).

According to the norms of the technical specifications in force in the Russian Federation, microcrystalline powder cellulose for the food and pharmaceutical industries must have a polymerization degree of no more than 300, a water-retaining capacity of at least 30%, and an iodine sorption capacity of at least 10 mg/g. These requirements are met by almost all manufactured pulp samples. Obviously, as the optimal cooking mode at this stage of the study, we can take the conditions of experiment No. 4 (Table 1), in which the product with the highest yield was obtained.

Studies were carried out in the laboratory “Deep processing of plant raw materials” of Reshetnev Siberian State University of science and technology. This work was supported by the Ministry of Science and Higher Education of the Russian Federation within the framework of State Assignment of the “Technology and equipment for the chemical processing of biomass of plant raw materials” project (FEFE-2020-0016).

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# AIR HEAT PUMPS WITH MOVEBIT SYSTEM

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***Abstract.*** *The prospects for the use of heat pump installations in systems for creating a microclimate are shown. Air source heat pumps are the most cost-effective in terms of operation, but their use in countries with cold climates is limited due to the formation of frost on the surface of the evaporator unit heat exchanger. This leads to a decrease in the transformation ratio and heat output. Existing ways to combat frostbite in the outdoor unit are accompanied by additional energy costs. This paper presents a developed method for ice destruction using mechanical vibrations generated by a magnetostrictive emitter. The use of air source heat pumps with the MOVEBIT system doubles the efficiency of the heat pump system compared to the operation of an air source heat pump without an anti-icing system.*

***Keywords.*** *Heat pump, transformation ratio, frost, magnetostrictive radiator.*

Currently, much attention is paid to problems with energy and the environment. Abroad and in Russia, maintaining a comfortable indoor temperature is the costliest item of utility costs. In addition to high prices for utilities, the requirements for maximum allowable $CO_2$ emissions into the air are becoming more stringent. In this regard, much attention is paid to energy-saving measures in construction [1,2].

A promising direction of energy saving is the use of renewable and non-traditional energy sources (Fig. 1), which include the bowels of the earth (geothermal), air (aerothermal), water (hydrothermal), as well as thermal emissions from ventilation systems, technological processes of industrial enterprises, etc. . Heat pumps are the most rational way of converting energy. This system has lower operating costs and emits less harmful substances into the atmosphere [3,4].

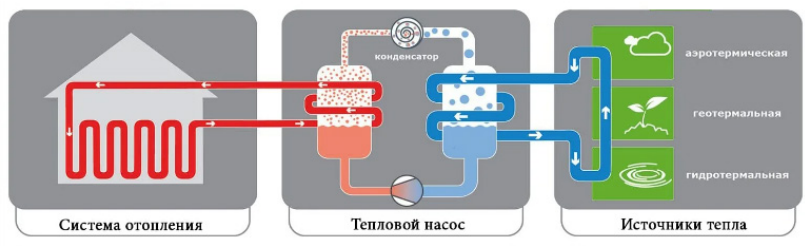


***Figure 1.*** *Energy sources for a heat pump*

Market research has shown that the market for heat pumps is expanding. The main consumers are the countries of Europe, Southeast Asia, etc.

Of the above heat pump installations, air source heat pumps are the most energy efficient in operation and manufacture compared to geothermal and hydrothermal ones [5].

However, despite the advantage of air source heat pumps, their use is limited in regions with a cold climate, including Russia. At negative temperatures, water vapor condenses on the surface of the heat exchanger of the outdoor unit with the formation of frost and ice crust. This leads to an increase in heat transfer resistance and a decrease in the conversion coefficient. To solve this problem, various methods of ice removal are proposed in the form of refrigerant reverse, coolant supply, bypass. The above methods of combating frostbite of the outdoor unit of the heat exchanger are often used in combination, but at the same time, all of them ultimately (except for the method of spraying reagents) remove ice by temperature exposure, heating the entire evaporator to a positive temperature. Electricity consumption in all methods depends directly on the outdoor temperature and its humidity. The most effective method is the destruction of the ice crust using mechanical vibrations [6].

The current anti-freeze methods require significant energy consumption or an additional heat source integrated into the heating circuit. The development and improvement of methods of mechanical oscillations of the heat exchanger is the most promising direction in the fight against frostbite of the evaporators of air heat pumps, increases the time of uninterrupted operation and reduces the cost of parasitic electricity [7].

Our studies have shown that in order to increase the efficiency of heat pumps, it is necessary to develop the shape of the evaporative unit heat exchanger, select a material with the required thermophysical characteristics, select the source of vibrations, the material for manufacturing the core of the oscillatory circuit, and the method of its attachment to the surface of the heat exchanger. To confirm the effectiveness of the developed events of the ball, the installation was made and tested.

As an experimental sample for the evaporator of the outdoor unit, a heat exchanger was designed and manufactured from D16t alloy, which has properties that are most suitable for the passage of mechanical vibrations, thermal conductivity, and is also chemically neutral to the effects of POE synthetic oils and R 410a refrigerant.

The fastening of the permendura core for transmitting vibrations to the evaporator is carried out by means of a waveguide using an alloy obtained experimentally in the laboratory. The alloy consists of various metals, which is based on copper and silver with impurities of various metals. It may have differences in composition and methods of its manufacture. The main condition for efficient operation is a reliable fastening of the radiator with a heat exchanger for the best transmission of vibrations when the core end is displaced. When operating in a low-temperature regime and high-frequency vibration, fastening by means of bolted joints and epoxy compounds lost the ability to transmit a given frequency and impact force, which, over time, worsened the effect of bringing the evaporator into resonance. This problem was solved by prestressing the metal, when the elements turned out to be mutually self-attractive to each other, forming a connection that minimizes the scattering and reflection of the wave at the interface between the media.

The most suitable materials for the manufacture of a magnetostrictive emitter are pretentious materials such as permendur, alfer and nickel. Permendur 49K2F and 49K2FA have a high technical saturation magnetic induction and are most suitable for manufacturing the core of a magnetostrictive radiator [8, 9].

The developed air heat pump unit with the MOVEBIT anti-icing system (Fig. 2) was tested and worked for several days in real conditions at an outdoor air temperature from -6.4 ℃ to -10.4.℃.

***Figure 2.*** *Heat pump unit with MOVEBIT system*

The processing of a large amount of experimental data (more than 2000) was carried out in a computer program. Tests have shown that the unit only works when using the MOVEBIT anti-icing system. Analysis of the data obtained showed that when the outside air drops to -27 °C, the transformation ratio is 4-6, which corresponds to the operation of the heat pump at positive outside air temperatures [10]. Changes in the outdoor temperature did not significantly affect the energy efficiency of the equipment under test.

Heat recovery systems are widely used in ventilation systems of public buildings [11, 12], including those using heat pumps [13].

Thus, the use of magnetostrictive radiators in ventilation units with heat recovery makes it possible to increase the return of lost thermal energy by at least 2.0-2.5 times, expands the geography of the use of air heat pumps, as well as industrial air refrigeration units. The proven method of frostbite protection protects the compression equipment from liquid intrusion into the suction lines, which is the main reason for the shortened life of the heat pump equipment.

The data obtained showed that air source heat pumps with the outdoor unit of the MOVEBIT anti-icing system are able to effectively compete with geothermal heat pump installations.

The work was carried out as part of the implementation of the federal program to support universities “Priority 2030” using equipment based on the Center for High Technologies of the BSTU named after V.G. Shukhov.

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# VENTILATION AND HEAT RECOVERY SYSTEMS AT LIVESTOCK COMPLEXES

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***Abstract.*** *The ways of heat utilization in engineering systems are considered. The analysis of recuperation units in the ventilation of industrial premises of livestock complexes was carried out. The disadvantages and advantages of existing systems are highlighted. A ventilation system for livestock buildings with a heat exchanger is proposed. To intensify the heat transfer process in the heat exchanger, the use of centrifugal forces is provided. To ensure the required microclimate parameters, a heat pump installation with the MOVEBIT system is proposed.*

***Keywords:*** *Ventilation systems, recuperator, heat exchanger, animal husbandry, moisture, heat recovery, microclimate, energy efficiency.*

**Introduction.** Due to the increase in the volume of industrial premises, modern ventilation systems for livestock buildings require measures to reduce energy costs, that is, to increase the energy efficiency class of systems without compromising the quality of the created microclimate. Regulatory parameters of the microclimate in livestock buildings are achieved by removing excess hazards from the serviced area, in particular moisture and ammonia. Natural ventilation cannot solve this problem, therefore, in order to comply with the requirements of the microclimate, it is necessary to develop a mechanically driven ventilation system using heat pump units and recuperative devices that allow heating the air in the cold period and cooling it in the warm period, as well as drying and cleaning it from harmful emissions in accordance with current regulations.

The main hazards from pigs have been determined by many years of research and are fixed by indicators for livestock enterprises [1]. For example, for pigs, depending on the age group, body weight and gender of the individual, the indicators of harmful emissions fluctuate in the ranges: 1170.8 - 3212.5 kJ/h of full heat release, 42.5 - 117 l/h of carbon dioxide, 134 – 369 g/h of moisture [2,3]. Based on the above data and the classical method for determining the estimated flow rates of supply and exhaust air, subject to regulatory requirements, followed by determining the free cross-sectional area of the air ducts and the performance of the ventilation unit, as a rule, they end up with the selection of ventilation equipment and a complete set of ventilation chambers. If we consider livestock farms, for example, raising pigs with a production capacity of up to 15,000 heads / year, then the energy resources spent on preparing supply air in the cold and warm periods of the year will cost a significant amount.

At the same time, the sanitary and epidemiological rules state that at livestock enterprises it is not allowed to mix the air removed from the premises for keeping animals with the supply air supplied to the premises for keeping animals in order to prevent the return of unpleasant odors or pathogens. This condition prohibits the use of rotary and chamber heat exchangers, which contain moving parts, which does not exclude the possibility of mixing supply and exhaust air.

Therefore, when choosing recuperative or heat exchange devices, it is necessary to be guided not only by the conditions of economy, compactness, ease of use, but also by the requirements of sanitary, fire and other regulatory documents in order to ensure the normal functionality of living organisms in the serviced premises [4].

**Heat-trapping methods**

Scientific researchers and their predecessors have developed various ventilation systems for livestock buildings. As part of this study, we consider ventilation systems that deserve special attention.

Our compatriots have developed a patent of the Russian Federation for the invention No. 2076282 “Ventilation system for premises for keeping animals and birds” [5]. The system consists of supply and exhaust air ducts, a heat exchange device for utilizing the heat generated from the vital activity of animals and birds, a temperature limiter, an ejection air humidifier.

Also known is a ventilation system based on the invention of the USSR “Ventilation system for livestock buildings” [6]. The ventilation system was intended for livestock buildings with significant heat and moisture emissions. The system consists of supply and exhaust air ducts, which are placed horizontally in each other with a gap, forming a heat exchanger. The system also includes air outlets and an exhaust shaft with an air outlet window. Holes for moisture release are made in the lower part of the exhaust duct along the entire length.

Among the developments of domestic production, one can single out a shaft-type heat exchanger of the company “AgroProjectInvest” LLC. This unit of

supply and exhaust ventilation differs in that it includes an original heat exchanger made of self-supporting cellular polycarbonate. The system consists of supply and exhaust fans, and is also equipped with automatic flushing and defrost for the heat exchanger. The thermal efficiency coefficient of the heat exchanger is approximately 0.5, which makes it possible to save up to 80% when heating the supply air. It is most expedient to use this system on pig-breeding complexes of high productivity, since at a high density of filling the premises with animals, excess heat will satisfy the creation of effective heat recovery from exhaust air [7].

**Critical Analysis of Heat-trapping Systems**

The considered recuperative systems fully meet the requirements for the microclimate and fulfill the tasks that were set during their development. However, the regulatory documents for which they were developed, for the most part, have lost their force or have been supplemented, which indicates the inconsistency of the use of these systems today. Nevertheless, it is worth emphasizing some design features of certain recuperative systems developed to date and, on their basis, develop a system with a heat exchange device adapted to the current requirements of regulatory documents.

At the same time, it is worth considering the shortcomings of the modern Russian development produced by "AgroProjectInvest" LLC. The unit operates at design temperature conditions, which does not allow to constantly maintain the required supply air temperature. Also, the efficiency of the installation depends on the presence of calculated heat surpluses from animals, which does not allow controlling the process of heating the supply air. In the case of a decrease in the number of livestock, for example, a small increase in the herd, the efficiency coefficient of the heat exchanger will tend to zero, which will also negatively affect the preparation of the supply air.

**Proposed ventilation and heat recovery system**

Taking into account all the advantages and disadvantages of the above ventilation systems, we offer a comprehensive system of ventilation, heat recovery and trapping of harmful gases in livestock complexes.

The ventilation system includes a heat exchange device, in the lower part of which there is a condensate trap. The system also contains a shaft-type exhaust fan, local exhaust hoods, supply units, and air distributors. To ensure the required microclimate parameters, it is proposed to use a heat pump for additional heating or aftercooling of the supply air.

A feature of this system is the use of centrifugal force to swirl the upward flow of exhaust air and supply it to the walls of the air ducts, where heat is transferred from warm air to cold (supply) air. When condensate occurs, the process of trapping ammonia vapor with moisture and the formation of ammonia water, which is removed through the steam trap, occurs.

The evaporative unit of the air source heat pump, installed outdoors, for example on the roof, is equipped with an anti-icing system that allows operation at low temperatures. The most preferred anti-icing system MOVEBIT with magnetostrictive emitters to prevent and remove frost on the heat exchanger of the evaporator unit [8]. In addition, the heat pump is equipped with shut-off valves and a three-way valve for switching it to summer or winter operation.

**Conclusion**. A ventilation system is proposed, including a heat exchange device for utilizing the heat of the exhausted air, excess moisture, and also trapping harmful gases, in particular ammonia. All these features make it possible to increase the energy efficiency of the designed ventilation and heat recovery systems, to ensure the creation and maintenance of standard microclimate parameters in the working area of the premises in accordance with the requirements of sanitary standards for livestock enterprises.

Thus, in relation to livestock production complexes for various purposes, the use of energy-efficient ventilation and heat recovery systems will increase the productivity of animals, reduce energy costs, and obtain products of the highest quality.

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# ON THE EFFECT OF MIXING ON THE SURFACE ENERGY OF AQUEOUS SOLUTIONS

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***Abstract.*** *A series of experimental studies has been conducted to investigate the surface tension of aqueous solutions during mechanical and vibration mechanical activation, as well as in a resting state after the mechanical treatment. The time ranges in which the minimum surface energy was recorded were determined.*

***Keywords:*** *mechanical activation, vibration mechanical activation, aqueous solutions, surface tension.*

Targeted modifications of water properties in technologies where it plays an important role are carried out everywhere. In the process of mechanical activation, the dispersed medium transitions from one state to another, making it possible to use its properties more efficiently [1, 2, 3, 4]. Water that has been mechanically treated is obtained by passing it through filters, ultrafilers, and hyperfilters. The ion composition of water is changed (so-called "softening"), and distilled, deaer-

ated, deionized water, etc. can be obtained. Knowledge of the structure of water, its characteristics, and the ability to regulate it opens additional advantages in a wide range of technologies, such as wastewater treatment, water purification used for industrial and food purposes, intensification of biotechnological processes, and more. However, experimental data on low-intensity mixing is still insufficient. First and foremost, there is no information on the effect of mechanical activation on the surface energy of water and aqueous solutions.

The objects of the study were: distilled water (according to GOST R 58144-2018. Distilled water. Technical specifications); bottled drinking water "Berdovskaya taiga" (Certificate of state registration No. RU.42.21.01.006.E.000032.04.11 dated April 21, 2011); seawater from the waters of Russky Island; 3.3% NaCl solution; 1% aqueous solution of flour; complex solution containing 3.3% NaCl and 1% flour. The experiments were conducted in the laboratories of the Department of Mechatronics and Robotics of Technological Systems at Kemerovo State University and the Department of Technological Machines and Equipment of the Far Eastern State Technical Fisheries University.

At the beginning of mixing, the height of water rise in the capillary (h, mm) decreases over time ($\tau < 600$ seconds) and then transitions into an unstable region (Figure 1).

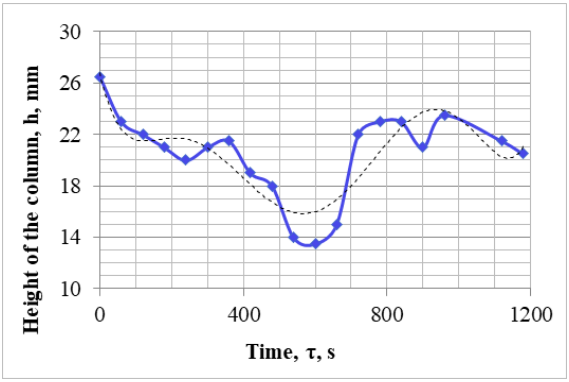


***Figure 1.*** *Variation of the height (h, mm) of a column of distilled water in a 0.1 mm capillary over time (τ, s) during mixing at a frequency of 100 min$^{-1}$*

The decrease of the height of water rising in the capillary is a direct confirmation of the drop in water surface energy in the first 10 minutes of the process to 20%. Then there is an unstable increase in the height of the liquid column, which is presumably associated with a decrease in the water temperature.

A noticeable difference in the surface energies of distilled water and bottled

drinking water "Berdovskaya taiga" is observed. The mixing of water containing ions, the composition of which is determined by the place of origin, decreases much faster. The graph is shown in Figure 2.

The graph (Figure 3) shows the dependence of the height of the column in the capillary (surface energy) on the temperature of the water, which changes during mixing. As can be seen, even a decrease in temperature does not increase the surface tension effect for mechanically activated water, but rather the opposite phenomenon is observed.

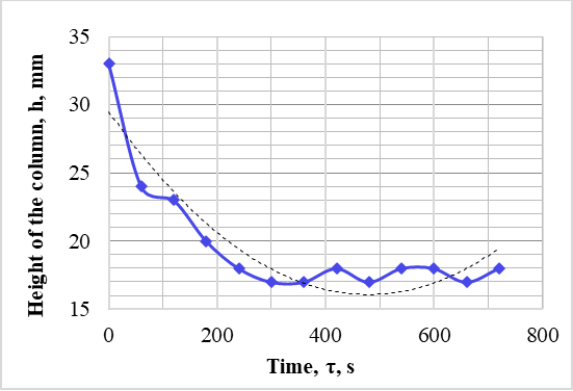


***Figure 2.*** *The variation in the height (h, mm) of the column of "Berdovskaya taiga" drinking water in a 0.1 mm capillary over time (τ, s) during stirring at a frequency of 100 min$^{-1}$*

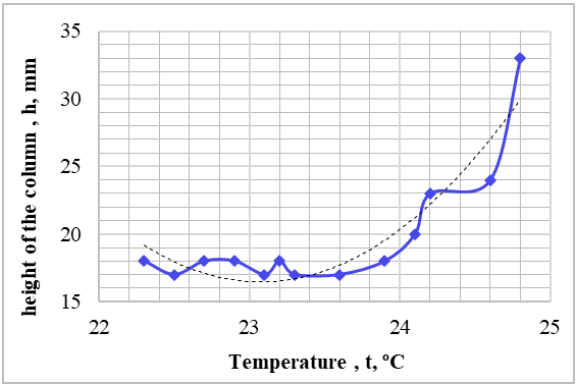


***Figure 3.*** *The graph shows the dependence of the height (h, mm) of the distilled water column in a capillary tube with a diameter of 0.1 mm on temperature (t, ºC).*

The graph in Figure 4 shows how long the reduced surface energy of water persists after mechanical activation. For distilled water, it takes only one minute to restore the properties characteristic of the state of rest.

The height of the rise of seawater rising in a capillary overtime (τ, s) is presented in Figure 5. Analysis of the curves (Figure 5a) allowed to establish that during vibration activation (v/a 1) and vibration mechanical activation (v-m/a 2), the height (h, mm) of seawater rising in the capillary has a stable growth. During vibration activation, the height (h,mm) of seawater rising in a capillary increases by 9%, and during vibration mechanical activation by 29%.

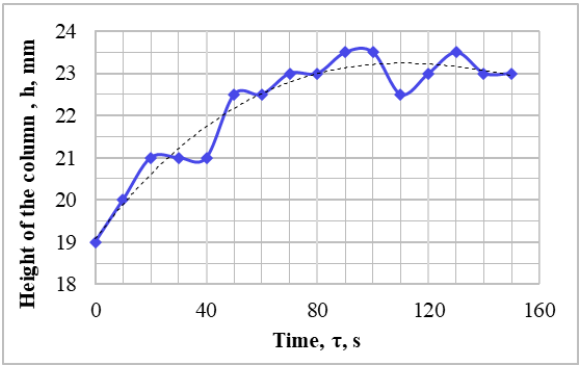


***Figure 4.*** *Changes in the height of the water column (h, mm) in a capillary tube of 0.1 mm over time (τ, s) after mechanical activation is in a state of rest.*

In the state of rest (figure 5-b), after vibration activation (v/a 1), the height of the rise (h, mm) of seawater in the capillary is unstable, showing a slight increase, followed by a sudden drop in height (h, mm) of seawater in the capillary by 26%, whereas the reverse process occurs after vibration mechanical activation (v-m/a 2) of seawater with an increase of 11%.

As the temperature increases, the surface tension of pure liquids decreases (the dependence σ = f(t) is close to linear) due to a decrease in the intensity of intermolecular forces. When a substance is added to a liquid, its surface tension can change depending on the nature of the dissolved substance and its concentration in the solution. Since seawater is a multicomponent system consisting of water molecules, salt anions and cations, and many other impurities, its parameters in most cases are determined by the partial composition of the elements in it. the most variable elements in seawater, and at the same time, the most significant factors affecting its behaviour, are salts [5, 6].

The graph (Figure 6) shows the dependence of the height of seawater rise in a capillary on the temperature (t, ºC), which changes during mechanical activation shown.

The surface properties of water solutions used in dough preparation in production were studied. The traditional ratio "flour/water/salt" of 100/60/2, also known as the "golden ratio," was used to prepare the solutions. The calculation was made for 2 liters of water. In physical terms, the ratio is 3.330 kg of flour / 2.000 kg of water / 0.066 kg of salt. The "water/salt" ratio gave a concentration of the aqueous salt solution of 3.33%.

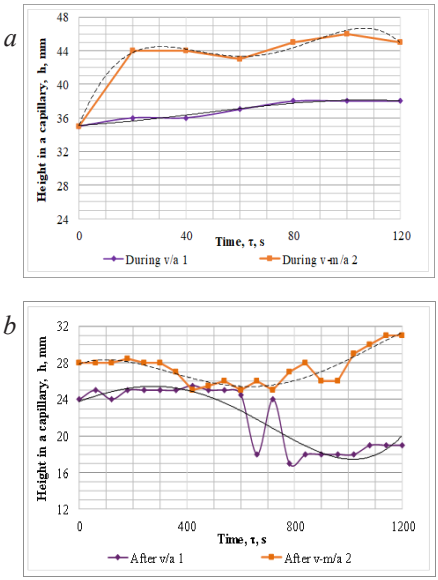


***Figure 5.*** *Height of the seawater rise (h, mm) in a capillary during vibration activation and vibration mechanical activation (a), and after vibration activation and vibration mechanical activation in a resting state (b) overtime (τ, s).*

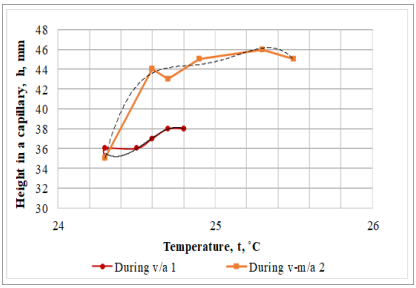


***Figure 6.*** *Dependence of the height of the seawater rise (h, mm) in a capillary on temperature (t, °C).*

Figure 7 shows the results of measurements of the height of the NaCl solution rise in a 0.1 mm diameter capillary. The surface tension of the salt solution decreases much faster compared to distilled water. The minimum is reached after 120-180 seconds of stirring. After 120 seconds, the surface energy decreases by 30%.

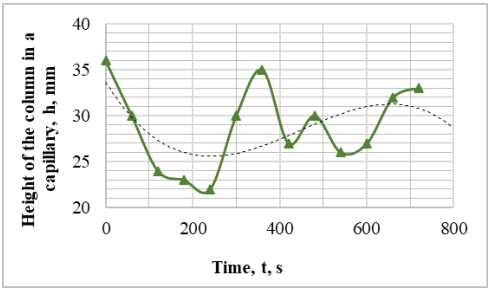


***Figure 7.*** *Dependency of the rise height (h, mm) of the NaCl solution (3.33%) in a 0.1 mm diameter capillary on mixing time (τ, s).*

The surface properties of a 1% flour solution were investigated during mixing. The measurement results are shown in Figure 8.

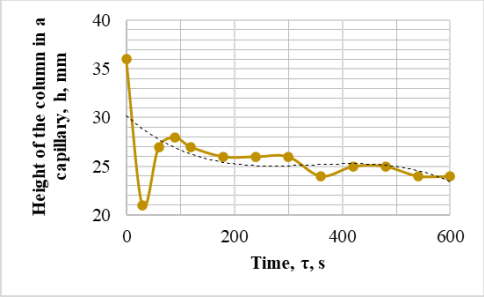


***Figure 8.*** *Dependence of the height rise (h, mm) of a 1% aqueous solution of flour in a capillary with a diameter of 0.1 mm on the mixing time (τ, s).*

The height of the solution column in the capillary sharply drops at the beginning of the process, decreasing by 40% in the first 60 seconds, then slightly increases but maintains a reduced value at the level of 25-30%.

Conclusion: 60 seconds of stirring is sufficient for the for mechanical activation of a 1% aqueous solution of flour.

An experiment was conducted to measure the surface energy during the stirring of a 3.3% NaCl solution with 1% flour. The results are presented in Figure 9.

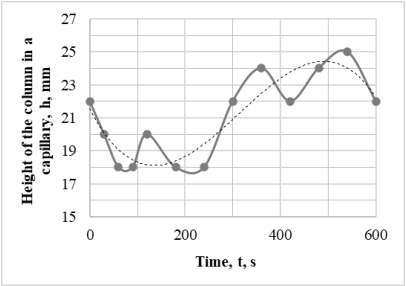


***Figure 9.*** *Dependence of the solution height (h, mm) of NaCl solution (3.33%) and flour (1%) in a capillary with a diameter of 0.1 mm on the mixing time.*

The minimum value of the solution column height in the capillary corresponded to a mixing time of 60–90 seconds. The decrease in the surface energy of the solution was approximately 20%.

When studying the effect of mixing (mechanical activation and vibration mechanical activation) solutions, it was shown that the minimum surface energy is achieved at a mixing time of 60–120 seconds.

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# ANALYSIS OF THE EFFECTIVNESS OF WELLBORE INTERVENTION TECHNIQUES ON INJECTION WELL STOCK

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***Annotation.*** *Analysis over the effectiveness of well intervention techniques on injection well stock is given in the article. The method of effectiveness evaluation over wellbore interventions on injection well stock is also presented. The research is being conducted by the way of functional relation determination of oil production reduction from the lack of well bore interventions on injection well stock. Retroactive prognosis of oil production increase is being viewed on production wells after well innervations being conducted on the system of reservoir pressure maintenance. The effectiveness of well workovers being conducted on the systems of reservoir pressure maintenance is evaluated in the article as well.*

***Keywords:*** *well workovers, wellbore intervention techniques, oil production ratio, reservoir pressure maintenance, bottomhole formation zone treatment.*

Wellbore interventions are being conducted on every oil deposit for the purpose of oil production maintenance stated in project documentation. These measures are being conducted on all the stages of oil field development but their role noticeably increases during the last oil field development stages. [1]

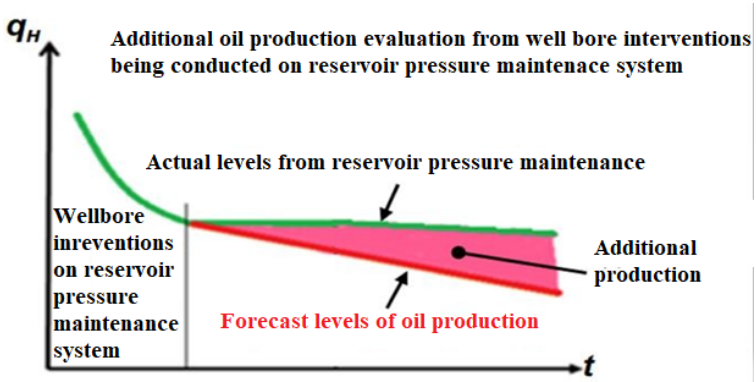
The fall in intake capability is inevitable during the work of an injection well due to some reasons such as: reduction of permeability in the bottomhole zone, loss of well containment between layers, decrease in displacement agent reservoir coverage due to asphaltene sedimentation, change in the operating mode of pumping equipment and other complications [2,3].

Wellbore intervention techniques are needed for oil production intensification by influencing on productive layers, to be exact – recovering and increasing permeability, increasing reservoir coverage by displacement agents, depression maintenance over the reservoir, isolation of waterflooded reservoirs and their intervals and etc.

In order wellbore interventions to be successful a comprehensive approach is needed [4]. The relevance of the work over wellbore interventions planning is due to further reasons:

- depletion of easily recovered oil stocks and the need of oil reservoir stimulation by applying different comprehensive technologies;
- by huge number of wells that require wellbore interventions;
- For technological effectiveness evaluation of wellbore interventions conducted on injection well stock a new method was developed that is based on the following algorithm:
- For functional dependence definition of oil production rate decline over the regions and oil and gas bearings with the usage of statistics over the wells without well innervations for additional production;
- For conducting oil production hindcasts of responding production wells with the usage of functional dependence of oil production rate decline from the moment of well innervations being conducted for reservoir pressure maintenance;
- Additional oil production ratio evaluation from wellbore interventions on reservoir pressure maintenance system as the difference of factual and retrospective levels of oil production over all responding production wells.

Described algorithm can be presented graphically on picture 1. Analysis of dependences obtained allows us to judge the effect of wellbore interventions conducted.




***Picture 1.*** *Additional oil production evaluation algorithm*

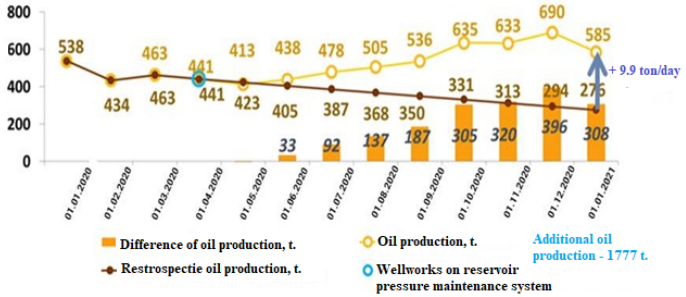
On picture 1 shown that initially the deposit was developed naturally, then implementation of reservoir pressure maintenance system was needed for full development of the hydrocarbon deposit. Without appliance of reservoir pressure maintenance system volume of produced oil would decrease according to forecast but factually volume of produced oil stabilized after implementation of reservoir pressure maintenance system and conducting wellbore intervention.

About 1194 injecting wells were analyzed with the usage of that method after wellbore workover having been conducted. Mean value of additional oil production amounted to 432 tones. Total additional oil production amounted to 516,557 tones. The average daily gain achieved up to 2.5 ton/day.

The main mean of oil production stabilization and increasing the effectiveness of oil reservoirs developing remains the method of conducting a huge number of wellbore interventions [6]. The importance of wellbore interventions being conducted on reservoir pressure maintenance system is as follows – zones with a huge volume of residual oil start to form during long periods of reservoirs development in the form of previously unreached oil saturated beds, lenses, bypassed hydrocarbons that causes the need of conducting such type of wellbore intervention as polymer solution injection into a reservoir with the purpose of blocking highly permeable and flooded areas and pressure redistributing in the reservoir. For example, polymer flooding leads to the development less oil saturated pores of a reservoir and allows to gain additional oil production.

Active planning of wellbore interventions allows to solve many tasks as the sum effect may lead to significant results.

On picture 2 presented an example of wellbore interventions being conducted effectively on reservoir pressure maintenance system during the year of wells exploitation [7].




***Picture 2.*** *The example of effectively conducted wellbore interventions on injection well stock*

Borehole zone treatment of the reservoir is one of the relatively inexpensive, effective and frequently used on the production method of injection wells' capacity increasing. For example, such technologies as injection of surfactant into borehole zone of injection well with the purpose of surrounding rocks hydrophilizing and also injection of acidic solutions for rock's permeability increasing significantly enhance capacity of injection wells that influences on oil production.

On picture 2 shown that oil production after applying wellbore interventions on the system of reservoir's pressure maintenance significantly more of projected oil production on the wells on which weren't conducted wellbore interventions. Oil production increase reached 9.9 ton/day which shows that applied methods of oil production intensification were highly effective. Thus, technological effectiveness evaluation of wellbore interventions conducted shows that oil production after all the measures having been taken significantly increased then on wells on which well works weren't conducted. In judging the appropriateness of wellbore interventions important to determine the primary production – production that would be on injection well stock without appliance of wellbore interventions and then to compare with known data of a similar oil deposit in which wellbore interventions were conducted. This will allow to produce oil more economically effectively on the exploited deposits.

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# A MODEL FOR CONSTRUCTING SHELL NUCLEI OF ATOMS BASED ON ELECTROMAGNETIC FORCES

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***Abstract.*** *In this paper, we propose a concept model for constructing atoms based on a shell structure model with justification for the need to arrange nucleons in a shell both geometrically and by spin orientation, models of some atoms and their isotopes are proposed, a model for the distribution of electrons by levels is proposed, and the process of the appearance of radiation is considered at transitions of electrons between levels, questions of the formation of angles, forces and the mechanism of chemical covalent bonds are considered.*

***Keywords:*** *mathematical model of the shell nucleus of an atom, models of atomic nuclei.*

**Model of the interaction of protons and neutrons in the shell model of the nucleus of atoms**

The proposed model of the interaction of protons and neutrons in the nucleus of atoms is based on the interaction of their magnetic fields and their charges. The assumption of the stability of their interaction in the shell of the nucleus of atoms is based on the fact that both neutrons and protons have a magnetic field, while taking into account that the force of interaction of electric charges is inversely proportional to the square of the distance between them, and the magnetic field is inversely proportional only to the distance. Accordingly, at , it was assumed that, as in the case with the model of the interaction of two protons, the system of neutrons and protons described in [1], in which these nucleons are oriented in such a way as to ensure their attraction by magnetic fields, will be able to be in some equilibrium as a result of the interaction of magnetic and Coulomb forces between them. The simulation took into account data on the internal structure (charge distribution) of the neutron. It should be noted that simulation calculations are based on the assumption that electrodynamics is valid at distances smaller than 10-14 cm.

In the simulation, it was assumed that protons and neutrons are in a stationary state, in the same plane, and their spins are perpendicular to the plane.

Data on the distribution of the electric charge of the neutron

The following data on the neutron charge distribution were found in the scientific literature: [2], [3], [4], [5], [6], [7].

Thus, we have 2 fundamental views on the charge distribution in the neutron - in one, the charge is divided into 2 parts, and in the other, the charge is divided into 3 parts.

In the work, the following charge distribution was adopted when distributing the neutron charge into 3 parts: the core with a radius of $\approx 0{,}25 \cdot 10^{-13}$sm, which has a total charge of $\approx +0{,}35$ *e*,. At a distance from $r_2 \approx 0{,}25 \cdot 10^{-13}$ to $\approx 1{,}4 \cdot 10^{-13}$sm this one has a total charge of $\approx -0{,}50$ *e*. Beyond a distance of $r_1 \approx 2{,}5 \cdot 10^{-13}$ sm from the center extends the shell carrying a total charge of about +0,15 *e*. Also, calculations were carried out with other proportions and charge distributions, even with the values of the distributed charge - the calculation models did not change significantly from these variations.

Accordingly, we have a scheme of forces in a simplified version, representing the neutron as a system of points with the charge of a proton and an electron located at a distance of 0.5 fm, and also a proton as a point (Fig. 1). Attention! Proportions are not met!

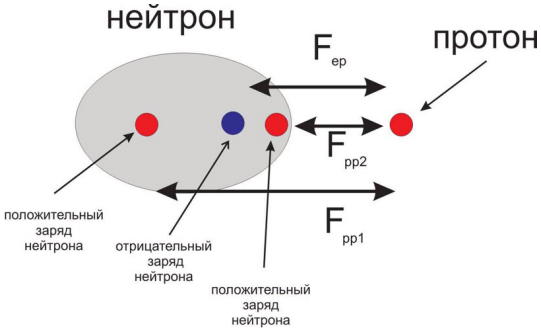



***Figure 1.*** *Scheme of forces of interaction between proton and neutron*

where Fep is the force of interaction between the positive and negative charges of the proton and neutron, $F_{pp1}$ is the force of interaction between the positive charge of the nucleus of the neutron and proton, , $F_{pp2}$ is the force of the interaction between the positive charge of the nucleus of the neutron and proton.

Let us introduce the notation of the distance between the regions of the neutron where $r_1$ is the distance from the middle of the outer positively charged region of the neutron to the middle of the negatively charged region of the neutron, $r_2$ is the distance from the center to the middle of the outer positively charged region (Fig. 2):

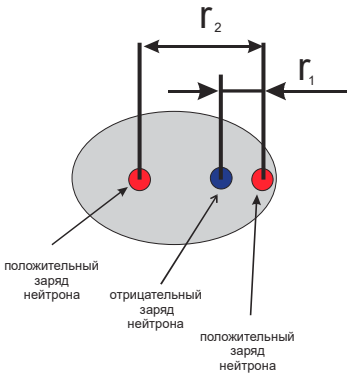



***Figure 2.*** *Designation of the distance between the regions of the neutron*

Let's introduce the designation of the distance between the regions of the neutron and the proton (Fig. 3)

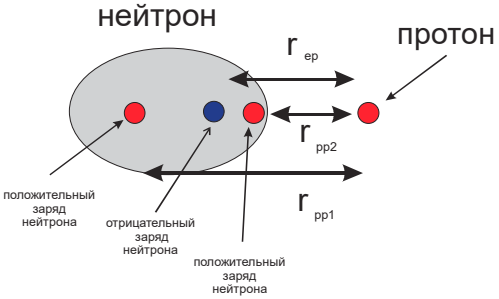



***Figure 3.*** *Designation of distances between proton and neutron regions*

Then we obtain an equation for calculating the electrostatic interaction of the charges of the neutron and proton regions

$$F_{np} = \frac{(0{,}5q_{ne}) \cdot q_p}{4\pi\varepsilon_0 r_{ep}^2} - \frac{(0.35q_{np}) \cdot q_p}{4\pi\varepsilon_0 r_{pp1}^2} - \frac{(0.15qn_p) \cdot q_p}{4\pi\varepsilon_0 r_{pp2}^2}$$

where $q_{ne}$- the negative part of the neutron charge, $q_{np}$ - the positive part of the neutron charge, $q_p$ - proton charge, $r_{ep}$ - distance from the part of the neutron with a negative charge to the proton, $r_{pp1}$ - the distance from the central part of the neutron to the proton, $r_{pp2}$ - the distance from the outer part of the neutron to the proton.

$$r_{pp1} = r_2 + r_{pp2}, r_{ep} = r_{pp2} + r_1$$

But it is necessary to take into account the interaction of the magnetic fields of the proton and neutron. Considering the proton and neutron as a system of conducting elements [1], we will calculate the interaction of these elements as the interaction of conductors with current.

As you know, conductors with unidirectional currents are attracted, and multidirectional ones repel (Fig. 4 below)

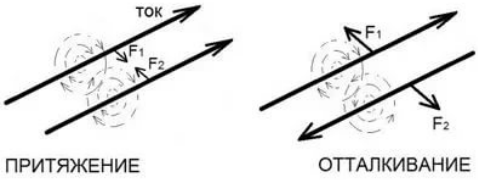



***Figure 4.*** *Interaction of conductors with current*

Let us consider the interaction of magnetic moments according to Fig. 5 below:

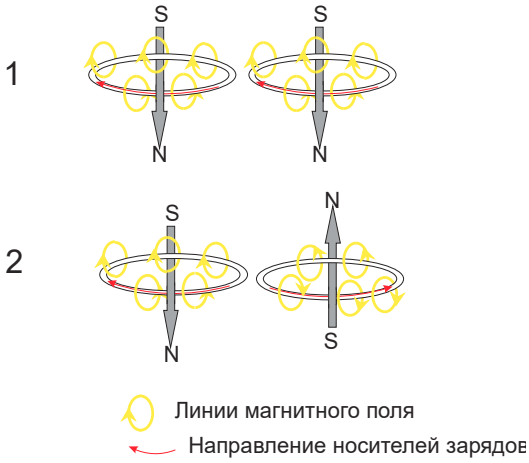



***Figure 5.*** *On the interaction of particle spins*

Thus, depending on the orientation of the spins, the spin magnetic interaction of nucleons (proton and neutron) will either attract [p.2 Fig.5 To the interaction of particle spins] or repel them [p.1 Fig.5 To the interaction of particle spins].

The force of interaction of 2 conductors with current is known to be determined by the formula:

$$F = \frac{\mu_0 I_1 I_2}{2\pi r} L$$

We believe that the magnetic force attracts a proton and a neutron, then the sum of the forces between one proton and one neutron lying in the same plane will be

$$F_{суммарная} = \left( \frac{(0{,}5q_e)\cdot q_p}{4\pi\varepsilon_0 r_{ep}^2} - \left( \frac{(0.35q_p)\cdot q_p}{4\pi\,\varepsilon_0 r_{pp1}^2} + \frac{(0.15q_p)\cdot q_p}{4\pi\varepsilon_0 r_{pp2}^2} \right) \right) + \frac{\mu_0 I_p I_n}{2\pi r_{pp1}} \cdot 0{,}175 \cdot 10^{-15}$$

where· $0{,}175 \cdot 10^{-15}$ estimated quark size [1].

We obtain the calculated data for one proton and one neutron at $q_p=1{,}60\cdot10^{-19}$ Kl, $q_1=2{,}40\cdot10^{-20}$ Kl, $q_2=8{,}00\cdot10^{-20}$ Kl, $q_3=5{,}60\cdot10^{-20}$ Kl, $r_1=1{,}50\cdot10^{-15}$ m, $r_2=2{,}50\cdot10^{-15}$ m.

| **rpp2, м** | 1,00E-19 | 2,00E-19 | 3,00E-19 | 4,00E-19 | 5,00E-19 | 6,00E-19 | 7,00E-19 | 8,00E-19 | 9,00E-19 | 1,00E-18 | 1,10E-18 | 1,20E-18 | 1,30E-18 | 1,40E-18 | 1,50E-18 | 1,60E-18 | 1,70E-18 | 1,80E-18 | 1,90E-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fсуммарная-оу, Н** | -3,06E+09 | -1,54E+09 | -5,86E+08 | -2,73E+08 | -1,39E+08 | -7,14E+07 | -3,40E+07 | -1,20E+07 | 1,69E+06 | 1,04E+07 | 1,60E+07 | 1,97E+07 | 2,22E+07 | 2,37E+07 | 2,47E+07 | 2,52E+07 | 2,54E+07 | 2,55E+07 | 2,54E+07 |

We get the calculated one proton and one neutron at $q_p=1{,}60\cdot10^{-19}$ Kl, $q_1=1{,}20\cdot10^{-20}$ Kl, $q_2=4{,}00\cdot10^{-20}$ Kl, $q_3=2{,}80\cdot10^{-20}$ Kl, $r_1=1{,}50\cdot10^{-15}$ m, $r_2=2{,}50\cdot10^{-15}$ m.

| **rpp2, м** | 1,00E-19 | 2,00E-19 | 3,00E-19 | 4,00E-19 | 5,00E-19 | 6,00E-19 | 7,00E-19 | 8,00E-19 | 9,00E-19 | 1,00E-18 | 1,10E-18 | 1,20E-18 | 1,30E-18 | 1,40E-18 | 1,50E-18 | 1,60E-18 | 1,70E-18 | 1,80E-18 | 1,90E-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fсуммарная-оу, Н** | -1,34E+09 | -5,47E+08 | -1,43E+08 | -2,39E+07 | 2,08E+07 | 3,95E+07 | 4,74E+07 | 5,04E+07 | 5,09E+07 | 5,03E+07 | 4,90E+07 | 4,74E+07 | 4,58E+07 | 4,41E+07 | 4,24E+07 | 4,08E+07 | 3,92E+07 | 3,78E+07 | 3,64E+07 |

We obtain the calculated data (one proton and one neutron at $q_p=1{,}60\cdot10^{-19}$ Kl, $q_1=4{,}80\cdot10^{-20}$ Kl, $q_2=1{,}60\cdot10^{-19}$ Kl, $q_3=1{,}12\cdot10^{-19}$ Kl, $r_1=1{,}50\cdot10^{-15}$ m, $r_2=2{,}50\cdot10^{-15}$ m.

| **rpp2, м** | 1,00E-18 | 1,10E-18 | 1,20E-18 | 1,30E-18 | 1,40E-18 | 1,50E-18 | 1,60E-18 | 1,70E-18 | 1,80E-18 | 1,90E-18 | 2,00E-18 | 2,10E-18 | 2,20E-18 | 2,30E-18 | 2,40E-18 | 2,50E-18 | 2,60E-18 | 2,70E-18 | 2,80E-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| **Fсуммарная-оу, Н** | -3,01E+07 | -4,99E+07 | -3,57E+07 | -2,51E+07 | -1,70E+07 | -1,08E+07 | -5,98E+06 | -2,17E+06 | 8,44E+05 | 3,26E+06 | 5,19E+06 | 6,76E+06 | 8,02E+06 | 9,04E+06 | 9,87E+06 | 1,05E+07 | 1,11E+07 | 1,15E+07 | 1,19E+07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

As can be seen from the calculated data, a point of stability is observed (highlighted by thick lines in the table) despite the use of different values of the charges of the neutron regions.

Consider 2 protons (Figure 6 below)

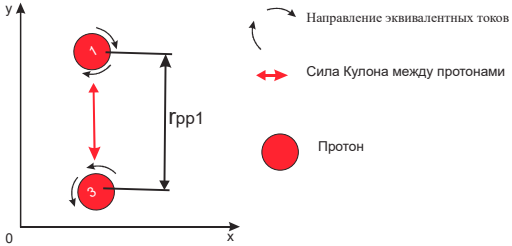



***Figure 6.*** *System of 2 protons*

For two protons, we obtain the calculated data

| **rpp1, м** | 1,00E-18 | 1,10E-18 | 1,65E-18 | 2,48E-18 | 3,71E-18 | 5,57E-18 | 8,35E-18 | 1,25E-17 | 1,88E-17 | 2,82E-17 | 4,23E-17 | 6,34E-17 | 9,51E-17 | 1,43E-16 | 2,14E-16 | 3,21E-16 | 4,82E-16 | 7,23E-16 | 1,08E-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fсуммарная-оу, Н** | -1,73E+08 | -1,39E+08 | -5,01E+07 | -1,46E+07 | -1,36E+06 | 2,80E+06 | 3,52E+06 | 3,08E+06 | 2,38E+06 | 1,73E+06 | 1,22E+06 | 8,41E+05 | 5,73E+05 | 3,88E+05 | 2,61E+05 | 1,75E+05 | 1,17E+05 | 7,84E+04 | 5,24E+04 |

As can be seen from the calculated data, there is a point of stability (highlighted by thick lines in the table).

Accordingly, we can assume a shell structure of the nucleus, similar to which is shown in Figure 7 below.


***Figure 7.*** *Estimated structure of the core in the shell model*

In this concept of building a kernel, it is possible to build an exclusively shell model, since it alone allows all the nucleons of the nucleus to be located on the surface of the sphere. The following elementary cells (constructives) of the core shell were calculated to obtain a stable state (Fig. 8 below):

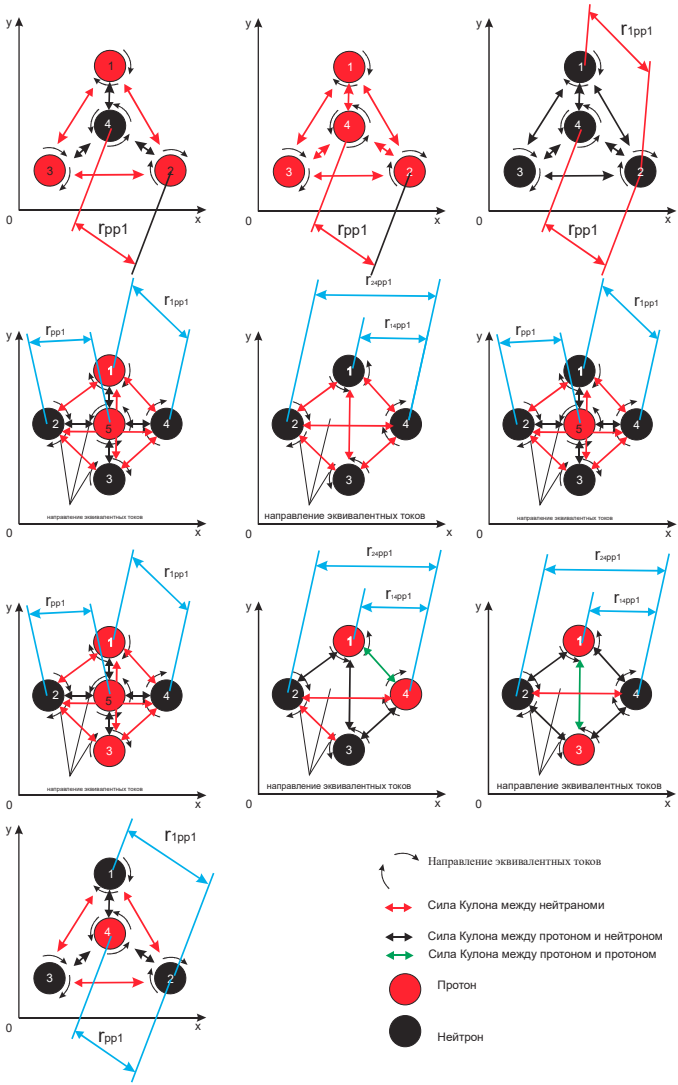



***Figure 8.*** *Elementary cells (constructs) of the shell of the nucleus*

**Conclusions**

1. when the neutron charges are distributed into 3 zones, a stable position of nucleons is observed with a certain distance between them, with the exception of the model of a cell of 3 neutrons around the neutron in which the nucleons are in contact. In the distribution of neutron charges, sticking of nucleons is observed in some constructs.

2. certain combinations are stable cells for building the nucleus.

Atomic isotope models

This chapter presents models of isotope nuclei of some atoms, created on the basis of calculated elementary cells, which was done in the previous chapter. In the models, protons and neutrons are numbered without number 6 in order not to confuse number 6 with number 9. The directions of equivalent currents are also indicated by arrows.

Helium

It will calculate the parameters of the helium nucleus, according to the model specified in [8], but taking into account the data obtained, we will finalize the model of the helium atom as shown in Fig. 9 The model of the helium atom:

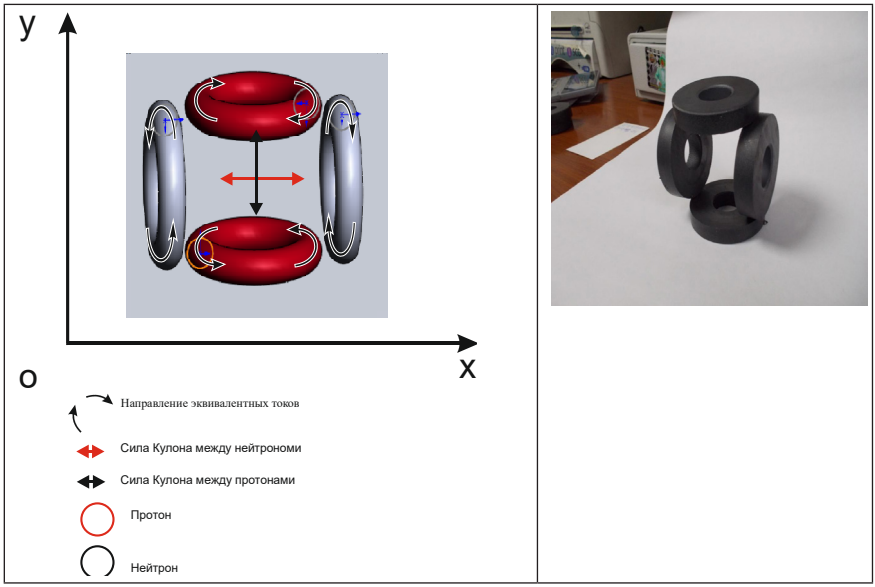



***Figure 9.*** *Model of helium nucleus 4 helium and simulation of helium nucleus 4 by permanent magnets without taking into account electrostatic interaction.*

We get the sum of forces

$$F_{суммарная-оу} = 2\left(\frac{(0{,}5q_e)\cdot q_p}{4\pi\varepsilon_0 r_{ep}^2} - \left(\frac{(0.35q_p)\cdot q_p}{4\pi\varepsilon_0 r_{pp1}^2} + \frac{(0.15\,q_p)\cdot q_p}{4\pi\varepsilon_0 r_{pp2}^2}\right)\right) - \frac{q_p^2}{4\pi\varepsilon_0 r_{pp1}^2} +$$

$$+2\cdot\frac{\mu_0 I_p I_n}{2\pi r_{pp1}}\cdot 0{,}175\cdot 10^{-15} - 2\cdot\frac{\mu_0 I_p I_p}{2\pi\cdot 1{,}41\cdot r_{pp1}}\cdot 0{,}175\cdot 10^{-15}$$

Get calculated data

| rpp2, м | rpp1, м | rep, м | Fпр-н кулона, Н | Fпр-пр кулона, Н | Fмагпр-пр, Н | Fмагпр-н, Н | | Fсуммарная-оу, Н |
|---|---|---|---|---|---|---|---|---|
| 1,00E-17 | 2,60E-16 | 1,20E-16 | -3,39E+05 | 3,41E+03 | 1,45E+05 | 1,50E+05 | | -6,71E+05 |
| 1,70E-17 | 2,67E-16 | 1,27E-16 | -1,14E+05 | 3,23E+03 | 1,41E+05 | 1,46E+05 | | -2,20E+05 |
| 2,40E-17 | 2,74E-16 | 1,34E-16 | -5,46E+04 | 3,07E+03 | 1,38E+05 | 1,42E+05 | | -1,03E+05 |
| 3,10E-17 | 2,81E-16 | 1,41E-16 | -3,12E+04 | 2,92E+03 | 1,34E+05 | 1,39E+05 | | -5,59E+04 |
| 3,80E-17 | 2,88E-16 | 1,48E-16 | -1,96E+04 | 2,78E+03 | 1,31E+05 | 1,36E+05 | | -3,29E+04 |
| 4,50E-17 | 2,95E-16 | 1,55E-16 | -1,32E+04 | 2,65E+03 | 1,28E+05 | 1,32E+05 | | -2,01E+04 |
| 5,20E-17 | 3,02E-16 | 1,62E-16 | -9,27E+03 | 2,53E+03 | 1,25E+05 | 1,29E+05 | | -1,24E+04 |
| 5,90E-17 | 3,09E-16 | 1,69E-16 | -6,74E+03 | 2,41E+03 | 1,22E+05 | 1,26E+05 | | -7,40E+03 |
| 6,60E-17 | 3,16E-16 | 1,76E-16 | -5,02E+03 | 2,31E+03 | 1,19E+05 | 1,24E+05 | | -4,05E+03 |
| 7,30E-17 | 3,23E-16 | 1,83E-16 | -3,82E+03 | 2,21E+03 | 1,17E+05 | 1,21E+05 | | -1,72E+03 |
| 8,00E-17 | 3,30E-16 | 1,90E-16 | -2,95E+03 | 2,11E+03 | 1,14E+05 | 1,18E+05 | | -6,33E+01 |
| 8,70E-17 | 3,37E-16 | 1,97E-16 | -2,31E+03 | 2,03E+03 | 1,12E+05 | 1,16E+05 | | 1,14E+03 |
| 9,40E-17 | 3,44E-16 | 2,04E-16 | -1,82E+03 | 1,95E+03 | 1,10E+05 | 1,13E+05 | | 2,03E+03 |
| 1,01E-16 | 3,51E-16 | 2,11E-16 | -1,45E+03 | 1,87E+03 | 1,07E+05 | 1,11E+05 | | 2,69E+03 |
| 1,08E-16 | 3,58E-16 | 2,18E-16 | -1,17E+03 | 1,80E+03 | 1,05E+05 | 1,09E+05 | | 3,19E+03 |
| 1,15E-16 | 3,65E-16 | 2,25E-16 | -9,43E+02 | 1,73E+03 | 1,03E+05 | 1,07E+05 | | 3,57E+03 |
| 1,22E-16 | 3,72E-16 | 2,32E-16 | -7,64E+02 | 1,66E+03 | 1,01E+05 | 1,05E+05 | | 3,86E+03 |
| 1,29E-16 | 3,79E-16 | 2,39E-16 | -6,21E+02 | 1,60E+03 | 9,96E+04 | 1,03E+05 | | 4,07E+03 |
| 1,36E-16 | 3,86E-16 | 2,46E-16 | -5,06E+02 | 1,55E+03 | 9,77E+04 | 1,01E+05 | | 4,24E+03 |
| 1,43E-16 | 3,93E-16 | 2,53E-16 | -4,12E+02 | 1,49E+03 | 9,60E+04 | 9,93E+04 | | 4,36E+03 |
| 1,50E-16 | 4,00E-16 | 2,60E-16 | -3,36E+02 | 1,44E+03 | 9,43E+04 | 9,76E+04 | | 4,45E+03 |

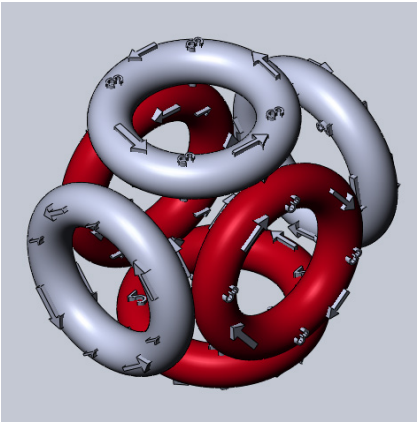
As you can see, the calculated data show the presence of a stability point (highlighted by bold lines in the table).

It should be noted that according to this scheme, in the center, both from protons and from neutrons, a region of meeting of oppositely directed magnetic field flows is formed, which plays the role of a plug in a magnetic trap, preventing electrons from penetrating into the center of the nucleus.

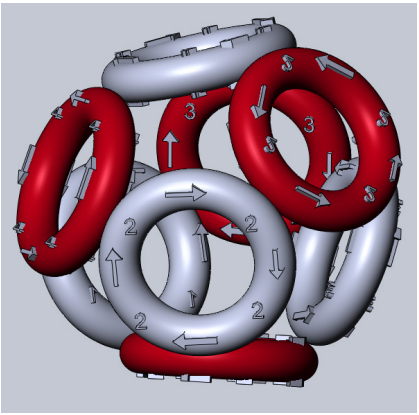
Models of some kernels

In the proposed models, protons are displayed in red, neutrons in gray. Arrows show equivalent currents

**Lithium 6**



**Beryllium 8**



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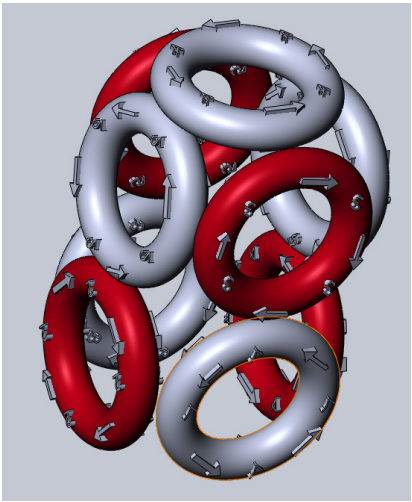

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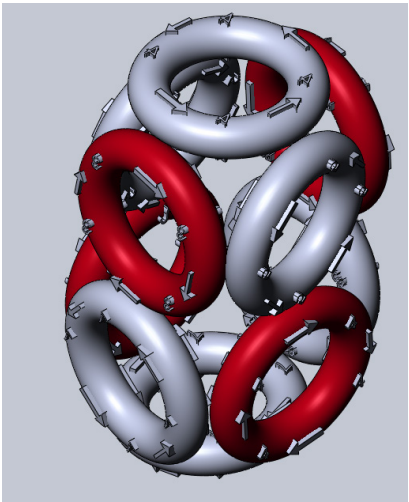

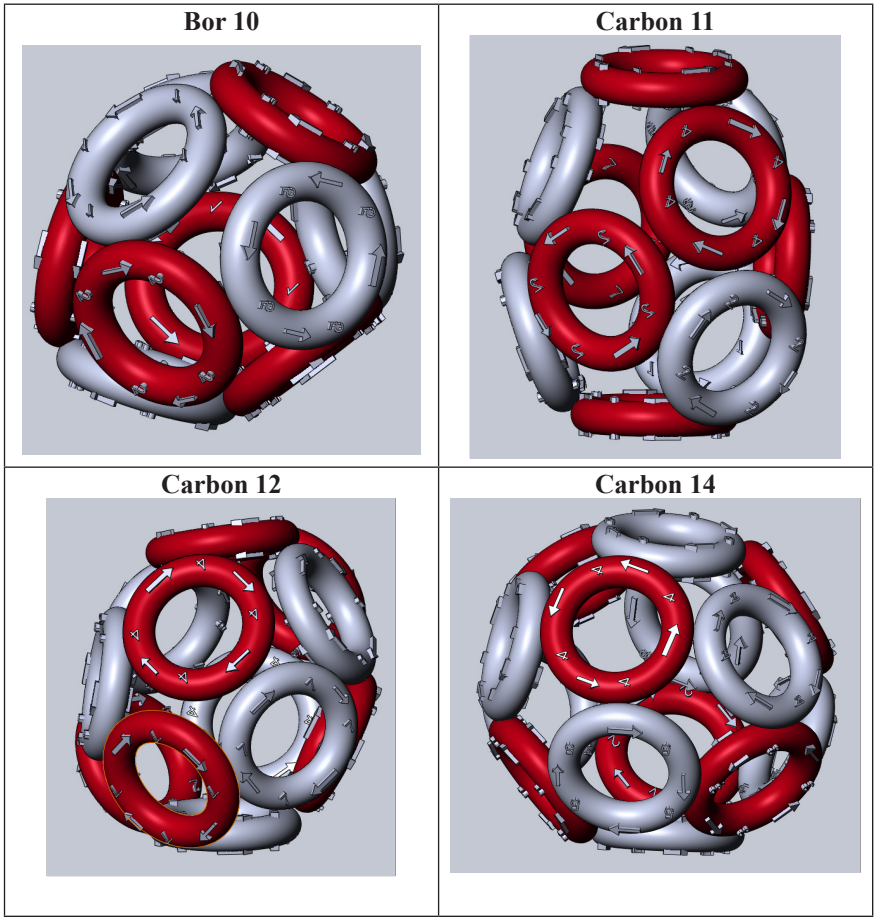


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# THE MODEL OF ELECTRON LEVEL DISTRIBUTION AND THE MECHANISM OF RADIATION FORMATION DURING THE TRANSITION BETWEEN LEVELS IN SHELL MODELS OF ATOMIC NUCLEI

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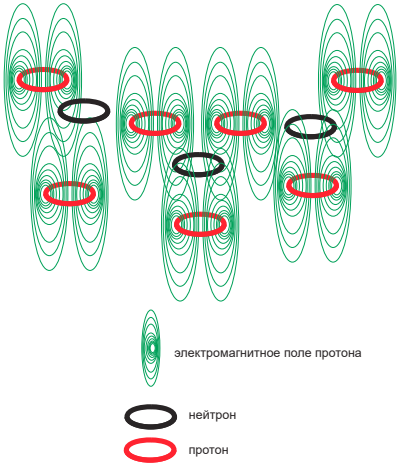
***Abstract.*** *In this paper, we propose for consideration a model of the distribution of electrons by levels and radiation during the transition between electron orbits in the shell nuclei of atoms.*

***Keywords:*** *model of distribution of electrons over levels, the mechanism of the appearance of radiation during the transition of an electron between the levels of an atom.*

**Model of distribution of electrons by levels**

Let's place several triangular-shaped kernel cells side by side to simulate a plot ядра




*core surface (Fig.1):*

***Figure 1.*** *Imitation of the surface of the nucleus.*

Each of the protons forms a magnetic mirror with its own electromagnetic field, which reflects the electron incident on the proton. The confinement process was considered in [1]; therefore, we only point out that the greater the energy, i.e. the speed of an electron moving in the field of a proton, the closer it will be to a proton, and vice versa - the lower the speed of an electron in the field of a proton, the farther it will be from the proton. This is due to the fact that the reflection effect is due to the fact that when a particle moves into a region of a stronger field, under certain conditions, its transverse velocity v^ increases and the "transverse energy" of the particle mv^2 associated with this velocity increases. Therefore, the lower the electron speed, the faster the transverse and longitudinal velocities will become equal and, accordingly, its movement to the area of increasing field strength will stop, i.e. to the proton.

The consequence is that electrons with the highest energy are located near the proton, that is, in the lowest orbits.

For simplicity and clarity of the formation of electron orbits, we present a simplified picture of the distribution of protons. We arrange several protons in a row as in Fig. 2 and place 1 electron in the field of each proton, respectively. It should be noted that the location of electrons above the proton plane does not correspond to the scale of the atom to reduce the size of the circuit.

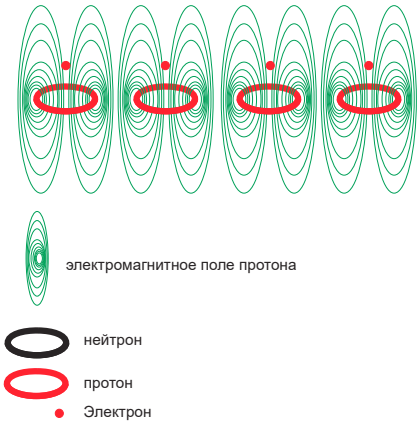



***Figure 2.*** *simplified picture of the distribution of electrons by levels*

It is obvious that the electrons will influence each other since they carry a charge and since it is extremely unlikely that all electrons will move simultaneously along exactly the same trajectories and the protons will also oscillate along absolutely the same trajectories, a situation will inevitably arise in which the electrons will occupy different heights above the plane of protons - Fig.3.

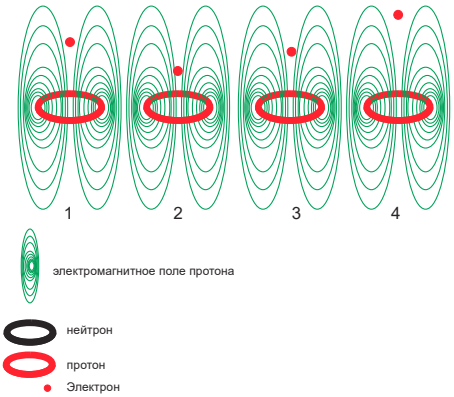



***Figure 3.*** *simplified picture of the distribution of electrons by levels*

It is obvious that an electron in the proton-electron system No. 2, rising above the proton plane, will, with its electrostatic field, push up the electrons in the neighboring proton-electron systems No. 2. At the same time, the electrons of systems No. 1 and No. 3, in an effort to descend to the plane of protons, will press the electron of system No. 2, preventing it from going higher. Thus, a system of electrons of different levels is formed in the nucleus.

The mechanism of the appearance of radiation during the transition of an electron between levels in an atom

Consider this process based on the shell model of the atomic nucleus. The heavier the nucleus, the more protons in it and, accordingly, the stronger its electric field. The stronger the electric field, the closer the electrons will be to the nucleus. The closer the electrons are to the nucleus, the closer the nuclei will be located to each other, i.e. electron shells will be smaller. Let us consider the transition process from level A (upper) to level B (lower) according to Figure 4 below:

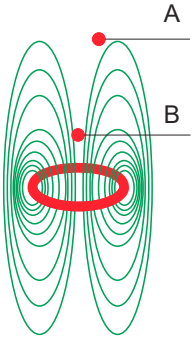



***Figure 4.*** *To the process of electron transition by levels*

Obviously, at level A, the electric field strength of the nucleus is less than at level B. Accordingly, when moving from level A to level B, the electron will be accelerated by the electric field of the atomic nucleus.

Let us estimate this energy, which an electron can gain when moving from the upper orbit to the level of the nucleus, using the example of a tungsten atom, which has 74 protons in the nucleus. We will assume that at point A the electron had no velocity in the direction of the nucleus, i.e. had speed $V_{\text{к ядру}}=0$.

From the theory of operation of linear accelerators, it is known that at high-voltage acceleration by an electrostatic field, the maximum energy of particles $\Delta E_{\text{макс}}$ after passing through the gap with a potential difference **U** is [2]:

$$\Delta E_{\text{макс}} = e \Delta U_{\text{макс}}$$

The radius of the tungsten nucleus is calculated by the formula $R \approx 1.3 A^{1/3} \cdot 10^{-13}$sm, where A – is the number of nucleons (the total number of protons and neutrons) in the nucleus [3].

Then $R \approx 1.3\ 184^{1/3} \cdot 10^{-13}\text{sm} = 7.4 \cdot 10^{-13}\text{sm} = 7.4 \cdot 10^{-15}$ m

For the radius of the upper orbit, we take the radius of the tungsten atom - $1{,}81 \cdot 10^{-10}$m

if the electron approaches the level of the nucleus, then the potential difference between the orbits is defined as $\varphi = \frac{kQ}{r_1} - \frac{kQ}{r_2}$=14400000 в

where k -coefficient,$r_1$ and $r_2$ are respectively the radii of the orbits, Q is the charge of the nucleus.

For comparison, the voltage in X-ray tubes is 50-200 kW. [4]

Field strength through potentials

$$E = \frac{\varphi_2 - \varphi_1}{l} = \frac{14400000}{1{,}81 \cdot 10^{-10} - 7.4 \cdot 10^{-15}} = 7.96 \cdot 10^{16} \text{v/m}$$

where $l$ - the distance between the points of the potentials, $\varphi_2$ and $\varphi_1$ the potentials of 2 points.

The maximum energy of the electron then $\Delta E_{\text{макс}}=2{,}304 \cdot 10^{-12}$ =14.4 MeV which is more than enough to generate X-rays with a radiation mechanism as in wigglers and undulators, since when reflected by a magnetic field, the electron will have to pass through the equipotential lines of the electromagnetic field of the nucleus, radiating and losing energy. Why would such an electron pass through equipotential lines? This will happen because a change in the mass and speed of an electron will cause a change in the Larmor radius of its movement in a field with a changing strength [5] (Fig. below).

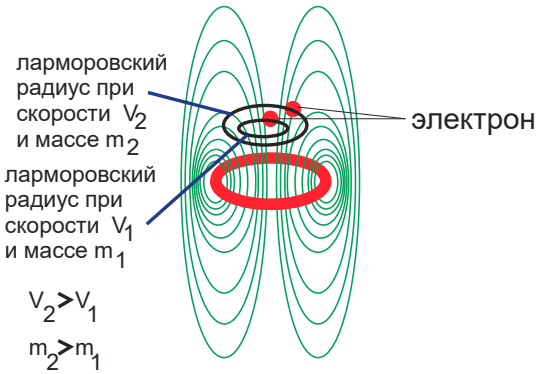



***Figure.*** *Change in the Larmor radius with a change in the electron mass*

In addition, although the energy of 14.4 MeV is not comparable with the GeV obtained in synchrophasotrons, it will correspond to the subluminal speed. Accelerating to subluminal speed, the electron will increase its mass. The larger the nucleus, the stronger it attracts the electrons - the greater the speed they have circling in the field of the proton and the greater the change in the energy of the electron and, accordingly, the more relativistic effects will appear. This means that it is no longer possible to use classical mechanics to calculate the trajectory of such electrons.

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# THE ROLE OF ADVANCED MINERALOGICAL STUDIES OF RARE METAL ORES IN PREDICTING TECHNOLOGICAL PROPERTIES AND CHOOSING OPTIMAL TECHNOLOGICAL SOLUTIONS

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***Abstract.*** *Modern problems of mineralogical and technological support in the system of geological study of the subsoil are considered. On separate actual examples, it is shown that with the development of new methods, technological mineralogy is becoming increasingly important every year in the complex of geological exploration in the evaluation of metal ores and industrial minerals. The results of studying the relationship between the composition, structure, physical properties and genetic characteristics of a mineral substance with its technological properties are considered. The results of geological and technological mapping are presented on the example of specific objects.*

***Keywords:*** *rare metal ores, stages of geological exploration, technological mineralogy, method, evaluation, geological and technological mapping.*

## Introduction

Metallurgical mineralogy summarizes geological and mineralogical-technological studies related to the study of the material composition, textural and structural features of minerals, and technological properties of minerals, aimed at developing rational benefication schemes, and the integrated use of mineral raw materials. Currently, metallurgical mineralogy takes the position of an independent discipline that serves as a bridge connecting the ore geology and the mineral processing techniques in order to obtain the final product. The relationship between the composition, structure, physical properties and genetic characteristics of a mineral substance with its metallurgical properties is studied, which determines the technological assessment of mineral raw materials. At the same time, the role of applied mineralogical research has sharply increased in predictive technological evaluation of mineral raw materials at different stages of study and development of deposits with a fairly high degree of reliability.

**Techniques and methods**

For a number of years, in the study of complex rare-metal ores, the IMGRE researchers have been using methods that provide complete quantitative analyzes: high-resolution optical microscopy, X-ray spectral microanalysis, scanning electron microscopy, X-ray quantitative phase analysis and, to a certain extent, IR-spectroscopy. The listed methods enable identification, diagnosis and evaluation of all the phases available for detection.

Results and discussion

The material composition specialties of rare-metal weathering profile were studied on the material of 50 metallurgical samples of the Chuktukon deposit [1].. Twenty and more 20 minerals are the components of the local ores.

The major ore minerals are goethite, hematite, and oxyhydroxides of manganese composing finely dispersed multi-mineral aggregates [2].

Niobium mineralization is carried by Minerals of the pyrochlore group are dominants of Nb mineralization; these are represented by several varieties: Sr-Ce, Sr-Ba, Sr, and Ba-Ce-Sr. Pyrochlore is noted as fine disseminations unevenly distributed in the ore. Figures 1.1 – 1.3 (BSE images) demonstrate the phase inhomogeneity of pyrochlore.

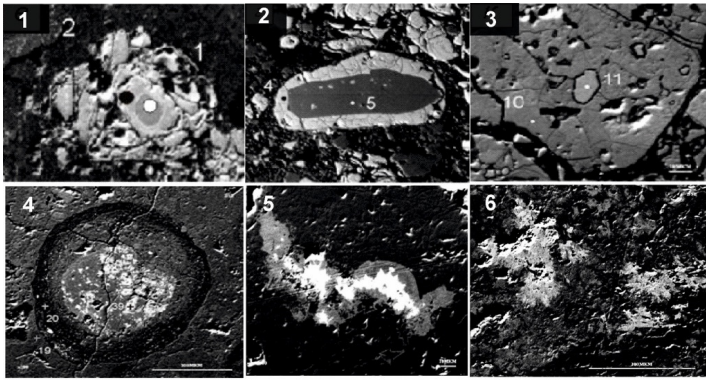


***Figure 1.*** *Forms of occurrence of ore minerals, the Chuktukon deposit: 1 - relic block of primary pyrochlore in secondary newly formed pyrochlore; 2 - skeletal forms of pyrochlore, with goyazite-florensite filling the inner zone, whereas Sr-pyrochlore concentrates in the outer zone;*
*3 - euhedral cuboctahedral crystals and substitution of internal parts of pyrochlore grains by goyazite-florensite; 4, 5 - BSE images of monazite (La) in oolitic ironstone (x300 and x600);*
*6 - BSE image of cerianite covering the walls of cracks filled out with sintered goethite*

Major rare earth minerals here are monazite and cerianite.

Monazite, which is the main rare earth mineral in the Chuktukon ores, has been reliably identified and studied by several mineralogical methods, among which methods of precision mineralogy dominated. Monazite occurs in the form of powdery masses and porous aggregates formed by tabular and elongated prismatic grains a few micrometers in size. The electron microscopy images clearly display two varieties of monazite: (i) cryptocrystalline block microstructure, sometimes with elements of metacolloidal microstructures, and (ii) collomorphic with pronounced metacolloidal features. It closely associates with lining Fe-hydroxides (Fig. 1.4, 1.5).

Cerianite was identified by X-ray analysis in trace amounts in globular siderite concretions containing quartz and kaolinite. The mineral forms aggregates of irregular, sometimes rounded shape (Fig. 1.6). It is rich in cerium (49.13–63.15%).

Ore minerals are closely associated with each other and rock-forming phases, forming polymineral aggregates of complex composition, frequently highly dispersed.

Natural features of pyrochlore-monazite-goethite ores of the Chuktukon ore field and its economic components: high dispersion of minerals and their close intergrowths with Fe-hydroxides, kaolinite and with each other; complex types of corrosion intergrowths of pyrochlore with iron hydroxides, increased fragility of secondary pyrochlore, and a tendency to overgrinding cause the impossibility of their mechanical concentration. The revealed patterns of the ratio of the main ore minerals - pyrochlore, monazite and non-metallic minerals with oxides, Fe- and Mn-hydroxides determined the technology for processing complex ores of the Chuktukon ore field, this new large-scale source of the rare metal mineralss. Multiple extraction of economic components from these ores is possible only by hydrometallurgy [3].

Algama (Khabarovsk krai, Russia) is among the three known Zr objects; it carries two major associating Zr minerals, baddeleyite and zircon. Two other deposits are Poços de Caldas, Brasil, and Kunek (a deposit of smaller potential) located in Central Kazakhstan.

Algama lies in the east of the Siberian Platform at its conjunction with the Yudomsk-Maysk pericratonic basin, NE of the Ingili Mass [4]. It occurs in sandstone and marmorized

Zirconium ore of Algama are of hydrothermal origin; these are of complex composition and occur in quartz-carbonate breccia.

Using a set of analytical techniques, we established mineralogical composition and structural features of the gravity concentrates – products of Algama ore processing, along with specialties of major Zr concentrators, zircon and baddeleyite.

Zr-bearing mineral aggregate, a close association of crypto-crystalline zircon spherolites with goethite, hydrogoethite, limonite, clay minerals, silica, quartz,

and carbonates, is a typical product of supergenic processes. Zircon, baddeleyite and limonite form cryptocrystalline accumulations which, along with quartz neoforms, cements the hosting rock (dolostone) fragments (fig. 2).

Zirconium occurs as oxides and silicates, which form fine intergrowings including other mineral species. Such aggregates are spherical (fig. 2.1), reniform (fig. 2.2), tabular (fig. 2.3). Spherical aggregates consist of radially oriented acicular microcrystals; reniforms are lamellar, whereas oxides (light gray) and silicates (dark gray) in their tabular aggregates are finely mixed.

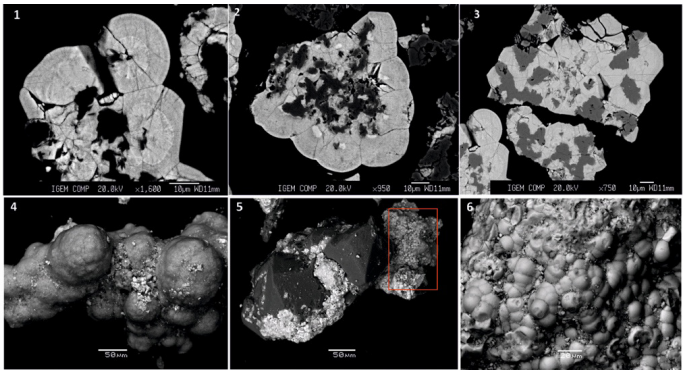


***Figure 2.*** *Forms of occurrence of zirconium phases in the ores of the Algaminskoe deposit:*
*1 - aggregates are spherical, 2 - reniform, 3 - tabular, 4 – Zr mineral coatings (groups of light-colored grains) covering finely fibrous crystals of a Ba-bearing Mn mineral (psylomelan group); 5 – coatings consisting of spherical aggregates covering quartz crystals and forming intergrowings with mica (red rectangle); 6 – colloform accumulations of spherical and reniform Zr phases;*

As a rule, central parts of these particles consist of silicates, whereas oxide prevails in their peripheries. With gradual substitution of silicates for oxides from center to periphery, the silicate component gains Ca, Al and P, whereas the oxide one absorbs U. Content of Hf remains within the 0.7 – 1.4 mass % interval. Figure 2.1-2.3 demonstrates that the rims are the most light-colored. The rims consist of the baddeleyite microaggregates what may signify gradual removal of silicates and carbonates from the solution whereas oxides remainedZr phases are represented as highly dispersed accumulations coating surfaces and filling out voids between grains of quartz and other minerals (fig. 2.4.-2.6).

Prevailing grain size of Zr minerals is ca. 20 – 40 μm. Thus their greatest proportion occurs in fine fractions of the ore.

The studies we carried out demonstrated chemical inhomogeneity of Zr microaggregates: superfine particles of Zr silicate (dark) and oxide (the lightest fragments in the photo) were formed at a micro-level: dimensions of the crystalline particles were much less than 1 μm.

Baddeleyite occurs as very fine (160-200 Å) particles. Thermal analysis established that these particles are cemented with quasi-amorphous silicate and/or carbonate substance and form radial axial or breccia-like micro-aggregates coexisting with this substance [6]. As minimum diameter of the electron beam is ca. 1 μm, capture of the Zr-bearing matrix parts occurs, what hampers XRA data interpretation. Thus, only chemistries of microaggregates could be discussed.

An important distinctive feature of the Algama Zr minerals is presence of significant $WO_3$ content (0.90 – 2.63%) and silica (1.32 – 14.18%). Speciation of tungsten remains unknown. Silicon occurs in the micro-aggregates as amorphous silica as confirmed by thermal analysis data.

Speciation of Zr minerals, their high dispersity, genetic relationship with hydroxyl group and amorphous components (poorly crystalline silica and carbonates) evidence its hydrothermal origin and explain deficient sum of elements when calculating the chemical budget using XRD data.

Data thus obtained became a base of the processing flow chart of these naturally disintegrated slime concentrates. The prospects for the processing of these ores should probably be associated with hydrometallurgical processing and the production of zirconium dioxide as a commercial product. One of the main problems in the implementation of hydrometallurgical schemes for the processing of concentrates is the production of valuable zirconium concentrates and products that do not contain radioactive components. The second most important problem is the solution of issues related to the disposal of generated radioactive waste, therefore, one of the tasks to be solved is to assess the distribution of radionuclides by products of the hydrometallurgical limit of Algaminskoye deposit concentrates.

**Conclusions**

Metallurgical mineralogy is becoming increasingly important every year in geological exploration, especially in studies of non-traditional types of mineral raw materials. Its methods and techniques make it possible to assess the metallurgical properties of raw materials at minimal cost and contribute to the creation of effective processing technologies, providing for the maximum possible extraction of all economic components.

The practical consequence of the results obtained is that in a single process of geological study of the subsoil, the mineralogical and metallurgical assessment of mineral raw materials is an integral part of it, ensuring the selection of the most promising objects for further study during the early stages and the conditions for the rational industrial use of the evaluated deposits [7].

**Final remarks**

The features of domestic rare metal ores that distinguish them from foreign analogues include their complex textural and structural patterns, including a significant amount of finely dispersed phases, a poly-mineral composition due to simultaneous presence of minerals of different parageneses, widely developed isomorphic substitutions, primarily in the structures of ore minerals, and radioactivity . Most of the ores belong to the category of refractory, and sometimes non-enrichable. Therefore, the geological study of rare metal objects and their industrial development should be accompanied by scientifically substantiated mineralogical and technological studies. Only in this case, it is possible to obtain reliable information about the material composition and technological properties of raw materials, which opens possibilities to correct strategic and tactical decisions regarding specific raw material objects.

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# PLACER GARNET - A NEW TYPE OF MINERAL RAW MATERIAL ON THE COAST OF THE WHITE SEA

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***Abstract.*** *One of the most popular abrasive materials at the moment is natural garnet sand. The quality of this abrasive material is largely determined by the morphostructural, chemical and genetic features of the main component - minerals of the garnet group. In the Arkhangelsk region, new placer occurences of garnet-containing sands have been identified. The development of that placers can provide the country with highly liquid, strategic raw materials.*

***Keywords:*** *garnet sand, morphostructural features, solid-phase inclusions, chemical composition, physical and mechanical properties, abrasive materials.*

## Introduction

Garnet is widely used as an abrasive material; currently, more than 1.5 million tons of this mineral are mined, primarily from alluvial deposits of coastal marine origin [1]. The coastal zone of the White Sea is considered as prospective for the discovery of placer deposits of abrasive garnet sands. Information about the presence of natural garnet concentrates in modern sediments of the coastal zone of the White Sea is given in various reports compiled on the basis of the results of geological studies both on the shelf and adjacent land. Garnet abrasive finds application in many industries. The use of garnet sand as an abrasive and filter material ensures high quality of surface treatment, liquid filtration and environmental safety of the process.

## Techniques and methods

The object of the study were samples of garnet placers located on the coast in the Arkhangelsk region. According to the results of work, the mineral composition

of placers, the minal composition of garnets, the composition of inclusions in garnets were determined. The features of garnet that affect its abrasive properties were evaluated.

In the course of the works, there were used sieve, gravity-magnetic, optical-mineralogical, micro-X-ray spectral analyzes and analysis by electron microscopy. Sieve analysis of samples taken in the Arkhangelsk region was carried out on a Retsch AS 200 analyzer. Optical-mineralogical analysis was carried out on an MBS-10 stereoscopic microscope and a Leitz Laborlux 12 Pol polarizing microscope in the Laboratory of Mineralogical Research of the Analytical Center of the Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements. X-ray microanalysis was carried out on a Jeol JXA-8100 microanalyzer. Electron microscopy analyzes were performed on a JSM-5610 scanning electron microscope manufactured by Jeol.

**Results and discussion**

Various technological processes require the use of abrasive material with certain parameters.

The most important physical and mechanical properties of abrasives are hardness, strength, viscosity, elasticity, high thermal and chemical resistance, heat capacity, grain size and degree of their uniformity, the fracture nature and the ability to self-sharpening, brittleness.

In the course of the studies, there were identified the important features that are characteristic of placers of garnet sands and minerals of the garnet group, which can affect the quality of the resulting abrasive material[2].

According to the granulometric composition, the sands of the useful strata are predominantly fine-grained, well sorted, less often medium-grained. Sometimes the sands contain interlayers of uneven-grained sands with gravel up to 10%.

The mineral composition of the garnet-bearing sands is polymictic, essentially quartzy. The predominant minerals are quartz, pyroxenes, garnets, amphiboles, feldspars, magnetite (titanomagnetite), ilmenite content is low. There are also small content of rock fragments in the samples. The average mineral composition of garnet sands selected in the Arkhangelsk region: quartz - 58.90% (including 9.25% ferruginous quartz); garnet - 10.8%; amphibole - 2.63%, pyroxene - 0.46%; ilmenite - 0.96%; feldspar - 6.5%; magnetite (titanomagnetite) - 1.94%; fragments of rocks - 2.7%. High garnet content is typical for areas of natural enrichment and formation of natural garnet concentrates. As a rule, these are sandy bays limited by capes, in which all conditions for the accumulation of material are created.

The morphostructural features of garnet grains were studied during the optical-mineralogical analysis. It was revealed that the garnet in placers retains its morphostructural features, which were inherent in it in the bedrocks. Based on the shape, composition, and volume of inclusions in garnet, one can make an

assumption about the conditions under which the mineral crystallized and in what rocks it could have been formed.

The ferruginous garnets are mainly suitable for abrasive purposes, primarily almandine, which has the highest hardness, good viscosity, and usually a well-defined network of fine fractures [3].

In the course of the works, there were studied more than 2000 grains of garnets selected from different parts of the White Sea coast. 79 grains of them were selected for detailed diagnostics using accurate methods (X-ray spectroscopy, Electron microscopy). The studied garnets had different colors from pinkish-red, orange-red to saturated red-purple. Most of the studied garnets were angular fragments with sharp spalls, but well-rounded grains were also found.

***Table 1***

*Chemical composition of the studied 79 garnets, %*

| | **The content of elements in terms of oxides, %** | | | | |
|---|---|---|---|---|---|
| | **MgO** | **$Al_2O_3$** | **CaO** | **MnO** | **FeO** |
| min | 0,89 | 12,92 | 0,64 | 0,16 | 0,66 |
| max | 38,43 | 25,91 | 21,11 | 16,66 | 35,37 |
| Average for 79 grains | 6,79 | 20,15 | 4,12 | 1,44 | 26.14 |

As a result, it was revealed that of the 79 grains studied, 5 grains were closer to pyrope, 7 grains had a transitional composition, but still 6 of them were closer to almandine, 1 grain corresponded to grossular in composition (Fig. 1). The remaining grains were almandine with one or another content of other minals.

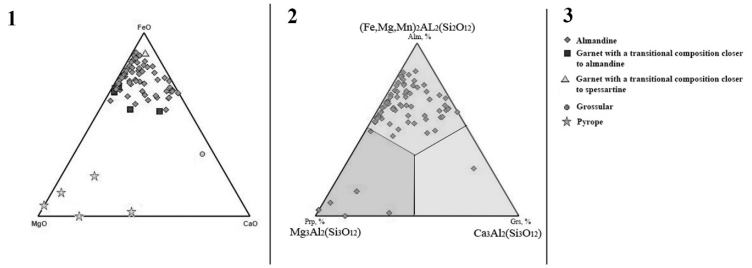


***Figure 1.*** *1- Composition of the studied garnets in coordinates FeO-MgO-CaO; 2 - composition of garnets in the coordinates of the main minals: almandine-grossular-pyrope; 3 - symbols for fig. 1.1.*

Despite significant differences in color from densely colored crimson red to pale pink, the studied garnets mostly correspond to almandine in composition,

which meets the requirements for abrasive raw materials. The degree of roundness and preservation of crystallographic outlines is also different for grains. But in terms of composition, almost all the studied grains are almandine (Fig. 1).

The characteristic ability of garnet to break into particles with sharp cutting edges during grinding and the surface fracturing of the mineral are the main properties of abrasive garnet [2].

Surface fracturing is a rare network of deep cracks and reduces the energy consumption for grinding large crystals. Surface fracturing, commonly seen in garnet grains, is considered to be a useful property of abrasive garnet. It promotes the regeneration of sharp edges during grinding, facilitating the chipping off of dull edges and thereby effectively affecting the self-sharpening of the abrasive [3].

In the course of works and the detailed study of 79 garnet grains by X-ray spectral microanalysis and electron microscopy, it was revealed that many garnet grains have cracking, which persists even after grinding the grains in the epoxy preparation while preparation for analysis. Also, there were found grains, that had kelyphite rims on their surface. The kelyphite rim often has a radially radiant structure. There were observed pelitomorphic neoformations between the base of the kelyphite rim and the surface of the garnet. Kelifitte rims, composed of mechanically unstable minerals, are easily abraded when the mineral is transferred in an aqueous medium or crack in the direction of the fibers [4].

It was determined that of the 79 grains, 64 grains had surface fracturing and rims (Fig. 3). Some grains had surface cracks and also kelyphite rims.

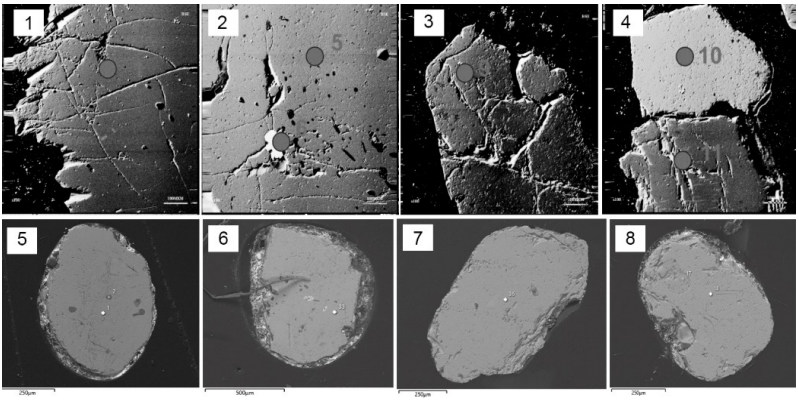


***Figure 2.*** *BSE image of garnet grains:. 1-4 surface fracturing according to X-ray spectral microanalysis data, the points of measurement of the chemical composition are marked with a round icon, 5-8 rims on the surface of garnet grains according to electron microscopy data.*

The electron microscopy and microprobe photographs clearly show both rims and surface fracturing in garnet grains (Fig. 2)

The presence of large solid-phase inclusions in the mineral can significantly reduce the abrasive properties of garnet. With a strong dynamic, temperature load in the abrasive process, garnet grains can crack along inclusions and fall out of the bonds in the abrasive tool. In this case, most likely, cracking will not contribute to the regeneration of abrasive properties, but rather to the destruction of the grain. Therefore, an urgent task is to search for industrially significant placers of garnet with a minimum number of inclusions.

Garnet is isotropic, and this property greatly simplifies its diagnosis. However, there are cases when garnet can exhibit weak anisotropy, for example, garnet with a significant proportion of spessartine minal. The inclusions represented by minerals of non-cubic syngony are anisotropic. That's why they stand out well against the background of isotropic garnet while being analyzed in the preparation.

During the optical-mineralogical analysis, there were found rather large inclusions of quartz, rutile, zircon, ilmenite in garnet grains (Fig.3-1,2,3). An analysis was also carried out by electron microscopy to identify microinclusions that cannot be diagnosed by analysis using conventional optical methods (Fig. 3-4,5,6). The result of analysis at point 2 (Fig. 3-6) corresponds to quartz with a minimum impurity of ferrum. The result at point 2 (Fig. 3-5) corresponds to hematite or magnetite. The result of the analysis at point 11 (Fig. 3-4) corresponds to the calculation formula for anorthite.

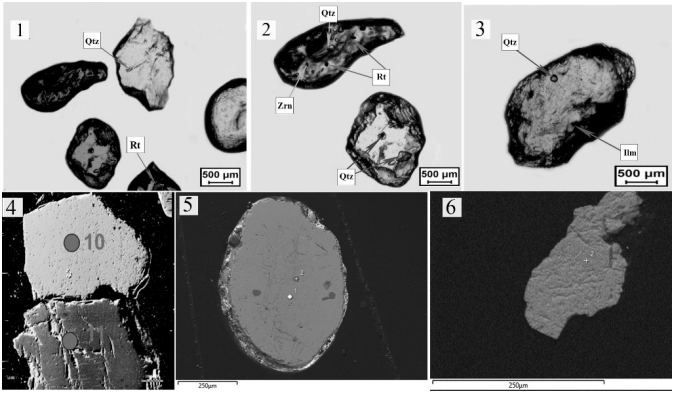


***Figure 3.*** *Inclusions in garnet mineral grains. 1-3 photos from Leitz Laborlux 12 Pol polarizing microscope. Symbols of minerals: Qtz - quartz, Rt - rutile, Zrn - zircon, Ilm - ilmenite; 4-6 BSE of garnet grains 4 - inclusion of anorthite, 5 - inclusion of quartz, 6 - inclusion of hematite or magnetite.*

***Table 2***

*Chemical composition of microinclusions in garnets, %*

| Point number | Method | $Al_2O_3$ | $SiO_2$ | CaO | MnO | FeO |
|---|---|---|---|---|---|---|
| 2 (Fig. 3-5) | Electron microscopy | | 99,25 | | | 0,76 |
| 2 (Fig.3-6) | Electron microscopy | | | | | 84,13 |
| 11 (Fig. 3-4) | X-ray spectral microanalysis | 21,19 | 57,35 | 6,61 | 0,02 | 0,26 |

In the garnet-bearing sands of this region, the percentage of garnet grains with inclusions is small. In this respect, the Arkhangelsk garnet is significantly different from, for example, the garnet sampled also on the coast of the White Sea, but to the west, in North Karelia. There, the percentage of garnet grains with inclusions is higher.

Almost all of the studied grains were fragmentary fragments of irregular shape. Rarely, there were found the garnet grains with several rhombic dodecahedron faces. According to the degree of roundness, the entire material can be divided into three groups: 1 - about 1% of the grains are well rounded to rounded or oval shapes; 2 - more than 75-80% of the grains are weakly rounded irregular shapes with uneven chips; 3 - 15-20% of the grains are practically unrounded, acute-angled. The percentage of less suitable for abrasive purposes rounded grains is small. The most of the garnet consists of grains with uneven chips with a weak degree of roundness and not rounded angular fragments at all. This indicator shows how abrasive the material is able to cut or abrade the material being processed. The main sources of roughness during grinding are: traces of cutting edges in the material being machined; plastic, elastic, temperature deformations, brittle fracture of the material of the surface layer; transfer to the treated surface of the particles of material remaining on the cutting edges of the tool [5].

The patterns of wear of an abrasive tool are directly related to the work of individual abrasive grains. Under the action of mechanical and thermal stresses occurs cracking, chipping of the cutting edges, chipping of individual abrasive grains and entire complexes from the bond[5].

The main parameter of an abrasive material is its hardness, quantified by microhardness and the Mohs scale. The studied minerals of the garnet group have a hardness of 7-7.5, which is considered medium and high hardness and is suitable for solving abrasive problems.

**Conclusions**

As a result of the research, it was found that: garnet is represented in all samples mainly by almandine, which meets the requirements for abrasive raw materials; according to the color and morphostructural features of the garnet, it is impossible to draw conclusions about its variety within the group, it is necessary

to apply accurate research methods: electron microscopy or X-ray spectral microanalysis; inclusions of other minerals were found in garnet grains: hematite or magnetite, quartz, anorthite, ilmenite, rutile, zircon, but the percentage of grains with inclusions is insignificant; garnet grains have surface fracturing, which is a useful property for solving abrasive problems; most of the garnets in the samples are not rounded angular grains.

An analysis of the data obtained on placer occurrences of technical garnet allows us to assume the presence of new deposits of this raw material in the Arkhangelsk region. These deposits can fully provide the enterprises of the Russian Federation with valuable strategic raw materials and be competitive in the international market.

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# ENVIRONMENTAL PROBLEMS OF GEOLOGY AND SUBSOIL USE

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***Abstract.*** *The article considers examples of the impact on the environment as a result of exploration and mining operations on solid minerals and hydrocarbon raw materials. Conclusions are drawn and recommendations are proposed for optimizing the consequences of the impact of production processes on the components of the environment and health of the population and professionals.*

***Keywords:*** *environment, exploration, mining enterprises, oil and gas production, population health.*

Works at the stages of prospecting, exploration, production and extraction of useful components from ores, hydrocarbon deposits, as well as all related technological processes, are under strict control in order to ensure monitoring of environmental pollution by enterprises of geological exploration, mining and processing of mineral and hydrocarbon raw materials. However, in near retrospect, technological processes were not as efficient, and there were no strict environmental protection standards. Evidence of this are abandoned mines, self-flowing oil wells, left without proper supervision of their current state, which are currently causing great damage to the environment in many countries of the world. To predict, prevent and overcome negative environmental consequences, it is necessary to carefully study and take into account all production chains and probable factors causing harm to the environment, as well as to public health by enterprises of the mining and geological and oil extraction complexes.

The authors in this paper propose to consider some aspects of the activities of enterprises of exploration and production complexes in order to create scientific and methodological foundations for forecasting, assessing and optimizing the impact of production factors on environmental components and public health.

Environmental aspects of the activities of exploration enterprises

The ecological state of the components of the environment (E) - soils, atmosphere, bottom sediments, water resources - is closely related to geological exploration and extraction of all types of minerals. The degree of impact on the environment during geological exploration (GE) for various types of minerals, as well as during the development of deposits of mineral and hydrocarbon raw materials, is different. It depends on the stages of exploration and subsequent mining systems [1; 2; 4].

The geological exploration complex includes the following stages of their implementation: geological survey and searches, including geologists' walking routes, excavation of rare pits and ditches, shallow boreholes; preliminary and detailed exploration with a significant amount of mining (driving ditches, pits and adits using explosives and heavy equipment) and drilling operations with the arrangement of energy and related facilities, especially difficult when working on oil and gas. At all stages, geophysical exploration methods are used with a complex of survey and accompanying works: preparation of forest clearings, road construction, drilling of exploration wells, blasting.

An analysis of the degree of influence of exploration work on the environment showed that the least harm to nature is caused at the stage of geological survey and prospecting work and during the exploration of water deposits. At these stages, excavation of mine workings (ditches and pits), single boreholes that do not require large-scale reclamation of territories upon completion of work is carried out.

Significant damage to landscapes and the geological environment is caused at the stage of preliminary and detailed exploration of solid mineral deposits, when the surface is disturbed and polluted on tens of square kilometers of work areas. At the same time, not all deposits after preliminary exploration are involved in detailed exploration and then in operation, however, the reclamation and further use of the territories of these deposits must be planned at the earliest stages of assessing economic and environmental risk.

Extreme damage to the environment is caused by work at the stage of prospecting and exploration of oil and gas fields: significant areas of drilling operations are disturbed and contaminated with chemical reagents; the construction of technological roads leads to the removal of thousands of square meters of soil cover; in case of violation of drilling technology, mixing and pollution of groundwater horizons with oil products occurs, surface watercourses are withdrawn from use; there are oil and gas emissions during well drilling, burning of gas flares, which

cause irreparable damage to vegetation, polluting the atmosphere with carbon, sulfur, nitrogen compounds, contributing to the development of the greenhouse effect [6].

Significant damage to nature is caused by regional geophysical work, in particular seismic exploration. The need to lay wide, long clearings in the taiga, the construction of temporary and technological roads, drilling of wells and blasting lead to the destruction of soil and vegetation cover, pollution of bottom sediments, surface watercourses. In the northern latitudes, where permafrost is developed, the technogenic impact of seismic exploration on the vegetation cover and upper soil layers is especially pronounced and the consequences of disturbance and destruction of ecosystems are not compensated for decades.

Environmental impacts of mining operations

A very wide range of geological materials extracted from the subsoil from fuel and energy minerals, non-metallic mineral raw materials - various clays, quartz, sand and gravel mixtures, which are used in various fields of construction and technology, agrochemical raw materials for agricultural needs and fertilizer production. However, the subject of the greatest attention and concern of environmentalists is the mining of metal ores - the basis of the mineral resource base of the metallurgical and other basic industries [3].

The cycle of mining and subsequent processing of mineral raw materials can be summarized in operations arranged in the following sequence: mining → crushing / grinding → enrichment of ore material → smelting / obtaining pure metal. Ores are mined mainly by mining - underground and open mining systems. In some cases, in particular during the development of “sandstone-type” uranium deposits, the extraction of the uranium-containing component is carried out by in-situ leaching with a high risk of groundwater pollution. Both underground and open pit methods of extracting metal ores form significant volumes of mining products, which are stored in the form of dumps on the surface near the deposits and mines themselves.

While the dumps of deposits with high concentrations of metal-bearing minerals pollute the environment, creating critical concentrations of heavy metals and potentially toxic elements (PTE) in the environment gradually, for long periods of time, following the extraction of technological processes associated with the processing and enrichment of mineral raw materials, lead to acute environmental problems requiring urgent solutions. For example, crushing and grinding ore is intended to separate minerals from an ore mass called waste rock. To increase separation efficiency, mined ore is crushed to the size of mineral grains. The very finely divided material remaining after separation, the so-called tailings, may contain residual concentrations of ore minerals along with the minerals of the host rocks and be a source of toxic effects on the environment.

Tailings, due to the minimum particle size of their constituent material, are easily subject to wind dispersal, their components can be carried by surface watercourses. Near many long-closed mines, tailings remain open and cause irreparable damage to the environment, polluting water and soil. The ingress of metal ions into surface and ground waters can lead to serious contamination of drinking water sources, therefore, at modern mines, tailings are stored in the aquatic environment in storage ponds protected from spills by artificially created dams. It should be noted that after the closure of the mines, due to the fact that the technological chains in the structure of which tailings were created and "wet tailings were stored" are broken, the storage ponds are drained, which contributes to the wind transfer of finely ground material to neighboring and even significantly remote territories. (In modern mines, tailings are isolated after they are shut down using modern materials that reduce the likelihood of environmental pollution).

The contents of tailings contain elements that are part of ore minerals, as well as elevated concentrations of trace elements, which often pose the same threat to the environment as the main components of mined ores. Among the impurity elements, perhaps the most common element is cadmium. It is widely distributed in zinc ores in concentrations of over 4.4% in individual ore samples.

The process of weathering in abandoned mines also affects ore minerals located in workings, in dumps and tailings of mining production and leads to leaching of both the main elements of ores and impurity elements. Soils and waters in areas adjacent to abandoned mines are subject to intense chemical pollution. The main minerals of non-ferrous metal ores - lead, zinc and copper are sulfides. Sulfide ores are the most dangerous for the environment, as they are easily oxidized in air to even more soluble sulfates. The formula for this process is:

$$ZnS+2O_2 \rightarrow ZnSO_4$$

Oxidation of sulfides leads to pollution of the surface and groundwater. The most dangerous sulfides are pyrite and marcasite (both have the formula $FeS_2$). These sulfides, oxidized, form various oxides and hydroxides, and a certain amount of sulfates. The common name for these compounds is ocher. Among other secondary products of the oxidation of sulfide ores, sulfuric acid, which is formed due to the influx of groundwater and tailings solutions, is of particular importance [7].

As acidity decreases and acid is neutralized as a result of dissolution and chemical reactions of drainage waters with host rocks, the concentrations of metals in ochers increase. Precipitating, ocher saturates watercourses with metals in dangerous concentrations, which has a negative impact on the components of the environment and, first of all, on the objects of the hydrosphere.

In many ore deposits adjacent to river valleys, huge masses of water are used for gravity enrichment - the separation of ores. As a result of this highly inefficient ore beneficiation process, significant volumes of highly contaminated sediments and fine grains of minerals end up in rivers. Floods inundate vast areas of river valleys, resulting in soils containing high concentrations of metals.

A particular problem is associated with the development of gold deposits, which leads to severe mercury pollution of the environment. Mercury has been used for many decades to extract gold from ores and concentrates using amalgamation. As a result, many gold mining areas have been affected by mercury pollution. Especially those of them where alluvial gold is mined, in particular the territories adjacent to the Amazon basin.

Among the impurity elements, in the deposits of non-ferrous metal ores, as noted above, the most common element is cadmium. It is widely distributed in zinc ores in concentrations of over 4.4% in individual ore samples. Using the example of cadmium, one can study the mechanisms and consequences of the impact of mining enterprises on public health. One of the most significant examples of metal-dependent diseases is Itai-itai Disease. Its cause - etiology - was the use of food contaminated with cadmium. Itai-itai is distributed in the Jintsu River Basin (JintsuRiverbasin) in Toyama Prefecture, Japan, near a zinc mine. The Jintsu River forms a fan at its confluence with the Toyama Plain. Soil and sand were brought in by the water stream and settled at the bottom of the river. Each time the dams collapsed, the paddies and fields were covered with cadmium-contaminated sediment, resulting in persistent soil contamination. Cadmium accumulated in agricultural products, primarily in rice. The inhabitants also used the water of the river for drinking and cooking and irrigation. Thus, cadmium accumulated in the human body, which led to the emergence of itai-itai morbidity foci [7].

Environmental consequences of oil and gas production

Oil and gas and related industries are one of the main causes of environmental degradation of environmental components. For example, oil refining creates conditions for the leakage of toxic substances into the environment. The objects of environmental impact of the oil and gas industry at various stages of the oil production process - reconnaissance, drilling, production, pipeline construction, transportation, spill control, territory cleanup and closure of the work site are coastal and tundra ecosystems, swamps [5].

Pollution of the environment in oil fields occurs during explosive phenomena in wells and during testing of equipment; at the stage of field development after the discovery of commercial oil reserves; in the process of oil refining, when toxic waste is generated; when transporting crude oil for export or its delivery through pipelines to domestic consumers.

Petroleum hydrocarbons enter the environment (E) as a result of geochemical,

biogenic and anthropogenic processes, regardless of the limitations in the form of pyrolysis and combustion of fossil fuels - oil, gas and coal, as well as wood, garbage and many other organic materials. As a result of the combustion and processing of hydrocarbon raw materials, millions of barrels of oil enter the environment as a result of leaks that do not comply with waste disposal technologies, evaporation, etc. In the "dry deposition" process, petroleum hydrocarbons are released into surface water and soil from the atmosphere. They are considered one of the most dangerous soil pollutants.

The components of petroleum hydrocarbons belong to the family of carcinogens and neurotoxins. Comprehensive studies on the effects of petroleum hydrocarbons inhaled by workers in the work environment, as well as people living near refineries and oil loading stations, show an increased risk of eye diseases, headaches, asthma, childhood leukemia, acute myeloid leukemia and multiple myeloma . Oil in contaminated areas reduces soil quality and productivity, and weathered oil residues can remain in soil for years.

In cold latitudes, oil spills are one of the most common and most environmentally damaging types of environmental pollution that adversely affect human health and the state of the environment due to its slow recovery.

The consequences of geological exploration and development of oil and gas fields pose a threat to the existence of the indigenous population, loss of biodiversity, desertification of territories and environmental pollution as a result of oil leaks and its discharge into hydrosphere objects.

In the Western Amazon, the development of oil and gas fields has caused environmental and social damage. Since the 1990s the Mississippi River Delta has experienced environmental pressure from the construction and development of energy facilities. The 1989 Alaskan Exxon Valdez oil spill resulted in shoreline pollution and subsequent loss of wildlife.

The environmental damage caused in the recent past and in the long term is always associated with the development of energy facilities in a broad sense and the activities of mining and oil and gas companies. For example, the problem of air pollution in Los Angeles during the summer is the result of photochemical smog and high levels of ozone in the atmosphere from the activities of the oil and gas industry. Ozone is formed as a result of complex chemical reactions of volatile organic compounds (VOC) with nitrogen oxides (NOx) in the air under the influence of sunlight. Ozone is a strong oxidant that impairs normal lung function and causes irreparable damage to plant tissues even at low atmospheric concentrations.

Discussion of the results of the analytical study

The impact of mining on the environment and the geological environment largely depends on the mining and geological conditions of the occurrence of ores in the

bowels and the resulting methods of mining reserves, i.e. should be considered in a single set of environmental measures. For example, during the extraction of iron ores, ore gold, many types of non-metallic raw materials and building materials, associated with the need to dig open pits and underground workings in rocks, there are irretrievable losses of significant areas of the earth's surface, which in rare cases can be used for artificial reservoirs or for other economic purposes. In addition, the development of such deposits leads to significant pollution of surface watercourses and disruption of the groundwater regime near quarries and mines, as well as air pollution during massive explosions.

Alluvial gold mining causes disturbance of the surface of river valleys and pollution of surface watercourses for many kilometers with mechanical impurities. However, if the waste areas are planned, then during the first decades the surface of the river valleys will recover and take on a look close to the original. It will take much longer to restore forest cover.

In the extraction of building materials - refractory clays, molding and glass sands, sand and gravel materials and other seam-like deposits occurring at a shallow depth, as in the case of coal mining, complete land reclamation with transfer to agricultural enterprises is possible. Pollution of ground and surface waters is moderate.

Exploration of deposits of fresh and mineral underground waters and their use, if the rules for the operation of wells are not violated, does not lead to changes in the environment. This provision can be extended to the method of extracting salt by underground leaching, if we exclude contamination of the surface of the brine field as a result of a careless attitude to pipelines and locking devices, on the one hand, and the dissolution of subsoil blocks, with the subsequent danger of failures and a catastrophic violation of the living conditions of the population.

The existing technology of exploration and production drilling, the toxicity of many of the materials and reagents used, the low environmental friendliness of waste collection and storage systems, the lack of industrially developed environmental protection means make us pay special attention to the development of hydrocarbon deposits. Exploration and development of oil and gas fields threatens with serious environmental consequences for nature, public health and biota in general. According to some estimates, about 20-25% of biological resources may be lost in the next few decades. A significant problem is the lack of differentiated consideration of the specific conditions of the landscape-natural complex. When designing work, it is necessary to take into account the probable damage from exploration to all types of natural resources: forest land, including those types of wood that are prohibited by law; preservation of the habitat of game animals; protection of water resources, including groundwater and brines.

*Conclusions*

A common disadvantage of geological exploration and mining is the poor use of the achievements of scientific and technological progress, the slow introduction of environmentally friendly methods of mining, low-waste and waste-free technological processes, closed water circulation, which ensure the integrated use of mineral raw materials.

Exploration drilling and geophysical operations have a tangible impact on the environment already in the initial period of exploration and development of deposits. Oil production, related work on the energy supply of oil fields, the work of transport workers and builders, in the absence of proper preliminary assessments of environmental damage, the state of the geopermafrost zone in the northern latitudes, coastal flora and fauna near equatorial territories, can lead to severe environmental consequences and affect the stage of operation of the fields, when they are equipped many hundreds of field wells, hundreds of kilometers of oil and gas pipelines, technological roads, emergency and planned emissions of oil, gas and brines will be produced. The amount of damage from these works and losses for maintenance of equipment and liquidation of accidents with inadequate consideration of geoecological conditions in the areas of work, even at the design stages, is estimated at billions of dollars.

It is possible to reduce the degree of influence of oil and gas prospecting and mining operations on the natural environment only by strictly following the geological task, by performing preliminary exploration and verification geophysical studies to clarify the boundaries of the explored object, as well as by fully complying with the drilling technology.

The degree of environmental hazards from industries must be brought into line with the responsibility of the manufacturer, government documents and the conditions of existence of certain ecosystems.

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# SURFACE PROPERTIES OF GRAY FOREST SOIL DURING THEIR LONG-TERM PLOWING

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***Abstract.*** *The surface properties of gray forest soil of different land use were studied: forest and arable land. The involvement of gray forest soil in crop rotation led to a change in the aggregate composition of soils: the transition of soil from one gradation to another.*

*A decrease in the content of organic matter increased the hydrophilicity of soil particles and increased the degree of dispersion of soil microaggregates.*

***Keywords:*** *gray forest soil, structure, specific surface area, particle size distribution, contact angle, organic matter.*

## Introduction

The important role of studies of surface phenomena in the soil was pointed out by A.D. Voronin [1]. He wrote that the joint study of the geometry, energy and properties of interfacial interfaces, the composition and energy of soil solutions, as well as chemicals artificially introduced into them, along with micromorphological studies of the organization of elementary soil particles, makes it possible to build real models of soil aggregates and link surface phenomena with the main macroscopic properties of soils, to find ways of their directed change, improvement and optimization. He noted that «the study of surface phenomena in the soil is, in

essence, the study of the processes and properties of soils and their management at the molecular level» [1] . Constantly developing instrumental technology, especially modern methods for studying colloidal and organic chemistry, make it possible to study soil properties at a new level and from new positions. One of such approaches is to study the surface properties of soils on an analytical complex for determining the textural characteristics of disperse systems (Vapor 100, Messo 222, 3P INSTRUMENTS, Germany) and to determine the contact angle using water drop shape analyzers (KRUSS, Germany).

The purpose of our study is to study the effect of long-term plowing on the surface properties of gray forest soil using modern instrumental methods.

**Objects and methods of research**

The studies were carried out on gray forest soils of different land use: forest section and arable land (Tula region, Shchekinsky district). We present a brief morphological description of the studied sections.

Morphological description of the section of gray forest soil under the forest (Tula region, Shchekinsky district; second floodplain terrace): section 1.

**Horizon O (0-1 cm):** fragmented litter of deciduous species of medium degree of decomposition (the litter of the previous year is preserved).

**Horizon AY (1-15 cm):** soil is moist, gray-brown, light loam, cloddy structure, very loose, pores are not visible, no cracks, many roots of different sizes, average amount of plant remains, there are wormholes, no inclusions, wavy border , the transition is gradual.

**AEL horizon (15-32 cm):** moist soil, dark gray, medium loamy, prismatic-cloddy structure, soft, loose structural composition, no cracks or pores, single roots and plant remains in the form of dead roots, there are wormholes, no inclusions , the border is wavy, the transition is gradual and noticeable.

**Horizon BEL (32-63 cm):** fresh soil, brown-gray, medium loam, nutty-prism-like structure, hard, dense structural composition, few small pores, no cracks, single roots and plant remains, there are wormholes, clay cutans, skeletons , inclusions - lithomorphs, wavy boundary, gradual transition.

**Horizon BT (63–90 cm):** soil is moist, light brown, heavy loam, nutty structure, hard, dense structural composition, many pores of various sizes, no roots and plant remains, clay cutans and skeletons are present, no inclusions.

Morphological description of gray forest soil. (Tula region, Shchekinsky district; second terrace above the floodplain): Section 2 - arable land:

**Ap horizon (0-32 cm):** moist soil, color - dark gray, brown, lumpy structure, large pores are absent, many small roots and plant remains, wormholes are present, the boundary is even, the transition is sharp, pyrogenic inclusions are present, density 21.5 kg/cm$^3$; in the lower part the structure deteriorates and becomes platy (plow pan).

**Horizon BEL (32-70 cm):** soil is moist, brown with whitish streaks, heavy loam (cord), hard, dense build, prismatic-nutty structure, few roots and plant remains, wormholes, indistinct clayey coatings and abundant skeletons; there are no inclusions, the border is lingual, the transition is gradual in structure and neoplasms; density 23.5 kg/cm$^3$.

**Horizon BT (70-92cm):** moist soil, heavy loam (cord), brown, nutty structure, loose structure.

In soil samples taken from soil horizons, the physical and physicochemical properties of soils were studied both by traditional methods of soil physics and with the involvement of modern instrumental methods [2,3,4]

Granulometric composition by laser diffraction, aggregate composition: dry sifting on a vibrating screen, wet sieving by the Savinov method, specific surface - external was determined by the method of thermal gas desorption on an analytical complex for determining the textural characteristics of dispersed systems (Vapor 100, Messo 222, 3P INSTRUMTNTS, Germany) and the total -weight method according to Kutelik. The carbon content of organic matter was measured by dry combustion in an oxygen flow on an AN 7529M analyzer (Gomel, Belarus). The contact angle was measured on a KRUSS drop shape analyzer (Germany).

**Results and discussion**

According to the classification of N.A. Kachinsky, the gray forest soils studied by us belong to medium loam (Table 1.) The content of physical clay (fraction < 10 μm) along the entire profile of sections 1 and 2 is ~ 40%. The content of fine fractions < 1 μm is insignificant 1.5-4.3% and its uniform distribution over the soil profile is noted. Of all the fractions, the coarse dust fraction prevails (fraction with sizes of 10-50 microns). The granulometric composition of gray forest soil has not changed during long-term agricultural use.

Soil is a polydisperse system. And one of the important characteristics of the soil is its structure. Structure is the size distribution of soil structural units (peds). When the soil is involved in crop rotation, the structure of the soil changes dramatically. For the upper humus horizons, the structure largely determines such important properties as soil resistance to adverse factors.

***Table 1.***

*Granulometric composition of gray forest soil (content of fractions in %)*

| | **Fraction size in μm** | | | | | | |
|---|---|---|---|---|---|---|---|
| Horizon, depth in cm Forest. Section 1 | 250-1000 | 50-250 | 50-10 | 5-10 | 2-5 | 1-2 | < 1 |
| Forest. Section 1 | | | | | | | |
| AY (1-15) | 0 | 7.06 | 48.18 | 18.29 | 17.59 | 7.3 | 1.58 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AEL(15-32) | 2.45 | 6.8 | 51.02 | 16.26 | 14.62 | 6.92 | 1.88 |
| BEL (32-63) | 3.77 | 7.34 | 51.72 | 12.95 | 12.55 | 7.91 | 3.74 |
| BT (63-90) | 2.54 | 7.45 | 50.32 | 14.27 | 13.14 | 8.18 | 4.1 |
| BC > 90 | 7.0 | 10.18 | 46.78 | 12.81 | 12.16 | 7.57 | 3.48 |
| Arable land. Section2 | | | | | | | |
| Ap (0-32) Cut 2 | 0 | 7.54 | 53 | 14.41 | 14.4 | 8.07 | 2.57 |
| BEL(32-70) | 0 | 5.62 | 52.58 | 15.17 | 14.08 | 8.55 | 4 |
| BT(70-92) | 1.32 | 5.36 | 51.14 | 15.17 | 14.11 | 8.65 | 4.22 |
| BC > 92 | 0 | 5.43 | 52.04 | 15.56 | 14.07 | 8.53 | 4.36 |

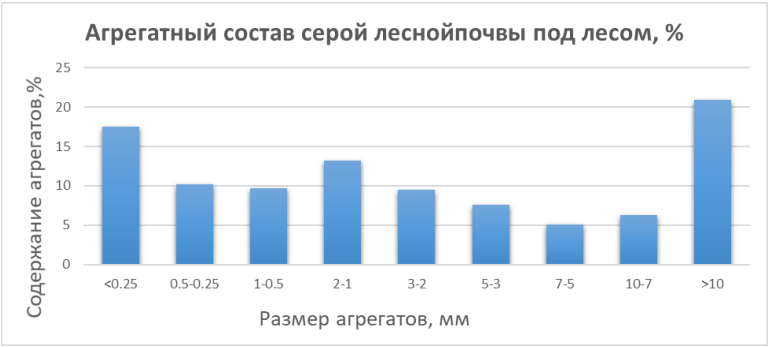


***Figure 1***

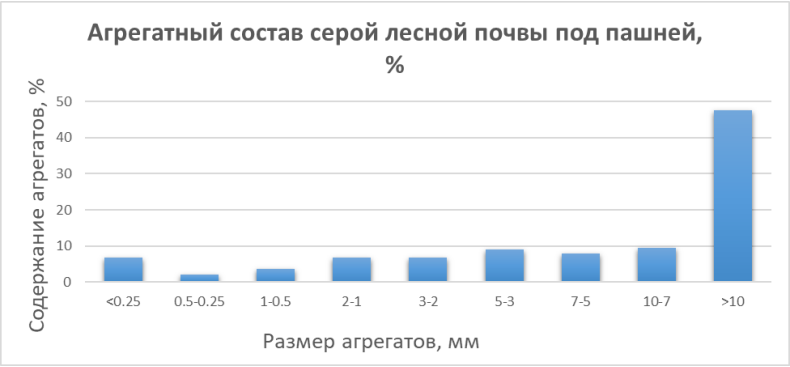


***Figure 2***

environment and potential fertility. In the gray forest soil studied by us, there is a sharp decrease in the content of agronomically valuable aggregates as a result of

long-term plowing of the gray forest soil (Figs. 1 and 2). The content of the blocky fraction > 10 mm increased almost twice. The macroaggregation of gray forest soil under the forest ( section 1.) refers to the gradation of excellent aggregation (the sum of fractions with sizes of 10-0.25 mm > 70%). As a result of long-term plowing, this indicator has decreased and is close to unsatisfactory (the sum of fractions with sizes of 10-0.25 mm = 40).

The main feature of highly dispersed systems such as soil is the presence of a highly developed interface. And the involvement of soil in crop rotation will primarily affect the surface properties of soils: on the value of the specific surface area and on the values of the wetting angle. It is known that the water resistance of aggregates is largely determined by the type of soil use. Usually, with an increase in anthropogenic load, the water resistance of the soil structure decreases. [ 5,6,7] . In our case, there is also a decrease in the content of water-stable aggregates in the upper humus-accumulative horizon as a result of long-term plowing. In this regard, the values of contact wetting angles associated with water resistance can, on the one hand, serve as a numerical expression of the anthropogenic load, and on the other. can help to better understand the nature of anthropogenic impact on soil structure. Table 2 presents data on the measurement of specific surface area by adsorbates of various nature. data on the carbon content of organic matter and the value of the contact angles of wetting.

The specific soil surface is the surface area of 1 g of solid-phase soil particles. It characterizes the dispersity of the soil and the state of the surface of soil particles. Depends on the granulometric and mineralogical composition of soils and the content of organic matter.

***Table 2.***

*Physical and chemical properties of gray forest soil*

| Horizon Depth, cm | pH aquatic | pH saline | C% | S total $m^2/g$ | S external $m^2/g$ | Wetting angle in degrees |
|---|---|---|---|---|---|---|
| Forest cut 1. | | | | | | |
| AY (1-15) | 5,45 | 4,13 | 1,99 | 51,4 | 2,8 | 83,6 |
| AEL (15-32) | 5,14 | 3,85 | 1,04 | 36,8 | 3,6 | 81,8 |
| BEL (32-63) | 4,86 | 3,68 | 0,72 | 86,6 | 26,7 | 76,2 |
| BT (63-90) | 4,88 | 3,73 | 0,26 | 90,2 | 14,5 | 73,8 |
| BC >90 | 4,54 | 3,86 | 0,21 | 72,2 | 15,9 | 68,5 |
| Arable land section 2. | | | | | | |
| Ap (0-32) | 5,18 | 5,03 | 1,03 | 48,4 | 5,8 | 63,2 |
| BEL (32-70) | 5,15 | 4,75 | 0,37 | 91,6 | 27,9 | 62 |
| BT (70-92) | 5,13 | 3,91 | 0,37 | 99 | 32,3 | 57,8 |
| BC > 92 | 4,73 | 3,94 | 0,32 | 104,1 | 24,3 | 48,2 |

The value of the total specific surface of the gray forest soil studied by us

Varies from 36.7 $m^2/g$ to 104 $m^2/g$. The upper humus-accumulative horizons are characterized by the smallest values of the total specific surface, which is associated with a high content of organic matter. The effect of organic matter on the degree of dispersity of soil particles is most pronounced when determining the value of the external specific surface area by the adsorption of nitrogen vapors. The involvement of soil in crop rotation in our case did not lead to an increase in the overall degree of soil dispersion (S total for water is the same in the upper horizons of sections 1 and 2).

Application

The analytical complex for determining the textural characteristics of the surface properties of soils made it possible to clearly note the effect of plowing on its dispersion. The value of the external specific surface on arable land increased by 1.5-2 times. This indicates a change in the microaggregation of soil particles. This is also evidenced by the data on the values of the contact angles of wetting. Soil particles during long-term plowing are characterized by lower wetting angles compared to their virgin counterparts.

**Conclusions**

Long-term plowing of soils has led to a change in the physicochemical properties of gray forest soils:

- the aggregate composition of gray forest soil from the excellent gradation approached the unsatisfactory gradation
- increased hydrophilicity of soil particles
- in the upper humus-accumulative horizons, the carbon content of organic matter decreased and, as a result, the value of the external specific surface increased

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# NOTES

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