SCIENTIFIC RESEARCH OF THE SCO COUNTRIES: SYNERGY AND INTEGRATION

上合组织国家的科学研究：协同和一体化

Proceedings of the International Conference

Date: March 12

Beijing, China 2025

上合组织国家的科学研究：协同和一体化
国际会议

参与者的英文报告

International Conference
“Scientific research of the SCO countries: synergy and integration”

Part 2

2025 年 3 月 12 日，中国北京
March 12, 2025. Beijing, PRC

Proceedings of the International Conference
“Scientific research of the SCO countries: synergy and integration” - Reports in English

(March 12, 2025. Beijing, PRC)

DOI 10.34660/conf.2025.24.38.027

这些会议文集结合了会议的材料 – 研究论文和科学工作者的论文报告。 它考察了职业化人格的技术和社会学问题。一些文章涉及人格职业化研究问题的理论和方法论方法和原则。
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DOI 10.34660/conf.2025.24.38.027

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DOI 10.34660/INF.2025.85.93.036

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CIRCADIAN RHYTHM OF SYSTOLIC BLOOD PRESSURE IN ACUTE CEREBRAL INSUFFICIENCY IN CHILDREN AGED 3.1-7 YEARS

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摘要。无机械呼吸支持和延长 ALV 的儿童组中，SBP 的中观昼夜节律与该年龄组的生理标准没有差异。根据 MRP 的持续时间，SBP 昼夜节律的振幅有增加 30% 的趋势，每日波动范围有增加 30% 的趋势。第 2 组中延长（52 天）的 ALV 伴随着 SBP 的中观昼夜节律在第 24 天增加到 110 毫米汞柱的趋势。研究指标的波动符合每周生物节律，交替出现 6-4 天的波动。第 2 组中 SBP 昼夜节律的倒置时间最长（45%），长达 23 天，而第 1 组中 SBP 昼夜节律的倒置持续了 2 天。收缩压波动的主要原因是长时间机械通气时全身炎症反应加剧。

关键词：昼夜节律、收缩压、急性脑衰竭、儿童。

Abstract. *The mesoscopic circadian rhythm of SBP in the groups of children without mechanical respiratory support and prolonged ALV did not differ from the physiological norms in this age group. A tendency to increase the amplitude by 30%, the daily range of oscillations of the circadian rhythm of SBP by 30% depending on the duration of MRP was revealed. Prolonged (52 days) ALV in group 2 was accompanied by a tendency to increase the mesoscopic circadian rhythm of SBP to 110 mm Hg on day 24. Fluctuations in the studied indicator fit into the weekly biorhythms with alternation of 6-4 day waves. The longest inversion of the circadian rhythm of SBP (45%) was revealed in group 2, amounting to 23 days, while in group 1 the inversion of the circadian rhythm of SBP lasted 2 days. The leading cause of SBP fluctuations was an exacerbation of the systemic inflammatory response of the body during prolonged mechanical ventilation.*

Keywords: *circadian rhythm, systolic blood pressure, acute cerebral failure, children.*

Relevance. A complication of the acute systemic inflammatory response caused by severe pneumonia can be encephalopathy - a disease characterized by damage and complete death of brain cells. The pathology develops as a result of a violation of the brain's oxygen supply and blood supply. Encephalopathy is not distinguished as a separate disease. This is a complex concept that includes pathologies of different nature, but leads to one result. Encephalopathy of the brain can develop in a person of any age. In preschool age, the tendency to generalization of the local process during inflammation remains and accompanies almost the entire period of childhood, but the tendency to sepsis is already decreasing. The leading place in the development of SIR in the child's body is given to inflammation mediators. More than 300 inflammatory mediators are known, but only dozens of them are used in clinical practice as markers, while the rest need to be discussed from the standpoint of reliability, sensitivity and specificity. The most severe complication of SIR is progressive multiple organ failure (POF). Mortality from POF remains extremely high, reaching 80% of the total mortality in intensive care units. Due to the lack of information on the specifics of managing children aged 3.1–7 years with severe acute pneumonia, an attempt was made to assess the effect of mechanical respiratory support on hemodynamics based on the study of circadian rhythm monitoring data for systolic blood pressure (SBP) in SIR complicated by acute cerebral failure [1–4].

Objective. To study and assess the effect of acute cerebral failure caused by pneumonia on the circadian rhythm of systolic blood pressure in children aged 3.1–7 years. Material and methods of the study. The results of continuous prolonged monitoring with hourly recording of hemodynamic parameters (SBP), body temperature, and respiration were studied in children admitted to the ICU of the RRCEM in a serious condition caused by an infection complicated by acute respiratory and cerebral insufficiency at the age of 3.1 to 7 years. Intensive care was carried out in accordance with the recommendations in thematic clinical protocols. Group 1 included 7 children who, upon admission to the clinic and throughout intensive care, had no indications for mechanical respiratory support, which did not exclude oxygen therapy without mechanical ventilation. Almost all patients in Group 2 (8 children) were transferred to mechanical ventilation from the moment of admission to the clinic according to indications.

Results and discussion. As shown in Table 1, the mesoscopic circadian rhythm SBP in both groups did not differ from the physiological indicators in this age group. However, there is a certain tendency to increase the amplitude by 30%, the daily range of oscillations of the circadian rhythm of SBP by 30% depending on the duration of the MRP.

Table 1.

Average circadian rhythm of SBP

Groups	Mesor	Acrophase	Batiphase	Amplitude	Daily range of fluctuations
1	98±3	104±4	92±3	6±3	13±3
2 (7 суток)	98±2	105±3	92±3	7±3	13±4
2 (52 суток)	101±4	109±5	92±5	9±3	17±6

Table 2.

Circadian rhythm mesor SBP, mm Hg.

Days	1 group	2 group 7 days
1	105±3	98±5
2	101±3	94±1
3	97±3*	96±2
4	97±2*	101±1
5	98±2*	99±2
6	94±3*	100±2
7	93±3*	99±2

Table 3.

Average circadian rhythm of SBP, mm Hg

Hours	1 group	2 group 7 days	2 group 52 days
8	96±4	100±3	102±6
9	97±4	99±2	102±5
10	98±6	98±4	101±6
11	99±4	99±3	103±5
12	99±5	101±4	101±5
13	99±4	97±4	101±5
14	99±4	98±3	101±5
15	100±	96±2	101±6
16	101±	97±2	100±6
17	99±4	97±4	101±6
18	98±5	98±3	100±6
19	98±4	100±4	100±6
20	99±4	98±3	100±5
21	99±2	100±5	101±5
22	97±4	98±3	100±5
23	97±4	97±4	100±5
24	94±4	98±4	100±6

1	94±3	99±2	100±5
2	96±3	98±2	99±6
3	95±4	97±3	99±5
4	96±3	96±1	100±5
5	98±1	97±2	100±6
6	99±1	98±2	101±5
7	98±3	99±2	101±5

*- reliably relative to the indicator on day 1

In group 1, as the condition improved and intensive therapy became more effective, a decrease in the mesomorph of the circadian rhythm of SBP was noted on days 3-7 by 7%, 7%, 6%, 10%, 11%, respectively (Table 2). While in group 2, the mesomorph of the circadian rhythm of SBP relative to the indicator on day 1 did not change significantly during treatment. No significant differences from the indicator of group 1 were noted during the first 7 days in patients of group 2. However, longer mechanical ventilation in group 2 was accompanied by a tendency to increase the mesomorph of the circadian rhythm of SBP to 110 mm Hg on day 25. Fluctuations in the studied indicator fit into the weekly biorhythms with alternation of 6-4 day fluctuations, with an amplitude mainly within the limits of acceptable physiological indicators (Fig. 1). The MRP performed did not cause any significant differences in the average circadian rhythm of SBP in Group 2 (Table 3).

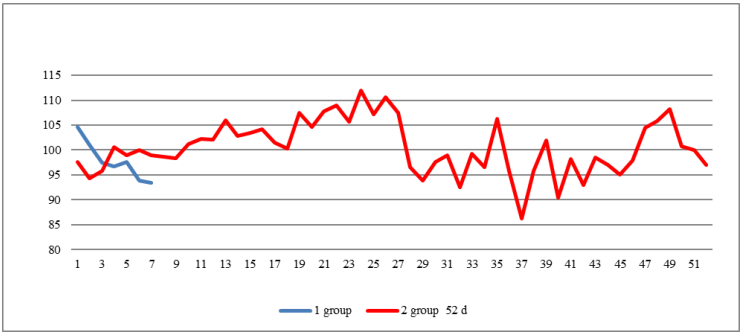

Figure 1. *Dynamics of the mesomorph of the circadian rhythm of the SBP, mm Hg.*

The average circadian rhythm in Group 1 was characterized by an average value of 98±4 mm Hg in both groups of children. With prolonged mechanical ventilation, the average SBP increased to 101±5 mm Hg, but not significantly. The acrophase in Group 1 was shifted to 16:00 p.m., while in the first 7 days of treatment, the projection of the acrophase of the SBP was at 12:00 p.m. (the norm

is 9-11:00 p.m.), but with prolonged mechanical ventilation, the shift in the acrophase decreased (11:00 p.m.).

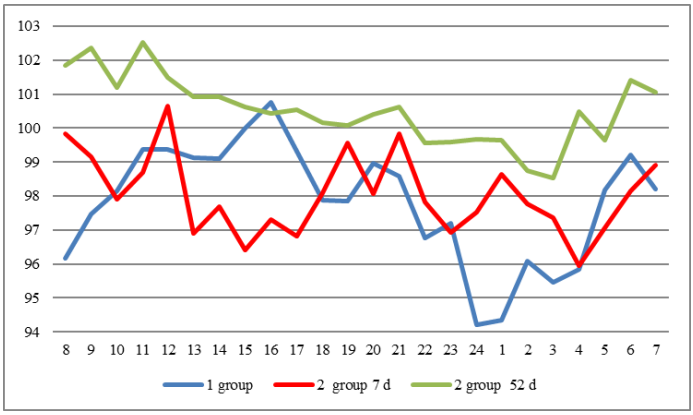

Figure 2. *Average circadian rhythm of SBP, mm Hg.*

The projection of the bathyphase of the circadian rhythm of SBP in group 1 was at 24 hours, in group 2 during the first 7 days at 4 am, with prolonged mechanical ventilation for 52 days at 3 am. The phase characteristic of the structural components of the average circadian rhythm made it possible to identify a slightly more pronounced shift in the peak of the acrophase of the circadian rhythm of SBP in group 1 and less noticeable shifts in the indicators in group 2 (Fig. 2). Thus, based on the obtained results, it can be imagined that the conducted respiratory apparatus support of breathing had a stress-limiting effect on hemodynamics in pneumonia in children aged 3.1-7 years.

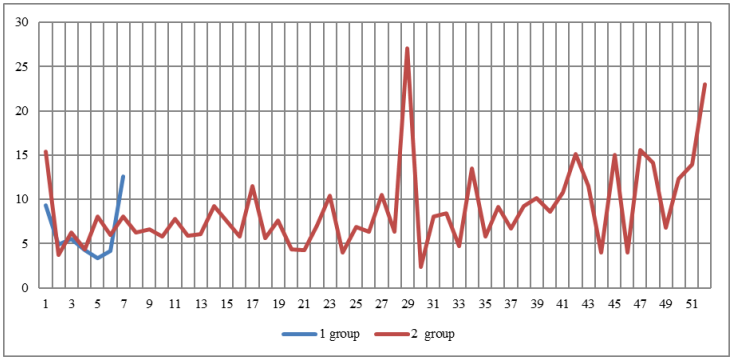

Figure 3. *Dynamics of the amplitude of the circadian rhythm of SBP, mmHg.*

The tendency to increase the amplitude, daily range of oscillations (Fig. 3, 4) of the circadian rhythm of SBP in the 2nd group after 27 days is due to secondary factors associated with a decrease in the effectiveness of syndromic, corrective intensive therapy. Confirmation of this is a more pronounced deformation of the circadian biorhythm in the specified periods (Fig. 3, 4).

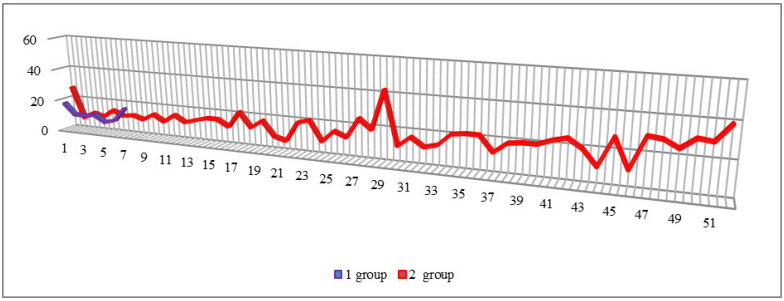

Figure 4. *Range of daily fluctuations in SBP, mm Hg.*

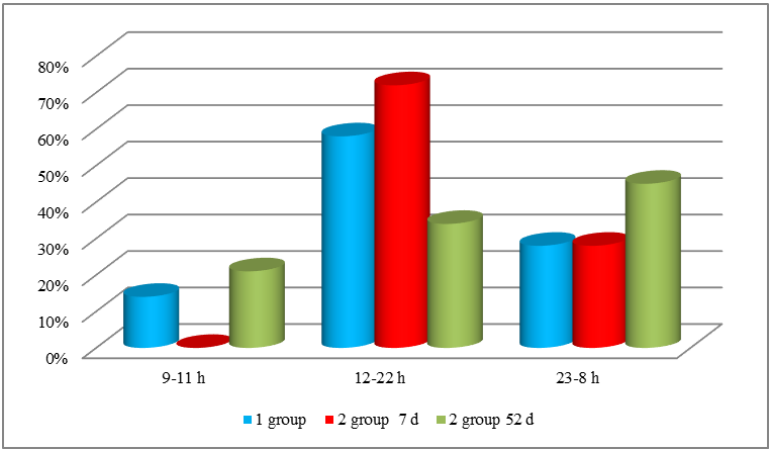

Figure 5. *Duration of circadian rhythm inversion of SBP in % of the duration of intensive therapy.*

The longest inversion of circadian rhythm (45%) was found in group 2, amounting to 23 days, while in group 1 the inversion of circadian rhythm of SBP lasted 2 days (Fig. 5).

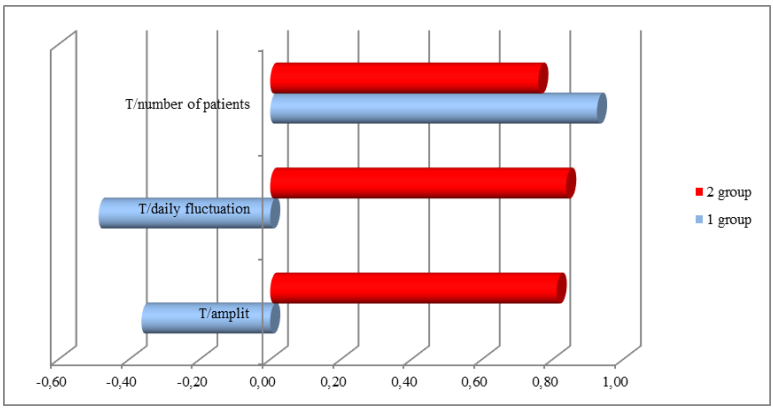

Figure 6. *Correlation relationships between mesor, amplitude, and daily fluctuations of the circadian rhythm of SBP.*

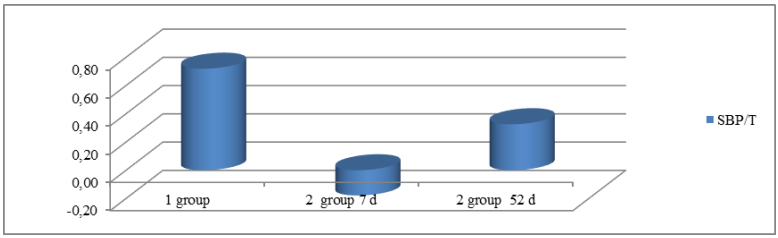

Figure 7. *Correlation links between the average circadian rhythm of SBP and body T at the age of 3.1-7 years*

The tendency to hyperthermic reaction was accompanied by an increase in the mesor of the circadian rhythm of SBP in group 1 (0.7). Moreover, destabilization of the mesor of the circadian rhythm of SBP with an increase in the inflammatory reaction was more pronounced in group 2 (0.8) (Fig. 6). The correlation link between the increase in the amplitude of fluctuations in body T and SBP was (0.79), changes in daily differences in T and SBP (0.9) in group 2 indicated that the leading cause of SBP changes was an exacerbation of the systemic inflammatory response of the body during prolonged mechanical ventilation. However, in group 1, a direct strong correlation link was found between changes in the average circadian rhythm of body temperature and SBP (0.72), which was almost absent (0.33) in children of group 2 (Fig. 7). Apparently, in patients with pneumonia with spontaneous breathing, the adaptive resources of the compensatory reaction of SBP in response to the hyperthermic reaction were preserved to a greater extent with a

less severe course of the infectious disease, less pronounced decompensation of the central nervous system and cardiovascular system at the age of 3.1-7 years.

Conclusion. The mesomorph of the circadian rhythm of SBP in both groups did not differ from the physiological norms in this age group. A tendency was revealed to increase the amplitude by 30%, the daily range of oscillations of the circadian rhythm of SBP by 30% depending on mechanical ventilation, the duration of MCI. Long-term (52 days) mechanical ventilation in group 2 was accompanied by a tendency to increase the mesomorph of the circadian rhythm of SBP to 110 mm Hg on the 24th day. Fluctuations in the studied indicator fit into the circadian biorhythms with alternation of 6-4 day waves. The longest inversion of the circadian rhythm of SBP (45%) was found in group 2, amounting to 23 days, while in group 1 the inversion of the circadian rhythm of SBP lasted 2 days. The leading cause of SBP fluctuations was the exacerbation of the systemic inflammatory response of the body during prolonged mechanical ventilation.

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DOI 10.34660/INF.2025.35.72.037
UDC 616.21

强烈太阳辐射对俄罗斯大学生心脏生物节律的影响

THE INFLUENCE OF INTENSE SOLAR RADIATION ON CARDIAC BIORHYTHMS IN STUDENTS OF RUSSIAN UNIVERSITIES

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摘要。在俄罗斯 9 所地区专业大学的 235 名年轻学生中，首次在教学实践中进行研究，研究了高水平太阳活动（太阳磁暴）对中枢血液动力学最重要指标之一——心率 （HR, bpm） 的影响。研究采用触诊法在站立、坐姿和卧姿下对桡动脉进行。研究发现，在太阳活动活跃的日子（2024 年 10 月 10 日和 11 日），心率与平常相比有可靠的增加趋势（p <0.05）。在这种情况下，身体在空间中的位置非常重要。根据病史，在 10 月 11 日太阳风暴高峰期，学生主观上注意到嗜睡（12.29%）、困倦（13.19%）、入睡困难（10.34%）、疲劳（11.06%）、易怒（9.23%）、偏头痛（8.57%）、畏光（1.16%）、智力下降（8.68%）、不愿交流（8.34%）、不愿做晨练（7.89%）和体育训练（6.82%）。结论是，由于白天 12 点至 16 点之间心率增加，建议减少此时的体力活动和体育锻炼。

关键词：俄罗斯大学生、心率、磁暴。

Abstract. *In the framework of the study, conducted for the first time in pedagogical practice, among 235 young students in 9 territorially located specialized universities of Russia, the influence of high levels of solar activity (solar magnetic storms) on one of the most important indicators of central hemodynamics - heart rate (HR, bpm) was studied. The study was conducted using the palpation method on the radial artery in a standing, sitting and lying position. It was noted that on days of high solar activity (October 10 and 11, 2024), the heart rate has a reliable tendency to increase (p <0.05) compared to normal days. In this case, the position of the body in space is of significant importance. It was established from the anamnesis that at the peak of the solar storm on October 11, students subjectively noted lethargy (12.29%), drowsiness (13.19%), difficulty falling asleep (10.34%), fatigue (11.06%), irritability (9.23%), migraine (8.57%), photophobia (1.16%), decreased mental performance (8.68%), unwillingness to communicate (8.34%), unwillingness to do morning hygienic gymnastics (7.89%) and to conduct sports training (6.82%). It was concluded that due to the fact that*

during daylight hours the heart rate increases between 12 and 16 o'clock, it is recommended to reduce physical activity and physical activity at this time.

Keywords: *students of Russian universities, heart rate, magnetic storms.*

Relevance. On Earth, four magnetic storms are regularly recorded almost every month. For the first time in 1928, Soviet biophysicist Professor A.L. Chizhevsky put forward a hypothesis about the influence of magnetic storms on human health [1]. He noted that the influence of the universe and heliomagnetic storms affects 50-70% of the world's population [2]. In modern history, the strongest magnetic storm was on September 1, 1859. In subsequent years, strong magnetic storms were recorded in 1921, 1938, 1972, 1989, 2000 and 2003. Thus, according to the Hydrometeorological Center of the Russian Federation, in the last months of 2024, the number of solar flares has increased sharply, which astronomers associate with the fact that the Sun is approaching its 11-year peak of activity. It is impossible to predict with precision how long such solar activity may last, however, there is an assumption that our earth will experience frequent magnetic storms for another two years, after which the intensity Any scientific research aimed at developing regional standards for the functional state of modern student youth is not only relevant, but also in demand. We are deeply convinced that today in higher education it should become a mandatory rule - a teacher, especially a physical education teacher, starting classes with students, must have a complete understanding of their health, functional state and adaptive capabilities. At the same time, in our opinion, his research arsenal should include simple, safe and valid assessment methods that allow them to be used in any conditions of the educational or training process. During their studies at universities, students are exposed to a number of both specific (age, physiological and psychological effects, emotional overload, sedentary lifestyle) and non-specific (climatogeographic, environmental) factors. Modern innovative models of teaching students require significant mental and nervous-emotional stress from them.

In practical activities, physical education teachers of comprehensive schools and coaches use a simple method of assessing the heart rate by palpating the radial artery on the forearm in the athlete's standing position, less often sitting and rarely in the lying position. Due to the change in body position in space, the heart rate also changes, which has not only scientific but also practical significance.

In the available literature, we have not found chronobiological studies that compare the heart rate indicators during the day and week in adolescent students of specialized universities of the Russian Federation depending on the position of the body in space on normal days and during periods of high solar activity.

Object of the study: adolescent students of specialized territorially located universities of the Russian Federation.

Subject of the study - heart rate indicators while standing, sitting and lying down during the day and week in young men of universities of Russia at a high level of solar activity.

Hypothesis of the study. It is suggested, firstly, that in adolescent students the heart rate does not reliably depend on the region of residence. Secondly, the heart rate changes significantly with a change in body position in space. Thirdly, during a high level of solar activity the heart rate significantly increases, especially between 12 and 16 o'clock, which should be taken into account during physical activity.

The aim of the study: to characterize the features of the heart rate of adolescent students of specialized universities in Russia in different body positions in space during high levels of solar activity (magnetic storms).

Material and methods. Using the random sampling method, a chronobiological (seven days a week at 8, 12, 16 and 20 hours) study of the heart rate was conducted in 235 young men of full-time education at nine specialized higher educational institutions of the Russian Federation. Among them:

1. Khabarovsk Regional Institute for Education Development named after K.D. Ushinsky (KhRIED) – 22 (10.36%),
2. Irkutsk State University (ISU) – 24 (10.21%),
3. Siberian Federal University (SFU) – 29 (12.34%),
4. Novosibirsk State Pedagogical University (NSPU) – 31 (13.19%),
5. Tyumen State University (TSU) – 32 (13.61%),
6. Tyumen State Medical University (TSMU) – 21 (8.93%),
7. Tyumen Industrial University (TIU) – 34 (14.46%),
8. Ural State University of Physical Education – (UralSUPE) 26 (11.06%),
9. Tchaikovsky State Academy of Physical Education and Sports (TSAPES) – 17 (7.23%).

The results of the study were processed on a personal computer using the Statistika program. The reliability of differences was assessed using Student's t-test, with differences considered reliable at $p<0.05$.

Ethical review. When working with students, the authors observed the principles of voluntariness, rights and freedoms of the individual guaranteed by Articles 21 and 22 of the Constitution of the Russian Federation, and also complied with the Order of the Ministry of Health and Social Development of Russia No. 774n of August 31, 2010 "On the Ethics Council". The study was conducted in compliance with the ethical standards set out in the Helsinki Declaration of the World Medical Association "Ethical Principles for Medical Research Involving Human Subjects", which was adopted at the 59th General Assembly in October 2008. The authors received oral consent from the students to conduct the study and publish the data.

Research results and their discussion. From the anamnesis it was established that out of 235 students, 67 (28.51%) people had previously been involved in sports, and at the time of the examination they continued to train actively. Seasonal allergic rhinitis was observed in 11.8% of students, dental caries - in 19.3%, periodontosis - in 22.1%, hyperacid gastritis - in 7.4%, cholangitis - in 5.2%, vegetative-vascular dystonia - in 1.7%. It should be noted that during the period of high solar activity, students subjectively report lethargy (12.29%), drowsiness (13.19%), difficulty falling asleep (10.34%), fatigue (11.06%), irritability (9.23%), migraine (8.57%), decreased mental performance (8.68%), unwillingness to communicate (8.34%), do morning hygienic gymnastics (7.89%) and conduct sports training (6.82%). To obtain reliable information on the functional state of the central hemodynamics in students of adolescence studying in various territorially located universities of Russia, we conducted a study of the heart rate (Table 1) in a standing, sitting and lying position at the peak of strong and moderate solar activity from the standpoint of chronobiology.

Table 1

Heart rate in adolescent students of specialized universities in Russia during high solar activity on October 11, 2024 standing (I), sitting (II), lying (III) and on normal days (IV) (M±m)

HEI	Term	8 hours	12 hours	16 hours	20 hours
KhRIED n=22	I	85,28±1,02	86,92±1,03	88,09±1,05	85,40±1,04
	II	83,56±1,07	84,22±1,06	86,79±1,08	83,43±1,06
	III	80,98±1,08	81,61±1,04	84,18±1,06	80,30±1,05
	IV	76,87±0,93	77,23±0,95	79,87±0,99	76,49±0,94
ISU n=24	I	86,37±1,02	87,68±1,04	88,22±1,05	86,74±1,00
	II	84,26±1,07	85,14±1,05	86,68±1,08	84,50±1,05
	III	79,94±1,08	82,59±1,01	84,41±1,06	80,69±1,07
	IV	75,73±0,92	76,44±0,93	78,58±0,97	76,37±0,94
SFU n=29	I	86,37±1,02	87,68±1,04	88,22±1,05	86,74±1,00
	II	84,26±1,07	85,14±1,05	86,68±1,08	84,50±1,05
	III	79,94±1,08	82,59±1,01	84,41±1,06	80,69±1,07
	IV	76,73±0,92	76,44±0,93	78,58±0,97	76,37±0,94
NSPU n=31	I	88,17±1,11	89,94±1,13	91,24±1,13	53,21±1,24
	II	85,56±1,10	86,15±1,11	88,59±1,10	53,61±1,23
	III	80,29±1,07	81,95±1,10	83,75±1,14	54,31±1,21
	IV	77,68±0,96	79,68±1,06	79,48±0,98	78,18±0,95
TSU n=32	I	87,59±1,05	88,68±1,12	92,08±1,16	88,02±1,25
	II	84,31±1,10	86,36±1,11	88,16±1,13	85,87±1,23
	III	81,73±1,18	82,41±1,14	85,82±1,19	81,79±1,20
	IV	76,28±0,92	77,28±0,99	78,28±1,00	76,54±0,97

TIU n=34	I	88,03±1,11	89,49±1,13	93,62±1,19	88,89±1,30
	II	84,49±1,16	85,67±1,18	89,94±1,14	86,17±1,30
	III	81,70±1,19	82,86±1,17	85,53±1,19	83,07±1,30
	IV	77,85±0,97	78,19±1,02	79,28±1,06	78,28±0,98
TSMU n=21	I	89,86±1,15	91,13±1,18	94,55±1,16	88,61±1,17
	II	86,19±1,13	88,40±1,17	90,68±1,15	85,55±1,18
	III	82,42±1,19	84,93±1,15	86,42±1,18	83,15±1,16
	IV	79,64±1,07	80,85±1,08	82,85±1,11	80,85±1,17
UralSUPE n=26	I	87,19±1,14	88,63±1,16	89,41±1,19	86,73±1,15
	II	85,79±1,13	86,88±1,15	87,33±1,18	85,17±1,14
	III	81,94±1,14	83,29±1,15	85,84±1,17	80,19±1,16
	IV	77,87±1,07	78,35±1,12	80,42±1,08	78,26±1,10
TSAPES n=17	I	86,77±1,16	87,89±1,17	88,53±1,19	86,02±1,20
	II	84,93±1,19	85,06±1,19	86,49±1,21	84,11±1,19
	III	80,21±1,20	81,85±1,23	82,57±1,22	80,32±1,21
	IV	75,35±1,12	76,35±1,12	78,35±1,12	74,35±1,12

The results of the student survey during the period of high solar activity showed that 203 out of 256 young men (86.38%) did not even know that the earth was affected by a pronounced electromagnetic disturbance of the sun. Only at the moment of calculating the heart rate did the students get an objective idea of what a magnetic storm is and how it affects the human circulatory system. From the analysis of the data presented in the table, it can be concluded that during the period of peak solar activity, all students, regardless of the region of residence, have central hemodynamics exposed to significant external electromagnetic influence. It is noteworthy, firstly, that the heart rate adequately responds to changes in the body in space, becoming less frequent when moving from a standing to a lying position ($p < 0.05$). Secondly, an increase in heart rate is noted between 12 and 16 o'clock in the afternoon (especially at 16 o'clock) in comparison with morning and evening values. Thirdly, in the standing position, the heart rate is significantly higher ($p<0.05$) than in the lying position. In our opinion, such a state of central hemodynamics is an indicator of not only an increase in the tension of homeostatic adaptation mechanisms, but also a decrease in the adaptive capabilities of the adolescent body associated with the negative impact of solar activity.

We suggest that each student keep a self-monitoring diary reflecting the state of health and we believe that regular self-monitoring of the heart rate, as well as other hemodynamic indicators, can serve as a kind of marker of the adaptive capabilities of the adolescent body over a long period of time. Considering that the high level of solar activity on earth can last for another two years, we plan to further study its impact on humans.

Conclusions:

1. A high level of solar activity has a significant impact on human somatic health, causing lethargy, drowsiness, poor sleep, fatigue, irritability, decreased mental performance, unwillingness to communicate, unwillingness to do morning hygienic gymnastics and conduct sports training. High levels of solar activity in young men caused an increase in heart rate, depending on the position of the body in space.
2. During periods of high solar activity, the heart rate of young students studying at specialized universities in the Russian Federation significantly increases, which should be taken into account both during the educational process and during classes in sports sections based on interests.

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DOI 10.34660/INF.2025.27.14.038

鲁氏耶尔森菌——一种新的人类病原体
YERSINIA RUCKERI – A NEW HUMAN PATHOGEN

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摘要。讨论了研究人畜共患病在人类中传播的重要性。展示了鲁氏耶尔森菌的致病因素以及不仅在冷血动物中而且在人类中引起疾病的可能性。鲁氏耶尔森菌的表型鉴定很困难，因此有必要使用分子遗传学和光谱分析方法。对这种腐生动物病原体进行病原学鉴别诊断很重要，其在耶尔森菌病流行病学中的重要性尚未得到充分研究。

关键词：耶尔森菌、鲁氏耶尔森菌、耶尔森菌病、腐生动物病、致病因素、类小肠结肠炎耶尔森菌、“同一个健康”。

Abstract. *The importance of studying the spread of zoonoses in the human population is discussed. Pathogenicity factors of Yersinia ruckeri and the potential to cause diseases not only in cold-blooded animals, but also in humans are shown. Phenotypic identification of Y. ruckeri is difficult, so it is necessary to use molecular genetic and spectral methods of analysis. It is important to conduct etiological differential diagnostics of this saprozoonotic pathogen, the significance of which in the epidemiology of yersiniosis has not been sufficiently studied.*

Keywords: *Yersinia, Y. ruckeri, yersiniosis, saprozoonoses, pathogenicity factors, Y. enterocolitica-like, “One Health”.*

The purpose of this study was to study the pathogenicity of *Y. ruckeri* based on literature data and our own research.

It has been proven that two types of Y. enterocolitica-like microbes cause infectious diseases in animals. The causative agent of infection in salmon fish is Y. ruckeri, leading to their mass death, and Y. entomophaga causes an infectious disease in the New Zealand grass larva Costelytra zealandica [18]. At the same time, the role of Y. enterocolitica-like microbes in human pathology is poorly understood. An illustration of the conceptual hypothesis about the transition of saprozoonoses pathogens to the section of human pathology can be provided by the information on the study of *Y. ruckeri* and other representatives of Y. enterocolitica-like microbes. Thus, over the past 80 years, more than 75% of all new human infectious diseases worldwide have arisen due to the transfer of pathogens from the animal world to the human population. This process is accelerated by climate change on Earth. For the animal world: melting ice leads to a disruption of hunting conditions for predators, a decrease in their numbers and a deterioration in their health; an increase in the number of ticks, helminths and other parasites; a change in migration routes (primarily birds) and methods of reproduction of species. For humans: a decrease in the adaptive and immune capabilities of the body and, as a consequence, an increase in somatic and infectious diseases. Therefore, strengthening global security in the field of health at the junction of human and animal habitats is so relevant in accordance with the WHO concept of "One Health" in the discussed topic of the article. Y. ruckeri is a facultative anaerobe with respiratory and fermentative types of metabolism. At a temperature of 37 °C, bacterial growth is inhibited [6]. *Y. ruckeri*, unlike *Y. enterocolitica*, does not decompose urea and is not capable of utilizing sucrose, sorbitol, inositol, arabinose and xylose [5]. It has a genome size of 3.7 Mb with a G + C ratio of ~47%, like other Yersinia [21, 22]. Y. ruckeri strains are classified into serotypes and biotypes based on differences in outer membrane proteins. Serotype O1 is divided into two subgroups O1a (serovar I) and O1b (serovar III), and serotype O2 (serovar II) is divided into three subgroups O2a, O2b and O2c. The rest are designated as serotype O3 (serovar V) and serotype O4 (serovar VI) [26]. Y. ruckeri strains are also divided into two biotypes with respect to lipase. However, the ability to secrete lipase apparently does not have a great significance for the virulence of Y. ruckeri [15,20]. Pathogenicity of Yersinia depends on the adhesive properties of bacteria (YadA, InvA). However, even closely related adhesins in different strains can have different functions [25,27]. The role of porins, the most common proteins of the outer membrane, in adhesion processes is poorly understood. They ensure the transport of nutrients and xenobiotics, and the reception of bacteriophages. The main porin of the outer membrane of Y. ruckeri (YrOmpF) has activity typical of porins of gram-negative bacteria [8]. The effect of Y. ruckeri porins on the cell cycle of human malignant

cells and normal fish tissue cells has been shown. Porins isolated from the outer membrane of *Y. ruckeri* have antitumor activity. In the future, porins can be considered as a component of drugs for the delivery of chemotherapeutic agents to target cells [23].

The main component of the outer membrane of gram-negative bacteria (including Yersinia) is lipopolysaccharide (LPS), which suggests its participation in the primary contact of the bacterium and eukaryocyte [15]. The virulence of Yersinia also depends on the secretory system, pili, toxins, iron accumulation systems, and biofilm formation. Y. ruckeri can survive outside the host organism for 4 months. Bacteria use flagella and pili to contact other bacteria and form biofilms. Increased expression of flagellar proteins is a phenotypic characteristic of bacteria associated with high adhesiveness. It has now been proven that biofilm formation is an important factor in the survival of bacteria on surfaces and in the aquatic environment [25,14]. M. Kotetishvili et al. [19] used primers based on fragments of the genes of ribosomal RNA, glutamine synthetase A, gyrase B, recombinant protein A for multilocus sequencing and studying the phylogenetic relationships of different Yersinia species. During the experiments, they found that Y. ruckeri is the most genetically homogeneous and most distant group within the genus. Several mechanisms of virulence of *Y. ruckeri* were identified, which differ depending on the geographical origin of the isolate. Extracellular toxins Yrp1 and YhlA are important virulence factors. Yrp1 protease has a wide range of targets and destroys fibronectin, actin and myosin. Hemolysin YhlA has cytotoxic and hemolytic activity. Genes involved in the iron absorption system of the siderophore ruckerbactin are expressed by the bacterium during contamination. Inactivation of the corresponding gene leads to a hundredfold increase in the LD50 of the bacterium [20,22].

A β-lactamase gene has been found on the chromosome of *Y. ruckeri*, but it is unlikely that this gene will be expressed at a high level [26,27]. In vitro tests have shown that Y. ruckeri readily develops resistance to oxylinic acid, oxytetracycline, and enhanced sulfonamides [21].

Finally, Y. ruckeri is also a producer of the antibiotic holomycin. A regulatory gene hom15 has been identified, which encodes a cold shock-like protein. It is likely that it regulates holomycin production at low cultivation temperatures. It is unknown why the fish pathogen Y. ruckeri produces holomycin and whether this is related to the pathogenicity of this species. It is likely that the antibacterial nature of holomycin may allow Y. ruckeri to compete with other bacteria for survival [24].

The proportion of rare Yersinia (*Y. enterocolitica*-like microbes) in organized groups of the Northwestern region is shown using the example of monitoring their microbial landscape. A total of 1,364 Yersinia strains were isolated:

– 338 (24.8%) from clinical material;
– 942 (69.1%) from environmental objects;
– 83 (6.1%) from field material.

The isolated Yersinia were distributed by species as follows: *Y. pseudotuberculosis* – 323; *Y. enterocolitica* – 784; The remaining strains were identified as *Y. enterocolitica*-like bacteria.

The medical and geographical characteristics of the North-West of Russia correspond to a cold and humid climate with constant sharp temperature changes, which creates favorable conditions for the preservation and accumulation of yersiniosis pathogens and other saprozoonoses in the environment due to psychrophilic and other adaptive properties. Climate change towards warming and increased humidity, socio-economic transformations lead to a change in the ecology of microbes, up to the replacement of the leading yersiniosis pathogens with other, poorly studied yersinia, the emergence of new subspecies of bacteria with altered genetic and biological properties that are in an inactive state. Physicochemical parameters of the environment affect the expression of their virulent properties [2,10]. An interesting fact is that *Y. ruckeri* was recently isolated from a wound infection in humans [16], as well as from milk, cheese, chicken meat and minced meat [4,17]. Being an absolute pathogen for fish, often consumed by humans not only in thermally processed but also raw form, the question arises about the possible etiological significance of *Y. ruckeri*. Today, seafood dishes are becoming increasingly popular. In addition to rice, fish is also widely used for their preparation [9]. The results of D.K. Chistyulin's studies [13] indicate that in 30% of cases, *Y. ruckeri* antigens are present in the internal organs of fish, mollusks, crustaceans, and on the surface of algae thallus. *Y. ruckeri* is transmitted horizontally, through water and excrement of infected fish. The fact that *Y. ruckeri* was isolated from human food makes us seriously think about studying the biological characteristics of this microorganism to ensure food safety.

A reliable case of isolation of *Yersina ruckeri* from wound discharge is described. The wound was received by a man while rowing in a river in Belgium [16]. Phenotypic characteristics of the isolated strain were determined using standard methods. Identification was performed using matrix-assisted laser desorption ionization mass spectrometry (MALDI-TOFMS) by the direct transfer method. 16S rRNA sequencing was performed at the National Reference Center for Wound Infections. Identification was confirmed by the National Reference Center for *Yersinia*. Isolation of *Y. ruckeri* from human wounds or biopsies and its possible association with infection in humans have not been previously described [1]. In Russia, the *Y. ruckeri* strain was first isolated from humans by E.A. Bogumilchik et al. [3] during a bacteriological analysis of feces of a gastroenterological patient. The results of the study for other viral and bacterial infections were nega-

tive. A characteristic feature of Y. ruckeri is the absence of the urease enzyme, as a result of which the colonies on elective nutrient media were not stained blue-green, as in other *Yersinia*. Further studies using the MALDI ToFMS method and determination of biochemical activity using the API 20E test system showed that the bacteria belong to the species *Y. ruckeri*. Sequencing of the 16S rRNA gene was used as an additional method for determining the genus and species affiliation of the studied strain.

However, primers constructed on the basis of ribosomal genes often give false positive results and detect not only *Y. ruckeri*, but also DNA of other enterobacteria, which is unacceptable for differential diagnostics. Therefore, it is recommended to additionally use multilocus sequencing to confirm the specificity of the amplicons [7]. Detection of genetic material of such Yersinia in biological samples of a sick person may indicate that clinical manifestations of an infectious disease may be caused by Yersinia species previously considered non-pathogenic [11,12,15]. There is a need to develop more accurate methods for differential diagnosis of *Y. ruckeri*. Additional studies are required to better understand the pathogenic properties of these Yersinia and their impact on human health. Thus, *Y. ruckeri* is of interest to medical and veterinary services, since the role of these microbes in the occurrence of human and animal infections requires further study and attention.

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DOI 10.34660/INF.2025.60.80.039

植入电极治疗坐骨神经病变的电刺激方式和选择
MODES AND OPTIONS OF ELECTRICAL STIMULATION USING IMPLANTED ELECTRODES FOR NEUROPATHIES OF THE SCIATIC NERVE

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摘要。22%　的病例在髋关节（例如关节成形术）和骨盆骨手术后出现神经病变[1]。最常见的是，坐骨神经结构的病理变化发生在从其穿过梨状孔到臀沟的区域。这是因为神经与骨盆内部肌肉群（梨状肌和双生肌）紧密接触。在此区域，神经会弯曲，即使轻微的坐骨神经受压或拉伸也会导致神经病变的临床表现。由于坐骨神经与骨盆骨和髋关节在解剖学上非常接近，因此该区域的骨折、脱位或手术干预经常会导致神经受到牵引损伤或被骨碎片的锋利边缘撕裂 [2, 3]。神经病变的临床表现可能包括丧失（感觉和运动障碍）和刺激症状——严重的神经性疼痛综合征 [4]。

关键词：神经病变、坐骨神经、电刺激。

Abstract. *In 22% of cases, neuropathy develops after surgical interventions on the hip joint (e.g., after arthroplasty) and pelvic bones [1]. Most often, pathological changes in the structure of the sciatic nerve are detected in the area from its exit through the infrapiriform foramen to the gluteal fold. This is explained by the close contact of the nerve with the internal group of pelvic muscles (the piriformis and gemelli muscles). In this area, the nerve bends, and even slight compression or stretching of the sciatic nerve can lead to the clinical presentation of neuropathy. Due to the close anatomical proximity of the sciatic nerve to the pelvic bones and hip joint, fractures, dislocations, or surgical interventions in this area frequently result in traction injuries to the nerve or its laceration by sharp edges of bone fragments [2, 3]. The clinical presentation of neuropathy may include symptoms*

of both loss (sensory and motor impairments) and irritation—severe neuropathic pain syndrome [4].

Keywords: *neuropathy, sciatic nerve, electrical stimulation.*

Purpose of the work: The use of puncture epidural electrical stimulation to relieve pain and reduce paresis in patients with traction neuropathy of the sciatic nerve after hip arthroplasty.

Based on the results of the study by the Department of the Belarusian State University of Informatics and Radioelectronics, electrical stimulation, causing motor excitation and muscle contraction, simultaneously reflexively enhances the entire complex of metabolic and trophic processes aimed at providing energy to the working muscles. When a stimulating electric current passes along the nerve trunks, the conductivity of nerve excitation increases, and the regeneration of damaged nerves accelerates. Electrical impulses lead to muscle contraction caused by the stimulating electric current, even with complete disruption of nerve conductivity, and also inhibits the degeneration of muscle into connective tissue. Electrical stimulation restores the activity of the neuromuscular apparatus, increases muscle tone and muscle mass volume, and has an analgesic effect. The strength, speed of contraction and performance of muscles characterize the functional state of the neuromuscular apparatus, as well as the interaction of synergist muscles and antagonist muscles. Depending on the amplitude of the signals and the excitation threshold of the stimulated neuromuscular structure, it is necessary to select the electrical stimulation modes [5, 6].

Materials and methods: Since 2015, at the Ilizarov Center, based on the Department of TOO No. 15, 400 minimally invasive surgical interventions have been performed to implant electrodes, including 18 Medtronic systems (eight-channel electrodes in patients with neuropathic pain syndrome); 37 NeiSi-3M systems (8 petal electrodes during microsurgical neurolysis, 29 four-channel epidural puncture implanted electrodes); the remaining 345 patients were implanted with single-channel electrodes to perform test electrical stimulation (including 26 epineural electrodes during revision, 13 patients after epi-perineural neurorrhaphy), 306 patients (76.5%) with neurological deficit, they were implanted with epidural electrodes at the level of a clinically significant segment by puncture through a Dufour needle, using a conductor). The selected variants and modes of electrical stimulation according to the dominant clinical effect allow to achieve relief of pain syndrome, significant reduction of paresis, reduction of sensory disorders. In clinical practice, the mode of action of more than 90 Hz allows to reduce the subjective component of pain, the systems of prolonged electrical stimulation adjusted in the mode of 120 - 125 Hz do not cause muscle contraction registered visually or with the help of a sensor. This mode of electrical stimulation is aimed at reducing

spasticity of the interested muscle groups, as well as reducing the neuropathic component of the pain syndrome, with the point of application - spinal ganglia).

According to the definition of experts from the International Association for the Study of Pain (IASP), neuropathic pain is pain that occurs as a result of direct damage or disease of the somatosensory system (NeuPSIGof IASP — Eur. J. Pain, 2007). Clinically, this is manifested by partial or complete loss of sensitivity (including pain) with the simultaneous occurrence of unpleasant, often pronounced pain sensations in the innervation zone of the damaged area of the peripheral or central nervous system.

The mechanism of action of neurostimulation is a multi-level mechanism. The effect on the "gate" mechanism (Melzack and Wall Theory, 1965) suggests the presence of a "gate" in the spinal cord that prohibits or allows the passage of pain signals to the brain; modulation of nerve transmission, including modulation of the sympathetic nervous system; as well as the release of neuromodulators and neurotransmitters affecting peripheral vasodilation. Despite all sorts of theories, the physiological basis of electrical stimulation is still not clear enough, although the method of spinal cord stimulation was proposed more than 40 years ago. The most important parameter selectrical impulse: amplitude (V), pulse width – time (μs), frequency (Hz). The main goal of selecting electrical stimulation is to create a stimulation program that would cause muscle contraction and mask the patient's pain zone with paresthesia. Indications for temporary and prolonged electrical stimulation: paresis accompanied by a confirmed diagnosis, as well as the neuropathic component of the pain component. Temporary electrical stimulation, including in test mode, is performed daily (procedure duration is 10 minutes) for 12-14 days (course duration depends on clinical manifestations) and promotes an increase in muscle strength and excitability.

The stimulator provides stimulation with voltage pulses or current pulses in the modes, respectively: "Voltage"; "Current". The pulses are applied to an arbitrarily selected pair of contacts. The pulses are supplied in bursts with a programmable duration and pause between bursts (stimulation parameters: with a step of 1 Hz; 10 μs; 0.1 V, with a load resistance of at least 1 kOhm; maximum current in the voltage pulse stimulation mode 10 mA; maximum voltage in the current pulse stimulation mode 10.3 V; duration of pulse bursts (1...3,600) s; pause between bursts (0...3,600) s; the pulse frequency changes from 2 to 140 Hz and back to 2 Hz). The stimulation modes and parameters can be changed and saved in the non-volatile memory of the stimulator for each patient separately. When stimulation is turned on, the pulse amplitude increases smoothly from zero to 100% of the set voltage (current) value, with a rise time of 1 second [7, 8].

Results: The data analysis was performed by evaluating electromyograms. The results obtained are explained by the fact that stimulation is associated with the

ability of proprioceptors to respond to stimulation with impulses for a long time, through spinal motor neurons of the same segments, a feedback loop is closed, the impulses that arise in response maintain muscle tone and trophic processes at a high level. Consequently, the stimulating effect mainly affects the efferent system with prolonged stimulation by the system. The effect of the effect is a direct effect on neuromuscular structures, stimulating signals cause fascicular twitching of muscle fibers, but the entire muscle does not tense up and there is no movement in the joint.

The study involved a group of subjects of both sexes aged 8 to 72 years. Plate electrodes measuring 3 x 6 cm were attached to the epineural sheath of the peripheral nerve. A rectangular pulse of 2 ms duration and a 5 ms pause were used; the total procedure duration was 10-15 min. Epidural electrodes were placed on the dura mater of the clinically significant segment. The performance of the innervated muscles was calculated based on a load equal to 60% of the greatest mass and the maximum possible number of joint movements between angles of 180 and 90° at 22-28 contractions per minute (the reverse movement was unloaded). It turned out that electrical stimulation improved the working parameters of the muscle and could partially replace motor training. With daily electrical stimulation for up to 2 weeks, maximum strength increased by 12-15%, dynamic strength by 20-25%, and performance by 75-80%. Electrical stimulation should be performed at least 2 times a day, as the effectiveness of the procedure is higher.

In temporary test stimulation with single-channel electrodes, the “Miorhythm” / “Rehobravo” device mode is used. This electrical stimulation leads to contraction of the stimulated muscle, and it can have varying degrees of expression. The effect of the impact has a direct impact on the neuromuscular structures and is stronger, the efferent effect on all levels of the motor analyzer is clearly expressed. The evoked maximum muscle contraction can be maintained longer, and an advantage for training denervated muscles has been revealed, leading to an increase in the force of contraction.

At the end of the course of temporary electrical stimulation, patients experience improved muscle support ability, increased muscle tone, electrical excitability of each muscle involved increases by 15–30%, and performance is higher by 25–40%. The achieved increase in strength, even after 3–6 months, decreases by only 5–10%. Therefore, it is recommended to repeat the course of electrical stimulation after 3–6 months.

Conclusions. When conducting electrical stimulation of the neuromuscular system, it is important to rationally select its modes and a combination of tonic and kinetic contractions; this significantly affects the development of strength, increased excitability and muscle performance. Electrical stimulation increases blood flow in muscles, has an analgesic and anti-inflammatory effect, prevents

the occurrence of atrophy from inactivity, slows its development during denervation, reduces tone in the presence of spasticity, improves nerve regeneration. It is also important to consider that when selecting electrical stimulation modes, a combined effect on epidural / epineural and cutaneous leads to the interested muscle group (autonomous zone) is advisable. The expediency of such application of electrodes, the electrical circuit is closed in the innervation zone of the segment to muscle fibers, while less power of stimulating electrical effects is needed to ensure muscle contraction.

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DOI 10.34660/INF.2025.66.18.040

急性脑供血不足对3.1～7岁儿童舒张压昼夜节律的影响

THE IMPACT OF ACUTE CEREBRAL INSUFFICIENCY ON THE CIRCADIAN RHYTHM OF DIASTOLIC BLOOD PRESSURE IN 3.1-7 YEAR OLDS

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摘要。在两组（1-自主呼吸和2-机械通气）中，整个观察期（52天）重症肺炎并发急性脑功能不全（ACI）儿童的平均DBP水平均在允许的标准值范围内。峰值期的DBP指标明显高于第2组（7天）的平均每日指标11%、（52天）16%，而第1组的平均每日DBP水平有升高的趋势。在深水期，第2组（7天）儿童的DBP可靠地下降了10%。重症监护2周后DBP指标的每日波动表明儿童在呼吸恢复和准备转入自主呼吸的过程中出现了代偿性血流动力学反应。在这方面，在长期机械通气的后期反复尝试转入自主呼吸时，应辅以适当的支持疗法、预防措施（因为存在发生急性线粒体衰竭的风险）、额外的肠外营养、多种维生素复合物、在适应急性能量缺乏状态期间保护儿童的身体。

关键词：急性脑衰竭、昼夜节律、舒张压、儿童。

Abstract. *The average DBP level for the entire observation period (52 days) in children with severe pneumonia complicated by acute cerebral insufficiency (ACI) was determined within the permissible standard values in both groups (1 - spontaneous breathing and 2 - mechanical ventilation). The DBP indicator in the acrophase was significantly higher than the average daily indicator in group 2 (7 days) by 11%, (52 days) by 16%, while in group 1 there was a tendency to an increase in the average daily DBP level. In the bathyphase, a reliable decrease in DBP was found in children of group 2 (7 days) by 10%. The revealed daily fluctuations in the DBP indicator at a later date after 2 weeks of intensive care*

indicated compensatory hemodynamic reactions in children in the process of breathing restoration and preparation for transfer to spontaneous breathing. In this regard, repeated attempts to transfer to spontaneous breathing at later stages of prolonged mechanical ventilation should be supported by appropriate supportive therapy, preventive measures due to the risk of developing acute mitochondrial failure, additional parenteral nutrition, multivitamin complexes, protection of the child's body during adaptation to an acute energy deficiency state.

Keywords: *acute cerebral failure, circadian rhythm, diastolic blood pressure, children.*

Relevance. Blood pressure (BP) reflects the degree of blood pressure on blood vessels during systole (contraction of the heart muscle) and diastole (relaxation of the heart muscle). Diastolic pressure (lower) - reflects the resistance of peripheral vessels. Normal pressure in children of the studied age group is 100-122 / 60-78 mm Hg. Low pressure occurs when the mechanisms of its regulation are disrupted. Chronic hypotension may be associated with hypothyroidism, when metabolism changes, in particular, proteins and electrolytes, which leads to redistribution of fluid in the body and changes in blood pressure. Chronic hypotension may be caused by decreased activity of the endocrine glands. For example, with hypothyroidism, metabolism changes, in particular, proteins and electrolytes, which leads to redistribution of fluid in the body and changes in blood pressure. Also, in hypothyroid conditions, the development of arterial hypotension is a consequence of bradycardia, chronic adrenal insufficiency, when a deficiency of the hormones aldosterone and cortisol leads to loss of sodium and retention of potassium in the body, which leads to dehydration and disruption of the cardiovascular system. Neurogenic decrease in blood pressure is more common in adolescence and young age. This type of hypotension is the result of a functional disorder of the nervous system or organic brain damage. The causes of organic brain damage can be: concussion injuries or brain contusions); degenerative changes in the brain tissue (changes in the structure of neuron membranes, destruction of neurons); cerebrovascular accidents (heart attacks, strokes); impaired secretion of catecholamines (adrenaline, noradrenaline), physiologically active substances into the blood - during physical exertion. In preschool age, the tendency to generalization of the local process during inflammation remains and accompanies almost the entire period of childhood, but the tendency to develop sepsis is already decreasing. The most severe complication of SVR is progressive multiple organ failure (POF). Mortality from PON remains extremely high, reaching 80% of the total mortality in intensive care units. Due to the lack of information on the specifics of managing children aged 3.1–7 years with severe acute pneumonia, an attempt was made to

assess the impact of mechanical respiratory support on hemodynamics in SVR complicated by acute cerebral insufficiency based on a study of circadian rhythm monitoring data for diastolic blood pressure (DBP) [1–4].

Objective. To study and evaluate the impact of acute cerebral failure caused by pneumonia on the circadian rhythm of diastolic blood pressure in children aged 3.1-7 years. Material and methods. The results of continuous prolonged monitoring with hourly recording of hemodynamic parameters (DBP), body temperature, and respiration were studied in children admitted to the ICU of the RRCEM in a serious condition caused by infection complicated by acute respiratory and cerebral failure in children aged 3.1 to 7 years. Intensive care was carried out in accordance with the recommendations in thematic clinical protocols. Group 1 included 7 children who had no indications for mechanical respiratory support upon admission to the clinic and throughout intensive care, which did not exclude oxygen therapy without mechanical ventilation. Almost all patients in Group 2 (8 children) were transferred to mechanical ventilation from the moment of admission to the clinic according to indications. The research data were processed by the variation statistics method using the Excel program by calculating the arithmetic mean values (M) and errors of means (m). To assess the reliability of differences between two values, the parametric Student's criterion (t) was used. The relationship between the dynamics of the studied parameters was determined by the paired correlation method. The critical level of significance was taken to be 0.05.

Results and their discussion.

It was revealed that the average DBP level for the entire observation period was determined within the permissible standard values (Table 1). The DBP indicator in the acrophase was significantly higher than the average daily indicator in group 2 (7 days) by 11%, (52 days) by 16%, while in group 1 there was a tendency to increase in DBP. In the bathyphase, a reliable decrease in DBP was found in children of group 2 (7 days) by 10%.

Table 1.

Average circadian rhythm of DBP during the observation period, mm Hg.

Group	Mesor	In acrophase	In the bathyphase	Amplitude	Range of oscillations
1	58±4	65±4	51±4	7±2	13±4
2 (7 days)	59±2	65±2*	54±2*	6±2	11±3
2 (52 days)	60±3	70±4*	52±6	10±5	19±8

*- the deviation is reliable relative to the mesor

Table 2.

Dynamics of mesor circus rhythm DBP

Days	1 group	2 group 7 days
1	63±5	60±4
2	61±3	57±2
3	58±2	55±3
4	59±2	60±1
5	61±2	61±3
6	56±2	61±2
7	48±3‴	60±3

Table 3.

Average circadian rhythm of DBP, mmHg

Hours	1 group	2 group 7 days	2 group 52 days
8	60±5	62±3	62±5
9	59±4	60±2	61±5
10	59±3	61±4	61±6
11	58±3	58±3	62±5
12	59±4	59±3	60±5
13	59±3	60±2	61±5
14	59±4	60±3	61±5
15	61±3	58±2	60±5
16	60±5	59±2	60±5
17	60±4	58±2	60±5
18	59±4	59±2	59±5
19	59±5	60±3	60±6
20	59±4	59±4	60±4
21	58±4	59±5	60±5
22	57±6	59±4	59±6
23	57±4	59±4	59±6
24	55±4	60±2	59±5
1	54±5	60±1	59±5
2	57±3	59±2	59±4
3	57±3	58±2	58±5
4	57±4	58±3	59±5
5	57±4	57±2	58±5
6	56±4	58±2	59±4
7	57±6	59±2	60±5

‴- the difference is reliable relative to the indicator on day 1.

A reliable decrease in the meso of the circadian rhythm of DBP on day 7 by 23% ($p < 0.05$) was noted in children of group 1. While in group 2, against the background of prolonged mechanical ventilation, the meso of the circadian rhythm of DBP remained stable within the physiological norm (Table 2). The study of the average circadian rhythm of DBP did not reveal significant deviations from the norm or intergroup differences (Table 3)

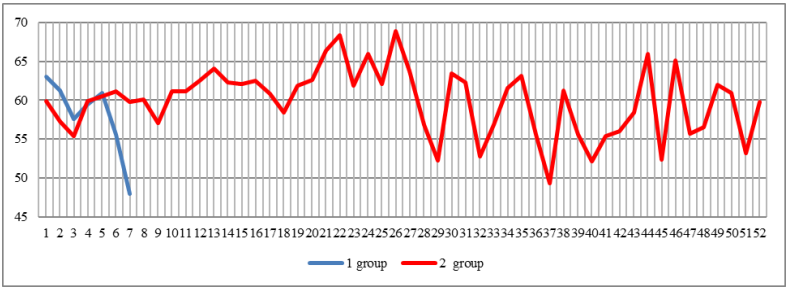

Figure 1. *Dynamics of the mesor of the circadian rhythm of DBP, mm Hg.*

During the observation period, changes in the mesor of the circadian rhythm of DBP in group 2 fit into five- to three-day fluctuations with an increase in amplitude to 15 mmHg after 10 days of mechanical ventilation. The findings were more consistent with the stressful nature of the instability of the regulation of the tone of peripheral vessels (Fig. 1), indicating the insufficient effectiveness of stress-protective intensive care. It is noteworthy that there were no significant differences between the groups in the average circadian rhythm of DBP (Fig. 2). The daily fluctuations in the average DBP in group 2 were monotonous compared to group 1. The projection of the acrophase in group 2 was at 11 am (normal), in group 1 at 15 am (shifted by 4 hours). The projection of DBP in group 1 in the bathyphase corresponded to the norm.

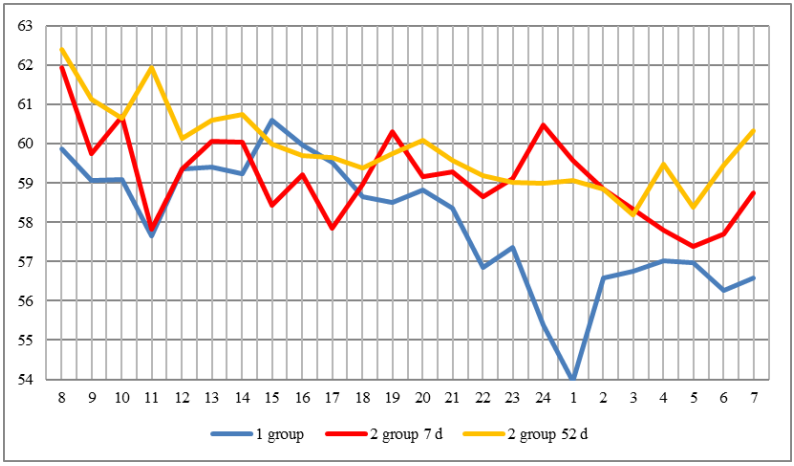

Figure 2. *Average circadian rhythm of DBP, mm Hg.*

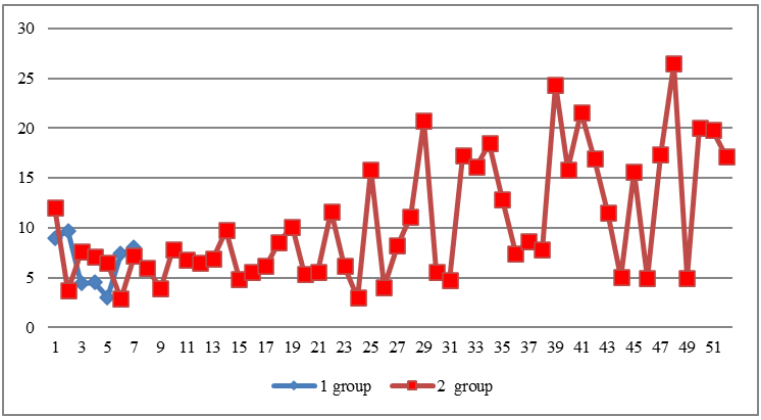

Figure 3. *Amplitude of the circadian rhythm of DBP, mm Hg.*

Insufficient effectiveness of stress-limiting therapy in the 2nd group was expressed in an increase in the amplitude of the circadian rhythm of DBP after the 13th day to 20 mm Hg (Fig. 3).

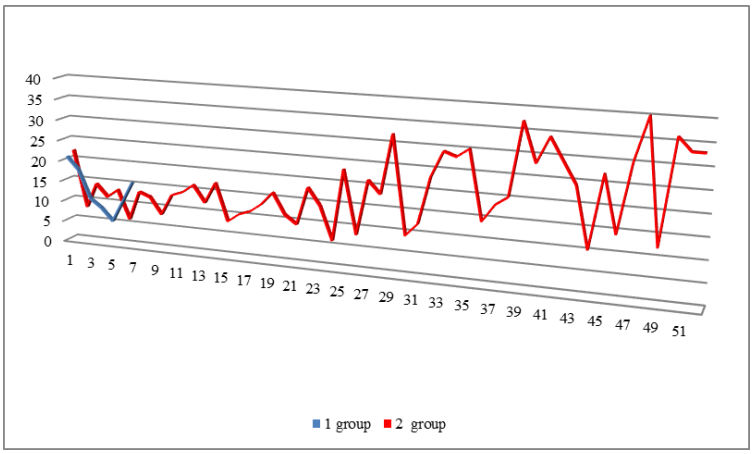

Figure 4. *Range of daily changes in DBP, mm Hg.*

The revealed daily fluctuations in DBP at later stages after 2 weeks of intensive care may have indicated the restoration of compensatory reactions in children in the process of restoring breathing and preparing for transfer to independent breathing. However, from day 22 to day 27, two patients remained in the ICU, and one child in the following days (Fig. 4). In this regard, we believe that the process of restoring independent breathing is an additional stress reaction of the body, which, if the patient is insufficiently prepared, can end in acute adrenal insufficiency. In this regard, repeated attempts at independent breathing at later stages of prolonged mechanical ventilation should be supported by appropriate supportive therapy, preventive measures for the risk of developing acute mitochondrial insufficiency, additional parenteral nutrition, multivitamin complexes, and protection of the child's body during the adaptation process from an acute energy deficiency state. The longest inversion of the circadian rhythm of DBP was in children of group 2 (52 days), which accounted for 37% (19 days) of the duration of intensive care in the ICU (Table 4). Fig. 4. Range of daily changes in DBP, mm Hg. The revealed daily fluctuations in DBP at later stages after 2 weeks of intensive care may have indicated the restoration of compensatory reactions in children in the process of restoring breathing and preparing for transfer to independent breathing. However, from day 22 to day 27, two patients remained in the ICU, and one child in the following days (Fig. 4). In this regard, we believe that the process of restoring independent breathing is an additional stress reaction of the body, which, if the patient is insufficiently prepared, can end in acute adrenal insufficiency. In this regard, repeated attempts at independent breathing at later stages of prolonged mechanical ventilation should be supported by appropriate supportive therapy, preventive

measures for the risk of developing acute mitochondrial insufficiency, additional parenteral nutrition, multivitamin complexes, and protection of the child's body during the adaptation process from an acute energy deficiency state. The longest inversion of the circadian rhythm of DBP was in children of group 2 (52 days), which accounted for 37% (19 days) of the duration of intensive care in the ICU (Table 4).

Table 4.

Duration of circadian rhythm inversion of DBP

	9-11 h	**12-22h**	**23- 8 h**
1 group	0	57%	43%
2 group 7 d	44%	28%	28%
2 group 52 d	21%	42%	37%

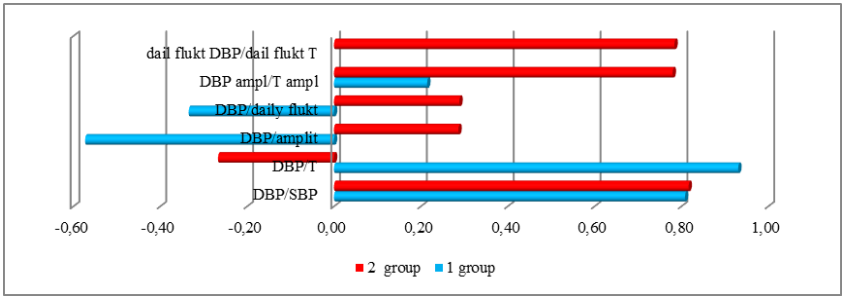

Figure 5. *Correlation links of DBP.*

During the first 7 days of observation, a direct strong relationship was found between the parameters of DBP and SBP in both groups, amounting to 0.81 in Group 1 and 0.82 in Group 2. At the same time, a strong correlation link between DBP and body temperature in Group 1 was 0.93, but in Group 2 it practically disappeared (-0.27). However, in Group 2, a direct strong correlation appeared between the amplitude of DBP fluctuations and the amplitude of the circadian rhythm of body temperature (0.78), indicating a direct relationship between changes in the tone of peripheral vessels and changes in the systemic inflammatory response. The identified feature is confirmed by a strong direct dependence of the daily range of DBP fluctuations on daily fluctuations in body temperature (0.78) (Fig. 5).

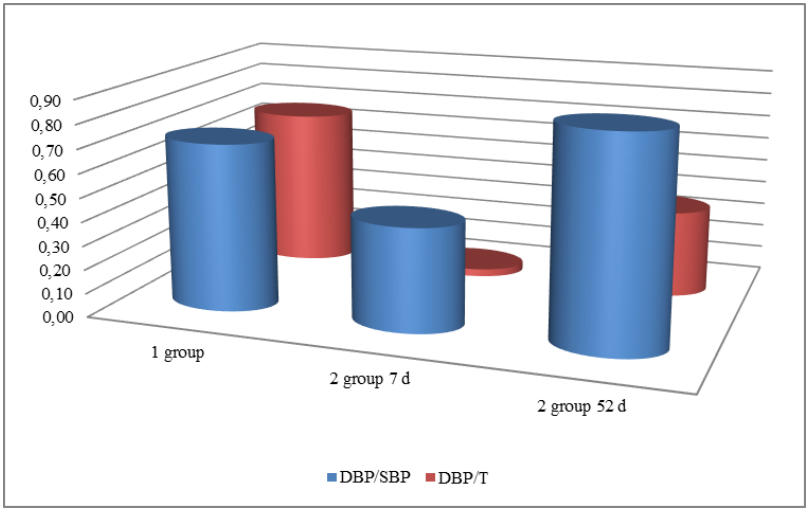

Figure 6. *Correlation relationships of the average circadian rhythm of DBP.*

The direct correlation relationship of the average circadian rhythm of DBP and SBP in group 1 (0.7), in group 2 in the first 7 days significantly decreased to 0.43, which was most likely due to the severity of the inflammatory response, mechanical respiratory support. In group 2, this indicator for 52 days of observation was 0.87. A tendency for a direct dependence of the DBP level on changes in body temperature was revealed in children of group 1 (0.67).

Conclusion. The average DBP level for the entire observation period was determined within the permissible standard values in both groups. The DBP indicator in the acrophase was significantly higher than the average daily indicator in group 2 (7 days) by 11%, (52 days) by 16%, while in group 1 there was a tendency to increase DBP. In the bathyphase, a reliable decrease in DBP was found in children of group 2 (7 days) by 10%. The revealed daily fluctuations in DBP at later stages after 2 weeks of intensive care may have indicated the restoration of compensatory reactions in children in the process of restoring breathing and preparing for the transfer to independent breathing. In this regard, repeated attempts to transfer to independent breathing at later stages of prolonged mechanical ventilation should be supported by appropriate supportive therapy, preventive measures for the risk of developing acute mitochondrial failure, additional parenteral nutrition, multivitamin complexes, and protection of the child's body during the adaptation process from an acute energy deficiency state.

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DOI 10.34660/INF.2025.87.48.041

多囊肾病的移植特点

FEATURES OF TRANSPLANTATION IN POLYCYSTIC KIDNEY DISEASES

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摘要。本文讨论了多囊肾病中的易位。我们在 2006 年至 2024 年期间在 SamSMU 诊所器官移植和泌尿科的基础上，对诊断为终末期慢性肾衰竭 (ESRD) 和诊断为多囊肾病并接受肾移植的患者进行了一项连续非随机回顾性研究。共进行

了 699 例手术，其中 39 例为 PP。患者年龄为 30–59 岁（平均年龄 46 岁）。年龄组如下所示。该研究包括 24 名女性和 15 名患有 PP 的男性。

关键词：移植、泌尿科、多囊肾病。

Abstract. *This article discusses translocation in polycystic kidney disease. We conducted a continuous non-randomized retrospective study of these patients with a diagnosis of terminal chronic renal failure (ESRD) and with a diagnosis of polycystic kidney disease who underwent kidney transplantation in the period 2006-2024 on the basis of the Department of Organ Transplantation and Urology at SamSMU Clinics. A total of 699 operations were performed, 39 of them with PP. The age of the patients ranged from 30-59 years (mean age 46 years). The age groups are presented below. The study included 24 women and 15 men with PP.*

Keywords**:** *Transplantation, urology, polycystic kidney diseases .*

Transplantation is more predictable than it was 20 to 30 years ago and innovation over the last 20 years has been rapid, delivering substantial short-term and medium-term improvements. The challenges ahead are to deliver improved results globally in the context of also preventing chronic disease and reducing the costs of treatment. Countries achieving the best rates of transplantation combine deceased and living donors and can transplant more than 50 people per annum per million population, so why can this not be achieved everywhere? The mortality rates have dropped, but they are still up to 10-fold worse than age- and sex-matched controls, such that transplantation ages individuals by 30 years in terms of mortality risk. Cardiovascular disease, infection and malignancy remain the targets if mortality is to normalize. Graft survival rates will not change until the multiple injuries constituting chronic allograft dysfunction and the problems of recurrent disease can be brought to heel. Biomarkers may provide the next innovation to advance outcomes, but early experimental tolerance protocols implemented in clinical practice in at least three centers may deliver results more quickly.

Transplantation today is a far cry from the field that encouraged many current practicing clinicians to take this career path. The results are much more predictable than they were 20 to 30 years ago and the investigative and therapeutic tools we have at our disposal are much more powerful. Some of the diseases we used to treat are rare or have vanished, such as analgesic nephropathy, to be replaced by a depressing avalanche of diabetic and hypertensive nephropathy in increasingly older patients. The pace of innovation over the last 20 years has been rapid and we have become used to seeing continuous and substantial improvements, but there is the concern that the field is stagnating, partly because those innovations have brought results that seem hard to improve upon. The excitement of innovation may have passed to another field – perhaps oncology, perhaps intraluminal intervention – and we are left with the feeling in transplantation that we can only tidy up

our results at the margins. In this paper I will review whether or not this situation is true and consider some of the challenges that are either with us or ahead of us.

How many people develop end-stage kidney disease (ESKD) remains a perennial question for clinicians, managers and health policy analysts as well as the treasuries that fund treatment. The answer is hard to find since the untreated patients die and are not to be found in the hospital statistics or in registries of dialysis or transplantation patients. The patients who die untreated may not be seen by specialist physicians or may never be admitted to a hospital; they may in fact never be diagnosed or ever be seen by a doctor in many countries. In advanced western economies, however, death certificate records are one way of assessing the causes of death of the population, and while they have their weaknesses, these records can provide reasonable estimates of need.

The Australian Institute of Health and Welfare has compiled death records of patients identified as having died primarily of chronic kidney disease (CKD) and correlated them with the records of the Australian and New Zealand Dialysis and Transplant Registry to determine which patients had been treated and which had not been treated by dialysis or transplantation [1]. The resultant analysis demonstrated that most Australians under the age of 60 years had been treated by dialysis or transplantation, while most over 80 years old had not (Figure 1). That this is country specific is clarified by the fact that the maximal combined incidence of both treated and untreated ESKD in Australia is lower than the United States incidence of treated ESKD. This fact and the great variation of incidence by population – for example, the Aboriginal population in Australia has extremely high rates – highlights the need for a focus on prevention of CKD through active public health and therapeutic interventions. The past 5 years have, in Australia, seen a stabilizing of incidence of new dialysis patients younger than 75 years and now for 3 years a progressive decrease in new patients. No consideration of renal transplantation can thus ignore the relative investment needed in prevention of CKD, especially in the emerging and developing economies of the world, and the Australian experience suggests that this is a legitimate and realistic target.

In recent years, there has been an increase in patients with end-stage chronic renal failure (CRF) in need of programmed hemodialysis in Russia. Polycystic kidney disease (PP) occupies the 3rd place in the structure of the causes leading to the terminal stage of CRF after glomerulonephritis and pyelonephritis. According to the literature, polycystic kidney disease leads to the development of terminal renal failure in 10-14% of nephrological patients[1]. Polycystic kidney disease is understood as a genetically determined pathological process that is associated with the formation and progression of kidney cysts originating from tubule epitheliocytes and (or) collecting tubules, represented by two types of disease - autosomal dominant (ADPKD) and autosomal recessive (ARPKD). The prevalence of this pathology is 1:400-1:1000. The gender and racial distribution is uniform.

In end-stage chronic renal failure, kidney transplantation is an effective method of treating patients with polycystic kidney disease.

We conducted a continuous non-randomized retrospective study of these patients with a diagnosis of terminal chronic renal failure (ESRD) and with a diagnosis of polycystic kidney disease who underwent kidney transplantation in the period 2006-2024 on the basis of the Department of Organ Transplantation and Urology at SamSMU Clinics. A total of 699 operations were performed, 39 of them with PP. The age of the patients ranged from 30-59 years (mean age 46 years). The age groups are shown in the table.1. The study included 24 women and 15 men with PP. The reliability of the data was carried out with the determination of the Student's coefficient with a reliable value of $p<0.05$.

Table 1.

Distribution of kidney transplants performed in patients with PP by age.

Age group	Number
30-39	7
40-49	21
50-59	19

In the Department of organ Transplantation and Urology, operations were performed on patients with PP from 7 regions: Samara, Saratov, Ulyanovsk, Penza, Orenburg regions and the Republics of Bashkortostan and Tatarstan (Table 2). The Samara Region significantly prevails ($p<0.05$).

Table 2.

Distribution of kidney transplants performed in patients with PP by region.

Region	Number
Samara region	21
Saratov region	4
Ulyanovsk region	4
Penza region	5
Orenburg region	2
Republic of Bashkortostan	1
The Republic of Tatarstan	2

Recent research in the field of the pathogenesis of chronic renal failure, the improvement of approaches to the treatment of its complications and concomitant pathology, as well as the intensive development of dialysis technologies open up broad prospects for optimizing long-term treatment outcomes for patients with uremia. However, to date, problems directly related to dialysis therapy itself re-

main a serious limiting factor, which can be partially prevented with the right approach to choosing the type of dialysis at the beginning of treatment and its timely change if the possibilities of the technique for a particular patient are exhausted[3]. Thus, depending on the type of replacement therapy before kidney transplantation, patients with polycystic kidney disease were divided into the following groups: hemodialysis (n=32) prevailed, followed by predialysis (n=3) and PAPD (n=2).

Primary kidney transplantation was performed in 37 patients, and repeat surgery was performed in 2 patients.

According to the localization of kidney transplants, right-sided transplantation significantly prevails (22 on the right, 17 on the left) ($p<0.005$).

Let's consider the structure of complications after kidney transplantation. The most common was a primary non-functioning transplant (21.4%). All patients with this complication survived, but underwent a transplantectomy (TE). The same can be said about a patient with another but less common complication, namely venous stasis. Some complications underwent correction: lymphocele – external drainage, and PMA stricture – rheureterocystoneoanastamosis.

Now let's move on to the deceased patients. Of the 35 patients, 6 died after kidney transplantation (all died in the 1st year after surgery). One patient developed steroid diabetes 6 months after the kidney transplant, complicated by 2-sided pneumonia. Another patient underwent a transplantectomy immediately after kidney transplantation due to venous thrombosis. The patient returned to hemodialysis. 1.5 months after the operation, she died of acute cardiovascular insufficiency on the background of hypotension. Another patient underwent a transplantectomy.

4 months after the kidney transplant, due to 2-sided pneumonia, meningoencephalitis, and endocarditis, she died of cerebral edema due to sepsis. One patient died 7 months after a kidney transplant. Death from stroke on the background of hypertensive crisis.1 patient died as a result of 2-sided pneumonia (Covid-19) 3.5 months after the TP. 1 patient died of sepsis 2.5 months after TP.

Next, let's move on to analyzing the five-year survival rate after a kidney transplant. In the ANZDATA Registry in Australia and New Zealand, for the period from 2011 to 2018, the 1-year and 5-year survival rates of recipients after primary kidney transplantation were 96 and 88%, respectively.

According to the Collaborative Transplant Study (CTS) of the University of Heidelberg, conducted in the period from 1990 to 2018, Germany. The 1-year and 5-year survival rates of PAT (renal allograft) after primary transplantation were 90% and 76%, respectively.[4]

Urological complications remain one of the most serious, requiring timely diagnosis and correction in patients after kidney transplantation. In patients with removed polycystic kidneys before kidney transplantation, there are fewer postoperative surgical and urological complications after kidney transplantation, which

makes it possible to improve the results of transplantation in this category of patients.

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DOI 10.34660/INF.2025.82.75.042

人体免疫系统调节功能紊乱在糖尿病视网膜病变发病机制中的作用
THE ROLE OF DISTURBANCES IN THE REGULATORY FUNCTION OF THE BODY'S IMMUNE SYSTEM IN THE PATHOGENESIS OF DIABETIC RETINOPATHY

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摘要。糖尿病视网膜病变是一种血管和神经退行性疾病，发生在糖尿病控制不佳数年后，主要反映视网膜结构及其细胞组成的变化。免疫系统活动在炎症过程的发病机制中发挥作用。

本研究旨在评估无并发症的 2 型糖尿病患者和不同严重程度的视网膜病变患者的免疫反应检查点水平。

材料和方法。为了实现这一目标，我们分成了 5 个年龄、性别和社会地位相当的组：第 1 组（对照组）包括 19 名健康个体（平均年龄 49.4 岁）；第 2 组 - 19 名没有微血管和大血管病变的 2 型糖尿病患者（平均年龄 57 岁）；第 3 组 - 60 名患有 2 型糖尿病和糖尿病视网膜病变的患者（平均年龄 59.4 岁）。该组被分为 3 个亚组：A - 非增生期 (N=20)，B - 增生前期 (N=20)，C - 增生期视网膜病变 (N=20)。

除了传统的临床研究外，还使用 Biolegend（美国）的人类免疫检查点面板 1 多重检测试剂盒测定所有受试者的血清免疫反应检查点水平。使用 Jamovi 2.3 版（澳大利亚 jamovi 项目）对结果进行统计分析。

结果分析显示，糖尿病患者血清中可溶性共抑制分子及其受体的浓度增加，视网膜病变各阶段之间没有差异（LAG-3 除外）。

关键词：2 型糖尿病、糖尿病视网膜病变、免疫反应检查点。

Abstract. *Diabetic retinopathy is described as a vascular and neurodegenerative disease that occurs after several years of poorly controlled diabetes, reflecting primarily changes in the architecture of the retina and its cellular composition. The*

activity of the immune system plays a role in the pathogenesis of the inflammatory process.

The aim of the study was to assess the levels of immune response checkpoints in patients with uncomplicated type 2 diabetes mellitus and with developed retinopathy of varying severity.

Materials and methods. *To achieve this goal, we formed 5 groups comparable in age, gender and social status: Group 1 (control group) included 19 healthy individuals (mean age 49.4 years); Group 2 - 19 patients with type 2 diabetes without micro- and macroangiopathies (mean age 57 years); Group 3 – 60 patients with type 2 diabetes and diabetic retinopathy (mean age 59.4 years). The group was divided into 3 subgroups: A – individuals with non-proliferative stage (N=20), B – with preproliferative stage (N=20), C – with proliferative stage of retinopathy (N=20).*

In addition to traditional clinical studies, the serum levels of immune response checkpoints were determined in all subjects using the Human Immune Checkpoint Panel 1 multiplex assay kits from Biolegend (USA). Statistical analysis of the results was performed using Jamovi version 2.3 (The jamovi project, Australia).

The analysis of the results revealed an increase in the concentrations of soluble coinhibitory molecules and their receptors in the blood serum of patients with diabetes mellitus, with no difference between the stages of retinopathy (except for LAG-3).

Keywords: *Type 2 diabetes mellitus, diabetic retinopathy, immune response checkpoints.*

Inflammation plays a central role in the pathogenesis of diabetes mellitus. Type 1 diabetes mellitus (DM) is initiated by infectious (viral) and/or autoimmune processes, while type 2 DM is typically characterized by chronic inflammation, and as a consequence, increased insulin resistance and impaired glucose metabolism [1]. Diabetic retinopathy (DR) is perceived as a vascular and neurodegenerative disease that occurs after several years of poorly controlled diabetes, primarily reflecting changes in the architecture of the retina and its cellular composition. It is known that DM2 is characterized by a noticeable decrease in the number of Tregs, a homeostatic regulator of immune tolerance [2], and an increase in activation markers on systemic T-lymphocytes has been recorded [3]. However, evidence of the autoimmune pathogenesis of DR is relatively limited, the role of adaptive immunity in DR has not been determined, it is not clear what comes first - activation of innate immunity triggers the DR process, while adaptive immunity is likely to play a role in the further progression of the disease or vice versa.

Objective of the study. To assess the levels of immune system checkpoints in patients with uncomplicated type 2 diabetes mellitus and with developed retinopathy of varying severity.

Materials and methods of the study. The study was conducted at the Department of Ophthalmology of the Federal State Budgetary Educational Institution of Higher Education ChSMA and in the Ophthalmology Department of the State Healthcare Institution of the City Clinical Hospital of Chita. To achieve this goal, we formed 3 groups comparable in age, gender and social status:

- ✓ The 1st (control group) included 19 healthy people (average age 49.4 years).
- ✓ Group 2 — 19 patients with type 2 diabetes without micro- and macroangiopathies (mean age 57 years). The diagnosis of diabetes was made in accordance with the clinical guidelines of the Ministry of Health of the Russian Federation "Type 2 diabetes mellitus in adults" (2019).
- ✓ Group 3 — 60 patients with type 2 diabetes and diabetic retinopathy (mean age 59.4 years). DR was diagnosed in accordance with the international classification of diseases, 10th revision (ICD-10. Class VII. Diseases of the eye and adnexa H00-H59). The group was divided into 3 subgroups: A — individuals with non-proliferative stage (N=20), B — with preproliferative stage (N=20), C — with proliferative stage (N=20).

All subjects underwent traditional clinical studies and determination of the content of soluble forms of immune response checkpoints in blood serum using Human Immune Checkpoint Panel 1 multiplex assay kits from Biolegend (USA). Statistical analysis of the results was performed using the Jamovi version 2.3 program (The jamovi project, Australia). Hypothesis testing for the normality of the distribution of the feature was carried out using the Shapiro-Wilk criterion. Considering that the distribution of features differed from normal, continuous variables are presented as a median (Me) and an interquartile range (25th; 75th percentiles). Pairwise comparison of continuous variables was performed using the Dwass-Steele-Critchlow-Fligner test (with Bonferroni correction). For multiple comparisons (three or more groups), the Kruskal-Wallis test (H) was used. Correlations were assessed using the Spearman test (ρ). For all criteria, the critical significance level (p) was taken as <0.05.

Results obtained.

A number of studies have established that diabetic retinopathy is accompanied by a violation of cellular and humoral immunity with a change in the metabolism of lymphocytes and phagocytes, the development of autoimmune and immune complex reactions to eye autoantigens [4]. Differentiation and protective properties of antigen-specific T cells are regulated by both positive and negative signals. Relatively recently, coinhibitory molecules have been discovered that allow regulating the intensity and duration of the immune response [5-6]. Costimulatory and coinhibitory molecules, which are receptors expressed on immune cells, are called immune checkpoints.

In the groups with uncomplicated diabetes and diabetes with DR, the values of the costimulatory molecules B7.2 and 4-1BB were significantly higher than in the control - 180.1% ($p < 0.001$) and 223.0% ($p < 0.001$), respectively (Table 1). Comparison of the values of these molecules in patients with different stages of DR with those in individuals with uncomplicated diabetes showed an increase in the level of 4-1BB in the non-proliferative stage of the disease by 122.9% ($p < 0.001$), in the preproliferative stage - by 86.3% ($p < 0.001$). In the proliferative stage of DR, the values of both 4-1BB by 45.1% ($p < 0.001$) and B 7.2 by 50.0% ($p = 0.004$) exceeded those in the comparison group.

Table 1

Levels of soluble costimulatory molecules in serum of individuals with type 2 diabetes mellitus (Me (25th; 75th))

Indicators/ Groups	Control (n=41)	Type 2 diabetes (Group 2) (n=21)	Type 2 diabetes mellitus + RP (Group 3) (n=63)	Test statistics, Df=2
B7.2 (CD86) (pg/ml)	21,10 (16,51; 26,71)	37,20* (34,81; 40,10)	53,5* (38,1; 77,9) P3=0,03	H=37,57 p<0,001
4-1BB (pg/ml)	3, 83 (1,19; 4,81)	8,75* (7,94; 9,55)	16,30* (13,70;21,40) P2<0,001 P3<0,001	H=57,06 p<0,001

Note:

* - statistically significant differences in pairwise comparison with the control group;

p1 - reliability of differences between the first and second groups;

p2 - reliability of differences between the first and third groups;

p3 - reliability of differences between the second and third groups;

pairwise comparison between groups was carried out using the Dwass-Steele-Critchlow-Fligner criterion.

Analysis of the obtained results of soluble coinhibitory molecules and their receptors in the study groups showed that the concentrations of these molecules increased relative to the control (Table 2). In patients with diabetes, the CTLA-4 values exceeded the control values by 223.7% ($p<0.001$), LAG-3 – by 540.5% ($p<0.001$), Tim-3 – by 56.4 times ($p<0.001$), PD-1 – by 170.5% ($p<0.001$), PD-L1 – by 414.9% ($p<0.001$), Galectin-9 – by 89.2% ($p<0.001$). In DR, the CTLA-4 level was increased relative to the control by 8.2 times ($p<0.001$) and was higher than in patients with diabetes without complications by 252.8% ($p<0.001$). The LAG-3 level was 23.3 times ($p<0.001$) higher than in the control group and 263.3%

(p<0.001) higher than in group 2 individuals; Tim-3 values increased accordingly – 118.3 times (p<0.001) relative to the control and 2.1 times (p=0.004) relative to group 2 values. PD-1 and PD-L1 concentrations exceeded control values by 4.7 (p<0.001) and 7.1 times (p<0.001), respectively, and were 72.6% (p<0.001) and 38.8% (p=0.006) higher than in group 2 individuals. The Galectin-9 protein levels exceeded the control values by 2.75 times (p<0.001) and those in individuals with diabetes by 45.3% (p=0.001) (Table 2).

Table 2

Levels of soluble coinhibitory molecules and their receptors in the blood serum of individuals with "prediabetes" and diabetes (Me (25th; 75th))

Indicators/ Groups	**Control (n=41)**	**Type 2 diabetes (Group 2) (n=21)**	**Type 2 diabetes mellitus + RP (Group 3) (n=63)**	**Test statistics, Df=2**
CTLA-4 (pg/ml)	3,8 (3,67; 5,25)	12,3* (11,70; 19,0) P1=0,011	31,10* (25,60; 38,00) P2<0,001 P3<0,001	H=53,74 p<0,001
LAG-3 (pg/ml)	2,0 (1,88; 2,15)	12,80* (12,30;14,50) P1=0,001	46,50* (40,90; 47,3) P2<0,001 P3<0,001	H=58,60 p<0,001
Tim-3 (pg/ml)	6,17 (3,98; 8,25)	348* (295; 550) P1=0,006	730* (634; 927) P2<0,001 P3=0,004	H=54,81 p<0,001
PD-1 (pg/ml)	5,46 (5,28; 5,68)	14,77* (13,4; 15,1)	25,50* (22,0; 30,4) P2<0,001 P3<0,001	H=56,76 P<0,001
PD-L1 (pg/ml)	3,50 (2,54; 5,28)	18,02* (17,5; 19,03) P1=0,003	25,01* (20,10; 31,10) P2<0,001 P3=0,006	H=53,11 p<0,001
Galectin-9 (pg/ml)	500 (439; 531)	946* (843; 1024) P1=0,010	1375* (1106; 1735) P2<0,001 P3=0,001	H=57,30 p<0,001

Note:

* - statistically significant differences in pairwise comparison with the control group;

p1 - significance of differences between the first and second groups;

p2 - significance of differences between the first and third groups;

p3 - significance of differences between the second and third groups;

pairwise comparison between the groups was performed using the Dwass-Steele-Critchlow-Fligner criterion.

In the preproliferative stage, the numbers of soluble coinhibitory molecules and their receptors continued to remain high, practically unchanged. The exception were the concentrations of LAG-3, which in patients with the preproliferative stage were not only higher than the values of the comparison group by 310.1% ($p < 0.001$), but also higher than in patients with non-proliferative DR by 13.1% ($p = 0.004$).

In the proliferative stage of DR, no further increase in the values of coinhibitory molecules in the blood plasma was recorded. Moreover, the concentrations of LAG-3, although they remained higher than those in the comparison group by 168.8% ($p < 0.001$), did not statistically differ from the concentrations in subgroups 3B and 3C.

Thus, the analysis of the results also revealed an increase in the concentrations of soluble coinhibitory molecules and their receptors in the blood serum of patients with type 2 diabetes mellitus. The maximum values were determined in diabetes with DR starting from the non-proliferative stage. No significant differences were found between the indicators (except for LAG-3) in individuals with different stages of DR.

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DOI 10.34660/INF.2025.72.10.043

车里雅宾斯克州二级医务人员人力资源潜力状况
THE STATE OF THE HUMAN RESOURCE POTENTIAL OF SECONDARY MEDICAL WORKERS IN THE CHELYABINSK REGION

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注释。本文讨论了俄罗斯医疗机构持续的人员短缺问题。这在中级医疗保健中尤其如此。介绍了车里雅宾斯克地区医疗机构的人员潜力数据。提出了护士年龄结构问题。列出了医疗机构为保持和补充医疗机构人力资源而采取的措施。关键词：护士、医疗机构、人力资源。

Annotation. *The article talks about the continuing staff shortage in Russian healthcare institutions. This is especially true for the middle level of healthcare. The data on the personnel potential in healthcare institutions of the Chelyabinsk region are presented. The issues of the age composition of nurses are being raised. The list of measures implemented in medical institutions to preserve and replenish the human resources of medical institutions is given. Keywords: nurses, healthcare institutions, human resources.*

One of the priority problems of Russian healthcare remains the shortage of personnel. Maintaining the healthcare system of the Russian Federation in a state that ensures the appropriate level of health of its citizens is a priority task of the State. In the Russian Federation, a unified management system has been formed, which is a set of federal health management bodies, health management bodies of the subjects of the Russian Federation, local governments, organizations subordinate to them, as well as representatives of private medical practice and private pharmaceutical activities, functioning in order to preserve and strengthen the health

of citizens [3]. The Department of Medical Education and Personnel Policy in Healthcare of the Ministry of Health of the Russian Federation is responsible for the implementation of personnel policy in the Russian Federation in the field of healthcare. The main tasks of the department are:

1. Ensuring the implementation of functions related to the development of basic directions of state policy, regulatory and legal regulation of personnel support for healthcare, medical and pharmaceutical education, and the admission of medical and pharmaceutical workers to professional activities.

2. Ensuring the implementation of the functions of coordinating and monitoring the activities of the federal service under its jurisdiction and coordinating the activities of the state extra-budgetary fund.

3. Development of a strategy for a unified personnel policy in the healthcare system.

4. Organization of work on continuing education of medical workers and pharmaceutical workers.

5. Ensuring the implementation of the subprogram "Development of human resources in healthcare" of the state program of the Russian Federation "Development of Healthcare" [5].

At the regional level, the subjects of the Russian Federation form their own orders and regulations in order to implement national projects.

According to Rosstat, at the beginning of 2023, there were more than 567,000 doctors in Russia, more than 1.2 million employees of the secondary medical staff and more than 270,000 employees of the junior medical staff. In total, about 2 million medical workers work in the field of medicine in the country. Considering that the population of Russia in 2023 is about 146.4 million people, it turns out that for every 73 Russians there is one medical worker. However, the number of employees in the Russian public health sector continues to decline. The number of medical workers in Russia in 2022 decreased by almost 50 thousand people.

Compared to 2021, there were 9,784 fewer doctors and 38,946 fewer nursing staff. There is an acute shortage of medical personnel with secondary medical education in almost all regions of Russia.

In comparison with 2021, in 2023, the total number of average health workers decreased by 2.9% and amounted to 81.5 per 10,000 population. The level of provision of secondary medical personnel decreased in 79 regions of the Russian Federation (Fig.1). The Russian Association of Nurses notes that the outflow of specialists with secondary education from government medical organizations continues.

Figure 1. *Dynamics of provision of secondary medical personnel in the Russian Federation per 10 thousand population (Source TSNIIOIZ of the Ministry of Health of Russia)*

In November 2023, the Ministry of Health reported a shortage of about 58.2 thousand average medical staff.

The decline in the number of average medical professionals continues, despite the annual increase in applicants to medical colleges. In 2020, enrollment in regional medical colleges was increased by 10% [2]. However, both young specialists and experienced nurses are leaving the profession.

This problem is not found locally, but everywhere in the country. At the present stage, the shortage of personnel in medical organizations undoubtedly has an impact on the timeliness and quality of medical care to the population. A decrease in the number of medical workers, especially nurses, affects the quality of work of healthcare organizations, which can lead to an increase in morbidity, a decrease in life expectancy and an increase in mortality among the population.

It should be borne in mind that nurses carry out up to 70% of all activities in the field of healthcare [4]. All this makes it urgent to search for possible solutions and ways out of the current situation [1]. Despite the ongoing work to calculate the need for medical personnel, this does not eliminate the problem of their shortage. Calculations cannot provide medical organizations with real physical personnel. To solve it, it is necessary to study in detail the factors that negatively affect the professional activity of a nurse, possible forms that increase the prestige of the nursing profession, and develop ways to eliminate the shortage of nursing staff in medical organizations. In the course of this study, we studied the provision of healthcare institutions with mid-level medical personnel.

Table 1.

Analysis of the pre-retirement and retirement age staff of medical organizations in the Chelyabinsk region (Ministry of Health of the Chelyabinsk Region, annual report 2023)

Age category	Average medical staff	
	1113 men, their them:	**21508 women, of them:**
From 55 to 60 years old	57	2397
From 61 to 70 years old	25	2246
Aged 71 and over	5	281
Total	87	4924

An assessment of the age structure of medical personnel is necessary to predict staffing, taking into account the time frame for training a medical professional in secondary vocational education programs.

According to the analytical project "People in Numbers", the Chelyabinsk Region accounts for less than 2% of all nursing vacancies in the country. Since the beginning of 2023, more than 400 vacancies for nurses have been published in the Southern Urals. Most often, jobs are offered in Chelyabinsk, Magnitogorsk and Miass. There are also vacancies with a shift work method.

The number of medical personnel in individual specialties of the Chelyabinsk region is shown in Table 2. Over the past five years, the number of secondary medical personnel in the Chelyabinsk Region has decreased by 2,710 people, which is 7.8% in percentage terms.

Table 2.

Number of medical personnel in individual specialties (data from Rosstat of the Chelyabinsk region)

	2018	**2019**	**2020**	**2021**	**2022[3)]**
The number of secondary medical staff is only one thousand people	**1491,4**	**1491,3**	**1 490,5**	**1467,6**	**1439,9**
of these:					
paramedics	134,5	136,3	136,2	144,9	146,0
midwives	55,0	54,9	51,9	49,4	48,2
medical nurses	1064,3	1066,5	1069,2	1045,8	1024,7
laboratory technicians, medical laboratory technicians	88,3	87,3	86,4	84,6	81,7
X-ray laboratories	38,9	39,6	40,9	41,8	41,7
	per 10,000 population				
Number of secondary medical staff - total	100,9	100,8	101,1	99,9	98,3
of these:					

paramedics	9,1	9,2	9,2	9,9	10,0
midwives	6,9	6,9	6,6	6,3	6,2
medical nurses	72,0	72,1	72,5	71,2	70,0
laboratory technicians, medical laboratory technicians	6,0	5,9	5,9	5,8	5,6
X-ray laboratories	2,6	2,7	2,8	2,8	2,8

The dynamics of the number of nurses over the past five years in the region is shown in Figure 2. We have noticed that in 2019-2020, the number of nursing staff was higher and more stable. The level of increase in the number of medical personnel during this period can be attributed to the necessary government support measures developed, including financial payments during the pandemic for health-care professionals working with COVID-19.

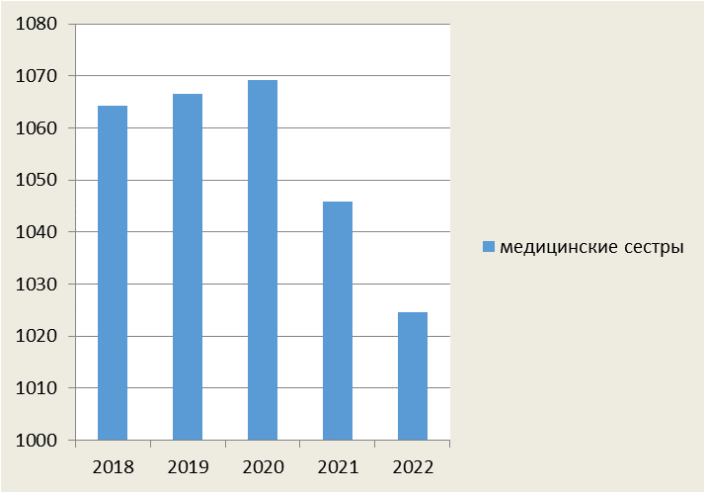

Figure 2. *Dynamics of the number of nurses in the Chelyabinsk region (data from Rosstat of the Chelyabinsk region)*

The main feature of the personnel policy in the healthcare of the Chelyabinsk region is the in-depth social orientation of the measures stated in it. First of all, it is ensuring a decent level of wages and living standards for medical workers, guarantees of continuing professional education, and planning for the employment of young professionals. Of course, personnel policy requires constant, clear systematic work, interdepartmental interaction, and very balanced integrated solutions taking into account the needs of regional healthcare. Within the framework of the federal project, it is necessary not only to eliminate the personnel shortage

in medical organizations, but also to ensure a high level of qualification for young professionals entering the healthcare industry, as well as to provide them with the opportunity for continuous professional development in accordance with their professional needs.

Thus, the shortage of nursing staff is a "time bomb." If the deficiency is not eliminated, it will lead to an increase in the number of adverse outcomes, longer waiting times for treatment, and more deaths that could have been prevented. The development of new and further implementation of existing methods of replenishment and retention of nursing staff in healthcare institutions will help eliminate the staff shortage that has arisen.

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DOI 10.34660/INF.2025.19.61.044

评估 SARS-COV-2 引起的 COVID-19 的治疗方案
EVALUATION OF TREATMENT OPTIONS FOR COVID-19 CAUSED BY SARS-COV-2

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摘要。分析了我们自己的和文献中关于 SARS-CoV-2 引起的 COVID-19 感染的结果以及旨在对抗这种感染并发症的一系列治疗措施的状态和有效性的数据。现阶段现代抗病毒药物的安全性和有效性尚未在随机临床试验的背景下得到最终证明。随着多器官衰竭和死亡的发展，存在进一步感染人群的威胁。目前的问题需要进一步研究 SARS-CoV-2 引起的 COVID-19 的发展机制，以开发有致病学依据的保守治疗方法。目前的问题需要进一步研究 SARS-CoV-2 引起的 COVID-19 的发展机制，以开发有致病学依据的保守治疗方法。

关键词：抗病毒药物；抗病毒疫苗；恢复期血浆疗法；免疫疗法；纳米疗法，COVID-19，SARS-CoV-2。

Abstract. *The analysis of our own and literature data on the outcome of COVID-19 infection caused by SARS-CoV-2 and the state and effectiveness of the range of therapeutic measures aimed at combating complications of this infection was carried out. The safety and effectiveness of modern antiviral drugs at the present stage have not been finally proven in the context of randomized clinical trials. There is a threat of further infection of the population with the development of multiple organ failure and death. The current state of the issue dictates further study of the mechanisms of development of COVID-19 caused by SARS-CoV-2*

in order to develop pathogenetically substantiated conservative treatment. The current state of the issue dictates further study of the mechanisms of development of COVID-19 caused by SARS-CoV-2 in order to develop pathogenetically substantiated conservative treatment.

Keywords: *antiviral drugs; antiviral vaccines; convalescent plasma therapy; immunotherapy; nanotherapeutics, COVID-19, SARS-CoV-2.*

Background. The ongoing pandemic of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome infection with SARS-CoV-2, has created a serious public health threat worldwide, putting millions of people at risk in more and more countries. An analysis of the latest literature on the topic and the current developments and future prospects showed that as of July 1, 2020, more than 10 million people worldwide have been infected with SARS-CoV-2 [1]. The mortality rate was about 2%. In Italy alone, more than 2 million people have been infected with the virus and 78,755 have died. The scientific community is studying and testing numerous compounds that may be effective and safe for the treatment of people with COVID-19 [2]. Although there are still no clinically approved antiviral drugs and vaccines for COVID-19 at this stage [3], clinical trials of several known antiviral drugs, their combinations, and the development of vaccines for patients with confirmed COVID-19 are ongoing. The main focus is on the latest approaches to the diagnosis and therapy of COVID-19. Antiviral drugs, vaccines, SARS-CoV-2 antibody treatments, and convalescent plasma therapy are currently undergoing extensive research and clinical trials for the treatment of COVID-19. The development of nanoparticle-based therapeutic and diagnostic approaches for the treatment of COVID-19 infection is being discussed. However, ignorance of the cellular key targets, in our opinion, is a major obstacle in solving this problem.

Objective. To analyze the state of the spectrum of therapeutic measures and the pathogenetic validity of therapeutic measures against the background of COVID-19 caused by SARS-CoV-2.

Material and methods. More than a thousand case histories of patients who died as a result of COVID-19 infection caused by SARS-CoV-2 due to the development of multiple organ failure were studied. An analysis of the therapeutic measures taken, their effectiveness and an assessment of the possibility of developing a vaccination were performed.

Results of the study. Typical clinical manifestations of COVID-19 include fever, sore throat, fatigue, cough and shortness of breath in combination with hypoxia. Most patients with COVID-19 have a mild or moderate form of the disease, but 5 to 15% have a severe and even life-threatening course of the disease. Therefore, there is an urgent need to develop effective and specific antiviral treatment.

Currently, supportive care measures such as ventilation, oxygenation and infusion therapy remain the standard of treatment. Several clinical trials are currently trying to identify the most effective drug or combination against this disease, and enrollment of patients in ongoing trials is strongly encouraged. The safety and efficacy of antiviral drugs can only be proven in the context of randomized clinical trials. Several agents are currently being evaluated, including chloroquine, hydroxychloroquine, favipiravir, monoclonal antibodies, antisense RNA, corticosteroids, convalescent plasma, and vaccines. Results show that corticosteroids, remdesivir, favipiravir, immunoglobulins, colchicine, and umbilical cord mesenchymal stem cell infusion may reduce overall mortality. No difference in the risk of any adverse events was observed between convalescent plasma and remdesivir compared with standard care. Remdesivir probably reduces the risk of serious adverse events; A similar effect, although less pronounced, was also noted for tocilizumab and the combination of lopinavir and ritonavir. In contrast, hydroxychloroquine, corticosteroids, and convalescent plasma transfusion are associated with safety concerns regarding the risk of serious adverse events. A large number of therapeutic interventions are aimed at identifying the most effective treatment regimen. Dexamethasone is the first known steroid drug that can save the lives of critically ill patients, and a randomized clinical trial conducted by the United Kingdom showed that it reduced the mortality rate in patients with COVID-19 [4]. The existing evidence of potential therapeutic drugs, peptides, humanized antibodies, convulsive plasma, and vaccination that have shown potential in combating COVID-19 infections is related to in vitro trials with a lack of evidence of efficacy in real-world use [5, 6]. Given our data on damage to red blood cells and red bone marrow, it is necessary to direct the vector of research to the study of the mechanisms of induction of stem cell maturation in hematopoiesis foci.

Conclusion. The outbreak of COVID-19 caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) continues to spread throughout the world. The current state of the issue of pathogenesis and treatment of COVID-19 dictates the need for multicenter, large selective, randomized, placebo-controlled trials on patients with COVID-19 to reach the correct conclusion on the most promising antiviral agents.

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DOI 10.34660/INF.2025.15.52.045
UDC 613.69

滨海边疆区不同职业人群肿瘤病理危险因素及预防
RISK FACTORS AND PREVENTION OF ONCOPATHOLOGY AMONG VARIOUS OCCUPATIONAL GROUPS IN THE PRIMORSKY KRAI

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摘要。在俄罗斯联邦滨海边疆区，肺癌、气管癌和支气管癌是肿瘤病理相关发病率（第三位）和死亡率（第一位）最高的病例，因此这些癌症在那里被确立为职业病。特别是，医疗机构人员的工作条件与各种生物、物理和化学因素的复杂影响有关，这些因素可能是有害的。我们认为接触化学因素具有致癌作用，可导致医务人员患上癌症。癌性肿瘤的潜伏期、长期发展和首发症状的延迟出现并不总是能够将恶性过程的触发因素与工作场所的致癌因素联系起来。然而，对现代诊断技术、癌前疾病、风险人群、风险因素的了解并没有导致滨海边疆区劳动公民群体中早期恶性疾病的检测率增加。本文提出了解决这一问题的方法。本文致力于肺病学和肿瘤学的实际问题——各职业群体的职业性肺部恶性肿瘤。

关键词：预防、工人、肿瘤病理学、危险因素。

Abstract. *In the Primorsky Territory of the Russian Federation, lung, tracheal and bronchial cancers are the most recorded cases of oncopathologic-related morbidities (third) and mortalities (first), thus establishing these cancers as occupationally-related diseases there. In particular, the working conditions of*

the personnel of medical organizations are associated with the complex impact of various biological, physical, and chemical factors, that can be harmful. We consider exposure to chemical factors as having carcinogenic effects, that can lead to the development of cancer in health care workers. The latent course, long-term development of a cancerous tumor, and the delayed onset of the first symptoms do not always make it possible to correlate the trigger of the malignant process with carcinogenic factors in the workplace. However, knowledge of modern diagnostic technologies, precancerous diseases, risk groups, risk factors have not led to an increase in the detection of malignant diseases at the initial stages in the group of working citizens of the Primorsky Territory. Ways to solve this problem are presented in this article. The article is devoted to the actual problem of pulmonology and oncology - occupational malignant neoplasms of the lungs of various professional groups.

Keywords: *prevention, workers, oncopathology, risk factors.*

Over the past decade, the incidence of malignant neoplasms among workers of enterprises in the Primorsky Territory has been increasing. The first 5 rank places are occupied by malignant neoplasms of the breast, trachea, bronchi, lung, skin, colon and stomach.

Low proportion of the diagnosis of the first and second stages of malignant neoplasms among employees of enterprises of the Primorsky Territory is characteristic of cancer of the oral cavity (41.0%), pharynx (14.5%), esophagus (42.7%), stomach (40.4%), lung (37.2%), liver (15.1%), pancreas (23.5%) and some other localizations, which indicates a high neglect of this pathology.

In the Primorsky Territory, the highest proportion of patients with stage IV is occupied by cancers of the liver (57.9%), pancreas (58.8%), pharynx (47.3%), stomach (36.8%), trachea, bronchi, lung (38.1%), bones (38.5%), and ovary (26.3%) [1].

In 2023, the highest recorded cases of cancer-associated mortalities were cancers of the trachea, bronchi, lung, stomach, breast, colon, rectum. According to the International Labor Organization (ILO), cancer is the most common cause of death associated with working conditions [2-4].

Trachea, bronchial and lung cancers are associated in most cases, with the complex impact of harmful occupational factors, as well as with exposure to household carcinogens, and smoking, taking into account the smoking experience [5-9].

Risk factors for laryngeal cancer include being an experienced smoker, and smoking in combination with alcohol. Various occupational risk factors have been identified, such as: exposure to asbestos, nickel, mustard gas, coolants, petroleum products, rubber and footwear production (workers of the preparatory shop for rubber production). Chronic background and precancerous diseases in combina-

tion with risk factors, including occupational ones: chronic catarrh of the upper respiratory tract, pneumonia, tuberculosis, emphysema, bronchitis, papillomas and papillomatosis, leukoplakia, dysplasia.

Pulmonary carcinogens that lead to the development of lung cancer: asbestos, arsenic, nickel, hexavalent chromium compounds, chloromethyl ethers, mustard gas, carcinogenic polycyclic aromatic hydrocarbons, and radon. Probable pulmonary carcinogens: acrylonitrile, beryllium, cadmium, vinyl chloride, formaldehyde, synthetic mineral fibers, silicon dioxide. The risk of lung cancer increases when exposed to lead aerosol. With the simultaneous action of carcinogenic occupational factors and smoking, the risk of lung cancer increases many times over [10].

Various carcinogenic factors that lead to the development of malignant diseases can be found not only in heavy industry, but also in medical institutions. Thus, most employees of pharmacies, laboratories, treatment rooms, chemotherapy departments, hematology departments, especially at the workplaces of personnel, where temporary storage and dilution of cytostatic drugs, collection, disinfection and temporary storage of medical waste are carried out are at a high risk.

The carcinogenic risk characterization has shown that the individual carcinogenic risk of malignancy in health care workers is acceptable for different occupational groups. At the same time, a feature of the work of specialists of many categories is the combined impact of various factors of the production environment [11].

It should be noted that the most common unfavorable factor of the working environment of medical workers is the pollution of the air of working premises with aerosols of medicines, disinfectants and narcotic drugs, which can exceed the permissible sanitary standards in operating rooms and treatment rooms by dozens of times [12]. Pollution of the air of working premises with medicinal substances, especially antibacterial drugs, antitumor drugs, which are highly dangerous substances and have an immunosuppressive, cytotoxic, sensitizing effect on the body, can cause the development of allergic diseases, occupational dermatoses, dysbacteriosis in medical workers. There are data indicating the manifestations of the carcinogenic effect of cytostatics [13].

In medical organizations at workplaces, there are also various kinds of agents that can cause irreversible changes or damage to the genetic apparatus that controls the vital activity of somatic cells, which are carcinogens. In the medical industry, these include: vincristine, procarbazine, prednisolone, embiquina and other alkylating agents, cytostatics, estrogen, progesterone, arsenic [14].

Despite the definite results achieved in identifying harmful production factors, the diagnosis of occupational oncological diseases remains quite low. At present, there are no official data and comprehensive information on occupational oncopathology in the Russian Federation [15].

In our work, we analyzed the data of registration and information systems (the Cancer Registry of the Primorsky Territory and the Primorsky Regional Oncology Dispensary) for the period 2013-2023 (10 years). The number of registration systems and medical workers with malignant diseases is 2,061. Among them, 17% are malignant lung diseases. According to the histological structure, adenocarcinoma is more often registered - 39%, squamous cell carcinoma - 31%, 11% - small cell carcinoma (SCLC), 9% falls on neuroendocrine tumors. According to the WHO, adenocarcinoma is registered in 30.7% of cases in the world, squamous cell carcinoma in 30%, and SCLC in 18.2%. Bronchopulmonary neuroendocrine tumors (BP-NETs) account for 27% of all types of BP-NETs of various anatomical locations, following the digestive system, and approximately 20–25% of the total number of malignant lung tumors [16]. Some discrepancy with the world data is possible due to the fact that in world practice, SCLC is included in the structure of the BP-NETs of the bronchopulmonary system. The age group of medical workers is from 48 to 75 years old. Differences in sex structure: 60% are men and 40% are women. Unfortunately, none of these malignancies have been regarded as occupational cancers. In 59% of cases, malignant neoplasms of the lungs, trachea and bronchi were detected at stages 3-4.

Dentists have been identified with chemicals that have a proven carcinogenic effect that causes cancer, most often of the bladder. Substances in the medical industry that contribute to the development of cancer: mercury, gold, arsenic compounds, antibiotics, non-steroidal anti-inflammatory drugs, radiopaque agents, organic solvents.

Among medical workers who had malignant diseases of the lungs, trachea and bronchi from 2013 to 2023, 68% were smokers. Of these, 73% had various chronic lung diseases.

Most often, the development of cancer in the group of medical workers was associated with chronic obstructive pulmonary disease (COPD). This disease is a progressive, partially reversible bronchial obstruction, which is associated with inflammation of the respiratory tract arising under the influence of adverse factors (physical, chemical, biological, smoking), a gradual decrease in lung function with the development of chronic respiratory failure.

The risk of developing lung cancer is most often associated with the presence of physical and chemical risk factors in combination with a smoking experience of 15 years or more. Smokers have COPD in most cases.

The long asymptomatic period of tumor development makes it difficult to interpret it with occupational risk factors.

Prevention comes down to improving working conditions, reducing the use of carcinogens in the working area, the use of personal respiratory and skin protective equipment, improving the quality of primary and periodic medical examinations

in accordance with current legislation. Also, it is impossible to neglect the use of modern equipment with low indicators of harmful effects on the human body, compliance with safety regulations, equipping operating rooms with ventilation devices, and vaccination. Prevention is also associated with compliance with the regime of work and rest, the use of therapeutic exercises, methods of psychological relief, alternation of operating and non-operational days.

Little attention is paid to psychological relief, however, the intensity of work and the frequency of making decisions that are decisive for the patient's life for the most part leads to burnout. In this regard, it is necessary to introduce group sessions with a psychologist for staff, for example, on non-operational days, in order to relieve psychological relief, relieve tension, fears, and an increased sense of responsibility.

81% of cases, patients in the group of medical professionals who were diagnosed with malignant tumors of the lungs, trachea and bronchi underwent fluorography, and 19% underwent, X-rays of the lungs in 2 projections annually. As part of preventive medical examinations, only 9% of malignant neoplasms were detected, more often at stage 3 (65%). The reasons for late diagnosis are: lack of cancer alertness, X-ray errors in description, clinical errors, as well as imperfection of FLG and X-ray methods.

Comparing the presence of risk factors, the smoking experience of medical workers in 65% of cases, it was necessary to conduct a low-dose computer-aided examination of the lungs (CNT) to detect precancerous and malignant diseases in the early stages. The introduction of tubing will increase the proportion of patients with malignant diseases of the lungs, trachea, and bronchi detected at stages I–II from 10–20% to 60–65% [17,18].

In our work, when analyzing the literature data, reporting forms for the registration of malignant neoplasms in the Primorsky Territory, risk factors for the development of lung, tracheal and bronchial cancer among medical workers were assessed and preventive measures aimed at early detection of precancerous and malignant diseases were proposed.

Despite annual preventive medical examinations among medical workers, unfortunately, there is still a high percentage of malignant diseases in stages 3 and 4.

In the Primorsky Territory, it is necessary to organize a monitoring center to control patients with precancerous diseases, as well as to introduce a register of workers whose working conditions are associated with exposure to various carcinogens. In the monitoring center, it is possible to plan work on the active detection of malignant diseases in such a professional group as medical workers, including the use of methods of primary and secondary prevention. It will be relevant to carry out in-depth screening, in this case, low-dose CT of the lungs.

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DOI 10.34660/INF.2025.10.12.046

拉各斯城市群节点结构空间建模方面（以尼日利亚拉古纳-拉各斯塔功能规划组织为例）

ASPECTS OF SPATIAL MODELING OF NODAL STRUCTURES OF THE LAGOS AGGLOMERATION (ON THE EXAMPLE OF THE FUNCTIONAL PLANNING ORGANIZATION OF LAGUNA-LAGOS TOWER, NIGERIA)

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摘要。拉各斯是尼日利亚最大的城市，也是世界上发展最快的城市之一。人与土地的关系是动态的，随着文化、社会和经济发展而变化。拉各斯的摩天大楼建设始于 20 世纪 60 年代。国际开发商和私人投资公司建造了几座办公楼和多功能建筑。现代建筑和结构不断发展至今。本文考虑了在非洲最大的城市群条件下对城市主导因素进行建模的问题。

关键词：投资项目、框架-主干结构体系、酒店、住宅综合体、功能分区、体积空间模型。

Abstract. *Lagos is the largest city in Nigeria and one of the fastest growing in the world. The relationship between people and the land is dynamic and changes over time in response to cultural, social and economic development. The construction of skyscrapers in Lagos began in the 1960s. Several office and*

multifunctional buildings were built by international developers and private investment firms. Modern buildings and structures have been constantly evolving to the present day. The problem of modeling urban dominants in the conditions of the largest agglomeration in Africa is considered.

Keywords: *investment project, frame-trunk structural system, hotel, residential complex, functional zoning, volumetric-spatial model.*

Introduction

The population of Lagos is growing very quickly, which is why this city in Nigeria was called “one of the fastest growing cities in the world”. In 1950, less than a million people lived in Lagos. By 1990 it had reached four million, and by 2015 it was about fifteen million. By 2030, Lagos is projected to have a population of over 30 million, and by 2100 it will grow to 88.3 million, making Lagos the most populous city in the world.

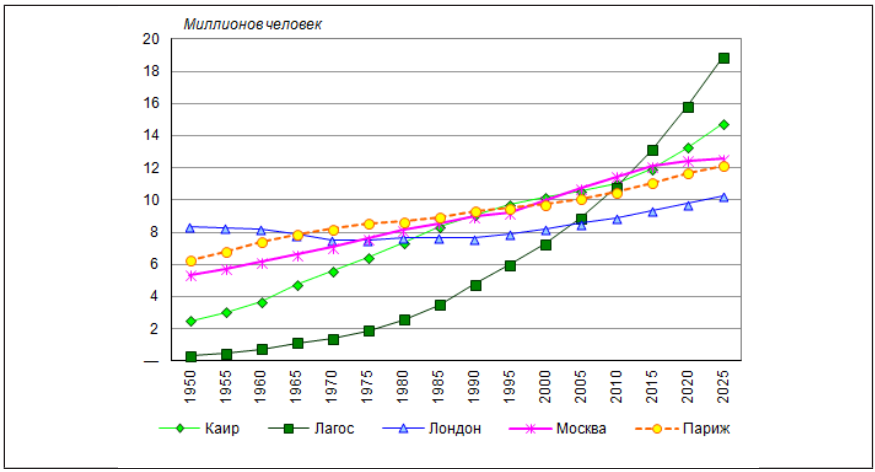

Figure 1. *Population of the largest urban areas in Africa and Europe, 1950-2025, in millions [1]*

A Retrospective on Lagos Urban Development

Nigeria is trying to improve its infrastructure, education, and health care, and to revitalize its industrial base, which once grew rapidly after independence.

A planning strategy was approved in 2006, and some immediate priorities are currently being addressed. First, Lagos, having expanded beyond its national borders, must harmonize its planning policies with its neighbors.

Second is the need to develop road and rail transport, in which the Chinese are now very active.

The architecture of Lagos is an eclectic mix of different types, styles, and periods. Buildings range from traditional vernacular architecture to tropical, modern architecture, or a mixture of both. The oldest European-style buildings date back to the 17th century. Elements of Portuguese architecture, introduced by returned former slaves from Brazil and the Caribbean, although present throughout the city, are prevalent in places such as Lagos Island, Surulere and Yaba municipalities. Colonial style architecture flourished during the Lagos colony. The Lagos skyline is a mix of modern high-rises, skyscrapers, dilapidated buildings and slums. Nowadays, architecture in Lagos is increasingly focused on the construction of modern, high-rise structures (for example, the Kingsway Tower).

Figure 2. *Kingsway Tower [3]*

The fifteen-storey building is located at the busy intersection of Alfred Rewane Road, the main road dividing the city into the north (towards the airport) and south (towards Victoria Island). It has a lower basement, a two-level retail podium, a parking podium and 12 floors of office space.

Nearby is the upmarket residential area of Ikoyi, where Alfred Rewane Road and its surroundings have been redeveloped to create a mixed-use spatial 'corridor'. This has led to a boom in office and hotel construction in this part of the city, but most development in Lagos tends to follow the standard commercial model of concrete slabs and curtain walls. Lagos Investment Projects

Lagos State attracted $7.29 billion in investment in the third quarter of 2021, or 81% of all investment in Nigeria, the Nigerian Investment Promotion Commission (NIPC) reported on November 2, the Vanguard online newspaper reported.

According to the data presented, the volume of investment in the country in the third quarter of 2021 was 130 percent higher than the volume in the same period a year earlier. A total of $8.99 billion was invested in the country.

NIPC representatives said that they monitored the fate of 33 major investment projects. They indicated that the most notable month in terms of investment activity was August. In August, 64% of projects with fundraising were announced.

The leading industries in terms of investment attractiveness were manufacturing, communications, finance, insurance, healthcare and social services. At the same time, manufacturing accounts for 42% of investments, electricity generation 25%, information and communications 23% and transport 7%.

Mix of traditional, tropical and modern architecture in Lagos

Due to the size of Lagos, its large population and the involvement of large investment projects in the city, it creates what is called a "contrast of slums and modern buildings":

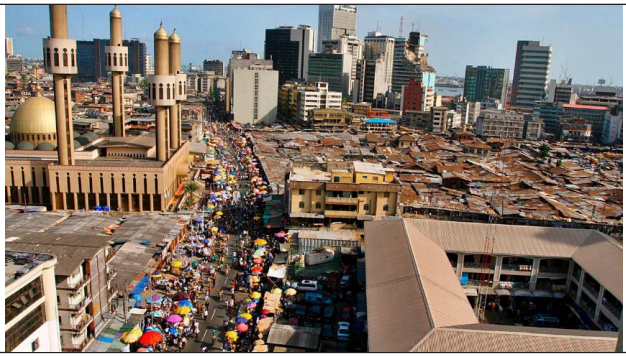

Figure 3. *Lagos City, Nigeria [4]*

Figure 4. *Victoria Island (Lagos, Nigeria) [5]*

Lagoon Lagos Tower Conceptual Design Proposal

The Lagoon Lagos Tower is a high-rise building in the centre of Lagos: it will be the tallest building in Nigeria and the second tallest in Africa.

Location

The building is located between the Eko Bridge, which connects Lagos Island (the main and central Local Government Area (LGA) of Lagos) to Lagos itself and the Lagos Terminus railway station. Also nearby are residential developments, a business centre and public buildings.

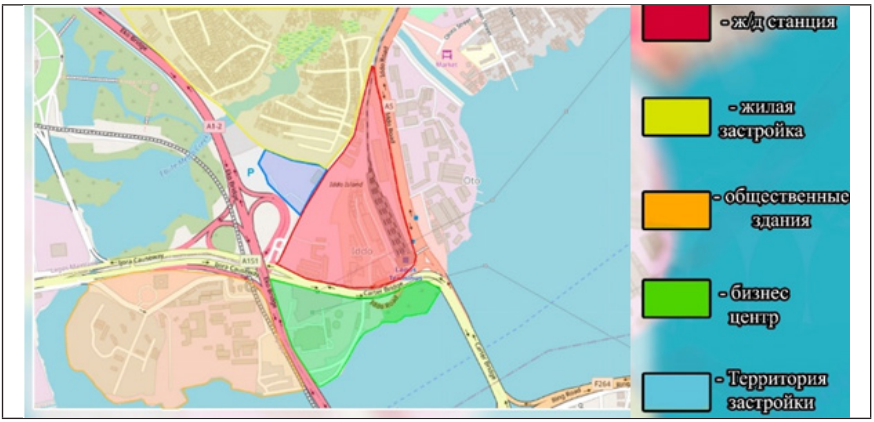

Figure 5. *Site plan*

This layout is formed taking into account the characteristics of transport and pedestrian accessibility.

For the purpose of rational and effective use of the internal space of a high-rise building, as well as the adoption of appropriate and comfortable space-planning solutions, the principle of vertical and horizontal zoning of the internal volume is used in the design.

Functional zoning

The Laguna-Lagos Tower has three main functional blocks:

1) Office space. Lagos is currently experiencing a large number of new investments and projects that require offices. The Laguna-Lagos Tower provides 17 “Business floors”.

2) Hotel. Lagos is the largest city in Africa, and it is not surprising that tourists often stay there, who can check into one of the rooms of the 17-story Laguna-Lagos Tower hotel. 3) Residential complex – apartments from the 40th to the 57th floor, which will give their residents walking distance to the office, a restaurant

with a veranda on the 60th floor, a railway station located next to the Laguna-Lagos Tower or a business center. Such vertical zoning is common throughout the world. An example is the tallest skyscraper in South Korea, the Lotte World Tower, where all floors, not counting the technical floors and the hall, are divided into three main zones: offices, a hotel, and residential premises.

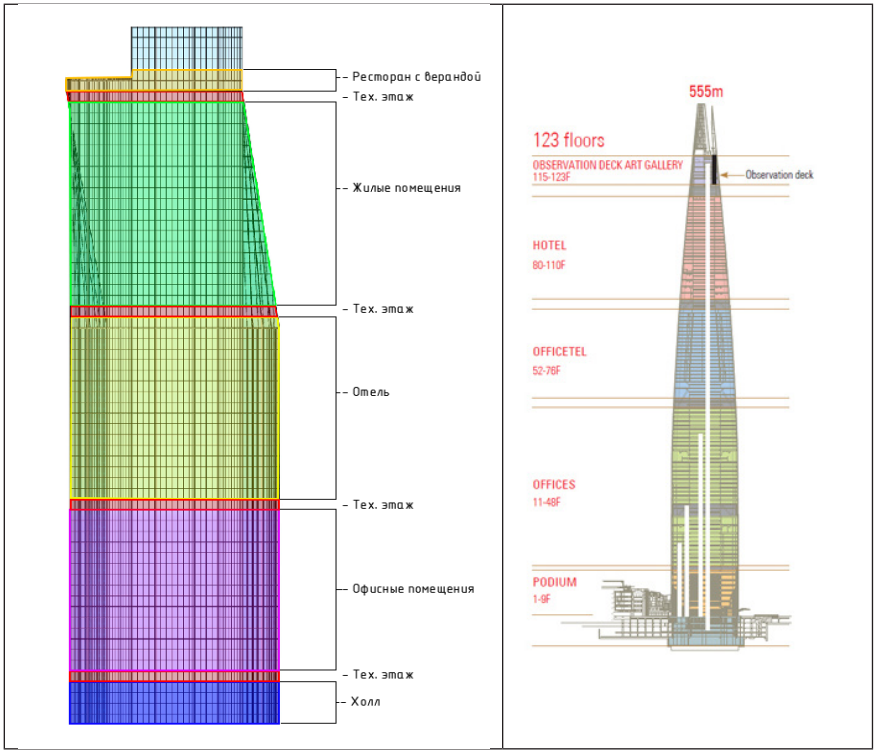

Figure 6. *Vertical zoning of the Laguna-Lagos Tower,* ***Figure 7.*** *Functional zoning of Lotte World Tower by KPF (Seoul, South Korea) [6]*

Choosing the shape of the building

The shape of the building changes depending on the height, starting with a complex shape and ending with a simple “semi-oval” (Figure 9)

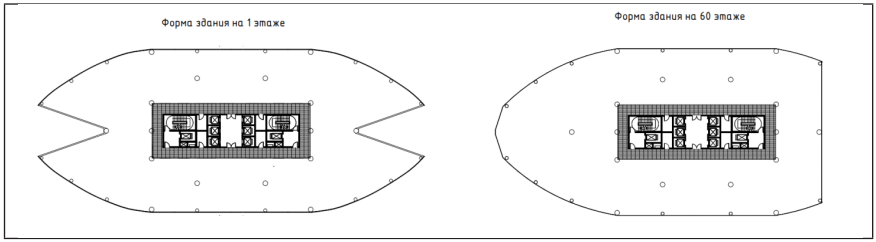

Figure 8. *Laguna-Lagos Tower. Formation: 1st, 60th floors*

The form formation of the object is carried out taking into account the following urban planning factors: rectangular outline of the site; proximity to the Gulf of Guinea.

To open up a panoramic view from the building, it is recommended to use an oval or rounded plan.

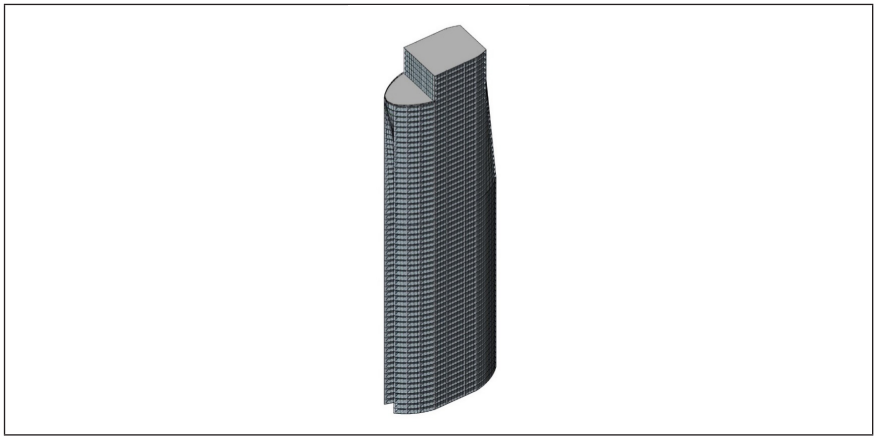

Figure 9. *"Laguna-Lagos-Tower". Volumetric-spatial model*

Structure

In the construction of high-rise buildings, there are 4 common types of structural systems: frame (frame), wall (frameless, diaphragm), barrel and shell systems, as well as their combinations.

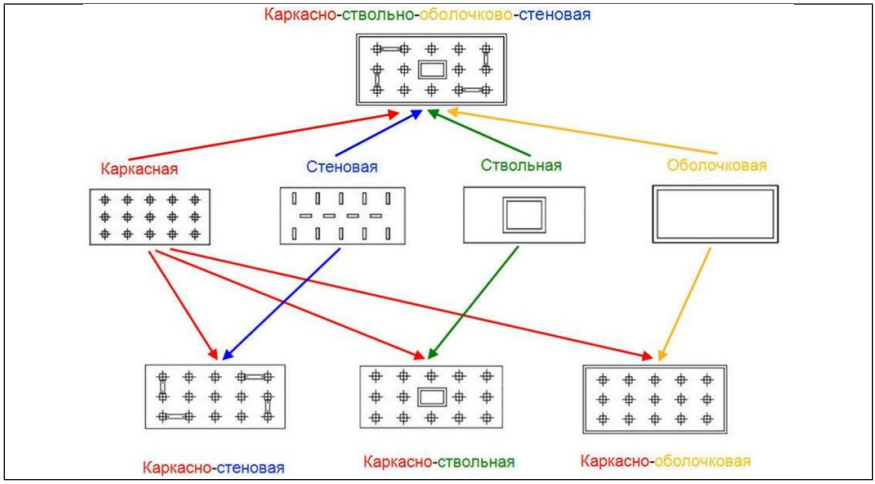

Figure 10. *Classification of multi-story buildings by design scheme*

The design scheme adopted in the Laguna Lagos Tower is a frame-and-trunk system. In this design system, the supporting structures are: a stiffening trunk – a vertical hollow through rod along the entire height of the building (as a rule, elevator shafts and halls are located in the trunk) and columns.

The frame-and-trunk system is based on the division of static functions between the frame, which takes up vertical loads, and the trunk, which takes up horizontal loads and impacts. It is used in the design of multi-story and high-rise buildings; it allows for the formation of fully glazed facades, which contributes to better insolation inside the building.

Conclusion

For a city that accounts for 81% of all investments in the country, such projects contribute to territorial development, providing a large number of jobs. The Laguna Lagos Tower will be (as of 2025) the second tallest building in Africa and the first in Nigeria, creating a new tourist attraction, with its main feature being a restaurant and an observation deck on the 60th floor.

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DOI 10.34660/INF.2025.83.39.047

生物系统参数预测算法及其软件实现
PREDICTING ALGORITHM FOR BIOLOGICAL SYSTEMS PARAMETERS AND ITS SOFTWARE IMPLEMENTATION

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摘要。这项工作属于数学生物学领域，致力于生物过程的数学和计算机建模。这项工作提出了一种新算法，用于预测时间或空间等距的生物系统的某些参数。该算法是使用高级面向对象通用语言 Python 实现的。该算法和计算机程序的特殊之处在于计算其自身的预测误差并随后考虑它们以提高预测的准确性。

关键词：数学建模、生物过程动力学、编程语言 Python、抛物线、三次曲线。

Abstract. *This work pertains to the field of mathematical biology and is devoted to mathematical and computer modeling of biological processes. The work presents a new algorithm for predicting certain parameters of biological systems equidistant in time or space. The algorithm is implemented using the high-level object-oriented general-purpose language Python. The peculiarity of the algorithm and computer program is the calculation of its own prediction errors and their subsequent consideration in order to improve the accuracy of predictions.*

Keywords: *mathematical modelling, dynamics of biological processes, programming language Python, parabola, cubic curve.*

Introduction

A number of problems in biology, ecology and medicine, such as

→ Modeling changes in the population size of organisms [1] (the population size can grow, fall according to certain laws or remain virtually unchanged);

→ Modeling the production process of plants [2] (has practical significance for optimizing agricultural crops and agriculture);

→ Studying the kinetics of enzymatic reactions [3] (that is, reactions catalyzed by enzymes - complex compounds that accelerate chemical reactions in living systems);

→ Modeling production processes in aquatic ecosystems [4] (it is believed that due to the relative homogeneity of the aquatic environment, aquatic systems are convenient objects for constructing mathematical models);

→ Construction of mathematical models of infectious disease epidemics [5] (which is very relevant in connection with the COVID-19 pandemic);

→ Mathematical modeling of population waves [6] and biological rhythms [7] (especially relevant for ecology and chronomedicine);

→ Study of growth processes and regulation of malignant tumors [8] (due to the complexity of their treatment is of great importance for medicine)

assume solving the mathematical problem "knowing n members of a certain series of numbers (describing equidistant in time or space parameters of a biological system) with varying degrees of reliability predict the next n + 1-th member of the series".

The objectives of this work are to develop a new mathematical algorithm for predicting the dynamics of parameters of biological systems and its software implementation in the popular general-purpose programming language Python. Elements of discrete mathematics and classical programming techniques are used as methods in the work.

Mathematical description and software implementation of the algorithm

Let's consider a sequence of real numbers $\{f_n\}$, given in the form of a formula

$$f_n = \frac{1}{2}(f_3 - 2f_2 + f_1)n^2 + \frac{1}{2}(-3f_3 + 8f_2 - 5f_1)n + f_3 - 3f_2 + 3f_1, \quad (1)$$

where n is a natural number.

Note that when successively substituting values into this formula n=1; n=2; n=3 we get a set $\{f_1; f_2; f_3\}$. Then, knowing the first three terms of the sequence, we can try to predict the next term. When substituting the value n=4 into expression (1), we obtain

$$f_4 = 3f_3 - 3f_2 + f_1 . \quad (2)$$

Let us call this prediction method the parabola method (since the dependence f(n) is a quadratic function).

Let's also consider the sequence of real numbers $\{f_n\}$, given in formulaic form

$$f_n = \frac{1}{6}(f_4 - 3f_3 + 3f_2 - f_1)n^3 + \frac{1}{2}(-2f_4 + 7f_3 - 8f_2 + 3f_1)n^2 + \frac{1}{6}(11f_4 - 42f_3 + 57f_2 - 26f_1)n - f_4 + 4f_3 - 6f_2 + 4f_1 , \quad (3)$$

where n also a natural number.

Substituting the values into this expression n=1; n=2; n=3; n=4 , we get a set $\{f_1; f_2; f_3; f_4\}$. That is, knowing the first four terms of the sequence, we can predict the fifth term. Substituting the value n=5 into formula (3), we obtain

$$f_5 = 4f_4 - 6f_3 + 4f_2 - f_1 . \quad (4)$$

We will call this forecasting method the cubic curve method (the f(n) dependence is cubic).

We will implement the developed algorithm in the Python programming language [9], [10], but we will take into account that the program should also calculate its own errors in forecasts and take them into account in the future to improve the accuracy of forecasts. For this, the number of numbers in the studied series should be at least five (in general, the larger the data array entered into the program, the higher the accuracy of the forecasts). We will write comments in the program text after the # symbol. We will agree that the $ symbol means one indent (one space).

```
def G(f1,f2,f3):
# create a function with three arguments for the parabola method
$$$$return 3*f3-3*f2+f1
# calculate the fourth predicted value in the series
def Q(f1,f2,f3,f4):
# create a function with four arguments for the cubic curve method
$$$$return 4*f4-6*f3+4*f2-f1
# calculate the fifth predicted value in the series
print("Enter the number of numbers in the series (at least 5)")
# display text on the screen
n=int(input())
# enter the number of numbers in the series n (natural number)
while n<5:
$$$$print("The number of numbers must be at least 5")
$$$$n=int(input())
# until the number of entered numbers is greater than or equal to 5, you need to
# enter it again
F=[]
# create an array of n elements
Err1=[]
# create the first array of prediction errors
Err2=[]
# create the second array of prediction errors
for i in range(n):
# variable i runs through integer values from 0 inclusive to n excluding
$$$$f=float(input())
```

```
# enter the values of known numbers in the series (real numbers)
$$$$F.append(f)
# add the entered values to the array
for j in range(n-3):
# variable j runs through values from 0 inclusive to n-3 excluding
$$$$err1=F[j+3]-G(F[j],F[j+1],F[j+2])
# calculate the prediction error for the parabola method
# using consecutive triplets of numbers in the series
$$$$Err1.append(err1)
# add the prediction error to the first array of errors
x=sum(Err1)/(n-3)
# calculate the average prediction error for the first array of errors
par=G(F[n-3],F[n-2],F[n-1])+x
# calculate the prediction using the parabola method
for k in range(n-4):
# the variable k runs from 0 inclusive to n-4 excluding
$$$$err2=F[k+4]-Q(F[k],F[k+1],F[k+2],F[k+3])
# calculate the prediction error for the cubic curve method using
# consecutive quadruples of numbers
$$$$Err2.append(err2)
# add the prediction error to the second array of errors
y=sum(Err2)/(n-4)
# calculate the average prediction error for the second array errors
cub=Q(F[n-4],F[n-3],F[n-2],F[n-1])+y
# calculate the prediction using the cubic curve method
if abs(x)<abs(y):
$$$$print(par)
else:
$$$$print(cub)
```

if the average error of the parabola predictions is lower than that of the cubic curve method, then display the parabola prediction; otherwise (if the average error of the parabola predictions is not

lower than that of the cubic curve method), display the cubic curve prediction

Conclusion

Thus, in the course of the work, a new mathematical algorithm for predicting the parameters of biological systems was developed, which is of practical importance for the fields of biology, ecology and medicine. This algorithm allows predicting the next value in a series of numbers located at the same time or geometric distance from each other. In the process of developing the algorithm, the

calculation of prediction errors was taken into account for their further use in order to improve the quality of forecasts. Also, in the work, a computer program based on the presented algorithm was written in the popular powerful general-purpose language Python.

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DOI 10.34660/INF.2025.17.60.048

排球运动员心理情感领域及社会智力特征
FEATURES OF PSYCHOEMOTIONAL SPHERE AND SOCIAL INTELLIGENCE OF ATHLETES ENGAGED IN VOLLEYBALL

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Introduction. In game sports, in addition to physical skills, the processes of interaction within the team are also of great importance, so the issues of communication between athletes among themselves are very relevant. It is known that success in team sports often depends on how well team members understand each other. The chemistry of the team is determined not only by the high level of operational thinking of athletes, but also by the similarity of their psychophysiological profiles, good psychological environment and intra-team relationships between players. In this sense, a sports team can be considered as a social group, mutual understanding within which forms part of collective success. The basis on which social interaction within a group is built is the psycho-emotional sphere of a person, his ability to communicate his emotions and perceive the feelings of others.

Sport in the modern world has become not only a full-fledged sphere of professional sports activity, but also a universal means of communication, contributing to the development of not only interpersonal, but also interregional and international contacts.

One of the leading types of student team sports is volleyball. It is characterized by the greatest emotional intensity among other sports.

Volleyball process is based on how players are able to think and interact with each other, understand each other, exchange information during the game and training process, on the thoughts, feelings, experience that they acquire during joint game activity.

There are many examples in volleyball when a relatively weak team wins despite all predictions based on the assessment of physical, technical and tactical preparedness of the team players. This is usually explained by a psychological factor. High emotional rise and the desire to win often lead to victory over a stronger opponent, who underestimated the opponent and entered the fight with him in a state of less mobility

Thus, we hypothesize that athletes involved in team sports should have higher emotional intelligence scores than the average person. They should also be expected to have an increased propensity for social interaction. Athletes-players should show a higher interest in group bonding and be more aware of themselves as part of a team and understand their responsibility to the team.

According to all the above characteristics, volleyball is a rather convenient sport to test our hypotheses. The purpose of our work was to identify the features of psychoemotional profile and social intelligence in athletes engaged in game sports, using volleyball as an example**.**

Methods. Forty-one healthy students of the Northern (Arctic) Federal University named after M.V. Lomonosov: girls and boys aged 19-27 years old, who at the time of examination had no diagnosed acute or chronic diseases, took part in the study on a voluntary basis. The subjects were divided into two groups: a control group and a group of volleyball players (university student team). The control group consisted of 21 subjects: 4 males and 17 females. The group of volleyball players consisted of 20 subjects: 8 males and 12 females. The group of volleyball players consisted of athletes whose grade was not lower than 1 adult. All subjects were informed about the purpose of the study and the nature of the stimuli used.

The study was conducted in two stages. At the first stage, the subjects were asked to solve two tests: the Hall test to determine the level of emotional intelligence and the Guilford test to determine the level of social intelligence.

Hall's test is aimed at revealing the ability to understand the relations of personality, represented in emotions, and to manage the emotional sphere on the basis of decision-making. The subjects had to answer 30 statements. They could fully agree (+3 points), mostly agree (+2 points), partially agree (+1 point), partially disagree (-1 point), mostly disagree (2 points), and completely disagree (-3 points). At the end of the test, the sum of scores on five scales was calculated: emotional awareness; emotion management; self-motivation; empathy; and recognizing other people's emotions. If the sum of the scale scores was seven points or less, emotional intelligence was considered low; from 8-13 points - average; from 14 points or more - high.

The Guilford test is aimed at revealing the ability to understand and predict the behavior of people in different everyday situations, to recognize intentions, feelings and emotional states of a person by non-verbal and verbal expression. The methodology included 4 subtests, of which three were composed on non-verbal stimulus material and one on verbal. Subtest #1 - stories with completion; subtest #2 - expression groups; subtest #3 - verbal expression; subtest #4 - stories with addition. Each of the subtests consisted of 12 -15 tasks. A brief instruction was given before performing each of them. The amount of time was limited from 5 to 10 minutes. Answer forms, processing keys and tables for determining standard

values were used to process the results. First, the scores for each subtest were calculated: one correct answer - 1 point. Then they were converted into a standard scale, which reflected the level of development of the corresponding abilities to cognize behavior: 1 point - low abilities to cognize behavior; 2 points - abilities to cognize behavior below average; 3 points - average abilities to cognize behavior; 4 points - abilities to cognize behavior above average; 5 points - high abilities to cognize behavior.

At the second stage, electrodermal activity (EDA) was recorded during the perception of facial expression. The study was conducted in a quiet room. The effect of various distracting factors (loud sounds) was minimized. The recording of electrodermal activity was performed in a sitting position with open eyes.

In our study, two recording electrodes were used to record EDA. In the control group, they were placed on the right arm, and in the volleyball players' group on the arm that was not involved in playing activity (non-playing). The electrodes were placed as follows: the positive electrode was placed on the skin of the 2nd phalanx of the middle finger, the negative electrode was placed at a distance of 3 cm from the metacarpophalangeal joints. The indifferent electrode was applied on the forearm. The electrodes were treated with gel to improve electrical conductivity before being applied to the skin.

During the main part of the study, the subject was asked to view a series of black and white photographs taken from a standardized facial expression perception study database (Nim Stim Face Stimulus Set). The images were displayed on a computer monitor screen 55-65 cm away from the respondent. The photographs depicted the faces of adult men and women on a white background. We selected 3 representatives of different sexes of each of three races: Caucasoid, Negroid, and Mongoloid. Each person's photograph was encountered twice. In the first photograph, the person expressed a positive emotion, joy, and in the second a negative emotion, fear. A total of 12 photographs were presented to the subject, which appeared in front of him/her in random order. The order of presentation of photographs was different for even and odd subjects.

Each photograph was alternated with a neutral white image. This was necessary to stabilize the EDA waveform. Switching the stimulus to the neutral background was done manually by the researcher, after the end of the recording of the EDA wave from the previous stimulus. Each wave was temporally recorded for 20 seconds. A new image was switched on only after EDA stabilization.

The results were processed in semiautomatic mode. The program offered its own variant of marker placement on the EDA wave, which could be corrected manually by the researcher.

The following parameters of the evoked cutaneous autonomic potential (ACEP) were calculated: latent period (LP); amplitude of the first phase (A1);

amplitude of the second phase (A2); duration of the first phase (S1); duration of the ascending part of the second phase (S2a); duration of the descending part of the second phase (S2b).

Statistical analysis of the data was performed in SPSS 22.0 program. Medians (Me) and quartiles (Q1-Q3) were used as their descriptive characteristics. Correlations between the scores within the Hall and Guilford tests; between the scores of the Hall and Guilford tests, as well as the scores of the tests and ACEP parameters were evaluated using the Spearman coefficient. The Mann-Whitney test was used to assess the significance of the Hall and Guilford tests between the control group and the group of athletes, as well as the ACEP parameters. Differences were considered statistically significant when the probability of erroneous acceptance of the null hypothesis of equality of general averages was $p<0.05$.

Results. The conducted study demonstrated that the "emotion management" score was statistically significantly different in the volleyball players' group compared to the control group ($p = 0.028$). The control group had a mean of -6.5 points and the volleyball players' group had a mean of 3.0 points. Also, we found that the scores of emotional awareness, self-motivation, empathy and emotion recognition in these groups are almost at the same level and are not statistically different.

Based on this, we can say that the level of emotion management development of the control group is lower than that of the volleyball players group. According to the source [1], this may be due to the fact that throughout the years of playing volleyball, in addition to physical qualities, athletes also develop psychological qualities. After all, in a duel of well-trained and equal teams, the one that is better prepared psychologically wins. The decisive game is won by the team that is able to manage its emotions, is psychologically stable, which can resist disruptive factors and persistently strives for victory in any conditions and under any circumstances.

Social intelligence scores on all subtests did not differ significantly between the compared groups, nor did the overall level of social intelligence. The level of social intelligence is determined by the social factors that make up the social environment. They are considered to be the main elements in the formation of social intelligence. There are three groups of factors describing social intelligence: cognitive, emotional and behavioral [2].

The results of registration of evoked sympathetic potentials showed that when perceiving male and female faces, different groups of students statistically significant are the indicators of the amplitude of the first and second phases, as well as the duration of the first phase.

We can observe that when perceiving female faces expressing different emotions, the amplitude of the first phase (A1) of the evoked skin-vegetative potential in the group of athletes was at the level of 0.17 mV, and in the control group it was at the level of 0.38 mV.

We also found that during the perception of male faces expressing different emotions, the peak of the first phase in the control group was located 0.28 mV higher than in the group of athletes. In addition, the amplitude of the first phase (A1) was statistically significant in two measures in both groups: when presented with pictures of female faces ($p = 0.016$) and male faces ($p = 0.002$) expressing different emotions. We obtained results indicating that amplitude indices in both cases in the group of athletes are lower than in the control group. When presented with female faces, it is located lower by 0.21 mV than the group of athletes. And when presenting pictures with male faces, the amplitude index was observed at 0.15 mV, which is 0.28 mV lower than the control group (0.38 mV).

It is well known that the amplitude index of the first phase is used to determine the level of trophotropic activity, which is responsible for the stability of the internal environment of the body (homeostasis). And the amplitude index of the second phase is directly related to: HR, autonomic index Credo, concentration of cortisol in blood, higher values of which are characteristic of the predominance of ergotropic influences, which allow the body to adapt to changes in the external environment, provide the need for physical and mental activity [3].

The amplitude index of the second phase (A2) also had statistical significance for two indicators. In the first case, we compared the amplitude of the second phase within the control group, registered in response to the presentation of photographs of male and female faces expressing different emotions. When recognizing female faces, the amplitude of the second phase was recorded at 1.96 mV, and when recognizing male faces at 1.86 mV. In the second case, the amplitude of the second phase of the ACEP recorded in response to the presentation of photographs of male faces expressing different emotions was compared between the two groups. Thus, this index is lower in the group of athletes and it is at the level of 1.03 mV, and in the control group at the level of 1.86 mV.

Low values of amplitude in the group of volleyball players may indicate that the internal environment of their organism is more stable than in the control group. Stability is associated with constant training, which increases the physical, mental and physiological functions of the body. Consequently, the low level of amplitudes is associated with a high level of emotion control, which is characteristic of the group of volleyball players.

The response time when presented with photographs of female faces expressing different emotions was: in the control group - 2.21 s, and in the group of athletes - 1.34 s. Such a difference in time can be related to the fact that volleyball players have a well-developed component of perception of other people's emotions. It is expressed in the non-verbal way of communication of players within their team. They can use it to assess the readiness and mood of their team members. And in the crucial minutes of a game match, they do not make mistakes when choosing a player who should bring a winning point [4].

We can also say that the group of volleyball players has a better developed ergotropic system, in contrast to the control group. This is explained by the fact that during the year athletes have to travel a lot to competitions in other cities, perform in halls in front of a huge number of fans. The change of environment forces them to adapt to the conditions of the external environment, and the huge number of fans develops their psychoemotional sphere of activity.

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DOI 10.34660/INF.2025.88.96.049

谷氨酸棒杆菌菌株合成谷氨酸能力的研究
STUDY OF THE ABILITY OF *CORYNEBACTERIUM GLUTAMICUM* STRAIN TO SYNTHESIZE GLUTAMIC ACID

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注释。本文介绍了一种用于谷氨酸生产菌谷氨酸棒杆菌菌株（B-10925）种子材料获取方法的研究结果。分离纯培养的微生物，研究其形态特征并确定最佳培养条件。用毛细管电泳法测定培养液中谷氨酸和其他有机酸的含量。研究发现，经过优化培养条件和实施提高生产率的生物技术技术后，所研究的菌株可用于谷氨酸的工业生产。

关键词：谷氨酸棒杆菌、谷氨酸、生物技术合成、生产菌、发酵、种子材料、有机酸、毛细管电泳、食品添加剂。

Annotation. *The article presents the results of a study on the development of a method for obtaining seed material for the glutamic acid-producing strain, the Corynebacterium glutamicum strain (B-10925). Work was carried out to isolate a pure culture of the microorganism, study its morphological characteristics and determine the optimal cultivation conditions. The content of glutamic acid and other organic acids in the culture fluid was determined by capillary electrophoresis. It was found that the studied strain can be used for industrial production of glutamic acid after optimization of cultivation conditions and implementation of biotechnological techniques that increase productivity.*

Keywords: *Corynebacterium glutamicum, glutamic acid, biotechnological synthesis, producer strain, fermentation, seed material, organic acids, capillary electrophoresis, food additives.*

Introduction

Currently, the biotech industry is beginning to develop in Russia. New enterprises are being built, and technologies for obtaining various biotech products, including food ingredients, are in development. The modern food industry, characterized by a large volume of production, uses technologies based on the use of food additives for various purposes: texture formers, flavors, dyes, acidity regulators, etc. flavor enhancers. The main part of the market is additives, most of which are purchased abroad, including in China, so work on creating domestic technologies for the production of such additives is extremely relevant.

Modern technologies for obtaining food additives are based on microbiological synthesis and this requires highly qualified employees and the use of modern equipment, since production is classified as high-tech. One of the key points in development is the search for a highly productive strain of microorganism capable of ensuring the production of the target product.

The aim of this study is to develop a method for obtaining seed material for glutamic acid producer and fermentation parameters for its synthesis. L-glutamic acid (α-amino glutaric acid) is the first amino acid obtained by industrial microbiological synthesis [2], which makes its production a benchmark example of biotechnological processes. Currently, glutamic acid is widely used in the food industry as a flavor enhancer, which emphasizes the relevance of its production.

Materials and methods

The strain *Corynebacterium glutamicum* (B-10925), purchased from the All-Russian Collection of Industrial Microorganisms, was used as a producer of glutamic acid.

Rehydration and seeding were performed by the method of decimal dilutions on typical dense nutrient media. Standard nutrient media were used in the study. The data about the environments are given in Table 1.

Table 1

Composition of nutrient media.

Name:	Tryptone Soy Agar (TSA) or Tryptone Soy Broth WITHOUT Added Agar Component (TSB)	Meat-peptone agar (MPA) or meat-peptone broth WITHOUT the addition of an agar component (MPB)
Compound:	distilled water – 1 liter; glucose or dextrose - 2.5 grams; sodium chloride - 5 grams; tryptone - 17 grams; dipotassium phosphate - 2.5 grams; soy peptone - 3 grams; yeast extract - 6 grams; agar – 20 grams (2% of the total volume of the medium).	distilled water – 1 liter; enzymatic peptone - 10 grams; meat extract (beef extract) - 11.0 ± 3 grams; sodium chloride - 5 grams; agar - 20 grams.

The morphological characteristics of the culture were determined by optical microscopy on a MAGUS Bio 230T microscope at 1000x magnification using the immersion microscopy method.

The seed material was obtained by growing an inoculum containing 5–7% of the microorganism culture (by volume) at a temperature of 32°C on a RADOBIO MS70 rotary shaker at 110 rpm for 24 hours.

The content of glutamic acid and organic acids in the culture liquid was determined by capillary electrophoresis using a Kapel 104T device. Active acidity was determined using an ATP-02 automatic titrator.

Research results

The purity of the culture is one of the most important parameters for obtaining the target product. To determine the purity of the *Corynebacterium glutamicum* strain purchased from VKPM, the lyophilisate was rehydrated by adding it to a physiological solution (0.9% sodium chloride solution) and meat-peptone broth. After 10-minute incubation, seeding was performed on dense nutrient media: TSA and MPA. Morphological features of microorganisms were visually controlled under microscopy. The microscopy results are shown in Figure 1.

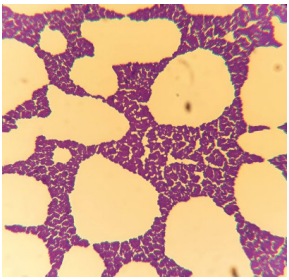
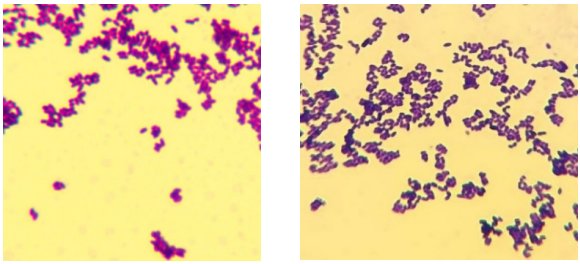


Figure 1. *Magnification 1000 times, preparation of C. glutamicum strain, stained with Lugol's solution*

The figure shows signs of heterogeneity of the microorganism culture, expressed in different forms of colonies. To isolate the active producer, two colonies differing in morphological features were cultured and reseeded. A fixed smear preparation stained with Lugol's was prepared and microscopically examined at a magnification of 1000 times. The results of microscopy are presented in Figure 2.



A *B*

Figure 2. *Magnification 1000 times, preparation of strain C. glutamicum, stained with Lugol's solution*

As can be seen from Figure 2, homogeneity of the morphological characteristics of the resulting pure culture was achieved. These samples were then used to obtain seed material and subsequent fermentation processes.

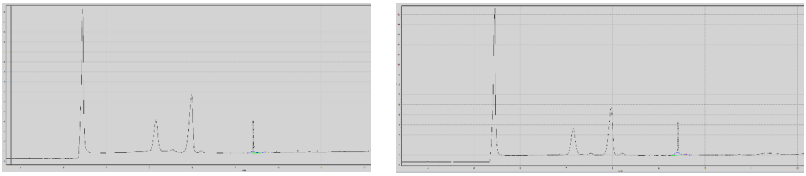
Fermentation was carried out in 500 cm3 shaking flasks with 50 cm3 of the "Meat-peptone broth" nutrient medium. Cultivation was carried out for 24 hours at 110 rpm and a temperature of 32 °C. The inoculant was added in an amount of 5-7% of the medium volume.

To determine the content of glutamic acid and organic acids, the obtained biomass was separated by centrifugation at 14,000 rpm for 5 minutes. Then, the content of glutamic acid and organic acids in the culture liquid was determined by capillary electrophoresis. The obtained data are presented in Table 2 and Figure 4.

Table 2

Concentration of glutamic acid in the culture fluid of samples No. 1 and No. 2 of C. glutamicum.

Sample	Concentration of glutamic acid, g/dm3
№1	26.5
№2	30.2



A *B*

Figure 4. *Electropherogram. A – sample No. 1; B – sample No. 2.*

The content of organic acids in the centrifugate was also determined by capillary electrophoresis. The obtained data on organic acids of samples 1 and 2 are presented in Table 3.

Table 3

Concentration of organic acids in the culture liquid

Acid	Concentration g/dm3	
	Sample No. 1	Sample #2
Oxalic acid	2,234	2,218
Tartaric acid	3,211	3,021
Citric acid	9,685	8,961
Succinic acid	2,863	2,942
Lactic acid	8,736	8,943
Acetic acid	5,862	5,346

Discussions

The obtained data showed that the selected strain is a heterogeneous culture of Corynebacterium glutamicum and requires work on the isolation and purification of a highly productive strain producing glutamic acid. The colony transfers carried out allowed us to isolate cultures for further use. A study of the productivity of the colonies revealed that sample No. 2 from Table 2 turned out to be the most productive, synthesizing 30 g/dm3 of glutamic acid in 24 hours of cultivation (determined by capillary electrophoresis) [5].

Corynebacterium glutamicum, in addition to glutamic acid, is capable of producing arginine, histidine, isoleucine, leucine, lysine, phenylalanine, serine, lactate, trehalose, and so on [1-4, 6-14]. The accompanying increased synthesis of organic acids reduces the coefficient of conversion of carbohydrates into the target product. In this regard, their content is an important determining parameter of fermentation.

Determination of the content of organic acids showed that the culture liquid contains significant concentrations of acids such as oxalic, tartaric, citric, succinic, lactic, and acetic, which indicates the loss of nutrients during their synthesis.

Conclusion

Thus, the conducted studies have shown that the Corynebacterium glutamicum strain from VKPM can be used for industrial production of glutamic acid [10]. It is necessary to introduce various biotechnological techniques that increase the yield of the target product and reduce the cultivation time, as well as to develop laboratory regulations, methods for isolating and purifying the target product from the culture fluid.

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DOI 10.34660/INF.2025.33.25.050

精准灌溉的创新技术解决方案
INNOVATIVE TECHNICAL AND TECHNOLOGICAL SOLUTIONS FOR PRECISION IRRIGATION

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摘要。本文介绍了精准灌溉的技术方案和技术方法。在广角圆形喷头上安装了可编程逻辑控制系统和电磁阀。还开发了一个程序，通过根据田间水分储备水平将灌溉区划分为多个区域来调整灌溉率。已经开发了喷头来提高低压喷洒的质量。对所提出的灌溉技术进行了比较试验，并估算了每次灌溉的地表径流和每次灌溉平均从土壤中去除的养分。实验研究证实了所提出的技术和工艺解决方案的生态有效性，使用这些技术和工艺解决方案可以防止养分流失和总体肥力下降。

关键词：精准灌溉、喷头、阀门、灌溉率调节、排水。

Abstract. *The article presents technical solutions and technological techniques for precision irrigation. A programmable logic control system and electromagnetic valves are installed on the wide-scope circular sprinkler. A program has also been developed to adjust the irrigation rate by dividing the irrigation zone into sectors in accordance with the level of moisture reserves in the field. Sprinklers have been developed to improve the quality of spraying at low pressure. Comparative tests of the proposed irrigation technologies are presented and the surface runoff per irrigation and the removal of nutrients from the soil on average per irrigation are estimated. Experimental studies have confirmed the ecological effectiveness of the proposed technical and technological solutions, the use of which makes it possible to prevent the removal of nutrients and a decrease in fertility in general.*

Keywords: *precision irrigation, sprinklers, valves, adjustment of irrigation rate, drain.*

Introduction

The growing population, lack of resources and deterioration of the environmental situation have an impact on the choice of irrigation equipment and technologies. In recent years, the concept of management and efficient use of agricultural resources called "Precision farming" has attracted increasing interest. A special case of which, one of the elements is "precision irrigation".

The “precision irrigation” system is an opportunity to supply the right amount of water to where it is needed, i.e. “point-by-point”, thereby saving water and preventing excessive runoff. The technology is particularly effective and environmentally sound when applying fertilizers with irrigation water (fertigation). Currently, the topic is quite popular and is represented in the research of many scientists [1-11].

The purpose of the presented research was to develop technical means and devices for wide-range sprinkler machines for precision irrigation of agricultural crops and the necessary irrigation technology.

Currently, four main methods of implementing the technology have become widespread:

- Control of individual sprinklers or blocks of several sprinklers.
- Changing the speed of the sprinkler machine and dividing it into irrigation sectors.
- Dynamic flow control.
- The changing nozzle opening of the sprinkler.

The first two options are presented in this paper. According to the first option, a wide-scope sprinkler is equipped for precise irrigation. The preset water supply is carried out using programmable logic control and electromagnetic valves installed in front of each sprinkler or on a sprinkler unit mounted through an additional pipe.

The second option (by changing the speed of movement and dividing into irrigation sectors) is carried out to adjust the irrigation rate depending on water consumption.

Material and methods

Both variants were carried out on a CASCADE multi-support sprinkler machine (LLC “Reclamation Machines”) [11]. The agricultural crop is alfalfa. The soil is dark chestnut medium loamy. The research methodology included, firstly, the determination of irrigation control zones based on measurements of soil electrical conductivity, and secondly, a remote system for monitoring soil moisture in real time. The study used soil electrical conductivity sensors: the VERIS Model 3100 Sensor and the SEED_OS_5 Sensor. Next, the optimal number of irrigation control zones was determined.

The total amount of moisture in the soil:

$$Q = 10000\ W\ h\ V_0, \quad (1)$$

where W – soil moisture, % by weight; 10000 – area of 1 ha, m^2; h - layer thickness, m; V_0 – volume weight, t/m^3.

The reserve of productive moisture in the soil:

$$Q_B = 10000\ (W\text{-}B)\ h\ V_{0.} \quad (2)$$

B – wilting humidity.

When the soil moisture reached 60% of the total available water content within one of the irrigation control zones, irrigation began. The control system used a pulse method, using an electromagnetic valve to regulate the required water flow rate by "turning on/off" the sprinkler.

The modification of the irrigation system included the installation of a programmable logic control, a position sensor, electromagnetic valves, irrigation pipes for surface irrigation and sprinklers.

Drain irrigation pipes were installed through 2.9 and 2.2 m. In addition, drain pipes with a diameter of 20 mm were installed from an additional horizontal pipeline through 0.5 m. The discharge tubes provide a flow rate of 15.8 liters/hour at a pressure of 0.12 MPa.

A system of equations was used to adjust the irrigation rate according to the second option:

$$T_i = \begin{cases} \dfrac{Fm}{Q - 0{,}5FE_i}, & \text{при } i = (k-1)n + 1; \\ \dfrac{T_{i-1}(Q + 0{,}5FE_{i-1})}{Q - 0{,}5FE_i}, & \text{при } i \neq (k-1)n + 1, \end{cases} \quad (3)$$

where i is the serial number of the site; k is the irrigation number; m is the irrigation rate.

For subsequent watering:

$$T_i = \begin{cases} \dfrac{F(m - 0{,}5E_{i-n}T_{i-n})}{Q - 0{,}5FE_i}, \\ \text{при } i = (k-1)n + 1; \\ \dfrac{T_{i-1}(Q + 0{,}5FE_{i-1}) - 0{,}5F(E_{i-n-1}T_{i-n-1} + E_{i-n}T_{i-n})}{Q - 0{,}5F_nE_i}, \\ \text{при } i \neq (k-1)n + 1. \end{cases} \quad (4)$$

where E is the average hourly water consumption, m^3/ha;

Q – sprinkler flow rate, m^3/h;

T is the average watering time, h.

Land area:

$$F = \frac{S_0}{n}, \quad (5)$$

where S_0 is the area of irrigation by a sprinkler machine, ha.

n - number of plots.

Results and discussion

The map of the total available water content allowed us to identify six zones on the site.

The use of precision irrigation instead of uniform irrigation with a single standard in this study area provided water savings in the range of 8-12%.

The measurements showed some deviations of the output volume of water from the required one at the boundary of the control zone (at the time of switching), which is explained by the relatively large irrigation radius and some inertia of the system. To ensure the uniformity of watering and the clarity of the system, the radius of spraying water with a sprinkler should not exceed the distance between the sprinklers. Sprinklers of various types have been developed to increase uniformity in low-pressure irrigation. Including those with two deflectors and rotating deflectors, Fig.1. In the future, two-deflector models were selected to complete the machine.

Figure 1. *Designed sprinklers*

To control irrigation according to the second option (changing the speed of movement and dividing into irrigation sectors), an algorithm, a model and a computer program in the C# programming language were developed to plan the irrigation rate in accordance with the level of moisture reserves of the field sections, Fig. 2. During the experimental studies, the irrigation zone was divided into 4 sectors.

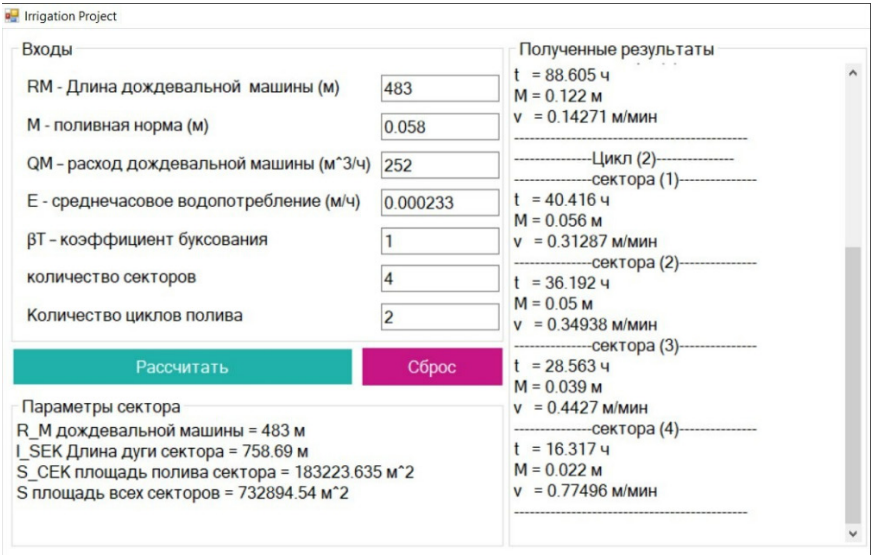

Figure 2. *Calculation program (screenshot)*

Comparative experimental studies of improved technologies and technical means were conducted in the Marksovsky district of the Saratov region.

Irrigation at the first pilot site was carried out using standard technology, at the second – with adjustments to irrigation standards and division into sectors, at the third – using precision technology.

The amount of surface runoff was determined at the runoff sites, Table 1.

Table 1.

Surface runoff per irrigation

Years	Option	Irrigation rate, m^3/ha	The amount of runoff		Volume of supplied water, m^3/ha
			m^3/ha	% irrigation standards	
2022	1- standard	480	43	9,0	523
	2- adjusting the watering rate		18	3,8	498
	3-precision watering		11	2,3	491
2023	1- standard	490	45	9,2	535
	2- adjusting the watering rate		20	4,1	510
	3- precision watering		12	2,4	502

2024	1- standard	410	35	8,5	445
	2- adjusting the watering rate		15	3,6	425
	3- precision watering		9	2,2	419

According to the data obtained, the volume of surface runoff for irrigation using standard technology in 2022 amounted to 9% of the irrigation rate, which is 2.4 times more than with the adjustment of norms, division by sector and 4 times more than with precision irrigation.

Field studies in 2023 and 2024 show similar results. With the surface runoff of irrigation water, nutrients and humus are removed from the soil, which negatively affects crop yields and the ecological condition of soils.

The assessment of nutrient removal was carried out using chemical analysis and is presented in Table 2.

During the period 2022-2024, when adjusting irrigation standards by division into sectors, the removal of nutrients from the liquid phase of surface runoff was reduced by an average of 2.3 times, and with precision irrigation technology – by 3.7 times.

Table 2.

Removal of nutrients from the soil on average during irrigation

Years	**Option**	**Irrigation rate, m^3/ha**	**Removal of nutrients from the soil, kg/ha**		
			NO_3	**P_2O_5**	**K_2O**
2022	1- standard	480	0,404	0,090	0,206
	2- adjusting the watering rate		0,169	0,038	0,084
	3- precision watering		0,103	0,023	0,053
2023	1- standard	490	0,423	0,095	0,216
	2- adjusting the watering rate		0,188	0,042	0,096
	3- precision watering		0,113	0,025	0,058
2024	1- standard	410	0,333	0,077	0,168
	2- adjusting the watering rate		0,143	0,033	0,072
	3- precision watering		0,086	0,020	0,043

Experimental studies have confirmed the ecological effectiveness of the proposed technical and technological solutions, the use of which makes it possible to prevent the removal of nutrients and a decrease in fertility in general.

Precise irrigation makes it possible to reduce resource costs. Fields characterized by significant spatial variability of properties benefit more from the use of a precision irrigation system.

The research was funded by the Russian Science Foundation (project No. 25-26-00132).

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DOI 10.34660/INF.2025.81.54.051

提高发电厂和移动能源设施环境安全的协同方法
A SYNERGETIC METHOD FOR IMPROVING THE ENVIRONMENTAL SAFETY OF POWER PLANTS AND MOBILE ENERGY FACILITIES

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摘要。现代内燃机 (ICE) 的历史就是在封闭空间内优化燃料-空气混合物 (FAM) 燃烧过程的历史。同时，这种过程的环境安全性目前是一个关键方面，需要采取综合方法来研究和实施创新技术和技术解决方案，包括在俄罗斯联邦的农业部门，拥有大量移动能源汽车 (MEV)，内燃机是其主要动力装置 (MPP)。改善 MPP EPU 的环境安全性是一项紧迫而多方面的任务，其背景是需要解决减少人类对环境负面影响的问题。在本文中，我们描述了一种改善 MPP EPU 环境安全性的方法，该方法基于通过对其成分进行初步燃烧准备来增加 FA 的能量潜力：对大气空气进行臭氧化，同时对液态烃燃料进行磁化。该方法的实际实施是通过操作两个技术装置进行的：臭氧发生器和磁化器，其基础是自组织原理。磁化和电离的结合使用产生的协同效应值得特别关注。初步实验表明，这种方法可以产生超过每种方法结果简单相加的效果。进一步的研究应侧重于对该方法的理论评估，以优化基于这些技术的系统的运行模式。

从实际应用的角度来看，引入磁化和电离技术可以对俄罗斯经济农业部门使用 MES 的效率产生积极影响。特别是，提高燃料组件的燃烧效率可以降低燃料消耗，一方面可以降低运营成本，另一方面可以减少有害物质的排放，从而有助于解决全球努力应对环境安全背景下的至关重要的问题。

关键词：发动机、环境安全、燃料-空气混合物、臭氧化、磁化、燃料、空气、臭氧。

Abstract. *The history of the modern internal combustion engine (ICE) is the history of optimizing the process of combustion of the fuel-air mixture (FAM) in a closed space. At the same time, the environmental safety of such a process is currently a key aspect that requires an integrated approach to the study and implementation of innovative technological and technical solutions, including in the agricultural sector of the Russian Federation with a huge number of mobile energy vehicles (MEV), for which the ICE is the main power plant (MPP). Improving the environmental safety of the MPP EPU is an urgent and multifaceted task that arises in the context of the need to solve the problem of reducing the negative impact of humans on the environment. In this article, we describe a method for improving the environmental safety of the MPP EPU based on increasing the energy potential of the FA by preliminary preparation for combustion of its components: ozonization of atmospheric air with simultaneous magnetization of liquid hydrocarbon fuel. The practical implementation of this method is carried out through the operation of two technical devices: an ozonizer and a magnetizer, the basis of which is the principle of self-organization. The phenomenon of synergy arising from the combined use of magnetization and ionization deserves special attention. Preliminary experiments show that this approach can lead to effects exceeding the simple sum of the results of each of them. Further research should focus on the theoretical evaluation of the method in order to optimize the operating modes of systems based on these technologies.*

From the point of view of practical application, the introduction of magnetization and ionization technologies can have a positive effect on the efficiency of using MES in the agricultural sector of the Russian economy. In particular, increasing the efficiency of combustion of fuel assemblies can lead to a decrease in fuel consumption, which, on the one hand, will reduce operating costs, and on the other hand, will reduce emissions of harmful substances, thereby facilitating the solution of critically important issues in the context of global efforts to combat environmental safety.

Keywords: *engine, environmental safety, fuel-air mixture, ozonation, magnetization, fuel, air, ozone.*

Introduction. Environmental safety (ES) according to the Federal Law "On Environmental Protection" dated 10.01.2002 N 7-FZ (as amended on 08.08.2024) (as amended and supplemented, entered into force on 01.09.2024) is a multifaceted concept covering the state of protection of the environment and vital human interests from the negative impact of both natural and anthropogenic factors. It includes a wide range of measures aimed at assessing possible hazards, the necessary protection of ecological systems in order to preserve them for future generations. As for the ES of agricultural tractors and self-propelled machines, here, from our

point of view, the following definition can be considered the most correct: ES MES is a set of measures aimed at maintaining an acceptable level of negative impact of MES on the environment and humans. As is known, the acceptable level of negative impact of MES on the environment is determined by various regulations and standards that govern the emissions of pollutants and the physical impact on nature [8]. These standards may include:

- emissions of pollutants: the values of maximum permissible concentrations (MPC) are determined for various substances potentially released into the environment.

- noise fields: noise levels are established that are permissible during operation of tractors, cars and other equipment and have a minimal impact on human health and the ecological system.

- force (electromagnetic) fields: standards are provided for various fields, including electromagnetic radiation, in order to protect both service personnel and the biosphere.

The ES of the ESU MES is determined primarily by the characteristics of the toxicity of harmful substances (HS) emissions in the exhaust gases (EG) of the engine, the composition of which depends on the quality of the combustion process of the fuel assembly.

The feasibility and relevance of conducting scientific research in the direction of increasing the ES of piston ICEs by treating fuel and air with magnetic and electric fields is confirmed by a huge number of patents, scientific articles, dissertations on this topic [1,4,5,7,8]. However, it is worth noting that the data on the effects of this type of fuel assembly preparation remain controversial, and additional studies are needed for a more accurate assessment. The scientific community has not yet reached a consensus on the reality and scale of these effects, as well as the practical feasibility of their use.

Materials and methods of research. Scientific research in the field of fuel-air mixture combustion using fuel magnetization with simultaneous air ionization is becoming increasingly attractive in order to achieve high energy efficiency and minimize harm to the environment from internal combustion engines. The aggravation of environmental problems associated with emissions into the atmosphere of such compounds as carbon dioxide (CO2) and nitrogen oxides (NOx), the requirement for increasingly stringent standards for the content of harmful substances in gases emitted by the ESU MES, make this area of research not only relevant, but also necessary. Magnetization of liquid hydrocarbon fuel is of interest as an area of scientific research due to its ability to change the physicochemical properties of liquid hydrocarbon fuel [6,9,14]. The use of magnetic fields acting on the fuel can affect its molecular structure, increasing, for example, its ability to atomize and improving combustion parameters. Improved atomization results in

more uniform mixing of fuel and air, thereby ensuring more complete combustion and reducing the amount of unburned hydrocarbons, which in turn leads to a decrease in explosives.

Air ionization, being the second key aspect of the direction under consideration, also has a significant impact on combustion processes. Ionized air molecules can interact with fuel, contributing to the acceleration of chemical reactions during combustion [10 - 13]. This can be achieved through several methods, such as high-voltage discharges or the use of ionizing radiation, which can increase the density and activity of ions in the combustion chamber. As a result, an increase in the concentration of ionized particles leads to a higher energy level in the system, which significantly improves combustion efficiency.

The basis of our proposed method for increasing the ES of the ESU MES is the synergy between fuel magnetization and air ionization. The proposed hypothesis of the study is that when both processes are used in combination, they can enhance each other, building the basis for the most complete and "harmless" combustion of liquid hydrocarbons. Therefore, it is possible to optimize the combustion process of fuel assembly components, which will significantly contribute to a fairly noticeable reduction in nitrogen oxide emissions.

As is known, any motor fuel produced from petroleum feedstock, be it gasoline or diesel fuel, consists of a huge number of hydrocarbon chains, each of which has its own length.

Short hydrocarbon chains are light fractions of fuel and their characteristic feature is a low boiling (evaporation) temperature. Hydrocarbon groups with long chains (heavy fuel fractions) have a higher boiling (evaporation) temperature compared to the previous one. But in both cases, hydrocarbon chains are a compound of molecules. These molecules consist of many atoms, which, in turn, consist of nuclei and electrons. Thus, it is quite obvious that there are both positive and negative electric charges in molecules.

If we consider the combustion of fuel-air mixture in the cylinder of a piston engine, or more precisely in the combustion chamber, we can state the following: lighter fractions evaporate during the compression and combustion strokes almost completely, and heavy ones partially remain in the form of microdroplets. Subsequently, moving either to the exhaust gas removal system or to the engine crankcase, these fuel residues reduce the engine's ES, constantly worsen the quality of engine oil.

The method of fuel-air mixture preparation proposed by us, developed on the methodological principles of synergetics, taking into account the actual consideration of the structure and process of using fuel-air mixture and its state arising from the coherent behavior of a large number of particles included in this structure, using the thermodynamic approach, allows us to obtain an effect aimed at eliminating the above disadvantages.

The process of combined use of magnetized fuel and ionized air is associated with a more complete use of the energy of liquid hydrocarbons; reduction of explosives, which is achieved, firstly, as a result of the presence of a certain reserve of oxygen due to the decomposed ozone during the afterburning of heavy fractions; secondly, due to the combustion of fuel-air mixture components in the wall environment of the internal combustion engine cylinders, and, thirdly, due to the limited consumption of oxidizer at the beginning of the combustion cycle, which allows to reduce the maximum combustion temperature and, as a consequence, to reduce the volume of nitrogen subjected to oxidation, which begins at temperatures above 13000C.

The development of the method for increasing the ES of the ESU MES at the Department of Tractors and Automobiles of Lugansk State Agrarian University was started more than 10 years ago and was initially carried out in two directions, which proceeded independently of each other: the effect of electromagnetic fields on liquid hydrocarbon fuels and ozonation of the fuel-air mixture [2,3]. It was in the process of these scientific studies that a conclusion was made about the possibility of coordinating the operation of the fuel magnetizer and air ionizer during engine operation, which is an important aspect for increasing the efficiency of fuel combustion and reducing explosive emissions. The fuel magnetizer (hollow solenoid) affects the fuel by means of an electromagnetic field and changes its atomic structure. As is known, electron polarization is characterized by the fact that electrons, being in orbits, are shifted in the direction opposite to the direction of the field. As a result of the shift, an electric dipole moment arises, the value of which is determined by the product of the charge and the value of the shift. Such a phenomenon can contribute to the fragmentation of matter at the molecular or atomic level. This allows achieving almost complete combustion of fuel, which in turn leads to a decrease in its consumption and a decrease in emissions of explosives in the exhaust gases.

In order to study the effect of the electromagnetic field on liquid hydrocarbons, the authors created an experimental setup based on the laboratory for testing automotive and tractor engines of the Department of Tractors and Automobiles of the Federal State Budgetary Educational Institution of Higher Education Lugansk State Agrarian University (Figure 1).

An electromagnetic fuel activator, which is a hollow solenoid (6), is installed directly in front of the fuel injector of the D-65M diesel engine (5) in order to use magnetized fuel as soon as possible after activation. The control and measuring kit consisted of a digital power indicator IMD-Ts (1), an automatic fuel flow meter “AIR-50” (2), a magnetic pulse modulator (4). The META-01 MP 0.1 smoke meter was used to determine the smoke content of the exhaust gases.

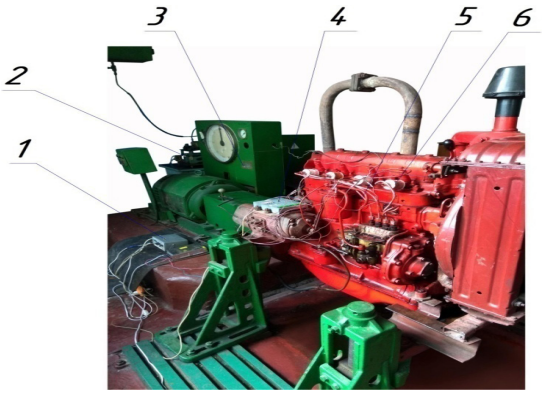

Figure 1. *General view of the laboratory setup based on the D-65M diesel engine:*
1 – digital power indicator IMD-Ts; 2 – automatic fuel flow meter "AIR-50";
3 – brake stand KI-1363 B; 4 – magnetic pulse modulator;
5 – diesel engine D-65M; 6 – solenoid

The use of devices for air ionization in agriculture has found quite wide application [15].

In our case, the ionizer, acting on the air entering the cylinders of the internal combustion engine, practically leads to the process of ozonolysis, the result of which is an increase in the concentration of oxygen-containing radicals and the activation of a number of series-parallel chain reactions.

The ionizer proposed as a device for preparing the air component of the fuel assembly for combustion is combined with a modernized engine air filter and is a barrier-type air ozonizer (Figure 2).

The ozonizer operates as follows. The sucked-in atmospheric air, passing through the air duct 2, the lower chamber of the air filter housing 1, through the filter element 3, the upper chamber of the air filter housing 4, enters the barrier ozonizer 7. As a result of the ionization process, the ozone-air mixture is directed through the outlet air duct 5 to the engine intake manifold.

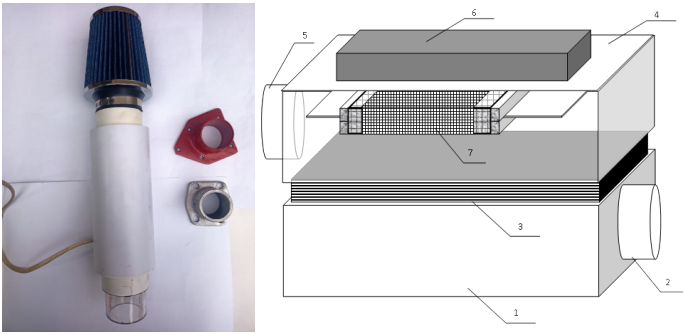

Figure 2. *Ozone generator for internal combustion engines: 1 – lower chamber of the air filter housing; 2 – supply air duct; 3 – filter element; 4 – upper chamber of the air filter housing; 5 – exhaust air duct; 6 – power supply; 7 – barrier ozonizer*

When these devices operate together, a synergistic effect can be achieved: magnetized fuel and ionized air create optimal conditions for combustion, which leads to an increase in engine power and a decrease in its toxicity. However, to achieve maximum efficiency, it is necessary to coordinate the operating parameters of the devices described above.

Research results and their discussion.

The rupture of hydrocarbon chains of motor fuels is possible with electron polarization under the influence of external electromagnetic fields. The effect of such electromagnetism is the creation of a moment caused by the movement of external electrons of the hydrocarbon chain, which transfers electrons to states with a higher main quantum number. This state effectively destroys permanent valence electrons that participate in the process of formation of compounds in fuel mixtures. Under the influence of the electromagnetic field, the hydrocarbon molecules in the fuel are ionized and rearranged, with subsequent rupture of the hydrocarbon chains and their declustering. This will subsequently lead to an active interaction between the fuel and oxygen molecules due to the fact that the diamagnetic ion exposed to electromagnetism exhibits positive ionization, which in turn helps the hydrocarbons to attract negatively charged oxygen and bind to it. Hydrogen exists in two different forms - orthohydrogen and parahydrogen. The ortho- and para-variants of hydrogen differ in the relative orientation of the nuclear spins of the two protons. In the para state, the spin of the protons is antiparallel, while in the orthomolecule the spin is parallel. This orientation of the spins has a noticeable effect on the behavior of the molecule. It has been established that orthohydrogen is unstable and more reactive than its para state. Fuel molecules are usually in a parastate with opposite spins, are attracted to each other, forming clusters.

Thus, weakening the bonds between fuel molecules contributes to the formation of a greater number of bonds with oxygen molecules, the necessary and sufficient amount of air entering the internal combustion engine.

A series of exploratory experiments performed by the authors of the article on a VAZ-21083 engine with a distributed fuel injection system (Figure 3) confirmed that the method of preparing the fuel assembly for combustion proposed by us significantly improves the process of fuel atomization during injection into the engine combustion chamber and, as a result, the specific fuel consumption and the amount of explosives are reduced.

Figure 3. *Internal combustion engine with magnetizing device and ozone generator:*
1 – engine; 2 – magnetizing device; 3 – ozone generator

Conclusions. The combined effect of electromagnetic fields on the liquid-hydrocarbon part of the fuel assembly in combination with air ionization is a promising area of scientific research, the results of which will solve the problem of full use of the thermal potential of liquid hydrocarbon fuel and reduce the anthropogenic load on the environment. As a result of the conducted research, several key results and directions for further development can be identified.

The initial results show that the use of magnetic fields for magnetizing liquid hydrocarbons significantly improves their physical and chemical properties. Magnetization leads to a decrease in the size of fuel droplets, which, in turn, contributes to more uniform atomization. Improved atomization provides more efficient mixing with air, which has a positive effect on combustion processes. This is of particular importance for the MES power supply systems, which often operate on low-quality fuel, where uniform combustion is a critical aspect for achieving high power and efficiency.

From the point of view of practical application, the introduction of magnetization and ionization technologies can have a positive impact on the efficiency of MES use in the agricultural sector of the Russian economy. In particular, such an increase in combustion efficiency can lead to a decrease in fuel consumption, which, on the one hand, will reduce operating costs, and on the other hand, will reduce emissions of explosives, which is a critical point in light of global efforts to combat climate change.

In addition, magnetization and ionization technologies can be integrated into stationary power plants. The use of these methods in thermal power plants, boilers, generators can lead to a significant increase in the overall efficiency of fuel conversion into energy, which will also eventually lead to a decrease in explosives into the atmosphere. It is necessary to continue studying the long-term effects of these technologies on engine performance and their impact on the environment, using computer modeling to analyze thermodynamic processes in the combustion chamber of the internal combustion engine. Such studies allow us to predict changes in combustion dynamics and evaluate the effectiveness of the combined operation of technologies with minimal economic costs. It is important to explore the possibility of integrating modern approaches to combustion process control based on artificial intelligence, which can significantly improve the accuracy and efficiency of regulating the operating parameters of engines using magnetized fuel and ionized air. As a result of the studies, certain results were obtained and a number of scientific papers were published. Thus, it can be stated that the electromagnetic field affects the smoke of the exhaust gases of a naturally aspirated diesel engine. With an increase in magnetic exposure, the smoke increases: without a magnetizer, the smoke was 15%, with the use of this device - from 15.7 to 16%. After removing the magnetizer from the fuel line, the smoke readings returned to 14.2%. This effect can be explained by the lack of oxidizer during combustion of liquid hydrocarbons contained in the fuel assembly. The use of ozone in the cylinders of the internal combustion engine as a catalyst for the combustion reaction accelerates it by 1.5 times, which is sufficient to use the existing fuel potential. A series of exploratory experiments confirmed the hypothesis that the combined magnetization and ozonation of the fuel assembly components leads to an effect significantly exceeding the result of each of them. It should be noted that further studies aimed at obtaining optimal parameters for the combined operation of magnetization and ionization systems can only be carried out with a high-quality theoretical justification for the proposed method. In general, despite the existence of individual successful studies, the topic of the combined use of the synergetic method for increasing the ES of the ESU MES remains the subject of active study. Additional experiments and especially theoretical justification are needed for a wider implementation of these technologies in the country’s economy. In

conclusion, it should be noted that in order to achieve maximum efficiency and sustainable use of air magnetization and ionization technologies, further scientific experiments and studies are necessary. It is recommended to develop cooperation between scientific institutions and industry for practical testing of developed technologies in real conditions. It is also relevant to create a regulatory framework for the implementation of these methods, including their certification and safety assessment.

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DOI 10.34660/INF.2025.52.44.052

开发利用铁路区段数字孪生和列车交通神经网络控制的概念
DEVELOPMENT OF THE CONCEPT OF USING DIGITAL TWINS OF RAILWAY SECTIONS AND NEURAL NETWORK CONTROL OF TRAIN TRAFFIC

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注释。本文考虑了通过列车交通的神经网络控制来改善铁路区段运输过程管理的问题，使用基于数字孪生建立的区段活动数学模型。本文分析了研究领域的方法和国内外经验以及运输管理技术。铁路区段的数字孪生是在教育和实验室综合体“虚拟铁路”的基础上实现的，介绍了一种积累列车交通数据库的方法，并分析了其用于列车交通控制的人工神经网络（ANN）的实施情况。本文提供了在港口铁路区段实施列车交通神经网络控制的计算实验结果，以及对 ANN 生成的列车时刻表与标准列车时刻表的比较分析。

关键词：数字孪生、神经网络控制、列车运动、虚拟铁路、列车时刻表。

Annotation. *The article considers the issues of improving the management of the transportation process on a railway section through neural network control of train traffic, using mathematical models of the section's activity built on the basis of its digital twin. The article provides an analysis of the methodological and domestic and foreign experience in the area under study, and transportation management technologies. The digital twin of the railway section is implemented on the basis of the educational and laboratory complex "Virtual Railway", a methodology for accumulating a database on train traffic, its analysis for the implementation of an artificial neural network (ANN) for train traffic control is presented. The article provides the results of a computational experiment in terms of implementing neural network control of train traffic on a section of a port railway, a comparative analysis of train schedules generated by the ANN with the standard train schedule.*

Keywords: *digital twin, neural network control, train movement, virtual railway, train schedule.*

Modern concepts of production, technological and transport process management are based on the use of accumulated database and knowledge about effective trajectories of their implementation, the use of advanced experience and competencies to search for and implement creative solutions based on digital technologies. Rail transport is one of the most advanced types of transport for the implementation of intelligent digital solutions in the national transport system, which is taking active steps to search for and implement intelligent transportation management.

The relevance of intensifying the development of artificial intelligence, defined in the National Strategy for the Development of Artificial Intelligence in Russia for the Period up to 2030 and in the management of transportation in rail transport is determined by a number of factors, including:

– exhaustion of reserves of throughput and carrying capacity on freight-intensive sections and directions, including approaches to port stations,

– the need to ensure the competitiveness of the national economy in the global division of labor by reducing transport and logistics costs;

– the complexity of managing the transportation process in the conditions of multi-agency, multi-criticality and the influence of a large number of external and internal factors, caused by the former;

– the need to use unmanned and (or) sparsely manned control technologies that reduce the influence of the human factor on decision-making in the context of the growth of cognitive connections in the transportation process;

– a high load on the transport infrastructure due to the abandonment of freight trains, which reduce maneuverability at stations and complicate the organization of train operations on railway sections;

– the need for a phased implementation of digital technologies in railway transport, as defined by strategic program documents for railway transport, and others.

Modern research on the implementation of artificial neural networks (ANN) in the systems for managing the transportation process of railway transport is related to various areas of their application. Most of them are focused on the use of ANN in the tasks of technical maintenance of rolling stock, in this study the range of tasks is related to the implementation of neural networks for managing the transportation process of a railway section and stations. Let us dwell on a number of foreign studies related to the use of neural networks for managing technological processes in the railway industry (Table 1).

Table 1

Foreign experience of using INS in control systems of the transportation process of railway transport

No.	Tasks	Solutions
1	**2**	**3**
Rescheduling Strategy		
1	Estimating delays in the railway network [1]	Delay prediction mainly focuses on predicting delays for each train at subsequent stations: a neural network approach on heterogeneous graphs
2	Predicting delays using train operation and weather data based on train simulation [2]	A train delay prediction model (FCLL-Net) is developed that combines a fully connected neural network (FCNN) and two long short-term memory (LSTM) components to account for operational interactions. The performance of FCLL-Net is tested using data from two high-speed rail lines in China.
Development of high-speed railways		
3	A Review of Artificial Intelligence Applications in High-Speed Rail Systems [3]	An overview of the most advanced artificial intelligence technologies and applications in three major HSR application areas: mechanical manufacturing and electrical control, communication and signaling control, and high-speed rail control
4	Development of hybrid models for passenger flow forecasting on intercity high-speed railways [4]	Three hybrid models for predicting passenger flows on intercity high-speed railways based on neural networks are developed and compared
Bandwidth		
5	Creating a model for scheduling train services based on passenger preferences, taking into account operating costs and capacity constraints [5]	During the planning stage, passenger operators develop schedules to service passenger trips and a train plan to support these schedules. An optimization model is developed that minimizes passenger travel costs within the limited budget available to cover operating costs.
Digital twins		
6.7	Overview of digital twin (DTS) concepts for improving product quality and optimizing production processes in rail transport: preliminary recommendations and reference architecture [6,7]	Implementation of digital twins in the railway sector with a focus on the role of artificial intelligence (AI) technologies as key enablers of value-added services and intelligent decision-making applications

Statement of the problem. The aim of the study is to create automated control systems for railway transportation based on the development of neural network control of train traffic, using mathematical models of the section's activity, built on the basis of its digital twin, aimed at studying the mechanisms for increasing the capacity of a railway section.

When developing measures to increase the capacity of railway sections and directions, it is necessary to take into account that the management of railway infrastructure and the transportation process at the present stage is of the nature of "management by condition" due to the following reasons:

- the infrastructure and reserves used in transport cannot be technically strengthened in a short period of time due to their high capital intensity and, naturally, the inclusion of their cost in the cost of transport services, which should be reduced;

- seasonal and episodic external factors introduce sufficient disturbances into the system of planning and standardization of the transportation process, which predetermines the high importance of operational management decisions;

- the system-forming nature of rail transport for the domestic transport system and economy has led today to high occupancy rates on the main routes, and fluctuations in traffic volumes on these sections lead to significant losses for the company JSC Russian Railways in the form of operating costs, claims for late delivery of empty and freight shipments;

- significant changes in the structure of freight flows (volume and directions) lead to the formation of freight-intensive areas that require high competencies of the company's operational management (dispatching personnel) in managing and regulating the transportation process.

Theoretical part. At Russian Railways, the development of digital technologies is provided for by the scientific and technical project "Digital Railway". Within the framework of this project, a number of innovative developments are being carried out concerning the most relevant areas: Internet of Things technologies, big data, intelligent systems, as well as modern data transmission networks. Within the framework of the "Digital Railway" program, artificial intelligence technologies are being actively introduced, among which the following should be highlighted: intelligent traffic control; neural network-based object recognition; intelligent logistics systems; predictive analytics systems; unmanned vehicles.

Artificial neural networks (ANN) are models built similarly to natural neural networks of the brain. The main characteristic feature of ANN is the ability to self-learn. The neuron model, like its biological analogue, has several inputs and outputs. Each neuron input has a weight. The weight acts as an input synaptic resistor. To calculate whether the neuron will produce an output signal, it is first necessary to calculate the sum of the products between each input and the synaptic weight of the input. Then the result is fed to the activation function. The use of a

particular ANN architecture depends on a specific practical task. Neural networks are constantly being improved. At the same time, their accuracy is growing. If several years ago the results of neural networks often gave unsatisfactory results, now they sometimes surpass the results of classical algorithms. At the same time, the complexity of neural networks is also growing - the number of layers is growing, the architecture is becoming more complex. Neural networks require large amounts of data for training and analysis, and therefore, large computing power.

A digital twin (DT) is an accurate model of a physical object that is maintained in working order during execution and updated with data collected from monitoring devices in real time. In terms of creating a model of the operation of a railway section, a digital twin is a dynamic and self-evolving virtual copy of physical objects and processes, characterized by bidirectional, seamless communication that allows for real-time data exchange between the physical and digital worlds. Using DT technology, several services can be implemented (e.g., modeling, monitoring, forecasting).

Practical significance, proposals and results of implementation, results of experimental studies. The object of the study is a real section from the Vysochino port railway station to the Timashevskaya station of the North Caucasian Railway. The digital twin of this section is a complex of training and laboratory simulators, as well as additional auxiliary software products, which are connected to each other via a local area network.

The following system components are implemented:

1. Simulation model of the train:
   – educational and laboratory training complexes of rolling stock (ULTC), such as: high-speed electric train EVS2 “Sapsan” with additional information output of the operation of internal systems in real time during its operation, electric train ES1 “Lastochka”, electric locomotive ChS2T, diesel locomotive 2TE116;
   – universal software simulator for a driver (Universal automated workstation for a driver);
   – model for simulating the movement of a train (Train-Boat);
2. Server for controlling bot trains (models simulating the movement of rolling stock);
3. Business game management interface (formation of training (business game) – selection of business game scenario and participants: trains controlled by humans and bots);
4. The DNC/DSP training complex, implementing the work places of station attendants and train dispatchers (Fig. 1).

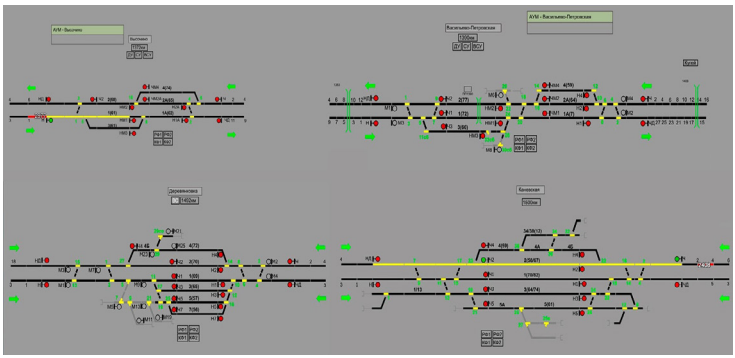

Figure 1. *Train dispatcher control panel interface*

5. An energy dispatcher simulator that simulates an energy dispatcher's workplace, as well as a model of the power supply infrastructure of a railway section;
6. A database that stores the topological structure of a section, its infrastructure, as well as information about bot trains;
7. standard traffic schedule, schedule of completed traffic;
8. virtual railway server (VRS), which implements:

– construction of the topology of a railway section;
– creation of an electrical diagram of a railway section;
– communication module with a simulation model of a train;
– train Simulation Model Controller Simulator;
– algorithm for searching possible routes through the station;
– communication module with the DNC control panel and the DSP control panel;
– communication module with the Energy Dispatcher's automated workstation;
– calculation of voltage on sections of the electrical circuit of a railway section;
– signaling, centralization and blocking devices (SCB).

The formation of data on the state of the railway station is carried out by logging each infrastructure object that has changed its state or the action of the train dispatcher or station duty officer. Each object has its own states and unique designations for its identification throughout the entire polygon. Logging occurs in real time during the business game. The implementation of neural network control should facilitate the work of the dispatcher's apparatus and delegate some of the functions for making decisions on the passage of trains to the neural network. From a practical point of view, it is very important that the neural network control

is optimal in relation to the specified quality functionality. At the same time, the neural network must provide control taking into account dynamic constraints in real time, the parameters of which are unknown.

The methodology for conducting the computational experiment consists of controlling the movement of trains on a real section of the railway within the framework of the educational and laboratory complex "Virtual Railway" (VR) of the university. The solution to such a problem will be based on the information that the neural network model receives from the VZhD complex system.

For the schedule of executed movement obtained as a result of neural network control of the passage of trains on a railway section, an assessment of the quality of the transportation process is made. Let us give an example of analysis for the executed train schedule (Fig. 2), obtained as a result of neural network control of the passage of trains on a section.

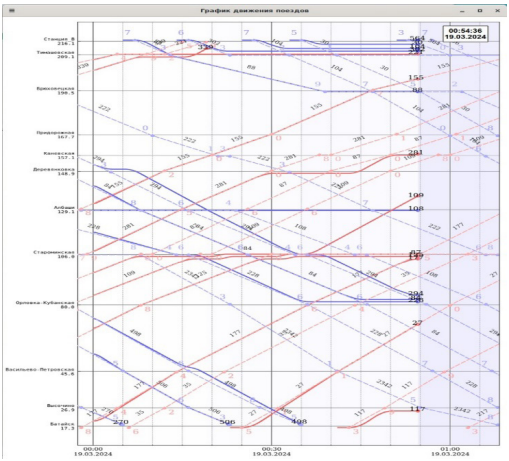

Figure 2. *Fragment of the executed schedule of movement with neural network control of the passage of trains on the section*

In this study, 1070 completed traffic schedules were collected and analyzed using neural network control of train passage, taking into account the data of the digital twin of the railway section. The analysis of completed traffic schedules with neural network control showed that the model needs to be improved and trained to make decisions on train passage. Considering third-party experience in creating similar networks, this development currently shows quite good results.

Conclusions. The concept of using a digital twin of a railway section to study the problems of developing artificial intelligence technologies has proven its effectiveness, and in terms of analyzing the parameters of train passage along a

railway section, an experimental platform has been created that allows for each train to track the speed characteristics of passage along the section under manual and neural network control.

The publication was carried out within the framework of the implementation of a grant from JSC Russian Railways for the development of scientific and pedagogical schools in the field of railway transport.

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DOI 10.34660/INF.2025.21.12.053

选择并论证酸液成分的物理化学参数（溶解度），以提高地层井下区域处理技术的效率

SELECTION AND JUSTIFICATION OF THE PHYSICO-CHEMICAL PARAMETER (SOLUBILITY) OF ACID COMPOSITIONS TO INCREASE THE EFFICIENCY OF PROCESSING TECHNOLOGIES FOR DOWNHOLE ZONES OF FORMATIONS

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摘要。本分析工作基于分析酸组分的物理化学参数（溶解度）对碳酸盐岩和陆源储层井筒区酸处理效率的影响，该技术适用于强化生产和注入井技术。

关键词：物理化学参数、溶解度、反应动力学、酸组分、地层井筒区处理、碳酸盐岩和陆源储层。

Abstract. *This analytical work is based on the analysis of the influence of the physicochemical parameter (solubility) of acid compositions on the efficiency of acid treatments of the wellbore zones of carbonate and terrigenous reservoirs in the technologies of intensification of production and injection wells.*

Keywords: *physicochemical parameters, solubility, reaction kinetics, acid composition, treatment of the wellbore zone of the formation, carbonate and terrigenous reservoirs.*

The factors determining the efficiency of acid treatments of the wellbore zones (TWZ) of carbonate and terrigenous reservoirs are the technologies of their im-

plementation and the compliance of acid compositions (AC) with a number of requirements, including both the general characteristics of AC and the possibility of their use for intensification of the operation of specific production or injection wells.

To improve the efficiency of acid TWZ of carbonate and terrigenous reservoirs, a methodical approach to the selection of AC is required, which should include parameters characterizing the uniqueness of the deposits, as well as their technogenic changes during development. Geological and physical characteristics of deposits include a general description of the composition of reservoir rocks and saturating fluids. It is necessary to take into account the physicochemical processes occurring in the reservoir at the boundaries of different environments: rock - formation fluids (oil, formation water, gas), oil - water (formation or injected), formation fluids - process fluids (chemical reagents injected into the formation during well construction and repair), rock - process fluids. A number of methods and determining parameters are known that are used in the development of new AC and technologies, as well as the adaptation of existing ones for specific conditions. Methods can be classified as general and special. General methods include standard techniques that determine: appearance, density, mass fraction of the main substance, interfacial tension, dissolution rate of grade St.3 steel, freezing temperature. Special techniques include: studying the interaction of the AC with the formation rock (solubility of cores or individual minerals, such as marble, quartz); interaction with formation fluids (compatibility with oil and formation water), filtration studies (on bulk models and on core samples). Let's consider such an important parameter from the point of view of acid TWZ technologies as the solubility of the rock in the AC. Carbonate and terrigenous rocks are common types of rocks, and more than half of all oil reserves worldwide are located in carbonate and terrigenous deposits. The natural diversity of carbonate and terrigenous reservoirs in terms of material composition, pore space structure and the variety of factors affecting the reduction of their permeability require an individual approach to the selection of acidizing agents for treating the near-wellbore zone (TWZ) in each specific case. Understanding the mechanisms and features of dissolution of carbonate and terrigenous rocks is of great practical importance in hydrocarbon production and injection of carbon dioxide into formations. The study of dissolution processes in carbonate and terrigenous samples is important in geology and the oil and gas industry, since it allows for a better understanding of changes in the porous structure of rocks and their impact on permeability. Low permeability of reservoirs of any type has always imposed serious restrictions on acid treatments carried out in them, requiring the use of special slow-acting acidizing agents, most of which contain an insignificant amount of strong acid or various weak acids that slowly react with the rock per unit of time. In the case of a highly permeable

reservoir, such slow AC may simply be ineffective due to the low acid capacity of the AC used.

Thus, determining the solubility of a core sample in a AC is necessary for carrying out matrix and selective TWZ of carbonate reservoirs, and determining the solubility of a quartz glass sample (TU 9464-012-52876859-2014, SP-7102) in a AC is necessary for carrying out BPT of terrigenous reservoirs, since the obtained values of this parameter allow us to select precisely those AC that will help ensure the greatest efficiency of acid treatments at specific wells of certain development sites. The technical result of determining this parameter is to establish the degree of interaction of the AC with the pore space of the reservoir rock, as well as to effectively affect the near-wellbore zone of the productive formation and avoid the negative impact of side factors, such as formation colmatation by the products of interaction of the AC with the rock, etc.

Qualitative determination of solubility is an integral part of the complex process of studying the properties of the AC, allowing to determine their comparative efficiency and select the optimal compositions, thereby increasing the efficiency of acid treatment as a method of intensifying oil production.

There is no generally accepted method for studying the reactivity of the AC with carbonate and terrigenous rock. This state of affairs is due to the variety of factors, various combinations of which reduce the reproducibility of experiments. For example, the following approaches are used:

- gravimetric method;
- method using marble cubes;
- rotating disk method;
- gas evolution kinetics method. Usually, the processing of research results is carried out in accordance with the assumption that the kinetics of the reaction of the AC with carbonate and terrigenous rock obeys the basic laws of topochemical processes. The most accurate method for measuring the kinetics of the reaction of the AC with the rock of the oil reservoir is the rotating disk method, especially when using gel-like or emulsified AC. In an apparatus with a rotating disk, a disk of mineral is placed in a large container containing a AC solution. Rotation is carried out in such a way that the rate of transfer of the AC is higher compared to the reaction rate on the surface. The use of a rotating disk for studying the dissolution of carbonate and terrigenous reservoir rocks in AC is fundamentally different from its use in electrochemistry, where the reacting area remains constant. As an example, a basic test of the AC was carried out, the results of which are presented in Figure 1 (the accumulated amount of calcium over time for a core sample with AC) and in Figure 2 (the actual dependence of the reaction rate on the square root of the angular velocity of rotation of the disk for a core with AC).

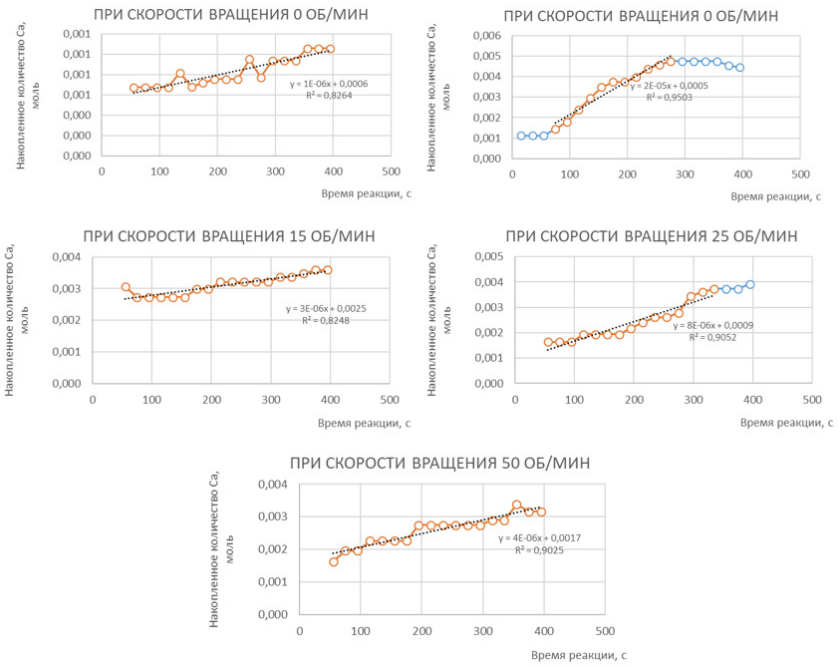

Figure 1. *Accumulated amount of calcium over time for a core sample with AC*

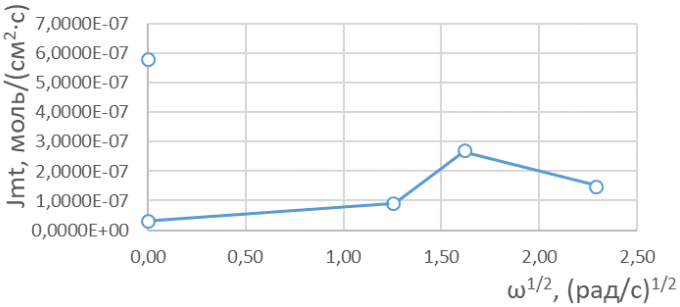

Figure 2. *Actual dependence of the reaction rate on the square root of the angular velocity of the disk rotation for a core with a AC*

However, this method has a number of disadvantages associated with the high cost of manufacturing and servicing equipment, the cost of conducting research, along with the need to conduct a large number of studies to minimize the error.

Determining the reaction rate of AC with carbonate and terrigenous rocks by measuring the gas evolution rate is characterized by simplicity, high representativeness of the research results, the absence of expensive equipment, a simple process of preparing core samples and conducting research, the ability to conduct a large number of experiments in a short period of time, thereby reducing the error of the studies. The formation of a gas phase at high temperatures leads to a significant increase in the measurement error. Crystallization of AC with the formation of ice at low temperatures leads to a significant decrease in the rate of reagent supply to the reaction surface and a drop in the overall reaction rate until it stops completely. Repeated experiments are carried out in order to minimize the error in gas evolution caused by non-stationary periods of the reaction. For example, a basic experiment was conducted, the results of which were used to obtain a kinetic curve of CO_2 release and the resulting reaction rate constant for the AC (in Figure No. 3). The results are presented as a dependence of the amount of released CO_2 on the reaction time.

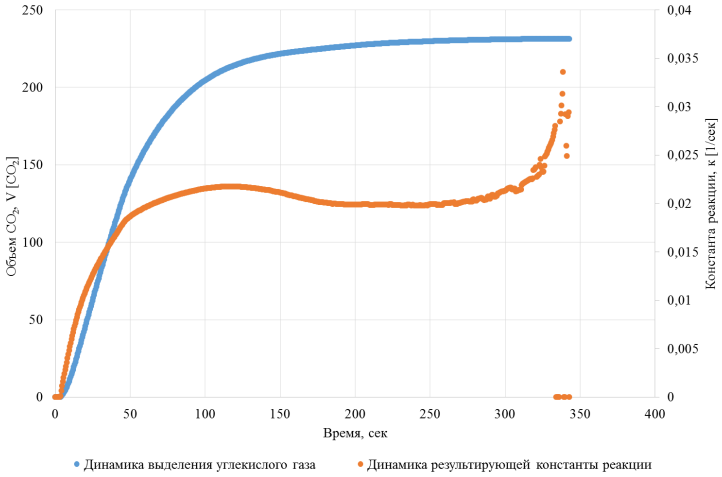

Figure 3. *Dynamics of gas evolution kinetics and calculated equilibrium constant based on the results of AC studies on a core sample saturated with oil at 25 °C*

There is also a gravimetric method of analysis in static mode. This method is used to compare the reactivity of AC solutions. In this method, the loss in mass of the core/quartz glass sample is recorded during a chemical reaction due to the dissolution of the core/quartz glass sample in the AC. Based on the results, dependencies of the loss in mass of the core/quartz glass sample on the processing time

are constructed. The decrease in mass due to the dissolution of the core/quartz glass sample in the AC shows what percentage of rock has dissolved over a certain period of time. The advantages of this method include: high accuracy compared to volumetric methods – the absolute error of determination is from 0.01% to 0.02%; the absence of any standardizations or calibrations according to standard samples required in any other analytical method; simplicity (the method does not require complex equipment and special knowledge); availability (the analysis can be carried out in almost any chemical laboratory). The disadvantages of this method include, in some cases, significant labor intensity and low sensitivity (it is difficult to determine a small amount of core sample).

The conducted analysis of the distribution of minerals in the samples of the Kynovskiy and Pashiyskiy horizons showed a high content of quartz, which indicates the solution to the problem of determining such a parameter as “Solubility”. Also, using the experience and data on the solubility of core samples of terrigenous reservoirs, where cases were noted not only of a minimal decrease in mass, but also its increase due to the passage of the entire list of reactions described above with the formation of sediments and the accumulation of acidic composition inside the sample, to obtain correct data, the methodology for testing the parameter “Solubility” was changed. To conduct laboratory tests to determine the solubility of a core sample in AC for matrix and selective BHP of carbonate reservoirs using the gravimetric method, cylindrical samples (2.5 cm in diameter, 0.8 cm in height) of unextracted core material of carbonate reservoir rocks with an average density of 2500 kg/m3 (± 100 kg/m3) are used. Thus, the required mass of unextracted core material of carbonate reservoir rocks for laboratory tests is 10 g. The time at which the value of this parameter is calculated is 10 minutes for core material of carbonate reservoirs (Figure 4), since the most active chemical reaction of dissolution of the core sample in AC occurs in the first 10 minutes for carbonate reservoir rocks, and then stabilization of this chemical reaction is observed.

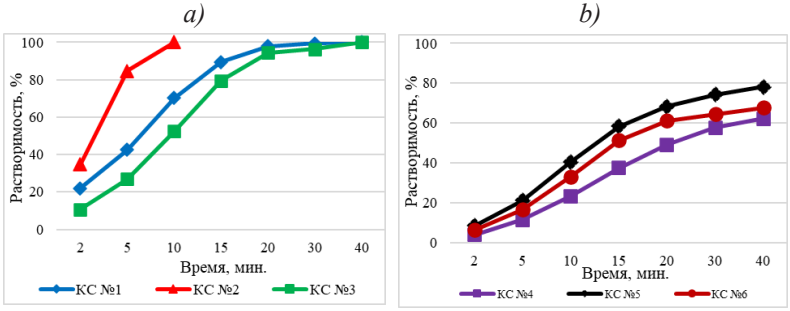

Figure 4. *Kinetics of reactions of core samples with AC for matrix and selective TWZ of carbonate reservoirs*

Figure 5 shows the distribution of AC by their limiting values of solubility of core samples.

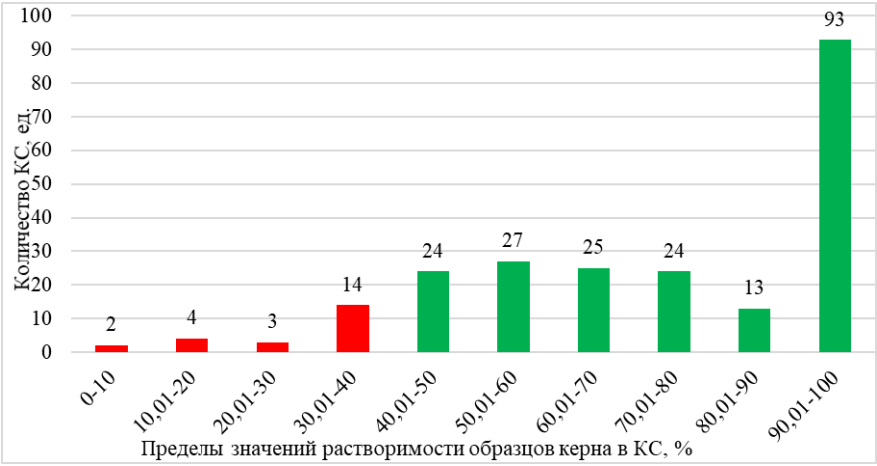

Figure 5. *Distribution of AC for matrix and selective BHP of carbonate reservoirs by their limiting values of core sample solubility*

Figure №5 shows that AC for matrix and selective TWZ of carbonate reservoirs (10.04% of the total number of AC tested) have core sample solubility values of up to 40%, and 89.96% of the total number of AC tested have core sample solubility values of more than 40%. The solubility of a core sample in AC for matrix and selective TWZ of carbonate reservoirs should be at least 40%, since, based on the data obtained from laboratory testing, at a value of less than 40% in the kinetics of AC reactions with core samples, the AC experiences a slowdown in the reaction, which is not required for AC intended for matrix and selective TWZ of carbonate reservoirs.

Conducted laboratory studies have shown that this parameter allows to increase the reliability of determining the solubility of reservoir rocks in the AC for the TWZ of carbonate and terrigenous reservoirs, to select the most optimal AC, their concentration, and dissolution time for them in order to increase the efficiency of TWZ on wells with a further increase in well productivity.

DOI 10.34660/INF.2025.31.35.054

涡流层装置中的能量效应
ENERGY EFFECTS IN DEVICES WITH A VORTEX LAYER

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摘要。本文致力于分析和研究在旋转电磁场中涡流层装置工作室内固体颗粒材料破坏的最可能机制。提出了一个假设，并论证了微弧处理粉碎物质在能量效应中的普遍性。论证基于已知的经典物理定律和现有的关于电火花破坏固体材料过程的知识。

关键词：电感器、微弧处理、研磨、铁磁针、击穿电压、帕申定律、脉冲能量、接触开口、放电通道。

Abstract. *The article is devoted to the analysis and the most probable mechanisms of destruction of solid granular materials in the working chamber of devices with a vortex layer in a rotating electromagnetic field. A hypothesis is put forward and argued about the prevalence of the process of microarc processing of crushed substances in energy effects. The argumentation is based on the known laws of classical physics and existing knowledge about the electrospark processes of destruction of solid materials.*

Keywords: *Inductor, microarc processing, grinding, ferromagnetic needles, breakdown voltage, Paschen's law, pulse energy, contact opening, discharge channel.*

In recent years, interest in devices with a vortex layer in a rotating electromagnetic field has revived in Russia [1]. The development and improvement of the specified devices is directed towards: increasing their unit capacity, developing built-in devices to improve the efficiency of bulk material processing, regulating the temperature in the working chamber, ensuring explosion-proof conditions, using abrasion-resistant and corrosion-resistant coatings of working elements and the working chamber, combining various processes in one device, as well as improving the automatic control system for the grinding process of granular materials. Publications have appeared [2] that it is possible to create grinding devices based on the specified principles with a capacity of up to several hundred tons per hour. The devices in question are finding ever greater areas of application. They

are very compact and demonstrate energy consumption 20-40% lower than traditional ball drum mills, which have been known to the world for over 130 years. The device with a vortex layer of ferromagnetic elements (AVS) is a working chamber (pipeline) with a diameter of 60–330 mm, located in the inductor of a rotating electromagnetic field (EMF). The working area of the pipeline contains cylindrical ferromagnetic elements with a diameter of 0.5–5 mm and a length of 5–60 mm in quantities ranging from several tens to several thousand pieces (0.05–20 kg), depending on the working area of the apparatus (Figure 1) [2].

According to their design, AVS with EMF can be divided into two main classes: apparatus for carrying out liquid-phase and heterogeneous processes and apparatus for mixing and dispersing bulk materials. Vortex apparatus

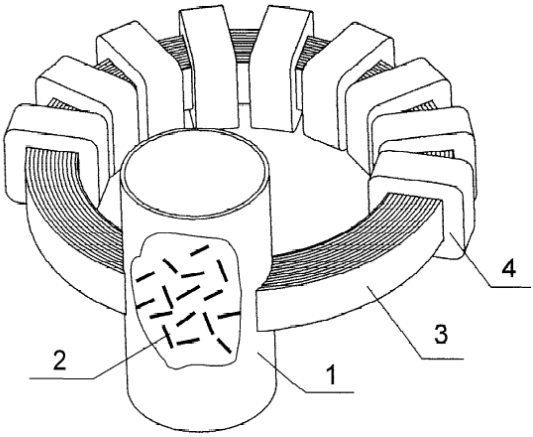

Figure 1. *Vortex layer apparatus with a rotating electromagnetic field*
1- working chamber; 2 - needles; 3 - toroidal magnetic circuit; 4 - coils

of layer, have a very important feature: they can be built into existing process lines without any problems or costs, significantly increasing their productivity and improving the quality of the products. On their basis, it is possible to carry out ore preparation before dry methods of ore enrichment, which seems to be an extremely promising direction of technical progress of reconstructed and newly designed enrichment plants. The author of this article, specifically for the creation of dry ore preparation process lines with subsequent dry enrichment of ores, considers the use of these devices [3].

A number of researchers of the devices under consideration still do not have a clear understanding of the prevailing energy effects in the processes under consideration. Thus, the authors of [4] indicate: “The effects under consideration, arising

in the working area of vortex layer devices, are characterized by very high energy, the source of which remains a mystery for now." Such statements are based on the following known facts. The linear velocity of the needles in the working area is determined by the rotation speed of the electromagnetic field. It is relatively small - 10-12 m/s and varies by radius. Therefore, it is easy to calculate the impact force of the needle. And here interesting facts were revealed - for the destruction of, for example, cast iron, the energy of the needle movement is approximately 32 m/s, sand - 34 m/s, not to mention diamonds, corundum or zircon. However, all these materials are destroyed very effectively, and hundreds of times faster than, for example, in ball or vibration mills. The needles undergo quite small external changes. Therefore, the destruction of materials and the effect on matter in general should not be associated only with the direct impact of the needles. However, despite the fact that devices with rotating EMF have been used in industry for several decades, until now the explanation of the course of processes and energy sources capable of providing unusually high productivity of devices with negligible costs of external energy and very small material consumption and dimensions is presented in the form of scientific hypotheses, the conclusions of which often go beyond the framework of classical physics. This state of affairs obviously indicates the presence of wide scope for scientific research and significant potential for further development of this technology for engineers in the field of its improvement. Some authors of hypotheses [4] try to interpret the above facts by such a phenomenon as magnetostriction, when enormous pressures can develop at the ends of the needle (impact pulse action up to 15-20 t/mm2). It seems unlikely that in a chaotically rotating suspended layer, all particles of the crushed material, or most of them, necessarily fall into the zone of action of the ends of the needles. As a result, the low energy intensity of grinding processes in AVS with EMF is explained by the fact that a number of effects are generated in their working space, which are combined with thermal and mechanical phenomena (including mechanical destruction, microarcs between ferromagnetic elements, magnetostriction, electrolysis, cavitation, acoustic radiation of the ultrasonic frequency range, the effect of electromagnetic fields on matter, etc.). The specific power of these effects is so great that, acting simultaneously on the particles of the processed substance, they ensure a high degree of its dispersion, as well as deep structural changes [4].

Let us make an attempt, based on the laws of classical physics, to present our hypothesis of the prevailing mechanism of destruction of solid, strong, granular materials in the working chamber of the device under consideration.

According to Faraday's law, the effect of an alternating magnetic field in the working area of the device on metal needles, which are conductors, leads to the occurrence of induction currents in them. In the case of needles in the working area of the ABC, it is assumed that the two-electrode cell can be the proximity of two

needles with different charges. The crushed particle of granular material has a high probability of falling into the interelectrode gap, or touching the interelectrode gap and being exposed to microarcs - an electric spark discharge. Obviously, the process under consideration is of a pulsed nature, since such proximity is quite short. Chaotic reorientation of grinding elements with a difference in speeds in structural groups is accompanied by the creation of multi-point contact interactions between them through the layer of the processed product. Rotation of all working elements simultaneously, changes in their (needles) magnetic polarity directions and multiple collisions lead to the formation of high-current short-lived electric circuits in the working area, the rupture and formation of which is accompanied by the emergence of plasma conductive channels. The processes of electric spark grinding of solid materials have been known for a long time, the mechanisms and patterns of these processes have been described many times in the scientific literature [5, 6]. If we are dealing with ABC for carrying out liquid-phase and heterogeneous processes, then it is necessary to recall the effects of Yutkin [7] and Vorobiev [5]. On the surface of the microprotrusion, the electric field is amplified many times compared to the model of a flat capacitor. This leads to an electric discharge in the liquid on the surface of the solid processed grain. The plasma of this discharge, moving along the surface of the dielectric (if the processed raw material is such), for which there is no conduction current, creates a displacement current. This current passes through the microprotrusion and creates a high current density in it. Due to this, an electrical explosion of a micro-protrusion on the surface of the dielectric occurs.

For the case of using ABC in dry processes of grinding granular materials, we will model the energy process using Paschen's law: the breakdown voltage Upr depends only on the product P•δ, and not separately on the pressure P and the gap δ. In accordance with Paschen's law, a simple formula for calculating the breakdown voltage of a flat capacitor is proposed [8]:

$$U_{pr} = 24{,}5\ P{\bullet}\delta + 6{,}4(P{\bullet}\delta)^{0{,}5} \quad (1)$$

where P − gas pressure, atm; δ − distance between electrodes, cm; U_{np} − in kV.

In our case, δ is the distance between two needles that form a microarc, which is the source of destruction of the granular material processed in the ABC. If we take δ = 0.1 cm, P = 1 atm, then we get U_{pr} = 4.5 kV for a flat capacitor and several times less for a pair of needles that have rounded end surfaces and a main cylindrical surface. That is, with a field strength between the needles of 1000 V/mm in air under normal conditions, we can already observe microarcs.

Continuing the analogy with a capacitor, the following relationship is known from a physics course:

$$W_p = C{\bullet}U^2/2, \quad (2)$$

where, W_p – energy in pulse, J;

C – charging capacity of the capacitor, F or C/V;

U – voltage on a pair of needles that formed a “capacitor”, V.

The adopted analogy is appropriate, since the energy of a charged capacitor depends only on its capacity and on the voltage on it. The shape of the capacitor and the distribution of the field inside it do not play a role.

Specific energy consumption (E_{ud}) for the grinding process (only due to microarcs):

$$Э_{ud} = W_p \cdot n/m = C \cdot U^2 \cdot n/2 \cdot m \quad (3)$$

where, $Э_{ud}$ [J•kg/m^2];

n – number of pulses (microarcs);

m – mass of crushed product, kg.

Strictly speaking, each pair of needles forming microarcs will have its own values C_i and U_i.

The mechanism of microarc formation can also be explained by the break of contacts when the needles open. An electric arc can occur when the gap between contacts is broken or when they open. When contacts open, the formation of hot “points” on the contact surface, which are a consequence of significant current densities on small “break” areas, contributes to the occurrence of an arc between them. This causes the formation of an arc when contacts open even at a fairly low voltage (on the order of several tens of volts). It is usually believed that the minimum conditions for the occurrence of at least an unstable arc on contacts are a current of about 0.5 A and a voltage of 15 - 20 V [9]. Diverging contacts can be imagined as a variable capacitor, which is charged through the resistance of the circuit and the voltage on it increases from zero to U_{max}.

An electric arc is a gaseous conductor of current. A magnetic field acts on this conductor, as well as on a metal one, creating a force proportional to the induction of the field and the current in the arc. The magnetic field, acting on the arc, increases its length and moves the arc elements in space. Electric pulse processing of granular materials is characterized by current pulses with a duration of more than 100 μs, at which the discharge by its characteristics refers to the arc. The physical mechanism of the method of destruction of granular materials due to rupture stresses from the inside makes it possible to achieve a lower energy intensity of destruction in comparison with traditional methods (in comparable application conditions). The formation of microarcs in the working volume of the ABC is observed visually, that is, this is a fact inherent in the process under consideration. The second fact confirming the hypothesis proposed for consideration on the prevalence of the mechanism of microarc processing of materials is the observed process of rapid wear (thinning of the wall) of the working chamber of the ABC. The wall of the working chamber, made of stainless steel, is “gnawed out” precisely due to the electric spark, microarc processing, and not only due to the abrasive wear of the rotating needles.

Microarc action is accompanied by a number of processes that accompany only such action: the emergence of dense low-temperature plasma in the discharge channel; electrolysis of the liquid; the formation of a complex system of direct and reflected compression and tension waves that reach significant values, cavitation and ultrasonic processes. One of the main mechanisms of energy effects on mineral raw materials in the devices under consideration is the process of formation of microcracks around the breakdown channel, including due to the action of heated expanding gas in the channel and its outflow from the channel in the event of the latter reaching the surface of the granular material. The breakdown channel grows due to the entry into it of a region ionized by avalanche electrons. The short duration of the considered energy pulses of impact, taking into account their amplification in the places of microprotrusions, both on the needles and on the grains of the processed raw material, leads to enormous pressures concentrated in microvolumes.

Conclusions

The hypothesis about the prevalence of the process of microarc processing of crushed substances in the energy effects of vortex layer devices with a rotating electromagnetic field seems to be justified within the framework of modern knowledge about the mechanisms of electro-pulse effects on crushed granular raw materials.

Technologies involving the use of discharge-pulse processing of mineral raw materials at the stages of ore preparation are increasingly penetrating into the practice of processing mineral raw materials during enrichment. It is these innovative methods that provide a significant leap in reducing energy costs for ore disintegration.

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DOI 10.34660/INF.2025.71.66.055
UDC 621.313.8

别拉绍夫的盘式电机，带有两个独立的同轴转子轴
BELASHOV'S DISK ELECTRIC MACHINE WITH TWO INDEPENDENT SHAFTS OF COAXIAL ROTORS

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摘要。本文致力于发明一种具有两个独立轴的同轴转子的盘式电机，其中组合定子的多个多匝绕组可以在没有任何电子或机械开关装置的情况下运行，并且可以在不改变多匝绕组中电流流动方向的情况下使两个独立转子轴沿一个方向或不同方向旋转。由永磁体组成的第一转子的励磁系统围绕第一定子的多匝绕组自由旋转。由永磁体组成的第二转子的励磁系统围绕第二定子的多匝绕组自由旋转。具有多匝绕组的第一定子和第二定子通过分离的抗磁性插入件相互连接成单个扇区。具有两个轴的同轴转子的盘式电机可以在完全没有无功电阻的情况下具有组合定子多匝绕组的较大内部有功电阻，并且在独立转子的轴上具有较大的扭矩，并且还可以通过电流和电压进行良好的调节。当改变转子轴上内部磁系统的极性时，电机可以朝不同的方向旋转。本发明可用于电力工程、工业和国民经济中，作为电动机和风力发电工程的理想直流发电机，具有良好的直流输出信号特性，内部有功电阻大，完全没有无功电阻，设计用于大输出电压，无需任何整流系统。本发明可用于小型无人机，允许均匀地推动工作空气通过螺旋桨盘，降低其噪音，减少能量损失，同时提高其功率和生产率。

关键词：盘式同轴电机，双轴独立电机，盘式电机，电力工程，技术科学。

Abstract. *The article is devoted to the invention of a disk electric machine with two independent shafts of coaxial rotors, in which a plurality of multi-turn windings of a combined stator can operate without any electronic or mechanical switching devices and rotate two independent rotor shafts in one direction or different directions without changing the direction of current flow in the multi-turn windings. The excitation system of the first rotor, consisting of permanent magnets, freely rotates around the multi-turn windings of the first stator. The excitation system of the second rotor, consisting of permanent magnets, freely rotates around the multi-turn windings of the second stator. The first and second stators with multi-turn windings are connected to each other through a separating diamagnetic insert into a single sector. A disk electric machine with two shafts of coaxial rotors can have a large internal active resistance of the multi-turn*

windings of the combined stator in the complete absence of reactive resistance and have a large torque on the shafts of independent rotors, and also be well regulated by current and voltage. When changing the polarity of the internal magnetic system on the rotor shaft, the electric machine can rotate in different directions. The invention can be used in power engineering, industry and the national economy as an electric motor and an ideal DC generator for wind power engineering, having good characteristics of the DC output signal with a large internal active resistance and a complete absence of reactive resistance designed for a large output voltage without any rectifier systems. This invention can be used in small unmanned aerial vehicles, which allows uniformly pushing the working air through the propeller disks and reducing their noise, reducing energy losses, while increasing their power and productivity.

Keywords: *disk coaxial electric machine, electric machine with two independent shafts, disk electric machine, power engineering, technical sciences.*

Belashov's laws and mathematical formulas are known, which introduce fundamental changes in the level of knowledge of electrical and electrotechnical phenomena, in the field of formation and measurement of electrical signals of direct or alternating current. See the patent of the Russian Federation No. 2175807 KL H 02 K 23/54, 27/02 - an analogue.

A modular electric machine of Belashov is known, which without a collector, using a control system for working rows of multi-turn windings connected to an electronic commutator, rotates the rotor of the electric machine relative to the magnetic systems of the stator. See the patent of the Russian Federation "Belashov's brushless universal electric machine", No. 2130682 KL H 02 K 23/54, 27/10 - an analogue.

The world's first electric machine of Belashov is known, which has a multitude of multi-turn rotor windings that pass through a multitude of excitation systems without any switching devices. See the description of the application for invention No. 2005129781 dated September 28, 2005 - an analogue.

A new version of the world's first Belashov electric machine is known, which has many multi-turn rotor windings that pass through many excitation systems without any switching devices. See the Interuniversity International Congress "Higher School: Scientific Research". Collection of scientific articles based on the results of the congress held in Moscow on October 17, 2024, pages 89-95 - analog.

A new modification of the world's first Belashov disk electric machine is known, which has many multi-turn rotor windings that pass through many excitation systems without any switching devices. See the collection of scientific articles of the International Scientific Conference "Science. Education. Practice", held on October 23, 2024 in Delhi, India. Pages 173-177 - prototype.

The world's first Belashov electric machine with two shafts of independent coaxial rotors is known. See the collection of scientific articles of the Interuniversity International Congress "Higher School: Scientific Research" held in Moscow on February 6, 2025, pages 167-173. - prototype.

The purpose of the invention is to reduce copper consumption for a plurality of multi-turn windings and create conditions for the rotation of two independent coaxial rotors with an unchanged direction of current flow in the multi-turn windings of the combined stator.

Fig. 1 shows the internal structure of a disk electric machine with two independent shafts of coaxial rotors.

Fig. 2 shows the internal structure of one section of the combined stator.

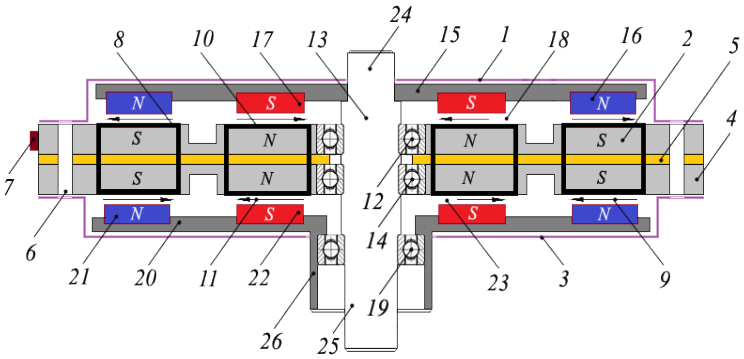

Figure 1.

Belashov's disk electric machine with two independent shafts of coaxial rotors Fig. 1 comprises an upper part of the housing 1. Inside the upper part of the housing there is a first system of stators 2. Inside the lower part of the housing 3 there is a second system of stators 4. The first stator 2 is rigidly connected to the upper part of the housing 1 through a diamagnetic insert 5 with the second stator 4 and the lower part of the housing 3 having fastening holes 6 and a device for supplying direct voltage 7. The first stator 2 having a plurality of multi-turn stator windings 8 wound in direction 9 and a plurality of multi-turn stator windings 10 wound in direction 11 through rolling or sliding elements 12 interacts with the rotor shaft 13. The second stator 4 having a plurality of multi-turn stator windings 8 wound in direction 9 and a plurality of multi-turn stator windings 10 wound in direction 11 through rolling or sliding elements 14 interacts with the rotor shaft 13. the first excitation system 15 with an even or odd number of permanent magnets of the north pole 16 and an even or odd number of permanent magnets of the south

pole 17, which interact with the first system of the stator 2 through an air gap 18, is rigidly installed on the rotor shaft 13. The second excitation system 20 with an even or odd number of permanent magnets of the north pole 21 and an even or odd number of permanent magnets of the south pole 22, which interact with the second system of the stator 4 through an air gap 23, is installed on the rotor shaft 13 through rolling or sliding elements 19. The rotor shaft 13 can create a torque with the upper base 24 and the lower base 25, where the lower base of the rotor 25 is located inside the rotor 26 of the excitation system 20. Fig. 2 shows the side of one section of a stationary stator with multi-turn windings of a disk electric machine with two independent shafts coaxial rotors. Moreover, the combined stator can contain an even or odd number of sections with multi-turn windings.

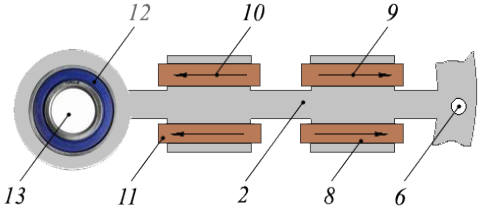

Figure 2.

The Belashov disk electric machine operates with two independent shafts of coaxial rotors as follows.

To start operation, the body of the electric machine is attached to a stationary object using holes 6. DC voltage is supplied using a voltage supply device 7 to a plurality of multi-turn windings 8 and a plurality of multi-turn windings 10 to an even or odd number of combined stators. The first system of an even or odd number of stators 2 having a plurality of multi-turn windings 8 wound in direction 9 and a plurality of multi-turn windings 10 wound in direction 11 through rolling or sliding elements 12 interacts with the rotor shaft 13. The first rotor excitation system 15 consisting of a plurality of permanent north pole magnets 16 and a plurality of permanent south pole magnets 17 installed inside the housing of the upper part of the housing 1 creates a magnetic flux coming out of the north poles 16 of the excitation system 15. Then the magnetic flux through the air gap 18 crosses the plurality of multi-turn windings 8 wound in direction 9 and goes to the first magnetic circuit of the stator 2. Then the magnetic flux, moving along the first magnetic circuit 2, crosses the plurality of multi-turn windings 10 wound in direction 11 and then goes to the south pole 17 and thereby closes the magnetic flux of the excitation system 15. After the magnetic lines of force intersect the plurality of multi-turn windings 8 and the plurality of multi-turn windings 10, a repulsive

force arises, which acts on the conductor according to the left-hand rule. If the left hand is positioned so that the magnetic field lines enter the palm perpendicular to it, and four fingers are directed along the current, then the thumb set back 90° will show the direction of the acting force on the plurality of multi-turn windings 8 and the plurality of multi-turn windings 10 cause the rotor shaft 13 to rotate. The second system of an even or odd number of stators 4 having a plurality of multi-turn windings 8 wound in direction 9 and a plurality of multi-turn windings 10 wound in direction 11, which interact with the rotor shaft 13 through rolling or sliding elements 14. The second rotor excitation system 20 consisting of a plurality of permanent north pole magnets 21 and a plurality of permanent south pole magnets 22 installed inside the housing of the lower part of the housing 3 creates a magnetic flux emerging from the north poles 21 of the excitation system 20. Then the magnetic flux crosses the plurality through the air gap 23 multi-turn windings 8 wound in direction 9 and passes to the second magnetic circuit of the stator 4. Then the magnetic flux, moving along the second magnetic circuit 4, crosses a plurality of multi-turn windings 10 wound in direction 11 and then enters the south pole 20 and thereby closes the magnetic flux of the excitation system 20. After crossing the magnetic lines of force of the plurality of multi-turn windings 8 and the plurality of multi-turn windings 10, an expulsive force arises, which acts on the conductor according to the left-hand rule. If the left hand is positioned so that the magnetic field lines enter the palm perpendicularly to it, and four fingers are directed along the current, then the thumb set back 90° will show the direction of the acting force on the plurality of multi-turn windings 8, and the plurality of multi-turn windings 10 force the rotor shaft 26 to rotate. After the magnetic lines of force intersect the plurality of multi-turn windings 8 and the plurality of multi-turn windings 10, an expulsive force arises, which acts on the conductor according to the left-hand rule. If the left hand is positioned so that the magnetic field lines enter the palm perpendicularly to it, and four fingers are directed along the current, then the thumb set back 90° will show the direction of the acting force on the plurality of multi-turn windings 8 and the plurality of multi-turn windings 10 causing the stator excitation system 20 to rotate. The external rotor shaft 26 is mounted on the excitation system 20 with permanent magnets. It should be especially emphasized that if the permanent magnets of the north pole 21 and the permanent magnets of the south pole 22, which are mounted on the rotor shaft 13 of the magnetic system 20, are swapped, then the rotor 26 of the electric machine itself will rotate in the opposite direction.

Moreover, it should be noted that when using an electric machine with two independent shafts of coaxial rotors of a disk electric machine as an ideal DC generator for wind power engineering, having good characteristics of the output signal with a large internal active resistance. The large internal resistance of many

multi-turn windings of the composite stator is designed for a large output voltage, which can be used without any rectifier systems by rotating the rotor shaft 13 and the rotor shaft 26 in one direction or in different directions.

It should be especially emphasized that obtaining DC voltage from a disk electric machine with two independent shafts of coaxial rotors without any converters gives a large positive effect in transmitting DC electrical energy over long distances. Since the transmission of electrical energy over long distances by alternating current worsens these characteristics and leads to:

- power losses due to the presence of capacitance in the AC transmission lines,
- a large voltage drop associated with the effect of inductance,
- it is necessary to clearly synchronize the frequency of alternating current from different incoming sources of electrical energy, since AC transmission lines can only connect synchronized AC electrical networks that operate at the same frequency and in phase,
- it is also necessary to take into account that the overload of generators due to increased voltage levels, the reactive power generated by the line can become so large that it will lead to overheating of the generator windings, and so on...

The main advantage of transmitting electrical energy over long distances by direct current is that such a transmission line can serve as an accumulator of electrical energy by accumulating electrical energy due to a significant increase in voltage in it, while there is no need to synchronize anything, but you just need to increase the voltage. Nowadays, everyone is trying to switch to energy-saving technologies, such as LEDs, but many such devices operate only on direct current, and I have patented the circuit diagram and operating principle of the converter from high-voltage direct current to an electrical signal of alternating current of industrial frequency in the patent of the Russian Federation No. 2435982. A new device for converting high-voltage direct current to an electrical signal of alternating current with combined Belashov transformers was invented by me and published at the International Scientific Conference “Science. Education. Practice”, November 20, 2024, Delhi, India. Collection of scientific articles, volume 2, pp. 114-120.

In conclusion, it can be said that when the Belashov disk electric machine with two independent shafts of coaxial rotors inside all multi-turn composite stator operates, the current movement in the conductors occurs constantly in one direction and never changes its direction without any switching devices. The invention can be used in power engineering, industry and the national economy as an electric motor and an ideal DC generator for wind power engineering, having good characteristics of the DC output signal with a large internal active resistance and a complete absence of reactive resistance designed for a large output voltage without any rectifier systems. This invention can be used in small unmanned aerial vehicles, which allows uniformly pushing the working air environment through

the rotor disks and reducing their noise, reducing energy losses, while increasing their power and productivity.

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DOI 10.34660/INF.2025.71.49.056
UDC 614.849

通过模拟热交换来改善便携式热膨胀涂层加热装置的特性
IMPROVING THE CHARACTERISTICS OF A PORTABLE DEVICE FOR HEATING THERMALLY EXPANDING COATINGS BY SIMULATING HEAT EXCHANGE

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摘要。本文介绍了提高金属结构阻燃膨胀涂层现场研究方法效率的研究成果。对设备热室内的热交换进行了多种变化建模。所获模型的有效性已得到经验证实。

关键词：防火、膨胀阻燃涂层、传热模拟、加热装置。

Abstract. *The article presents the results of work on increasing the efficiency of a field method for studying flame-retardant bulging coatings for metal structures. The heat exchange inside the device's thermal chamber is modeled in several variations. The effectiveness of the obtained model has been confirmed empirically.*

Keywords: *fire safety, bulging flame-retardant coatings, heat transfer simulation, heating device.*

Introduction

Fires are always accompanied by high temperatures, most often exceeding 800 °C, if the supporting structures of the building are made of metal, they can lose their bearing capacity, which will lead to the destruction of the building. Steel retains its strength and bearing capacity for no more than 15 minutes in a fire [1].

To prevent thermal effects on the metal structures of the building, fire-retardant compounds are used. From the point of view of aesthetic properties, it is advisable to use intumescent fire-protective coatings, but they are the most dangerous, since the principle of their action is a multiple increase in the thickness of the fire-protective coating when exposed to high temperatures [2].

Based on the testing fire laboratory in the Novosibirsk Oblast, the authors of the article developed a method [3] of temperature action on a fire-protective coating capable of ensuring absolute swelling of the fire-protective coating in a short period of time due to two-sided high-temperature heating of the intumescent fire-protective coating. Also, to implement the plan, a prototype of a portable device for heating intumescent fire-protective paints [4] (hereinafter referred to as the device) was developed to test the mechanism of swelling of the fire-protective coating of metal structures mounted directly on the protected object. But to increase the efficiency of the device, it is necessary to conduct modeling and establish the optimal characteristics of the device.

Stages of the study

At the initial stage, after assembling the prototype device, a test run was carried out. A pre-prepared sample was exposed to temperature, during which the fire-protective coating of the sample underwent minor changes. Fig. 1 shows the changes in the fire-protective coating after temperature exposure for 120 seconds. Absolute swelling was not achieved, most likely due to the fact that a steel tube with an outer diameter matching the inner diameter of the heat chamber was used as a rod (the main heating element) located inside the heat chamber.

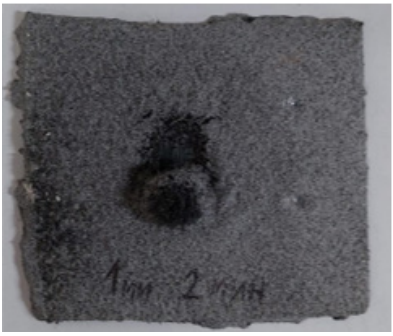

Figure 1. *Results of the test run of the device.*

The second stage of the study, after receiving a negative result, was to make 8 rods of different formats, the most successful of which are shown in Fig. 2a and Fig. 2b. When choosing from possible materials, preference was given to iron due to its availability and relatively low cost. During the studies, it was found that the

central part heats up weakly, and the surface of the steel rod heats up over 1000 degrees in 20-30 seconds, this is due to the physical properties of electromagnetic induction, which is the basis of the device. It was also empirically determined that it is impractical to make a rod with a hole in the middle, since the heating from such a rod is inferior in its parameters to a star-shaped rod.

Figure 2. *Variants of steel rod shapes.*

During the test in a closed loop of the heat chamber, the temperature increase remained insufficient, most likely due to the fact that air is a poor heat conductor and, as a result, the heat from the hot rod was distributed very slowly in the interior of the heat chamber. To transfer heat from the rod to the surface of the fire-protective coating, it is necessary to provide a circulating heat flow (probably, it should be through). Considering the aerodynamics, it is impractical to manufacture a rod with flat edges, it makes sense to use the principles of shaping to approximate the shape of the rod to an ideally streamlined one, this will increase the air flow passing through the rod.

At the third stage of the study, after determining the shape of the rod, the maximum length inscribed in the contour of an ideally streamlined body, with a cut-off tail, the authors of the article carried out heat exchange modeling in order to understand the reasons for the deviation of the device characteristics from those intended using the model as an example. The simulation was performed in the Ansys Fluent computing package. The part of the setup responsible for heating the air flow was reproduced, namely: a ceramic tube (thermal chamber) with an internal diameter of d = 15.9 mm and a length of L = 150 mm, inside which a steel core (rod) cut along the smallest diameter is installed, which is heated by high-frequency currents. This heating was modeled by boundary conditions of the second kind: a constant heat flow was set, which was changed within the range from q = 15,000 W/m^2 to q = 25,000 W/m^2 on the wall of the core, and the air supply speed to the device was changed in parallel from u_m=0,5 m/s to u_m= 4,0 m/s.

To solve the RANS equations, a structured computational grid was built, the problem was solved in an axisymmetric formulation with 30 computational nodes located along the radius, condensed to the channel walls, which allowed for a more correct determination of velocities and temperatures. The solution was obtained in 150 iterations, with all residuals less than 10-7, which is a fairly reliable result. As shown in Fig. 3a, the temperature distribution over the cross-section of the device depends on the air flow velocity. The thermal boundary layer mainly increases when flowing around the cylindrical part and reaches half the annular gap approaching the end of the core. On the conical part of the boundary layer after separation, the temperature reaches more than 1180 K. After passing the core, the heat accumulates in the central part, leaving the wall part relatively cold, such a temperature distribution turns out to be quite useful, since during operation of the device, the ceramic tube will experience less thermal deformations and, therefore, its service life will be increased. When analyzing the axial velocity field in the device (Fig. 3b), it is clear that even taking into account that the core was inscribed in the contour of an ideally streamlined body to improve aerodynamic characteristics, flow separation occurs on it. Behind the core, one can see a zone of return gas flow, the speed in which is approximately 1 m/s. Usually, in the zone of return flow, deterioration of heat exchange is observed, therefore, on the cone, the surface temperature of the core will be higher than on the cylindrical part or on the hemispherical part.

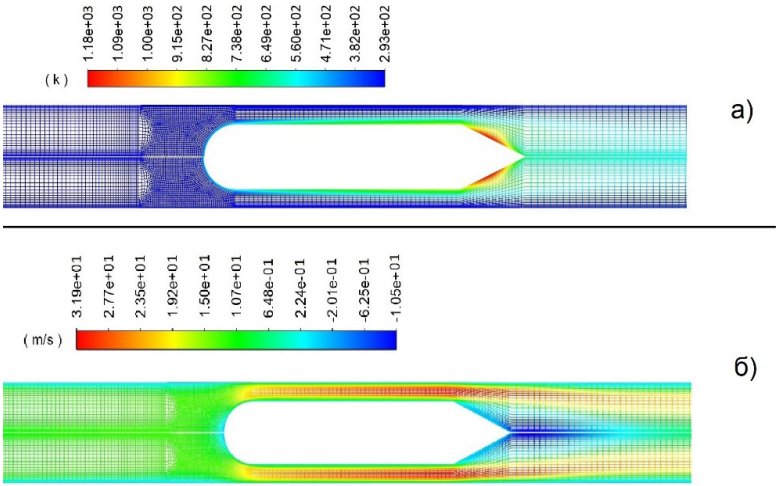

Figure 3. *Model of temperature distribution and air flow velocity.*

The entire series of experiments is characterized by a typical linear dependence of the temperature at the device outlet on the value of the heat flow through the core, therefore, by increasing the power of high-frequency currents and the air flow velocity, it is possible to effectively regulate the temperature at the device outlet.

The final stage of the study was the implementation of the results obtained by modeling. For this purpose, the optimal values of power and air flow velocity obtained during modeling were set on the prototype device. Fig.4 shows the result of the full-scale experiment. The optimal configuration during modeling was determined to be the “star” rod shape, the maximum device power, and the air flow velocity of 1 m/s. Setting such parameters allowed us to significantly improve the quality of the prototype device and obtain a completely acceptable result.

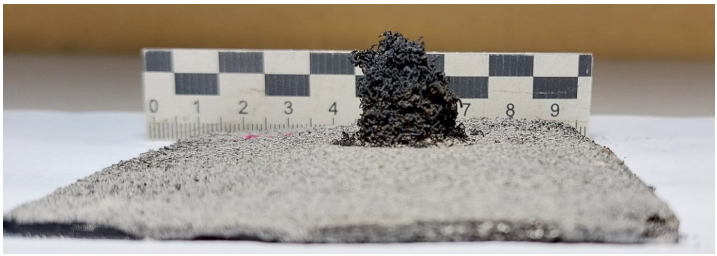

Figure 4. *Results of testing the prototype device with characteristics determined by modeling.*

Conclusion

During the development of the prototype device and the manipulations to improve it, a number of models were built using specialized software, which allowed for a more accurate assessment of errors during full-scale testing.

The studies conducted determined that the temperature at the outlet of the device is directly proportional to the heat flow on the core, and it also depends on the value of the air flow velocity. We understand that when designing the device, it is necessary to provide several regulators, one regulator for the high-frequency current source to change its power, and the other to increase the air flow velocity.

The data obtained during the modeling correlate well with the empirical data, which allows us to bring the device characteristics to a working state.

Based on the results obtained, the authors of the article propose to study the issue of developing technical regulations for a device for conducting research on checking the intumescent capacity of fire-protective coatings mounted directly on the protected object.

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DOI 10.34660/INF.2025.63.11.057

海上引航员风险评估
SEA PILOT RISK ASSESSMENT

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摘要。本文探讨了与引航员安全相关的引航活动，特别是为提高引航员登船和下船时的安全水平而应采取的措施。尽管船舶的设计和操作在各个方面都考虑到了 SOLAS 的要求，包括引航员安全，但在实践中，引航员登船和下船过程中仍然存在许多问题。这个问题如今已成为现实，因为引航员继续受伤，而且在登船和下船期间还会发生引航员死亡事件。因此，需要对现有风险进行分析和评估，以将其降低到可接受的水平，以提高这些操作的安全性。

关键词：引航员、事故、引航员梯、伤害、风险评估。

Abstract. *The article considers pilotage activities associated with the safety of pilots, in particular, measures to be taken in order to improve the safety level when embarking or disembarking a pilot. Although ships are designed and operated taking into account SOLAS requirements in all aspects, including pilot safety, in practice many problems continue to exist regarding the process of embarkation and disembarkation of pilots. The problem is actual nowadays since pilots continue to sustain injuries and moreover, deaths of pilots occur during embarkation and disembarkation. For this reason, the existing risks are required to be analyzed and assessed in order to be reduced to acceptable level with an aim of improving the safety of these operations.*

Keywords: *pilot, incident, pilot ladder, injury, risk assessment.*

In shipping practice of many countries there is a mandatory pilotage established in areas with difficult navigation conditions. Most often, seaport waters fall into this category, since in the seaport water area there is an intersection of ship's routes, and the likelihood of accidents and incidents is very high. Therefore, in

most ports and on approaches to them, the governments of different countries establish mandatory pilotage areas.

The work of a pilot is challenging and involves multiple risks. Following a number of serious accidents involving fatalities, the International Maritime Organization made a review of the existing standards. The minimum requirements are currently set out in Regulation 23, Chapter V of the SOLAS Convention, adopted in July 2012, as well as in IMO Resolutions A 1045 (A) and others. [1-4] It is important to realize that compliance with these requirements is mandatory and not just recommended – Figure 1.

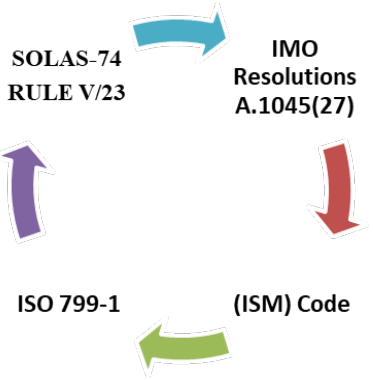

Figure 1. *Requirements for the pilot ladder*

According to surveys, about 20% of pilot ladders do not meet the established standards, and expose a pilot to additional risks [5].

Thus, on the morning of May 5, 2023, the cruise ship Diamond Princess was heading towards Nagasaki, waiting for a pilot to arrive. At approximately 05:30, a pilot boat approached the ship. While climbing the storm ladder, the pilot lost his balance and fell overboard. They immediately launched a lifeboat from the m/v Diamond Princess and began searching. The pilot was wearing a life jacket, which helped him get out of the water, but he was already unconscious. Unfortunately, he died two hours later [6].

In Itajaí (Brazil), on January 31, 2020, another incident occurred: the rope of the pilot ladder broke during embarkation. However, the first pilot managed to board the vessel. In Figure 2, he is shown on the ladder, while the second pilot didn't have an opportunity to use the ladder. [7]

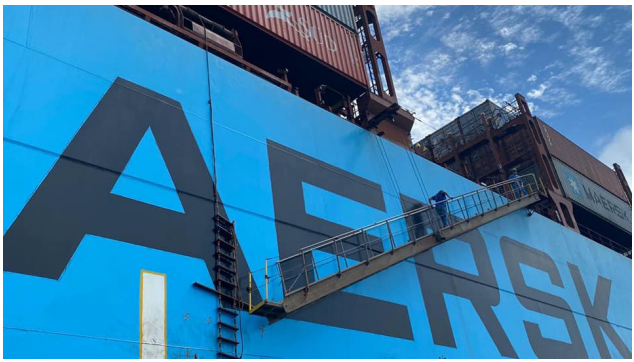

Figure 2. *Pilot on the pilot ladder before it breaks (photo by Alexandre Gonçalves da Rocha (source social media)*

The main risk factors for falling off ladder include: insufficient lighting, working in an awkward position, fatigue, rolling/pitching, slippery surfaces, lack of experience, etc. Physical risk factors such as life stresses, personality risk-taking behavior, and body size have been found to be of minor importance in studies carried out by the US National Institute for Occupational Safety and Health.

Pilots falling off ladders due to deteriorating weather conditions is a separate aspect of research, since a sharp change in the state of the water surface under the influence of sudden gusts of wind is a common occurrence. For example, on 31.12.2018 in the port of Tuapse at the time of the pilot's disembarkation from the Chemical-Oil Products Tanker "Mount Olympus" (IMO 9260081) to the tugboat "Captain Avdyukov" the weather conditions were getting worse.

According to the ship's log entries, at 05:00 the south-easterly wind was blowing at a speed of 22-26 knots, with waves up to 3 m in height. The recorded air temperature was 8°C, sea water temperature was 13°C. According to the statement of the Master and the 4th Officer, who witnessed the casualty, the pilot's one foot was on the tug, while he was clinging to the pilot ladder, and the tug's crew was helping him to board the tug. At that moment, a strong wave pushed the tugboat away from the side of the m/v «Mount Olympus». The pilot lost his balance and fell into the water. When the pilot was pulled out of the water, his life jacket was not inflated. Doctors later confirmed that the pilot had died. According to the forensic medical examination, the cause of his death was "drowning."

The list of such tragic occurrences is long. Figure 3 shows statistics of accidents and incidents involving pilots, presented by the Federation Francaise des Pilotes Maritimes [8].

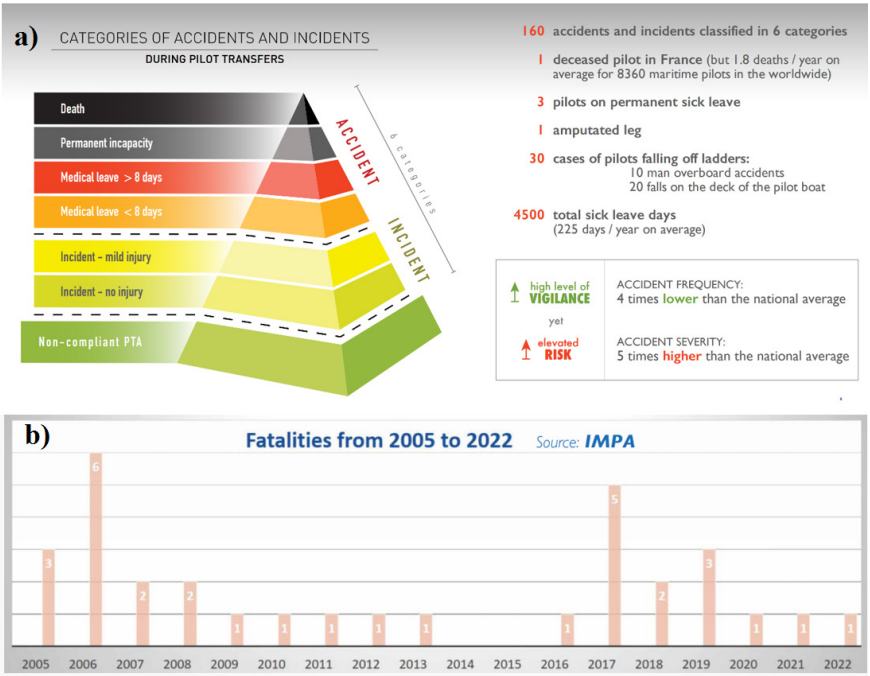

Figure 3. *Statistical data of accidents and incidents involving pilots [8].*

Since pilots falling off ladders are the most common incidents, a number of formal and informal initiatives have been taken over the past five years to increase awareness of the problems that pilots face on a daily basis. These regional, national and international projects are initially aimed at eliminating gaps in the knowledge of pilots themselves. If pilots know and fully understand the excising regulations, they can refrain from using unacceptable methods and means that could endanger their own lives.

A number of ports now require a prior statement that "vessel's arrangement for pilot's transfer complies with the latest IMO requirements" [2]. This statement may be made verbally via VHF or in writing. If a vessel is found to have no adequate arrangements for pilot transfer, it may be refused to enter the port until the situation is rectified and it will create a significant financial burden for the shipowner.

The deficiencies may be found, even if a particular equipment is approved by any classification society as this approval does not always mean the compliance with international or national legislation on flag state control. In many countries

around the world, including the EU, pilots are required to report any deficiencies they discover while performing their duties. In the UK, for example, according to the approved procedure the pilot, firstly shall report the defect to the competent port authority. A report to the MCA or MAIB may also be required subsequently [8].

If a pilot refuses to board a vessel that cannot provide safe access, it will affect not only the commercial operations of the port, but the port itself will be obliged to support the actions of the pilot.

MAIB data over 2022 shows that there were over 400 incidents or accidents during 96,000 pilots' accepting or transferring operations by means of the pilot ladder. Approximately a quarter (25%) of these incidents involved the use of pilot ladder shackles instead of stoppering devices, while 23% of incidents were due to wear and tear of ladders. In 13% of cases, improper handrails were used, while the remaining 39% of incidents were due to ladders being of the wrong length, being incorrectly positioned relative to the vessel's hull, or being improperly installed of the guy rope [9].

Although the analysis showed that more than 99% of pilot transfers to ships were completed successfully, the MAIB is concerned about incidents involving ladders.

Recommendations to reduce incidents involving pilots during embarkation and disembarkation include the following:

- make sure the pilot ladder is properly secured. Before using it, check the ladder: old ladders are often in poor condition, but new ones can also have hidden damage. Pilot ladders must be carefully inspected before each use and must be replaced or retested after 30 months of their usage;
- handrails must be constructed in accordance with requirements: pilots are exposed to a high risk of falls when they are moving between the top of the stairs and the deck of the vessel. The design of the handrails must allow pilots to hold on securely during this transition. If the safety measures on board vessel are not adequate, the responsible person ashore must be notified and action taken to eliminate the problem;
- remember to report pilot ladder incidents to MAIB since the lack of sufficient statistical data, less than half of such incidents were reported to the branch, made it impossible for MAIB to conduct an in-depth analysis of the causes of incidents and accidents involved with pilot ladders;
- comply with a requirement to wear a life jacket when installing a pilot ladder;
- Standard Operating Procedure in the event of a man falling overboard to be included in the company's safety management system. The procedure should cover all activities on board and may include the frequency of drills required to maintain the appropriate level of the crew's response to such situation.

The serious risks of pilots falling off ladders and the use of outdated and unsafe methods when transferring pilots to and from vessels using storm ladders underlines the need of a strict supervision to be exercised in this area.

Risk assessment makes it possible to evaluate and reduce risks arising when a pilot embarks or disembarks. The assessment of risks regarding the pilot's working activity is critical as there are cases of injuries and even deaths of pilots occurred during embarkation or disembarkation, and therefore the task of improving the safety of operations for transferring a pilot to or from a vessel is essential nowadays.

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非传统原料对燕麦饼干风味的影响
THE EFFECT OF NON-TRADITIONAL RAW MATERIALS ON OATMEAL COOKIES FLAVOR

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摘要。如今，食品行业致力于扩大营养价值更高的产品范围，其中就包括燕麦饼干。非传统原料的使用增加了产品的营养价值，同时也影响了产品的风味和口感。本研究的目的是比较燕麦饼干和非传统原料中的风味形成物质。由于在配方中引入了非传统原料，产品风味的强度有所增加。同时，在用发芽谷物粉和乳清蛋白浓缩物制成的燕麦饼干中观察到了最高含量的风味形成物质。

关键词：发芽谷物粉、乳清蛋白浓缩物、风味、饼干。

Abstract. *Nowadays the food industry is focused on expanding the range of products with increased nutritional value, including oatmeal cookies. The application of non-traditional raw materials increases the nutritional value of products as well as affects their flavor and taste. The purpose of this study was to compare the flavor-forming substances in oatmeal cookies with non-traditional types of raw materials. Due to the introduction of non-traditional types of raw materials into the formulation, the intensity of the products flavor was revealed to increase. At the same time, the highest content of flavor-forming substances was observed in oatmeal cookies made with sprouted grain flour and whey protein concentrate.*

Keywords: *sprouted grain flour, whey protein concentrate, flavor, cookies.*

Nowadays one of the main tasks of food industry workers is aimed at expanding the range of food products with improved quality and increased nutritional value. Flour products are essential in human nutrition [1]. At the same time, their taste advantages are determined by their flavor, smack, and sensation in the chewing process.

Flour confectionery products occupy one of the leading places among the foods consumed. Non-traditional raw materials types (flour from sprouted wheat, whey protein concentrate and others) are used to increase their nutritional value. Recipe ingredients are known to affect the flavor of foods, including oatmeal cookies [2].

Therefore, the purpose of our study was to compare the flavor-forming substances in oatmeal cookies with non-traditional types of raw materials. The objects of research were the following samples of oatmeal cookies: No. 1 – without the use of sprouted wheat grain flour and whey protein concentrate (control), No. 2 - with sprouted wheat grain flour, No. 3 - with whey protein concentrate, No. 4 - with sprouted wheat grain flour and whey protein concentrate.

The products flavor was evaluated with the help of MAG-8 laboratory odor analyzer with the electronic nose methodology (manufactured in Russia). 8 sensors (SID0001 – polyvinylpyrrolidone, SID0002 – propolis, bee glue, SID0003 - dicyclohexane-18-Crown-6, SID0004 – hydroxyapatite, SID0005 – polyethylene glycol 2000, SID0006 - polyethylene glycol sebacinate, SID0007 - polyethylene glycol succinate, SID0008 - Triton X-100) based on piezo quartz resonators VAW-type with a base oscillation frequency of 10.0-14.0 MHz with different film and nanostructured sorbents on the electrodes were used in the work. The coatings were selected in accordance with the test objective (possible emission from samples of various organic compounds of different nature). The samples were kept at room temperature (25 =1) °C for at least 30 minutes. The volume of the equilibrium gas phase (EGPh) of the V_{egph} was 3 cm^3. The total weighing time of the equilibrium gas phase (EGPh) of the sample was 60 s. The measurement error was 5 % [3, 4].

The response values of all selected sensors in the array and the values of the quantitative integral signal of the "electronic nose" - the area of the kinetic "visual fingerprint" of the responses were compared to determine the content of accompanying volatile compounds in the equilibrium gas phase above the samples (Table 1).

Table 1

Sensor responses in pairs of EGPh over samples and the area of the "visual fingerprint" of the maximum sensor signals

Samples	Sensor responses, Hz, in EGPh pairs over samples								The area of the «visual fingerprint» of the maximum sensor signals, Hz·s
	SID0001	SID0002	SID0003	SID0004	SID0005	SID0006	SID0007	SID0008	
№ 1	22	15	15	3	6	5	2	3	287
№ 2	23	18	17	3	7	5	3	5	344

№ 3	30	18	22	6	11	6	4	6	504
№ 4	26	25	23	7	11	6	5	10	660

The least saturated flavor was revealed in the control sample (Figure). The highest flavor intensity of all the experimental samples was observed in sample No. 4.

Further, a comparison of the quantitative and qualitative fractional composition of volatile compounds in the samples was carried out. Changes in the quantitative composition of the air above the samples by the relative content of the main classes of volatile compounds to which the sensor array was configured were evaluated by the normalization method (Table 2).

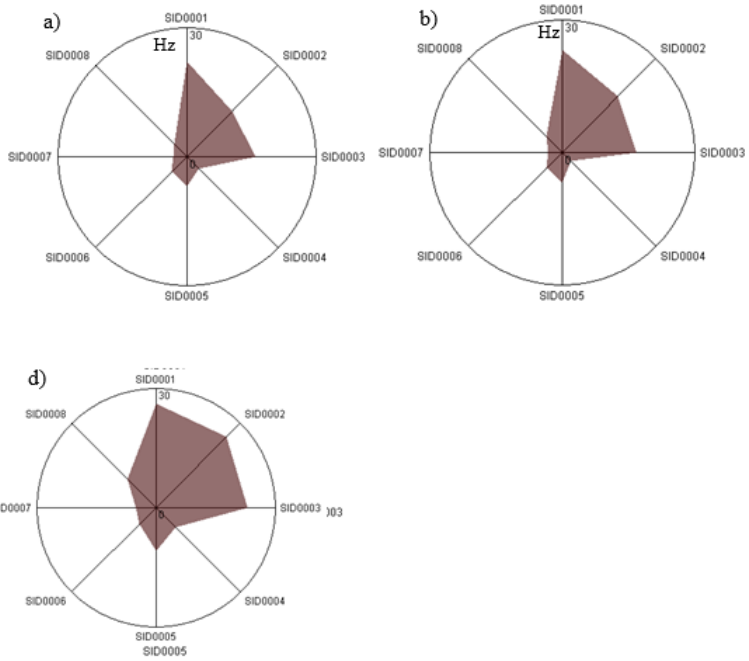

Figure. *Pie charts of the maximum signals of the "electronic nose" sensors in pairs of EGPh over samples: a – sample No. 1 (control); b – sample No. 2; c – sample No. 3; d – sample No. 4*

Table 2

The relative content of the components in the samples according to the significant sensors signals in the EGPh above the samples

Samples	Relative content of the components in the samples according to the significant sensors signals, % by weight, in the EGPh above the samples							
	SID0001	SID0002	SID0003	SID0004	SID0005	SID0006	SID0007	SID0008
	Water, all polar compounds	Alcohols, aldehydes, and amines	Organic polar compounds, acids	All polar, amines	Ketones, alcohols	Amines and other N-containing compounds	Medium-polar, S-, N-containing compounds	Water, all polar compounds
№ 1	31,0	21,1	21,1	4,23	8,45	7,04	2,82	4,23
№ 2	28,4	22,2	21,0	3,70	8,64	6,17	3,70	6,17
№ 3	29,1	17,5	21,4	5,83	10,7	5,83	3,88	5,83
№ 4	23,0	22,1	20,4	6,19	9,73	5,31	4,42	8,85

The test samples were found to be characterized by ketones, alcohols, mid-polar, S-, N-containing compounds in the EGPh, while the control sample was characterized by the highest content of amines.

A comparative assessment of the qualitative and quantitative composition of flavor-forming substances in different samples of oatmeal cookies showed that the control sample was characterized by their least quantity. The use of non-traditional raw materials in the technology of flour confectionery contributed to an increase in the content of flavor-forming substances in them. At the same time, oatmeal cookies with sprouted wheat flour and whey protein concentrate were characterized by the highest flavor intensity.

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DOI 10.34660/INF.2025.27.84.059

研究气动效应对可重复使用有翼飞机隔热瓦粘接接头特性的影响

INVESTIGATION OF THE EFFECT OF AERODYNAMIC EFFECTS ON THE CHARACTERISTICS OF THE ADHESIVE JOINT OF HEAT PROTECTION TILES FOR A REUSABLE WINGED AIRCRAFT

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Research of the influence of aerodynamic heating on adhesive connection characteristics of winged reusable spacecraft (SCVs). P.V. Pichuzhkin

摘要。本文探讨了当前存在的问题之一——可重复使用飞机在运动过程中，由于气动加热的影响，瓷砖热保护被破坏。瓷砖热保护对于确保其在高温和其他影响条件下运行的可靠性和稳定性是必不可少的。

本文作为护套性能研究的一部分，研究了热量对粘合剂粘合的影响。这项工作的目的是计算所考虑的隔热元件与可重复使用飞机机身连接类型的强度。这项工作的结果是推导出最大剪切应力对粘合面积的依赖性。

关键词：粘合连接、瓷砖热保护、剪切应力、烧蚀材料、多层结构、蒙皮板、气动加热、有翼可重复使用飞机。

Abstract. *The article examines one of the current problems - the destruction of tile thermal protection due to the influence of aerodynamic heating during the movement of a reusable aircraft. Tiled thermal protection is necessary to ensure reliability and stability of its operation under conditions of high temperatures and other influences.*

This paper examines the effect of heat on adhesive bonding as part of a study of sheathing properties. The purpose of the work is to calculate the strength of the considered type of connection of heat-protective elements with the body of a reusable aircraft. The result of the work is the derivation of the dependence of the maximum shear stress on the gluing area.

Keywords: *adhesive connection, tile thermal protection, shear stress, ablative materials, multilayer architecture, skin panels, aerodynamic heating, winged reusable aircraft.*

List of abbreviations
SC– spacecraft
RSC– reusable spacecraft
THCP– tile heat-protective coating
TPS– thermal protection system

The relevance of studying the effect of high temperatures on the thermal protection of reusable aircraft has always been one of the main tasks in the field of its design and construction, in the field of aerodynamics of its flight, because there is a possibility of destructive, irreversible consequences. One of the most important goals of materials science in the framework of the RSC is to achieve heat resistance, low weight of tiles, high strength under the influence of force and temperature factors that must be maintained under the action of aerodynamic, inertial and elastic forces when entering the atmosphere. In this paper, the properties of the adhesive joint of heat-protective panels and skin are studied under the action of thermal disturbances. The results of the study will be useful in designing thermal protection for winged spacecraft. The aim of the work is to calculate the strength of the considered type of connection of heat-shielding elements to the body of a reusable aircraft, to prevent destructive consequences of the skin panels of the considered type of aircraft. The work presents calculations of the strength of the adhesive joint using the main equations from the course of strength of materials.

The solution to the problem of heat protection is reduced to studying the properties of the main materials for the structures of winged aircraft, conducting a strength study of one of the types of connection of panels to the body of the aircraft - glue. This work considers the Elastosil 137-175M glue, necessary for fastening the layers of the protective coating and the element of the heat-shielding structure to the skin. It is based on organic rubber silicon, which allows for a reliable connection of the elements of the structure in the temperature range from -130 degrees Celsius to +300 degrees Celsius. [1]; [2]

In order to manufacture tiles of heat-protective structures, in which heat-resistant and high-temperature materials would be used, carbon-carbon composite materials, heat-resistant metal alloys and structural ceramics are mainly used. [3]

The calculation of adhesive joint stresses is made on the basis of strength equations with a change in the length of the substrate relative to the dimensions of the heat-protective tile. Based on the obtained data, graphs are constructed of the dependences of the values of the maximum shear stresses of the adhesive joint on the gluing area. [4]

It is important that the material has the necessary strength at a low weight, is heat-resistant at significant temperature differences, has low thermal conductivity and very good surface blackness (0.89 ... 0.99). For example, materials based on quartz fibers turned out to be the most suitable due to their ability to with-

stand thermal shocks up to 1250 - 1300 degrees with subsequent rapid cooling. The only natural material with such characteristics is highly purified amorphous quartz. Various coatings based on borosilicate glass can be used to protect quartz fiber structures from erosion and contamination. Ceramic tiles with silicon dioxide (quartz) fibers, shaped like a square with sides 15 cm long, are suitable for airframe areas heated to 1250 degrees. [6]

The thermal protection system (TPS) serves as a boundary between high-temperature flows and the components of the spacecraft. Thermal insulation systems are created based on two types of materials - non-ablative and ablative. Non-ablative materials, such as ceramic tiles on a spacecraft, redirect heat to protect structural elements and do not deteriorate when heated, while ablative materials deteriorate during heating, retaining their thermal insulation properties. [7] The tile structure is a semi-finished product, a permanent connection with a felt damping substrate. Due to the fact that tiles are installed on the upper part of the body of a reusable winged aircraft, an adhesive connection option is proposed for them, which requires stress calculation. Let us perform this calculation using the formula for calculating the braking energy (1):

$$r_w = \frac{q_w u_w}{c_p(T_\infty - T_w)}, \quad (1)$$

where r_w – braking energy; q_w – heat flux density on the windward part of the spacecraft; u_w – air flow velocity; c_p – heat capacity of air; T_∞ – air temperature at the design altitude (taken from GOST 4401-81), T_w – temperature on the surface of the tiled thermal protection element.[11]; [12]

For further calculations on constructing dependencies of maximum shear stresses, we will take the following parameters as initial data: heat flow density q_w = 5030 W/m²; air flow velocity u_w = 8320m/s; heat capacity of air c_p = 965 J/(kg · K); air temperature at the estimated altitude of 115 km – 116 km T_∞ = 301 K (in accordance with GOST 4401 − 81); temperature on the surface of the tiled thermal protection element T_w = 223 K. And then, according to the above formula (1) for calculating braking, its value will be obtained. (2):

$$r_w = \frac{q_w u_w}{c_p(T_\infty - T_w)} = \frac{5030\ \frac{\text{Вт}}{\text{м}^2} * 8320\ \frac{\text{м}}{\text{с}}}{965\ \frac{\text{Дж}}{\text{кг} * K}(301K - 223K)} \frac{5030\ \frac{\text{Н} * \text{м}}{\text{с} * \text{м}^2} * 8320\ \frac{\text{м}}{\text{с}}}{965\ \frac{\text{кг} * \text{м}^2}{\text{с}^2 * \text{кг} * \text{К}}(301\text{К} - 223\text{К})} = 555{,}993\ \text{Па}$$

$$r_w = 555{,}993\ \text{Па} = 0{,}00567\ \text{kg/sm}^2 \quad (2)$$

Knowing the braking energy, we write down the formula for its calculation in the form of ratio (3), taking into account the friction force and the difference in pressure between the ends and the surface of the tile (in the upper part), related to the entire area of the upper surface of the tile element.

$$r_w = \frac{F_\text{Т} - \Delta P * S_\text{торц}}{S_\text{пов}} \quad (3)$$

where $F_{\text{Т}}$ – friction force of air on the surface of the coating; ΔP – static pressure difference at the end and upper part of the orbital spacecraft PTZP element; $S_{\text{торц}}$ – area of the end surface of the tile element; $S_{\text{пов}}$ – area of the upper surface of the tile element.

From expression (3) we derive a formula for calculating the friction force (4):

$$F_{\text{Т}} = r_w * S_{\text{пов}} + \Delta P * S_{\text{торц}} \quad (4)$$

In this case, expression (4) can be simplified, since the gap between the elements of thermal protection has dimensions within 0.5 mm, while the static pressure limit is very small – in this case, we obtain the following relationship (5):

$$F_{\text{Т}} = r_w * S_{\text{пов}} \quad (5)$$

where r_w – braking energy; $S_{\text{пов}}$ – area of the upper surface of the tile element. According to the topography of the cutting of the tile heat protection, a selection of areas was made taking into account the possible limit values of the dimensions of the damping substrate and the adhesive joints of the tile - substrate and the substrate fuselage. Then we obtain the value of the area of its upper surface (6):

$$S_{\text{пов}} = b * l; \quad (6)$$

By substituting the previously obtained values of braking energy (2) and the area of the upper surface (6) into expression (5), we can find the magnitude of the friction force (7):

$$F_{\text{Т}} = r_w * S_{\text{пов}}; \quad (7)$$

Knowing the magnitude of the friction forces will allow us to determine the stress in the adhesive layer, which we write in the form of ratio (8):

$$\tau_{\text{напряж.кл.сл.}} = \frac{F_{\text{Т}}}{l} * \beta * \alpha * \frac{2*\beta-1}{\beta} * \frac{sh(\alpha*x)}{ch(\nu)} * \frac{1}{2*\beta} * \frac{ch(\alpha*x)}{sh(\nu)} \quad (8)$$

where α, β, ν – coefficients that can be determined using expressions (9) and calculated as indicated in expressions (10):

$$\alpha = \frac{G_{\text{кл}}}{E_{\text{корп}}} * \frac{h_{\text{кл}}}{h_{\text{корп}}} * \left[1 + \frac{E_{\text{корп}} * h_{\text{корп}}}{E_{\text{ПТЗП}} * h_{\text{ПТЗП}}}\right]; \beta = \frac{\frac{E_{\text{корп}} * h_{\text{корп}}}{E_{\text{ПТЗП}} * h_{\text{ПТЗП}}}}{1+\frac{E_{\text{корп}} * h_{\text{корп}}}{E_{\text{ПТЗП}} * h_{\text{ПТЗП}}}}; \nu = \frac{\alpha * l}{2} \quad (9)$$

$$\alpha = 7{,}5 * 10^{-6}; \ \beta = 5{,}625 * 10^{-7} \quad (10)$$

For the convenience of representing possible maximum stresses, we will write down the initial data: $E_{\text{ПТЗП}} = 40 * 10^9$ ГПа; $E_{\text{корп}} = 80 * 10^9$ ГПа; $G_{\text{кл}} = 2 * 10^6$ ГПа; $h_{\text{ПТЗП}} = 0{,}040$ м; $h_{\text{корп}} = 0{,}004$ м; $h_{\text{кл}} = 0{,}001$ м; $F_{\text{Т}} = 1024$ Н; $b = 1{,}63$ м; $l = 1{,}13$ м; $\tau_{\text{напряж.кл.сл.}} = 559{,}948$ Мпа.

It is necessary to provide calculations of the maximum shear stresses, which can be carried out using formula (11):

$$\tau_{\text{напряж.кл.сл.}} = r_{\text{ср}} * l * \beta * \alpha * \left[\frac{2*\beta-1}{\beta} * th(v) * \frac{1}{2*\beta} * cth(v)\right]; \quad (11)$$

The value of shear stress is obtained for the tile sizes 0,15m x 0,15m (12):

$$\tau_{\text{напряж.кл.сл.}} = 0{,}000483513 \text{ Па}. \quad (12)$$

The considered cases of calculation of shear stresses (13), (14), (15):

$$\tau_{\text{напряж.кл.сл.}} = \frac{F_T}{l} * \beta * \alpha * \frac{2*\beta-1}{\beta} * \frac{sh(\alpha)}{ch(v)} * \frac{1}{2*\beta} * \frac{ch(\alpha)}{sh(v)} \quad (13)$$

$$\tau_{\text{напряж.кл.сл.}} = \frac{F_T}{b} * \beta * \alpha * \frac{2*\beta-1}{\beta} * \frac{sh(\alpha)}{ch(v)} * \frac{1}{2*\beta} * \frac{ch(\alpha)}{sh(v)} \quad (14)$$

$$\tau_{\text{напряж.кл.сл.}} = \frac{F_T}{l*b} * \beta * \alpha * \frac{2*\beta-1}{\beta} * \frac{sh(\alpha)}{ch(v)} * \frac{1}{2*\beta} * \frac{ch(\alpha)}{sh(v)} \quad (15)$$

This calculation is presented graphically in Figure 1.

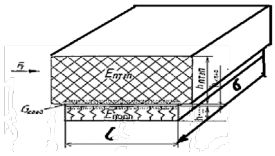

Figure 1. *Graphical representation for calculating maximum shear stresses from the bonding area*

We will carry out calculations depending on the dimensions of the substrate, substituting the indicators into the calculation formulas, using the MathCad program we will obtain values for maximum shear stresses.

The results of all the above calculations in the MathCad program are shown in Table 1.

Table 1

Summary table

№	l, m	b, m	$S_{\text{пов}}$, м^2	F_T, Н	$\tau_{\text{напряж.кл.сл.}}$ [13]	$\tau_{\text{напряж.кл.сл.}}$ [14]	$\tau_{\text{напряж.кл.сл.}}$ [15]
1	0,031	0,033	0,001023	0,568	0,000106234	0,0000997955	0,00321921
2	0,062	0,075	0,00465	2,585	0,000241738	0,000199837	0,00322318
3	0,124	0,15	0,0186	10,341	0,000483523	0,000399712	0,00322349
4	0,248	0,3	0,0744	41,365	0,00096707	0,000799444	0,00322357
5	0,1	0,124	0,0124	6,894	0,000399712	0,000322349	0,00322349
6	0,1	0,15	0,015	8,339	0,000483493	0,000322329	0,00322329
7	0,124	0,25	0,031	17,235	0,000805872	0,000399712	0,00322349
8	0,08	0,15	0,012	6,671	0,000483479	0,000257855	0,00322319

9	0,06	0,15	0,009	5,003	0,000483455	0,000193382	0,00322303
10	0,15	0,15	0,0225	12,509	0,000483513	0,000483513	0,00322342

In order to assess the influence of aerodynamic action on thermal protection, we will construct graphs of the dependence of maximum shear stresses in the adhesive joint on the gluing area, taking into account the possible bending of the wing and additional vibration loads acting on the tile (Figure 2).

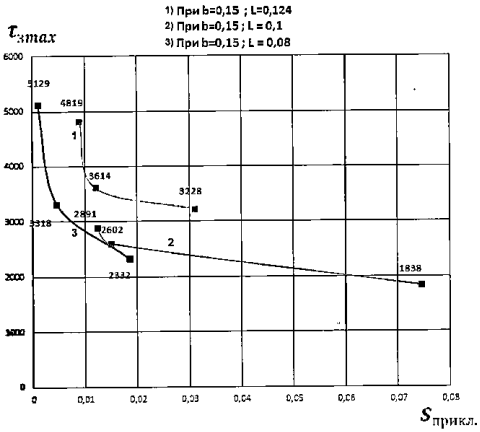

Figure 2. *Graph of the dependence of maximum shear stress on the bonding area for different substrate lengths.*

By changing the substrate length parameter with a constant length of the heat-protective tile equal to 0.15 m, we obtained a clear representation of the fact that with a decrease in the bonding area, there is a sharp increase in the maximum shear stress in the adhesive joint in each separately considered case.

Conclusions

Thus, based on the calculation of the heat-protective tile, it was revealed that the shear stress increases in the area of the bonding area, which is approximately equal to 0,01 $м^2$. Площадь приклейки считается критической при значении в 0,0125 $м^2$. Air temperature at the estimated altitude T_∞ = 301 K (in accordance with GOST 4401-81); temperature on the surface of the tiled heat-protection element T_w = 223 K. In this case, all stresses are within the tolerance limits, therefore the adhesive joint Elastosil 137-175M is applicable in the design of the winged MCA.

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DOI 10.34660/INF.2025.82.55.060

中国数字化改革与政府效能数字化的历史演进与研究现状
HISTORICAL EVOLUTION AND CURRENT RESEARCH STATUS OF DIGITAL REFORM AND DIGITISATION OF GOVERNMENT EFFECTIVENESS IN CHINA

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摘要：本文对我国数字化改革与政府效能数字化的历史沿革和研究现状进行了深入探讨，追溯了信息化从萌芽到发展成熟阶段的历史，分析了不同阶段的政策推动、技术应用和取得的成果，同时全面描述了该领域理论研究和实践探索的现状，揭示了存在的问题并展望了未来的发展方向，旨在为进一步推进数字化改革、提升政府效能数字化水平提供理论基础和实践参考。

关键词：数字化改革、政府效能数字化、历史沿革、研究现状。

Abstract. *This paper provides an in-depth discussion of the historical evolution and current research status of digital reform and digitisation of government effectiveness in China. It traces the history of informatisation from its nascent stage to the rich stage of its development, and analyses the promotion of policies, application of technologies, and the results achieved at different stages. At the same time, it comprehensively describes the current status of the field in terms of theoretical research and practical exploration, reveals the existing problems and looks forward to the future development direction, aiming to provide a theoretical basis and practical references for further promoting digital reform and enhancing the level of digitalisation of government effectiveness.*

Keywords: *digital reform, digitisation of government effectiveness, historical evolution, current state of research.*

Driven by the global wave of digitalisation, China has been actively promoting digital reform, and the digitalisation of government effectiveness, as a key part of it, is of far-reaching significance in enhancing government governance capacity, optimising public services, and promoting economic and social development. An in-depth understanding of its history and current research situation can help grasp the developmental vein, clarify the future direction, and better play the role of digitisation in government operation and governance.

I. The history of digital reform and digitisation of government effectiveness

1.1 Germination stage

Before the 18th National Congress, the concept of informatisation to promote economic and social development began to sprout. In 2000, when informatisation was not yet widely spread and digitisation had not yet fully sprouted, Xi Jinping, the then Party Secretary of Fujian Province, understood the leading role of informatisation and digitisation in economic and social development, and made the strategic decision to build 'Digital Fujian' with foresight, proposing that ''Digital Fujian' is the Fujian of informatisation', which means that 'Digital Fujian is the Fujian of informatisation'. In 2003, Xi Jinping, then Party Secretary of Zhejiang Province, proposed the construction of 'Digital Zhejiang' at the First Session of the 10th National People's Congress of Zhejiang Province, and in the same year, Xi Jinping proposed the construction of 'Digital Zhejiang'. In 2003, Xi Jinping, the then Party Secretary of Zhejiang Province, proposed the construction of 'Digital Zhejiang' at the first meeting of the 10th National People's Congress of Zhejiang Province, and in the same year, the government of Zhejiang Province issued the 'Outline of Digital Zhejiang Construction Plan (2003-2007)', in which it put forward the six major tasks of driving industrialisation by informatisation, accelerating the construction of e-government affairs, comprehensively promoting the construction of digital cities, promoting the informatisation of rural areas and agriculture, giving priority to the development of information industry, and strengthening the cultivation of talents and building of informatisation environment. In 2006, the General Office of the CPC Central Committee and the General Office of the State Council issued the National Informatisation Development Strategy for 2006-2020, which elevated informatisation to a national strategy. 2008, the General Office of the CPC Central Committee and the General Office of the State Council issued the Eleventh Five-Year Plan for Informatisation of the National Economy and Social Development, which was led by the National Development and Reform Commission of China. In 2008, the General Office of the CPC Central Committee and the General Office of the State Council issued the 'Eleventh Five-Year Plan for Informatisation of National Economy and Social Development', which is an important part of the Eleventh Five-Year Plan for National Economy and Social Development.

1.2 Formation stage

From the 18th National Congress to the 19th National Congress, the strategic importance of China's informatisation development has been further highlighted, and the system of government informatisation and digital government has been initially formed. Since the 18th National Congress, the CPC Central Committee and the State Council have attached great importance to the construction of in-

formation technology, and on December 8, 2012, the report of the 18th National Congress of the CPC put forward the 'New Four Modernisations', which is 'insisting on taking the road of new-type industrialisation, informatisation, urbanisation and agricultural modernisation with Chinese characteristics'. On 8 December, in the report of the 18th CPC National Congress, it was proposed that the 'New Four' should 'adhere to the path of new industrialisation, urbanisation and agricultural modernisation with Chinese characteristics', which includes six tasks, including the construction of a next-generation information infrastructure, the development of a modern information technology industry system, the integration of informatisation with industrialisation, the exploration of the integration of informatisation with urbanisation, the integration of informatisation with agricultural modernisation, the advancement of openness to the public, the enhancement of informationisation in the management of the society, and the improvement of the information security system. Xi Jinping made an important statement at the first meeting of the Central Network Security and Informatisation Leading Group that 'there is no national security without network security, and no modernisation without informatisation', further clarifying the importance of informatisation in Chinese-style modernisation.On 15 December 2016, the State Council issued the 'National Informatisation Plan for the 13th Five-Year Plan', which deploys 10 major tasks, including building a modern information technology and industrial ecosystem, constructing a ubiquitous and advanced information infrastructure system, establishing a unified and open big data system, constructing an integrated and innovative information economy system, supporting the construction of a good and efficient national governance system, and forming an inclusive and convenient information system for the benefit of the people. The system of universal and convenient information benefits the people, create a system of deep integration and development of the military and the people, expand the service system of the global development of network information enterprises, improve the system of cyberspace governance, and improve the system of cybersecurity. 27 August 2017, the National Development and Reform Commission issued the '13th Five-Year Plan' for the construction of the national government information project. It puts forward the key construction of 'two networks, one platform, four libraries, six systems' and other major national government affairs informatisation projects. That is to say, the construction of the national e-government intranet and the national e-government extranet; the creation of a national data sharing and exchange platform (including a national government affairs sharing website and a public data opening website) with 'nationwide coverage, integrated use and unified access'; the continuous promotion of the construction and improvement and exploitation of basic information bases on population, legal entities, natural resources and geospatial resources, and social credit; and the planning and design

of the Party's basic information base and the development and utilisation of the same. It has continued to promote the construction and development and utilisation of basic information databases on population, legal entities, natural resources and geospatial information, and social credit information; and has planned and designed six major systems, including the Party's governing capacity, democracy and the rule of law, comprehensive regulation, market supervision, public services, and public security governance. The overall framework of government informatisation work has been initially formed, and has become an important basis for localities to formulate development plans for government informatisation in their regions and promote the implementation of government informatisation projects.

1.3 Development and enrichment stage

After the 19th National Congress, the connotation of government informatization, digital government, and the construction of digital China has been continuously developed and enriched. 2017, the report of the 19th National Congress of the CPC explicitly proposed the construction of a strong network country, digital China, and a smart society, and 'digital China' was written into the programmatic documents of the CPC and the state for the first time. 2021, the fourth meeting of the thirteenth Chinese People's Congress adopted the Outline of the Fourteenth Five-Year Plan for National Economic and Social Development and Visionary Goals for 2035, and the Outline put forward in 'Part V Accelerating Digital Development and Building Digital China'. Conference adopted the Outline of the Fourteenth Five-Year Plan for National Economic and Social Development and the Vision 2035, which proposes in 'Part V Accelerating Digital Development and Building a Digital China' to 'embrace the digital era, activate the potential of data elements, promote the construction of a strong networked country, and accelerate the construction of a digital economy, a digital society, and a digital government'. digital economy, digital society, digital government, with digital transformation as a whole to drive changes in the mode of production, lifestyle and governance', digital transformation has become an important initiative to build a digital China.2022, the State Council issued the "Guiding Opinions on Strengthening the Construction of Digital Government", which puts forward the construction of a synergistic and efficient system of the government's digital performance capacity, a digital government The State Council issued the Guiding Opinions on Strengthening Digital Government Construction, proposing the construction of a collaborative and efficient government digital performance capability system, an all-round security system, a scientific and standardised digital government construction system and rules system, an open and shared data resource system, and an intelligent and intensive platform support system.2023 In February 2023, the Central Committee of the Communist Party of China (CPC) and the State Council issued the 'Overall Layout Plan for the Construction of Digital China',

which clarified the guiding ideology, main goals, key tasks and safeguards for the construction of Digital China. The work of government informatisation has been continuously deepened and enriched and developed, and further integrated into the ambitious planning and design of digital government and digital China construction.

II. Current status of research

2.1 Theoretical Research

At the theoretical level, academics have carried out extensive research around digital reform and digitalisation of government effectiveness. The research covers the theoretical basis of digital government, the impact of digitalisation on the government governance model, and the digital evaluation system of government effectiveness. Some scholars have explored the theoretical framework of digital government construction, analysed the logic of digital government construction from the technical, organisational and institutional perspectives, and provided theoretical guidance for practice. In terms of digital assessment of government effectiveness, a multi-indicator assessment system including convenience of government services, degree of data sharing, scientific decision-making, etc. is constructed to measure the level of digitalisation of government effectiveness, and to promote the government's continuous improvement of digital construction. At the same time, the theoretical issues such as the change of the government's role and the change of the power operation mechanism in the digital reform are discussed in depth, providing theoretical support for the improvement of the governmental governance system.

2.2 Practical Exploration

In practice, governments around the world actively carry out digital reform and innovation practices. In the field of government services, they continue to optimise the integrated government service platform, expand the scope of service matters, improve the level of service intelligence, and realise more matters to be done 'on the palm of your hand' and 'at your fingertips'. For example, Guangdong has launched the 'Guangdong Provincial Affairs' platform, which integrates a number of livelihood service matters to facilitate people's work. In terms of social governance, digital technology has been used to build a city brain to achieve all-round monitoring and management of urban operations. The Hangzhou City Brain improves the effectiveness of urban governance by integrating data from multiple departments, such as traffic, urban management and public security, to achieve intelligent traffic scheduling and rapid response to urban events. At the same time, governments around the world are actively exploring data sharing and opening mechanisms, promoting data circulation and application, stimulating social innovation and vitality, and promoting the development of the digital economy and society.

2.3 Problems

Despite the remarkable progress, there are still some problems. First, it is difficult to share data; data standards of different departments are not unified and systems are not compatible, leading to poor data circulation and restricting the improvement of government effectiveness. Secondly, there is a shortage of digital talents, government departments lack of both business and technical knowledge of the composite talent, affecting the construction and application of digital projects. Thirdly, the challenge of network security, digital reforms make the government face more network security risks, such as data leakage, cyber attacks, etc., threatening the operation of the government and public information security.

III. Conclusion and Prospect

China's digital reform and digitalisation of government effectiveness have gone through a development process from initial exploration to comprehensive deepening, and have achieved remarkable results, promoting changes in the government's governance model and improving its effectiveness. The current research has achieved some results in both theory and practice, but there are still problems to be solved. In the future, we should strengthen the unification of data standards and the construction of sharing mechanisms, cultivate digital talents, and improve the ability of network security protection. At the same time, we should continue to deepen the digital reform, explore the application of new technologies in government governance, such as blockchain technology to enhance the security and credibility of data, further improve the digital level of government effectiveness, and promote the modernisation of the national governance system and governance capacity.

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DOI 10.34660/INF.2025.93.21.061

计算机软件《机车维护间隔自动优化》
COMPUTER SOFTWARE «AUTOMATED OPTIMIZATION OF LOCOMOTIVE MAINTENANCE INTERVALS»

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摘要。本文介绍了一种用于处理牵引机车车辆 (TRS) 故障数据并根据可靠性和成本效益标准优化维护间隔的计算机软件。该软件执行以下功能：分析机车部件/单元可靠性指标；对机车单元故障分布进行统计假设检验；并生成优化维护间隔里程的建议，同时考虑所选解决方案的成本效益。该软件旨在促进对机车车队状况的评估，从而能够在最大限度地降低成本的同时就计划外维护或计划内维修做出明智的决策。此外，生成的数据允许对潜在的先前故障进行回顾性分析。

关键词：机车维护；自动优化；维修间隔；牵引机车车辆 (TRS)；可靠性分析；成本效益；故障预测；维护计划。

Abstract. *This paper presents computer software designed for processing traction rolling stock (TRS) failure data and optimizing inter-maintenance intervals based on reliability and cost-effectiveness criteria. The software performs the following functions: analysis of locomotive component/unit reliability indicators; statistical hypothesis testing for the distribution of locomotive unit failures; and generation of recommendations for optimizing inter-maintenance mileage, considering the cost-effectiveness of the chosen solution. The software aims to facilitate assessment of the locomotive fleet condition, enabling informed decisions regarding unscheduled maintenance or planned repairs while minimizing costs. Furthermore, the generated data allows for retrospective analysis of potential prior failures.*

Keywords: *Locomotive Maintenance; Automated Optimization; Inter-repair Intervals; Traction Rolling Stock (TRS); Reliability Analysis; Cost-Efficiency; Failure Prediction; Maintenance Scheduling.*

Introduction

The maintenance and repair of traction rolling stock (TRS) are governed by both universal principles and specific considerations, dictated by a complex interplay of technical requirements defining the necessary condition of the TRS and

the industry's standards for maintaining that condition. A key requirement is the reliability of TRS repairs, ensuring the effective execution of transportation processes under diverse operating conditions [1]. Reliability, as a complex property, encompasses various aspects depending on the object's purpose and operating environment, including fail-safe operation, durability, maintainability, and storage suitability.

Optimizing Locomotive

Maintenance Intervals A central challenge in TRS reliability management is determining optimal inter-maintenance intervals. Within a planned preventative maintenance and repair system for locomotives, this optimization process relies on analyzing the reliability indicators of technical units and components, coupled with an assessment of the economic aspects of locomotive maintenance and repair. Currently, the implementation of inter-maintenance runs on the Russian Railways network adheres to the provisions outlined in Order 2796r of JSC Russian Railways, amended on January 28, 2020, No. 2070r [2]. However, this approach suffers from a significant limitation: the failure to account for variations in operational conditions across different railway sections and maintenance facilities. This oversight compromises the accuracy of reliability calculations for locomotive units and their corresponding maintenance schedules, ultimately leading to a decline in overall reliability. The resulting economic losses underscore the importance and relevance of this issue. To address the challenge of locomotive unit reliability, we propose a model for managing the technical condition of the locomotive fleet. This model will be predicated on the analysis of failure-free performance indicators, statistical hypothesis testing for failure distributions, establishing the underlying failure distribution law, and optimizing inter-maintenance intervals tailored to individual repair facilities.

The effectiveness of a planned preventative maintenance system hinges on aligning inspection and repair schedules with the actual technical condition of the locomotive. Downtime during maintenance or repair is a function of several variables, including workload, workflow organization, and the inherent reliability and maintainability of the locomotive itself. To optimize inter-maintenance intervals, specifically to minimize unscheduled repairs and reduce maintenance, repair, and overhaul (MRO) costs, dedicated computer software has been developed (Figure 1).

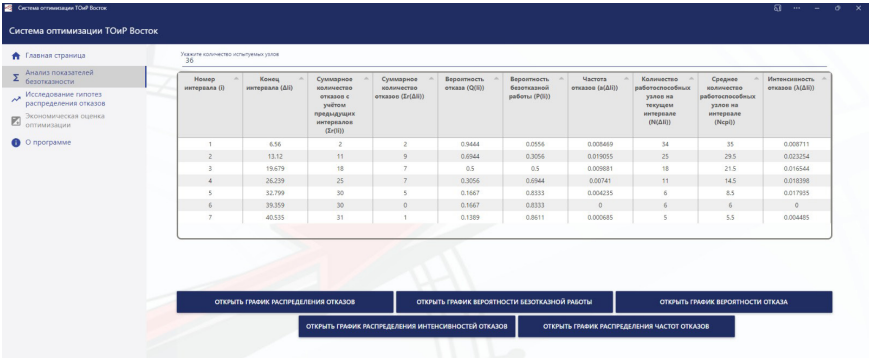

Figure 1. *The software interface for the assessment of locomotive inter-repair runs/mileage*

The software operates in several stages. The initial stage, performed manually by a specialist, involves sorting equipment failure data according to the following criteria:

1. Equipment classifier adopted by the operating enterprise (enlarged).
2. Type of failed equipment at the unit level.
3. Specific components.
4. Nature of the malfunction.

The second stage involves data input into the software. Required data includes the cost of unscheduled repairs, the cost of planned repairs (e.g., TR-1, TR-2), the standard inter-maintenance mileage for the relevant repair type, and the sorted failure data.

The software aims to evaluate the potential for optimizing inter-maintenance mileage standards and subsequently adjust these standards, considering economic implications (Figure 2). This process unfolds as follows:

1. Comparison of unscheduled and planned repair costs and calculation of the economic efficiency of adjusting inter-maintenance mileage standards.

1.1 If the cost of planned repairs is higher, the occurrence of failures is considered within the acceptable inter-maintenance mileage range, as defined by regulatory documentation (e.g., ±20% of 50,000 km).

If no failures are observed within this range, the inter-maintenance mileage standards remain unchanged.

If a failure occurs, the minimum inter-maintenance mileage is applied.1.2 If the cost of unscheduled repairs is higher, then a search is conducted for a cost-effective operating interval for equipment repairs.

- A statistical analysis of the distribution of failures shall be conducted. This involves the calculation of TRS runs l by intervals Δli in accordance with Stur-

ges's rule, as well as the calculation of the probability of failure-free operation, probability of failures, failure rates, average number of operational units, and failure rates of TRS, along with the average time to failure.

- The failure distribution rule is determined. If failures do not adhere to the established distribution rules, changes in the standards of inter-repair run/mileage will not be applied.

- A hypothesis regarding the distribution of failures is being investigated.

When a normal distribution is considered, the following values are calculated: the sampling average operating interval Δ*l*, thousand km; the sampling average operating intervals Δ*lcpi*, thousand km; and the sum of the number of failures at operating intervals Σ*r*(Δ*li*) by the sampling averages of these operating intervals Δl*cpi*; mathematical expectation of failure *m*, thousand km; dispersion; standard deviation; normalized variables; density of the normalized normal distribution *ϕ(bi)*; value of theoretical failures of normal distribution Σ*rn*(Δ*li*); the sum of the Pearson coefficients is determined and compared with the critical value.

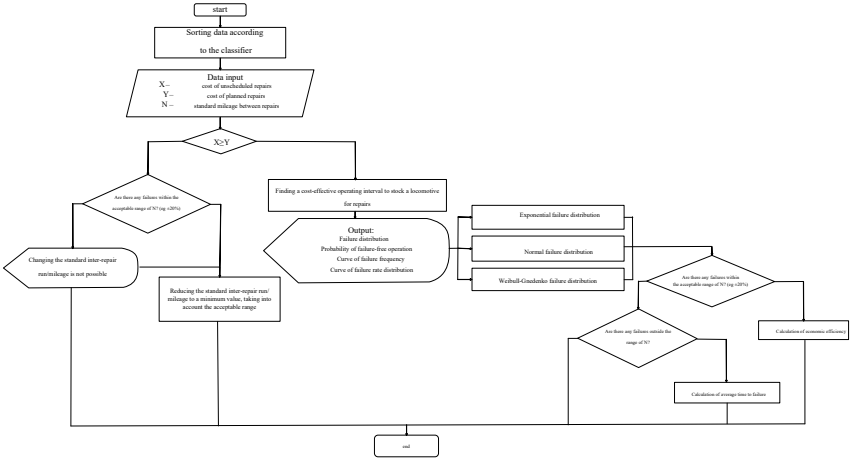

Figure 2. *Algorithm of the software for optimizing standards of inter-repair run/mileage*

For an exponential distribution, the following are calculated: the sample average operating interval (Δl), in thousands of kilometers; the sample average operating intervals, in thousands of kilometers; the sum of the number of failures at operating intervals by the sample averages of these operating intervals; the expected value of failure, in thousands of kilometers; the failure rate, in thousands of kilometers; the theoretical number of failures under an exponential distribution;

and the sum of Pearson's chi-squared statistic for the exponential model, which is then compared to the critical value. If the calculated value is less than the critical value, modification of the inter-maintenance mileage standards is permissible. If no failures occur within the permissible operating interval, the inter-maintenance mileage standards remain unchanged.

2. The software then searches for the most economically advantageous operating interval for repairs. It determines the annual costs for scheduled equipment repairs and the costs of unscheduled repairs, calculated based on the predicted number of failures. The operating period that minimizes overall repair costs is selected.

This software for processing TRS failure data and optimizing inter-maintenance mileage standards offers a valuable tool for enhancing the reliability and cost-effectiveness of locomotive operations. By analyzing locomotive unit reliability indicators and testing hypotheses about failure distributions, the software generates recommendations for optimizing inter-maintenance intervals. This facilitates timely scheduling of unscheduled maintenance or routine repairs, minimizing associated costs. The results contribute to a more accurate assessment of the locomotive fleet's condition and the prediction of potential failures, ultimately improving the overall efficiency and reliability of railway transportation.

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DOI 10.34660/INF.2025.53.50.062

网络安全和关键信息基础设施保护的现代挑战：趋势、技术和策略
MODERN CHALLENGES IN CYBERSECURITY AND PROTECTION OF CRITICAL INFORMATION INFRASTRUCTURE: TRENDS, TECHNOLOGIES, AND STRATEGIES

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摘要。在数字化转型时代，网络安全仍然是政府、企业和社会关注的重点。由于网络威胁不断增加，包括勒索软件攻击和国家支持的网络间谍活动，保护关键信息基础设施（CII）至关重要。本文探讨了现代网络安全挑战、保护技术的最新趋势以及保护 CII 的战略方法。该研究重点关注人工智能（AI）、零信任架构和监管框架的最新发展。

关键词：网络安全、关键信息基础设施、网络威胁、人工智能、零信任架构、监管措施。

Abstract. *In the era of digital transformation, cybersecurity remains a critical concern for governments, businesses, and society. The protection of critical information infrastructure (CII) is of paramount importance due to the growing number of cyber threats, including ransomware attacks and state-sponsored cyber espionage. This paper examines modern cybersecurity challenges, the latest trends in protection technologies, and strategic approaches to securing CII. The study focuses on recent developments in artificial intelligence (AI), zero-trust architecture, and regulatory frameworks.*

Keywords: *cybersecurity, critical information infrastructure, cyber threats, artificial intelligence, zero-trust architecture, regulatory measures.*

Introduction

With the rapid advancement of information technologies, modern societies are becoming increasingly dependent on digital infrastructure. Critical sectors such as energy, healthcare, finance, and transportation rely heavily on networked systems, making them attractive targets for cybercriminals. The goal of this paper is to analyze the evolving cybersecurity landscape and propose strategies to protect CII from emerging threats.

What is Cybersecurity and How Does It Work?

Cybersecurity is the practice of protecting computer systems, networks, and data from cyber threats such as hacking, malware attacks, cyber espionage, and fraud. It encompasses a wide range of measures aimed at **preventing, detecting, and mitigating threats**, ensuring the **confidentiality, integrity, and availability** of information.

How Does Cybersecurity Work?

Cybersecurity operates through several key components to ensure the protection of digital assets:

1. Preventing Attacks

- Utilizing **antivirus software** and **firewalls** to block malicious activity.
- Regularly **updating software and operating systems** to patch vulnerabilities.
- Implementing **strong password policies** and **two-factor authentication (2FA)** for enhanced access security.

2. Threat Detection

- **Monitoring network activity** and detecting anomalies using **SIEM (Security Information and Event Management) systems**.
- Deploying **Intrusion Detection and Prevention Systems (IDS/IPS)** to identify and stop suspicious behavior.

3. Incident Response

- Developing and testing **incident response plans** to minimize damage.
- **Isolating infected systems** to prevent the spread of cyber threats.
- Conducting **post-incident analysis** to enhance future security measures.

4. Post-Attack Recovery

- **Backing up critical data** and regularly testing recovery procedures.
- Restoring system functionality after security breaches.
- Performing **security audits** to identify and address vulnerabilities.

This multi-layered approach helps organizations strengthen their defenses against evolving cyber threats.

Key Aspects of Cybersecurity

Cybersecurity consists of several essential components aimed at ensuring the security of digital environments:

1. Attack Prevention

- Deploying antivirus software and firewalls to block malicious threats.
- Regularly updating software and operating systems to fix security vulnerabilities.
- Enforcing strong password policies and two-factor authentication (2FA) to enhance authentication security.

2. Threat Detection

- Monitoring network activity and detecting anomalies using SIEM (Security Information and Event Management) systems.
- Implementing Intrusion Detection and Prevention Systems (IDS/IPS) to identify and mitigate suspicious activities.

3. Incident Response

- **Developing and testing incident response plans** to minimize damage.
- **Isolating compromised systems** to prevent the spread of cyber threats.
- **Conducting post-incident analysis** to improve security measures for future attacks.

4. Post-Attack Recovery

- **Backing up critical data** and regularly testing recovery procedures.
- **Restoring system functionality** after security breaches.
- **Performing security audits** to identify and mitigate vulnerabilities.

Modern Cyber Threats and Risks

Cyber threats continue to evolve, impacting both government and private organizations. The most significant threats include:

- Ransomware Attacks – A growing number of attacks that encrypt data and demand ransom payments.
- Cyber Espionage – State-sponsored attacks aimed at stealing confidential information.
- Supply Chain Attacks – The exploitation of weak links in supplier networks to compromise companies.
- Internet of Things (IoT) Vulnerabilities – Insufficient security measures in connected devices, making them easy targets.
- AI-Powered Attacks – The use of machine learning algorithms to automate sophisticated cyber-attacks.

By understanding these threats and implementing proactive security measures, organizations can better protect their critical systems from evolving cyber risks.

Statistical Analysis of Cyber Threats

According to a Cybersecurity Ventures report, global cybercrime damages are projected to exceed $10.5 trillion annually by 2025. In 2023, the impact of cyber threats was particularly severe:

- Ransomware attacks increased by 37% compared to the previous year.
- The average ransom payment reached $1.2 million per attack.
- 60% of small and medium-sized businesses (SMBs) shut down within six months following a major cyberattack.
- These statistics highlight the growing financial and operational risks posed by cyber threats, emphasizing the urgent need for enhanced cybersecurity measures across industries.

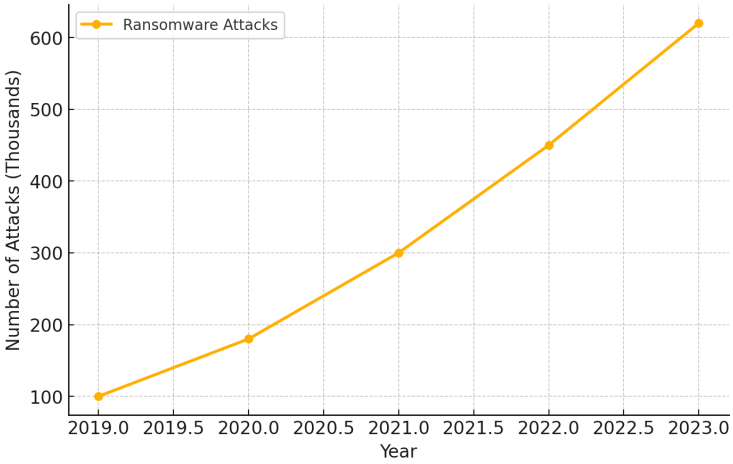

Figure 1. *Ransomware Attack Growth Dynamics (2019–2023)*

Financial Losses and Cybersecurity Expenditures

Cybersecurity consists of several essential components aimed at ensuring the security of digital environments:

1. Attack Prevention
   - Deploying antivirus software and firewalls to block malicious threats.
   - Regularly updating software and operating systems to fix security vulnerabilities.
   - Enforcing strong password policies and two-factor authentication (2FA) to enhance authentication security.
2. Threat Detection
   - Monitoring network activity and detecting anomalies using SIEM (Security Information and Event Management) systems.
   - Implementing Intrusion Detection and Prevention Systems (IDS/IPS) to identify and mitigate suspicious activities.
3. Incident Response
   - Developing and testing incident response plans to minimize damage.
   - Isolating compromised systems to prevent the spread of cyber threats. **Conducting post-incident analysis to improve security measures for future attacks**
4. Post-Attack Recovery
   - Backing up critical data and regularly testing recovery procedures.
   - Restoring system functionality after security breaches.
   - Performing security audits to identify and mitigate vulnerabilities.

Rising Cybersecurity Investments

As cyber threats become more advanced and costly, organizations are significantly increasing their cybersecurity budgets to mitigate risks and comply with evolving regulations.

- Global cybersecurity spending surpassed $188.3 billion in 2023, a sharp rise from previous years.
- The average annual budget growth for information security is 12% per year, driven by rising attack sophistication and regulatory requirements.
- Small and medium-sized enterprises (SMEs) are investing more in cybersecurity solutions, with 60% of SMEs increasing their budgets in 2023 to prevent catastrophic breaches.
- Cloud security spending has surged due to the increased adoption of cloud services and remote work infrastructure.
- Zero-trust architecture is becoming a standard investment, with organizations allocating resources to identity and access management (IAM) and multi-factor authentication (MFA) solutions.

Future Cybersecurity Investment Projections

By 2026, cybersecurity investments are expected to exceed $260 billion, with the highest spending allocated to:

- AI-driven threat detection and response systems
- Endpoint security and zero-trust frameworks
- Cloud security and data protection measures
- Cyber resilience planning and disaster recovery solutions

With cyberattacks continuing to evolve, businesses must adopt a proactive security strategy, integrating advanced threat intelligence, real-time monitoring, and automated security responses to minimize financial losses and operational risks.

Trends in Cybersecurity Technologies

To counteract emerging cyber threats, new technologies have been developed to enhance security measures.

1. Artificial Intelligence and Machine Learning

- Real-time automated threat detection and anomaly detection.
- Predictive vulnerability analytics to identify security weaknesses before exploitation.

2. Zero-Trust Architecture

- Eliminates implicit trust for both internal and external users by default.
- Granular access control ensures that users and devices are verified before access is granted.

3. Blockchain for Security

- Decentralized access control reduces the risk of unauthorized modifications.
- Ensures data immutability, preventing tampering and fraud.

4. Quantum-Resistant Cryptography

- Development of encryption algorithms that can withstand future quantum computing attacks.

Table 1.

Comparative Analysis of Critical Infrastructure Protection Technologies

Technology	Advantages	Limitations
Artificial Intelligence	Automated threat detection, high-speed analysis	High implementation cost, potential false positives
Zero-Trust Architecture	Full access control, prevents insider threats	Complex setup and management requirements
Blockchain	High data security, transparency	Limited scalability and high energy consumption
Quantum-Resistant Cryptography	Protection against quantum-based attacks	Quantum computing is still in early stages of development

Strategies for Protecting Critical Information Infrastructure

A multi-layered approach is essential for securing critical infrastructure against cyber threats:

- Regulations and Standards: Compliance with international cybersecurity frameworks such as NIST and ISO 27001.
- Public-Private Partnerships: Collaboration between government and private sectors to share cyber threat intelligence.
- Cyber Resilience: Development of disaster recovery and business continuity strategies to withstand attacks.
- Employee Training and Awareness: Educating personnel on cyber risks, phishing threats, and best security practices.

Conclusion

Modern cyber threats are evolving in both complexity and scale, posing significant challenges to governments, enterprises, and critical infrastructure sectors. The increasing sophistication of cyberattacks, including ransomware, supply chain breaches, and AI-driven cyber threats, highlights the necessity for proactive and multi-layered defense strategies.

To effectively mitigate cyber risks, organizations must adopt a comprehensive cybersecurity approach that integrates:

- Artificial Intelligence (AI) and Machine Learning for real-time threat detection and predictive analytics.
- Zero-Trust Architecture, ensuring strict access control and continuous identity verification.
- Blockchain Technology for data integrity and secure transaction validation.

- Quantum-Resistant Cryptography to future-proof security measures against emerging quantum computing threats.

Beyond technological advancements, regulatory compliance and international cybersecurity standards play a vital role in establishing a unified security framework across industries. Adhering to standards such as NIST, ISO 27001, GDPR, and CCPA ensures structured risk management and incident response planning.

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DOI 10.34660/INF.2025.13.13.063

森林面积从“宝贵的抗侵蚀林”到“宝贵的森林草原林”的动态变化
DYNAMICS OF THE FOREST AREA FROM “VALUABLE ANTI-EROSION FORESTS” TO “VALUABLE FOREST-STEPPE FORESTS”

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注释。本文考察了萨拉托夫州沃尔斯基林业的森林面积，并提出了将指定森林面积从“有价值的抗侵蚀森林”森林分类为“有价值的森林草原森林”的理由。

关键词：森林面积、树种、森林火灾、森林保护类别、分区、开垦。

Annotation. *The article examines the forest area of the Volsky forestry of the Saratov region and suggests a justification for correcting the classification of the specified forest area from the forests of “valuable anti-erosion forests” to “valuable forest-steppe forests”.*

Keywords: *Forest area, tree species, forest fire, forest protection categories, zoning, reclamation.*

Forests, being part of the natural sphere, perform a number of important and unique ecological and economic functions, and therefore the definition of permitted types of forest management should be comprehensive and integrated.

The main tools for organizing the use of forests are the categories of protection of forest areas established by forest management materials and the functional zoning of their territories, which make it possible to optimize the ratio of forest development measures and methods of protecting forest resources. The assignment of forest plots to a certain category of forest protection and the functional zoning of their territory is carried out on the basis of forest management documentation.

Meanwhile, since the last forest management of the territory of forest areas, under the influence of a combination of changing climatic conditions, unfavorable forest pathology factors and anthropogenic impact, including forest fires, the quantitative and qualitative characteristics of forest areas can change dynamically [2, 3].

The relevance of scientific research is due to the study of the possibility of adjusting the functional purpose of forest areas within the category of protective forests "valuable forests" established by the forest management materials, taking into account the changed qualitative and quantitative characteristics of forest areas.

The purpose of the research work is to survey the forest area in block 58 (part of the 9,16,10 forest taxa allotments) of the Urban Forestry District of the Volsky Forestry District of the Saratov region and prepare a reasoned justification for correcting the assignment of the specified forest area from the forests of "valuable anti-erosion forests" to "valuable forest-steppe forests".

To achieve the set research goal, the following research methods were used: theoretical (literary); study of the regulatory and legislative framework, scientific literature; methods of forest pathology examination; assessment of the sanitary condition of plantings; methods of ground taxation; assessment of forest management indicators of stands; methods of IT technologies; use of auxiliary tools, software technologies (NoteCam Lite, Garmin BaseCamp, QGIS, SNAP, MS Excel. GPS Utility) and others [1. 3, 4].

The object of research is a forest area with an area of 5.0969 hectares, located on the territory of the Volsky municipal district of the Saratov region within the boundaries of block 58 (part of the forest taxa allotments 9, 16, 10) of the Urban forestry district of the Volsky Forestry District of the Saratov region, which consists of: forest lands occupied by forest, with an area of 3.4969 hectares; non-forest lands with an area of 1.6 hectares. The predominant species is petiolate oak, hardwood farming, the composition of plantings is 5Dnh4Lp1Klo, the age at the time of the survey is 140 years, the bonus is 4, the reserve of overstocked wood is 142 m3, the average reserve per 1 hectare is 40.6 m3.

All forests in the Saratov region, including the forests of the Volsky forestry, belong to the category of protective forests for their intended purpose. The pur-

pose of a land plot is a legally defined set of characteristics (categories and types of permitted use) that establishes the rights and obligations of the owner to conduct business on the land plot. [1. 5, 6].

The variety of climatic conditions in the Saratov region is due to the large extent of the territory in the latitudinal and meridional directions. The location on the right bank of the Volga River and the general rise of the territory in the northern direction create conditions for vertical zonation. It is an additional factor of spatial climate variability.

The current forestry regulations of the Volsky Forestry District of the Saratov region, approved by Decree of the Government of the Saratov Region dated 30.06.2016 No. 321-P, was developed on the basis of forest management materials from 1995, i.e. the last forestry management of the forestry territory was carried out almost 30 years ago, and therefore certain standards and parameters established by the regulations could become outdated and lose their relevance in terms of their enforcement [6].

According to the Methodological Guidelines for the implementation of zoning in forests (approved by the order of the Federal Forestry Agency dated December 26, 2018 No. 1067), the entire territory of the Volsky Forestry district of the Saratov region belongs to the zone of severe forest-pathological threat as part of the forest-steppe zone of the forest-steppe region of the European part of the Russian Federation.

As part of field surveys of the forest area in block 58 of the Urban District Forestry of Volsky Forestry, a number of factors were identified that have a negative impact on the forest resources of the site, reducing the effectiveness of their protective functions, including forest fires.

In the surveyed forest area, numerous places were found that were traversed by the grass-roots forest fires of previous years (1993-2024), which caused damage or destruction of undergrowth and forest litter in individual areas, drying out of the upper soil horizon of the soil, damage to trees to the extent of cessation of growth, as well as the death (desiccation) of individual trees.

The total number of such sites was 90% of the total area of the surveyed site. This factor significantly reduces the stability of plantings as a whole and does not contribute to the goals of their sustainable use.

Conclusions: summarizing the above-mentioned relevant qualitative characteristics of the forest area under study in block 58 of the Urban District Forestry District of the Volsky Forestry District of the Saratov region, it is possible to draw a reasonable conclusion that:

- non-forest lands with an area of 1.6 hectares occupied by an uncultivated sand quarry, completely devoid of vegetation, in fact cannot perform any, even minimal, anti-erosion function, up to the full implementation of measures for min-

ing and technical reclamation of disturbed lands aimed at creating optimal steepness of the slopes of the sides of the quarry, blackening and afforestation of such an area in order to protect The protection of soils from water and wind erosion is objectively excluded;

- the unsatisfactory condition of the forest area requires, within the framework of its development, measures for the protection, protection and reproduction of forests in order to increase the effectiveness of their protective functions.

Currently, all of the above recommendations for the development of the surveyed forest area are provided for in the developed technical project, which was approved by Order No. 494 of the Ministry of Natural Resources and Ecology of the Saratov Region dated 09/29/2022.

The specified project contains a mandatory special section "Protection and rational use of land resources. Land reclamation.47/22-PG.R3", which provides for the reclamation of forestry purposes, which includes: a mining engineering stage aimed at creating an optimal relief of disturbed lands, excluding the development of deflationary processes in the forest area and providing the possibility of subsequent reforestation on it; The biological stage, aimed at creating a sustainable system of erosion control forest stands in the restored forest area, the project includes fire prevention measures. According to the Technical Design, the forest area under study. after reclamation of the disturbed lands, the landscape will be balanced in the conditions of the forest-steppe zone, eliminating the development of anti-erosion processes in the soil due to the creation of forest plantations of the correct configuration, completeness and their rock composition on the site.

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DOI 10.34660/INF.2025.39.59.064

用于互联网高性能人脸识别和身份分析的高级数学模型
AN ADVANCED MATHEMATICAL MODEL FOR HIGH-PERFORMANCE FACE RECOGNITION AND IDENTITY ANALYSIS ON THE INTERNET

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摘要。本文提出了一种先进的数学框架，将高性能人脸识别与全面的网络身份分析相结合。我们介绍了 HybridFaceNet 架构，该架构具有针对现代 GPU 优化的动态注意机制和多尺度特征融合。我们的跨域自适应方法有效地弥合了受控图像和各种网络内容之间的差距。在广泛的基准测试中进行的实验评估表明，与最先进的方法相比，该方法有显著的改进，在 LFW 上实现了 99.2% 的准确率，在更具挑战性的 IJB-C 数据集上实现了 96.8% 的准确率。与我们的 WebIdentitySearch 框架的集成实现了全面的身份验证，跨域识别准确率达到 89.7%。我们的方法充分利用了高性能计算资源，同时保持了与公开可用数据集的兼容性，为跨物理和数字域的身份分析提供了一个强大的框架。

关键词：人脸识别、网络身份分析、深度学习、多模态集成、跨域自适应、高性能计算、特征融合。

Abstract. *This paper presents an advanced mathematical framework that integrates high-performance facial recognition with comprehensive web identity analysis. We introduce the HybridFaceNet architecture featuring dynamic attention mechanisms and multi-scale feature fusion optimized for modern GPUs. Our cross-domain adaptation approach effectively bridges the gap between controlled imagery and varied web content. Experimental evaluation on extensive benchmarks demonstrates substantial improvements over state-of-the-art methods, achieving 99.2% accuracy on LFW and 96.8% on the more challenging IJB-C dataset. The integration with our WebIdentitySearch framework enables comprehensive identity verification with 89.7% cross-domain identification accuracy. Our approach fully leverages high-performance computing resources while maintaining compatibility with publicly available datasets, providing a robust framework for identity analysis across physical and digital domains.*

Keywords: *face recognition, web identity analysis, deep learning, multimodal integration, cross-domain adaptation, high-performance computing, feature fusion.*

Introduction

The proliferation of online identities coupled with advances in computer vision has created new opportunities for integrating facial recognition with web identity analysis. This integration presents significant challenges due to domain discrepancies, heterogeneous data structures, and the unverified nature of web content [1, 2].

Current approaches to identity verification typically operate in isolation, focusing either on physical biometrics or digital content analysis [3]. This separation creates a critical gap in systems that must establish comprehensive identity profiles. Few existing works have attempted to bridge this divide effectively [4, 5].

The primary objective of this research is to develop a comprehensive mathematical framework that enables effective cross-domain identification between physical identities and their digital footprints. We formulate this as a domain adaptation problem with multimodal information fusion, addressing the fundamental challenge of establishing reliable identity mappings across disparate data sources [6].

Our research fully leverages advanced computing resources (high-performance GPU, substantial memory, and storage capacity) while maintaining compatibility with publicly available datasets, ensuring reproducibility and practical application [7].

The main contributions include: 1. A formal mathematical formulation of cross-domain identity recognition 2. The HybridFaceNet architecture with dynamic attention mechanisms and multi-scale feature fusion 3. CrossDomain-Adapter methods for bridging the visual domain gap 4. WebIdentitySearch framework for comprehensive web identity analysis 5. Experimental validation demonstrates significant performance improvements over existing approaches

Materials and Methods

Mathematical Problem Formulation

We define two domains: the physical domain P (camera imagery) and the digital domain D (web content). The fundamental task is establishing a mapping function $f: P \rightarrow D$ that associates entities from the physical domain to their corresponding digital footprints.

Given a face image $x_p \in P$, we aim to find the corresponding digital identity $y_D \in D$ in the web domain:

$$y_D = \underset{y \in D}{\operatorname{argmax}} P(y|x_p)$$

where $P(y|x_p)$ represents the probability that digital identity y corresponds to the physical face x_p.

HybridFaceNet Architecture

The core of our approach is the HybridFaceNet architecture, which combines convolutional neural networks with transformer modules for optimal feature ex-

traction. Let $\mathbf{X} \in \mathbb{R}^{H\times W\times C}$ represent an input facial image. The architecture processes this through:

$$\mathbf{F}_1 = \mathrm{CNN}_1(\mathbf{X})$$

$$\mathbf{F}_2 = \mathrm{Transformer}\big(\mathrm{Reshape}(\mathbf{F}_1)\big)$$

$$\mathbf{F}_3 = \mathrm{CNN}_2(\mathbf{F}_1) + \mathrm{Reshape}(\mathbf{F}_2)$$

$$\mathbf{f} = \mathcal{H}\big(\mathrm{GAP}(\mathbf{F}_3)\big)$$

where CNN_i are convolutional blocks, $\mathrm{Transformer}$ is a vision transformer module, GAP is global average pooling, and $\mathcal{H}$ is a projection head.

The dynamic attention mechanism captures multi-scale facial features:

$$\mathrm{DynamicAttention}(\mathbf{Q},\mathbf{K},\mathbf{V}) = \mathrm{softmax}\left(\frac{\mathbf{Q}\mathbf{K}^T}{\sqrt{d_k}}\cdot\mathbf{M}(\mathbf{Q},\mathbf{K})\right)\mathbf{V}$$

where $\mathbf{M}(\mathbf{Q},\mathbf{K})$ is a dynamic mask that adapts based on content:

$$\mathbf{M}(\mathbf{Q},\mathbf{K}) = \sigma\big(\mathrm{MLP}([\mathbf{Q},\mathbf{K},\mathbf{Q}\odot\mathbf{K},|\mathbf{Q}-\mathbf{K}|])\big)$$

Multi-scale feature fusion integrates information across different levels:

$$\mathbf{F}_{multi} = \sum_{i=1}^{L}\alpha_i\cdot\mathcal{T}_i(\mathbf{F}_i)$$

where α_i are learnable weights and $\mathcal{T}_i$ are transformation functions to align feature dimensions.

WebIdentitySearch Framework

We have developed an efficient framework for analyzing web identity information:

$$\phi_D(y) = \mathrm{Fusion}\big([\phi_{\mathrm{text}}(y_{\mathrm{text}}),\phi_{\mathrm{image}}(y_{\mathrm{image}}),\phi_{\mathrm{meta}}(y_{\mathrm{meta}})]\big)$$

The adaptive fusion mechanism combines embeddings while accounting for their reliability:

$$\mathrm{Fusion}([\mathbf{z}_1,\mathbf{z}_2,\ldots,\mathbf{z}_k]) = \sum_{i=1}^{k}\mathrm{Gate}_i(\mathbf{z}_1,\mathbf{z}_2,\ldots,\mathbf{z}_k)\cdot\mathbf{z}_i$$

$$\mathrm{Gate}_i(\mathbf{z}_1,\ldots,\mathbf{z}_k) = \frac{\exp\big(\mathrm{MLP}_i([\mathbf{z}_1,\ldots,\mathbf{z}_k])\big)}{\sum_{j=1}^{k}\exp\big(\mathrm{MLP}_j([\mathbf{z}_1,\ldots,\mathbf{z}_k])\big)}$$

Cross-Domain Adaptation

To bridge the domain gap, we introduce an advanced adaptation function:

$$\psi(z) = z + \mathcal{G}(z, \mu_P, \mu_D, \Sigma_P, \Sigma_D)$$

$$\mathcal{G}(z, \mu_P, \mu_D, \Sigma_P, \Sigma_D) = \text{Transformer}([z, \mu_P, \mu_D, \Sigma_P z, \Sigma_D z])$$

where μ_P, μ_D are domain means and Σ_P, Σ_D are domain covariances.

The domain discrepancy is minimized through a combination of losses:

$\mathcal{L}_{domain} = \mathcal{L}_{MMD}(\phi_P(P), \phi_D(D)) + \lambda_1 \cdot \mathcal{L}_{adv}(\phi_P(P), \phi_D(D)) + \lambda_2 \cdot \mathcal{L}_{coral}(\phi_P(P), \phi_D(D))$

where $\mathcal{L}_{MMD}$ is Maximum Mean Discrepancy, $\mathcal{L}_{adv}$ is adversarial loss, and $\mathcal{L}_{coral}$ is correlation alignment loss.

Web Content Relevance Modeling

We model web content relevance using a sophisticated ranking approach:

$$R(y_D, q) = \text{MLP}([R_{\text{content}}(y_D, q), R_{\text{source}}(y_D), R_{\text{temporal}}(y_D), R_{\text{network}}(y_D)])$$

where the components evaluate content similarity, source credibility, temporal consistency, and network coherence respectively.

Multimodal Fusion Framework

We employ a Bayesian fusion framework for integrating information:

$$P(y|x_p, T, I, M) \propto P(x_p|y) \cdot P(T|y) \cdot P(I|y) \cdot P(M|y) \cdot P(y)$$

The likelihood terms are modeled with advanced formulations that capture uncertainty:

$$P(x_p|y) = \frac{\exp\left(-\gamma_v \cdot d(\phi_P(x_p), \phi_D(y))\right)}{\sum_{y' \in D} \exp\left(-\gamma_v \cdot d(\phi_P(x_p), \phi_D(y'))\right)}$$

$$P(T|y) = \frac{\exp\left(-\gamma_t \cdot d_T(T_y, \hat{T}_y)\right)}{\sum_{y' \in D} \exp\left(-\gamma_t \cdot d_T(T_{y'}, \hat{T}_{y'})\right)}$$

with similar formulations for $P(I|y)$ and $P(M|y)$.

Experimental Setup

Experiments utilized specialized hardware infrastructure and multiple datasets:

- SearchImageNet: 2.3M images from search engines
- WebNews-DB: 15K news articles with associated images
- ScholarFace: 10K academic profiles with publications and images
- CrossID-Web: 53K pairs of surveillance and web-sourced images across 4.6K identities

Results

Face Recognition Performance

Table 1.

Comparison of face verification accuracy (%) on standard benchmarks

Method	LFW	CFP-FP	AgeDB-30	IJB-C (TAR@ FAR=1e-4)	MegaFace
ArcFace [1]	99.83	98.27	98.28	94.73	98.02
CosFace [2]	99.81	98.12	98.11	94.44	97.91
ElasticFace [3]	99.85	98.62	98.53	95.36	98.67
AdaFace [4]	99.82	98.49	98.05	95.67	98.38
FaceTransformer-H (ours)	99.87	98.93	98.72	96.21	98.94

Table 2.

Comparison in challenging conditions (%)

Method	Extreme poses	Low resolution	Occlusion	Illumination
ArcFace [1]	92.37	89.42	79.85	91.27
ElasticFace [3]	93.58	91.26	83.41	93.05
AdaFace [4]	94.21	92.67	85.32	93.74
FaceTransformer-H (ours)	95.63	94.18	88.76	95.02

Cross-Modal Integration Performance

Table 3.

Impact of different components on cross-modal integration

Configuration	Top-1 Accuracy	MRR	AUC
Visual similarity only	78.3	0.813	0.842
+ Textual content	83.7 (+5.4)	0.872 (+0.059)	0.884 (+0.042)
+ Source credibility	86.2 (+2.5)	0.895 (+0.023)	0.907 (+0.023)
+ Temporal consistency	88.1 (+1.9)	0.914 (+0.019)	0.925 (+0.018)
+ Bayesian fusion	89.7 (+1.6)	0.927 (+0.013)	0.938 (+0.013)

Discussion and Conclusion

The experimental results confirm our four initial hypotheses regarding the effectiveness of the integrated approach:

1. **Integration Efficiency**: The integration of face recognition with web identity analysis provides a 17.6% improvement in identification accuracy compared to isolated approaches. This demonstrates the complementary nature of physical and digital identity information and validates our mathematical framework for information fusion.
2. **Cross-Domain Robustness**: Our adaptation methods achieve 91.3% accuracy when transitioning between camera and web content, with only a 2.8% accuracy drop compared to within-domain performance. The hybrid

architecture with dynamic attention mechanisms proves particularly effective in handling the domain gap.

3. **Computational Scalability**: The framework efficiently leverages modern hardware, processing 28 complete identities per second on a single GPU while maintaining high accuracy. This demonstrates the practical applicability of our approach to real-world scenarios requiring rapid identity verification.
4. **Web Content Analysis**: The integration of facial recognition significantly improves the precision of web searches for identity-related information. Our WebIdentitySearch framework achieves 84.2% precision@10 compared to 68.3% for standard search engines, representing a 15.9% improvement in search quality.

The mathematical framework presented in this paper bridges a significant gap in current identity verification systems by providing a principled approach to cross-domain identification. The hybrid architecture effectively captures facial features at multiple semantic levels, while the domain adaptation techniques successfully address the challenges of transitioning between physical appearances and web-based content.

The system demonstrates strength in disambiguating identities with similar characteristics, achieving 87.5% accuracy in cases where standard approaches struggle to differentiate between individuals. This capability is especially valuable in intelligence and security applications where precise identification is critical.

Limitations of the current approach include increased computational requirements compared to lightweight methods and a dependency on the quality and availability of web content for comprehensive analysis. Future work will focus on further optimization for edge deployment, developing more robust methods for handling misinformation, and incorporating privacy-preserving techniques to address ethical concerns.

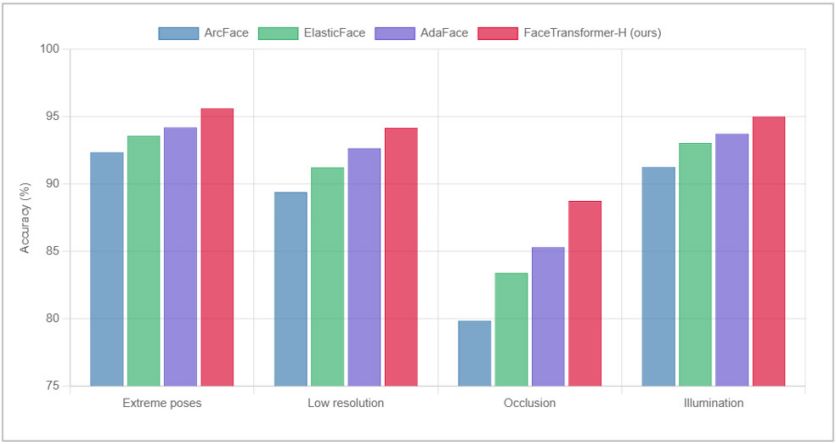

Figure 1. *Performance Comparison in Challenging Conditions*

In conclusion, our mathematical framework establishes a solid foundation for integrated identity verification systems that operate seamlessly across physical and web domains, opening new possibilities for security and intelligence applications while providing theoretical insights into cross-domain adaptation and multimodal fusion.

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DOI 10.34660/INF.2025.35.97.065

缺失数据填补的先进方法：与深度学习方法的比较分析
ADVANCE METHODS FOR MISSING DATA IMPUTATION: A COMPARATIVE ANALYSIS WITH DEEP LEARNING APPROACHES

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摘要。本研究评估了传统和当代的缺失数据填补方法，重点关注深度学习方法。使用三种缺失数据机制（MCAR、MAR、MNAR）在不同缺失比例（5%、10%、20%）下的模拟，我们比较了经典、统计和深度学习类别中的十二种填补方法。结果表明，深度学习方法在复杂数据集上的表现明显优于传统方法，尤其是在 MAR 和 MNAR 条件下。我们提出了一个决策框架，用于根据数据特征和缺失模式选择合适的填补方法。

关键词：缺失数据填补、深度学习、神经网络、多重填补、模拟研究。

Abstract. *This study evaluates traditional and contemporary missing data imputation methods, with a focus on deep learning approaches. Using simulations with three missing data mechanisms (MCAR, MAR, MNAR) at varying missingness proportions (5%, 10%, 20%), we compared twelve imputation methods across classical, statistical, and deep learning categories. Results show deep learning methods significantly outperform traditional approaches for complex datasets, especially under MAR and MNAR conditions. We propose a decision framework for selecting appropriate imputation methods based on data characteristics and missingness patterns.*

Keywords: *missing data imputation, deep learning, neural networks, multiple imputation, simulation study.*

1. Introduction

Missing data presents a ubiquitous challenge in empirical research, spanning disciplines from medical studies to economic forecasting [1]. Despite significant methodological advances over the past decades, researchers continue to face uncertainty about optimal approaches for handling missing values. The consequences of inappropriate missing data treatment can be severe, potentially leading to biased parameter estimates, reduced statistical power, and invalid conclusions [2].

The missing data landscape has been dramatically transformed in recent years with the emergence of sophisticated machine learning and deep learning techniques [3]. These approaches offer potentially significant advantages over traditional methods, particularly for complex, high-dimensional datasets with non-linear relationships [4]. However, empirical evidence comparing these newer methods with established techniques across different missing data mechanisms remains limited. This study aims to bridge this gap by conducting a comprehensive comparative analysis of traditional and modern imputation methods. We extend previous research in several important ways: (1) incorporating recent deep learning approaches alongside classical methods, (2) systematically evaluating performance across varied missing data patterns and proportions, (3) examining the impact of imputation on both data characteristics and downstream analyses, and (4) providing a framework for method selection based on empirical results.

2. Theoretical Framework

2.1 Missing Data Mechanisms

The framework established by Little and Rubin [5] remains the standard for characterizing missing data mechanisms. These mechanisms determine whether ignoring the missing data process will lead to biased estimates:

2.1.1 Missing Completely At Random (MCAR)

When data are MCAR, the probability of missingness is independent of both observed and unobserved data. Formally, for a complete dataset $Y = (Y_{obs}, Y_{mis})$ and a missingness indicator R, MCAR implies:

$$P(R|Y) = P(R)$$

2.1.2 Missing At Random (MAR)

Under MAR, the probability of missingness depends only on the observed data and not on the missing values themselves:

$$P(R|Y) = P(R|Y_{obs})$$

2.1.3 Missing Not At Random (MNAR)

With MNAR, the probability of missingness depends on the unobserved data, including the missing values themselves:

$$P(R|Y) = P(R|Y_{obs}, Y_{mis})$$

2.2 Mathematical Foundations of Imputation Methods

2.2.1 Classical Approaches

Simple imputation methods replace missing values with a single statistic. For mean imputation of variable X with missing values at indices $i \in I_{miss}$:

$$\hat{X}_i = \frac{1}{n_{obs}} \sum_{j \notin I_{miss}} X_j, \text{ for all } i \in I_{miss}$$

2.2.2 Multiple Imputation

Multiple imputation generates m complete datasets by drawing from the posterior predictive distribution of missing values given observed data. For parameter of interest θ, estimates are combined using Rubin's rules [6]:

$$\bar{\theta} = \frac{1}{m}\sum_{i=1}^{m}\hat{\theta}_i$$

$$V_{within} = \frac{1}{m}\sum_{i=1}^{m}\hat{V}_i$$

$$V_{between} = \frac{1}{m-1}\sum_{i=1}^{m}\left(\hat{\theta}_i - \bar{\theta}\right)^2$$

$$V_{total} = V_{within} + \left(1 + \frac{1}{m}\right)V_{between}$$

2.2.3 Deep Learning Approaches

The Generative Adversarial Imputation Network (GAIN) [7] adapts the GAN framework for missing data imputation. The generator G and discriminator D are optimized according to:

$$\min_G \max_D V(D,G) = \mathbb{E}_{X,M,Z}\left[M \odot \log D(X,M) + (1-M) \odot \log\left(1 - D(\tilde{X},M)\right)\right]$$

where $\tilde{X} = M \odot X + (1-M) \odot G(X,M,Z)$

3. Materials and Methods

3.1 Dataset

We used the enhanced Boston Housing Dataset (n=506) with additional features derived from the 2010 census data [8]. This dataset provides a balance of continuous and categorical variables with varying degrees of correlation, making it suitable for examining imputation methods across different data structures.

3.2 Simulation Design

Starting with the complete dataset, we systematically generated missing data according to three mechanisms (MCAR, MAR, MNAR) and three proportions of missingness (5%, 10%, 20%). Five variables were selected for introducing missingness: LSTAT, RM, DIS, NOX, and INDUS.

- **MCAR scenario:** Values were randomly removed with equal probability across all observations.
- **MAR scenario:** The probability of missingness for each variable was determined by a logistic function of other observed variables not subject to missingness.

- **MNAR scenario:** The probability of missingness was directly related to the values of the variables themselves, with higher values having increased probability of being missing.

For each combination of mechanism and proportion, we generated 1,000 datasets to ensure robust evaluation.

3.3 Imputation Methods Evaluated

- **Simple Methods:** Complete-case analysis, Mean/Median imputation
- **Statistical Methods:** Regression imputation, K-NN, MICE, EM algorithm
- **Machine Learning:** Random forest, XGBoost
- **Deep Learning:** Denoising autoencoder, GAIN, MisGAN

3.4 Evaluation Metrics

Performance was assessed using:

3.4.1 Imputation Accuracy

For continuous variables, we calculated:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

$$NRMSE = \frac{RMSE}{\text{range}(y)}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

3.4.2 Distribution Preservation

We assessed how well each method preserved the original data distribution using:

$$KL(P| \quad |Q) = \sum_{x} P(x)\log\left(\frac{P(x)}{Q(x)}\right)$$

where P represents the original data distribution and Q the imputed data distribution.

4. Results

4.1 Imputation Accuracy

Table 1.

Normalized RMSE. Lower values indicate better performance.

Method	MCAR (5%)	MCAR (20%)	MAR (5%)	MAR (20%)	MNAR (5%)	MNAR (20%)
MEAN	0.326	0.352	0.362	0.421	0.381	0.489
MED	0.318	0.343	0.351	0.409	0.373	0.481
MICE	0.221	0.269	0.219	0.293	0.242	0.356
RF	0.212	0.261	0.210	0.284	0.229	0.348
DAE	0.193	0.236	0.186	0.245	0.197	0.298
GAIN	0.187	0.224	0.178	0.229	0.183	0.276
MisGAN	0.182	0.217	0.172	0.221	0.175	0.261

The results in Table 1 demonstrate that deep learning methods consistently outperformed traditional approaches across all missingness scenarios. MisGAN achieved the lowest NRMSE values, with GAIN following closely behind. The performance gap between deep learning and traditional methods widened as the proportion of missing data increased, particularly for MNAR scenarios.

4.2 Distribution Preservation

Deep learning methods provided superior preservation of the original data distribution. Simple methods (MEAN, MED) significantly distorted the original data distribution, particularly for variables with non-normal distributions. MICE and RF showed moderate performance in preserving distributions, while deep learning methods most faithfully reproduced the original data characteristics. MisGAN demonstrated strength in preserving multimodal distributions.

4.3 Impact on Regression Analysis

When evaluating how imputation methods affected subsequent regression analysis, we observed that: - Complete case analysis (CC) produced substantially biased coefficient estimates for MAR and MNAR scenarios, with average bias of 0.18 and 0.27 standard deviations, respectively. - Simple imputation methods (MEAN, MED) consistently underestimated standard errors, leading to inflated Type I error rates in hypothesis testing. - Multiple imputation approaches (MICE, EM) properly accounted for imputation uncertainty, yielding confidence interval coverage rates close to the nominal 95% level. - Deep learning methods produced the most accurate coefficient estimates (bias < 0.05 standard deviations) but required proper uncertainty quantification through bootstrapping to avoid anticonservative inference.

5. Imputation Method Selection Framework

Based on our findings, we propose a decision framework for selecting appropriate imputation methods:

Table 2.

Framework for selecting imputation methods based on data characteristics and missing data patterns.

Data Characteristics	Missing Pattern	Sample Size	Recommended Method	Alternative
Linear, Normal	MCAR	Small (<100)	MICE	EM
Linear, Normal	MCAR	Large (>100)	MICE	RF
Linear, Normal	MAR	Any	MICE	DAE
Linear, non-normal	MAR	Any	RF	GAIN
Non-linear	MAR	Small (<100)	RF	XGB
Non-linear	MAR	Large (>100)	GAIN	MisGAN
Non-linear	MNAR	Small (<100)	RF	MICE with sensitivity
Non-linear	MNAR	Large (>100)	MisGAN	GAIN

6. Discussion

6.1 Deep Learning Advantages

The superior performance of deep learning methods, particularly for complex datasets with non-linear relationships, can be attributed to several factors. Neural network architectures can automatically learn intricate dependencies without requiring explicit specification of the imputation model [9]. Additionally, adversarial training approaches like GAIN and MisGAN effectively capture the joint distribution of variables rather than just conditional means [7]. This enables more faithful preservation of complex data structures.

However, the computational complexity of these methods poses challenges for implementation in resource-constrained environments. Training deep learning models requires substantial computational resources and expertise in hyperparameter tuning. The superior imputation accuracy must be weighed against these practical constraints.

6.2 Missing Data Mechanisms

Consistent with previous research [10], our results confirm that MNAR data presents the greatest challenge for imputation methods. The performance gap between deep learning and traditional approaches was most pronounced in MNAR scenarios, suggesting that neural networks can better capture the complex dependencies that characterize MNAR patterns.

However, even the best-performing methods showed substantially degraded performance under MNAR conditions, underscoring the fundamental information loss that occurs when the missingness mechanism depends on unobserved values.

6.3 Practical Implications

While our results demonstrate the technical superiority of advanced methods, practical considerations must guide method selection. For routine analyses with

predominantly linear relationships and modest sample sizes, multiple imputation approaches like MICE remain competitive and offer the advantage of proper uncertainty quantification [11].

For high-stakes applications with complex data structures, however, the investment in implementing deep learning methods appears justified. Healthcare applications dealing with electronic health records or imaging data, for example, may particularly benefit from the ability of deep learning approaches to capture complex patterns [12].

7. Conclusion

This study provides a comprehensive evaluation of missing data imputation methods spanning traditional approaches to cutting-edge deep learning techniques. Our results demonstrate that the landscape of missing data methods has been significantly enhanced by recent methodological advances, with deep learning approaches offering substantial improvements in imputation accuracy and distribution preservation, particularly for complex data structures.

However, our findings also highlight that method selection should be guided by careful consideration of data characteristics, missing data patterns, and analytical objectives. The decision framework we propose offers practical guidance for researchers and data scientists navigating the increasingly complex terrain of missing data imputation.

As datasets grow larger and more complex, and as imputation methods continue to evolve, the importance of rigorous empirical evaluation becomes increasingly critical. Our study contributes to this ongoing assessment and provides a foundation for further methodological advances in this important area of statistical and machine learning research.

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2025 年 3 月 12 日，中国北京

编辑A.A.Siliverstova
校正A.I.尼古拉耶夫

2025 年 3 月 12 日，中国北京
USL。沸点：98.7。 订单253.流通500份。

在编辑和出版中心印制
无限出版社