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ИЗВЕСТИЯ

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NEWS

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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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S. M. Ozdoyev¹, N. S. Abduev¹, V. A. Popov¹, N. Tileuberdi¹, Ma Hua Dong²

¹Satbayev University, Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan.

²The research center of nature resources and ecological environment in Xinjiang, Xinjiang, China.

E-mail: Ozdoyevsultan@mail.ru; Nureke-17@mail.ru

**COMMON AND DIFFERING GEOLOGICAL FEATURES
OF THE ALAKOL AND CHINESE DZUNGARIAN TROUGHS
IN VIEW OF THEIR OIL-AND-GAS PROSPECTS**

Abstract. In the current paper, an attempt has been made to consider the history of geological development of the Alakol trough in East Kazakhstan and the Dzungarian trough in China. Reconstruction of commonness and difference in development of these troughs has been implemented on the base of the analysis of their thickness, lithological structure and paleogeographical conditions of rock reservoirs with purpose of determining the prospects of their oil-and-gas content.

Key words: the Alakol trough, the Dzungarian trough, paleographic conditions, lithology, rocks, the Paleozoic age, the Cenozoic age, conglomerates, sandstone, clay, carbonate, tectonic movements, oil-and-gas content.

Many researchers see similarity between the two original troughs, emphasising their common geological features, which are manifesting in the continuity of petroleum strata between the Dzungarian to the Alakol trough [1, 2].

The article considers works of the pioneers, thus paying the due tribute. References are made to the works published in recent years, their materials being sufficiently substantiated.

In order to inspect the geological structure of these troughs, we considered the following works: A.K.Buvalkin (1960), A.K. Buvalkin and V.I.Vlasov (1961), A.K.Buvalkin and M.Ts.Zhaimin (1958), A.Kh.Ivanov (1962), K.V.Kurdukov (1954), V.Ya.Kolubin (2002), G.Zh.Zholtaev and S.M.Ozdoyev (2010), N.S. Abduev, S.M.Ozdoyev and R.Kh.Ostapenko (2010) – on Alakol, and A.Kh.Ivanov (1962), F.S.Maisenko and G.K.Nevsky (1960), V.A.Obruchev (1948), N.M.Saidov (1956), N.P.Tuaev (1963), L.Chzhan, A.V.Sidnev (2010), Go Ming and A.V.Sidnev (2015), G.P.Kuznetsova, Van Tse and Lu Inzhu (2017) – on the Dzungarian trough.

The authors of the current paper do not pretend to the exceptional accuracy of the study on history of geological development of these peculiar structures.

Alakol is a promising oil and gas bearing region, geologically associated with the intermountain trough of the same name, limited in the north by the Tarbagatai range, in the southwest by the Dzungarian Alatau range, and in the southeast by the Berlik and Maily ranges. The area of the trough is 25,600 sq.km.

Rocks of the Paleozoic, Mesozoic and Cenozoic ages take part in the geological composition of the trough. Paleozoic rocks within the trough are not exposed and have been studied only in its framing boundaries. They are intensely dislocated, broken by faults and intrusions, and form the Alakol trough's foundation [3]. According to geophysical data, volcanogenic and volcano-sedimentary deposits of the Early and Middle Devonian with thickness of up to 4,000 m are supposed to be developed under the trough.

The Dzungarian intermountain trough, located in the western part of China with the area of 130 thousand sq.km, is limited in the northwest by spurs of the Maily-Dzhair range, in the south by the East Tian-Shan, in the east by the branch of the Karamaily range and in the southeast is framed by the Mechinula range.

Recent studies within the Dzungarian sedimentary basin have revealed new additional structural elements of the second order: uplifts, deflections, depressions, which made it possible to map the complex geological structure and revise the basin's structural plan [4, 5].

Paleozoic, Mesozoic and Cenozoic rocks take part in geological structure of the basin; the foundation is considered by some researchers as heterogenic, by others as composure of Caledonite and Hercynide rocks.

The Atlas of lithological and paleogeographic, structural, palinspastic and geo-ecological maps of Central Eurasia, compiled in 2002 with participation of experts from geological services of China, adopted the Paleozoic age of the foundation, while it is rather confined to the Lower Paleozoic. The base of the Dzungarian trough is formed by crystalline shale, occurred at depths of 16 km down in the south part and monoclinical wedging for 2 km to the north [3]. The main capacity of the sedimentary cover rocks is concentrated within the Urumqi trough. There is no information on the Alakol trough in the Baikal tectonic epoch, at the end of the Proterozoic and in the beginning of the early Paleozoic. At that time, the eastern part of the nascent Dzungarian basin was a land with non-segmented deposits.

Starting from the Ordovician, under marine conditions, deposits accumulate on the continental slope of the Alakol trough. In the Dzungarian trough, marine conditions are preserved, forming a deep-water trough, composed of siliceous shale and sandstone rocks of up to 1000 m thick.

In the Silurian and Devonian ages, the sea transgression increased, rock formation took place in the Alakol trough's inner shelf zone, with activation of volcanism. Formations of various lithological composition are represented by tuffy sandstone, siltstone, siliceous shale, conglomerates, limestone, tuffs and porphyrites of up to 800 m thick.

Deep-water troughs expanded in the Dzungarian basin. Tectonic activation of folding processes led to deposition of metamorphic shales, argillites and basalts up to 3000 m thick on the continental slopes. In the Lower Devonian age, a shift occurred along the submeridional fault touching the junction area of the Alakol and Dzungarian troughs. It was the faults formed in the Ordovician that determined difference in tectonic conditions and geological development records of the Alakol and Dzungarian troughs. Common to them is manifestation of horizontal movements, as well as shifts along the two boundary faults of sublatitudinal strike in the Lower Devonian.

In Early Carboniferous, due to increased tectonic activity in the troughs, differentiation of the lithological-paleogeographical situation occurred, along with spatial dissociation of rock formation conditions.

In the southern part of the Alakol trough, the inner-shelf marine conditions for formation of coarse-clastic rocks with thickness of up to 720 m were preserved, while continental volcanic movements in the northern part, shaping rhyolites, dacites and andesites of up to 1300 m thick, were active.

Minor changes occurred in the Middle Carboniferous age. The northern part of the trough was busily occupied with orogenic manifestations. Lime deposits with peltsipodic fauna and inclusions of tuffy aleurolites of total capacity of up to 700 m accumulated on the main part of the trough.

In the Dzungarian trough, rocks formed at the foot of the continental slope, under deep oceanic conditions; sediments were composed of metamorphic shales and mudstones of up to 2000 m.

In the Middle Carboniferous, the Dzungarian trough experienced regression of the sea, development of coastal plains, foothills of continental slopes and contrast relief of mature island arcs with accumulation of limestone, sandstone, tuff sandstone, clay sandstone with organic remains of trilobites, corals and terrestrial flora. According to the borehole data, thickness of deposits in the Urumqi deflection is 2375 m.

In the Early Permian age, accumulation of sediments takes place under the plain-coastal paleogeographic conditions, with formation in the north part of the Alakol trough of continental volcanic mountains up to 1300 m high. Lithologically, rocks are similar to those of underlying rocks of the Middle Carboniferous with thickness of up to 700 m.

In the Early Permian, the Dzungarian trough undergoes deflecting with development of coastal plains and lakes. Lithologically, these are green and dark-gray sandstone, conglomerates, shales; their thickness in the Karamaily district is 1470 m, reaching in the Urumqi trough 4700 m. Found among the rocks, are bituminous shale and coal interlayers.

By the end of the Early Permian age, mobility of geodynamic directions of the quasi-platform cover is exhausted.

It is believed that in the Lower Permian age the time came for transition from geological development to the orto-platform stage.

Ascending movements in the platform development process during the Permian age did not construct significant mountains. Surface of the inspected troughs is characterised by acclivous accidental terrain, they were not affected by sharp tectonic movements.

In the Triassic age, the entire territory of the Alakol trough was represented by low mountains in the northeast part of the country, developing elevations in the southwest part, and these landscapes were separated by an active sublatitudinal fault.

In the lower Triassic, continental coarse-clastic rocks were accumulating in the western part of the Alakol trough, on the Permian effusive sedimentary deposits with angular disagreement. In the Middle Triassic age, the planar erosion prevailed.

In the Lower and Middle Triassic ages, conglomerates of violet-red colour, sandstone, and clays of thickness of up to 700 m deposited in the Dzungarian trough under lacustrine-alluvial conditions.

In the Upper Triassic age, downward movements were noted, especially explicit in the south of the Dzungarian trough as they favoured accumulation of conglomerates, sand-clay rocks and coal interlayers in the Urumqi trough. The general thickness exceeded 1500 m.

In general, the Triassic occupies an intermediate position during the transitional period in geological development of the Hercynian and Alpien epochs of upward tectonic movements in eastern troughs of Kazakhstan and Dzungaria.

For the Alakol trough area, the Jurassic period is divided into two epochs, according to paleographic rock formation conditions. In the Middle Jurassic time, the Alakol trough was a two-part sublatitudinal space. The northeast side was covered with hills, and the southwest was a scene for formation of foothill and intermountain troughs with carrying-out of coarse-clastic material with thickness of up to first hundreds of meters.

In the Dzungarian trough, downward movements which had already started in the Lower Triassic continued in the Lower and Middle Jurassic ages. At this time, the Dzungarian trough expanded sharply to east, where sediment accumulation occurred on lowland plains under lacustrine-alluvial conditions. The lithological composition of rocks includes conglomerates, sandstones, clays, coal interlayers with inclusions of vegetal residues. Thickness of the rocks increases from north to south, from 130 to 982 m in the Urumqi trough.

In the Lower Jurassic time, the Alakol trough area was totally represented by the paleographic situation of denudated elevations and formation of terrigenous rocks.

In the Upper Jurassic time, the size of the Dzungarian trough slightly decreased. Clayey formations, sandstones with terrestrial flora and ostracodal fauna were depositing in the remaining trough area. Sediment thickness varied between 69 m in the north to 683 m in the south.

Nascent in the end of the Upper Jurassic age, upward movements influenced the Alakol trough in the Early Cretaceous age too, as the denudation space of elevated plains. Processes of land levelling were taking place during this time.

In the Early Cretaceous age, all deflections of the Dzungarian trough got involved into the uplift. The trough area reduced a little more, and the formed rocks of sandy-clay composition accumulated with angular disagreement on the Jurassic deposits. The rock thickness of the Lower Cretaceous is 80 m in the north, 684 m in the centre of the trough and 526 m in the south of the Urumqi trough.

Accumulated rocks and conditions of their formation indicate that the Lower Cretaceous age was the time of the least tectonic activity.

In the Lower Cretaceous age, paleographic conditions of lowland plains and uplands with accumulation of lacustrine-alluvial sediments were existent in the Alakol trough. This period is characterised by some increase in tectonic activity. Downfolds of the Alakol trough, located in the southeast along the Dzungarian fault, started developing again, according to the inherited plan, laid yet in the Triassic and Jurassic ages; the sandy clay deposits accumulated there.

In the Upper Cretaceous age, significant reduction of the Dzungarian trough occurred due to continued development of downward movements in its south part. Sandy-clay deposits with thickness of 70 m and 468 m respectively accumulated in the north and the centre of the trough. In the Urumqi trough, conglomerates and sandy clay deposits of dark-brown, redbrick-red colours accumulated with maximal

thickness of 513 m. Thickness of accumulated rocks in the trough indicates a decline in intensity of downward movements during the Upper Cretaceous age.

In the Eocene epoch of the lower Paleogene, the sea advance is reinforced with capture of almost the entire area of these troughs, except for plain stripes of denudation elevations. In the Alakol trough, lakes with increased salinity accumulated argillites with interlayers of anhydrites 20-100 m thick. Only in the northeast of the trough, did the coarse-clastic rocks accumulate with clay interlayers.

At this time, the Dzungarian trough developed in the paleographic environment of lowland plains, where, under lacustrine-alluvial conditions, rocks were accumulated, lithologically represented by sandstones in northwest and sandy clay formations with admixtures of tuff lavas throughout the rest of the trough. Thickness of the rocks varies from 74 m in the north to 300 m in the south.

In the same epoch, the Urumqi trough experienced elevation, and coarse rocks and conglomerates 83m thick were torn down from the surrounding ridges.

Because of tectonic activation of the region, the sea was getting shallow. In the Miocene time of the Lower Neogene, shallow marine carbonate deposits accumulated uniformly in the Alakol trough. Encountered are interlayered argillites with lime sandstones and interlays of ash streams of volcanic zones with rocks of reddish tint of up to 100 m thick.

The paleographic situation did not change significantly in the troughs; the paleographic conditions of lacustrine-alluvial sedimentation were preserved. The rocks are composed of greenish-grey clays and reddish-brown sandstones up to 800 m thick.

In the Dzungarian trough, marine paleographic conditions expanded. In the northern part of the trough, sandy-clay rocks accumulated to thickness of up to 435m. The central part accumulates limestones, shallow carbonate deposits, clays with fossilized fish fauna, ostracode and gastropod. The deposits are 196 m thick.

In this time, coarse-clastic rocks with clay interlays of 101 m thick were accumulating in the Urumqi trough.

Active tectonic movements in Pliocene of the upper Neogene of the Alpien tectogenesis conditioned sharply differentiated block movements. Accumulated deposits of considerable thickness of 2700 m speak for intense immersion of some blocks and rise of others. Accumulated sediments include gray conglomerates, light-brown and straw-gray aleurolite, sandstone and clay.

The section of the sedimentary cover of the Dzungarian basin is crowned by conglomerates of the Quaternary system with thickness of up to 100 m.

The oil and gas content of sedimentary strata of the Dzungarian basin is associated to almost all suites of the Paleozoic, Mesozoic and Cenozoic deposits. Commercial oil reserves have been established in Carboniferous, Permian, Triassic, Lower-Middle Jurassic, Lower Cretaceous, Paleogene and Miocene deposits.

In total, around 20 oil fields were revealed in the Dzungarian basin. Chinese geologists lay high hopes on discovery of new oil fields in Dzungaria.

During 2006-2010, the oil and gas prospecting (with a break of 48 years) was resumed by the "Remas" company in the Alakol trough. The MOGT-2D seismic surveys were also carried out in the coastal strip around the lake. Two profiles were located in the water area (across the basin's spread), 35 km away from each other.

Local structures were identified only on land; 3 of them were deep drilled into four wells. According to GIS data, only the A-1 well had revealed 3 perspective horizons, but the well was closed without testing.

The wells were drilled without testing; 5m-core was sampled at the intervals of 1917-1922 m, SKV.72. It should be noted, that sludge from the wells no.1 and no.2 was tested for minerals and bitumoids in the Satpaev Institute of GeoSciences. Analyses have shown up to 0,003% of hydrocarbons of the "MCBA" and "CBA" types of bitumen giving the blue glow.

One of most important indicators in the formation of hydrocarbon deposits are hydrodynamic conditions of water-bearing complexes in basins' sedimentary strata, as the outcome of an operation mode of illusive and infiltration water exchanges.

In our case, in accordance with the geological structure of the intermountain Alakol trough, the surface and underground runoff from the ridges of the Dzungarian Alatau and Western Tarbagatai drains towards the zones of active water exchange in the central parts of the Sassik-Kol and Alakol lakes.

Known data of analyses of hydrogeological conditions of the upper part of the sedimentary cover, the water chemical composition allow attributing them to surface and infiltration types. They are classified as waters of free exchange with earth surface, negatively affecting the preservation of hydrocarbon deposits.

In the northern part of the Alakol basin, the water pressure gradient is smaller, and it can be seen as a result of decreased geostatic load and reduced rock compaction. Therefore, we may think that the role of the hydrodynamic factor in the formation of oil deposits in the northern part of the Alakol basin was insignificant.

The situation was different within the southern hydrodynamic area of the Alakol basin, where the flow lines in the connate water pressure system are directed from the zones of greatest deflection to the zones with lower pressure.

As a result, the underground force, moving hydrocarbons along the regional uprising of strata, was added up to water pressure of those reservoirs, where traps, properly locking the anti-current wing, could hold hydrocarbons [6]. These could be northern wings of local structures that are worth paying attention to, when planning oil and gas exploration boreholes.

Even basing on the wing amplitude of 35-40 m/km of structures capable of holding hydrocarbons, oil reserves are to be expected in deposits of the southern part of the Alakol basin with increasing capacity of the sedimentary cover.

Thus, hydro-geological and geological conditions of Mesozoic and Paleozoic sedimentary strata especially in the southern part of the Alakol basin do not contradict to the view about the active participation of hydrodynamic forces in the formation of hydrocarbon deposits.

Thus, the aforesaid, as well as consideration of published papers and geological-geophysical materials, allow drawing a conclusion that the sedimentary basin of the Alakol trough should be considered as an independent perspective object for detecting commercial hydrocarbon reserves. Study of tectonic development of the region and its cover indicates that hydrocarbons could be accumulated in deposits of stratigraphic levels of the Permian-Triassic, Jurassic and Paleogene reservoir rocks.

It should be assumed that formation of hydrocarbon potential of the sedimentary complex is conditioned mainly by vertical flow of hydrocarbon fluids from the underlying Paleozoic terrigenous and terrigenous-carbonate deposits.

Common features in tectonic structure of intermountain troughs of the South-East Kazakhstan and Xinjiang of China, in particular Dzungaria, are in similarity of their sedimentary cover. Deposits' maximal thicknesses concentrate in deflections of the southern framing of deep faults, and the cover is monoclinaly reduced towards the north. Such asymmetric development of intermountain troughs is explained in terms of plate tectonic manifestations, differentiated nature of rise and falls of strata blocks.

Discrepancies between Alakol and Dzungarian troughs are not essential as both developed mainly in the platform stage. The difference can be attributed to somewhat greater role of duration of downward movements in case of the Dzungarian trough.

As a result, the capacity of accumulated sedimentary cover in the Dzungarian trough is

16 km [7], while that of Alakol is four times less. The Dzungarian trough area is five times larger than that of Alakol. This is characteristic to a much lower intensity and differentiation of tectonic activity which disposed the Alakol trough to ascending movements.

The Alakol trough shows direct and indirect signs of the oil-and-gas bearing capacity. Here, we observe periods of intense accumulation of multi-meter coal strata in the Carboniferous and Jurassic ages, which is one of the favourable conditions for the formation of oil and gas source rocks.

Undoubtedly positive signs of oil-and-gas bearing capacity in the region are: mud volcanism, spread of bituminous rocks, ozokerites, asphaltites, presence of dissolved heavy gases and phenols in water sources. Significant oil and gas accumulation zones are associated with widely developed mobile structures of the Dzungarian Alatau range. This is confirmed by debris of Mesozoic formations carried out to surface through chimneys of mud volcanoes along the Dzungarian Devonian-Carboniferous fault [8]. A direct sign of oil-bearing capacity can be seen in water self-discharging from a well located 5 km westward from the Zharbulak village: the water bears a film of oil.

Having these obvious prospects for detecting oil and gas deposits in the Alakol basin, most of the issues affecting the geological structure and oil-and-gas bearing capacity will have to be clarified by the upcoming geophysical and exploration work.

С. М. Оздоев¹, Н. С. Абдуев¹, В. А. Попов¹, Н. Тілеуберді¹, Ма Хуа Дон²

¹Сәтбаев Университеті, Қ. И. Сәтбаев атындағы геологиялық ғылымдар институты, Алматы, Қазақстан,

²Шинзяндағы табиғи ресурстар мен экологиялық ортаны зерттеу орталығы, Шинзян, Қытай

**МҰНАЙ-ГАЗДЫЛЫҚ ПЕРСПЕКТИВТІЛІГІНЕ БАЙЛАНЫСТЫ АЛАКӨЛ ОЙПАТЫ МЕН
ҚЫТАЙДЫҢ ЖОҢҒАР ОЙПАТЫНЫҢ ГЕОЛОГИЯЛЫҚ ҚҰРЫЛЫСТАРЫНЫҢ
ҰҚСАСТЫҚТАРЫ МЕН АЙЫРМАШЫЛЫҚТАРЫ**

Аннотация. Мақалада Шығыс Қазақстандағы Алакөл ойпаты мен Қытайдағы Жоңғар ойпатының геологиялық дамуының тарихы қарастырылды. Ойпаттардың дамуындағы ұқсастықтар мен айырмашылықтарды табу олардың мұнай-газдылық перспективтілігін анықтау мақсатында қабаттар қалыңдығын талдау, литологиялық құрылымы және таужыныстардың қалыптасуының палеогеографиялық жағдайына негізделіп жасалынды.

Түін сөздер: Алакөл, Жоңғар, ойпат, палеогеографиялық жағдай, литология, таужыныстары, палеозой, кайнозой, конгломераттар, құмтастар, саздар, карбонаттар, тектоникалық қозғалыстар, мұнай-газдылық.

С. М. Оздоев¹, Н. С. Абдуев¹, В. А. Попов¹, Н. Тлеуберди¹, Ма Хуа Дон²

¹Сатпаев Университет, Институт геологических наук им. К. И. Сатпаева, Алматы, Казахстан,

²Исследовательский центр природных ресурсов и экологической среды в Синьцзяне, Синьцзян, Китай

**ОБЩНОСТЬ И РАЗЛИЧИЕ ГЕОЛОГИЧЕСКОГО РАЗВИТИЯ АЛАКОЛЬСКОЙ ВПАДИНЫ И
ДЖУНГАРСКОЙ ВПАДИНЫ КИТАЯ В СВЯЗИ С ПЕРСПЕКТИВАМИ НЕФТЕГАЗОНОСНОСТИ**

Аннотация. В статье сделана попытка рассмотреть историю геологического развития Алакольской впадины Восточного Казахстана и Джунгарской впадины Китая. Восстановление общности и различия развития впадин проводилось на основе анализа мощностей, литологического строения и палеогеографических условий образования пород с целью определения перспектив их нефтегазоносности.

Ключевые слова: Алакольская, Джунгарская, впадина, палеогеографические условия, литология, породы, палеозой, кайнозой, конгломераты, песчаники, глины, карбонаты, тектонические движения, нефтегазоносность.

Information about authors:

Ozdoyev S. M., Satbayev University, Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan; Ozdoyevsultan@mail.ru; <https://orcid.org/0000-0003-0262-1583>

Abdudev N. S., Satbayev University, Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan; Remas_abd1949@mail.ru; <https://orcid.org/0000-0003-0500-0272>

Popov V. A., Satbayev University, Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan; 1934popov@mail.ru; <https://orcid.org/0000-0001-6178-1283>

Tileuberdi N., Satbayev University, Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan; Nureke-17@mail.ru; <https://orcid.org/0000-0003-0781-2434>

Hua Dong Ma, The research center of nature resources and ecological environment in Xinjiang, National 305 Project office, Xinjiang, China; mhd618@qq.com; <https://orcid.org/0000-0002-4487-8267>

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**L. R. Sassykova^{1*}, S. Sendilvelan², Y. A. Aubakirov¹, Zh. Kh. Tashmukhambetova¹,
A. A. Batyrbayeva¹, R. N. Azhigulova¹, Sh. N. Kubekova³, K. O. Sharipov⁴,
R. G. Ryskaliyeva¹, B. B. Tyussyupova¹, M. A. Sarybayev¹**

¹Al-Farabi Kazakh National University, Almaty, Kazakhstan,

²Department of Mechanical Engineering, Dr.M.G.R. Educational and Research Institute,
University, Chennai, Tamilnadu, India,

³Satbayev University, Kazakh National Research Technical University after K. I. Satpayev, Almaty, Kazakhstan,

⁴Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan.

E-mail: larissa.rav@mail.ru

METAL BLOCK CATALYSTS FOR COMPLEX CLEANING OF HARMFUL EMISSIONS OF TRANSPORT AND THE INDUSTRY

Abstract. The aim of the work is the synthesis and testing of catalysts on metal block carriers in the processes of complex gas cleaning of CO, C₃H₈, NO and deep oxidation of propane-butane and CO. The active phase of the catalysts was prepared on the basis of the compounds Pt, Pd, Ir, Au, Mn, Fe, Ni. The washcoat composition was based on alumina and zeolites. Catalysts prepared from colloids Pt, Pd, Ir, Au, possess high activity in the oxidation of hydrocarbons (100% in the range 573-773 K) and in the reduction reaction of nitrogen oxides - up to 67.0-69%. Among the catalysts containing manganese in the active phase, the most active was a catalyst prepared by introducing an organometallic compound based on polyethylene glycol into a washcoat suspension: the degree of CO oxidation was 93-100%, hydrocarbons - up to 82-83.2% at 623 K. While studying full-size samples of catalysts based on platinum on the stand on the basis of a diesel generator the degree of conversion of CO - 100%, hydrocarbons - above 98-99%, nitrogen oxides - 58-63% was achieved.

Keywords: motor transport, industry, harmful emissions, catalysts on metal blocks, complex gas cleaning, deep oxidation.

Introduction. The experience of last decades shows that the intensive economic development of many countries, based on extensive, irrational, and often predatory use of natural resources, leading to an unfavorable and irreversible phenomena in the environment. The poor state of water and air at the moment is one of the global problems of today. The deterioration of the state of the environment proceeds because of the uncontrolled production of performing business and thoughtless spending of natural resources [1-5]. The principal sources of air pollution are industrial plants and motor vehicle exhaust. The level of air pollution due to the development of industry and transport increases in tens of times year by year. Most industrial enterprises either do not keep records of emissions or perform it very inaccurately and tentatively. In some cases, it is not known exactly which pollutants come from one or another industrial facility. Alkanes, CO, NO_x, organic solvents, sulfur-containing compounds and many others belong to harmful toxiferous emissions of the industry and motor transport and which negatively influence on human health. Contamination of soil, vegetation, water bodies, the huge consumption of oxygen, heat radiation, the burning of associated gas contributes to the greenhouse effect, acid rain and climate change [6-8].

There are 3 main sources of air pollution by toxic substances emitted by vehicles:

- the exhaust gases which are coming out the muffler,
- the crankcase gases coming to the atmosphere from the system of ventilation of the engine,
- the evaporating fuel getting to the environment from fuel system of the engine and a fuel tank [9-12].

Constantly increasing growth in car numbers is one of the reasons for the deterioration of the ecological situation in the cities and towns. Condition of air is particularly important, because in contrast to other factors of the external environment air comes in direct and fast contact with very large physiologically active surfaces of the human body. In the absence of appropriate treatment methods also many industrial plants contaminate the air with the combustible or odorous compounds. A strong air pollution is very noticeable to cities with a bad natural ventilation, to which, in particular, belongs a number of industrial cities of Kazakhstan [7, 8]. Deep catalytic oxidation of organic compounds to carbon dioxide and water is one of the most effective methods of fighting against of the waste gases of industry and the motor transport. The catalysts-neutralizers of the exhaust (catalytic converter, an afterburner) are the mandatory option for all cars in the developed countries. Today, the monolithic metal blocks are considered as the most appropriate catalysts used for the solution of environmental problems [13-17]. High heat conductivity of metal carriers provides the good thermoregulation preventing an overheat of catalysts and interfacing constructional details. Plasticity, the characteristic of metals, allows to manufacture carriers in any idle time and a form, convenient for operation, with rather high specific geometrical surface area and gas permeability. The most typical catalysts are the three-way catalysts based on platinum, palladium and rhodium deposited on the ceramic or the metal blocks coated with alumina. However, the high cost of these metals and their low resistance to poisons stimulate carrying out of scientific research aimed at the creation of more optimal from an economic and technological point of view, the compositions and methods of preparation of the catalytic neutralizers. One of the perspective directions in this area is the partial replacement of noble metal on the oxide component [18-21]. Application of the low-percentage supported catalysts on the basis of the colloid metals with the chosen homogeneous particle size and with the low content of the active phase allows obtaining such examples of catalysts which provide necessary activity and selectivity. The use of the organometallic complexes instead nitrates and metal chlorides in the step of preparing of the active phase of the catalyst systems makes it possible to reduce the emissions of toxic substances formed during the preparation of the catalysts and reduce corrosion of the exploited equipment.

The purpose of this work was synthesis and test of the efficient and stable catalysts on metal block carriers with the reduced content of platinum metals in the active phase of catalysts for processes of neutralization of harmful emissions of the industry and combustion gases of motor transport.

Materials and methods. In this work, the catalysts on the basis of platinum and basic metals have been created by the technique earlier developed [22-26]. Catalysts on the basis of Pt, Pd colloids (particle size approx. 15-25 nm) have been produced. Metal block carriers have been made of the metallic foil (figure 1). The concentration of platinum metals was changed in the range of 0.05-0.2%. Also rare-earth metals have been added to composition of the active phase for increasing the thermal stability of the catalysts. The sols of metals have been supported on the block carriers. The samples of catalysts containing in their compositions Pt, Pd, Ir, Au with a low content (0.01-0.1%, on Pt basis) and 0.05 to 0.2% (on Pd, Ir, Au basis) have been prepared. In a stage of synthesis of a washcoat alumina with a zeolite additive

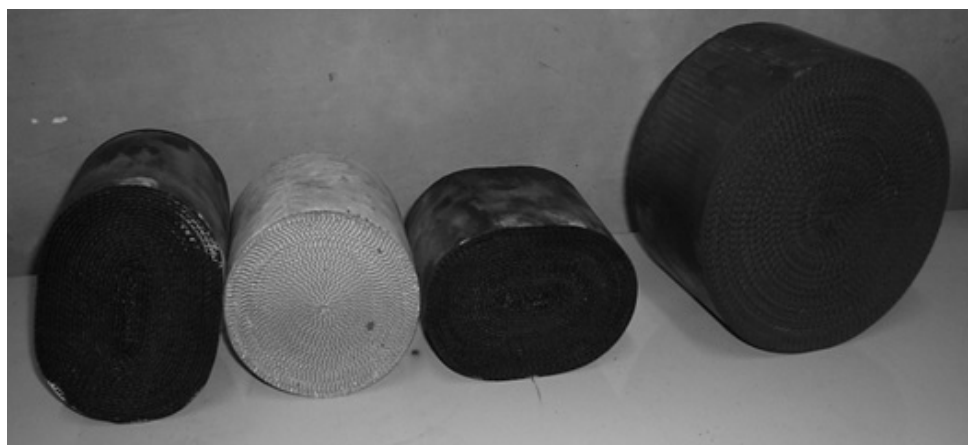


Figure 1 – Catalysts on the metallic blocks for tests at the experimental stand on the basis of a diesel generator

has been used. Different organic compounds for prevention or decreasing coagulation of the produced colloids have been chosen. Into the aqueous solutions of stabilizers (for example, polyethylene glycol, PEG) the necessary amount of salts of platinum metals dissolved in water was entered. By results of the conducted experiments the important technological parameters for preparation stable colloid particles of Pt, Pd, Ir, Au have been determined.

In the work along with the catalytic systems on the base of platinum metals, catalysts with the active phase containing of Mn, Ni, Co, Fe have been created and examined. For their preparation formates and acetates have been used. In the research one- and two-component catalytic systems on the basis of the compounds of Fe, Ni, Pt, Pd, with the different additives have been created. A wet hydrogel of aluminum hydroxide (80% humidity) was used as a binder. For preparation the such catalysts ZSM-5 zeolites with the module 30 and NaY with the module 5.1 were applied. Procedure of deposition of the active component have been carried with the use of a method of impregnation on a moisture capacity.

The prepared catalysts were tested in the reactions of oxidation of CO, a mixture of propane-butane (PB), hydrocarbons (HC) and in the reaction of nitrogen oxides reduction at temperature 423-973 K. Before testing, the catalyst sample was kept in the reactor for 30 min. in the flow of the reaction mixture at 773 K. After that, the gas temperature was reduced to given values, and the conversion of NO_x , CO and hydrocarbons was determined. The possible formation of CO in the reaction was also noticed. A characteristic activity of the catalyst is the degree of initial reagent (hydrocarbon, carbon monoxide, nitrogen oxide) conversion (α). The volumetric flow rate of the gas mixture was varied in the limits from 36, 000 to 50,000 h^{-1} .

The processes were researched in the flow catalytic installing with an integral tubular reactor type and with optimized parameters of the catalyst bed (figure 2). In the work also has been made a stand on the basis of the diesel generator for testing full-size samples of catalysts in the real exhaust gases (figure 3). The samples before and after the catalyst were selected in all operating modes of the diesel engine (idle mode-4 Kv) directly from the exhaust pipe with "OPTOGAZ-500.3" gas analyzer. Investigations have been carried out in the load range 0-4.0 Kv. The temperature in the catalyst zone has been measured with the help of a chromel-alumel thermocouple and IRT.

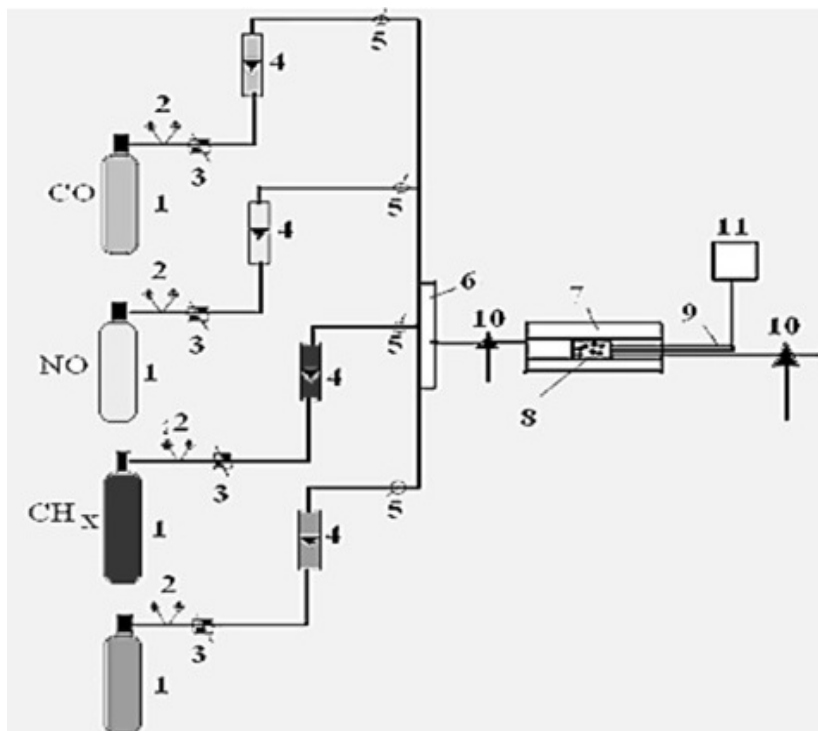


Figure 2 – Flow installation diagram:

1 - gas cylinder; 2 - pressure gauge; 3 - valve of a fine regulation; 4 - rotameter;
5 - crane; 6 - mixer; 7 - system of heating; 8 - sample of a catalyst; 9 - thermocouple; 10 - sampling; 11 - IRT

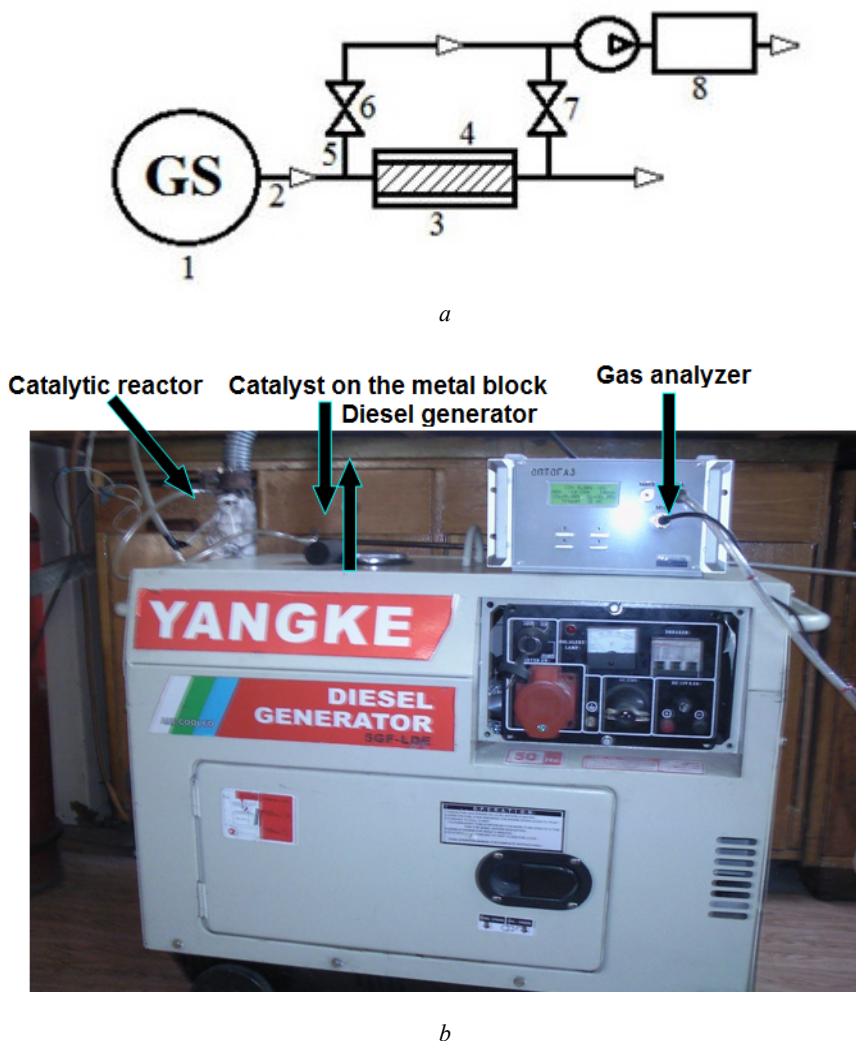


Figure 3 – Stand on the base of diesel generator:

a – schematic drawing of the experimental installation, consisting of a diesel-generator (1), pipe for exhaust gases (2), a reactor for catalysts' test (3), sample of a catalyst (4), gas operated probe (5), and 6,7 - valves for sampling; 8 - a gas analyser;
b - general view of the experimental installation

Results and discussions. The tests show that the catalytic activity (efficiency) depends as on the content of an active metal as on the method of the active metal deposition. The complexing composition for a colloid preparation also influenced. At the identical technique of platinum introduction into a washcoat the catalyst activity is increased with increasing of the platinum content in a range 0.05%-0.1%. The activity of 0.05% platinum-containing catalyst was 18% (at 523 K) and 100% (at 773 K).

In table 1 the results of studying activity of the catalysts synthesized by introduction of colloids of platinum metals to an alumina-oxide matrix by various methods are shown. It is visible, that activity depended on the contents of active metal and a method of introduction. At an identical method of introduction of platinum to the secondary carrier of the block metal catalyst (a washcoat) with increase in the contents of platinum from 0.05 % up to 0.1 %. activity of 0.05 % of the platinum catalyst was reduced from 100 % at 773 K up to 18.0 % at 523 K while with increase in the contents of platinum in 2 times activity grown and was 89.3 % at 523 K and 100% at 623 K.

At transition to Pd catalysts their activity at the contents of a palladium equal of 0,1 %, below, then platinum (No5 and No1). At preparation of the colloid Pd catalyst with use in quality complex former No2 activity increases to 94.2-100% at temperatures 623-773 K.

In the process of the complex cleaning of gases (table 2) was also demonstrated the high activity by the catalysts on the basis of colloids of palladium (with different concentrations) deposited on alumina.

Table 1 – Influence of concentration and a method of introduction of active metal on activity of catalysts in the reaction of HC oxidation and NO_x reduction

No	Catalyst (metal+No of complex former)	The active metal concentration, %	Conversion, % at different temperatures, K			
			773	623	523	423
1	Pt+1	0.05	100	76.9	18.09	0
2	Pt+1	0.1	100	100	89.3	10.7
3	Pt+2	0.1	100	88.0	40.0	0
4	Pt+3	0.1	100	87.3	11.5	0
5	Pd+1	0.1	92.0	82.1	6.0	0
6	Pd+2	0.1	100	94.2	11.6	0
7	Pd+1	0.05	93.0	79.2	5.4	0

Table 2 – Influence of concentration of palladium on activity of catalysts in the processes of HC oxidation and NO_x reduction

Pd concentration, wt. %	The degree of conversion HC/NO _x gases (%) at different temperatures, K			
	773	623	523	473
0.2	100/40.8	98.0/42.6	31.5/30.4	18.0/15.6
0.1	100/38.0	60.0/23.0	21.6/18.3	13.0/9.2
0.05	100/24.8	58.0/21.0	19.2/16.8	8.0/9.4

The degree of HC conversion on catalysts containing Pd-0,2%, with a decrease in the temperature from 773 to 623 K is reduced slightly - from 100% (773 K) to 98.0% (623 K), for catalysts on the basis of 0.1% and 0.05% Pd conversion decrease more sharply: from 100% to 60.0% (for 0.1% of Pd-contacts) and 58.0% (0.05% of Pd). For catalysts with the content of 0.2% of Pd in the field of temperatures 623-773K conversion degree of HC was equal to 97.4-100%, and NO_x - 40.8-42.6%. With decrease of content of palladium to 0.1% an activity of catalysts is decreased, for example, at 623 K conversion degree of HC is decreased to 60.0%, nitrogen oxides - to 23.0 %. With a decrease the content of palladium in catalysts to 0.05% are required higher temperatures (773 K) for the deep oxidation of hydrocarbons, at 523 K the degree of hydrocarbon conversion is reduced to 19.0-25.0%, and the conversion degree of nitric oxide is reduced slightly (to 16. 8%).

The method of introducing and the magnitude of dispersion of colloidal metal affected the activity of the catalysts based on the colloids of Pt, Pd, Ir, Au. So, on the catalyst on the basis of Pd when using as a complexing-PEG, the catalytic activity at change of ways of introduction is ranged between 69.0% to 94.2-100% in the temperature interval 623-773K. With increasing concentration of the metal in the catalyst is increased its activity depending on the nature of the metal and a complexing. When the palladium content 0.2% in the temperature interval 623-773K the catalyst activity was equal to is 98.0-100% on a methane. With the reduction of the noble metal content up to 0.1% activity of the samples - by methane is reduced to 60.02% at 623K. With the further decrease of the palladium content up to 0.05% the total methane oxidation was carried out at a higher temperature (623-773K), and at 523K the catalyst activity was decreased to 19.0-25.0 % by hydrocarbons, for nitrogen oxides the catalyst activity was not substantially changed. Thus, by results of the performed researches it is found that the synthesized on the basis of colloids of noble metals (Pt, Pd, Ir, Au) catalysts have high activity in oxidizing reaction of hydrocarbons (100% at 573-773 K) and reduction of nitrogen oxides - to 67.0-69.0%. On the catalytic activity in reaction of the complete oxidation of the propane - butane mixture the catalysts on the basis of colloids of noble metals form a series: Pt > Pd > Ir (Au), in the reaction of complex cleaning of exhaust gases of the motor transport: on CO-conversion degree on all noble metals almost identical (98-100%, depending on the process conditions), for nitrogen oxides the most efficient catalyst – on the basis of Pt.

The effectiveness of catalysts containing manganese in the composition of the active phase was determined during the deep oxidation of CO+C_xH_y in the temperature range 373-773 K (table 3). The content of CO in the mixture with air was 1%, propane-butane (PB) - 0.5%, the volumetric rate - 50,000 h⁻¹. It

Table 3 – The oxidation reaction of CO (1%) and PB (0.5%) over the different manganese catalysts, volume flow rate –50, 000 h⁻¹

Temperature, K	Conversion degree (%) at the different catalysts					
	Manganese nitrate		Manganese acetate		PEG-manganese oxide	
	CO	PB	CO	PB	CO	PB
773	85.8	29.5	100	38.0	100	95.4
623	68.9	0	95.5	12.1	100	83.2
523	53.8	0	74.7	9.0	94.6	10.0
473	34.9	–	39.9	–	63.0	–
423	0.3	–	7.0	–	9.7	–

was established that catalytic systems, the active phase of which was prepared on the basis of manganese nitrate and acetate, showed low activity in the oxidation of CO and oxidation of the propane-butane mixture. The maximum degree of CO conversion was 85.8-100%, and the propane-butane mixture was 29.5-38.0% at 773 K. Adding the same compound of manganese with polyethylene glycol (PEG) contributed to increasing the efficiency of the catalyst. When use this catalyst the carbon monoxide and hydrocarbons begin to be oxidized with the sufficiently high activity at low temperatures. Thus, at 523 K carbon monoxide is oxidized to 94.6%, and hydrocarbons - up to 83.2% at 623 K. On this catalyst 100% CO oxidation is achieved at a temperature of 623 K, and the maximum conversion of PB (95.4%) is observed at 773 K.

The catalyst on the basis of PEG containing 5.0% of oxide of manganese was tested in oxidizing reaction of 1% CO and 0.5% of propylene in the air at the volume speed 35,000 h⁻¹ (table 4). At lower volume rate of gas flow (35,000 h⁻¹) and in the presence of a propylene the catalyst begins to demonstrate activity already at 423 K, and the complete oxidation of CO is observed at 503 K. It should be noted a high activity of the catalyst in the reaction of propylene oxidation: at 503 K conversion degree is 86.7% and 100% of propylene oxidation proceeds at 573 K.

Table 4 – Activity of 5% Mn-containing catalyst in the oxidation reaction of 1% CO and 0.5% propylene in the air (the gases volumetric flow rate - 35,000 h⁻¹)

The temperature of test, K	Conversion degree, %	
	CO	propylene in air
403	5.7	0
423	44.3	1.7
443	89.1	3.3
463	98.6	18.3
483	99.4	56.7
503	99.9	86.7
523	100	96.7
553	100	99.1
573	100	100

In the case of systems on the basis of Fe, Ni, Pt, Pd with additives of zeolites irrespective of the nature of introduced zeolite, the noticeable transformation of NO_x began at temperature over 473 K, gradually increased with increase of temperature and reached a maximum value at T=773 K. Among the Fe-containing catalysts the biggest activity at reduction of nitrogen oxides by propylene was revealed for the sample, modified by NaY zeolite. The catalyst with the same composition was the most effective also for C₃H₆ oxidation. At 473 K the degree of C₃H₆ conversion on this catalyst was 35.8%, and complete conversion is observed at 573 K. The degree of conversion of C₃H₆ at 573 K on the catalysts of this series decreased in the series: Fe/NaY>Fe/ZSM-5>Fe/Al₂O₃. Oxidation of propylene at the Ni-containing zeolites happened, in comparison with the Fe-containing block catalysts, with lower degrees of conversion: 100% transformation of C₃H₆ was observed on Ni/HY catalyst only at 773 K. The other samples of Ni-based catalysts are less active and the degree of C₃H₆ conversion at them was little varied depending on

the zeolites nature. Noticeable NO conversion at Ni-containing zeolites was observed at temperatures above 473 K. Depending on the nature of the modifying zeolite activity of the Ni-containing zeolites in reaction of reduction of NO at 573 K is decreased in the series: Ni/HY>Ni/NaY>Ni/ZSM-5.

Effectiveness of the Ni, Fe/zeolite catalysts was determined by heat stability at T=973 K during 50 h in the gaseous environment. It is appeared that the most stable sample at all temperatures was Ni/HY, at 673 K degree of NO_x conversion was equal to 67.0% and the conversion of propylene - 100%.

Activity of prepared catalysts has been defined at the experimental installation, consisting of the diesel-generator with 4 Kv (figure 3). Dimensions of catalysts were the following: d - 30 mm, h - 90 mm, V - 63.4 mm³. The data of experiments in the bifunctional mode at various loadings of operation of the engine are shown in table 5. The catalyst containing 0.1% of Pt is effective already at 540 K, transformation degree of CO was 99.6 %, hydrocarbons - 80.7% and nitrogen oxides - 44.4%. When engine capacity was increased to 3-4 Kv than conversion degree of NO_x to 58-63% was reached.

Table 5 – Results of the analysis of toxic emissions on the diesel generator on the block platinum catalyst at various loads

The consumed capacity, kV	Temperature of the exhaust gases, K	Degree of the exhaust gases cleaning, %		
		CO	CH _x	NO _x
Idle motion	293	90.6	21.5	3.0
2	540	99.6	80.7	44.4
3	581	100	95.6	61.1
4	700	100	99.3	63.0

The prepared catalysts were examined by different physical and chemical research techniques (figure 4–6).

The study of Pt and Pd - containing catalysts for thermal stability was carried out by holding the chosen catalyst during 5 hours at T = 673 and 773 K in the reaction gas mixture with a content of 0.5% propane-butane with further analysis of the reaction products. Duration of the such test was 100 hours. The catalysts obtained from Pt acetates proved to be the most stable, while those based on Pd acetates were less stable.

X-ray phase analysis of tested catalysts has been performed on X-ray diffractometer DRON-4-0.7 with a copper anode. It was revealed scattering of the spectrum for Pt- and Pd-catalysts, and this fact confirmed the high dispersion of metals [26]. Catalysts have been examined on TEM on EM-125 K by the single-step replica method (figure 4, 5). At zoom 33,000 there were found semi-transparent regions of polymer bunches filled with dispersed particles 3 nm in size in the case of Pt-, Pd-catalysts. At zoom 62,000 times the small sparse clusters of denser particles 5 nm in size have been also revealed (figure 5).

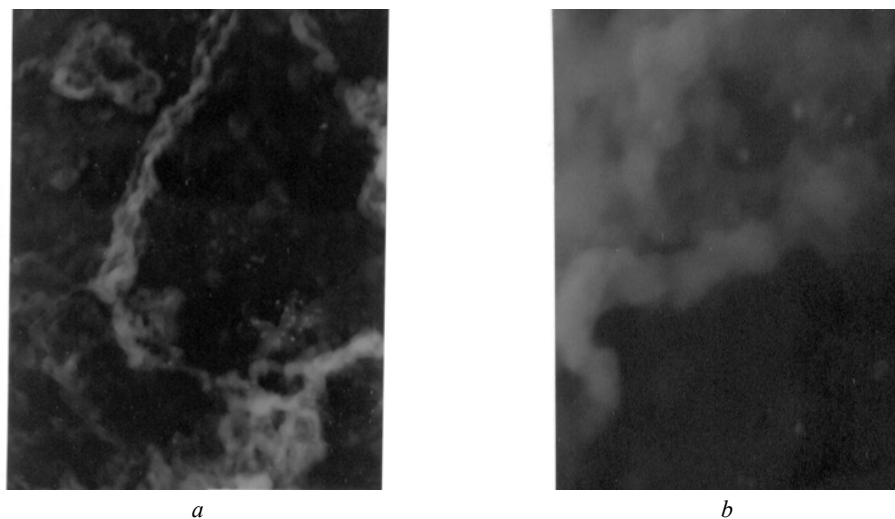


Figure 4 – TEM-images of catalysts on the base of platinum metals: *a* - Pt-containing catalyst, *b* - Pd-containing catalyst

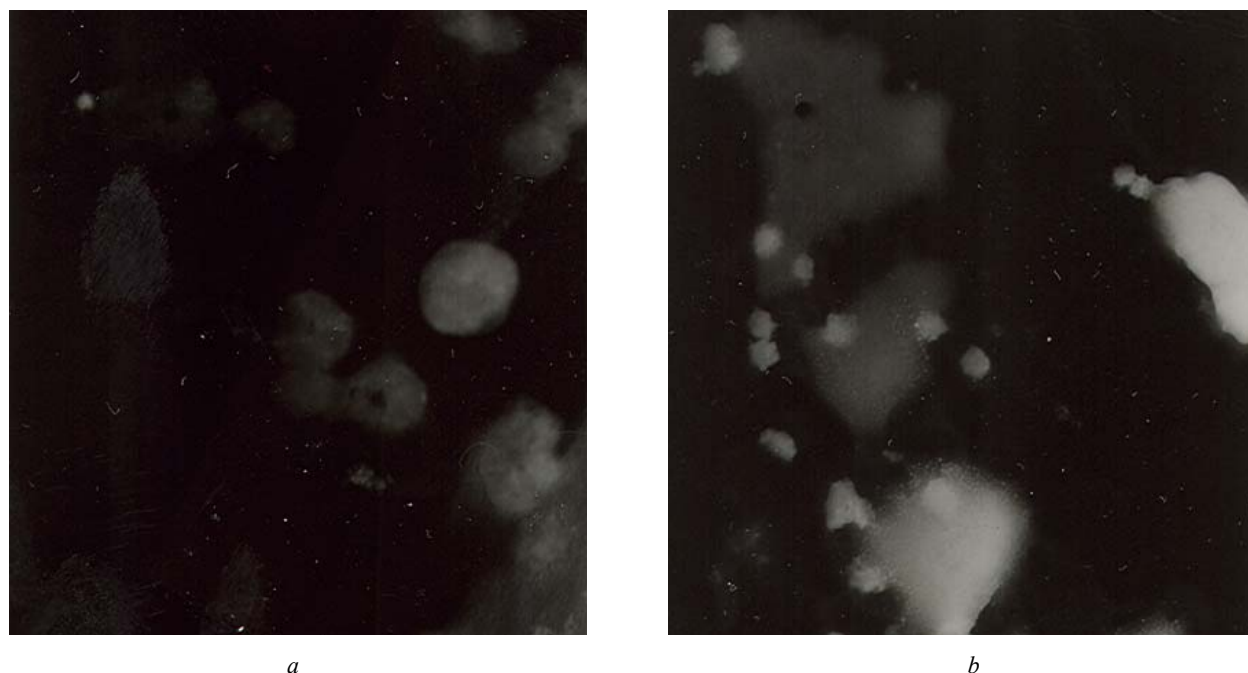


Figure 5 – TEM images of fragments of metal clusters:
a - Pt-particles, *b* - clusters of denser Pd particles 5 nm in size

The thermostability of the prepared catalysts was calculated by definition of activity of the initial catalyst on the diesel engine - generator working under loading in 3 Kv, with the subsequent fractional calcinations of the neutralizers at 873 K with an interval of 5 hours in the muffle furnace. During 100-hour test the high thermostability was shown.

The characteristics of some samples of catalysts on the basis of Pt and Pd obtained with use of the TPD NH_3 method are shown in table 6. The total concentration of acid sites of Pt- and Pd-promoted catalysts of nickel and manganese oxides is higher than that of the initial alumino-platinum and palladium catalysts. Pt- and Pd-containing catalysts have similar values of the total concentration of acid sites 620-660 $\mu\text{mol/g}$, but they are characterized by different ratios of centres of different force, and it apparently determines the differences in their catalytic properties. The catalysts based on Pt/Ni-Mn/ Al_2O_3 have a greater concentration of strong acid sites (280 $\mu\text{mol/g}$) and for Pd/Ni-Mn/ Al_2O_3 catalyst is revealed the highest concentration of weak acid sites - 250 $\mu\text{mol/g}$ (figure 6).

Table 6 – TPD data of Pt- and Pd-catalysts

Catalyst sample	Pore structure of catalysts		The total concentration of the acid sites, $\mu\text{mol/g}$
	The specific surface area, m^2/g	Pore volume, cm^3/g	
Pt-containing	200	0.348	240
Pd-containing	205	0.356	110
Pd/Ni-Mn/ Al_2O_3	350	0.274	620
Pt/Ni-Mn/ Al_2O_3	370	0.290	660

It was found by the TPD method of ammonia that in case of catalysts on the basis of basic metals introduction to the carrier of Co and Mn oxides led to small increase in a share of the retained volume of ammonia, i.e. force of the acid centers of the catalyst is slightly increases. Possibly, activity of the oxide-coated catalyst is influenced by the structural changes arising at introduction of oxides of cobalt and manganese into the carrier. For catalysts based on the colloids of Pt, Pd, Ir, Au revealed high dispersion (25.0-30.0 nm), colloids demonstrated good stability over 1-1.5 months at room temperature. XPS and EM data showed that the platinum metals in the starting monodisperse catalysts are in an oxidized state with uniform distribution of the metal particles on the carrier and they are characterized by high thermal

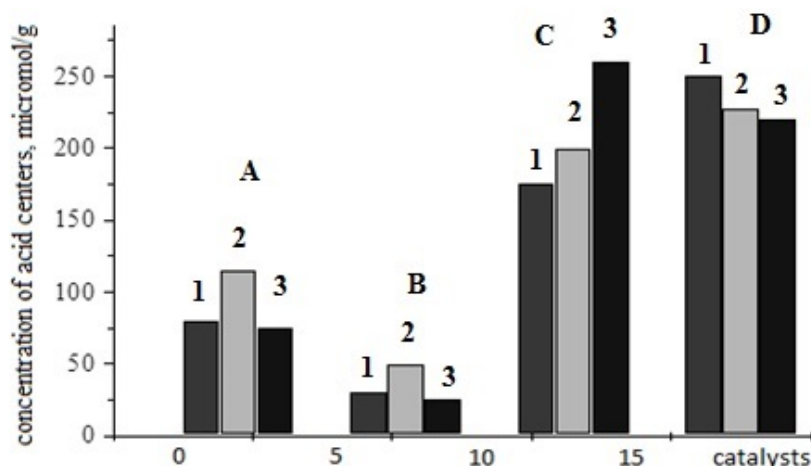


Figure 6 – Acid centres' share for different active phases of catalysts:
 A - on the basis of platinum, B - on the basis of palladium, C - on the basis of platinum, nickel and manganese,
 D - on the basis of palladium, nickel and manganese; 1 - weak centers, 2 - medium centers, 3 - strong centers

stability. By the EM and RFA methods it is found that in the Mn-containing catalysts on the basis of PEG are formed the particle which are finely divided, evenly distributed on a surface of the carrier. The catalysts prepared from acetate and also on the basis of manganese nitrates, had larger particles, which causes, may decrease the activity of manganese catalysts in hydrocarbon and CO oxidation.

Results of physical and chemical research of catalysts prepared confirmed literature data [6, 13, 14, 27-30].

Conclusion. Thus catalysts on the basis of colloids of noble metals and compounds of basic metals on block metal carriers were prepared. Catalytic efficiency of the prepared catalysts was tested in the reactions of complex cleaning of gases from CO, C₃H₈, NO and in the oxidizing reactions of propane-butane mixture and CO. The catalyst activity prepared with the noble metals depends on the active metal content and on the deposition method of the active metal (complexing composition for preparing of the colloid). The catalysts synthesized on the basis of colloids of noble metals (Pt, Pd, Ir, Au) catalysts have high activity in oxidizing reaction of hydrocarbons (100% at 573-773 K) and reduction of oxides of nitrogen - to 67-69%. It was found that in a series of manganese-containing catalysts the introduction of the Mn-compound with PEG increased a catalytic activity. So, at CO is oxidized to 93-100% (at 523-623 K, and hydrocarbons are oxidized to 82-83.2% at 623 K. On this catalyst the maximal transformation of propane-butane mixture (95.5%) is observed at 773 K. The full-size samples of the catalysts on the basis of platinum were tested on the stand on the basis of a diesel-generator. The degree of conversion of CO was equal to 100%, hydrocarbons – more than 98-99%, nitrogen oxides – 58-63%.

Л. Р. Сасыкова¹, С. Сендилвелан², Е. А. Әубәкіров¹, Ж. Х. Ташмухамбетова¹,
 А. А. Батырбаева¹, Р. Н. Ажигүлова¹, Ш. Н. Кубекова³, К. О. Шарипов⁴,
 Р. Г. Рыскалиева¹, Б. Б. Төсүпова¹, М. А. Сарыбаев¹

¹Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан;

²Department of Mechanical Engineering, Dr. M.G.R Educational and Research Institute, University, India,

³Қ. И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті,

Институт химических и биологических технологий КазННТУ им. К. И. Сатпаева, Алматы, Казахстан,

⁴С. Д. Асфендияров атындағы Қазақ ұлттық медициналық университеті, Алматы, Казахстан

КӨЛІК ЖӘНЕ ӨНДІРІСТЕН ШЫҒАРЫЛАТЫН ЗИЯНДЫ ЗАТТАРДЫ КЕШЕНДІ ТАЗАЛАУДЫҢ МЕТАЛЛ БЛОКТАҒЫ КАТАЛИЗАТОРЛАРЫ

Аннотация. Жұмыстың мақсаты металл блоқты тасымалдағыштағы катализаторды синтездеу және газдың құрамындағы CO, C₃H₈, NO кешенді тазалаумен пропан-бутанды және CO терең тотықтыру процестерінде сынау. Катализатордың белсенді фазасын Pt, Pd, Ir, Au, Mn, Fe, Ni қосылыстары негізінде дайындалды.

Pt, Pd, Ir, Au коллоидтары негізіндегі катализаторлары көмірсутектерді тотықтыруда (100% ,573-773 К температура аралығында) және азот оксидінің тотықсыздану реакциясында 67,0-69 % дейін жоғары белсенділік көрсетті. Катализаторлар арасында біріншілік тасымалдағыш суспензиясына полиэтиленгликоль негізіндегі металлоорганикалық қосылысты енгізу арқылы дайындалған белсенді фаза құрамында марганец бар катализатор белсенділік көрсетті: 623 К температурада СО-ның тотығу дәрежесі 93-100%, көмірсутектердің тотығу дәрежесі - 82-83,2% дейін болды. Платина негізіндегі катализатордың толық өлшемді үлгілерін қабырғалық дизель-генераторда зерттегенде СО-ның конверсия дәрежесі - 100%, көмірсутектер - 98-99% жоғары, азот оксидтері - 58-63%.

Түйін сөздер: автотранспорт, өндіріс, зиянды заттар, металл блоқты катализаторлар, газды кешенді тазалау, терең тотығу.

Л. Р. Сасыкова¹, С. Сендилвелан², Е. А. Аубакиров¹, Ж. Х. Ташмухамбетова¹,
А. А. Батырбаева¹, Р. Н. Ажигулова¹, Ш. Н. Кубекова³, К. О. Шарипов⁴,
Р. Г. Рыскалиева¹, Б. Б. Тюсюпова¹, М. А. Сарыбаев¹

¹Казахский национальный университет им. аль-Фараби, Алматы, Казахстан,

²Department of Mechanical Engineering, Dr. M.G.R Educational and Research Institute, University, India,

³Казахский национальный исследовательский технический университет им. К. И. Сатпаева, Институт химических и биологических технологий КазННТУ им. К. И. Алматы, Казахстан,

⁴Казахский национальный медицинский университет им. С. Д. Асфендиярова, Алматы, Казахстан

КАТАЛИЗАТОРЫ НА МЕТАЛЛИЧЕСКИХ БЛОКАХ ДЛЯ КОМПЛЕКСНОЙ ОЧИСТКИ ВРЕДНЫХ ВЫБРОСОВ ТРАНСПОРТА И ПРОМЫШЛЕННОСТИ

Аннотация. Целью работы является синтез и испытание катализаторов на металлических блочных носителях в процессах комплексной очистки газов от CO, C₃H₈, NO и глубокого окисления пропан-бутана и СО. Активную фазу катализаторов готовили на основе соединений Pt, Pd, Ir, Au, Mn, Fe, Ni. Состав первичного носителя был на основе оксида алюминия и цеолитов. Катализаторы, приготовленные из коллоидов Pt, Pd, Ir, Au, обладают высокой активностью в окислении углеводородов (100% в интервале 573-773 К) и в реакции восстановления оксидов азота - до 67,0-69 %. Среди катализаторов, содержащих в активной фазе марганец, наиболее активным был катализатор, приготовленный введением металлоорганического соединения на основе полиэтиленгликоля в суспензию первичного носителя: степень окисления СО была 93-100%, углеводородов - до 82-83,2% при 623 К. При изучении полноразмерных образцов катализаторов на основе платины на стенде на основе дизель-генератора достигнута степень конверсии СО - 100%, углеводородов - выше 98-99%, оксидов азота - 58-63%.

Ключевые слова: автотранспорт, промышленность, вредные выбросы, катализаторы на металлических блоках, комплексная очистка газа, глубокое окисление.

Information about authors:

Sassykova Larissa R., Ph.D., Prof. of the Department of Physical Chemistry, Catalysis and Petrochemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; larissa.rav@mail.ru; <https://orcid.org/0000-0003-4721-9758>

Sendilvelan Subramanian, Prof., Dean, Department of Mechanical Engineering, Dr. Sc. M.G.R Educational and Research Institute, University, Chennai, India (*Hirsch index 13*); sendilvelan.mech@drmgrdu.ac.in; <http://orcid.org/0000-0003-1743-4246>

Aubakirov Yermek A., Prof., Head of the Department of Physical Chemistry, Catalysis and Petrochemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; miral.64@mail.ru; <https://orcid.org/0000-0001-5405-4125>

Tashmukhambetova Zheneta Kh., Ph.D., Ass. Prof. of the Department of Physical Chemistry, Catalysis and Petrochemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; zheneta@mail.ru; <https://orcid.org/0000-0003-4125-4114>

Batyrbaeva Aigul A., Ph.D., Ass. Prof. of the Department of Physical Chemistry, Catalysis and Petrochemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; batyrbaeva_aigul@mail.ru; <https://orcid.org/0000-0003-2280-4846>

Azhigulova Ryskul Ninilovna, Ph.D., Ass. Prof. of the Department of Physical Chemistry, Catalysis and Petrochemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; razhigulova@gmail.com; <https://orcid.org/0000-0003-4498-8439>

Kubekova Sholpan N., Associated professor, Candidate (Ph.D.) of Technical sciences, Department of Chemical Technology of Inorganic Substances, Institute of Chemical and Biological Technologies, KazNTRU after K. I. Satpayev, Almaty, Kazakhstan; kubekova_10@mail.ru; <https://orcid.org/0000-0001-8665-9970>

Sharipov Kamalidin Orynbaevich, Professor, Doctor of Biological Sciences, Head of the Department of Biochemistry, Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan; skamalidin@mail.ru; <https://orcid.org/0000-0001-5946-5521>

Ryskaliyeva Roza G., Ph.D., Ass. Prof. of the Department of General and Inorganic Chemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; roza12_11_64@mail.ru; <https://orcid.org/0000-0002-9591-1477>

Tyussypova Bakyt B., Ph.D., Ass. Prof. of the Department of Analytical, Colloidal Chemistry and Technology of Rare Elements, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; baimuratovna78@mail.ru; <https://orcid.org/0000-0001-6149-2326>

Sarybayev Madiyar A., Ph.D., Senior Lecturer of the Department of Physical Chemistry, Catalysis and Petrochemistry, Faculty of Chemistry and Chemical Technology, al-Farabi KazNU, Almaty, Kazakhstan; sarybayev.madiyar@gmail.com; <https://orcid.org/0000-0003-4488-5659>

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A. A. Kovtun¹, A. D. Mekhtiyev¹, V. V. Yugay¹, A. D. Alkina¹, U. A. Sekretarev²

¹Karaganda state technical university, Kazakhstan,

²Novosibirsk state technical university, Russia.

E-mail: kovtun.a73@mail.ru, barton.kz@mail.ru, slawa_v@mail.ru, alika_1308@mail.ru, sekretarevua@mail.ru

GENERAL PRINCIPLES OF OBTAINING SITUATIONAL ESTIMATES OF THE EQUIPMENT OF COMPLEX STRUCTURES OPERATION MODES

Abstract. The article is devoted to solving problems of creating methods for situational management of Complex Structures Operation Modes. The general principles of obtaining situational estimates of the operational status of power plant equipment are considered. The division of the situational management process into the main stages related to the operational reliability of the plant blocks was accomplished. When estimating a larger (almost unlimited) number of factors, a modified method of obtaining weights using a three-point system can be used. The procedure for obtaining expert estimates by the method of successive preferences is formulated, based on the interpretation of the Cherkmen-Akoff procedure (sequential preference procedure) with computer implementation.

Key words: factors, management, situation, power plant, situational control, object of control, efficiency of functioning, control procedure, reliability, control parameters.

General principles for obtaining situational assessments of the operational status of power plant equipment can be summarized in a series of symbolic expressions by means of which it is possible to describe the process of controlling the power plant (1-5), allows us to approach the assessment of the operational state of the equipment operating on it from the point of view of the situational approach. The current situation at the stations $S_{\Theta t}$ and S is determined by a number of economic parameters and reliability parameters R_{Θ}^* and R_H^* which characterize the actual state of the operating equipment at time t . In this connection, a natural question arises about the dimension of the regime parameters, the control of which makes it possible to determine R_{Θ}^* and R_H^* and to obtain on their basis estimates of the situations $S_{\Theta t}$ and $S_H t$ according to (1).

$$S: S_t \times S_{\Theta t} \times S_H t \rightarrow S_{t+1}, \quad (1)$$

where S is the complete situation (by definition);

S_t is current situation in the PP, formulated in the form of requirements that are required for the operation of the power plant under the conditions of covering the active and reactive loads; S_t^H, S_t^{Θ} are current situations associated with the actual mode of the plant, which are determined by the economy and reliability of equipment operating on it; U^* is vector of multipurpose management; S_{t+1} is the new current situation at the plant as the Cartesian product of the preceding ones.

Under normal PP operation conditions, a cartesian product will be understood as a conjunctive convolution of current situations:

$$S_{t+1}^C \supseteq S_t \times S_t^{\Theta} \times S_t^H = \inf(S_t, S_t^{\Theta}, S_t^H). \quad (2)$$

Since the change in the current situation is made in this case by changing the composition of the power plant equipment, then the projection of these situations takes place in the general, regime space Ω , i.e.

$$\text{Proj}(S_{t+1}^C) \supseteq \text{Proj}(S_t) \cap \text{Proj}(S_t^{\Theta}) \cap \text{Proj}(S_t^H). \quad (3)$$

The format of the projections is determined both by the type of management U^* , and the information level of the description of current situations, as noted above. The formation of the multipurpose management of vector U^* within the framework of the described process is a multipurpose convolution of the form:

$$U^* = DE(KS_t, KS_t^{\ominus}, KS_t^H), \quad (4)$$

where DE are defined by some logical-multiple operation, with the help of which the goals or criteria KS_t , $KS_t^{\ominus}$ and KS_t^H are rolled up.

In the decision making process we usually consider as binary [1,2], we rewrite (4) in the following form:

$$U^* = DE_1[DE_1(KS_t^{\ominus}, KS_t^H), KS_t]. \quad (5)$$

Here it is important to note that the convolutions DE_1 and DE_2 in (5) can in general be different. The system of expressions (1-5) is a formalized description of the process of managing a power plant from the standpoint of a situational approach. Change of the current situation at the plant is carried out in this case by changing the composition of the equipment running on it as one of the phases of operational management. In the very designation of the system of operational control of the number and composition of hydroelectric units, two interrelated aspects of management are objectively laid. On the one hand, this is an automatic regulation of the aggregate mode by working out the number, composition and distribution of the load between the units, this regulation is undoubtedly an integral part of the regime automation of the HPP. On the other hand, it is operational dispatch control, which is determined by the current changes, both the modes of the hydrounit and the plant. Here the main means of control is not so much the regime automatic (which carries out the process of regulation), but the ability of the person to make decisions. This duality was reflected even in the name of these devices: an automatic operator and rational management of the composition of aggregates. Both these names speak of the hybrid nature of such a management system. The first is in the immediate compound title, the second is through the concept of rational, that is, weighted effective.

The main characteristic, by means of which the economic work of the unit at the station is estimated, is the amount of energy resource consumption (water flow at the hydraulic unit or fuel consumption at the thermal unit) or its efficiency, which can be recalculated into cost parameters, for example, the costs associated with the production of energy at the plant [1]. Thus, if the actual efficiency of the block at time t is determined (ηt), then an economic evaluation of its operation mode can be obtained in the form

$$R_s^* = \eta t. \quad (6)$$

Such a characteristic as the efficiency of the block based on the construction of its economic characteristics has been worked out quite fully, although the practical implementation encounters a number of intractable problems [2 ... 7]. Using a situational approach allows them to be successfully overcome. In contrast to the economy, the regime parameters characterizing the operational reliability of the unit are quite numerous. They form a multidimensional space of the form

$$R_H^* = (R_m^*, R_B^*, R_{\text{эл}}^*, R_y^*, R_{\text{нп}}), \quad (7)$$

where R_m^* , R_B^* , $R_{\text{эл}}^*$, R_y^* , $R_{\text{нп}}$ are parameters of temperature, vibration, electrical states, parameters characterizing the deviation of water and oil levels, air pressure at the monitored units of the unit, and a number of others. In principle the current deterioration of the unit can be used as a universal parameter characterizing the operational reliability of the unit operation, similar to the efficiency in assessing its efficiency. However, this complicated problem has not yet been solved methodologically. Absence of strict models for calculating the current wear of the power block makes it necessary to take an indirect account of operational reliability on the basis of control, and to change the numerous parameters in accordance with (6). This requires the development of special procedures for obtaining them, bringing the parameters to a single dimension, as well as ranking the monitored parameters, since the degree of their information value for decision making in the operational management loop is generally different.

Assessment of the importance (weight) of the monitored parameters of the unit, regardless of the current situation, but determined only by the degree of responsibility of control, behind a separate unit of the hydrounit. Such an assessment can be called "basic":

$$B(\Pi_i) = (R_{\Pi}^*, i=1, \dots, n), \quad (8)$$

where i is the number of the monitored parameter Π , which determines the operational reliability of the unit R_{Π}^* .

Obtaining "current" estimates that characterize the degree of operational reliability of the unit at the time of acceptance of t . Obviously, these estimates are directly determined by the current situation at the plant.

$$T(\Pi_i) = (R_{\Pi}^*, j=1, \dots, \kappa), \quad (9)$$

where j is the number of the monitored parameter Π , the value of which at current time t deviates (or does not deviate) from the nominal value.

Determination of "resulting" estimates of operational reliability for each currently operating hydraulic unit. They can be obtained by imposing "current" estimates of controlled parameters on their "basic", in particular, as a product:

$$J(\Pi_i) = (R_{\Pi}^*, B(\Pi_i) \cdot T(\Pi_i), i = 1, \dots, n). \quad (10)$$

This will mean the formation of a certain level of description, which is the projection of the map f_1 in the general information space of the plant's regime parameters. Based on $J(\Pi_i)$, the DMO can make a decision related to changing or not changing the mode of the equipment running on the plant. In order to implement these steps, which are related to the operational reliability of the plant units, it is necessary to determine those sources of obtaining primary information, on the basis of which the above-mentioned indicators can be calculated, and subsequently used in the operational dispatching management of the plant from the positions of the situational approach. By methods of control and value, the information obtained on the operational status of the main equipment of a hydroelectric station can be divided into 3 main groups [1-8]:

- a) automatic control for the operational state of HPP equipment using relay protection and automation devices;
- b) periodic monitoring of the operational status of the equipment by semi-automated means by plant personnel or using an automated control system;
- c) control checks and tests of units, elements and parts of the main equipment of hydroelectric power stations.

Let us dwell on each of these groups. Specific diagnostic information on the state of the elements of the nodes of the unit block is provided by relay protection and automation devices that monitor deviations (within the limits of permissible or emergency), temperature, electrical, chemical and other parameters of the regime from their normal value. The monitoring of the condition of relay protection devices is carried out automatically, according to the principle of "yes-no", that is a certain parameter of the regime deviates from the norm. The emergency deviations of the parameters of the regime are characterized by the unequivocal action of the relay protection devices to disconnect the equipment, which allows to stop the further development of the accident on it. Deviations of parameters close to emergency settings, but not exceeding them, are fixed by a warning signal. The appearance of a warning signal indicates abnormal operating conditions of the equipment and forces operational personnel to make a specific decision aimed at eliminating the cause of the signal.

Since the warning signal is not emergency, control aimed at preventing an emergency may be called preventive control in normal modes. The warning signaling covers almost all the elements of the aggregate block and its auxiliary equipment, which means that it is possible to obtain a practically complete volume of diagnostic information, its operability [1-8]. In addition to Relay Protection and Automatic Equipment, periodic monitoring of the state of assemblies and elements of the main equipment is carried out by means of standard measuring sensors in a semi-automated way by plant personnel, or by means of an automated control system. With its help it is possible to carry out not only check of the facts of functioning of equipment elements (for example, as the fact of operation of preventive protections), but also to receive an objective volumetric quantitative estimation on average size and dispersion of the measured parameter. This is due to the fact that the measuring sensors are installed at many points of the monitored element and their number, as a rule, considerably exceeds the number of RPA sensors. The value of information

obtained on the basis of periodic monitoring is both in quantifying the current state of the equipment, and in the possibility of using it for forecasting the state in future periods of operation.

Questions of methodology and practice for assessing the state of equipment for a system of control checks and tests have been developed quite thoroughly. Control checks and tests are carried out after the vibration state of the hydraulic unit as a whole and its individual components and parts. In contrast to periodic monitoring, inspections and tests are much less frequent: when starting up and adjusting the hydraulic unit, preventive and diagnostic tests, in the output for repair to clarify its volume and commissioning after repair to assess its effectiveness, as well as for special tests. It should be noted the special importance of vibration control. In particular, with its help it is possible to increase the reliability of the diagnosis, i.e. identification of the place, nature and extent of damage to the generator. Despite the attractiveness of obtaining the most accurate and complete characteristics of the operational state of the equipment, with the help of tests, it is first and foremost necessary to further improve and develop operational methods and standard monitoring tools, in order to detect the faults that have arisen with quite high accuracy at early stages of their development. In addition, the diagnostic information obtained as a result of control checks and tests, quickly becomes obsolete, which requires its current refinement and correction. Thus, the system of existing control, due to the operational reliability of the unit, allows obtaining diagnostic information about the state of the equipment that can be used in the preventive management of the equipment operating at the plant [1-8].

Basic estimates of operational reliability of hydraulic units, determined on the basis of the fact of operation of preventive protection. Sufficiently objective information about the current operational status of the equipment is provided by the operation of relay protection and automation devices. To account for the condition of the equipment in the normal mode of operation can be limited to information obtained on the fact of the warning alarm on the hydraulic units. Therefore, if a system of information analysis of the fact of the operation of preventive protection is created, it is possible to obtain estimates of the operational state on the basis of sufficiently representative information.

The idea of such an analysis is as follows. Any precautionary protection, when triggered, causes a different response in the DMO. This is because the importance of the information obtained for DMO depends on which or what protection has worked. In other words, each preventive protection has its own "information weight". Therefore, to implement the analysis, it is necessary to weigh all preventive protections in terms of their effect on the operational reliability of the entire aggregate unit. As a procedure allowing to carry out the process of "weighing", you can use the method of expert assessments [6-9].

At a number of hydro power stations, studies were carried out aimed at obtaining "weights" of warning signaling using the emergency assessment procedures [6-8]. Let us formulate the purpose of such an examination. Using the proposed list of protections, operational personnel should assess the importance of each protection, in terms of deciding whether to stop or replace hydraulic units [6-9]. For example, if from the DMO point of view, the signaling about the rise in the temperature of the footplate of the hydro-generator affects the operational reliability of the generator to a greater extent than the signaling about the inclusion of a reserve oil pump, then the weight of the first protection should be higher. The degree of difference in "weights" in the general case is determined by experience and established norms of management, as well as the procedure used to obtain expert estimates.

Table 1 shows the total "weights" of precautionary protection in percentages of the elements of the aggregate block. Total "weights" of elements such as turbine, turbine bearing and so on, were 2-3 times less than those allocated. The allocated elements of the aggregate block made it possible to determine the most important operational factors (by the "weight" of the preventive protection included in them), characterizing the operability of the main units of the hydrounit and the block transformer. To the same group of factors, undoubtedly, it is necessary to include the vibrational state of the hydroelectric unit, the influence of which was not considered here due to the absence of standard vibrating sensors at the present time. The analysis of the received information showed that more than 60% of the "weight" of all preventive protections is related to the operating conditions of the block transformer, thrust bearing, bearing and winding of the generator. It is obvious that such a control method, under the operating condition of the hydraulic unit, provided that the "weight" scale of specific factors is obtained, allows using them in the decision-making process of the DMO on changing the operation mode of HPP [12].

Table 1 – Total "weights" of precautionary protection for the elements of the aggregate block in percent

Element of the aggregate block	HPP		
	Novosibirsk	Krasnoyarsk	Votkinsk
Block transformer	24,17	26,48	22,43
Winding of the generator	13,12	20,64	17,31
The thrust bearing of generator	18,21	17,01	14,31
Bearing of the generator	11,48	9,05	10,01
The amount of "weight"	66,98	73,18	64,06
Turbine	5,8	6,74	5,61
Turbine bearing	4,27	3,77	6,34
Other elements and ancillary equipment in the amount of	22,95	16,31	23,99

Let us dwell on the procedures for obtaining expert estimates and on the possibility of their adaptation to the conditions of operational management of the plant regime. Expert assessments relate to the class of heuristic information and give the opportunity to obtain various factors of importance or weight, using both the accumulated experience of the DMO, as well as a deep knowledge of the specifics of the equipment used. Therefore, the information obtained in this way has great managerial value, since it represents its qualitative characteristic, which can be expressed by a numerical measure called the weight [18]. The resulting group assessment of factors should be characterized a sufficient degree of agreement among experts on the parameters being evaluated. At the heart of expert estimates of the acquisition are some common properties.

Each event or factor corresponds to a real nonnegative number V , which is regarded as the true significance (value, utility) of this event (factor) 0, i.e. some number corresponds to some V . If the event (factor) O_j is more important than the factor O_k , then $V_j > V_k$. If the factors considered are equivalent, then $V_j = V_k$. If the estimates V_j and V_k correspond to the factors O_j and O_k , then $(V_j + V_k)$ corresponds to the general result of O_j and O_k . This is a property of additivity of estimates.

First of all, it should be noted that the use of a procedure is determined by the number of factors assessed, provided that the expert group meets all the requirements: the number and competence of [10-12]. In the case of a significant number of factors considered (> 20), it is advisable to use either a paired comparison procedure or its interpretation (for example, a three-point evaluation procedure). If the list of factors does not exceed 15 ... 20 titles, the most effective weighing procedure is the successive preference procedure (the Churchman-Akoff procedure).

The procedure of pairwise comparisons of all factors is performed in pairs in order to establish the most important factor in each pair. If the factor A_i is more preferable than the factor A_j , then the estimate V_i is 1, and V_j is 0.

The results of the comparison are recorded in the matrix of paired comparisons, table 2. The matrix is square with an unfilled main diagonal, since the comparison of the factor with itself does not make sense. The expert evaluates the factors horizontally, the matrix corresponds to the following comparison results: factor A_1 is less preferable than A_2, A_3, A_4 and is more preferable than A_5 ; factor A_2 is more preferable than A_3, A_4, A_5 , factor A_3 is more preferable than A_4, A_5 , factor A_4 is more preferable than A_5 .

Table 2 – Matrix of paired comparisons for five factors

Factor	A_1	A_2	A_3	A_4	A_5	Sum of scores
A_1	–	0	0	0	1	1
A_2	1	–	1	1	1	4
A_3	1	0	–	1	1	3
A_4	1	0	0	–	1	2
A_5	0	0	0	0	–	0

The results of the comparison show that the expert assigned the highest score to factor number 2 (the sum of points is 4), and factor 5 was, in his estimation, generally insignificant (the sum of points is 0). It should be noted a special case when, according to the expert, none of the factors considered in the pair has a preference, i.e., the i -th and j -th factors are equivalent. Then the estimate for them can be formed as follows:

$$V_i = V_j = 0,5. \quad (11)$$

The formalized procedure for obtaining expert estimates by the method of successive preferences, based on the interpretation of the Cherkmen-Akoff procedure (the procedure of successive preferences), specially developed for computer implementation. It should be noted that expert evaluations are more qualitative in terms of information completeness, if the weighing is carried out by the method of successive preferences. This procedure makes it possible to obtain "weights" taking into account that the weight of the highest priority protection can be less (more) of the sum of the "weights" of less priority. Thus, the received "weights" possess property of the integrated estimation that is their main advantage at decision-making at plant.

Suppose there are n factors that need to be weighed: $O_1, O_2, \dots, O_n$. One of the factors is assigned a baseline score (weight). Let the factor O_1 be assigned V_b . Factors are placed in order of priority, where the first priority is the most priority factor, and the latter is the least priority. For the sake of simplicity of the subsequent arguments, we assume that the ranked series of factors is the series $O_1, O_2, \dots, O_n$, i.e. so they were placed by an expert. The expert compares each priority factor with the sum of other, less priority ones. As a result of this consideration, the following inequalities are formed (in the particular case this may be equality). Suppose we have received such a set of conditions:

$$\begin{aligned} O_1 &\geq O_2 + O_3 + \dots + O_n, \\ O_2 &\geq O_3 + O_4 + \dots + O_n, \\ O_{n-1} &\geq O_n. \end{aligned} \quad (12)$$

At this point, the expert's work ends and computer processing takes place, consisting of two calculation procedures. Procedure 1. Inequalities of the form (11) are replaced by the equalities:

$$\begin{aligned} O_1 &= O_2 + O_3 + \dots + O_n, \\ O_2 &= O_3 + O_4 + \dots + O_n, \\ O_{n-1} &= O_n; \end{aligned} \quad (13)$$

26-13 From the system of equations (13) is the weight of the least priority factor, which we call a , equal in this case to the weights of the factors O_n and O_{n-1} , i.e. $a = V_n = V_{n-1}$. Solving this system, we can obtain the value

$$a = \frac{V_\delta}{2^{k-2}}, \quad (14)$$

where V_δ is base estimate; k is the number of factors considered. Weights of other factors are determined by the formula:

$$x_b = a \cdot 2^{b-2}, \quad (15)$$

where b is the ordinal number of the factor in the back-ranked series.

Procedure 2. The received estimates are adjusted in accordance with the conditions (15). Consideration of inequalities necessarily holds from below - upwards. The correcting term for the i -th factor is determined from expression

$$\Delta V_i = (V_{i+1} + V_{i+2} + \dots + V_n) / C, \quad (16)$$

where C is an integer that scales the difference in the estimates of the weights obtained. Further, the estimation of the i -th factor is corrected.

If the inequality has the form $V_i > V_{i+1} + V_{i+2} + \dots + V_n$, then it is replaced by an equality of the form:

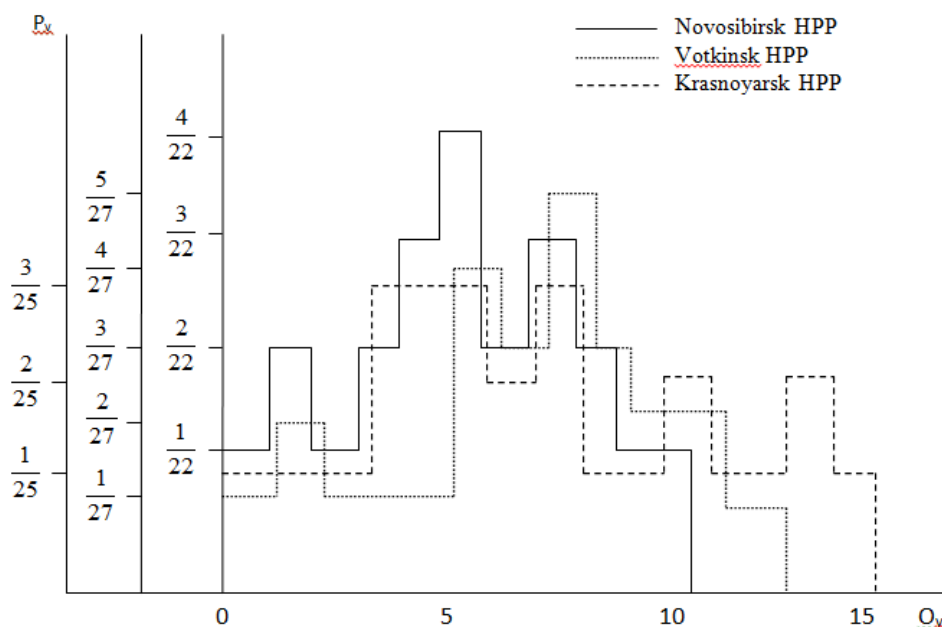
$$V_i = V_{i+1} + V_{i+2} + \dots + V_n + \Delta V_i. \quad (17)$$

If the inequality has the form $V_i < V_{i+1} + V_{i+2} + \dots + V_n$, then it is replaced by the following equation:

$$V_i = V_{i+1} + V_{i+2} + \dots + V_n - \Delta V_i. \quad (18)$$

Consistently going from bottom to top, we pass to the following inequality of the form (18). Then these assessments are checked for statistical reliability, normalized and used in further work.

Procedure of a three-point evaluation. The processing of the results of the examinations carried out according to the formalized procedure of consecutive preferences for the Novosibirsk, Votkinsk and Krasnoyarsk hydropower stations made it possible to construct histograms – the distribution of weights for the list of factors (preventive protection) in question, which are shown in figure. Analysis showed that weight estimates can be assigned to one of three groups: priority, equal-priority and non-priority [6].



Graph of changes in the density of weight indicators

The weightings of the priority and non-priority groups have the lowest density of estimates. This suggests that the weights in these groups differ sharply. The density of the weights in the equal-priority group is much higher. From this it follows that the priority (weight) of factors in different groups is felt by experts in different ways: for the priority and non-priority groups, the experts' assessments are more delineated, for the equal priority, they are more blurred. Thus, when estimating a larger (almost unlimited) number of factors, a modified method of obtaining weights using a three-point system can be used: priority factors receive a score of 3, priority factors are rated at 2, and non-priority ones score 1. This method was used to assess preventive protection at Votkinsk HPP (39 items). Based on these considerations, and considering that these estimates should be recalculated periodically, the general procedure was adopted as a one-step procedure. The developed software package allows you to obtain expert estimates on the factors of interest to the DMO, as well as to calculate the qualitative characteristics of the expertise.

А. А. Ковтун¹, А. Д. Мехтиев¹, В. В. Югай¹, А. Д. Алькина¹, Ю. А. Секретарев²

¹Қарағанды мемлекеттік техникалық университеті, Қазақстан,

²Новосібір мемлекеттік техникалық университеті, Ресей

ҚИЫН ҚҰРЫЛЫМДЫ ОБЪЕКТІЛЕРДІҢ ҚҰРЫЛҒЫЛАРЫНЫҢ ЭКСПЛУАТАЦИОНДЫ КҮЙІНІҢ ЖАҒДАЙЛЫҚ БАҒА АЛУЫНЫҢ ЖАЛПЫ ПРИНЦИПТЕРІ

Аннотация. Мақала қиын құрылымды объектілерді басқару әдістерін құру сұрақтарына арналған. Электростанция құрылғыларының эксплуатационды күйлеріне жағдайлық баға беру принциптерінің жалпы сұрақтары қарастырылды. Станция блоктарының эксплуатационды беріктілігін ескере отырып, жағдайлық басқаруды процессі негізгі бөліктерге бөлінді. Бағалау кезінде әсер ететін факторлардың саны тым көп болса, үш балды жүйе бойынша модификациялы әдіс қолданылады. Компьютермен іске асатын Черчмен-Акофф процедурасының (тізбектей қалайлар процедурасы) интерпритациясы негізінде тізбектей қалаулар әдісі арқылы эксперттік баға алу процедурасы анықталды.

Түйін сөздер: факторлар, басқару, жағдай, электр станциясы, жағдайлық басқару, басқару объектісі, жұмыс істеу тиімділігі, басқару процедурасы, беріктілік, басқару параметрлері.

А. А. Ковтун¹, А. Д. Мехтиев¹, В. В. Югай¹, А. Д. Алькина¹, Ю. А. Секретарев²

¹Қарагандинский государственный технический университет, Казахстан,

²Новосибирский государственный технический университет, Россия

ОБЩИЕ ПРИНЦИПЫ ПОЛУЧЕНИЯ СИТУАЦИОННЫХ ОЦЕНОК ЭКСПЛУАТАЦИОННОГО СОСТОЯНИЯ ОБОРУДОВАНИЯ СЛОЖНЫХ ПО СТРУКТУРЕ ОБЪЕКТОВ

Аннотация. Статья посвящена решению вопросов создания методов ситуационного управления объектами со сложной структурой. Рассмотрены общие принципы получения ситуационных оценок эксплуатационного состояния оборудования электростанций. Выполнено разделение процесса ситуационного управления на основные этапы, связанные с учетом эксплуатационной надежности блоков станции. При оценке большего (практически неограниченного) числа факторов можно использовать модифицированный метод получения весов по трёхбалльной системе. Сформулирована процедура получения экспертных оценок методом последовательных предпочтений на основе интерпретация процедуры Черчмена-Акоффа (процедура последовательных предпочтений) с компьютерной реализацией.

Ключевые слова: факторов, управление, ситуация, электрическая станция, ситуационное управление, объект управления, эффективности функционирования, процедура управления, надежность, параметры контроля.

Information about authors:

Kovtun A. A., Karaganda state technical university, Kazakhstan; kovtun.a73@mail.ru; <https://orcid.org/0000-0003-3013-1944>

Mekhtiyev A. D., Karaganda state technical university, Kazakhstan; National Research Tomsk Politechnic University, Tomsk, Russia; barton.kz@mail.ru; <https://orcid.org/0000-0002-2633-3976>

Yugay V. V., Karaganda state technical university, Kazakhstan; slawa_v@mail.ru; <https://orcid.org/0000-0002-7249-2345>

Alkina A. D., Karaganda state technical university, Kazakhstan; alika_1308@mail.ru; <https://orcid.org/0000-0003-4879-0593>

Sekretarev U.A., Novosibirsk state technical university, Russia; sekretarevua@mail.ru; <https://orcid.org/0000-0001-7908-9586>

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N. Ramazanova¹, Zh. Berdenov¹, S. Ramazanov²,
N. Kazangapova³, S. Romanova⁴, S. Toksanbaeva¹, Jan Wendt⁵

¹L. N. Gumilyov Eurasian national university, Astana, Kazakhstan,²Deputy Director of the West Kazakhstan regional center of History and Archaeology, Uralsk, Kazakhstan,³S. Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan,⁴Al-Farabi Kazakh national university, Almaty, Kazakhstan⁵Gdańsk University, Faculty of Oceanography and Geography, Institute of Geography, Gdańsk, Poland.E-mail: berdenov-z@mail.ru; nurgulram@gmail.com; serik-ram@mail.ru; kazangapova@bk.ru; sofiyarom@mail.ru; sabina.toksanbaeva@mail.ru; jan.wendt@ug.edu.pl

LANDSCAPE-GEOCHEMICAL ANALYSIS OF STEPPE ZONE BASIN ZHAIYK

Abstract. The need to study the landscape-geochemical analysis of steppe Zhaiyk river basin area has arisen because of human impacts on the landscape of the steppe zone, pollution Zhaiyk river basin. For the study was taken steppe zone, as the steppe zone - this is one of the most favorable areas for human settlement, and this study is very relevant today. These experiments allow describing the landscape of steppe Zhaiyk river basin area and showing the landscape and geochemical characteristics of the study object. The aim of the study is to describe the landscape, exploring the nature and landscape-geochemical analysis of the steppe zone Zhaiyk basin. The article shows a landscape-geochemical analysis of the steppe zone Zhaiyk basin. For this purpose was drawn landscape map of steppe zone Zhaiyk river basin and characteristics carried out geochemical state of landscapes on plant and soil samples, water in key areas in the zone of anthropogenic impact. Established chemical elements such contamination in plant samples as a Cu, Ni, Cd and Co, soil Zn, Cu, Ni, total phosphorus in water, Mg, Pb, K, Na, chlorides, water hardness and pH.

Keywords: basin, geochemistry landscape, landscape-geochemical analysis of chemical compounds.

Introduction. Geochemistry of the landscape as well as geophysics of landscape, has roots that go back centuries, but as an independent science landscape geochemistry was formed only in the 30-40-ies. of XX century [1]. Chemistry - Geochemistry - Geochemistry of the landscape - such is the way of formation of landscape geochemistry [2]. From domestic scholars a prominent role in the development of geochemistry belongs V.I. Vernadsky and his disciple A.E. Fersman [3]. The first, which laid the foundations of the new science of landscape geochemistry, was B.B. Polynov [4]. Another outstanding classic landscape geochemistry undoubtedly called A.I. Perelman [5]. The modern landscape geochemistry operates a broad set of indicators, which is caused by multiple tasks facing science [6]. This theoretical problem arising in the study of migration patterns of chemical elements and practical aspects related to the development on the landscape basis of geochemical techniques to the study of natural systems of states in technogenesis and conduct forward-looking landscape-geochemical studies [7].

In the modern period, geochemical and landscape analysis are closely interrelated, and the study of landscapes is just as important in the studies [8]. So the steppe zone of the river basin Zhaiyk West Kazakhstan region has been studied for a long time, but it is at the moment the study was more thorough and detailed. An example is the study of landscapes of the West Kazakhstan region such scholars as V.I. Amelchenko, M.A. Galimov, S.K. Ramazanov, T.A. Tereshchenko, G.A. Kabdulova, T.F. Cherevatova. They had 31-isolated landscape of class lowland landscapes, divisible into two subclasses: the relatively lowered plains and elevated plains [9]. Also taken into account geochemical studies [10, 11].

Considerable latitude and the meridian stretch, the diversity of natural conditions and factors, particularly economic use of the territory Zhaiyk river basin in the steppe zone, predetermined factors of the spatial distribution of adverse environmental phenomena and processes. In the north-east of the territory dominated by agricultural use, in the north-western and central prevail pasture use. In the north area of widespread industrial impact on the environment. As a result of industry, various types of waste are generated. The main ones are mucus and dust from gas cleaning equipment. Usually wastedumped under a layer of water in artificial reservoirs [12-14].

Materials and methods of the study. Landscape ecological analysis takes into account landscape differentiation of the territory with allocation of ecological-landscape zones and expresses sustainability of the territory to external impacts delivered in certain parts of the landscape (areas, stows, substows, and facies). The result is a territorial frame of nature management with ecologically homogeneous areas. It seems necessary to use a differentiated approach to assess the landscape ecological state of the delta territories. This, in turn, entails the presence of structuring criteria of the ecological state of landscape complexes of the corresponding taxonomic rank. Specification of a representative set of analytical and synthetic quantitative indicators should be based on structural specifics of morphological complexes (first on terrain types and their variants, and groups of stow kinds) that set the landscape capacity of the relative region [15].

Zhaiyk river - one of the largest transit rivers of Kazakhstan, which flows through the territories of Russia and Kazakhstan, the third extent river in Europe after the Volga and the Danube river, originates on the slopes of the hill ridge tops round Uraltau in Uchaly Bashkortostan region Southern Urals [16, 17]. In the beginning, the river flows from north to south, meeting the lofty plateau of the Kazakh steppe, turns sharply to the north-west of Orenburg changes the direction of south-west, near the city of Uralsk makes a new sharp bend to the south and in the main direction, twisting the to the west, the east, flows into the Caspian sea. The river basin occupies the sixth place in size among Russian rivers and equals 237 000 km². Its length is 2428 km, including in Kazakhstan river length is 1082 km. The basin is made up of rivers flowing from the Common Syrt and rivers flowing from the Subural plateau. For the West Kazakhstan region Zhaiyk river is an important character.

The objects of research were the landscapes of the steppe zone of the river basin Zhaiyk 20 key areas. Of which 10 samples of plant and soil samples, water samples at 10. Medium-scale maps (1: 500 000) landscapes of the steppe zone Zhaiyk river basin (figure 2) is based on a generalization of cartographic material and statistical data using ArcGIS software with standard tools. Statistical calculations and processing study data and materials of field work were conducted using software of Microsoft Office, Statistica 6.0, MapInfo Professional 11, ArcGIS 10.1 [18]. The legend landscape card (number on the map, figure 1) are grouped depending on the class, type and kind, characterizing the morphology and genesis of relief with the description of vegetation and soil (Note to figure 1). To carry out complex physical and geographic research in the early stages of research were defined support points are selected key areas on which the semi-field studies were carried out on the basic elements of the natural environment components. Location of key sections of samples of plant and soil samples, water on the landscape map steppe Zhaiyk basin area are shown in table 1, 2 and figures 3, 4. Chemical analyzes of samples of vegetation, soil and water (30 samples) for the content of individual ingredients of pollutants made in the testing laboratory of State Enterprise in West Kazakhstan State University named after Makhambet Utemisov MES RK Uralsk. Results of analyzes of chemical compounds of plant and soil samples, water samples for the content of individual pollutant components shown in tables 3, 4 and 5.

Results and discussion

In the study of steppe Zhaiyk Basin area 20 landscapes were allocated: 18 plain landscapes and 2 valley landscape. The flat landscapes attributed to the steppe type, of which 7 denudation plains and 11 accumulative plains. Below is a figure 2 and landscapes map legend steppe Zhaiyk basin area (note to figure).

Location of key areas of physical and geographical studies of a steppe zone on samples of plant and soil samples Zhaiyk river basin are shown in table 1. In the top ten key areas of plant samples and soil samples dominated territory and Zelenovsky Burlin district, 2, 19, 20 landscapes (figure 2).

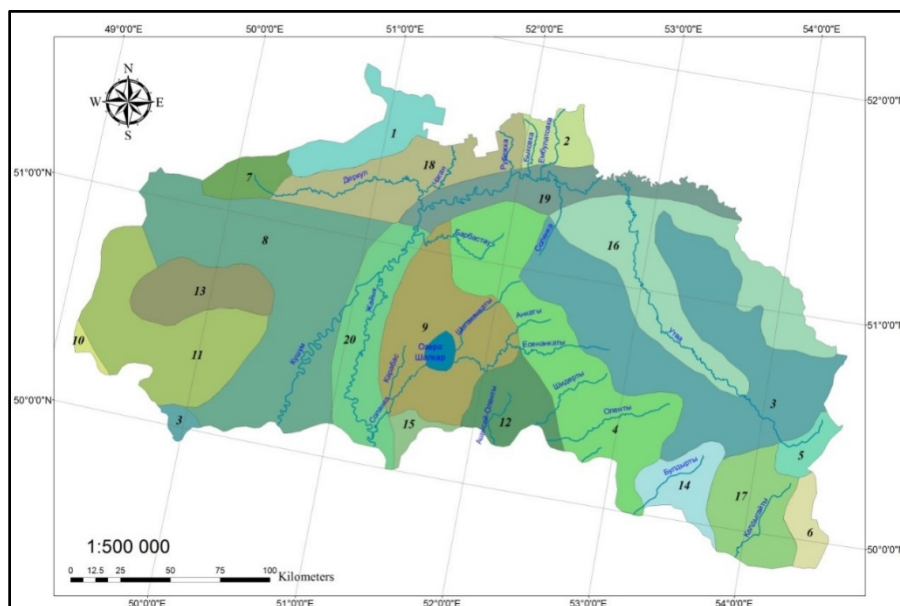


Figure 1 – Map the landscape of steppe zone Zhaiyk basin

Note to Figure

The flat landscape

Steppe

Plains denudation

1. Structural dissected plateau, composed of clays, loess, loams, sandy loams with fescue-grass vegetation on southern chernozems, in conjunction with wormwood-white wormwood vegetation on intermediate-solonetz

2. The reservoir-plinth pologovolnistoy plain, made of sand, clay, sandstone, limestone with herb-peristokovynoy vegetation on the southern solonetzic chernozems with solonetz and meadow-bog soils

3. Produced intensively dismembered plain, made of clay, loess loam with fescue-grass vegetation on dark-chestnut normal soils

4. Produced steeply sloping plain, made of clay, loess loam with fescue-grass vegetation on chestnut soils

5. Produced intensively dissected plain, made of clay, sandstone, limestone with fescue and herb-erkekoyovoy vegetation on chestnut normal and incompletely developed soils

6. Household remnant plateau, folded shales, limestones, sandstones with polynnotyrsovoy vegetation on chestnut normal and residually calcareous soils

7. Structural and steeply sloping hills and plateaus, composed of clay, loam, loess with xerophytic-forb and fescue-grass vegetation on dark chestnut soils

Plains accumulative

8. Marine undivided plain, made of clay, loam, sand with fescue vegetation on solonetz svetlokashatnovoy with chestnut solonetz meadow soil

9. Sea slaboraschlenenoy plain, made of clay, loam, sandy loam with fescue-feather grass steppes on meadow-chestnut and meadow soil

10. Marine dissected plain, made of clay, loam, sand with chernopolynnoy kokpekovo-chernopolynnoy, Anabasis salsa-chernopolynnoy vegetation on light chestnut alkaline soils, combined with meadow solonetz

11. Sea plain with numerous beams lows (estuaries), composed of clays with modern talus deposits with herb-pyreynikovoy vegetation on meadow soils solodized

12. Marine hilly plain, made of clay, loam, sand with grass-perhovopolynnoy vegetation on light-normal and meadow-chestnut soils with solonetz

13. Sea plain with small lakes, composed of clay, loam, sand with forb-grass-meadow vegetation on meadow soils

14. Alluvial hilly plain, folded sand, loam with herb-erekovoy vegetation on meadow, brown meadow soils and sands

15. Alluvial plains, lakes, salt domes, composed of clay, loam, sandy loam with white wormwood-fescue-zhitnyakovoy vegetation on meadow kashatnovoy solonetz, meadow-chestnut, light chestnut soils on solonetz

16. Slaboraschlenenoy alluvial plain, composed of loam, sandy loam, sand with white wormwood-fescue and zhitnyakovoy vegetation on chestnut soils with meadow solonetz

17. Alluvial-proluvial plain, made of loam, clay, sand with herb-erkekoyovoy vegetation on the meadow-chestnut and light-chestnut soils

18. Talus-proluvial dissected plain, made of gravelly loams and clays with fescue-grass vegetation on dark kashatanovoy carbonate-alkaline soils

Valley landscapes

19. Flood plains composed of loam, sand, gravel and pebbles with forb-grass meadows and aspen forests in the floodplain meadow soils

20. Floodplain strongly dissected, folded loam, sandy loam, sand with tree and shrub, and wheatgrass and herbs on the meadow and alluvial meadow marsh soil

Table 1 – Key areas of physical and geographical studies of a steppe zone Zhaiyk basin (on samples of plant and soil samples)

Number on the map	Key areas	Coordinates	Selection date	The water temperature, °C
1	Burlin district, Kanai village	51° 24' 46,8" N 52° 36' 32,3" E	07.07.16.	22
2	Burlin district, river Utva	51° 25' 11,6" N 52° 47' 14,2" E	07.07.16.	24
3	Burlin district, Oblavka village, river Gayik	51° 28' 22,9" N 52° 57' 17,3" E	07.07.16.	21
4	Burlin district, Zharsuat village	51° 29' 13,4" N 53° 17' 15,1" E	07.07.16.	22
5	Zelenovskiy district, Rubezhka the mouth of the river	51° 23' 05,6" N 51° 58' 07,9" E	09.07.16.	24
6	Zelenovskiy district, river Bykovka	51° 37' 0,0" N 52° 07' 3,9" E	09.07.16.	21
7	Zelenovskiy district, Bykovka mouth of the river, near the village Spartacus	51° 25' 5,6" N 52° 2' 35,7" E	09.07.16.	22
8	Zelenovskiy district, river Bykovka, and the area between Bykovka Zhaiyk	51° 27' 54" N 52° 2' 39,7" E	09.07.16.	24
9	Zelenovskiy district, river floodplain Embulatovka	51° 33' 17" N 52° 17' 56,7" E	15.07.16.	22
10	Zelenovskiy district, the mouth of the river Barbastau	51° 06' 17,0" N 51° 17' 20,0" E	15.07.16.	24

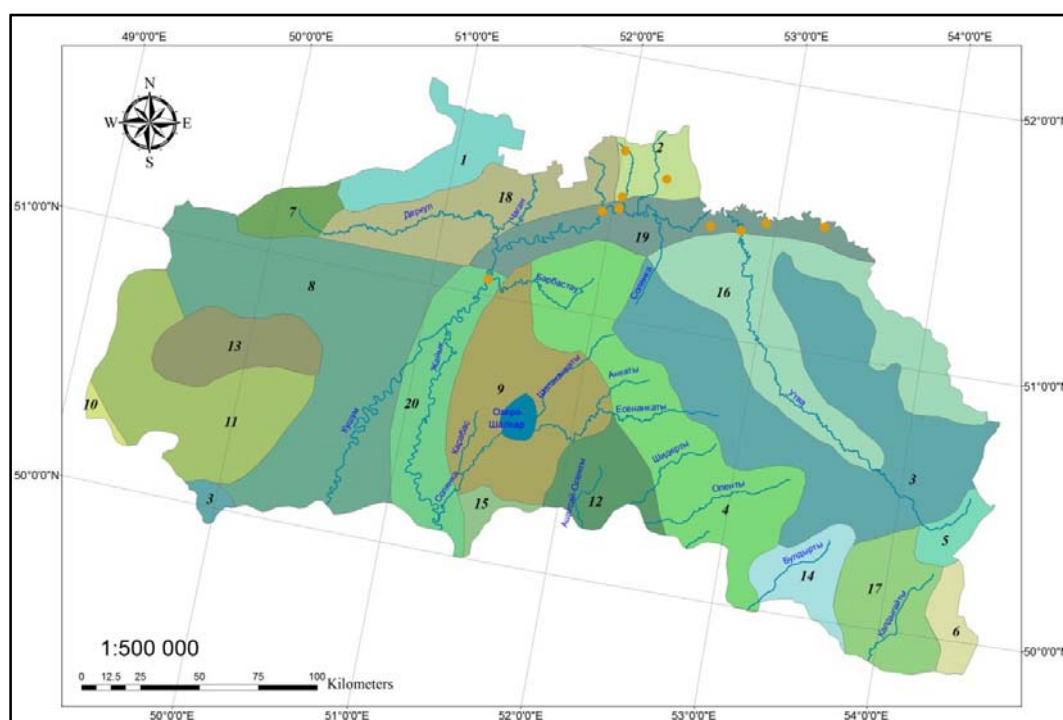


Figure 2 – Map of the location of the key areas of plant and soil samples in the sample landscapes steppe zone Zhaiyk Basin

Table 2 shows the 10 key areas of physical and geographical research steppe Zhaiyk basin area for the natural samples, surface water. In the water samples also dominated the territory and Zelenovsky Burlin district and the lake area Shalkar 2, 9, 16, 18, 19, 20 landscapes (figure 3).

Table 2 – Key areas of physical and geographical studies of a steppe zone Zhaiyk Basin

Number on the map	Key areas	Coordinates	Selection date	The water temperature, °C
1	Burlin district, Kanai village, river Burla	51° 24' 53,1" N 52° 34' 52,0" E	07.07.16.	20
2	Burlin district, river Utva	51° 25' 11,6" N 52° 47' 14,2" E	07.07.16.	22
3	Zelenovskiy district, river Rubezhka	51° 29' 35,6" N 51° 53' 07,2" E	09.07.16.	21
4	Zelenovskiy district, Rubezhka the mouth of the river	51° 23' 05,6" N 51° 58' 07,9" E	09.07.16.	22
5	Zelenovskiy district, river Zhaiyk	51° 23' 05,6" N 51° 58' 07,9" E	09.07.16.	20
6	Zelenovskiy district, river floodplain Embulatovka	51° 33' 17" N 52° 17' 56,7" E	15.07.16.	22
7	Zelenovskiy district, the mouth of the river Barbastau	51° 06' 17,0" N 51° 17' 20,0" E	15.07.16.	21
8	Zelenovskiy district, river Chagan	51° 17' 17,0" N 51° 20' 20,0" E	15.07.16.	20
9	Zelenovskiy district, river Derkul	51° 18' 17,0" N 51° 0,0' 0,0" E	15.07.16.	22
10	Lake Shalkar	50° 38' 17,0" N 51° 40,0' 0,0" E	15.07.16.	21

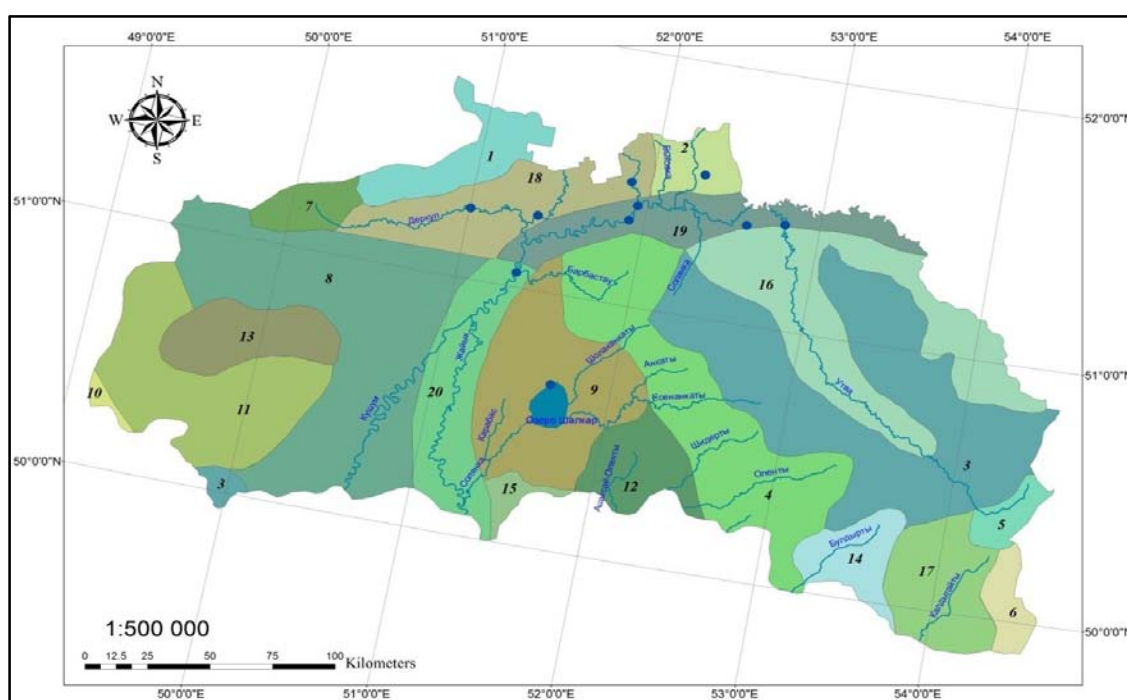


Figure 3 –Map of the location of the key areas of water samples on the landscapes of the steppe zone Zhaiyk Basin

Table 3 shows the results of tests on samples of plant specimens of the steppe zone Zhaiyk basin. According to the analysis in Burlin district in the village Zharsuat $\text{Cu} > \text{MAC}$ at 2.41 mg/dm^3 , $\text{Ni} > \text{MAC}$ at 4.23 mg/dm^3 on samples of plant specimens. On the territory of the district in Zelenovsky Rubezhka estuary has exceeded MAC by Ni and in the river Bykovka for Cd 0.27 mg/dm^3 , a significant excess of maximum allowable concentrations of Ni in 38.17 mg/dm^3 and Co 0.21 mg/dm^3 . In the area of flood plain Zelenovsk Embulatova river $\text{Ni} > \text{MAC}$ at 5.16 mg/dm^3 . Results of analyzes of plant samples shown in table 3.

Table 3 – Results of the analyzes of the chemical compounds of plant samples steppe Zhaiyk basin area (as of July 2016)

Number on the map	Cu, mg/dm ³	Zn, mg/dm ³	Cd, mg/dm ³	Pb, mg/dm ³	Ni, mg/dm ³	Co, mg/dm ³
1	0.82	0.65	0.01	not upd.	1.04	0.04
2	1.31	0.70	0.03	0.04	0.52	not upd.
3	3.05	0.97	0.004	0.27	0.63	0.02
4	32.41	25.64	0.06	0.97	7.23	0.17
5	25.88	13.59	not upd.	0.76	3.56	0.08
6	18.51	6.0	0.001	0.54	11.19	0.15
7	1.78	1.98	0.01	0.02	0.70	not upd.
8	12.62	0	0.57	6.11	41.17	1.21
9	11.56	0	0.005	0.99	8.16	0.12
10	2.02	1.29	0.03	not upd.	1.42	0.02
MAC	30.0	50.0	0.30	5.0	3.0	1.0

Table 4 below shows the results of analyzes of chemical compounds on soil samples of the steppe zone Zhaiyk basin. According to the analysis in the village of Burlin district Kanai found exceeding maximum allowable concentrations of Zn at 9.85 mg/dm³, a significant excess of maximum allowable concentrations of Cu to 25.39 mg/dm³ and Ni in 79.76 mg/dm³. On the territory of Burlin district Utva rivers are the maximum allowable concentration of organic substances 1.93% at Cu ratio of 9.86 mg /dm³, according to Ni in 21.56 mg/dm³, the river village Oblavka Zhaiyk Cu and Ni > MAC. On the territory of Burlin district Zharsuat Cu > MAC settlement on 11.56 mg/dm³ and Ni, significantly exceeding the MAC at 64.61 mg/dm³. In Zelenovsk area Rubezhka estuary has exceeded MAC by organic matter, Cu and Ni in the Ni River Bykovka > MAC at 29.55 mg/dm³, at the mouth of the river Barbastau has exceeded MAC by organic matter, Cu, Zn and significant excess at Ni. On the territory of the region between the rivers Zelenovsky Bykovka and Zhaiyk are the maximum allowable concentration for Cu and Zn, in the flood plain Embulatovka are the maximum allowable concentration for Cu and Ni, in Barbastau estuary has exceeded MAC by Cu and Zn.

As shown by studies carried out on the river Zhaiyk on samples of water into the channel of the river village Burla total phosphorus > MAC at 0.1239 mg/dm³ in Burlin district total phosphorus > MAC at 0.8399 mg/dm³. In Zelenovsk near the mouth of the river Rubezhka water hardness exceeds MAC by 0.5 mmol/dm³, in the area of flood plain Embulatovka have exceeded MAC by 0.3 mmol/dm³ stiffness in Barbastau estuary pH > MAC at 0.1 mg/dm³.

Table 4 – Results of analyzes of chemical compounds on soil samples steppe Zhaiyk Basin area (as of July 2016)

Number on the map	Organic matter, %	Total phosphorus, %	Cu, mg/dm ³	Pb, mg/dm ³	Zn, mg/dm ³	Cd, mg/dm ³	Ni, mg/dm ³	Co, mg/dm ³
1	3.70	0.16	28.39	12.3	32.85	0.26	83.76	2.09
2	5.93	0.13	12.86	9.0	0	0.21	25.56	0.85
3	2.11	0.12	13.19	6.87	21.51	0.24	47.89	1.25
4	1.38	0.10	14.56	7.83	21.44	0.18	68.61	1.71
5	6.82	0.15	8.76	5.88	20.86	0.15	41.94	0.97
6	2.70	0.07	11.87	6.53	17.92	0.05	33.55	1.09
7	5.74	0.24	34.42	14.03	27.07	0.33	100.02	2.41
8	2.56	0.14	26.11	11.41	31.07	0.20	81.47	2.37
9	0.38	0.04	3.60	3.10	7.45	0.03	24.98	0.63
10	2.39	0.18	21.48	10.87	28.97	0.27	73.12	2.0
MAC	2.1-4.0	–	3.0	32.0	23.0	0.5	4.0	5.0

On the river Chagan Zelenovsky district pH> MAC 0.3 mg/dm³, the river Derkul pH> MAC 0.1 mg/dm³. The area of the lake Shalkar has exceeded MAC by pH> MAC at 1.0 mg/dm³ chlorides> MAC at 669.7 mg/dm³, stiffness> MAC 27.3 mmol /dm³ of Mg> MAC at 208.4 mg/dm³, Pb> MAC at 0.02 mg/dm³, K> MCL 3.8 mg/dm³, Na> MAC at 2837 mg/dm³.

Results of analyzes of chemical compounds in the water steppe Zhaiyk basin area are shown in table 5.

Table 5 – Results of analyzes of chemical compounds to mimic natural, surface water steppe Zhaiyk Basin area (as of July 2016)

Number on the map	pH, mg/dm ³	Chloride, mg/dm ³	Alkalinity, mg/dm ³	Ca, mg/dm ³	Mg, mg/dm ³	SO ₄ ²⁻ , mg/dm ³	Ni, mg/dm ³	Fe, mg/dm ³	Cu, mg/dm ³	Pb, mg/dm ³	Zn, mg/dm ³	Total phosphorus, mg/dm ³	K, mg/dm ³	Na, mg/dm ³
1	8.5	96	5	74	28.8	129.6	0.01	0.18	0.01	not upd.	0.03	0.124	10.9	67.2
2	8.4	253.8	4.4	96	25.2	163.2	not upd.	0.322	0.02	not upd.	0.02	0.084	11.6	161.0
3	8.3	82.3	4.6	68	20.4	91.2	not upd.	0.10	0.009	not upd.	0.03	not upd.	10.4	81.5
4	8.5	123.5	4.5	78	19.2	96	0.003	0.02	0.007	not upd.	0.03	0.12	10.6	98.4
5	8.2	137.2	4.7	80	21.6	81.6	0.002	0.34	0.01	not upd.	0.02	not upd.	10.5	96.5
6	8.4	54.9	5.2	76	18	139.2	not upd.	not upd.	0.004	not upd.	0.02	not upd.	10.3	52.8
7	8.6	115.4	2.2	36	20.4	124.8	0.002	0.2	0.01	not upd.	0.02	–	10.6	120.6
8	8.8	81.5	1.8	30	15.6	110.4	not upd.	0.2	0.02	0.006	0.03	–	11.3	87.6
9	8.6	122.2	2.4	58	15.6	110	0.04	0.12	0.02	0.01	0.01	–	11.1	103.3
10	9.0	1019.7	3.6	130	308.4	254.4	0.0002	0.2	not upd.	0.05	0.02	–	23.8	3037
MAC	6.5-8.5	350	6.5	200	100	500	0.1	0.3	1.0	0.03	1.0	0.0001	20	200

Conclusions. Compiled medium-scale maps (1: 500 000) steppe landscapes Zhaiyk river basin areas where identified 20 landscape.

Observations and analysis of river basin Zhaiyk possible to establish an association of major pollutants, such as the chemical elements Cu, Ni, Cd, Co, Zn, total phosphorus, hardness, pH.

As a result of monitoring of hydrochemical investigations revealed that the most polluted landscapes steppe Zhaiyk Basin area are plains 9 and 19 landscape valley landscape of key areas 1, 2, 4, 5 and 10, also has a landscape with the norm of the MPC - 2 denudation plains landscape.

Pollution caused by the fact that the main sources of water pollution in the river Zhaiyk steppe zone are Novotroitsky refinery, as well as water Ilek rivers that are polluted waste products Aktope plant of chromium compounds, and chemical plant Alga Aktope drive. What is clearly reflected in the research [19]. Small rivers are polluted mainly animal waste and MSW settlements. Exceeding MPC due to the fact that pollutants come mainly due to flushing of the river during the floods from the territory of livestock farms, industry and fields adjacent to open water, in connection with which the rivers increases the concentration of nitrogen-containing compounds, phenol and petroleum.

Thus, the aggregate of samples included superficial natural water in key areas of the steppe zone of the river basin Zhaiyk can characterize it as a moderate level of pollution and Shalkar lake as a high level of pollution.

The main measure to reduce the negative impact on the components of the environment is the strict rational use of natural resources and the use of various sewage treatment plants. One of them is the biological treatment [17].

The soil cover of the steppe Zhaiyk River Basin area is characterized by man-made breach caused by the operation of industrial facilities and transportation, and considerably less agricultural objects. Most have a greater impact on the company of oil and gas production and processing. Soil pollution is melkoploschadnoy and linear, in a significant excess of certain chemical compounds.

The same characteristic is and vegetation of the steppe zone Zhaiyk Basin [15].

**Н. Е. Рамазанова¹, Ж. Г. Берденов¹, С. К. Рамазанов²,
Н. Б. Казангапова³, С. М. Романова⁴, С. Т. Токсанбаева¹, Jan Wendt⁵**

¹Л. Н. Гумилев атындағы Еуразиялық ұлттық университеті, Астана, Қазақстан,

²Батыс Қазақстан облысы әкімдігінің Батыс Қазақстан облыстық тарихи-өлкетану мұражайы мен мәдениет басқармасының орталығы, Орал, Қазақстан,

³С. Сейфуллин атындағы Қазақ агротехникалық университеті, Астана, Қазақстан,

⁴әл-Фараби атындағы Ұлттық университеті, Алматы, Қазақстан,

⁵Гданск университеті, Гданьск қаласы, Польша

ДАЛА АЙМАҒЫНЫҢ ЖАЙЫҚ ӨЗЕНІНІҢ АЛАБЫНДА ЛАНДШАФТЫ-ГЕОХИМИЯЛЫҚ ТАЛДАУ

Аннотация. Жайық өзені алабының ландшафты-геохимиялық талдауын зерттеу қажеттілігі дала аймағының ландшафтына антропогендік факторлардың әсерінен және алаптың ластануынан туындайды. Далалық аймақты зерттеу үшін елді мекендер қолайлы аймақтардың бірі болып табылады және бұл зерттеу бүгінгі күні өте өзекті.

Жүргізілген далалық жұмыстары Жайық өзен алабының ландшафттарын сипаттауға және зерттеу объектісінің ландшафты-геохимиялық жағдайын көрсетуге мүмкіндік береді. Зерттеудің мақсаты - дала аймағының Жайық алабы ландшафтын, табиғатын сипаттау және ландшафты-геохимиялық талдауын зерттеу болып табылады. Мақалада дала аймағының Жайық алабы ландшафты-геохимиялық талдауы көрсетілген. Осы мақсатта Жайық өзені алабында дала аймағының ландшафтық картасы жасалды және антропогендік әсер аймағында негізгі учаскелерде өсімдіктер, топырақ және су үлгілері бойынша ландшафтардың геохимиялық жағдайы сипаттамасы берілді. Өсімдік үлгілерін (Cu, Ni, Cd, Co), топырақты (Zn, Cu, Ni) және суды (жалпы фосфор, Mg, Pb, K, Na, хлоридтер мөлшері, судың кермектігі, pH) ластайтын химиялық элементтер анықталды.

Түйін сөздер: өзен алабы, геохимиялық ландшафт, химиялық қосылыстардың ландшафты-геохимиялық талдауы.

**Н. Е. Рамазанова¹, Ж. Г. Берденов¹, С. К. Рамазанов²,
Н. Б. Казангапова³, С. М. Романова⁴, С. Т. Токсанбаева¹, Jan Wendt⁵**

¹Евразийский национальный университет им. Л. Н. Гумилева, Астана, Казахстан,

²Западно-Казахстанский областной центр истории и археологии
управления культуры акимата Западно-Казахстанской области, Уральск, Казахстан,

³Казахский агротехнический университет им. С. Сейфуллина, Астана, Казахстан,

⁴Казхский национальный университет им. аль-Фараби, Алматы, Казахстан,

⁵Гданский университет, Гданьск, Польша

ЛАНДШАФТНО-ГЕОХИМИЧЕСКИЙ АНАЛИЗ СТЕПНОЙ ЗОНЫ БАСЕЙНА РЕКИ ЖАЙЫК

Аннотация. Необходимость изучения ландшафтно-геохимического анализа территории бассейна реки Жайык возникла из-за антропогенного воздействия на ландшафт степной зоны, загрязнения бассейна реки Жайык. Для исследования была выбрана степная зона, так как степная зона - это одна из самых благоприятных зон для населенных пунктов, и это исследование очень актуально сегодня. Эти эксперименты позволяют описать ландшафт территории степной зоны бассейна реки Жайык и показать ландшафтно-геохимические характеристики объекта исследования. Целью исследования является описание ландшафта, изучение природы и ландшафтно-геохимический анализ степной зоны Жайыкского бассейна. В статье представлен ландшафтно-геохимический анализ степной зоны Жайыкского бассейна. Для этого была составлена ландшафтная карта степной зоны бассейна реки Жайык и дана характеристика геохимического состояния ландшафтов по образцам растений и почв, воды на ключевых участках в зоне антропогенного воздействия. Определены химические элементы-загрязнители в растительных образцах, как Cu, Ni, Cd и Co, почвы Zn, Cu, Ni, общий фосфор в воде, Mg, Pb, K, Na, хлориды, жесткость воды и pH.

Ключевые слова: бассейн реки, геохимический ландшафт, ландшафтно-геохимический анализ химических соединений.

Information about authors:

Ramazanova Nurgul Yesenovna, PhD, Associate Professor, Department of Physical and Economic Geography, Astana, Kazakhstan, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan; nurgulram@gmail.com; <http://orcid.org/0000-0001-9120-7995>

Berdenov Zharas Galimzhanovich, PhD, and Associate Professor of the Department of Physical and Economic Geography, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan; berdenov-z@mail.ru; <http://orcid.org/0000-0002-2898-8212>

Ramazanov Serik Kishbekovich, Candidate of Geographical Sciences, Deputy Director of the West Kazakhstan regional center of History and Archeology, Uralsk, Kazakhstan; serik-ram@mail.ru; <https://orcid.org/0000-0003-4812-1357>

Kazangapova Nurgul Burkitbaevna, Candidate of Geographical Sciences, Senior Lecturer Department of Forest Resources and Forestry, Saken Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan; kazangapova@bk.ru; <http://orcid.org/0000-0002-3504-3348>

Romanova Sofiya Maksimovna, Doctor of Geographical Sciences, Professor al-Farabi Kazakh National University; sofiarom@mail.ru; <http://orcid.org/0000-0002-4875-1749>

Toksanbaeva Sabina Tursynovna, Master of Geography, Lecturer, Department of Physical and Economic Geography, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan; sabina.toksanbaeva@mail.ru; <https://orcid.org/0000-0002-4411-9623>

Wendt Jan, PhD, Full Professor Gdańsk University, Faculty of Oceanography and Geography, Institute of Geography, Department of Regional Geography Development; jan.wendt@ug.edu.pl; <https://orcid.org/0000-0003-1712-4926>

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V. Ya. Zhaimina¹, E. I. Kulagina²

¹Satbayev University, Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan,

²Institute of Geology – Subdivision of the Ufa Federal Research Centre of the Russian Academy of Sciences
(IG UFRS RAS), Ufa, Russia.

E-mail: svenax@bk.ru, zhaimina@mail.ru, elenkul@mail.ru, kulagina@ufaras.ru

**FEATURES OF DEVONIAN AND CARBONIFEROUS BOUNDARY DEPOSITS
IN THE KARAMURUN SECTION OF THE BOLSHOI KARATAU MOUNTAINS**

Abstract. Subcommission on Carboniferous Stratigraphy of the International Commission on Stratigraphy conducts and completes studies of the boundary deposits of the Carboniferous and Devonian systems in order to carry out global correlations and prepare an unified International Stratigraphic Scale of the Carboniferous system. The Global Boundary Stratotype Section and Point (GSSP) of the Tournaisian base, Mississippian subsystem and the Carboniferous system was established in the La Sierra section in Southern France. The boundary was defined by conodonts and other fauna and flora (ammonoids, foraminifera, ostracodes, myospores, corals and brachiopods). However, the existing GSSP currently being revised. In the Karamurun reference section of the Bolshoi Karatau Mountains Devonian and Carboniferous boundary deposits are observed in the reefogenic facies with biogermes. Such conditions of sedimentation and stratigraphic levels are promising in search for oil and gas deposits in Kazakhstan and the world. Foraminifer complexes allow tracing zones, identified in other regions and acceptable for correlation and substantiation of location of the Devonian-Carboniferous boundary at a modern level. The near-boundary level is marked by big biotic re-buildings caused by abiotic changes.

Key words: boundary, Devonian, Carboniferous, Karamurun, section, reef, foraminifer, zone, the International Stratigraphic Scale, correlation.

The Subcommission on Carboniferous Stratigraphy of the International Commission on Stratigraphy sets tasks of studying and completion of knowledge on the boundary between the Carboniferous and Devonian systems in order to carry out global correlations and create a single International Stratigraphic Scale of the Carboniferous system [1; 2]. Special work teams are dedicated to the study of boundaries. The International Work Group (IWG) on Devon and Carboniferous Boundary Problems recommended setting the boundary in accordance with the decision of the II Geerlen Congress near the level of goniatite zones of *Wocklumeria-Gattendorfia*, on the first appearance of *Siphonodella sulcata* conodonts, which precedes the appearance of *Gattendorfia* in Henetal and corresponds to the base of layers with *Acutimitoceras* [1].

The Global Boundary Stratotype Section and Point (GSSP) fixing the base of the Tournaisian stage, the Mississippian Subsystem and the Carboniferous system were established in the La Sierra section in Southern France. The boundary was determined by the first appearance of the conodontic species *Siphonodella sulcata* in the phylogenetic sequence of *Siphonodella praesulcata* – *S. sulcata*. The decision was approved by the International Stratigraphic Committee and published in 1991. However, the existing GSSP of the Carboniferous is currently being revised due to the discovery of *Siphonodella sulcata* below the established boundary [3]. The New Joint Devonian–Carboniferous Boundary GSSP Reappraisal Task Group including Devonian and Carbon specialists, is currently working on developing new criteria for determining position of the D-C boundary and choosing a new tie section [4, 5].

In 1986, the Interdepartmental Stratigraphic Committee in Minsk accepted the boundary of Devonian and Carboniferous at the bottom of the *Acutimitoceras prorsum* subzone of the *Gattendorfia* [6-8], this level corresponds to the base of the conodont zone of *Siphonodella sulcata* Zone, the ostracod *Richterinalia* – *Pseudoleperditia tuberculifera*-*Gryptophyllus socialis* Zone and the beds with forami-

nifera *Tournayellina pseudobeata* and remnant *Quasiendothyra*. Similar foraminiferal assemblage have been studied in recent decades in sections of the Bolshoi Karatau, including the Karamurun section, where boundary deposits are observed in the reefogenic facies with biogermers. Such conditions of sedimentation and stratigraphic levels are promising in search of oil and gas deposits in various regions of Kazakhstan and the world. In this case, they are disposed on surface and are available for research [9-12].

There was a decision of the Kazakhstan Stratigraphic Committee to delimitate the Devonian-Carboniferous boundary within the regional Carboniferous setup, conditionally at the base of the Kassian Horizon and foraminiferal beds with *Bisphaera malevkensis* – *Earlandia minima* [7]. In the new version, the boundary is placed in the zone below.

In South Kazakhstan, R.E. Alekseeva and A.I. Sidyachenko [13] were engaged in stratigraphy of the Famennian-Tournaisian deposits of the Bolshoi Karatau. They described stratigraphy and brachiopods of Famennian deposits in the central and south-east parts of the Karatau range. Here, B.V. Poyarkov [14] studied Devonian foraminifera, including those of the Famennian. He identified six foraminiferal assemblages in the Upper Devonian. In 1960, O. I. Bogush and O.V. Yuferev studied biostratigraphy and fauna of the Upper Devonian and Carboniferous of the Bolshoi Karatau [15]. During many years, the Famennian-Carboniferous foraminifera of the Bolshoi Karatau, Talas-Ugam and other regions in Carboniferous, Carboniferous-terrestrial section types were studied by M.M. Marfenkova [16]. She proposed the Aksuran (Baizhansai) section as a reference section for the boundary deposits of the Devonian-Carboniferous of the Karatau-Talas Structural-Facial Zone (SFZ), where an Upper Famennian *Septaglomospiranella rauserae* – *Quasiendothyra communis* Zone was identified. She proposed to compare the base of the Carboniferous system with the base of *Quasiendothyra kobeitusana* – *Q. konensis*, over which the *Bisphaera malevkensis* – *Earlandia minima* zone was individuated (1988). The same successive change of zones was also identified by M. M. Marfenkova for the Takhtamysh-Sai section located at the southeast end of the Akuyuk syncline of the Bolshoi Karatau.

During 1993-1998 and 2000-2018, the boundary deposits D₃/C₁ of the Bolshoi Karatau have been studied by the author [10, 11, 17, 18]. During the 2017 International Field Trip to the upper part of the Karamurun reef, the Upper Famennian ammonoids were discovered and collected for the first time [12].

As a result of this work, we managed to find the foraminiferal assemblages which allow us tracing the zones identified in other regions and acceptable for correlation and justification of the location of the Devonian-Carboniferous boundary at the present level [19].

The section is compiled by A.E. Zorin, basing on the central part of the Karamurun cover-syncline [10] (figure 1). The reef deposits are rest on limestone of the Khatynkamal series (layers 1-5, figure 2). The upper part of the Karamurun reef complex consists of the following units (from up downwards).

6. Limestones: white, light grey, dark grey in spots, large-plate massive algal boundstones (figures 3-6). Numerous stromatolite textures are present. Algae (renalcises) – are the reef builders. Large accumulations of gastropods and brachiopods, are observed everywhere, crinoids and single rugoses also present. Foraminifera: *Archaeosphaera* sp., *Neoarchaeosphaera* cf. *polypora* Antropov, *Vicinesphaera* cf. *angulata* Antropov, *V.* cf. *squalida* Antropov, *Bisphaera* sp., *Parathuramminites* cf. *cushmani* (Suleimanov), *P.* cf. *vasiljevae* (Pojarkov), *Parathuramina* cf. *dagmarae* Suleimanov, *P.* cf. *breweradiosa* Pojarkov, *Suleimanovella* cf. *suleimanovi* (Lipina), *Cribrosphaeroides* cf. *ovalis* (Pojarkov), *C.* cf. *simplex* (Reitlinger), *Bykovaella* cf. *crassithea* Antropov, *Rauserina notata* Antropov, *Corbiella* ? sp., *Parastegnammina pseudocamerata* Pojarkov, *Paracaligelloides*? *florenensis* Conil et Lys, *Tournayella* aff. *Præsegmentata* (Bogush et Yuferev). Algae *Issinella* cf. *devonica* Reitlinger and *Renalcis* sp. Thickness: 55 m.

7. Limestones: white, light grey, coarse-plate recrystallized boundstone, similar to those described in the layer 6. Foraminifera: *Archaeosphaera* cf. *magna* Suleimanov, *A.* cf. *minima* Suleimanov, *Vicinesphaera* cf. *squalida* Antropov, *V.* cf. *angulata* Antropov, *Suleimanovella* cf. *suleimanovi* (Lipina), *Parathuramina* sp., *Cribrosphaeroides* sp., *Bisphaera* ? sp., *Irregularina* ? sp., *Eotournayellina*? sp.; problematic *sphaeras* *Radiosphaera* cf. *basilica* Reitlinger. Thickness: 60 m.

8. Limestones: white, light grey, large-plate, massive algal boundstones. There are cracks 2-5 cm wide, secant to the layer in its upper part, made by needle calcite. The cracks are 4-10 m long. Foraminifera: *Parathuramina* sp., *Bisphaera* sp., *Auroria* cf. *ferganensis* Pojarkov, *Paracaligelloides* ? sp. Algae *Renalcis* sp. Thickness: 105 m.



Figure 1 – General view of the section: the Karamurun reef massif (foreground), outcrop rocks of the Lower Shalkia subsuite (centre), and outcrop rocks of the Upper Shalkia subsuite (above)



Figure 2 – The top part of the Karamurun reef. The Famennian stage with Clymeniida



Figure 3 – Ammonoid-rich bed of the Karamurun reef massif, the upper part (detail).
The Famennian stage with Clymeniida. 1 – Clymeniida



Figure 4 – The Karamurun reef massif, the upper part.
The Famennian stage with Clymeniida and nautiloids (detail). 1 – Nautiloids, 2 – Clymeniida.



Figure 5 – The Karamurun reef massif, the upper part (detail).
The Famennian stage: abundant accumulations of gastropods



Figure 6 – The Karamurun reef massif, the upper part (detail).
The Famennian stage: stromatolite textures

9. Breccias: grey, boulder-massive, coarsely clastic, unsorted, carbonate of composition. Fragments of angular shape, 0.5 cm-10 m, are represented exclusively by algae limestone (boundstone), underlying the buildings. The cementing matrix is composed of fine crystalline calcite. Numerous remnants of crinoids are found in the debris. In general, breccias are the accumulation of fragments of different size. Thickness: 132 m.

10. Breccias: gray, boulder-massive, coarsely clastic, carbonate. Rubbles are not rolled, ranging in size from 1 cm to 3-4 m, represented by algae limestones (boundstone). The cementing matrix is represented by medium-coarse-grained bioclast-lithoclastic limestones (grainstones). Thickness: 65 m.

The Karamurun reef thickness along the section is 417 m. Above, are regular beddings of the Shalkiya suite deposits (figure 7).



Figure 7 – Outcrops of the Lower Shalkiya subsuite

The Shalkiya Suite ($D_3 - C_{1slk}$).

The first attempts to identify carbonaceous-siliceous-carbon deposits under this title were made by geologists of the Karamurun geological exploration team at the Shalkiya polymetallic deposit field.

The Shalkiya Suite integrates carbonates and carbonaceous-siliceous-clayey-carbonate sediments of the carbonate platform slope and its base, which lie on the Karamurun reef massif.

The section of the Lower Shalkiya subsuite is compiled within the Karamurun syncline, which contains the following deposits located on the Karamurun reef massif (from down to up, figures 7-10):

11. Breccias: massive grey with unrolled debris and boulders (from 0.1 to 3-4 m) of algae limestones (boundstone) and anisometric gradation-layered limestones (turbidites) in different proportions. The cementing matrix is composed of bioclast-lithoclastic limestone (grainstone) from debris flow depositions. Foraminifera are determined from fragments of turbidites: *Archaeosphaera* cf. *suleimanovi* Boguch et Yuferev, *A. cf. crassa* Lipina, *A. cf. grandis* Lipina, *A. cf. minima* Suleimanov, *Neoarchaeosphaera* cf. *polypore* Antropov, *Vicinesphaera* cf. *angulata* Antropov, *V. cf. squalida* Antropov, *Suleimanovella* cf. *suleimanovi* (Lipina), *S. cf. paracushmani* (Reitlinger), *Parathuramminites* cf. *cushmani* (Suleimanov), *Parathurammina* cf. *dagmarae* Suleimanov, *P. cf. spinosa* Lipina, *Cribrosphaeroides* cf. *ovalis* (Pojarkov), *Uralinella* cf. *bicamerata* Bykova, *Bisphaera* sp., *Corbiella* cf. *fungeiformis* Pojarkov, *Tuberporina* sp., *Rauserina notata* cf. *polycellata* Antropov, *Eotuberitina* sp., *Bituberitina* sp., *Diplosphaerina* sp., *Eotournayellina primitiva* Lipina. Thickness: 57 m.

12. Alteration of limestones: 1) grey, thin-plate, medium-finegrained with thin interlayers of dark-grey silicium and 2) grey medium-plate, coarse-medium-grained, bioclast-lithoclastic, gradation-layered

(grainstone) forming the Ta,b-rhythms. Thin-plate differences prevail. Foraminifera: *Neoarchaesphaera* sp., *Archaesphaera* sp., *Vicinesphaera* cf. *squalida* Antropov, *V.* cf. *angulata* Antropov, *Cribrosphaeroides* cf. *ovalis* (Pojarkov), *Suleimanovella* cf. *suleimanovi* (Lipina), *Parathurammina* sp., *Uralinella* cf. *bicamerata* Bykova, *Auroria* ? sp., *Bisphaera* sp., *Eovolutina* cf. *elementa* Antropov; problematic sphaeras *Asterosphaera* sp., Thickness: 20 m.

13. Alternation of thin-plate and middle-plate (in different proportions) turbidite differences is similar to the layer 12. Horizons up to 0.5 m of medium-clastic breccias of grain flows are noted. Foraminifera: *Radiosphaera* cf. *basilica* Reitlinger, *Archaesphaera* cf. *grandis* Lipina, *Archaesphaera* cf. *crassa* Lipina, *Vicinesphaera* cf. *angulata* Antropov, *V.* cf. *squalid* Antropov, *Suleimanovella* cf. *suleimanovi* (Lipina), *Parathurammina* sp., *Cribrosphaeroides* sp., *Auroria* cf. *ferganensis* Pojarkov, *Bisphaera* cf. *grandis* Lipina, *Eotuberitina* sp., *Septaglomospiranella* sp., *Quasiendothyra* cf. *konensis* (Lebedeva); problematic sphaeras *Radiosphaera* cf. *basilica* Reitlinger. Thickness: 105 m.

14. Alternation of limestones: 1) grey, large-plate, coarse-grained bioclast-lithoclastic (up to 1 m of grainstone beds, - grain flow depositions); 2) grey, middle-large-plate, gradation-layered, coarse-middle-grained, bioclast-lithoclastic grainstones (turbidites Ta,b); 3) grey, middle-plate gradation-layered medium-fine-grained (turbidites Ta, b, c); and 4) thin-plate, up to 2 cm, carbonaceous-siliceous “in-situ” sediments with remnants of radiolarians. In the roof of the unit, there are single large re-deposited blocks of algal boundstone (2x7 m) in large-coarse-grained turbidites. Foraminifera: *Neoarchaesphaera* sp., *Archaesphaera* sp., *Vicinesphaera* sp., *Suleimanovella* cf. *suleimanovi* (Lipina), *Parathurammina quadrata* Brazhnikova et Vdovenko, *Bisphaera* sp., *Tubeporina* ? sp., *Caligella antropovi* Lipina, *Baituganella vulgaris* Lipina, *Eotournayellina* sp., *Tournayellina* cf. *vulgaris* Lipina, *Clomospiranella* sp.; problematic sphaeras *Radiosphaera* sp. Thickness: 26 m.

15. Alternation of the beds, similar to that described in the unit 14, except for the appearance the package of the gradation breccias grain flows (2-3 m thick) omnideveloped. The unrolled lithoclasts up to 70 cm in size are represented by different types of limestone. Floating packs. The cementing matrix is composed of a coarse-grained bioclast-lithoclastic grainstone. In most cases, breccias' bodies have erosive relations with underlying deposits. Foraminifera: *Neoarchaesphaera* ? sp., *Archaesphaera* cf. *crassa* Lipina, *A.* cf. *grandis* Lipina, *A.* cf. *magna* Suleimanov, *A.* cf. *minima* Suleimanov, *Vicinesphaera* cf.



Figure 8 – Outcrops of the upper part of the Lower Shalkiya Subsuite with biogermers



Figure 9 – Outcrops of the upper part of the Lower Shalkiya Subsuite with biogerms (detail)



Figure 10 – Outcrops of the upper part of the Lower Shalkiya Subsuite with biogerms, overlaid by deposits of the Upper Shalkiya Subsuite

squalida Antropov, *Suleimanovella* cf. *suleimanovi* (Lipina), *Parathurammia* cf. *tuberculata* Lipina, *P.* cf. *spinosa* Lipina, *Baituganella* cf. *vulgaris* Lipina, *Septaglomospiranella primaeva* cf. *minima*, *Septaglomospiranella* cf. *parva* Durkina, *Tournayellina* sp., *Quasiendothyra* cf. *communis* Rauser-Chernousova, *Quasiendothyra* cf. *konensis* (Lebedeva), *Quasiendothyra* aff. *baidjansaica globosa* Durkina, *Quasiendothyra kobeitusana* Rauser-Chernousova. Thickness: 95 m.

Deposits of the Upper Shalkiya Subsuite compose the nuclear parts of the Karamurun and Mynbulak synclinals. Tectonic relations between the Upper and Lower parts of the Shalkiya subsuites are fixed everywhere.

Upper Shalkiya Subsuite is represented by dark-grey to black medium-thin-plate, rhythmically built thin-layered micrite carbonaceous-clayey-siliceous-carbonate, siliceous-carbonate, clayey-carbonate, siliceous (in situ) deposits [20], grey, dark-grey, middle-plate, multi-grained (from coarse-grained to fine-grained differences) with admixture of terrigenous material, limestone, dolomitized limestone (turbidites Ta, b, c), represented by bioclast-lithoclastic packstones and wackestones. In situ carbonaceous-clay-siliceous-carbonate deposits are accompanied by unburdened body strike (first meter thick) and creep breccian lenses of poorly lithified deposits, formed by fragments of host rocks and dark carbonate micrite material. Horizons of breccias of grain and debris flows (first meters thick; much rare 15-25 m) are composed of unrolled fragments of skeletal bioclast-lithoclast algae limestone, gradation-layered limestone, silicon, carbonaceous-clayey-siliceous-carbonate thin-layered deposits, cemented by lithoclast-bioclast medium-coarse-grained matrix. Thin bedded carbonaceous-clayey-siliceous-carbonate deposits are characterized by presence of the bed-by-bed thin syngenetic pyrite embedding. Numerous remnants of radiolarians and sponge spicula are observed in the beds of the essential siliceous composition.

The limestones are bioclast and bioclast-intraclastic micrograined (packstone), almost micrit, with numerous fragments of algae of various shapes and sizes. In algae limestones (packstones), beds and algal fragments are recrystallized, very poorly preserved. Intraclasts (calcite, dolomite) are often replaced by ore matter. Bioclasts are represented by organic residues of poor preservation (algae, radiolarians). The micrite matrix is recrystallized, contains bioclasses of sludge dimension and the shale-developed carbonaceous substance. The carbonaceous substance is either distributed unevenly over the shale or thinly scattered over the entire slice. Inclusions of ore mineral of different shapes and sizes are found in slices, and small inclusions of ore mineral, including pyrite of cubic and hexagondohedral forms, are often scattered. Often the ore mineral is developed in veins and algae, sometimes it is unevenly distributed throughout the entire slice, often replacing organic residues. The rock is often flaky and permeated with two generations of calcite veins.

Numerous relics of undefined organic matter (small crustaceans or ostracodes, radiolarians, algae) can be found in bioclastic limestones. There are single foraminifera of very poor preservation: *Parathurammina* ? sp., *Bisphaera* sp., *Diplosphaerina* ? sp., *Auroria* cf. *ferganensis* Pojarkov, *Auroria* sp., *Paracaligella* sp., *Parastegnammina* sp., *Tournaellina* sp. (*Tournayellina* cf. *primitiva* Lipina), *Quasiendothyra* (*Eoendothyra*) sp., and problematic *Archaeosphaera* sp., encountered, mainly, in Famennian (D₃fm) and Tournaisian deposits (C₁t) of various regions [10].

The algae are: *Kamaena* cf. *delicata* Antropov, *Kamaena* sp., *Issinella* cf. *devonica* Reitlinger, *Issinella* cf. *grandis* Tchuvachov, *Parachaetetes*? (*Thomilition*) *jonsoni* Masslov, *Epiphyton* sp., *Pseudonanolopora* cf. *stockmansii* Mamet et Roux, *Conglutinella* aff. *tikhii* Shuysky, rare *Solenopora* (D₃-C₁) [8]. Found in slices were single fragments of recrystallized moss animals, foraminifera *Eotuberitina lesovaja* Michno and algae *Epiphyton* sp. (D₃fm). Spongolites (siliceous recrystallized limestone) with numerous sponges, radiolarians, and single algae are found, including *Kamaenidae*, more often *Renalcis*.

In the section, the main background of the foraminifera complex of the Upper Famennian are monocameral forms. Present in large quantities are: *Parathurammina dagmarae*, *P. brevirostrata*, *P. sp.*, plenty of *Radiosphaera basilica*, *R. ponderosa*, *Vicinesphaera angulata*, *Asterosphaera pulchra*. Encountered: *Bisphaera paracompressa*, *B. malevkensis*, *Cribrosphaeroides simplex*, *Suleimanovella suleimanovi*, as well as *Auroria* sp., *Irregularina* sp., *Paracaligella* sp., *Rauserina* sp. Above, are rare multicameral *Tournayellina vulgaris*, *T. pseudobeata*, single *Septatournayella rauserae*—of *Tournayellina pseudobeata* Zone of the Lower Tournaisian (figure 11).

The presence of monocameral forms and rare representatives of *Tournayellina pseudobeata*, *T. beata*, *Quasiendothyra* (*Eoendothyra*) *communis* and the first primitive *Chernyshinella* brings the complex closer to Tn1b I Avesnois (Conil, Lys. 1969) or allows comparing it with the standard *Tournayellina pseudobeata* Zone [21].

The lower boundary of the Tournaisian in the Bolshoi Karatau was previously proposed to be located at the base of the *Bisphaera malevkensis* - *Earlandia minima* Zone. The *Bisphaera malevkensis* occurs in the Devonian [20] and is quite widespread in the Famennian Stage [14], and occur en mass, in the lower part of the Tournaisian, forming "bispherabeds".

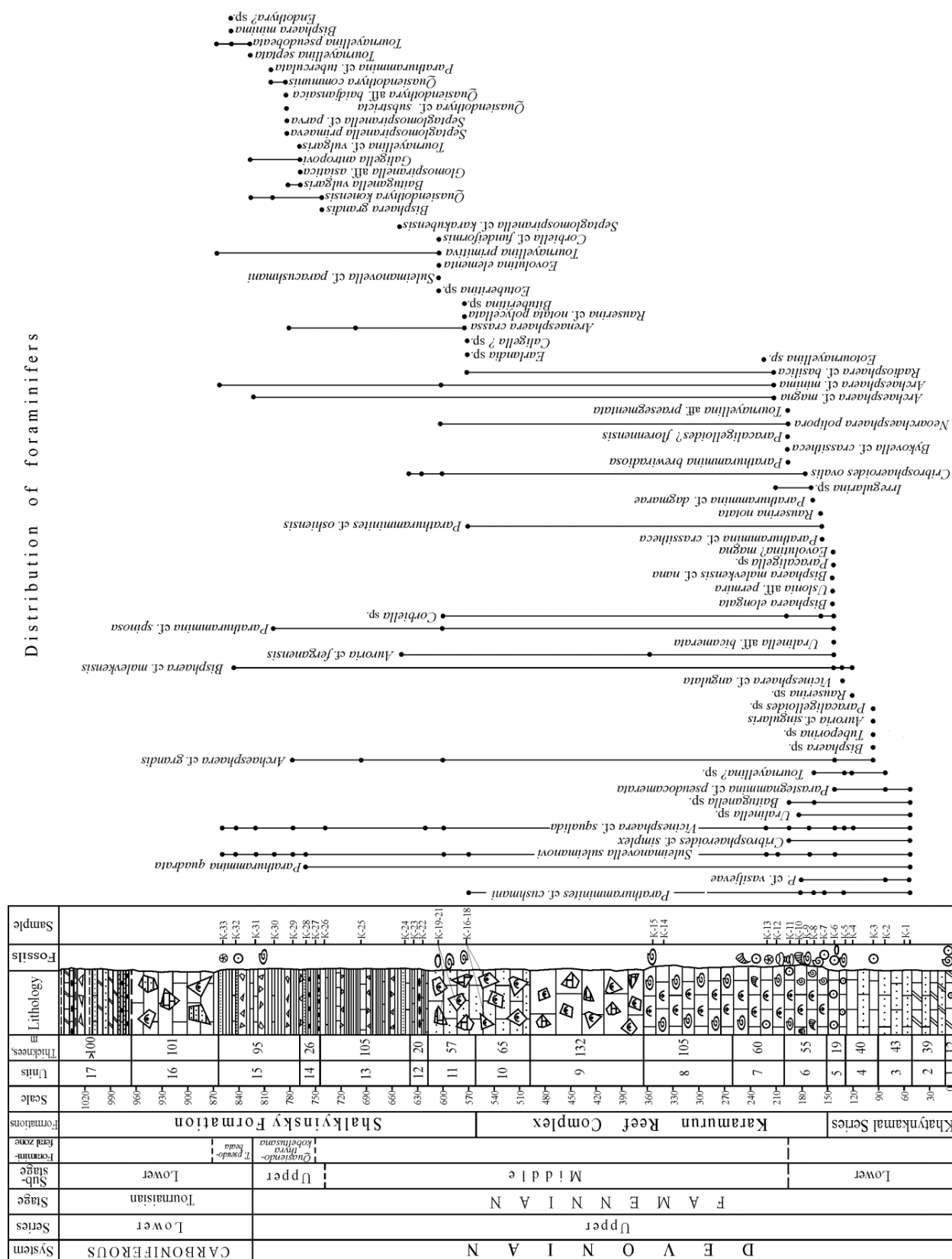


Figure 11 – The Karamurun section. Lithology and distribution of foraminifera in the Famennian-Lower Tournaisian deposits(A.E. Zorin, V.Ya. Zhaimina, 2003-2016)

The presence above of the *Earlandia minima* and *E. elegans*, rare *Tournayellina beata* allow correlating the strata with the *Bisphaera malevkensis*–*Earlandia minima* Zone of the Russian Platform (Unitized,... 1991) [8] and dating them as Tournaisian.

Thus, near the boundary of Devonian and Carboniferous systems, a significant reorganization of foraminiferal assemblage, are observed. It is expressed by extinction of the quasiendothyrids and the development of the Tournaisian *Chernyshinella* and *Endothyra*, i.e. the near-boundary level is marked by large biotic reconstructions, the main feature of which is the change of faunistic communities (figure 11). Biotic reconstructions were caused by abiotic changes, the shallowing in the near-boundary time.

One of the indicators of a major abiotic event in marine sections, at the boundary of the two systems, is dolomitization and the presence of breccias. With eustatic sea level fluctuations, the Carbonate platform collapsed, and coarse-clastic Carbonate fragments was formed.

It is necessary to study the section further, with a more detailed selection of all organic residues, their definition and monographic description to present it as a stratotype.

В. Я. Жаймина¹, Е. И. Кулагина²

¹Сәтбаев Университеті, Қ. И. Сәтбаев атындағы Геологиялық ғылымдар институты, Алматы, Қазақстан,

²Геология институты – Ресей Ғылым Академиясының Уфа Федералдық зерттеу Орталығы бөлімшесі, Уфа, Ресей

ҚАРАМҰРЫН ҚИМАСЫНДАҒЫ ДЕВОН ЖӘНЕ ТАС КӨМІР ЖҮЙЕСІНІҢ ШЕКАРАЛЫҚ ҚАБАТТАРЫНЫҢ ЕРЕКШЕЛІКТЕРІ (ҮЛКЕН ҚАРАТАУ, ОҢТҮСТІК ҚАЗАҚСТАН)

Аннотация. Тас көмір жүйесі бойынша халықаралық комиссия жаһандық түзетулер мен тас көмір жүйесіне қатысты халықаралық бірыңғай стратиграфиялық шкала енгізу мақсатында тас көмір мен девон жүйелерінің тыңғылықты зерттеуде. Турней жікқабатының, Миссисипий ішкі жүйесі мен Тас көмір жүйесінің Жаһандық Үлгі Қимасы Оңтүстік Францияның Ла-Сиерр қимасында орын тапқан. Аталмыш шекара конодонттар мен басқа да фауналар мен флоралар (аммоноидтер, фораминиферлер, остракодтар, миоспорлар, маржандар мен брахиоподтар) бойынша анықтау өлшемшартына ие. Үлкен Қаратауағы Қарамұрын тіректі қимасының шөгінді жыныстар рифогенді фацияларда биогермалармен қоса байқалады. Шөгінділердің осы тұсы Қазақстан мен әлемде мұнай - газ кенорындарын табуда кеңінен қолданылады. Фораминиферлер, қазіргі таңда, жүйесі таңдап алынған басқа да аудандар мен девон мен таскөмір шекараларын анықтауда аса маңызды роль ойнайды. Шекаралық деңгей абиотикалық өзгерістерге байланысты үлкен биотикалық өзгерістермен белгіленеді.

Түйін сөздер: шекара, девон, тас көмір, Қарамұрын, қима, рифтер, фораминиферлер, аймақтар, Халықаралық Стратиграфиялық шкала, түзету (корреляция).

В. Я. Жаймина¹, Е. И. Кулагина²

¹Сатпаев Университет, Институт геологических наук им. К. И. Сатпаева, Алматы, Казахстан,

²Институт геологии – Отделение Уфимского Федерального Исследовательского Центра Российской Академии Наук (ИГ УФИЦ РАН), Уфа, Россия

ОСОБЕННОСТИ ПОГРАНИЧНЫХ ОТЛОЖЕНИЙ ДЕВОНА И КАРБОНА РАЗРЕЗА КАРАМУРУН (БОЛЬШОЙ КАРАТАУ, ЮЖНЫЙ КАЗАХСТАН)

Аннотация. Международная подкомиссия по стратиграфии каменноугольной системы изучает и доизучает пограничные отложения каменноугольной и девонской систем с целью проведения глобальных корреляций и создания единой Международной стратиграфической шкалы каменноугольной системы. Глобальный Стратотипический Разрез и Точка (GSSP) основания турнейского яруса, Миссисипской подсистемы и каменноугольной системы установлены в разрезе Ла-Сиерр в Южной Франции. Граница имеет критерии определения по конодонтам и другой фауне и флоре (аммоноидеи, фораминиферы, остракоды, миоспоры, кораллы и брахиоподы). Однако в настоящее время положение этой границы пересматривается. В опорном разрезе Карамурун Большого Каратау пограничные отложения наблюдаются в рифогенных фациях с биогермами. Подобные обстановки осадконакопления и стратоемкости перспективны для обнаружения

месторождений нефти и газа в Казахстане и Море. Комплексы фораминифер позволяют проследить зоны, выделенные в других регионах, приемлемые для корреляций и обоснования положения границы девона и карбона на современном уровне. Пограничный интервал отмечен крупными биотическими перестройками, обусловленными изменениями абиотическими.

Ключевые слова: граница, девон, карбон, Карамурун, разрез, рифы, фораминиферы, зоны, Международная Стратиграфическая шкала, корреляция.

Information about authors:

Zhaimina V. Ya., doctor of Geological and Mineralogical Sciences Institute of Geological Sciences named after K. I. Satpaev, Almaty, Kazakhstan; svenax@bk.ru, zhaimina@mail.ru;
<https://orcid.org/0000-0001-6153-4813>

Kulagina E.I., doctor of Geological and Mineralogical Sciences Institute of Geology – Subdivision of the Ufa Federal Research Centre of the Russian Academy of Sciences (IG UFRS RAS), Ufa, Russia; elenkul@mail.ru, kulagina@ufaras.ru;
<https://orcid.org/0000-0002-1684-3366>

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**G. V. Novikova¹, G. V. Zhdankin², O. V. Mikhailova¹, M. V. Belova¹,
V. G. Semenov³, D. A. Baimukanov⁴, K. Zh. Iskhan⁴, A. K. Karynbayev⁵**

¹State budgetary educational institution of higher education «Nizhny Novgorod State Engineering and Economic University», Knyaginino, Nizhny Novgorod Region, Russia,

²Federalstate budgetary educational institution of higher education

«Nizhny Novgorod State Agricultural Academy», Nizhny Novgorod, Russia,

³Federalstate budgetary educational institution of higher «Chuvash State Agricultural Academy»,
Cheboksary, Russia,

⁴Non-Commercial Joint-Stock Company «Kazakh National Agrarian University», Almaty, Kazakhstan,

⁵M. H. Dulati Taraz state university, Taraz, Kazakhstan.

E-mail: NovikovaGalinaV@yandex.ru, gdankin@inbox.ru, ds17823@yandex.ru, maryana_belova_803@mail.ru,
semenov_v.g@list.ru, dbaimukanov@mail.ru, uznijr.taraz@mail.ru

INSTALLATIONS FOR COMPLEX INFLUENCE OF ELECTROPHYSICAL FACTORS ON RAW MATERIALS

Abstract. Two microwave installations have been developed with quasi-stationary resonators with rectangular and circular torus sections. In both installations in the condensing part of the resonator, there is an electro-gas-discharge lamp connected to the source of kilohertz frequency according to the D'Arsonval principle. Therefore, the installations provide a complex effect of electrophysical factors on raw materials, including the potato tubers and onion sets during preplant treatment. *In the first installation* with a quasistationary toroidal resonator of rectangular cross section in the condensing part, the distance between the walls is less than at the edges and not less than a quarter of the wavelength. The resonator is designed as coaxially arranged non-ferromagnetic cylinders, the lower bases of which form its condensing part, and the arrangement of the internal cylinder is adjustable in height.

The annular space between the side walls of the cylinders on the top is closed with a non-ferromagnetic surface containing the nodes of the threaded height regulator of the internal cylinder. Inside the annular space, there is a cylinder, an air offtake and an electro-gas-discharge lamp connected to kilohertz frequency source. In the condensing part, there is a batcher. The emitters from magnetrons located on the side surface of the outer cylinder with a shift of 120 degrees are directed to the condensing part of the resonator.

In the second installation, the toroidal resonator is represented in the form of a torus with a circular cross section and docked plane-parallel circular surfaces in the central part. Inside the torus is a dielectric grid conveyor. In the central part of the resonator, there is a rotating disk, over which a dielectric distributor is mounted. Emitters are directed into the torus, and electro-gas-discharge lamps connected to kilohertz frequency sources are directed into the condensing space. At the center of the resonator, a feed hopper is installed, and under the torus - an induction heater is mounted so that the segment of the bottom of the torus surface is its secondary winding.

Keywords: ultrahigh frequency generator, quasi-stationary toroidal resonator, electro-gas-discharge lamps, kilohertz frequency source, induction heater.

Introduction. It is known that the treatment of onion sets before planting is carried out in order to avoid low germination, bacterial damage, and intensive “shooting”. Immediately before planting, onions are heated at a temperature of 35-40 °C for 10-12 hours. Further, phytosporinis used to suppress the development of pathogenic soil microflora. There is a way to warm the onion sets in hot water (45-50 °C) for 10-12 minutes and then in cold water, also 10-12 minutes, then treatment with pests and nutrient solutions. At the same time for uniform heating and cooling of onion sets in farms, it is necessary to have water heaters and additional mechanisms for mixing.

There is a method of preplanting treatment of onion sets in an electromagnetic high-frequency field [1]. At the same time, high-frequency installations of *periodic action* and with fixed frequencies (27.12 MHz, 40.68 MHz) were used, where the working chamber is a condenser made of two parallel-arranged plates. Long-term laboratory and field studies of these authors on the application of electromagnetic high-frequency fields for preplanting treatment of onion-seed showed that there is an increase in sowing and productive indicators, improving product quality.

In the Federal State Budgetary Educational Institution of Higher Education "Stavropol State Agrarian University", there were received positive results of research on the preplanting treatment of onions with a pulsed electric field to improve their sowing qualities [2].

It is known that the yield of potatoes depends largely on the quality of sown tubers. Today, preplanting treatment is carried out with agricultural preparations for the prevention of diseases, pests, growth stimulation. Most often for disinfection these drugs are used: Maxim, Phytosporin-M, they are combined with other fungicides and growth stimulants. They protect the crop from diseases at all stages of growth, but do not exclude side effects on humans [3].

The positive results of electrophysical methods of processing products are known [4-7]. For example, the electrophysical factors processing technology of potato tubers prevents the contamination of agricultural land and, without chemical intervention, makes more efficient the use of the capabilities of the potato tuber itself. Known methods of preplanting treatment of potato tubers with low-frequency (8-19 Hz) magnetic fields [8]. The installation contains an inductor, but the processing time at a frequency of 16 Hz reaches up to 15-20 min, which is a disadvantage.

Conditions, materials, and research methods. The development of constructional design of cavity resonators was carried out on the basis of the analysis of electrophysical factors influencing the raw materials, based on the theory of the electromagnetic ultrahigh frequency field, induction heating and d'Arsonvalization [9].

The object of the research is technological processes that ensure the prevention of potato tubers and onion sets from pests and growth stimulation; experimental samples of installations that implement the complex effect of electrophysical factors on raw materials in a continuous mode.

The aim of preventive treatment of potato tubers and onion sets before planting by the complex effect of electrophysical factors is disinfection from a number of pests, activation of potato tuber cells to accelerate and promote their germination, with the exception of side effects on the physico-chemical composition of grown potatoes.

Results and discussion. Below are described two developed microwave installations with toroidal resonators, providing complex effect of electrophysical factors on raw materials in continuous mode.

The first installation. For disinfection from a number of pests, for activation of onion sets germination and potato tubers in continuous mode in order to increase productive indicators, we suggest processing them before planting with a complex effect of the electromagnetic ultrahigh frequency field (EMUGFF) and corona discharge, which provides air ionization and ozonation. The implementation of the complex effect of these electrophysical factors is possible in the microwave installation with the quasistationary toroidal resonator [1, 2] of rectangular cross section, containing below-cutoff waveguides that ensure the observance of electromagnetic safety when moving onion sets through the resonator. An electro-gas-discharge lamp connected to kilohertz frequency source according to the D'Arsonval principle [12, 14] provides a corona discharge and radiation of a bactericidal flux of ultraviolet rays, moreover, this lamp filled with argon or neon and located in the electromagnetic ultrahigh frequency field coronates more powerfully.

The technological task of development is the preplanting treatment of vegetable crops in order to increase their sowing and productive indicators by the complex effect of electrophysical factors in continuous mode with the provision of high electric field intensity and ozonation for decontamination of raw materials and compliance with electromagnetic safety.

The microwave installation (figure 1) for preplanting processing of vegetable crops consists of the vertically located quasistationary toroidal resonator 1 with a rectangular cross section.

It is known that the shape of the profile of the toroidal resonator determines the structure of the excitable electromagnetic fields. The electric field is mainly concentrated in the condensing part of the resonator, where the distance between the walls is small, i.e. this part of the resonator is capacitive in effect. The magnetic field energy is concentrated in the periphery part of the resonator (in the torus) [10].

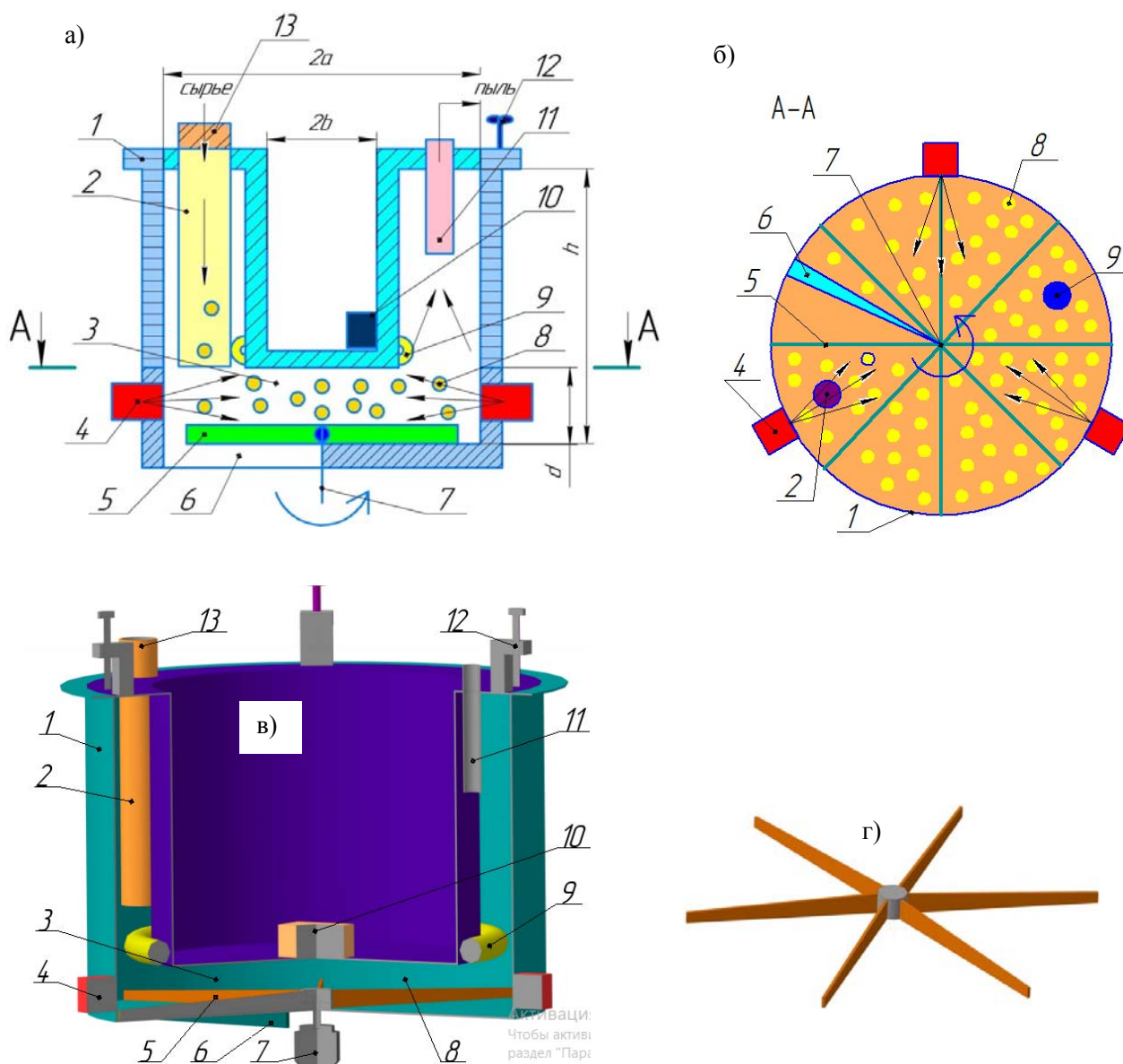


Figure 1 – Microwave installation for preplanting processing of onion sets in continuous mode: а, б) schematic illustration of the front view and A-A; в, г) space image of the installation in the section and batcher; 1 – quasistationary toroidal resonator; 2 – dielectric cylinder for feeding raw materials; 3 – condensing part of the quasistationary toroidal resonator; 4 – magnetrons with emitters; 5 – batcher with radially located dielectric scrapers; 6 – discharge opening with the below-cutoff waveguide in the form of a regular triangular prism; 7 – drive shaft of the scraper batcher; 8 – raw material; 9 – circular electro-gas-discharge lamp; 10 – kilohertz frequency source; 11 – dielectric air offtake; 12 – threaded height regulator of the internal cylinder; 13 – below-cutoff waveguide of circular section

The annular space between the side walls of the cylinders is on top closed with a flat surface, where there are openings for the dielectric air offtake 11 and for the below-cutoff waveguide 13 joined with the dielectric cylinder 2. Inside the annular space, there is the dielectric cylinder 2, the dielectric air offtake 11 and the circular electro-gas-discharge lamp 9. This lamp has the ring form is put on the inner cylinder with a gap between them at the level of its base. The electro-gas-discharge lamp 9 is connected to kilohertz frequency source 10, located on the side surface of the inner cylinder, from the inside. In the condensing part, there is the batcher 5 with radially located scrapers, mounted on the shaft 7 of the electric motor coaxially with the base of the outer cylinder, where there is the discharge opening 6 in the form of a sector. The below-cutoff waveguide in the form of the regular triangular prism is docked to the discharge opening.

The emitters from magnetrons 4, located on the side surface of the outer cylinder with a shift of 120 degrees, are directed to the condensing part of the resonator, where there is raw material 8. The capacity of the condensing part of the resonator is regulated by changing the vertical position of the internal cylinder. For this, there is a threaded height regulator for the lift of the inner cylinder 12. In this case, the electric field intensity is adjusted by changing the distance between the bases of the non-ferromagnetic cylinders.

The technical process of preplanting processing of potato tubers or onion sets is as follows. Turn on the drive of the air offtake 11 and the batcher 5 with dielectric scrapers. Set a certain distance between the bases of the cylinders, calibrated to the required value of the electric field intensity, sufficient for disinfecting onion sets or potato tubers. Turn on the kilohertz frequency source 10, after which due to the occurrence of corona discharge between the side surface of the inner cylinder and the electro-gas-discharge lamp 9, the air ionization occurs, ozonation, the lamp will be a source of ultraviolet rays of the "C" area. Next, turn on the conveyor to feed the raw material into the dielectric cylinder 2 through the below-cutoff waveguide 13 of circular cross section. Turn on the ultrahigh frequency generators 4. When the raw material enters the condensing part 3 of the quasi-stationary resonator 1, it is exposed to the electromagnetic ultrahigh frequency field in the process of moving with the scraper batcher, it is heated (up to 35-40 °C), disinfected due to the high electric field intensity (above 1.5 kV/cm), as well as ozonation and bactericidal action of ultraviolet rays.

Moreover, the electric field intensity is adjusted by changing the distance between the bases of non-ferromagnetic cylinders using a threaded height regulator of the inner cylinder lift 12. After one turn of the shaft of the electric drive 7 of the scraper batcher, the processed raw material 8 is poured out through the discharge opening 6 and the below-cutoff waveguide in the form of the triangular prism. Through the air offtake 11, dust, husks, others are removed. The technical process of preplanting treatment of onion sets or tubers of seed potatoes goes is underway in continuous mode.

During the operation of the kilohertz frequency source (by D'Arsonval principle), impulse high voltage and low power currents affect the raw materials. The current passes through the electro-gas-discharge lamp. Between the lamp and the side surface of the inner cylinder, there is a corona discharge of different intensity depending on the gap between them (0.5-2 cm). Herewith, there is a release of ozone and air ionization, a formation of ultraviolet rays. The current on the electro-gas-discharge lamp is not more than 0.2 mA, the voltage is 12-15 kV, the pulse frequency is 110 kHz [14]. The released ozone and ultraviolet rays of the "C" area have a bactericidal effect. Bacteria and microorganisms present in the treated seeds die. With the complex effect of various electrophysical factors, the cells of potato tubers and onion sets are activated, which increases the germination energy, germination, growth force and yield. When designing the quasistationary toroidal resonator for operation in continuous mode, it is necessary to strive to reduce the equivalent capacitance at a given resonant frequency and increase the equivalent inductance (toroidal surface). In this case, the loss of microwave energy in the toroidal resonator is reduced, and the efficiency increases [10].

Low radiation losses due to the presence of below-cutoff waveguides and losses in the walls of the quasi-stationary toroidal resonator made of aluminum lead to the fact that this resonator in the microwave range has a high-quality factor of its own.

The second installation for preplanting treatment of potato tubers or onion sets by electrophysical factors (figure 2) consists of the toroidal resonator 1, made in the form of the circular torus, the average perimeter of which is a multiple of half the wavelength. The middle part of the toroidal resonator is made of two plane-parallel circular planes, forming the condensing space 13. In this space, the disk 5 is installed coaxially with the resonator, which is driven by the electric motor. Above the disk 5 is rigidly installed dielectric distributor of tubers 6 in the form of a streamlined surface. Through the upper circular plane, detachable electro-gas-discharge lamps fed from the kilohertz frequency sources 12 are directed uniformly around the perimeter into the condensing space.

Electro-gas-discharge lamps are surrounded by the grid that protects from the impact of tubers. In the center of the same circular plane, the filling hopper 14 is installed. Microwave energy emitters 2 from magnetrons are directed through the surface of the torus. They are located with a shift of 120 degrees in order not to disrupt the operation of neighboring magnetrons. Inside the torus, the conveyor 4 and the scrapers 9 move by means of the driven pulley 8 and the drive gear mounted on the shaft. The discharge dielectric limiter 11 is rigidly fixed above the conveyor, directing the potato tubers to the window 10 with the below-cutoff waveguide. The fluoroplastic scrapers 9 mounted under the conveyor move with it, and

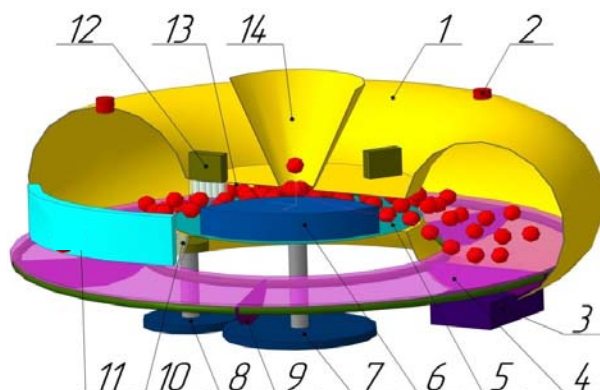


Figure 2 – Installation for preplanting treatment of potato tubers with exposure by electrophysical factors:
 1 – toroidal resonator; 2 – microwave energy emitters; 3 – induction heater; 4 – dielectric grid conveyor; 5 – rotating disk;
 6 – dielectric distributor of tubers; 7 – driving pulley; 8 – driven pulley for the grid conveyor drive;
 9 – dielectric scrapers for waste unloading; 10 – unloading window for tubers; 11 – discharge dielectric limiter;
 12 – kilohertz frequency sources; 13 – condensing space; 14 – filling hopper; 15 – window for discharging waste

they are intended for discharging waste from the torus through the window 15 and the below-cutoff waveguide. The induction heater 3 is installed under the torus, and the torus segment above it performs the secondary winding of the inductor [11].

So, the installation contains three different sources of electromagnetic radiation:

- ultrahigh frequency generators (main nodes - magnetron, emitter);
- induction heater (primary winding and torus segment);
- kilohertz frequency sources (generator and electro-gas-discharge lamps) that generate high-frequency alternating impulse current with high voltage, the value of which is in the range of 2-15 kV, current frequency - 110 kHz [12].

The technical process of preplanting processing of potato tubers is as follows. Load the potato tubers into the hopper 14. Turn on the electric drive of the disk 5, then the driven pulley 8 rotates by means of the driving pulley, driving the conveyor 4 and the scrapers 9. Turn on the kilohertz frequency sources 12 and induction heater 3, then ultrahigh frequency generators, emitters 2 of which excite in the EMUHFF toroidal resonator.

A traveling wave with the 2450 MHz frequency is excited in the toroidal resonator, and under the influence of the EMUHFF, the potato tubers endogenously heat up to 35 °C, which accelerates the enzymatic activity of the tubers, thereby increasing their germination. In the condensing space, the electric field intensity is high enough (more than 2 kV/cm), which ensures the prevention of potato tuber from diseases and pests.

Electro-gas-discharge lamps 12 are at a distance of several millimeters (3-5 mm) from the tubers. In this case, a small electrical discharge arises between the lamps and tubers, which accelerates biochemical reactions, saturates the tubers with oxygen, increases the elasticity of the tuber's jacket and its permeability [2]. The electric discharge has a bactericidal and bacteriostatic (delayed multiplication of bacteria) action. Discharges produce ozone with a disinfecting effect. The conversion of high-voltage voltage to the corona discharge of the required force is due to the electro-gas-discharge lamps. Complex physical and electrochemical processes with the participation of inert gases in the lamp can produce several factors. Inert gas acquires the properties of the electrical conductor, then through a layer of air between the lamp and the tubers of potatoes, through the potatoes and the disk 5 is closed to the ground. As a result, the corona discharge occurs, therefore, ozone, heat and ultraviolet radiation are released in the condensing space 13. This whole complex of factors contributes to the activation of potato tuber cells, which allows them to accelerate and increase their germination.

Because of the fact that *induction heaters* are installed under the torus bottom segment, the electromagnetic coil (primary winding) generates a magnetic field, and the torus surface bottom segment made of ferromagnetic material with a size of at least 70% of the surface of the induction cooker is heated by eddy currents. When there are pests, separated by the conveyor grid 4, by means of mobile fluoroplastic scrapers 9 to the heated torus segment, they are destroyed by a thermal burn and are output through the discharge window 15 and the below-cutoff waveguide.

The choice of modes of factors influence depends on the type and maturity of potatoes or onion sets. The use of such an installation with different electrophysical factors will allow to obtain environmentally friendly products that meet all the requirements of the standards. This installation is recommended for preplanting processing of potato tubers no larger than 6 cm. This is connected with the provision of the high electric field intensity in the condensing space, the depth of a centimeter wave penetration into the potato tubers, and also the simplification of the design of the below-cutoff waveguides. They are provided in the unloading windows 10 and 15. Uniform heating of the tubers and continuous operation of the installation is ensured by transporting in the torus with the help of the grid conveyor.

The technical specifications of the installation for preplanting treatment of potato tubers by the complex effect of electrophysical factors are given in table.

Installation specifications

Item	
Capacity, kg/h	250-300
Microwave generator power, kW	3.6
kilohertz frequency sources power, kW	0.225
Induction heater power at a heating temperature of 150 °C, kW	1.0
Power of motor reducer ESTA -6.3/12.5 for the conveyor drive, 2.4/4.8 r/min	0.043
Installation capacity, kW	4.9
Specific energy costs, kW·h/kg	0.015-0.2

Conclusions. Using the proposed installation, with the capacity of up to 300 kg/h, it is possible to handle the entire volume of potato tubers in farms before planting. Studies show that the duration of the effect from the complex impact of electrophysical factors is up to 6 days. Consequently, it is possible to carry out preplanting treatment of up to 20 tons of potato tubers, no larger than 6 cm in size, using one such installation, at specific energy costs of up to 0.2 kW·h/kg.

The developed installations contain various sources of electromagnetic radiation.:

- ultrahigh frequency generators, providing endogenous heating of planting material and prevention of diseases and pests; induction heater for the destruction of pests by means of thermal burns; high-frequency (110 kHz) alternating impulse current generators with high voltage (up to 15 kV) and electro-gas-discharge lamps, which accelerate biochemical reactions and disinfect the raw material due to ozonation.

This whole complex of energy sources contributes to the activation of sown and productive indicators of vegetables. Using a new method of preplanting treatment of onion sets and potato tubers can increase crop yields by up to 15% and improve product quality, increase hygienic safety requirements of the product, therefore, the developed installations are recommended for use in farms.

**Г. В. Новикова¹, Г. В. Жданкин², О. В. Михайлова¹, М. В. Белова¹,
В. Г. Семенов³, Д. А. Баймұқанов⁴, К. Ж. Исхан⁴, А. К. Қарынбаев⁵**

¹Жоғары білім берудің мемлекеттік бюджеттік білім беру мекемесі «Нижегород мемлекеттік инженерлік-экономикалық университеті», Нижегород облысы, Княгинино, Ресей,

²Жоғары білім берудің федералдық мемлекеттік бюджеттік білім беру мекемесі «Нижний Новгород мемлекеттік ауылшаруашылық академиясы», Нижний Новгород, Ресей,

³Жоғары білім берудің федералдық мемлекеттік бюджеттік білім беру мекемесі «Чуваш мемлекеттік ауылшаруашылық академиясы», Чебоксары, Ресей,

⁴«Қазақ ұлттық аграрлық университеті» коммерциялық емес акционерлік қоғамы, Алматы, Қазақстан,

⁵М. Х. Дулати атындағы Тараз мемлекеттік университеті, Тараз, Қазақстан

ШИКІЗАТҚА КЕШЕНДІ ӘСЕР ЕТЕТІН ЭЛЕКТРОФИЗИКАЛЫҚ ФАКТОРЛАРЫ БАР ҚОНДЫРҒЫЛАР

Аннотация. Төрт бұрышты және дөңгелек қимасы бар квази стационарлық резонаторлармен екі микротолқынды қондырғылар әзірленді. Екі қондырғыда да резонатордың конденсатор бөлігінде Дарсонваль қағидасына сәйкес килогерц жиілігінің көзіне қосылған электр разряд шамдары бар. Сондықтан, өсімдіктер алдын ала отырғызу кезінде электрофизикалық факторлардың шикізатқа, оның ішінде картоп пен пияз түйнегіне кешенді әсерін қамтамасыз етеді. Конденсатордың бөлігінде тікбұрышты көлденең қиманың квази-

стациялық тороидальды резонаторы бар алғашқы қондырғыда қабырғалардың арасындағы қашықтық шеттерге қарағанда аз және толқын ұзындығының төрттен бірінен кем емес. Резонатор коаксиалды ферромагниттік цилиндрлер ретінде құрастырылған, оның төменгі негіздері оның конденсатор бөлігін құрайды және ішкі цилиндрдің биіктігі реттеледі. Цилиндрлердің бүйірлік қабырғалары арасындағы сақиналық кеңістік ферромагниттік емес беткі қабатпен жабылады, ішкі цилиндрдің көтеру биіктігінің бұрандалы реттегішінің түйіндері бар. Сақиналық кеңістікте цилиндр, ауа ағыны және килогерц жиілігінің көзіне қосылған электр қуатын шығару шамы бар. Конденсатор бөлімінде дозатор бар. Сыртқы цилиндрдің бүйір бетінде 120 градусқа жылжуы бар магнетроннан шыққан сәуле таратқыш резонатордың конденсатор бөлігіне жіберіледі. Екінші қондырғыда тороидальды резонатор орталық бөлікте дөңгелек көлденең кимасы бар және торға параллельді дөңгелек беттермен тор түрінде ұсынылған. Тора ішінде диэлектрлік тор конвейері бар. Резонатордың орталық бөлігінде диэлектрлік бөлуші орнатылатын айналмалы диск бар. сәуле таратқыштар торға бағытталады және килогерц жиіліктер көздеріне қосылған электрогазоразрядты шамдар конденсатор кеңістігіне бағытталады. Резонатордың ортасында арна шұңқыры орнатылған, ал тор астында - тор бетінің төменгі бөлігінің екінші орамасы болатын индукциялық жылытқыш.

Түйін сөздер: жоғарытолқынды генератор, квазистационарлық тороидальды резонатор, электр разряд шамдары, килогерц жиілік көзі, индукциялық жылытқыш.

**Г. В. Новикова¹, Г. В. Жданкин², О. В. Михайлова¹, М. В. Белова¹,
В. Г. Семенов³, Д. А. Баймуханов⁴, К. Ж. Исхан⁴, А. К. Карынбаев⁵**

¹Государственное бюджетное образовательное учреждение высшего образования «Нижегородский государственный инженерно-экономический университет», Нижегородская область, Княгинино, Россия,

²Федеральное государственное бюджетное образовательное учреждение высшего образования «Нижегородская государственная сельскохозяйственная академия», Нижний Новгород, Россия,

³Федеральное государственное бюджетное образовательное учреждение высшего образования «Чувашская государственная сельскохозяйственная академия», Чебоксары, Россия,

⁴Некоммерческое акционерное общество «Казахский национальный аграрный университет», Алматы, Казахстан,

⁵Таразский государственный университет им. М. Х. Дулати, Тараз, Казахстан

УСТАНОВКИ ДЛЯ КОМПЛЕКСНОГО ВОЗДЕЙСТВИЯ ЭЛЕКТРОФИЗИЧЕСКИХ ФАКТОРОВ НА СЫРЬЕ

Аннотация. Разработаны две сверхвысокочастотные установки с квазистационарными резонаторами с прямоугольным и круглым сечением тора. В обеих установках в конденсаторной части резонатора предусмотрена электрогазоразрядная лампа, подключенная к источнику килогерцовой частоты по принципу Дарсонваля. Поэтому установки обеспечивают комплексное воздействие электрофизических факторов на сырье, в том числе на клубни картофеля и лука-севка при предпосадочной обработке. В первой установке с квазистационарным тороидальным резонатором прямоугольного сечения в конденсаторной части расстояние между стенками меньше, чем по краям, и не менее четверти длины волны. Резонатор выполнен как соосно расположенные неферромагнитные цилиндры, нижние основания которых образуют его конденсаторную часть, и расположение внутреннего цилиндра по высоте регулируется. Кольцевое пространство между боковыми стенками цилиндров сверху закрыто неферромагнитной поверхностью, содержащей узлы резьбового регулятора высоты подъема внутреннего цилиндра. Внутри кольцевого пространства установлены цилиндр, воздухоотвод и лампа электрогазоразрядная, подключенная к источнику килогерцовой частоты. В конденсаторной части имеется дозатор. Излучатели от магнетронов, расположенных на боковой поверхности наружного цилиндра со сдвигом на 120 градусов, направлены в конденсаторную часть резонатора. Во второй установке тороидальный резонатор представлен в виде тора с круглым сечением и состыкованных плоскопараллельных круглых поверхностей в центральной части. Внутри тора расположен диэлектрический сеточный транспортер. В центральной части резонатора расположен вращающийся диск, над которым установлен диэлектрический распределитель. В тор направлены излучатели, а в конденсаторное пространство – электрогазоразрядные лампы, подключенные к источникам килогерцовой частоты. По центру резонатора установлена загрузочная воронка, а под тором – индукционный нагреватель так, что сегмент дна поверхности тора является вторичной его обмоткой.

Ключевые слова: сверхвысокочастотный генератор, квазистационарный тороидальный резонатор, электрогазоразрядные лампы, источник килогерцовой частоты, индукционный нагреватель.

Information about authors:

Novikova Galina Vladimirovna, Doctor of Technical Sciences, Professor, Chief Researcher of the State Budgetary Educational Institution of Higher Education "Nizhny Novgorod State Engineering and Economics University, Knyaginino, Russia; NovikovaGalinaV@yandex.ru; <https://orcid.org/0000-0001-9222-6450>

Zhdankin Georgy Valeriyevich, Candidate of Economic Sciences, Associate Professor, First Prorector for Academic and Methodological affairs of the Federal State Budgetary Educational Institution of Higher Education "Nizhny Novgorod State Agricultural Academy", Nizhny Novgorod, Russia; gldankin@inbox.ru; <https://orcid.org/0000-0001-9283-240X>

Mikhailova Olga Valentinovna, State Budgetary Educational Institution of Higher Education "Nizhny Novgorod State Engineering and Economic University, Knyaginino, Russia; ds17823@yandex.ru; <https://orcid.org/0000-0003-1045-2003>

Belova Mariana Valentinovna, Doctor of Technical Sciences, Professor of the Department "Electrification and Automation", State Budgetary Educational Institution of Higher Education "Nizhny Novgorod State Engineering and Economics University, Knyaginino, Russia; maryana_belova_803@mail.ru; <https://orcid.org/0000-0001-8932-9352>

Semenov Vladimir Grigoryevich, Doctor of Biological Science, professor, honored worker of science of the Chuvash Republic, professor of Department of morphology, obstetrics and therapy of the Chuvash state agricultural academy, Cheboksary, Chuvash Republic, Russia; semenov_v.g@list.ru; <https://orcid.org/0000-0002-0349-5825>

Baimukanov Dastanbek Asylbekovich, Corresponding Member of the National Academy of Sciences of the Republic of Kazakhstan, Doctor of Agricultural Sciences, Professor of the Department of Physiology, Morphology, and Biochemistry named after academician N. U. Bazanova, NJSC "Kazakh National Agrarian University", Almaty, Kazakhstan; dbaimukanov@mail.ru; <https://orcid.org/0000-0002-4684-7114>

Iskhan Kairat Zhalelovich, Candidate of Agricultural Sciences, Associate Professor, Academician of the International Academy of Informatization, Professor of the Department of Physiology, Morphology and Biochemistry named after Academician N.U. Bazanova, NJSC "Kazakh national agrarian university", Almaty, Kazakhstan; Kayrat_Ishan@mail.ru; <https://orcid.org/0000-0001-8430-034X>

Karynbayev Amanbay Kambarbekovich, Doctor of Agricultural Sciences, Academician of the Russian Academy of Natural Sciences, Professor of the Department of Biology of the Faculty of Water Management, Ecology and Construction, M. Kh. Dulati Taraz State University, Taraz, Kazakhstan; uzniijr.taraz@mail.ru; <https://orcid.org/0000-0003-4717-6487>

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**Z. K. Masanov¹, Zh. T. Kozhabekov¹, G. K. Tugelbayeva²,
T. B. Madaliyev¹, S. Altybai², E. S. Abdraimov³**

¹Mechanics and engineering Academy named after academician U. A. Djoldasbekov, Almaty, Kazakhstan,

²Military Institute of Ground Forces of the Ministry of Defense, Almaty, Kazakhstan,

³Institute of engineering of National Academy of science, Bishkek, Kyrgyzstan.

E-mail: Gk0430@mail.ru, zein04@yandex.ru, engineer2013@inbox.ru

**WAVE SPREADING IN RESILIENT VISCOUS-PLASTIC LAYER
WITH CAVITY ON RIGID BASE**

Abstract. The research paper is devoted to studying wave spreading in resilient viscous-plastic layer with cavity, situated on a rigid base under the dynamic pressure of day surface. This problem is solved by “discontinuity disintegration” method of S. K. Godunov. The “discontinuity disintegration” method of S.K.Godunov is effective for hyperbolic type quasilinear systems equations numerical solution, for wide range problems solution of gas dynamics, aerodynamics, as well as for other problems of solid medium. Research results allow estimate the wave process parameters around rectangular cavity, and also define their tensed and deformed condition that can be used at assessment of underground construction durability and stability, as well as geodynamic task solution. And also at construction in particularly complex conditions (when soil is characterized as structural and unstable soil) industrial, civil, transport, and military constructions, where geomechanical processes differ from normally condensed soil.

Key words: layer, resilient viscoplasticity, cavity, pressure, wave, tensed and deformed condition.

Problem definition and aspen equations creation on resilient viscous-plastic wave spreading in layer with cavity situated on rigid base. Wave source is dynamic pressure, which affects on semi-sphere under the day surface at initial conditions [1, 2]:

$$u = v = \sigma_x = \sigma_y = \tau = 0; \quad \begin{cases} -\infty \leq x \leq \infty \\ 0 \leq y \end{cases} \quad npu \quad t = 0,$$

under the boundary conditions:

$$\begin{cases} v = tBe^{-At} \\ u = 0; \end{cases} \quad \text{if } \begin{cases} n_1 \leq x \leq n_2; \\ y = 0; \\ t \geq 0, \end{cases}$$

where $A, B = \text{const}$; v, u – respectively, the medium components velocity along the axis x and y ; $\sigma_x, \sigma_y, \sigma_z, \tau$ – respectively tension components.

From the day surface on cavity situated on depth h the dynamic pressure affect on segment $n_1 \leq x \leq n_2$ [3, 4].

There is need to determine the normal and tangential tension quantity at given initial and boundary conditions around a rectangular cavity situated on a rigid base. To solve this task the following output data

is used [4, 5]: $\Delta t = dt = 0.0024888$; $\Delta x = dx = 0.005$; $\Delta y = dy = 0.005$; $\gamma = \frac{a}{b} = 1.6$; $a = 320 \frac{m}{s}$;

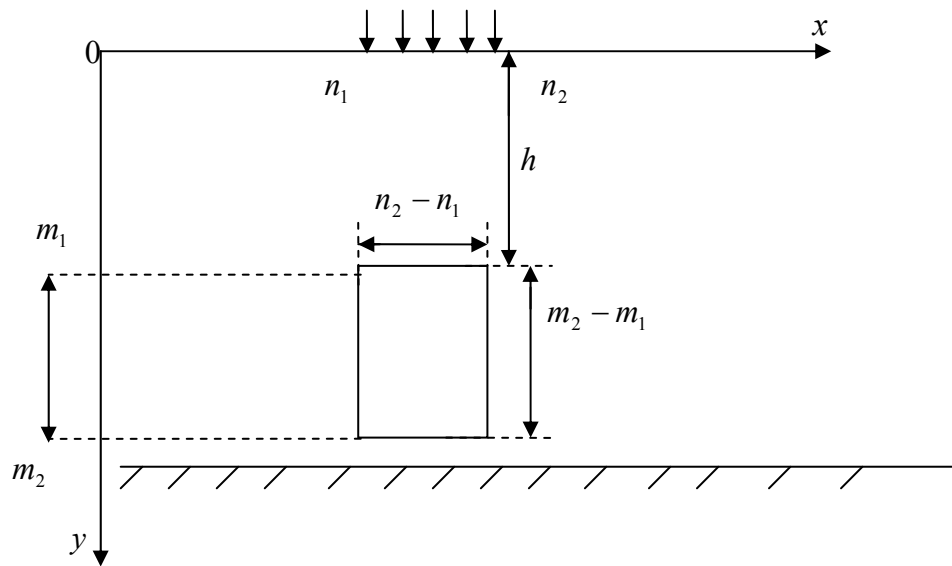


Figure 1 – Cavity in resilient viscous-plastic layer situated on a rigid base

$b = 200 \frac{m}{s}$; $\alpha = -0.02$; $\eta = 350 s^{-1}$; $\rho = 1.8 \frac{g}{cm^3}$; $k_0 = 0.62 kG/cm^3$; $v = kdtB \exp(-Akt)$,
 $A = 133.93335$; $B = 0.1193379$; $t = kdt$ and the research area size around the cavity $N_x = 400$;
 $M_y = 75$; $n_1 = 198$; $n_2 = 202$; $m_1 = 10$; $m_2 = 16$, $T = 300dt$.

As known, wave spreading equation in resilient viscous-plastic layer with cavity on rigid base has the type [6-8]:

$$\dot{\varepsilon}_{ij} = \frac{1}{2\mu} \dot{s}_{ij} + \frac{1}{2k_0} \dot{s} \delta_{ij} + \eta \langle \Phi(F) \rangle \left(\alpha \delta_{ij} + \frac{s_{ij}}{2\sqrt{J_2}} \right), \quad (1)$$

where μ - Lamé coefficient, η - viscosity coefficient, k_0 - yield strength at pure shear, α - parameter characterizing the soil expansion rate.

In order to predict the tension and deformed medium state, the equation describing plane deformation has been considered [9]:

$$\begin{aligned} \varepsilon_{11} = \varepsilon_{xx} &= \frac{\partial u_x}{\partial x}; \quad \varepsilon_{22} = \varepsilon_{yy} = \frac{\partial u_y}{\partial y}; \quad \varepsilon_{33} = \varepsilon_{zz} = 0; \\ \varepsilon_{12} = \varepsilon_{xy} &= \frac{1}{2} \left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x} \right); \quad \varepsilon_{13} = \varepsilon_{xz} = \varepsilon_{23} = \varepsilon_{yz} = 0, \end{aligned}$$

where u_x, u_y - shift along the axis x and y .

The equation describing volume deformation of resilient viscous-plastic medium has the type [10]:

$$\dot{\varepsilon}_{ii} = \frac{1}{3k_0} \dot{s} + 3\alpha \eta \langle \Phi(F) \rangle. \quad (2)$$

In equations (1) and (2), the quantity F is a plastic flow function describing the resilient viscous-plastic medium dynamic behavior and expressed by following formula [11]:

$$F = \frac{\alpha J_1 + \sqrt{J_2}}{k_0} - 1,$$

where $J_1 = \sigma_{11} + \sigma_{22} + \sigma_{33}$ - first invariant of tensor pressure and $J_2 = \frac{1}{2}s_{ij}s_{ij}$ - second invariant of tensor pressure, $s_{ij} = \sigma_{ij} - \frac{1}{3}\sigma_{kk}\delta_{ij}$ - deviator of tensor pressure [12, 13].

Function $\langle \Phi(F) \rangle$ in equations (1) and (2) is determined basing on an experimental researches on dynamic characteristics and medium properties, and generally presented as nonlinear function, which is defined by following formula:

$$\langle \Phi(F) \rangle = \begin{cases} 0 & \text{if } F \leq 0, \\ F & \text{if } F > 0. \end{cases}$$

For wave spreading movement equation definition in resilient viscous-plastic layer with cavity on rigid base the differential equation system has been considered [14, 15]:

$$\begin{cases} \frac{\partial u}{\partial t} = \frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \tau}{\partial y}; \\ \frac{\partial v}{\partial t} = \frac{\partial \tau}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y}; \\ \frac{\partial \sigma_{xx}}{\partial t} = \frac{\partial u}{\partial x} + \left(1 - \frac{2}{\gamma^2}\right) \frac{\partial v}{\partial y} + \Phi_1; \\ \frac{\partial \sigma_{yy}}{\partial t} = \left(1 - \frac{2}{\gamma^2}\right) \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \Phi_2; \\ \frac{\partial \tau}{\partial t} = \frac{1}{\gamma^2} \frac{\partial u}{\partial y} + \frac{1}{\gamma^2} \frac{\partial v}{\partial x} + \Phi_3. \end{cases} \quad (3)$$

The "discontinuity disintegration" method of S. K. Gudunov is used for differential equations system (3) solving. That is why the considering medium is divided onto elementary cells [16].

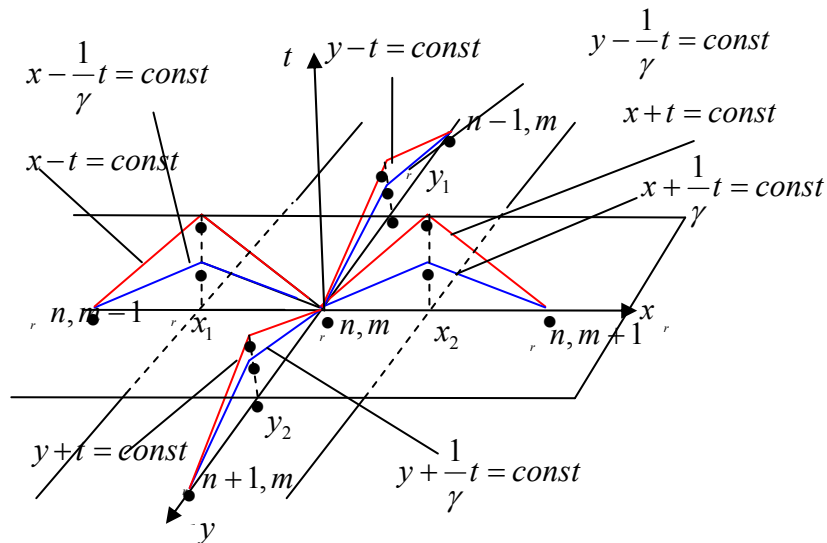


Figure 2 – Characteristic scheme on the template

The studying medium characteristics and properties show that it consists of layers. As it is mentioned above the considering medium is divided onto cells. It is well-known that wave spreading in cells is different. Therefore, the discontinuity disintegration occurs at the adjacent cells boundaries. In this case, the motion between two neighboring cells can be considered as one-dimensional. Consequently, the equations system (3) can be divided onto two equations systems, one of which depends only on x , and the other on y .

After some elementary transformations the equations system (3) can be presented as characteristic equations and their proportions [17, 18]:

$$\begin{cases} d(u + \sigma_{xx}) = \Phi_1 dt & \text{on the line } x + t = \text{const}; \\ d(u - \sigma_{xx}) = -\Phi_1 dt & \text{on the line } x - t = \text{const}; \\ d(v + \gamma\tau) = \gamma\Phi_3 dt & \text{on the line } x + \frac{1}{\gamma}t = \text{const}; \\ d(v - \gamma\tau) = -\gamma\Phi_3 dt & \text{on the line } x - \frac{1}{\gamma}t = \text{const}. \end{cases} \quad (4)$$

$$\begin{cases} d(u + \gamma\tau) = \gamma\Phi_3 dt & \text{on the line } y + \frac{1}{\gamma}t = \text{const}; \\ d(u - \gamma\tau) = -\gamma\Phi_3 dt & \text{on the line } y - \frac{1}{\gamma}t = \text{const}; \\ d(v + \sigma_{yy}) = \Phi_2 dt & \text{on the line } y + t = \text{const}; \\ d(v - \sigma_{yy}) = -\Phi_2 dt & \text{on the line } y - t = \text{const}. \end{cases} \quad (5)$$

Characteristic equations and their proportions (4) and (5) are used to derive finite-difference equations systems for calculating the medium parameters at various points and different instants of time [19, 20].

$$\begin{cases} u^{n,m} = u_{n,m} + \Delta t \frac{[\sigma_{xx,n2} - \sigma_{xx,n1}]}{\Delta x} + \Delta t \frac{[\tau_{m2} - \tau_{m1}]}{\Delta y}; \\ v^{n,m} = v_{n,m} + \Delta t \frac{[\tau_{n2} - \tau_{n1}]}{\Delta x} + \Delta t \frac{[\sigma_{yy,m2} - \sigma_{yy,m1}]}{\Delta y}; \\ \sigma_{xx}^{n,m} = \sigma_{xx,n,m} + \Delta t \frac{[u_{n2} - u_{n1}]}{\Delta x} + \Delta t \left(1 + \frac{2}{\gamma^2}\right) \frac{[v_{m2} - v_{m1}]}{\Delta y} + \Delta t \Phi_{1n,m}; \\ \sigma_{yy}^{n,m} = \sigma_{yy,n,m} + \Delta t \left(1 + \frac{2}{\gamma^2}\right) \frac{[u_{n2} - u_{n1}]}{\Delta x} + \Delta t \frac{[v_{m2} - v_{m1}]}{\Delta y} + \Delta t \Phi_{2n,m}; \\ \tau^{n,m} = \tau_{n,m} + \Delta t \frac{[u_{m2} - u_{m1}]}{\gamma^2 \Delta y} + \Delta t \frac{[v_{n2} - v_{n1}]}{\gamma^2 \Delta x} + \Delta t \Phi_{3n,m}, \end{cases} \quad (6)$$

$$\text{where } \Phi_1 = -\frac{1}{\gamma^2} \eta \langle \Phi(F) \rangle \left[(3\gamma^2 - 4)\alpha + \frac{1}{3} \frac{(2\sigma_{xx} - \sigma_{yy} - \sigma_{zz})}{\sqrt{J_2}} \right], \quad \Phi_2 = -\frac{1}{\gamma^2} \eta \langle \Phi(F) \rangle \times$$

$$\times \left[(3\gamma^2 - 4)\alpha + \frac{1}{3} \frac{(2\sigma_{yy} - \sigma_{xx} - \sigma_{zz})}{\sqrt{J_2}} \right], \quad \Phi_3 = -\frac{1}{\gamma^2} \eta \langle \Phi(F) \rangle \frac{\tau}{\sqrt{J_2}}.$$

Thus, the obtained finite-difference characteristic proportions (4), (5) and the equations system (3) constitute a complete equations system for posed task solution.

The finite-difference equations systems numerical solution results are presented in figures 3- 7, which correspond to changes in tension for different instants of time along the coordinates.

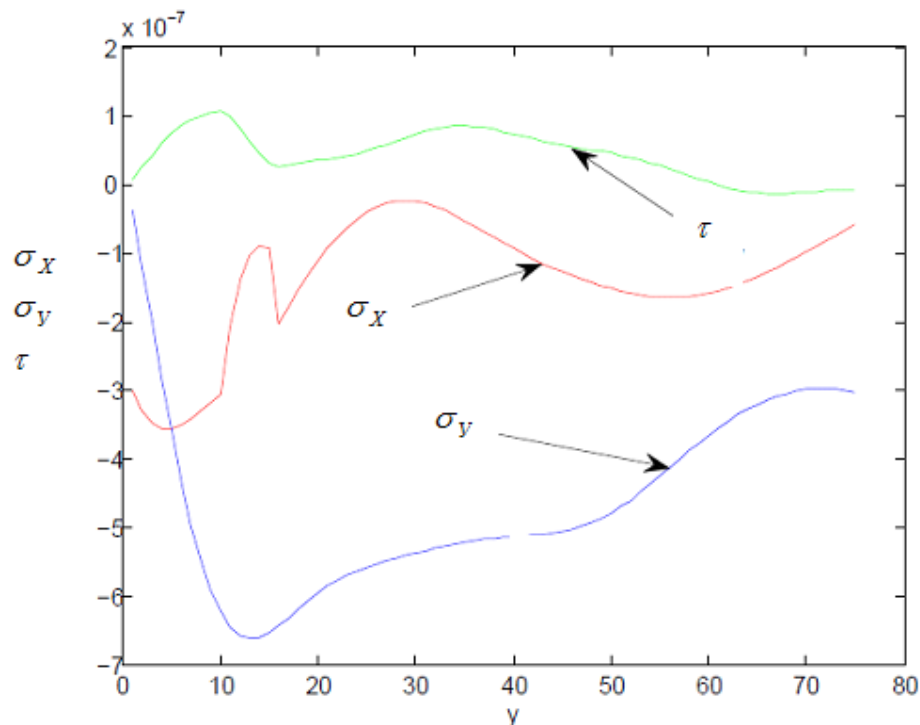


Figure 3 – Changes of indicated tension along the axis y , $x = 190dx$, at the depth below the cavity $y = 1dy - 75dy$, at the time $t = 295dt$

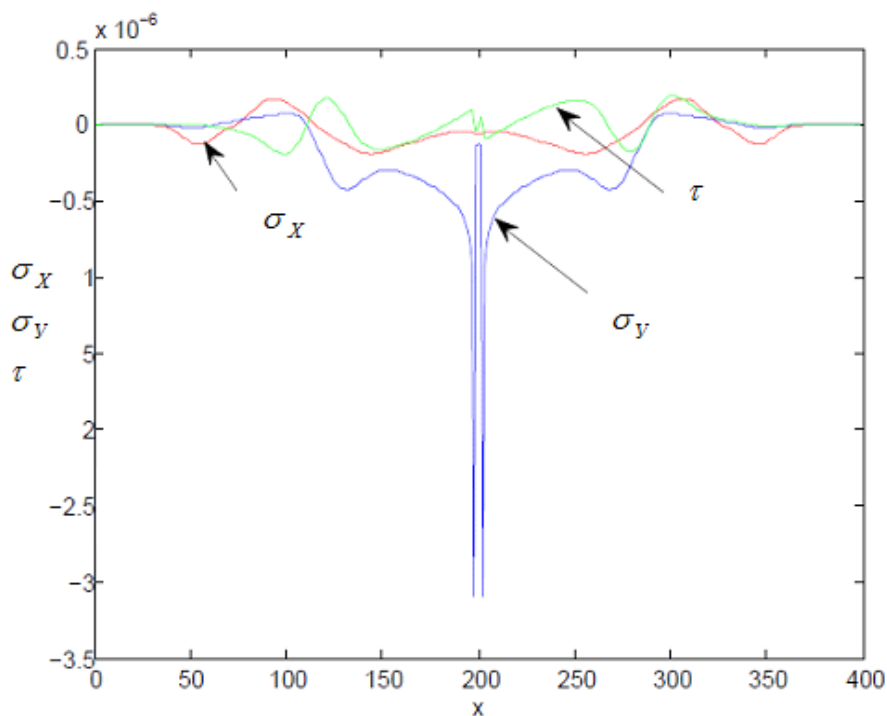


Figure 4 – Changes of indicated tension axis x , $x = 1dx - 400dx$, at a depth under the cavity $y = 25dy$ at the time $t = 295dt$

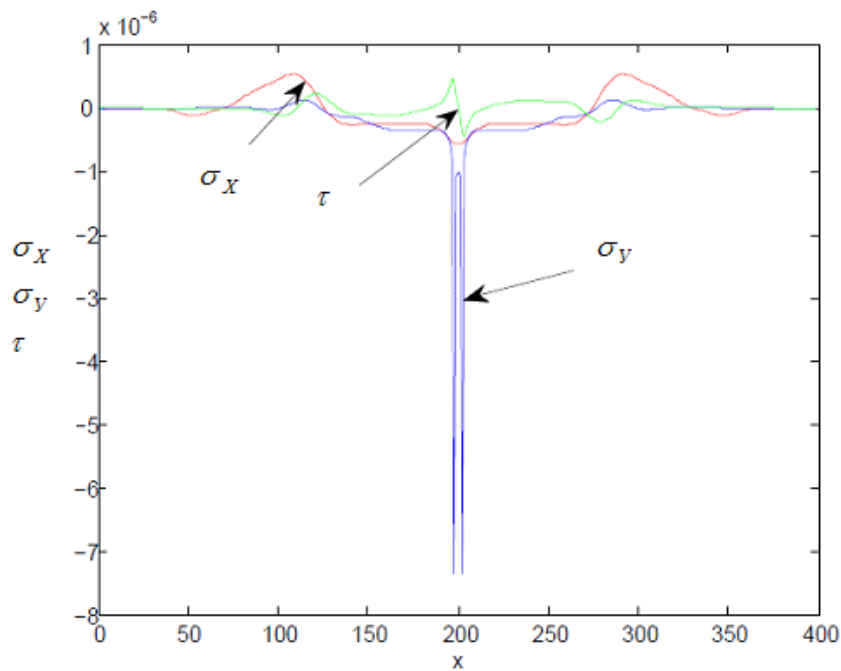


Figure 5 – Changes of indicated tension along the axis x , $x = 1dx - 400dx$, at a depth above the cavity $y = 5dy$ at the time $t = 295dt$

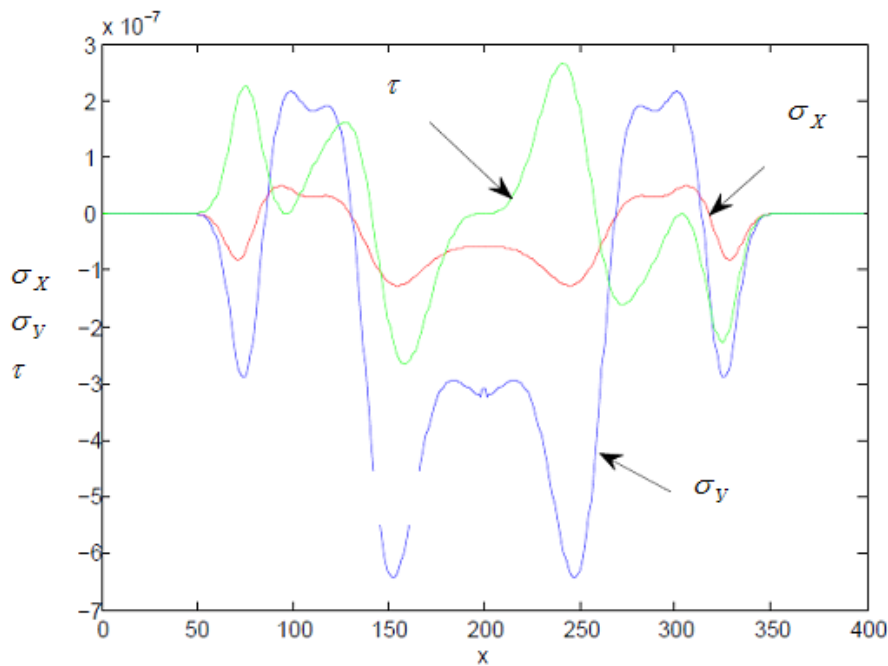


Figure 6 – Changes of indicated tension along the axis x , $x = 1dx - 400dx$, along the brink with rigid base at a depth $y = 75dy$ at the time $t = 295dt$

Conclusion. The finite-difference equation system and numerical results were received for resilient viscous-plastic wave spreading in layer situated on rigid base under the dynamic non-stationary pressure from a free surface. Analyzing the received numerical results shows up that at $198 \leq n \leq 200$ interval the gap occurs. It means vertical walls are under the maximum physical impact.

Constructors should take into consideration the calculation results mentioned above during the underground facilities designing.

Stable schemes for finite-difference equations systems solving are presented, in order to algorithm realization the algorithms are developed and applied programs packages are compiled.

The tension distribution patterns under different initial physical and geometric parameters have been established.

The research results allow determining wave processes characteristics around the cavity and their tensed and deformed condition that necessary for underground constructions durability estimation.

The received results and created applied programs package can be applied for wave field's estimation, tensed condition character determination in dealing with similar tasks with boundary conditions, at various underground facilities and constructions designing.

**Ж. К. Масанов¹, Ж. Т. Кожобеков¹, Г. К. Тугельбаева^{1,2},
Т. Б. Мадалиев¹, С. Алтыбай², Э. С. Абдраимов³**

¹Ө. А. Джолдасбеков атындағы Механика және машинатану институты, Алматы, Қазақстан,

²ҚР ҚМ Құрлық әскерлерінің Әскери институты, Алматы, Қазақстан,

³Ұлттық ғылыми академиясының машинатану институты, Бішкек, Қырғызстан

ҚАТТЫ НЕГІЗДЕ ЖАТҚАН ҚУЫСЫ БАР СЕРПІМДІ-ТҮТҚЫРЛЫ ПЛАСТИКАЛЫҚ ҚАБАТТА ТОЛҚЫННЫҢ ТАРАЛУЫ

Аннотация. Бұл жұмыста қатты негізде жатқан қуысы бар серпімді-тұтқырлы-пластикалық қабатқа бет жағынан әсер еткен динамикалық жүктеменің әсерінен пайда болған толқынның таралуын зерттеуге арналған. Берілген мәселені шешуге С. К. Годуновтың «ыдырау үзілу» әдісі қолданылған. Қазіргі уақытта Годуновтың «ыдырау үзілу» әдісі гиперболалық түрдегі квазисызықты теңдеулер жүйесін сандық түрде шешуге, газ динамикасы, аэродинамика мәселелерін кеңінен қарастыруда, сонымен қатар жалпы орта механикасының көптеген есептерін шешуде кеңінен қолданылады. Зерттеу барысында тікбұрышты қуыстың айналасындағы толқын үдірісінің шамаларын болжауда, оның кернеулі-деформациялық күйін бағалауда анықталған нәтижелер жер асты құрылыстарының беріктілігін және тұрақтылығын анықтауға және геодинамика есептерін шешу үшін қолдануға болады. Сонымен қатар қалыпты жағдайдан өзгешеленетін, геомеханикалық үдірісі күрделі аса қиын жағдайда жүргізілетін (құрылымы тұрақсыз жер) өндірістік, азаматтық, транспорттық және әскери құрылыстар салу барысында қолдануға болады.

Түйін сөздер: қабат, серпімді-тұтқырлы-пластикалық, қуыс, жүктеме, толқын, кернеулі-деформациялық күй.

**Ж. К. Масанов¹, Ж. Т. Кожобеков¹, Г. К. Тугельбаева^{1,2},
Т. Б. Мадалиев¹, С. Алтыбай², Э. С. Абдраимов³**

¹Институт механики и машиноведения им. У. А. Джолдасбекова, Алматы, Казахстан,

²Военный институт Сухопутных войск МО РК, Алматы, Казахстан,

³Институт машиноведения Национальной академии наук, Бишкек, Кыргызстан

РАСПРОСТРАНЕНИЯ ВОЛН В УПРУГО-ВЯЗКОПЛАСТИЧЕСКОМ СЛОЕ С ПОЛОСТЬЮ НА ЖЕСТКОМ ОСНОВАНИИ

Аннотация. Данная работа посвящена исследованию распространения волн в упруго-вязкопластическом слое с полостью, лежащей на жестком основании при воздействии динамической нагрузки со стороны дневной поверхности. В основе решения данной задачи использован метод «распада разрыва» С. К. Годунова. Метод «распада разрыва» С. К. Годунова является на сегодня эффективным для численного решения квазилинейных систем уравнений гиперболического типа, для решения широкого круга задач газовой динамики, аэродинамики, а также для других задачи механики сплошной среды. Результаты исследований позволят дать оценку параметрам волновых процессов вокруг прямоугольной полости, а также определить их напряженно-деформированного состояния, которые могут быть использованы при оценке прочности и устойчивости подземных сооружений, при решении задачи геодинамики. А так же при строительстве в особо сложных условиях (когда грунт, характеризуется как структурно-неустойчивый грунт) промышленных, гражданских, транспортных и военных сооружениях, в которых протекание геомеханических процессов существенно отличается от процессов, протекающих в нормально уплотненных грунтах.

Ключевые слова: слой, упруго-вязкопластичность, полость, нагрузка, волна, напряженно-деформируемое состояние.

Information about authors:

Masanov Z. K., Mechanics and engineering Academy named after academician U. A. Djoldasbekov, Almaty, Kazakhstan; <https://orcid.org/0000-0002-6337-7783>

Kozhabekov Zh. T., Mechanics and engineering Academy named after academician U. A. Djoldasbekov, Almaty, Kazakhstan

Tugelbayeva G. K., Military Institute of Ground Forces of the Ministry of Defense, Almaty, Kazakhstan; <https://orcid.org/0000-0002-8934-2685>

Madaliyev T. B., Mechanics and engineering Academy named after academician U. A. Djoldasbekov, Almaty, Kazakhstan; <https://orcid.org/0000-0001-5621-2609>

Altybai S., Military Institute of Ground Forces of the Ministry of Defense, Almaty, Kazakhstan; <https://orcid.org/0000-0002-4105-6209>

Abdraimov E. S., Institute of engineering of National Academy of science, Bishkek, Kyrgyzstan; <https://orcid.org/0000-0002-0818-0160>

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**K. S. Nadirov¹, N. Sh. Otarbaev¹, R. K. Nadirov²,
V. M. Kapustin³, A. S. Sadyrbaeva¹, G. Zh. Bimbetova¹**

¹M. Auezov South-Kazakhstan state university, Shymkent, Kazakhstan,

²Al-Farabi Kazakh national university, Almaty, Kazakhstan,

³Gubkin Russian state university of oil and gas, Moscow, Russia.

E-mail: a.sadyrbaeva@mail.ru

SEPARATION OF FREE FATTY ACIDS FROM COTTON TAR

Abstract. This article presents the results of study of influence of technological factors on the process of cotton tars' fatty acids saponification, necessary to develop technology for synthesis of new surface-active substances used in oil dehydration processes.

To substantiate the choice of alkali concentration (sodium hydroxide) and determine the effective modes of the neutralization process, the method of determining the minimum necessary alkali concentration depending on the boiling time of the "tar – saponified reagent" system was used. Based on the obtained data, it was concluded that the effective alkali solution concentration corresponds to 8-15%, while the alkali excess amount does not affect the "boiling" time. The dependence of the change in the hydroxyl number on the sodium hydroxide concentration in the solution was obtained under real conditions, where it was shown that the saponification degree increases with increasing the alkali solution concentration, but only to a certain concentration value. The effect of temperature on the neutralization process duration was established. It is shown that fatty acids are valuable and fairly affordable raw materials that find their application in various fields of the oil and gas industry, so their extraction from wastes, namely, from cotton distillation tars, with a content of up to 65%, is reasonable and economically sound.

Key words: fatty acids, saponification, oil, gossypol, demulsifier, boiling, viscosity, alkali, hydroxyl number, dehydration, reagent, emulsion.

Introduction. Today, the problem of efficient processing of secondary resources to obtain competitive products is relevant for the oil and gas industry in our country. However, despite the importance and economic feasibility of the most complete processing of secondary resources, the level of their use is still insufficient. Considering the potential of oil and fat enterprises in the south of Kazakhstan, the task of efficient processing of secondary resources of the oil and fat industry and obtaining valuable chemical reagents on their basis is of particular importance. The main component of the secondary resources obtained in the processing of plant oils, in particular, cotton oil, are tars of fatty acid distillation. Free fatty acids are a valuable feed stock for obtaining a number of complex-effect reagents, which are used for dehydration and desalting in complex oil treatment plants [1].

There is a special economic zone in the territory of Turkestan region, focused, among other things, on the cotton cluster development. Thus, it can be considered that tars, being by-products of cotton oil processing, are a renewable source of free fatty acids [2]. In addition, the tars of the fatty acid distillation, as well as soap stocks, must be processed from the point of view of ecology and environmental protection [3-6].

The purpose of the study is to select the optimal method and conditions for the implementation of the fatty acid (FA) extraction process, which will later serve as the feed stock for the synthesis of a non-ionic (non-dissociating) demulsifier from a mixture of cotton tar components (hereinafter referred to as tar) and purification from impurities.

Previously, it was shown that from the tar of the enterprise Shymkentmay JSC with an alkali solution it is possible to obtain a saponified fraction of salts of fatty acids and gossypol, which are then separated in a free form when treated with sulfuric acid [7-9]. Methods used to separate free fatty acids should satisfy the following conditions: determine the maximum selectivity of fatty acids interaction with reagents used for neutralization; provide the highest reaction rate; facilitate rapid and complete separation of the resulting phases; ensure the maximum extraction of fatty acids from the resulting neutralization products.

In the initial exploratory tests, the resulting mixture of fatty acids and gossypol derivatives was oxyethylated and etherified, and the obtained composition showed, in the tests, the properties of a sufficiently effective demulsifier. However, in modern conditions, more stringent requirements are specified to the reagents used for oil dehydration: they must have the highest possible demulsifying activity, must be biologically easily decomposed, non-toxic, cheap, affordable, and must not have bactericidal activity. In addition, these reagents in oil should not lead to equipment corrosion. Therefore, there was a need to study how the feed stock purity affects the process of oxyethylation and etherification. It is necessary to develop the optimal method for extracting the fatty acids from the mixture of tar components, to select optimal conditions for the process of extracting the fatty acids and to choose a method for preparing free fatty acids to obtain the reagent. As an optimization criterion, the quality of the final product – the oxyethylated or etherified product based on the feed stock extracted and purified by various methods was determined [10-14].

Research methods. The fatty part extracted from the cotton tar (the mixture of tar components) is a thick, viscous mass: the kinematic viscosity is 2340 cSt at 25°C; the color is dark brown; the specific weight is 0.981 t/m³; the acid number is 112.8 mg KOH/g; the saponification number is 228.3 mg KOH/g; the ether number is 155.43 mg KOH/g; the iodine number is 1.44 g I₂/100 g; the setting point is 37°C. The high mixture viscosity is due to the presence of saturated fatty acids in its composition, which are crystalline substances at temperatures below 50-70°C, but due to the partial solubility in unsaturated acids, the resulting mixture has the consistency of resin. Chromatographic separation of the fatty acid mixture was carried out by two methods: 1) the HPLC method according to the method [15] and 2) the GLC method according to the method GOST 30418-96.

When analyzing samples of the tar, it was found that using the standard method for determining the fatty acids does not allow obtaining adequate results, which is associated with the formation of a stable bulk emulsion layer. In this regard, the standard methods for determining the fatty acids were adjusted as applied to the tar. The content of soap and fatty acids in the tar after alkali treatment was determined by the modified method GOST 5480-59 – Plant oils and natural fatty acids. Methods for soap determination. To control the fatty acid content in model systems and in real resins, the acid number determination method was used according to GOST P 52110 – 2003. The pH of the reaction mixture was measured on the ANION pH meter 4100 (the accuracy class is 0.05). To determine the fatty acid content in the tar, the method of indirect pH-metering – measurement of the pH values of the special reaction mixture was used. The study of the influence of various impurities in the tar composition on the measurement error of the reaction mixture pH value showed that the error reaches 8-10%, therefore, other methods were used in some cases. In particular, the mass fraction of the fatty acids in the tar was determined by the method of high performance liquid chromatography using the technique of “Certificate No. 36-08 dated 04.03.2008 ΦP.1.31.2008.04633” [16]. The rheological properties of various technological mixtures from the tar and soap bases were determined on the Polymer Rotation Viscometer RPE-1M instrument. The estimation of the results and their statistical reliability was carried out using the application programs “MathCAD” and “Statistica”.

It was found that the main factors determining the efficiency of the crude fatty acids, gossypol and its derivatives saponification are concentration, amount of neutralizing agent, temperature and duration of the process, as well as amount of the saponified tar additive. In this case, the required neutralizing agent amount depends on the fatty acid content in the tar subjected to saponification [17]. The tar saponification was carried out in the high pressure reactor PBJ-2-150, the process efficiency was estimated by the values of the neutralization coefficient [14, 18].

To substantiate the choice of alkali concentration (sodium hydroxide) and determine the effective modes of the neutralization process, the method of determining the minimum necessary alkali concentration depending on the boiling time of the “tar – saponified reagent” system was used [19]. For this, the

tar was treated with the sodium hydroxide solution of 1-20% concentration, initially with 10% excess, and then – varying the excess. The resulting “tar – alkali solution” system was subjected to treatment in the electromagnetic field of super-high frequencies until the “boiling” effect. The efficiency of neutralization was estimated in terms of the fatty acid saponification degree. For the reliability of the control of the fatty acid saponification degree, the hydroxyl number index was used [17].

Research results. From the data presented in figure 1, it can be seen that in the concentration range of 1-8%, the boiling time of the system is 5-45 s, starting from the concentration of 5 to 10%, there is increase in the boiling time of the system from 26 to 48 s with formation of characteristic dependencies (figure 1). This dependence can be explained by decrease in the free moisture content in the neutralized tar. The change in the boiling time practically does not occur when the sodium hydroxide concentration is more than 15%.

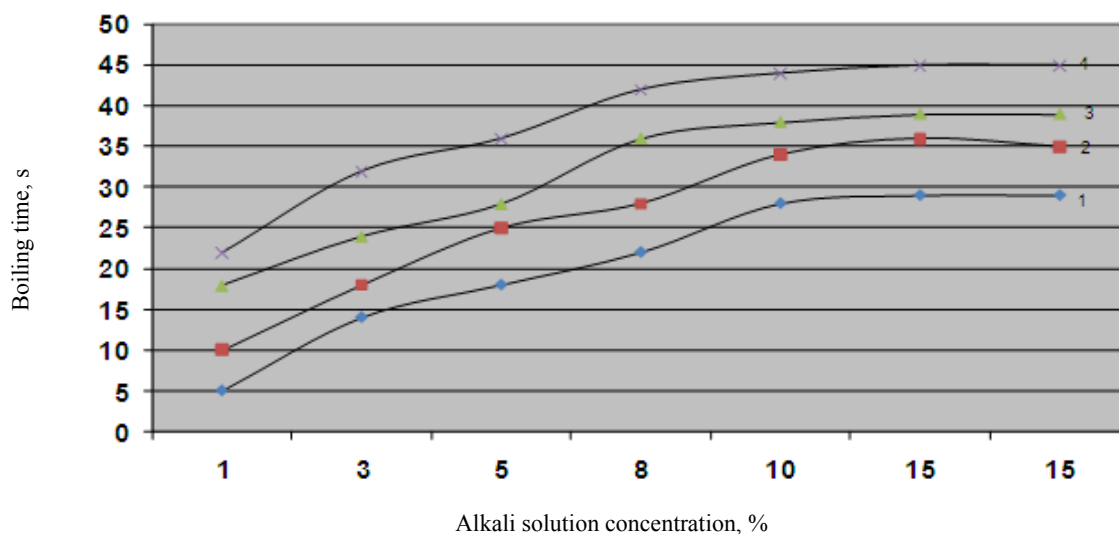


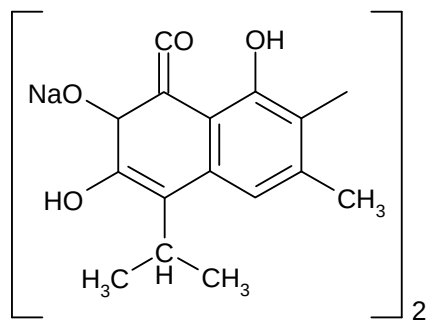
Figure 1 – Dependence of the “boiling” time of the “tar – alkali solution” system on the concentration of the alkali solution and its amount.

Conditions: the alkali excess, %: 1 – 0; 2 – 4; 3 – 7; 4 – 10. The saponified tar additive amount – 5%

The more intense tar interaction with alkali at initial concentrations is explained by the fact that the carboxyl group of the free fatty acids primarily interacts with the formation of R-COONa salts.

The glycerides remaining in the tar, which contain high molecular weight acids, are saponified more difficult compared to glycerides, which contain lower molecular weight fatty acids [12].

Approximately in the same order the gossypol derivatives enter into the reaction, since under conditions of high temperature, the gossypol in inactivated form is more likely to exist during refining and distillation, i.e. without initial aldehyde group at position 8, 8', with the formation of sodium salts of the oxidized gossypol molecule:



The hydroxyl groups of the naphthyl gossypol molecule fragment, according to the distribution of electron density on atoms, are more reactive centers. The most pronounced OH-bond at C₇ and C'₇ atoms, which acts as a strong electron-acceptor group of acid reagent, as the bond is highly polarized (the charges

on oxygen and hydrogen atoms are $-0.28e$ and $0.27e$, respectively). Thus, the hydroxyl gossypol groups at position 7, 7' of the naphthalene nucleus which are in the ortho-position to the aldehyde group under these conditions form salts of gossypol and its derivatives [20]. Further, when the alkali concentrations are 15 and 20, the boiling time remains almost unchanged, as glycerin, as well as bound fatty acids in the composition of glycerides, remain in the initial mixture.

A similar dependence is also characteristic of change in the hydroxyl number under real conditions, i.e. as the alkali solution concentration increases, the saponification degree increases, but only to the concentration of 15% (figure 2).

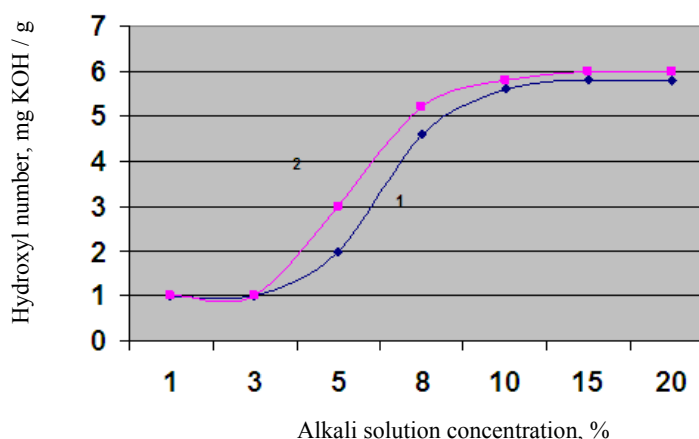


Figure 2 – Dependence of the change in the hydroxyl number on the alkali solution concentration.
Conditions: the alkali excess – 10%, the saponified tar additive amount – 5%,
the temperature, °C – 1 – 105, 2 – 110, the process duration – 120 minutes

Result discussion. Based on the obtained data, it was concluded that the effective alkali solution concentration when saponifying corresponds to 8-15%. It was found that the alkali excess amount does not affect the “boiling” time. However, the analysis of industrial practice on the use of various neutralization schemes confirms the basic point that for effective phase separation in all cases a certain alkali excess has a positive effect. If at the neutralization sufficiently concentrated alkali solutions are used, then the optimal alkali amount creates favorable conditions for the formation of soap flakes and less increase of non-saponified fatty acids. In the case of neutralization in a soap-alkali environment (using low concentration alkali solutions), a decrease in the free alkali content in the soap-alkali solution below the permissible level leads to the formation of acid soaps, reducing the dissolution efficiency of the resulting soap, as a result of which the soap and moisture content can significantly increase in the neutralized phase.

It is known that soap-alkali emulsions are formed by spontaneous emulsification of the mixture of fatty acid – aqueous alkali solution. A distinctive feature of the spontaneous emulsification in comparison with the mechanical emulsification is the emulsifier formation in the dispersed system itself. When neutralizing with the emulsifier in the system itself, the saponified part of the cotton tar acts. The authors studied the change in the saponified tar viscosity with the sodium hydroxide excess introduction, and showed that with increase in the neutralizing agent excess above 20%, the system viscosity increases again due to the change in the colloidal properties of the system, which subsequently leads to decrease in the emulsification degree and saponification rate. With increase in the temperature, the viscosity decreases (figure 3). In order to determine the aggregative emulsion stability, the dispersion of the soap-alkali tar emulsion was tested using electron microscopic images (figure 4). From the above photos it is seen that in the case of using the NaOH excess in the amount of 20%, the size of the dispersed phase droplets in the dispersion medium is the smallest and amounts to 8-10 microns, which has a favorable effect on the saponification process. The reaction that takes place in this system is on the droplet surface, while the internal mass transfer is the limiting stage.

The fatty acids are subsequently separated in the form of associates and individual molecules, the process as a whole follows the model of nonstationary convective diffusion with the introduction of concentration-dependent transfer coefficient. The analysis of the equation describing this model shows

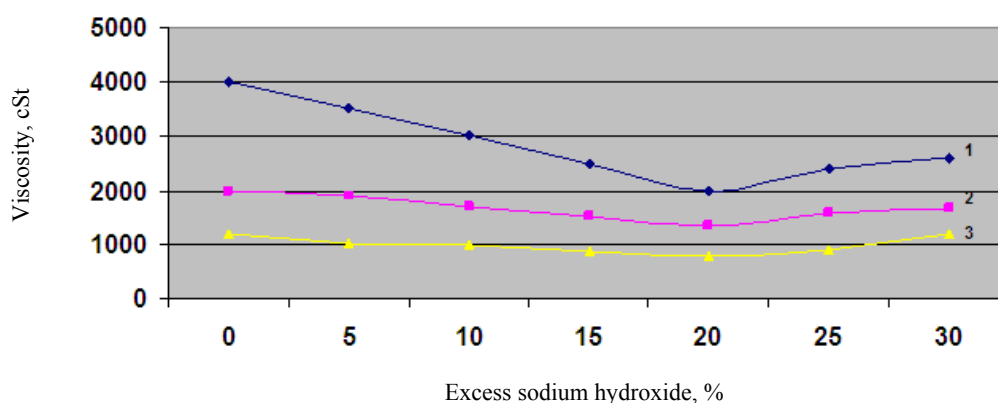


Figure 3 – The effect of the NaOH excess on the viscosity of the “cotton tar – fatty acids – alkali” system.
 Conditions: the alkali solution concentration – 10%; the saponified tar additive amount – 5%, the temperature, °C:
 1 – 65; 2 – 90; 3 – 115. the process duration – 120 minutes. The viscosity was determined 10 minutes after the start of the process

that the saponified fatty acids concentration on the drop surface is maximum at the beginning of neutralization and is proportional to the initial acid concentration in the tar mass and the saponified part concentration in the solution. Table shows the technological indicators of the cotton tars before and during the saponification process, which indicate that the alkali excess in the amount of 20% contributes to the viscosity decrease and provides the required rheological and filtration properties, as well as good phase separation during subsequent processing.

It is known that with increasing the temperature both direct and reverse reactions are accelerated, but to varying degrees. As a rule, the endothermic process is accelerated to a greater extent than the exothermic. When the temperature in the system of two reactions decreases, the exothermic process flows faster. Therefore, to determine the temperature effect on the chemical equilibrium, it is necessary to know the value of the thermal reaction effect. The greater the thermal reaction effect, the stronger the temperature effect. When studying the temperature effect on the tar neutralization process, it was found that increasing the temperature has a positive effect only up to 110°C, at higher temperatures due to increase in the rate of the reverse reaction, the saponification rate decreases (figure 5).

The soap-alkali emulsion formation process during the saponification of the cotton tar fatty acids takes place in the following order based on the emulsification mechanism [21]:

The fatty acids, gossypol and its derivatives in the tar composition during mechanical action on them in centrifugal pumps are crushed into large and medium drops and dispersed in the alkali solution to form the interfacial surface of the mixture: fatty acids – gossypol and its derivatives – alkali.

On the interfacial surface, the fatty acids, gossypol and its derivatives react with the alkali (the saponification or neutralization reactions) and the soap is formed on the drop surface, the soap begins to act as the emulsifier.

Molecules of the soap emulsifier are adsorbed on the drop surface, while the hydrocarbon chain or the hydrophobic part of the soap molecule is drawn into the inside of the drops, and the hydrophilic polar part of $R-COONa$ is located on the outer surface and forms a protective layer. In addition to the soap molecules, molecules of the dispersion medium, impurities, gossypol polyphenols and its derivatives are also included in the protective layer. As a result, the protective layer becomes adsorption-solvate, and the interfacial surface tension decreases tenfold compared with the tension at a critical micelle concentration, tending to zero.

Drops in which the soap concentration in the adsorption-solvate layer reaches the equilibrium value and the surface tension becomes small compared to the tension at the critical micelle concentration, break up into smaller drops. The dispersion process continues as long as there is decrease in the work of emulsification. The soap emulsifier concentration in the soap-alkali emulsion at the beginning of the dispersion process is insignificant and decrease in the surface tension is small. Therefore, the development of the spontaneous emulsification process flows very slowly and is ≈ 1 h in time (in the saponification reaction this time is equivalent to the time of the induction period).

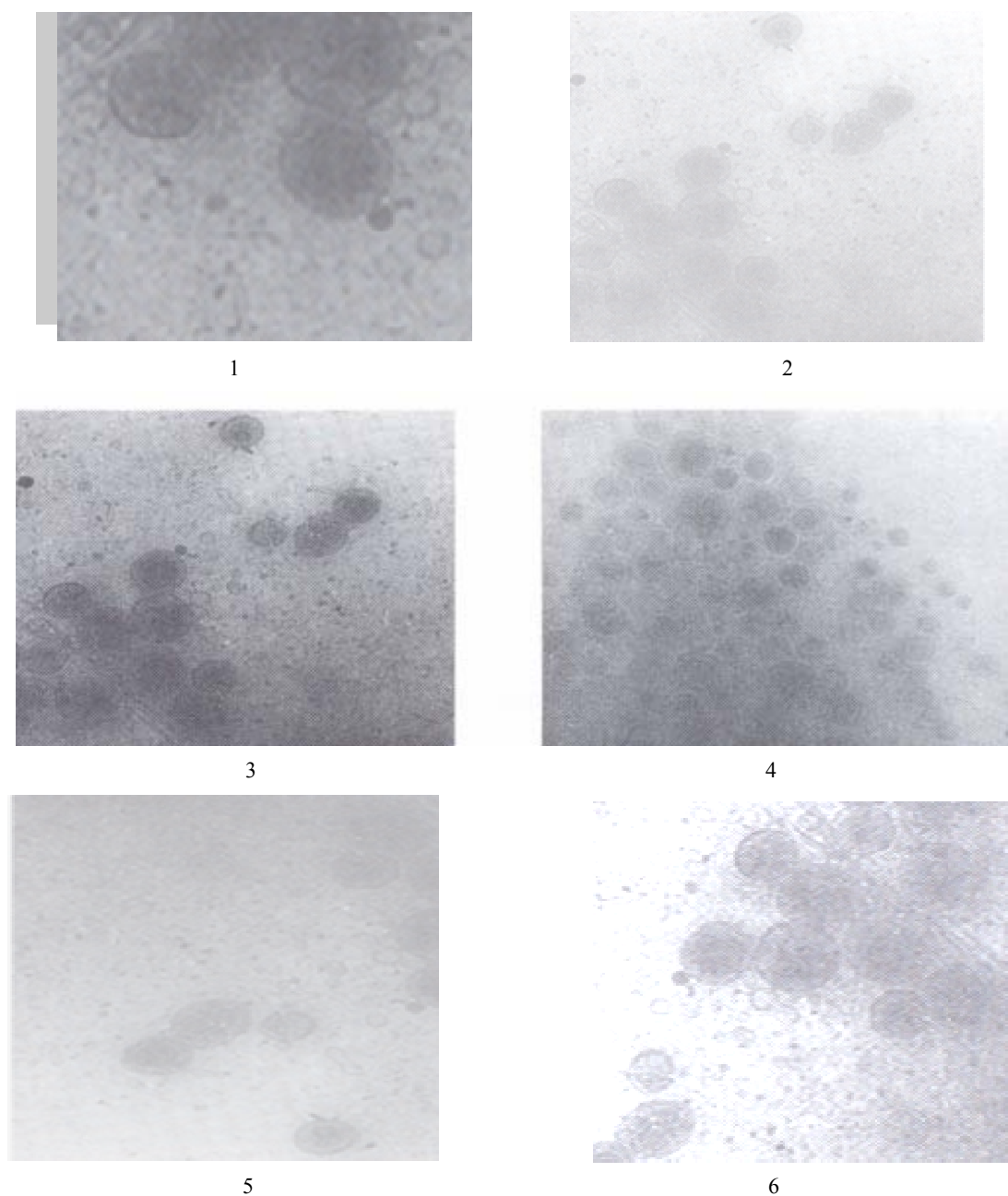


Figure 4 – Electro microscopic images of the soap-alkali emulsion “cotton tar – saponified fatty acid – alkali”.
The alkali excess, %: 1 – 10, 2 – 15, 3 – 18, 4 – 20, 5 – 24, 6 – 28

Technological indicators of the soap-alkali emulsion “cotton tar – saponified fatty acid – alkali”

Composition of the emulsion	Indicators of the emulsion at 65°C	
	Density ρ , kg/cm	Viscosity η , cSt
Tar	900	4000
Tar + 15% alkali solution	910	3550
Tar + 15% alkali solution (5% alkali excess)	920	3500
Tar + 15% alkali solution (10% alkali excess)	925	3055
Tar + 15% alkali solution (15% alkali excess)	930	2511
Tar + 15% alkali solution (20% alkali excess)	938	2050
Tar + 15% alkali solution (25% alkali excess)	950	2512

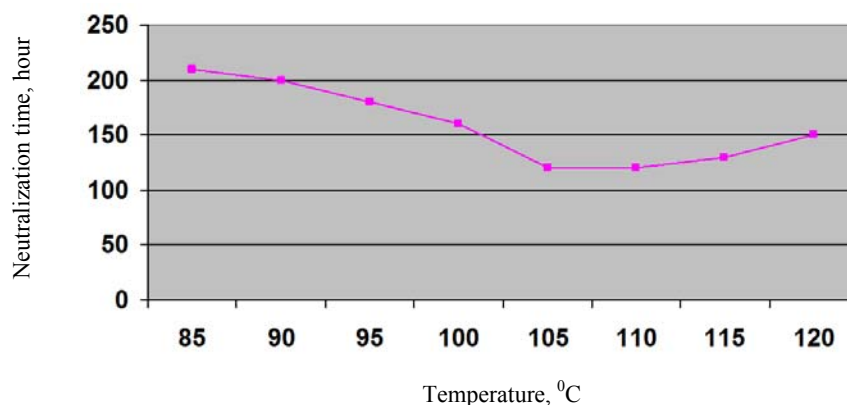


Figure 5 – The effect of temperature on the tar neutralization process duration.
Conditions: the effective alkali solution concentration corresponds to 15%,
the alkali excess – 20%, the saponified tar additive amount – 10%

To accelerate the emulsification process, a part of the saponified tar from the previous feed can be introduced into the initial reaction mixture. In continuous technologies, this additive can be easily implemented by recycling a part of the reaction mixture leaving the reactor. The authors studied how the saponified tar additive amount affects the time of the neutralization process in terms of the crude fatty acid initial content.

Conclusions. Thus, on the basis of the carried out experimental studies, the most favorable mode of saponification (neutralization) of the tar's fatty acids was determined, which subsequently provides the highest yield. The fatty acids are subsequently separated in the form of associates and individual molecules, the process as a whole follows the model of nonstationary convective diffusion with the introduction of concentration-dependent transfer coefficient. The increase in temperature has a favorable effect on the saponification process of the tar's fatty acids to a certain value, however, at higher temperatures, by increasing the rate of the reverse reaction, the saponification rate decreases. The obtained experimental data show that the cotton oil fatty acid distillation tars can be considered a valuable raw material of free fatty acids in order to obtain on their basis surface-active non-ionic substances used in the complex preparation of oil.

**К. С. Надиров¹, Н. Ш. Отарбаев¹, Р. К. Надиров²,
В. М. Капустин³, А. С. Садырбаева¹, Г. Ж. Бимбетова¹**

¹М. Әуэзов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан,

²Әл-Фараби атындағы қазақ ұлттық университеті, Алматы, Қазақстан,

³Губкин атындағы Ресей Мемлекеттік Мұнай және газ университеті, Мәскеу, Ресей

МАҚТА ГУДРОНЫНАН БОС МАЙЛЫ ҚЫШҚЫЛДАРДЫҢ БӨЛІНУІ

Аннотация. Берілген мақалада технологиялық факторлардың мұнайды сусыздандыру процесінде қолданылатын жаңа беттік белсенді заттардың синтездеу технологиясын әзірлеуге қажетті мақта гудрондарының майлы қышқылдарының сабындану процесіне әсерін зерттеу нәтижелері келтірілген.

Сілті (натрий гидроксиді) концентрациясын таңдауды негіздеу және бейтараптандыру процесінің тиімді режимдерін анықтау үшін «гудрон-бейтараптандырушы реагент» жүйесінің «қайнау» уақытына тәуелді сілтінің минимал қажетті концентрациясын анықтау әдістемесі қолданылған. Алынған мәліметтер негізінде сілті ерітіндісінің тиімді концентрациясы 8-15% сәйкестігі анықталған, бұл кезде сілтінің артық мөлшері «қайнау» уақытына әсер етпейді. Нақты шарттарда ерітіндідегі натрий гидроксиді концентрациясынан гидроксильді санның өзгеру тәуелділігі алынған, мұнда сілті ерітіндісінің концентрациясы артқан кезде сабындану дәрежесіде артатындығы көрсетілген, алайда концентрацияның белгілі бір мәніне дейін ғана. Температураның бейтараптандыру процесінің ұзақтығына әсері орнатылған. Майлы қышқылдардың мұнайгаз саласының

әртүрлі салаларында өз қолданысын тапқан құнды және қолжетімді шикізат болып табылатындығы көрсетілген, сондықтан оларды қалдықтардан, оның ішінде дистилляцияның макта гудрондарынан 65% мөлшермен бөліп алу мақсатқа сай және экономикалық негізделген.

Түйін сөздер: майлы қышқылдар, сабындану, мұнай, госсипол, деэмульгатор, қайнау, тұтқырлық, сілті, гидроксильді сан, сусыздандыру, реагент, эмульсия.

**К. С. Надиров¹, Н. Ш. Отарбаев¹, Р. К. Надиров²,
В. М. Капустин³, А. С. Садырбаева¹, Г. Ж. Бимбетова¹**

¹Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Қазақстан,

²Казахский национальный университет им. аль-Фараби, Алматы, Қазақстан,

³Российский государственный университет нефти и газа им. И. М. Губкина, Москва, Россия

ВЫДЕЛЕНИЕ СВОБОДНЫХ ЖИРНЫХ КИСЛОТ ИЗ ХЛОПКОВОГО ГУДРОНА

Аннотация. В данной статье приведены результаты исследования влияния технологических факторов на процесс омыления жирных кислот хлопковых гудронов, необходимые для разработки технологии синтеза новых поверхностно-активных веществ, используемых в процессах обезвоживания нефти.

Для обоснования выбора концентрации щелочи (гидроксида натрия) и определения эффективных режимов процесса нейтрализации использована методика определения минимально необходимой концентрации щелочи в зависимости от времени «закипания» системы «гудрон – омыляемый реагент». На основе полученных данных сделан вывод о том, что эффективная концентрация раствора щелочи соответствует 8-15%, при этом количество избытка щелочи не оказывает влияния на время «закипания». Получена зависимость изменения гидроксильного числа от концентрации гидроксида натрия в растворе, в реальных условиях, где показано, что при повышении концентрации раствора щелочи повышается степень омыления, но только до определенного значения концентрации. Установлено влияние температуры на продолжительность процесса нейтрализации. Показано, что жирные кислоты являются ценным и достаточно доступным сырьем, находящие свое применение в самых различных областях нефтегазовой отрасли, поэтому их извлечение из отходов, а именно, из хлопковых гудронов дистилляции, с содержанием их до 65%, является целесообразным и экономически обоснованным.

Ключевые слова: жирные кислоты, омыление, нефть, госсипол, деэмульгатор, скипание, вязкость, щелочь, гидроксильное число, обезвоживание, реагент, эмульсия.

Information about authors:

Nadirov Kazim Sadykovich, Doctor of Chemical Sciences, professor, M. Auezov South-Kazakhstan state university, Shymkent, Kazakhstan; nadirovkazim@mail.ru; <https://orcid.org/0000-0002-7113-3076>

Otarbaev Nurlybek Shyrynbeekovich, M. Auezov South-Kazakhstan state university, Shymkent, Kazakhstan; otarbaevn@mail.ru; <https://orcid.org/0000-0001-6610-3449>

Nadirov Rashid Kazimovich, Candidate of Technical Sciences, al-Farabi Kazakh national university, Almaty, Kazakhstan; rashid76@inbox.ru; <https://orcid.org/0000-0002-7934-9621>

Kapustin Vladimir Mikhailovich, Doctor of Technical Sciences, professor, Head of the Oil Refining Technology Department of the Faculty of Chemical Technology and Ecology of the Russian State University of Oil and Gas named after I. M. Gubkina, Moscow, Russia; kapustinbm@mail.ru; <https://orcid.org/0000-0003-4102-4044>

Sadyrbaeva Ainur Slambekovna, Candidate of Technical Sciences, M. Auezov South-Kazakhstan state university, Shymkent, Kazakhstan; a.sadyrbaeva@mail.ru; <https://orcid.org/0000-0001-6819-388X>

Bimbetova Gulmira Zhankabylovna, Candidate of Technical Sciences, M. Auezov South-Kazakhstan state university, Shymkent, Kazakhstan; gulmnaz@mail.ru; <https://orcid.org/0000-0002-6360-4173>

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S. S. Zhussupbekov¹, L. K. Ibrayeva¹, S.G. Khan¹, P. Komada²¹Almaty university of Power Engineering and Telecommunications, Almaty, Kazakhstan,²Lublin polytechnic university, Lublin, Poland.

E-mail: zhussupbekovs@mail.ru, ibrayeva_lk@mail.ru, khan.sv2011@gmail.com, p.komada@pollib.pl

**THE EXPERIENCE OF APPLICATION OF MEASUREMENT
UNCERTAINTY EVALUATION METHODS IN CALIBRATION**

Abstract. The article reviewed and analysed two methods for estimating the uncertainty of the relative error of an electromagnetic flow meter (GUM and Monte-Carlo) during its calibration at the developed laboratory equipment of a mobile geotechnological information and metrological complex (GIMC). Less commonly, the Monte-Carlo method has shown high confidence in estimating measurement uncertainty and can be considered as a practical alternative to the GUM method for estimating uncertainty.

Keywords: GUM and Monte-Carlo uncertainty estimation methods, calibration of an electromagnetic flowmeter, geotechnological information-metrological complex.

Problem statement. In underground leaching of uranium, a large number of technical flowmeters are applied to consider the flow of working solutions into the feed wells (in average, the number of flowmeters in a single mine varies from several hundreds to thousands).

To control the technical condition of the flowmeters it is necessary to carry out their periodic calibration. The existing calibration procedure requires the dismantling of the flowmeters from work positions. All this significantly affects the workflow and leads to an increase in production costs.

The authors conduct the research work on a state grant on the “Development and testing of a mobile Geotechnological Information-Metrological Complex (GIMC) to increase the efficiency of uranium mining” theme.

The purpose of the work is to develop GIMC for calibration of flowmeters, which allows to increase the economic efficiency of uranium mining processes using the underground well leaching method with application of modern methods for evaluation the measurement uncertainty. The concept of uncertainty is widely introduced in various areas of human activity in Kazakhstan [1].

The relevance of scientific research work is to develop a new calibration methodology for flowmeters with the evaluation of the uncertainty of their measurement and the creation of the mobile GIMC for the calibration of flowmeters without removing them from the operating site. And also, in the development of a program for calculating the uncertainty of measurement of technical flowmeters, based on the International “Guide to the Expression of Uncertainty in Measurement” (GUM-1993) [2], and its application in the metrological practice of the Republic of Kazakhstan. The Guide (GUM-1993) are an extremely important document. It unifies the methods for calculating the measurement uncertainty and therefore allows to compare the measurement results regardless of who made the measurements and where.

After this document was published, it is actively applied in the calibration measuring instruments [3], and was repeatedly audited, which provides the metrological community the opportunity to correct this document [4, 5].

“Guide to the Expression of Uncertainty in Measurement” (GUM-1993) considers two approaches to quantifying measurement uncertainty evaluation: GUM method and Monte-Carlo simulation method. Both of these methods are applied by the authors in the task of evaluation the uncertainty of measuring a Coriolis flowmeter applied as an etalon (standard) in GIMC [6].

In GUM method the main stages in evaluation of uncertainty include the formulation of the measurement task and the calculations. At the stage of formulation of the measurement task the following tasks are conducted: determination of the output (measured) value; identification of input values on which the output value depends; drawing up a measurement model. The calculation stage consists of calculating the mean of the output value, this mean is taken as the value of the estimated output value; standard deviation of the output value taken as standard uncertainty; coverage interval containing the output value with a given probability of coverage.

The algorithm for evaluation the uncertainty using this method is given in [1].

The idea of Monte-Carlo method is as follows: each time the measurement function is calculated, the generated random values of input variables are substituted into it, varying around their nominal value within the uncertainty interval in accordance with the distribution law.

To apply Monte-Carlo method, it is necessary to select the number m of model estimation that you need to produce, and the level of confidence p . It is best to choose the value of m a large enough compared to $1/(1-p)$, (for example, exceeding it 10^6 times). The algorithm of Monte-Carlo method is given in [7].

The research. In this article the authors explore the application of these methods to evaluate the measurement uncertainty of a working electromagnetic flowmeter (EMF).

The evaluation of the measurement uncertainty by GUM method is conducted on the basis of the standard of the Republic of Kazakhstan “Method of calibration of electromagnetic flowmeters” [8]. This standard regulates the evaluation of the uncertainty of the relative error of an EMF and offers the measurement model of the following type:

$$\delta = \frac{Q_r - Q_p}{Q_p} \times 100, \quad (1)$$

where Q_r is the result of flow measurement by an EMF; Q_p is the result of flow measurement with a calibration equipment (CE) (a standard Coriolis flowmeter in our work).

The calculation of the measurement uncertainty evaluations includes the evaluations of the uncertainty for type A and type B .

The calculation of type A uncertainty includes the statistical processing of the measurement results of the EMF and the CE: the calculation of the mean, variance and standard deviation.

The standard uncertainty of the EMF relative error on type A is found by the formula:

$$u_A(\delta) = \frac{\sigma(\delta)}{\sqrt{3}}, \quad \text{where} \quad \sigma(\delta) = \frac{\sigma(\Delta)}{\sqrt{n} \cdot Q_p}; \quad (2)$$

where $\sigma(\Delta)$ is the standard deviation of the EMF absolute error; n is the number of measurements.

The type B uncertainty calculation includes:

1) the uncertainty of the readings of the electromagnetic flowmeter Q_r , due to the discreteness of the readings of the EMF d_r , assuming the rectangular probability distribution:

$$u_{B1}(Q_r) = \frac{d_r}{2\sqrt{3}}, \quad (3)$$

2) the uncertainty of the CE readings is indicated in the document on it. In case of specifying in the document on CE only its errors Δp , assuming a rectangular probability distribution:

$$u_{B2}(Q_p) = \frac{\Delta p}{\sqrt{3}}, \quad (4)$$

where Δp is the CE error;

3) the uncertainty of CE indications due to the discreteness of its testimony, in the assumption of a rectangular probability distribution:

$$u_{B3}(Q_p) = \frac{d_p}{2\sqrt{3}}. \quad (5)$$

The total uncertainty of type B of EMF relative error is calculated by the formula:

$$u_B(\delta_Q) = \sqrt{C_{Qr}^2 u_{B1}^2(Q_r) + C_{Qp}^2 (u_{B2}^2(Q_p) + u_{B3}^2(Q_p))}, \quad (6)$$

where C_{Qr} is the sensitivity coefficient of the EMF:

$$C_{Qr} = \frac{100\%}{Q_p}; \quad (7)$$

where C_{Qp} is the sensitivity coefficient of the CE:

$$C_{Qp} = -\frac{Q_r 100\%}{Q_p^2}. \quad (8)$$

To calculate the total standard uncertainty of the EMF relative error, the formula is applied:

$$u_c(\delta_Q) = \sqrt{u_a^2(\delta_Q) + u_{B\Sigma}^2(\delta_Q)}. \quad (9)$$

The calculation of the expanded uncertainty of the EMF relative error is fulfilled applying the formula:

$$U_c(\delta_Q) = k \cdot u_c(\delta_Q). \quad (10)$$

Based on the above formulas the algorithms and programs have been developed for calculating the relative error of the EMF by two methods. The programs are implemented in the LabView graphical software.

GUM method calculation. The initial data are the readings of the EMF and the Coriolis flowmeter (as CE) received on the laboratory equipment of the GIMC. The experiment means the measurement of the flow value of $0.95Q_{max}$, dm³/h (Q_{max} is the maximum value of the measurement range of the calibrated EMF) by the calibrated flowmeter – Q_r and by the Coriolis flowmeter – Q_p ; the number of measurements is 11.

To determine the type B uncertainty according to the formulas (3-5), the values of the relative error and discreteness of the EMF readings and the CE are specified.

As a result of the calculation a measurement uncertainty budget has been compiled, into which the uncertainty components of the EMF relative error calculated by the above formulas (3–10) are entered. The program interface with the results of calculating the budget uncertainty of the EMF relative error is shown in figure 1.

The screenshot shows a LabView interface titled 'GUM method' with tabs for 'Monte Carlo method' and 'Results'. It contains several input fields and a table for the uncertainty budget.

Input Fields:

- Qmax, dm³/h:** 6000
- Checkpoint, %Qmax:** 95
- Qmeas, dm³/h 2:** 5700
- Calibrated flowmeter (EMF), dm³/h:** 0
- Calibration equipment (CE), dm³/h:** 0
- Start:** OK
- Error EMF, %:** 1
- Discret EMF, dm³/h:** 0,1
- Error CE, %:** 0,1
- Discret CE, dm³/h:** 0,01

UNCERTAINTY BUDGET Table:

Input value	Input value estimation	Type of uncertainty	Probability distribution	Sensitivity coefficient	Standard uncertainty	Uncertainty contribution
Flow rate according to the indications, of the calibrated flowmeter, Q_r , dm ³ /h	5688,92	A	NORMAL	0,017548	23,0685	0,404891
		B	UNIFORM	0,017548	0,0288675	1,00051
Flow rate according to the indications of the calibration equipment, Q_p , dm ³ /h	5700,29	A	NORMAL	0,017508	2,32846	0,0407667
		B	UNIFORM	0,017508	3,2909	0,057617
		B	UNIFORM	0,017508	0,011547	0,000202
Output value	Output value estimation	Combined standard uncertainty	Probability distribution	Coverage coefficient	Expanded uncertainty	
Relative error, %	-0,199436	0,4108	NORMAL	1,96	0,80516	

Nominal Relative error: 1 %

Expanded uncertainty: 0,8 %

RECORD RESULT

Figure 1 – The uncertainty budget of the EMF relative error

Monte-Carlo method calculation. The next stage of the research work was to apply Monte-Carlo method to evaluation the uncertainty of the EMF relative error. The modelling of the process of evaluation the uncertainty of the EMF relative error was performed as follows:

a) two arrays of random numbers, obeying the uniform distribution laws, of volume $m=10^6$ for input variables are generated:

- Q_r – the flow measurement results by the electromagnetic flowmeter;
- Q_p – the flow measurement results by the calibration equipment (Coriolis flowmeter);

b) an array of output value– the EMF relative error δ was generated;

c) estimates of the parameters of the obtained distribution are calculated:

- mean value: $M(\delta) = \frac{\sum_{i=1}^{11} \delta_i}{11}$; where δ_i is calculated by the formula (1);

- total standard uncertainty: $u_c(\delta) = \sqrt{\frac{\sum_{i=1}^{11} (\delta_i - M(\delta))^2}{10}}$;

- expanded uncertainty: $U(\delta) = \frac{1}{2}[\delta_{975000} - \delta_{25000}]$;

- coverage coefficient: $k = U(\delta)/u_c(\delta)$;

d) obtained measurement result: $\delta \pm U(\delta) \%$; $p=0.95$.

The program interface with the calculation results of the EMF relative error uncertainty by Monte-Carlo method is shown in figure 2.

The screenshot shows a software interface for Monte Carlo method calculations. It includes input fields for various parameters and displays the resulting uncertainty values. The 'Monte Carlo method' tab is active, showing a 'Nominal Relative error' of 1.0% and an 'Expanded uncertainty of relative error' of 0.7%. A 'RECORD RESULT' button is visible next to the results.

Figure 2 – The calculation results of the EMF relative error uncertainty by Monte-Carlo method

The analysis of the received results. Ten experiments were carried out for four nominal values of the measured flow (calibration points). The processing of the obtained experimental data was carried out by both methods - GUM and Monte-Carlo. The uncertainty values of the EMF relative error $U(\delta)$ for nominal value of 95% Q_{max} are given in table 1.

Table 1 – Experimental data obtained by GUM and Monte-Carlo methods for nominal value of 95% Q_{max}

Method GUM										
flow Q	5684,24	5695,98	5711,02	5700,13	5691,16	5691,16	5709,97	5696,67	5693,15	5693,95
$\delta_{max_permissible} \%$	1	1	1	1	1	1	1	1	1	1
uncertainty $U(\delta) \%$	0,832	0,805	0,744	0,964	0,619	0,63	0,726	0,781	0,837	0,666
coverage coefficient k	1,96	1,96	1,96	1,96	1,96	1,96	1,96	1,96	1,96	1,96
Method Monte-Carlo										
flow Q	5700,02	5700	5699,98	5699,98	5699,98	5699,98	5700,01	5700	5699,99	5699,99
$\delta_{max_permissible} \%$	1	1	1	1	1	1	1	1	1	1
uncertainty $U(\delta) \%$	0,653	0,653	0,655	0,655	0,654	0,652	0,654	0,655	0,654	0,655
coverage coefficient k	1,954	1,954	1,954	1,952	1,953	1,952	1,953	1,953	1,952	1,952

According to the table, the graphs of the dependence of the relative error uncertainty on the number of the experiment (x -axis is the number of the experiment) obtained by both methods were plotted (figure 3).

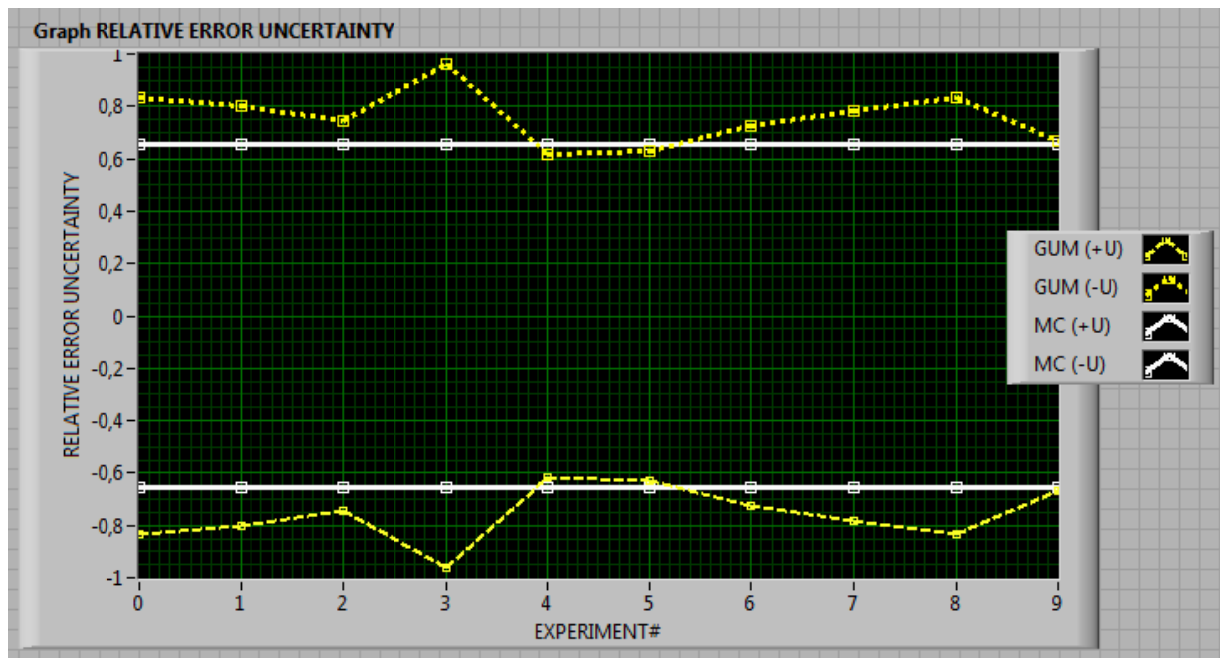


Figure 3 – The graphs of the dependence of the relative error uncertainty on the number of the experiment

The graphs received by Monte-Carlo method (solid lines) show a constant value of the uncertainty scatter of the relative error within $\pm 0,65\%$. The graphs received by GUM method (dotted lines) show variable value of scatter of uncertainty of the relative error within $\pm 0,9\%$. In this case, the limit of permissible relative error of EMF is equal $\pm 1\%$.

The received graphs let make the conclusions:

1. There are minor differences in the results of calculations by both methods.
2. GUM uncertainty values exceed Monte-Carlo values but do not exceed the permissible respective error of $\pm 1\%$. That is Monte-Carlo method provides high accuracy in evaluation of the measurement uncertainty.

The results of applying the methods of GUM and Monte-Carlo for the four test points during the calibration of the electromagnetic flowmeter are shown in table 2 (the estimations of the relative error δ , the expanded uncertainty U , the repeatability (convergence) limit u_r , the coverage interval CI).

From a comparative analysis of the data in Table 2 follow the conclusions:

1. Differences between estimates of the measured value (of the relative error) are not available; the differences of the expanded uncertainties are to 18.8%; the differences of the repeatability are to 16.9%.

Table 2 – Comparative table of the calculated values for the four test points by GUM and Monte-Carlo methods

Value of the verified point	The estimated parameter	By GUM	By Monte-Carlo	Difference, %
25% of Q_{max}	δ , %	0.007	0.007	0
	U	0.758	0.658	13
	u_r	0.379	0.337	11
	CI	[-0.751; 0.765]	[-0.651; 0.665]	13
50% of Q_{max}	δ	-0.003	-0.003	0
	U	0.790	0.651	17.5
	u_r	0.395	0.333	15.6
	CI	[-0.793; 0.787]	[-0.654; 0.648]	17.5
75% of Q_{max}	δ	0.01	0.01	0
	U	0.755	0.655	13.2
	u_r	0.377	0.335	11.2
	CI	[-0.745; 0.765]	[-0.645; 0.665]	13.2
95% of Q_{max}	δ	0.005	0.005	0
	U	0.805	0.653	18.8
	u_r	0.402	0.334	16.9
	CI	[-0.8; 0.81]	[-0.653; 0.658]	18.6

2. For all four verified points according to GUM method, the coverage intervals were wider (maximum by 18.6%) and shifted to the right (to the area of large values). However, at all test points the coverage intervals in both methods do not exceed $\pm 1\%$.

3. Monte-Carlo method gives more accurate values of estimated parameters, which is most likely due to the large number of generated values (is equal to 106).

4. Monte-Carlo calculation takes more time (due to sorting and processing of large arrays). But it can be performed by less qualified personnel (no deep knowledge of mathematics is required).

5. Monte-Carlo method can be considered as a practical alternative to GUM uncertainty evaluation method.

С. С. Жусупбеков¹, Л. К. Ибраева¹, С. Г. Хан¹, П. Комада²

¹Алматы энергетика және байланыс университеті, Алматы, Қазақстан,

²Люблин политехникалық университеті, Люблин, Польша

ӨЛШЕУ АНЫҚТАЛМАҒАНДЫҒЫН БАҒАЛАУ ӘДІСТЕРІН КАЛИБРЛЕУ ӨТКІЗГЕНДЕ ҚОЛДАНУ ТӘЖІРИБЕСІ

Аннотация. Мақалада әзірленген геотехнологиялық ақпараттық және метрологиялық кешенінің зертханалық жабдықтарында электромагниттік шығынөлшеуіштерге калибрлеу өткізгенде олардың салыстырмалы қателігінің анықталмағандығын бағалаудың екі әдісіне (Монте-Карло және GUM) шолу өткізіледі және анализденді. Монте-Карло әдісінің өлшеу анықталмағандығын бағалауының жоғары жинақталуы бар және бұл әдіс өлшеу анықталмағандығын бағалаудың GUM әдісінің альтернативасы болып табылады.

Түйін сөздер: анықталмағандықты бағалаудың GUM және Монте-Карло әдістері, электромагниттік шығынөлшеуішті калибрлеу, геотехнологиялық ақпараттық және метрологиялық кешен.

С. С. Жусупбеков¹, Л. К. Ибраева¹, С. Г. Хан¹, П. Комада²

¹Алматинский университет энергетики и телекоммуникаций, Алматы, Казахстан,

²Люблинский политехнический университет, Люблин, Польша

ОПЫТ ПРИМЕНЕНИЯ МЕТОДОВ ОЦЕНИВАНИЯ НЕОПРЕДЕЛЕННОСТИ ИЗМЕРЕНИЙ ПРИ КАЛИБРОВКЕ

Аннотация. В статье выполнен обзор и анализ двух методов (Монте-Карло и GUM) оценивания неопределенности относительной погрешности электромагнитного расходомера при калибровке на разработанном

лабораторном оборудовании мобильного геотехнологического информационно-метрологического комплекса. Метод Монте-Карло показывает высокую сходимость в оценке неопределенности измерения и может рассматриваться как альтернатива методу GUM оценки неопределенности.

Ключевые слова: методы оценивания неопределенности GUM и Монте-Карло, калибровка электромагнитного расходомера, геотехнологический информационно-метрологический комплекс.

Information about authors:

Zhussupbekov S. S., PhD, Professor of Almaty university of Power Engineering and Telecommunications; zhussupbekovs@mail.ru; <https://orcid.org/0000-0003-3220-713X>

Ibrayeva L. K., PhD, Professor of Almaty university of Power Engineering and Telecommunications; ibrayeva_lk@mail.ru; <https://orcid.org/0000-0002-8342-6685>

Khan S. G., PhD, Professor of Almaty university of Power Engineering and Telecommunications; khan.sv2011@gmail.com; <https://orcid.org/0000-0002-7918-6690>

Komada P., PhD, assistant Professor, Deputy Director for General Affairs of Institute of Electronics and Information Technology of the Lublin university of technology; p.komada@pollib.pl; <https://orcid.org/0000-0002-9032-9285>

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**B. T. Yermagambet¹, M. K. Kazankapova¹, A. T. Nauryzbaeva¹,
Z. A. Mansurov², G. T. Smagulova², B. B. Kaidar²**

¹LLP «Institute of coal chemistry and technology», Astana, Kazakhstan,

²RSE «Institute of Combustion Problems», Almaty, Kazakhstan.

E-mail: coaltech@bk.ru, maira_1986@mail.ru, asemai_2296@mail.ru, zmansurov@kaznu.kz,
smagulova.gaukhar@gmail.com, kaydar.bayan@gmail.com

PRODUCTION OF CARBON FIBERS BY ELECTROSPINNING METHOD

Abstract. The technique of carbon fibers synthesis by the method of electrospinning from the coal tar pitch of the Shubarkol deposit in laboratory conditions is described, the value of the interelectrode voltage is 18-20 kV. The elemental composition was determined and the morphology of the surface of the investigated sample was studied, the type of carbon fiber modification was revealed. As a result of energy-dispersive X-ray spectroscopy and SEM microscopy, the chemical composition (C – 84.73%, O – 14.05%, Si – 0.49%, S – 0.73%) was determined and carbon fiber diameter constitutes from 2 to 9 μm . Raman spectroscopy showed the presence of D peaks (1367 cm^{-1}) and G (1595 cm^{-1}), which characterizes carbon materials, as well as a peak at 2900 cm^{-1} , which indicates the presence of CH bonds.

Key words: carbon nanofibre, stone-pitch, electric spinning, composite.

Introduction. Currently, in order to reduce dependence on imports or exports of oil and natural gas, most countries are keen to actively develop coal chemistry, namely actively develop modern technologies for deep processing of coal and create materials and products of a new generation on the basis of coals of different grades. It should be noted that the products obtained by deep processing at a cost several times superior to the raw materials. Now it is important to understand which methods and technologies in the field of deep coal processing will be prioritized and will have a positive impact on economic growth.

Among a wide class of nanomaterials, carbon fibers (CF) occupy a separate position, due to the uniqueness of their physicochemical properties and the prospects for practical application [1]. Carbon nanofibers (CNF) are a class of materials in which curved graphene layers or nanocones are composed in the form of a quasi-one-dimensional filament whose internal structure can be characterized by an angle α between the layers of graphene and the fiber axis [2]. CNF attracted great attention of scientists with their potential thermal, electrical, shielding and mechanical properties [3], as well as high tension force, low specific gravity, low coefficient of thermal expansion and chemical inertness. Due to their exceptional properties and low cost, they are now increasingly used in various materials such as composites production [4]. Other areas of nanofiber technology include engineering, wires, capacitors, transistors, diodes for information technology, systems for transport, conversion and storage of energy, such as batteries and fuel cells, and structural composites for aerospace structures.

A unique property of carbon fibers is also their relatively high electrical conductivity. Fibers can be used as heating elements, since their electrical conductivity is close to the electrical conductivity of nichrome [5, 6].

In the early 1970s, Japanese researchers Koyama and Endo [7] were able to produce carbon fibers with a diameter of 1 μm and a length of more than 1 mm by deposition from the gas phase. Later, in the early 1980s, Tibbets [8] in the USA and Benissad [9] in France continued to improve the process of

obtaining carbon fibers by gas-phase deposition. In the US, more in-depth studies on the synthesis and properties of these materials were carried out for practical use by R. Terry K. Baker [10].

The first attempt to commercialize carbon fibers grown from the gas phase was undertaken by the Japanese company Nikosso in 1991 under the trademark Grasker [4], the same year Ijima published his famous article on the discovery of carbon nanotubes. Essentially, carbon nanofibers are produced by the same process as carbon fibers grown from the gas phase, only their diameter is generally less than 200 nm. At the present time, many companies around the world are actively involved in the commercialization of the production of carbon nanofibers and the introduction of new technical applications of these materials, the latest of which is a carbon nanofibre-porous composite that is used to eliminate oil spills.

The first developments in the production of carbon fibers from the pitch were carried out by Japanese researchers, who are still holding the first place in the world market for the production of carbon fibers. The technology for producing pitch-based carbon fiber includes several stages: preparation of the substrate, synthesis of the fiber by spinning from the melt, stabilization in an oxidizing atmosphere, carbonization in an inert atmosphere, graphitization at an elevated temperature. Activation of carbon fibers produces materials with a large active surface (from 300 to 1000 m²/g), which are sorbents. The application of catalysts on the fiber allows the development of catalytic systems with a developed surface. Due to the low density (1.7 to 1.9 g/m³), the specific value of mechanical properties, carbon fibers exceed all known heat-resistant fibrous materials [11, 12]. Special fibers from phenolic resins, lignin, coal and petroleum pitches can be used to produce CNF. In this respect, coal precursors are of particular interest, since they are economically viable, and also present in large quantities in various coal deposits.

Coal pitch - the remnant from the distillation of coal tar after pyrolysis. It is a hard, sometimes viscous mass of black. High-molecular aromatic hydrocarbons, higher phenols and organic bases predominate in the composition of coal tar pitch. The insoluble part includes free carbon (8-30%, depending on the melting temperature of the pitch), ash (0.2% and higher), and asphaltenes. The density of the pitch is 1.2-1.3 g/cm³. Pitch are not electrically conductive and insoluble in water, they dissolve only in organic solvents (pyridine, benzene, etc.) and are resistant to the action of acids [13-15].

Given the potential of nanofibers, interest in production technology is growing. Among technologies, including templating method, drawing method, phase separation and electrospinning attracted the greatest interest. We will use the method of electrospinning to produce CNF, since this method is economically effective on a semi-industrial scale.

Electrospinning is a process that leads to the formation of nanofibers as a result of the action of electrostatic forces on an electrically charged flow of a solution or a melt [16, 17]. The essence of the method of electrospinning is that the electrical voltage from 1-100 kV is applied to the solution (melt), which is fed through a capillary by means of a dispenser [18]. High voltage induces in the solution similar electrical charges, which, as a result of Coulomb electrostatic interaction, lead to the drawing of the solution into a thin flow [19, 20]. In the process of electrostatic jet stretching, a series of successive splittings into more thin flow can occur under a certain ratio of the values of viscosity, surface tension, and the density of electric charges in the fiber [21]. The resulting flow harden by evaporation of the solvent or as a result of cooling, turning into fibers, under the action of electrostatic forces drift to a grounded substrate having the opposite value of the electric potential. The precipitation electrode (collector) must have good electrical conductivity [22, 23].

The authors of [24] found that by varying the parameters of the process of electrospinning, it is possible to vary the thickness of the filaments in the range from hundreds of nanometers to several microns. The method of electrospinning is good because, unlike usual, mechanical drawing of fibers from a solution, it does not impose high requirements on the chemistry of the process, does not require high temperatures for solidification of the fiber, and therefore it allows the creation of fibers from long and complex molecules, as a result of the struggle between capillary and electrostatic forces. Also, the processes inside the solution, the charged drop itself lengthens, becomes thinner and dries out in flight.

Electrospinning is a universal and effective method for obtaining continuous nanofibers from submicron diameters to nanometer diameters, using a high-potential electric field [25, 26]. The technology can be easily used in the laboratory and can be scaled to the industrial process [27]. Electroconversion of nanofibers from polymer solutions or melts is of practical interest, since they have many potential applications [28].

Optimum nanofibers can be manufactured by controlling the solution, process and environmental parameters, since the characteristics of the electro-cord are determined by these parameters. It is very important to avoid the appearance of bubbles, especially for small nanofibres, by controlling the parameters it is possible to control the pore diameter [28].

A typical electrospinning installation, as shown in Figure 1, consists mainly of three components: a capillary tube with a pipette or a small diameter needle, a high voltage source, a metal collecting screen.

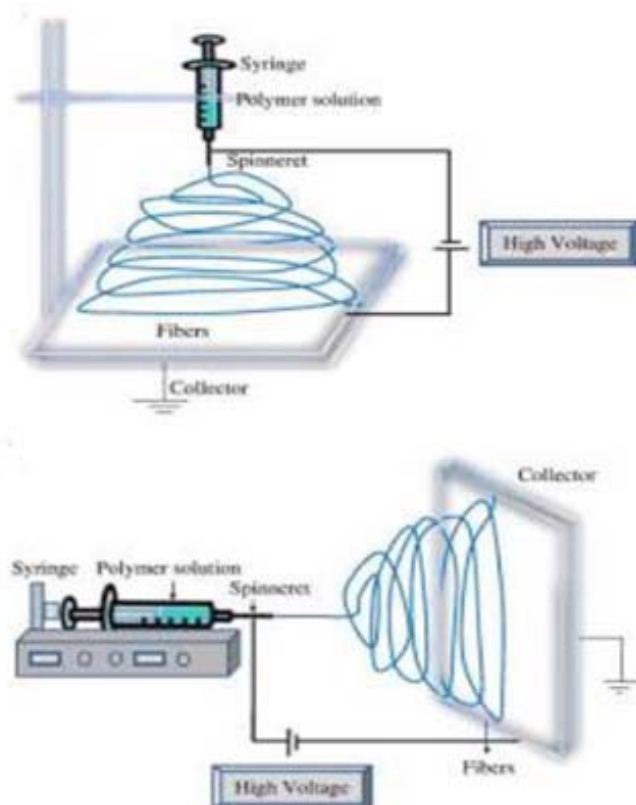


Figure 1 – Schematic diagram of the electrospinning installation

On the basis of the foregoing, the goal of the forthcoming work was formulated, which is to produce carbon fibers on the basis of coal-tar pitch by the method of electrospinning and the study of physico-chemical properties.

Research method. As a raw material, coal tar pitch, which is formed during the pyrolysis of raw materials, from coal of the Shubarkol deposit is used.

In the study, the method of electrospinning was used to produce nanofibers in laboratory conditions. The following instruments were used to prepare the raw material for the production of carbon nanofibers: ultrasonic bath, laboratory electro spinning device, SEM (Quanta 3D 200i) with an attachment for energy dispersive analysis from EDAX, HORIBA Jobin Yvon).

We have chosen the method of electrospinning to produce CNF, since this method is acceptable in laboratory conditions, and thin fibers are formed. Electrospinning is good in that, unlike the usual mechanical pulling of fibers from a solution, it does not impose high requirements on the chemistry of the process, it does not require high temperatures for solidification of the fiber, and therefore it allows the creation of fibers from long and complex molecules as a result of the struggle of capillary and electrostatic forces. Also, the processes inside the solution, the charged drop itself lengthens, becomes thinner and dries out in flight. Despite the complexity of the physical processes of electroforming, this method is characterized by hardware simplicity, high energy efficiency of production, wide versatility to the materials being formed and flexibility in controlling the parameters of the process. All this makes the electrospinning process attractive for industrial production of nanofibres.

Investigation of the elemental composition, structure, and dimension of CNF was performed using energy dispersive X-ray spectroscopy on a SEM device (Quanta 3D 200i) with an attachment for energy-dispersive analysis from EDAX (NNLOT, KazNU named after al-Farabi, Almaty). For the study, the samples were attached to a copper holder using conductive adhesive paper. The energy of the exciting electron beam in the analysis was 15 keV, the working distance was 15 mm.

A study of the type of carbon modification was carried out using Raman spectroscopy using the Raman scattering method. The Raman spectra of the samples were recorded on an Integra Spectra probe scanning microscope, using a laser with a wavelength of 473 nm. The spectra were recorded with a 20 second accumulation. Samples were supported as a thin replica on a glass substrate. The spectral detector CCD3, the wavelength $\lambda = 632.8$ nm (20 mV), the width of the spectral line was 2.08 cm^{-1} . Installation parameters: power - 35 mW, solid-state laser, grating -600/600.

Results and its discussion. The most important stage in the production of carbon fiber based on coal tar pitch is the process of obtaining the initial fiber. Pitches are a complex mixture of aromatic and aliphatic compounds. The molecular weight of the compounds is relatively small, and only a part of them can be attributed to oligomers. A coarse brittle fiber can be formed from such systems. Consequently, a good quality carbon fiber can not be obtained, so low-molecular volatile compounds must be previously removed to impart fiber-forming properties to the pitch. To increase the molecular weight, the pitch must be heat treated.

In order to obtain CNF by the method of electrospinning, coal tar pitch is placed in a quartz reactor and heated to 400°C at a heating rate of $10\text{--}15^\circ\text{C}/\text{min}$ and with holding at 400°C for 3-4 hours (figure 2). The quartz reactor was heated and cooled in an inert argon medium at a gas velocity of $80 \text{ cm}^3/\text{min}$. Then the reactor is cooled and intermediate pitches are collected (figure 3).

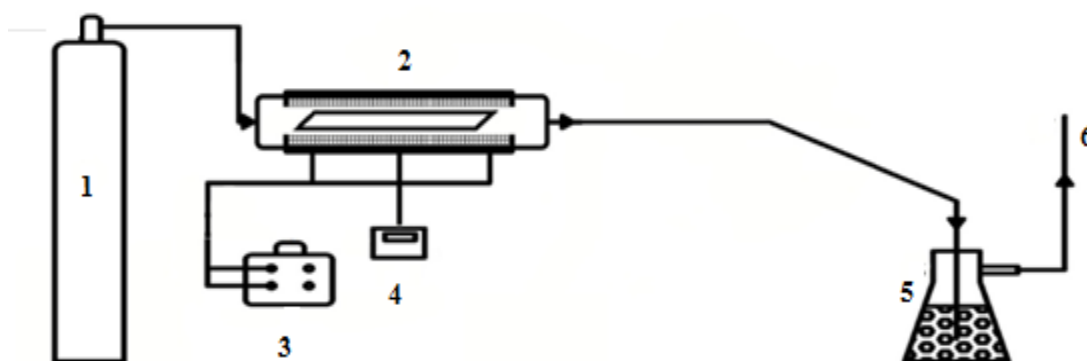


Figure 2 – Schematic diagram of the laboratory installation for the synthesis of CNF:
1 - gas cylinder (argon); 2 - quartz reactor; 3 - LATR; 4-temperature sensor; 5 - a flask to control the gas outlet; 6 - gas outlet

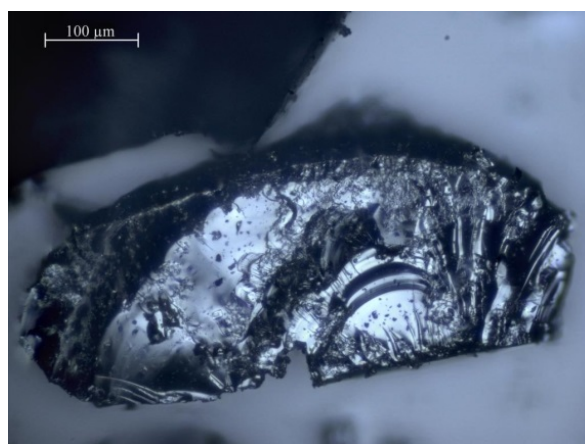
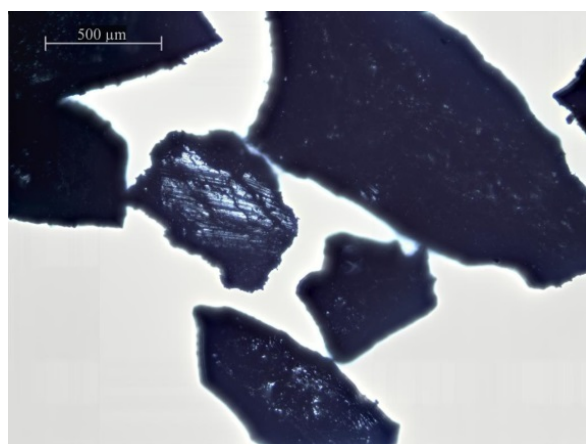


Figure 3 – Carboniferous coal tar pitch

The resulting pitch is crushed, 1,2-dichloroethane is added, afterwards the resulting mixture is placed in an ultrasonic bath for 10-20 minutes for complete mixing. Polymethyl methacrylate is used as a binder, which is also mixed with 1,2-dichloroethane in an ultrasonic bath for 10-20 minutes. The resulting mixtures in 1: 1 ratios are placed in an ultrasonic bath for 20-30 minutes.

Ready mixture is dialed into an insulin syringe and installed on the reversing motor. A charge is applied to the tip of the syringe. Then the engine starts, and with the advent of the first drop the opposite charge is turned on. The same charge is attracted to the substrate with the opposite charge and nanofibers are formed (figure 4). Nanofibers are cured by solvent evaporation. The value of the interelectrode voltage was 18-20 kV. High voltage is the basis of electroforming.



Figure 4 –
Carbon nanofibre obtained
by the method of electrospinning
Electron microscopic images
of nanofibres are shown in figure 5

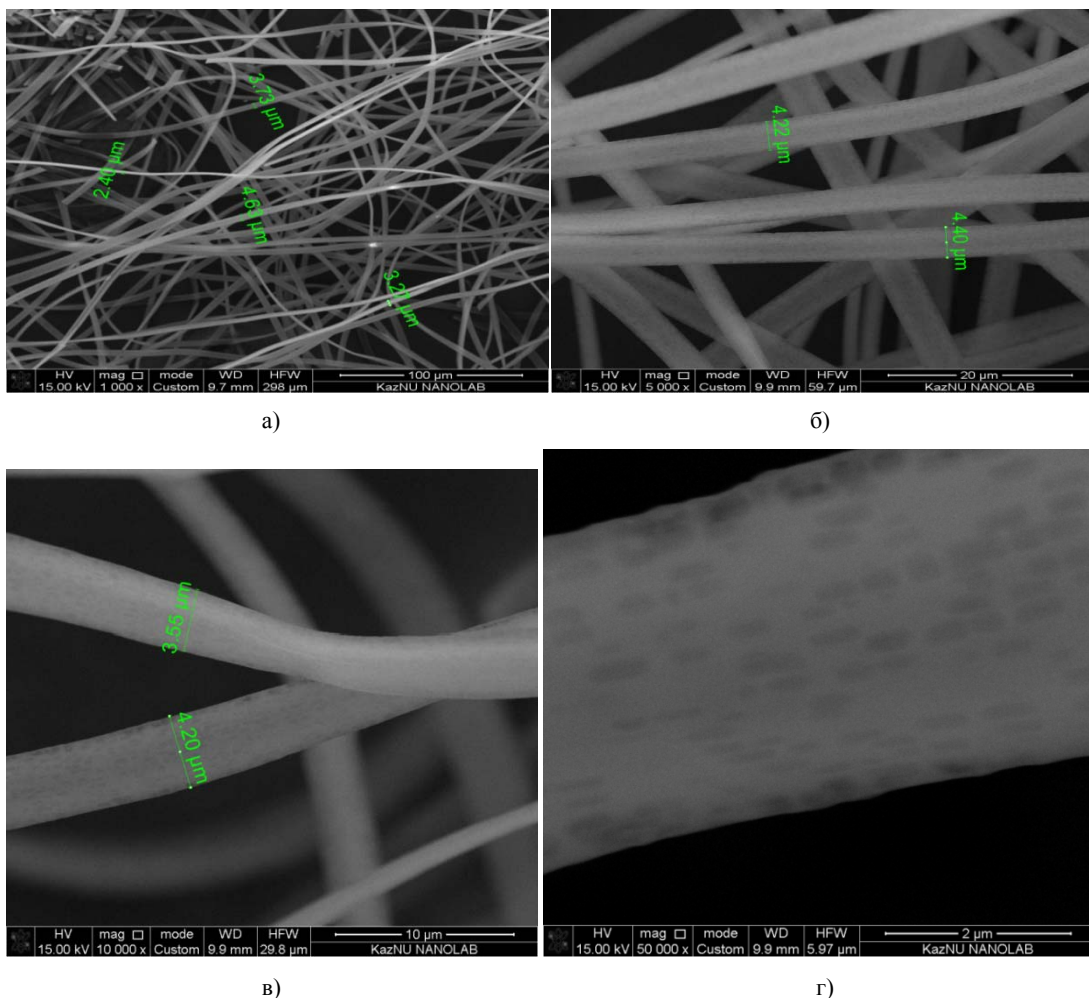


Figure 5 – Electron microscopic images of carbon fibers: a) x1000, b) x5000, c) x10 000, d) x50 000

The process of electroforming begins when the electrostatic forces between the charges accumulated in the molding solution and the electric field between the electrodes overcome the surface tension of the molding solution. The repulsive force between the charges of the same name stretches the viscoelastic flow of the molding solution.

In figure 5, nanofibers with a diameter of 2 to 9 μm are clearly visible, the structural elements take the form of fibrils-filamentary formations whose length exceeds their diameter by more than an order of magnitude.

The results of the elemental analysis are shown in figure 6.

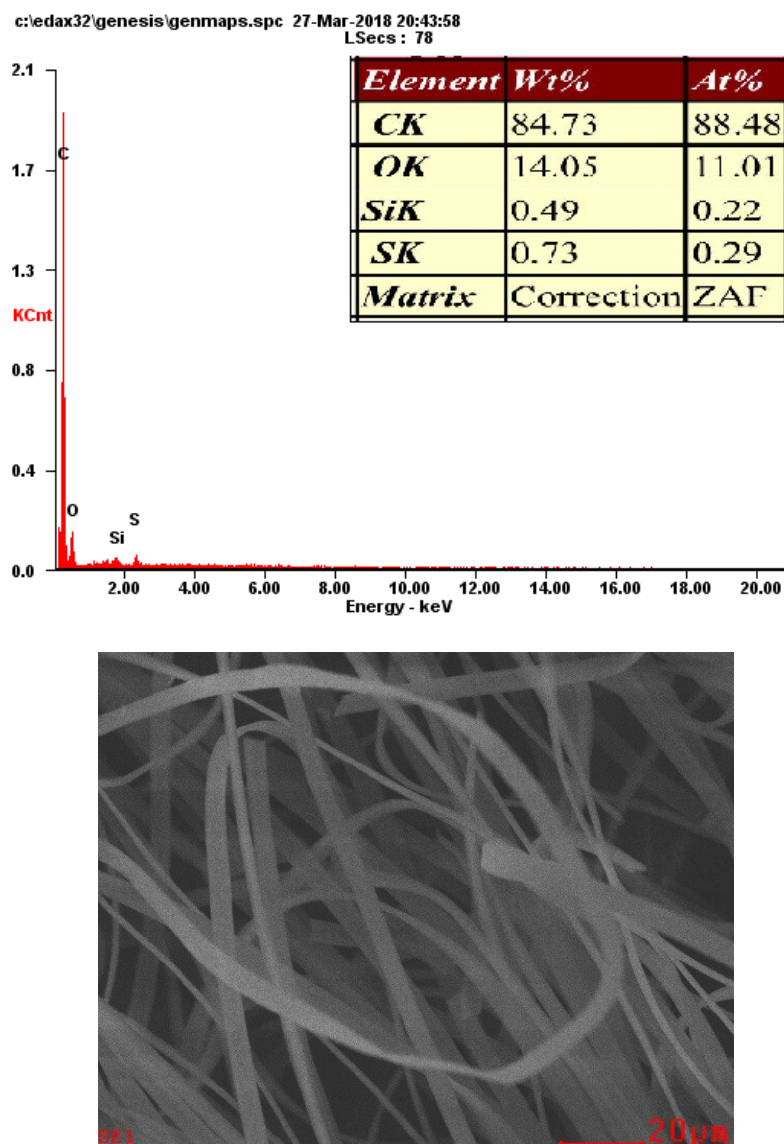


Figure 6 – Elemental analysis of carbon fiber

As shown in figure 5, the elemental composition of carbon fibers is composed by weight %: C – 84,73; O – 14,05; Si – 0,49; S – 0.73.

Figure 7 shows the Raman spectrum of the sample in the wave interval 200-3200 cm^{-1} . There are peaks D and G, which characterize carbon materials. The peak position is D – 1367 cm^{-1} , the intensity is 2900 units, the peak position is G – 1595 cm^{-1} , the intensity is 5401 units. There is also a peak at 2900 cm^{-1} , which indicates the presence of CH-bonds, which indicates the inclusion of polymers in the composition.

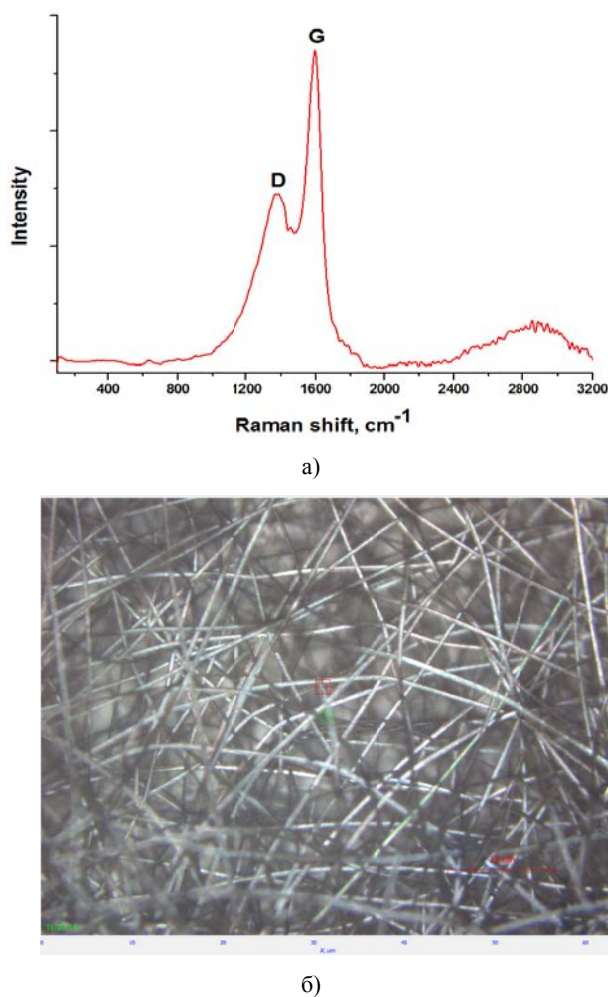


Figure 7 – Raman spectrum (a) and optical pattern (b) of carbon fibers

Further, we carry out a study on the oxidation and graphitization of the obtained CNF, since the formed fiber, as a rule, is characterized by low strength and increased brittleness. Such properties are natural for fibers from oligomers, which are essentially pitches. To increase the strength and impart a non-meltability, the formed fibers are oxidized in a gas or liquid medium. Oxygen (air), air with additives of ozone, oxygen or chlorine, a pair of nitroaromatic compounds (nitrobenzene, nitrophenol), dioxide and sulfur trioxide, ozone oxides serve as oxidants [5]. Since oxidation is carried out at elevated temperatures, it is heated at a low rate to produce a spun fiber. The oxidation temperature in the air stream is 280 °C for 1 hour at a heating rate of 1 °C. The oxidized fibers are carbonized at 800 °C for 10 minutes at a heating rate of 5 °C under a nitrogen atmosphere [6]. However, if the carbon content in the fiber is 95%, the heating rate can be increased to 10°C/min. In this case, the fiber yield reaches 85-90%.

The carbonized fiber is graphitized under tension both during electrical heating and when electric current is passed through the fiber. Elastic-strength indexes of fibers from pitch can be significantly increased by stretching during heat treatment at temperatures above 2800°C. Next, the finished fiber is wound on the coils [5].

Conclusions. Thus, the proposed method for producing carbon nanofibers is built on the basis of the method of electrospinning, which is the most promising method of industrial production and provides a product with a relatively high fraction uniformity, which determines the achievement of the strength characteristics required for structural materials.

In the case of providing Kazakhstani producers with a high quality product that meets all the requirements of the consumer, the need for importing UNV will decrease. There is no market for the production of carbon fiber based on coal pitch, although raw materials are not only cheap, but also affordable,

and the resulting product, in the final analysis, far exceeds analogues in terms of elasticity. Unique properties allow the use of carbon fiber in various areas of human life. However, at the moment, industrial technologies for the production of functional carbon fiber from coal are only under development.

The ecological effect of our study is to create an environmentally friendly technology based on the processing of secondary raw materials (coal tar and other coal mining waste) to produce carbon fibers and composites based on them. The creation of this technology will allow to solve the ecological aspect of utilization of this type of waste with obtaining an economically viable product.

Our technology is unique in that the raw materials we use to produce carbon fibers are a renewable resource, compared to the technology of obtaining fibers from a variety of other precursors (nylon, polyester, acrylic, polypropylene, etc.). Prospectivity of these studies lies in the possibility of large-scale production of carbon fibers from coal tar pitch, which will lead to the appearance of materials and composites based on domestic production on the Kazakhstan market.

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**Б. Т. Ермағамбет¹, М. К. Казанкапова¹, А. Т. Наурызбаева¹
З. А. Мансуров², Г. Т. Смагулова², Б. Б. Кайдар²**

¹«Көмір химиясы және технология институты» ЖШС, Астана, Қазақстан,
²ҚР БҒМ ҒК «Жану проблемалары институты» ШЖҚ РМК, Астана, Қазақстан

ЭЛЕКТРОСПИННИНГ ӘДІСІМЕН КӨМІРТЕКТІ ТАЛШЫҚ АЛУ

Аннотация. Зертханалық жағдайда «Шұбаркөл» кенішінің көмірінен алынған пек негізінде электро-спиннинг әдісімен көміртекті талшық алудың әдістемесі келтірілген, электродаралық кернеу 18-20 кВ құрады. Зерттелетін үлгінің элементтік құрамы, беттік құрылымы, көміртекті талшықтың модификация типі анықталды. Энергодисперсиялық рентгенді спектроскопия және СЭМ микроскопия нәтижесінде химиялық құрамы анықталды (С – 84,73%; О – 14,05 %; Si – 0,49 %; S – 0,73%) және көміртекті талшықтаң диаметрі 2-ден 9 мкм аралықты құрыды. Раман спектроскопия нәтижелері көміртекті материалдарды сипаттайтын D (1367 см⁻¹) және G (1595 см⁻¹) шыңдарын көрсетті, сонымен қатар СН-байланысына тән шың 2900 см⁻¹ анықталды.

Түйін сөздер: көміртекті талшық, таскөмір шайыры, электроспиннинг, композит.

**Б. Т. Ермағамбет¹, М. К. Казанкапова¹, А. Т. Наурызбаева¹
З. А. Мансуров², Г. Т. Смагулова², Б. Б. Кайдар²**

¹ТОО «Институт химии угля и технологии», Астана, Казахстан,
²РГП «Институт проблем горения», Алматы, Казахстан

ПОЛУЧЕНИЕ УГЛЕРОДНЫХ ВОЛОКОН МЕТОДОМ ЭЛЕКТРОСПИННИНГА

Аннотация. Приведена методика получения углеродных волокон из каменноугольного пека месторождения «Шубарколь» методом электроспиннинга в лабораторных условиях, значение межэлектродного напряжения составило 18-20 кВ. Определен элементный состав и изучена морфология поверхности исследуемого образца, выявлен тип модификации углеродного волокна. Выявлено, что в результате энергодисперсионной рентгеновской спектроскопии и СЭМ микроскопии обнаружен химический состав (С – 84,73%; О – 14,05 %; Si – 0,49 %; S – 0,73%) и диаметр углеродных волокон который составил от 2 до 9 мкм. Результаты Рамановской спектроскопии показал наличие пиков D (1367 см⁻¹) и G (1595 см⁻¹), которые характеризует углеродные материалы, так же обнаружен пик на 2900 см⁻¹, который указывает о наличии СН-связей.

Ключевые слова: углеродное волокно, каменноугольный пек, электроспиннинг, композит.

Information about authors:

Yermagambet Bolat Toleukhanuly, Doctor of Chemical Science, Professor, Director of LLP "Institute of Coal Chemistry and Technology", Astana, Kazakhstan; bake.yer@mail.ru; <https://orcid.org/0000-0003-1556-9526>

Kazankapova Maira Kuttybaevna, PhD, Senior Researcher of LLP "Institute of Coal Chemistry and Technology", Astana, Kazakhstan; maira_1986@mail.ru; <https://orcid.org/0000-0001-9016-3062>

Nauryzbayeva Asemay Turlanovna, bachelor, Junior Researcher of LLP "Institute of Coal Chemistry and Technology", Astana, Kazakhstan; asemai_2296@mail.ru; <https://orcid.org/0000-0003-4912-3856>

Mansurov Zulhair Aimukhametovich, Doctor of Chemical Science, Professor, General Director of RSE «Institute of Combustion Problems», Almaty, Kazakhstan; zmansurov@kaznu.kz; <https://orcid.org/0000-0002-8956-216X>

Smagulova Gaukhar Tolbayevna, PhD, Leading Researcher of of RSE «Institute of Combustion Problems», Almaty, Kazakhstan; smagulova.gaukhar@gmail.com; <https://orcid.org/0000-0002-2943-5222>

Kaidar Bayan, PhD student, Researcher of of RSE «Institute for Problems of Combustion», Almaty, Kazakhstan; kaydar.bayan@gmail.com; <https://orcid.org/0000-0001-6327-7531>

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A. G. Galstyan¹, S. N. Turovskaya², A. E. Ryabova¹, E. E. Illarionova², V. K. Semipyatniy¹,
I. A. Radaeva², A. N. Petrov³, D. E. Nurmukhanbetova⁴, E. K. Assembayeva⁴

¹All-Russian Scientific Research Institute of Brewing, Non-Alcoholic and Wine Industry –
branch of the Gorbатов's Federal Scientific Center of Food Systems of RAS, Moscow, Russia,

²All-Russian Research Institute of Dairy Industry, Moscow, Russia,

³All-Russian Scientific Research Institute of Preservation Technology –
branch of the Gorbатов's Federal Scientific Center of Food Systems of RAS, Vidnoye, Russia,

⁴Almaty technological university, Almaty, Kazakhstan.

E-mail: 9795029@mail.ru, conservlab@mail.ru, anryz@hotmail.com, conservlab@mail.ru,
semipyatniy@gmail.com, conservlab@mail.ru, vniitek@vniitek.ru, dinar2080@mail.ru, elmiraasembaeva@mail.ru

TECHNOLOGICAL ADDITIVES AS AN ELEMENT OF DRY MILK PROPERTIES DIRECTED FORMATION

Abstract. The modern development of the food industry is unthinkable without the use of food additives. Their use makes it possible to improve the finished products quality, give it consumerly attractive properties, increase shelf life, reduce losses during transportation, expand of the supply's geography logistics, facilitate the intensification of technological processes, etc. The carried out complex of studies has made it possible to establish that the introduction of salt-stabilizers has a significant effect on the change in the basic functional and technological dried whole milk properties. Analysis of experimental material, obtained for all indicators studied during the work, allows us to recommend the use of complex phosphate salts in dried whole milk technology. At the same time, it should be noted that dried whole milk samples with salts, obtained by introducing them into normalized milk and its subsequent drying, surpass samples with similar salts, obtained by dry mixing, in their qualitative characteristics. This is due to more intense mechanism stabilizing salts effect on milk protein complex before drying.

Keywords: powdered milk, food additives, technology, quality, dynamics in storage.

Modern innovative development of the food industry is unthinkable without use of wide range of food additives. Their use makes it possible to improve the finished products quality, give it consumerly attractive properties, increase shelf life, reduce losses during transportation, expand of the supply's geography logistics, facilitate the intensification of technological processes, etc. [1-4].

Currently, there are several legal interpretations of the “food additive” established by international - Codex Stan 192-1995, interstate EAEU - TR TS 021/2011, TR TS 029/2012 and national documents of the Russian Federation - FZ dated 02.01.2000 No. 29-FZ. Briefly, the essence of the concept can be summarized as follows: food additive is a substance or mixture of substances usually not eaten directly by human, deliberately used in food production with a technological purpose for ensuring production processes, transportation and storage [4-6].

In Russian Federation, food additives are divided into the following main functional classes: anti-caking agents (anti-boilers); antioxidants; flour treatment agents; glazing; acids and acidity regulators; preservatives; colorants; carriers; sweeteners; stabilizers, emulsifiers, fillers and thickeners; flavor enhancers and aromas; color fixatives (stabilizers) [6, 7].

From the given list of food additives one should single out such a widely used group as “stabilizers, emulsifiers, fillers and thickeners”, otherwise called technological food additives, which are manifested either in the purposeful modification of the product constituent parts during technological processing, or in giving the product a certain quality characteristics due to its own functional and technological properties

[5-7]. The substances of this additives group play an important role in modern technologies and find application in almost all sectors of food industry, including the dairy one [3, 6, 7].

Today in the dairy industry one of the urgent tasks is to improve the quality characteristics of canned dairy products used as dry dairy raw materials (DDRM), and in particular such indicators as thermal stability, solubility, etc. It is known, that from raw materials with low thermal stability and solubility is difficult to produce high-quality dairy products, especially with high organoleptic characteristics. The prospect of processing this raw material in other sectors of food industry, for example, in the confectionery, is very difficult due to used high-temperature treatment regimes and the high acidity of certain ingredients [8-18].

It should be noted, that for the various food products production, the most demanded of the DDRM is dried whole milk (DWM). In international practice (Codex Stan 207-1999), a wide range of food additives is used in its manufacture, namely: stabilizers, hardeners, acidity regulators, emulsifiers, antioxidants, as well as additives preventing caking and balling. On the territory of the member countries of the European Economic Union, including Russian Federation, DWM is produced according to GOST 33629-2015, which rationalizes its production only from dairy raw materials. On the one hand, this is a positive factor - especially when processing of DWM into reconstituted milk for direct consumption. On the other hand, in view of the limited amount of high-quality raw milk and the seasonality of its production, the possibility of producing DWM, for example, from non-heat-resistant raw materials, the quality of which can be improved by using food additives, is excluded. In this situation, the DWM production with use of salts is permissible to carry out under technical conditions or standards of organizations [2, 4, 19-21].

The purpose of this work was to establish the feasibility of using different salts to improve DWM quality characteristics, including depending on the method of their incorporation into dairy raw materials.

Research methods. Standard conventional and original experimental methods were used in the work [2, 5, 9]. In particular, were studied a number of functional and technological DWM indicators, including samples in a reduced form: acidity, heat resistance, solubility index, water activity (milk powder), viscosity, dissolution rate, etc. A three-dimensional experimental study of the samples was carried out on the "Jeol-840 A" electron microscope (Japan), for which they were previously glued onto special metal tables after being fixed and dehydrated, were sprayed with gold in the ionic spraying thin coatings "JFC - 1100". The indicator of the samples water activity was researched on the device "Hygrolab-3" of the company ROTRONIC (Germany) with digital ventilated station "AwVC-DIO" and results processing by "HW3" software. The granulometric composition is based on RETSCH analytical screening installation of the AS200 Control series, equipped with the Amplimatic microprocessor analysis control system and the Easysievet results processing program.

Milk powder with salts samples were obtained under production conditions on a spray drying unit. Making salt process was carried out in two ways: the method of normalized milk drying with salt (DWM1) and the method of dry mixing (DWM2), which provides for DWM dry mixing with a stabilizer salt on vibration mixers. At the same time, for the control salt-free sample and DWM1 samples, the raw material was used as close as possible to the characteristics. As a dry milk basis for DWM2 samples, dry milk from the control batch was used. During research, about 7.5 tons of powdered milk with various salts were produced and feedback was received on the processing of this raw material in various food industries, in particular on its use in the confectionery products development.

As stabilizer salts under research were used sodium citrate trisubstituted ($\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5,5\text{H}_2\text{O}$) according to GOST 31227-2004 (E331), sodium disubstituted phosphate 12-water ($\text{Na}_2\text{HPO}_4 \cdot 12 \text{H}_2\text{O}$) according to GOST 4172-76 (E339) and complex salt, representing a mixture of sodium phosphates (hereinafter referred to as polyphosphate). Each of stabilizer salt for all DWM samples were injected in equal amounts to the mass of the finished product.

Research results. Based on the analysis of preliminary experiments results on the preparation of DWM with various salts, it was found that, by the criteria of accessibility/quality/price/efficiency, it is most efficient to use complex polyphosphate salts. To assess the effectiveness of salt addition, salt-free DWM were further monitored, as well as with $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ and $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5,5\text{H}_2\text{O}$, produced using maximally one-type technologies.

A rational dosage of salts has been experimentally established previously – 0.3% by DWM weight, which ensures a stable increase in thermal stability by 1–3 groups and a decrease in solubility index by 2–3 times.

Visually researched salts differed in the degree of dispersion and the intensity of dissolution in water.

Figure 1 shows electron microscopic photographs of salt samples at different magnifications (1, 2, 3 - x500 and 1a, 1b, 1c – x4000, respectively), allowing demonstrate the differences in the structure of the objects under study clearer.

As follows from the figure, complex salt has a higher dispersion. In general, significant differences in the structure of the salts studied are well comparable with the data on their solubility in water. In DWM1 production, salts in normalized milk were made in the form of aqueous solutions, and in DWM2 technology – $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5,5\text{H}_2\text{O}$ and $\text{Na}_2\text{HPO}_4 \cdot 12 \text{H}_2\text{O}$ subjected to additional grinding in order to achieve a more uniform distribution in milk powder mass.

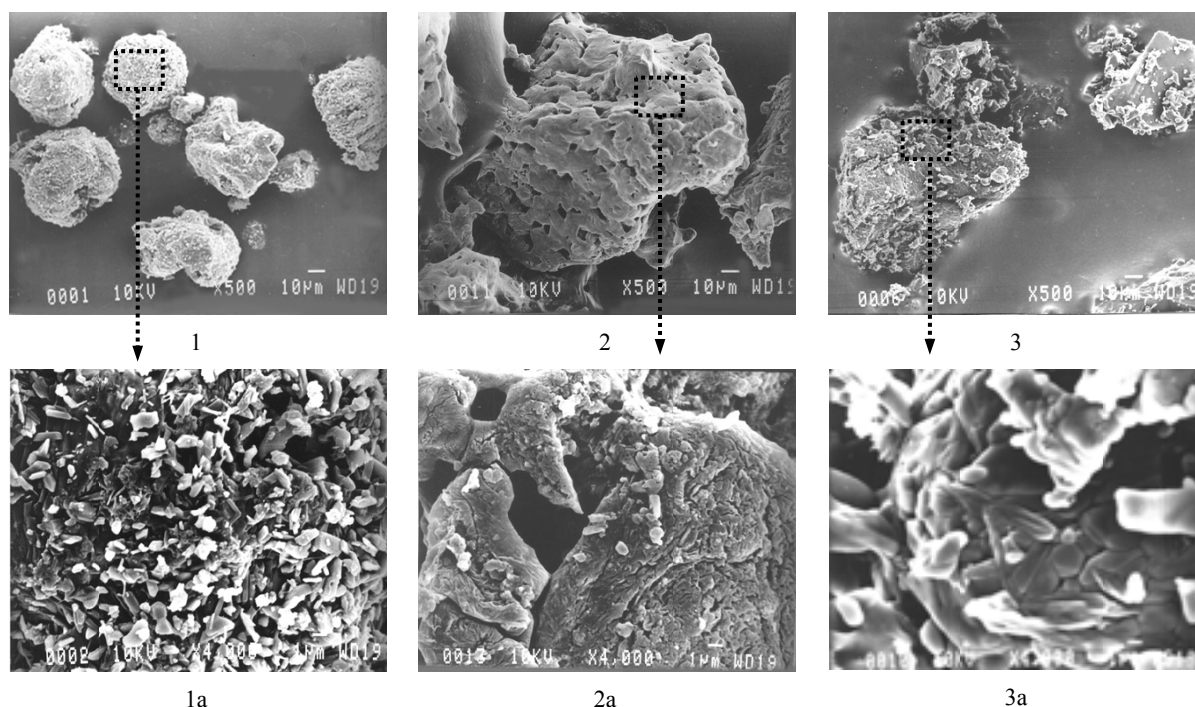


Figure 1 – Microstructure of the studied stabilizing salts

In order to more fully determine the differences between the studied milk powder samples, their microstructure was studied. Figure 2 shows electron microscopic photographs of the samples at different magnifications, which make it possible to demonstrate the differences in the structure of objects clearer.

As can be seen from figure 2, numerous globular particles with varying degrees of dispersion are detected in all tested milk powder preparations. So, in particular, compared with the control (4a and 4b), the DWM1 samples - 1a, 1b, 2a, 2b, 3a and 3b are characterized by larger globule size, which are largely connected to each other by means of connecting “bridges”. The presence of the latter causes the formation of a more coherent structure consisting of “conditional agglomerates”, which, in turn, has a positive effect on the rate of DWM dissolution process. In the control sample – 4a and 4b, as well as in DWM2 samples, a significant proportion of the particles is in free, unrelated state and only a small part is combined with each other. At the same time, a smaller globule size was observed for these samples. In accordance with the microstructural studies results, a satisfactory salt dispersion was revealed in DWM2 samples. Figure 2 part 5a and 5b shows the appearance of stabilizer salt particle on a dry milk globule, which clearly demonstrates the possibility of their identification in product mass.

Results of DWM dispersion, obtained by sieve method are shown in figure 3.

Analysis of the actual particle's distribution in DWM indicates a significant difference in the particle size distribution of the experimental products as compared with the control samples. It is noted that in all experimental samples the number of particles with sizes greater than 0.25 mm significantly exceeds the control ones. The highest level of passive agglomeration was found in DWM with polyphosphate salt. Has been established the dust fraction reduction in all DWM with salts, which implies a reduction in losses during drying process.

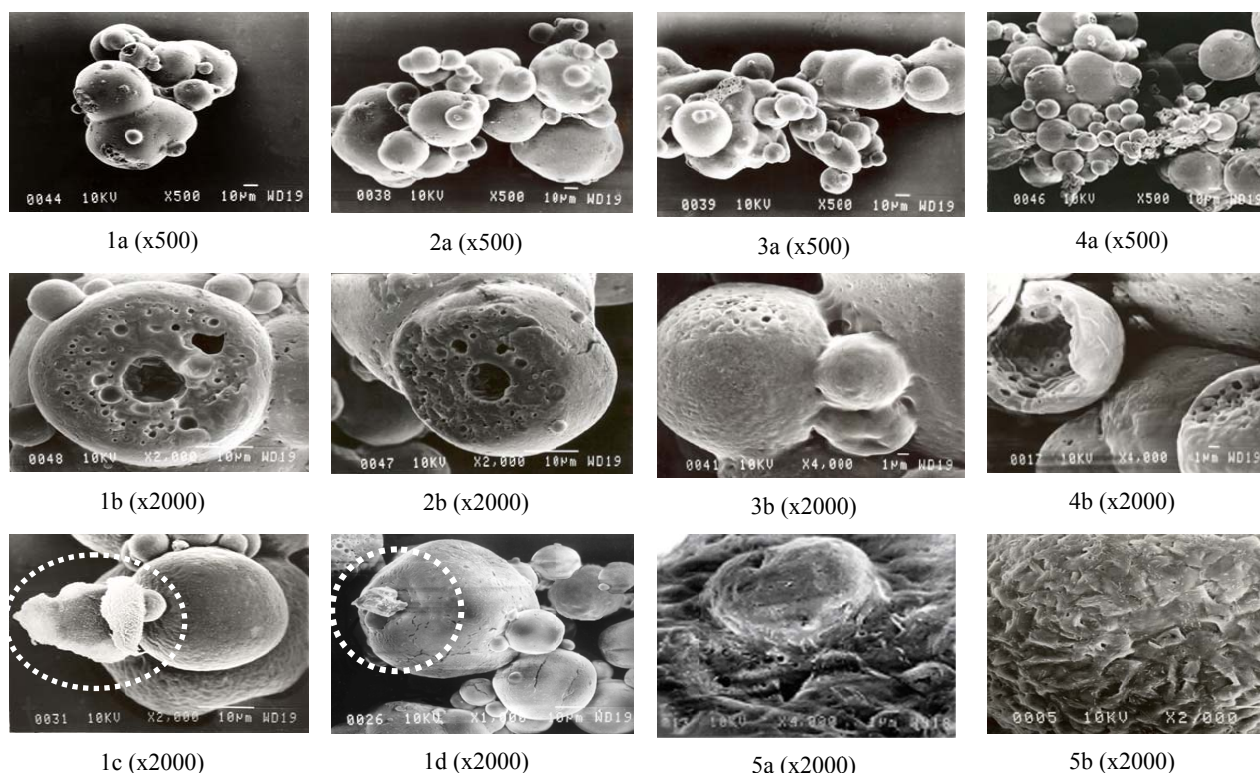
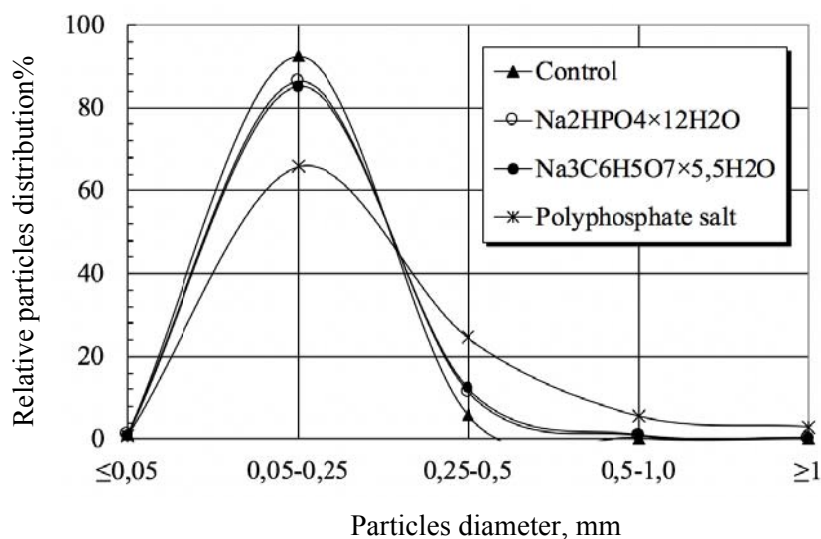


Figure 2 – Microstructure of the studied DWM samples:

1 – DWM with polyphosphate salt, 1a and 1b drying, 1c and 1d – dry mixing, a dotted line indicates salt particle on globule;
 2a and 2b – DWM with $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5,5\text{H}_2\text{O}$ drying; 3a and 3b – DWM with $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ drying;
 4a and 4b – control salt-free DWM; 5a – typical surface of control salt-free DWM; 5b – typical surface of DWM with salts



Analysis product	Regression equation	Equation coefficients, correlations, and standard errors
DWM – salt-free control	Vapor Pressure Model: $y = \exp(a + b/x + c \ln(x))$	$a=42.40$; $b=-42.28$; $c=24.17$; $S=0.383$; $r=0.99$
DWM with $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$	Rational Function: $y = (a + bx) / (1 + cx + dx^2)$	$a=0.36$; $b=-0.02$; $c=-0.85$; $d=0.17$; $S=0.388$; $r=0.99$
DWM with $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5,5\text{H}_2\text{O}$		$a=0.26$; $b=0.05$; $c=-0.85$; $d=0.17$; $S=0.143$; $r=0.99$
DWM with polyphosphate salt		$a=-0.64$; $b=0.92$; $c=-0.86$; $d=0.19$; $S=0.142$; $r=0.99$

Figure 3 – Granulometric composition of the analyzed DWM samples

The introduction of stabilizing salts a priori has a significant effect on milk powder thermal stability during heat treatment and post-technological storage.

Since the results of a set of controlled DWM indicators revealed the greatest efficiency from the use of polyphosphate salt, below (figure 4) shows the results of the thermal stability formation ($0 \rightarrow 0'$) and its kinetics in storage at $t_x (6 \pm 2)^\circ\text{C}$ for DWM developed with use of this salt.

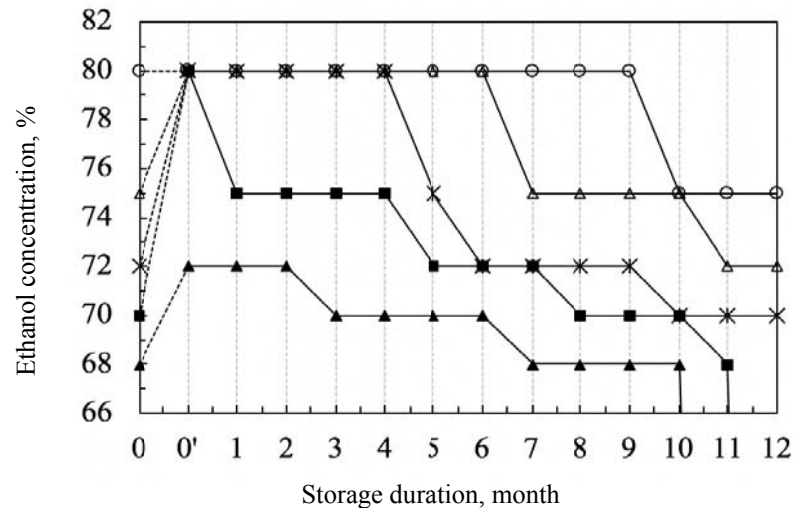


Figure 4 – Formation ($0 \rightarrow 0'$) and dynamics in storage ($0' \rightarrow 12$) T-in CMS with polyphosphate salt

It has been established that the use of polyphosphate salt contributes to an increase in thermal stability in the raw material – product chain ($0 \rightarrow 0'$) by 1–3 groups and forms its high value during storage. Similar studies of DWM with control salts showed a lower effectiveness of indicator initial growth (on average no more than 1 group) and a greater quality loss in storage. It is noted that the use of $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ and $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5,5\text{H}_2\text{O}$ with the initial value of thermal stability at the level of groups I-II is not rational.

The results of solubility index kinetics during storage of the control and experimental DWM samples are shown in figure 5.

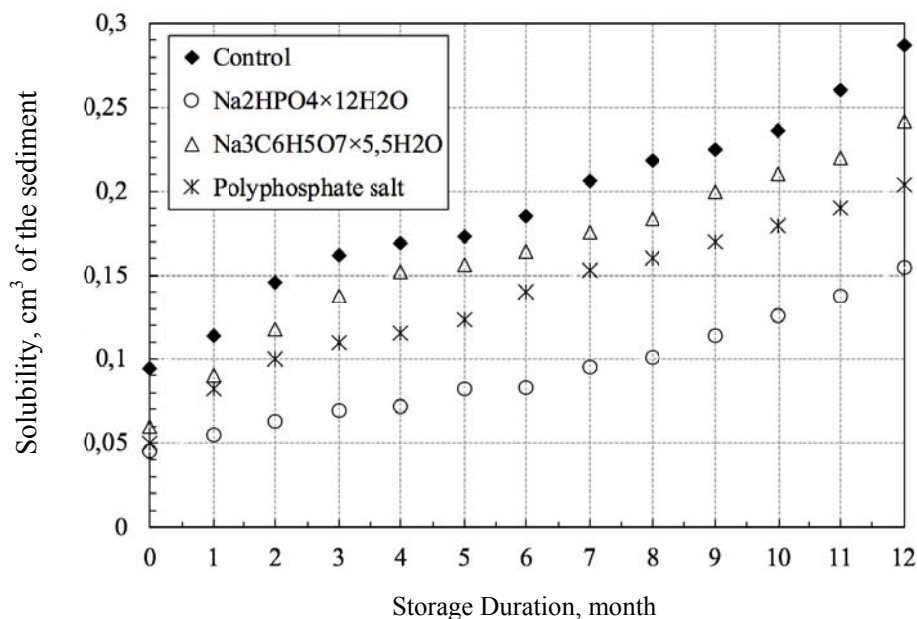


Figure 5 – Patterns of experimental DWM solubility dynamics when stored for 12 months at a temperature of $(6 \pm 2)^\circ\text{C}$

These dependences confirm the effectiveness of salts use, which were further confirmed by data on the viscosity kinetics of the reconstituted DWM samples during storage. So, at the beginning and at the end of the storage, the relative viscosity growth for the control (c) and experimental (e) samples was as follows: DWM-c + 27.93%, DWM-e + 9.3%. Consequently, the use of salt in DWM technology makes it possible to significantly stabilize their protein fraction.

Findings. The carried out complex of studies has made it possible to establish that the introduction of salt-stabilizers has a significant effect on the change in the basic functional and technological DWM properties. Analysis of experimental material, obtained for all indicators studied during the work, allows us to recommend the use of complex phosphate salts in DWM technology. At the same time, it should be noted that DWM samples with salts, obtained by introducing them into normalized milk and its subsequent drying, surpass samples with similar salts, obtained by dry mixing, in their qualitative characteristics. This is due to more intense mechanism stabilizing salts effect on milk protein complex before drying.

The obtained data are taken into account in the recommendations on the principles of the directed dry milk products quality indicators formation for producers and processors of this products group.

А. Г. Галстян¹, С. Н. Туровская², А. Е. Рябова¹, Е. Е. Илларионова²,
В. К. Семипятный¹, И. А. Радаева², А. Н. Петров³, Д. Е. Нурмуханбетова⁴, Э. К. Асембаева⁴

¹Бүкілресейлік сыра қайнату, алкогольсіз және шарап өнеркәсібі ғылыми-зерттеу институты – ФМБС филиалы В. М. Горбатов атындағы «Азық-түлік өнімдерінің федералдық ғылыми орталығы» РҒА, Мәскеу, Ресей,

²ФМБҒМ «Бүкілресейлік сүт өнеркәсібі ғылыми-зерттеу институты», Мәскеу, Ресей,

³«Бүкілресейлік консервілеу технологиясы ғылыми-зерттеу институты» ФМБҒМ В. М. Горбатов атындағы филиал ««Азық-түлік өнімдерінің федералдық ғылыми орталығы» РҒА, Мәскеу, Ресей,

⁴Алматы технологиялық университеті, Алматы, Қазақстан

ТЕХНОЛОГИЯЛЫҚ ҚОСПАЛАРДЫ ТІКЕЛЕЙ ЕНГІЗУ ЖОЛЫМЕН ҚҰРҒАҚ СҮТТІҢ ҚАСИЕТТЕРІН ҚАЛЫПТАСТЫРУ

Аннотация. Тамақ өнеркәсібінің қазіргі заманғы дамуын тағамдық қоспаларды пайдаланусыз мүмкін емес. Оларды пайдалану дайын өнімнің сапасын жақсартуға, тұтынушыға тартымды қасиеттермен қамтамасыз етуге, сақтау мерзімін ұзартуға, тасымалдау кезінде шығындарды азайтуға, жеткізудің географиясын кеңейтуге, технологиялық үдерістерді жеделдету және т.б. мүмкіндік береді. Орындалған зерттеулер тұрақтандырғыш тұздардың енгізілуі толыққанды құрғақ сүттің негізгі функционалдық және технологиялық қасиеттерінің өзгеруіне айтарлықтай әсер ететінін анықтауға мүмкіндік берді. Жұмыста зерттелген барлық көрсеткіштер үшін алынған эксперименттік материалдарды талдау кешенді фосфат тұздарын толыққанды құрғақ сүт технологиясында қолдануға ұсынуға мүмкіндік береді. Сонымен қатар, нормаланған сүтке енгізілген және одан кейінгі кептіру арқылы алынған тұзы бар толыққанды құрғақ сүт үлгілері, сапалық сипаттамалары бойынша ұқсас тұздарды құрғақ араластыру арқылы алынған сүт үлгілерінен асып кететінін атап өткен жөн. Бұл тұрақтандырғыш тұздардың сүтті-ақуыздық кешенге кептіруден бұрынғы әсерін тигізетін қарқынды механизміне байланысты.

Түйін сөздер: құрғақ сүт, тағамдық қоспалар, технология, сапа, сақтау кезіндегі динамика.

А. Г. Галстян¹, С. Н. Туровская², А. Е. Рябова¹, Е. Е. Илларионова²,
В. К. Семипятный¹, И. А. Радаева², А. Н. Петров³, Д. Е. Нурмуханбетова⁴, Э. К. Асембаева⁴

¹Всероссийский научно-исследовательский институт пивоваренной, безалкогольной и винодельческой промышленности – филиал ФГБНУ «ФНЦ пищевых систем им. В. М. Горбатова» РАН, Москва, Россия,

²ФГАНУ «Всероссийский научно-исследовательский институт молочной промышленности», Москва, Россия,

³Всероссийский научно-исследовательский технологий консервирования – филиал ФГБНУ «ФНЦ пищевых систем им. В. М. Горбатова» РАН, Москва, Россия,

⁴Алматинский технологический университет, Алматы, Казахстан

ФОРМИРОВАНИЕ СВОЙСТВ СУХОГО МОЛОКА ПУТЕМ НАПРАВЛЕННОГО ВВЕДЕНИЯ ТЕХНОЛОГИЧЕСКИХ ДОБАВОК

Аннотация. Современное развитие пищевой промышленности немислимо без использования пищевых добавок. Их применение позволяет улучшить качество готовой продукции, придать ей привлекательные для потребителя свойства, увеличить срок годности, сократить потери при транспортировке, расширить геогра-

фию поставок, ускорить технологические процессы и др. Выполненные исследования позволили установить, что введение солей-стабилизаторов оказывает существенное влияние на изменение основных функционально-технологических свойств сухого цельного молока. Анализ экспериментального материала, полученного по всем показателям, изученным в ходе работы, позволяет рекомендовать использование комплексных фосфатных солей в технологии сухого цельного молока. В то же время следует отметить, что образцы сухого цельного молока с солями, полученные путем введения их в нормализованное молоко и его последующей сушки, по своим качественным характеристикам превосходят образцы с аналогичными солями, полученными сухим смешиванием. Это связано с более интенсивным механизмом воздействия стабилизирующих солей на молочно-белковый комплекс перед сушкой.

Ключевые слова: сухое молоко, пищевые добавки, технология, качество, динамика при хранении.

Information about authors:

Galstyan Aram Genrikhovich, Head of the Interbranch Scientific and Technical Center for Food Quality Monitoring, Doctor of Technical Science, Professor of RAS, Corresponding Member of RAS, All-Russian Scientific Research Institute of Brewing, Non-Alcoholic and Wine Indus – branch of the Gorbатов's Federal Scientific Center of Food Systems of RAS; 9795029@mail.ru; <https://orcid.org/0000-0002-0786-2055>

Turovskaya Svetlana Nikolaevna, Senior Researcher of the Laboratory of Dairy Preserved Foods, All-Russian Research Institute of Dairy Industry; conservlab@mail.ru; <https://orcid.org/0000-0002-5875-9875>

Ryabova Anastasia Evgenievna, Senior Researcher of the Interbranch Scientific and Technical Center for Food Quality Monitoring, PhD, All-Russian Scientific Research Institute of Brewing, Non-Alcoholic and Wine Industry – branch of the Gorbатов's Federal Scientific Center of Food Systems of RAS; anryz@hotmail.com; <https://orcid.org/0000-0002-5712-2020>

Illarionova Elena Evgenievna, Researcher of the Laboratory of Dairy Preserved Foods, All-Russian Research Institute of Dairy Industry; conservlab@mail.ru; <https://orcid.org/0000-0002-9399-0984>

Semipyatniy Vladislav Konstantinovich, Senior Researcher of the Interbranch Scientific and Technical Center for Food Quality Monitoring, PhD, All-Russian Scientific Research Institute of Brewing, Non-Alcoholic and Wine Industry – branch of the Gorbатов's Federal Scientific Center of Food Systems of RAS; semipyatniy@gmail.com; <https://orcid.org/0000-0003-1241-0026>

Radaeva Iskra Alexandrovna, Chief Researcher of the Laboratory of Dairy Preserved Foods, All-Russian Research Institute of Dairy Industry; conservlab@mail.ru; <https://orcid.org/0000-0002-1920-0577>

Petrov Andrey Nikolaevich, Director of All-Russian Scientific Research Institute of Technology of Preservation – Branch of the V. M. Gorbатов Federal Research Center for Food Systems of RAS, Doctor of Technical Science; vniitek@vniitek.ru; <https://orcid.org/0000-0001-9879-482X>

Nurmukhanbetova Dinara Erikovna, candidate of engineering sciences, acting associate professor, Almaty technological university, Department of Food safety and quality; dinar2080@mail.ru; [orcid.org /0000-0002-8939-6325](https://orcid.org/0000-0002-8939-6325)

Assembayeva Elmira Kuandykovna, Master of Technical Sciences, Senior Lecturer, Almaty technological university, Department of Food Biotechnology; elmiraasembaeva@mail.ru; orcid.org/0000-0001-7964-7736

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**D. V. Karpenko¹, M. V. Gernet^{1, 2}, E. V. Krjukova¹, I. N. Gribkova²,
D. E. Nurmukhanbetova³, E. K. Assembayeva³**

¹Federal State Budgetary Institution of Higher Education "Moscow State University of Food Production",
Moscow, Russia,

²Federal State Budget Scientific Institution "All-Russian Research Institute of Brewing, Non-Alcoholic and
Wine Industry – branch of the Gorbатов's Federal Research Center of Food Systems of RAS", Moscow, Russia,

³Almaty technological university, Almaty, Kazakhstan.

E-mail: doka.65@mail.ru, institut-beer@mail.ru, kryukovae@gmail.com, dinar2080@mail.ru,
elmiraasembaeva@mail.ru

ACOUSTIC VIBRATION EFFECT ON GENUS *SACCHROMYCES* YEAST POPULATION DEVELOPMENT

Abstract. The intensive development of yeast populations determines the technological and economic efficiency of food and microbiological productions. Because of this, a large number of methods for the microbial biomass accumulation processes intensification have been developed and applied in industrial practice. The literature data analysis demonstrates that for the activation of biological, biochemical or other nature objects, the use of various types of effects is proposed: electromagnetic waves and electric field, laser and X-rays, electron-ion processing, microwave energy, ultrasound, ultraviolet rays, photoactivation, mechanical-acoustic treatment. However, the effect of inoculating yeast pretreatment by acoustic vibrations – by the audible range sound – with a fixed frequency practically has not been studied. The aim of our work was to determine such influence on the development of bottom-fermenting brewer's yeast populations and, subsequently, their technological characteristics.

For processing of the yeast with the audible range sound, a 3-watt PC column was used, which, in addition to acoustic, also generated electromagnetic vibrations.

To take into account their impact on the monitored indicators, a comparison variant was used in which the yeast was exposed only to electromagnetic oscillations, for which purpose the same column with a damaged diffuser was used. The yeast was treated with a sound of fixed frequency using the "Generator" program for a certain time with an amplitude of 100% and a sinusoidal waveform. The distance between the speaker and the object to be processed was 3 cm. The processing of the experimental variant was carried out in a soundproofed cell at room temperature. Yeast that was not subjected to sound and/or electromagnetic vibrations was used as a control. To assess the effect of acoustic and electromagnetic vibrations on yeast, the yeast populations of all three variants were cultivated - the control, experimental, and comparison – on a 5% sucrose solution for 3 days at 25-28 °C. Immediately after substratum inoculation, every day, and also at the end of cultivation, the total cell titer, the percentage of dead cells and the concentration of solids were determined. As a result of the research, a significant effect of acoustic treatment on the yeast populations development was revealed, and depending on the frequency of the sound, such treatment can be either positive or negative. The treatment only by electromagnetic vibrations had an effect on controlled indicators that was less pronounced and, at many frequencies, was different from that in sound processing, both in magnitude and in direction. It was established that the acoustic impact at rational parameters can be technologically expediently for yeast generation and for the activation of the main fermentation.

Keywords: treatment of yeast with a sound of audible range, treatment of yeast with electromagnetic vibrations, increasing the total titer of yeast cells, intensifying the utilization of dry matter, reducing the number of non-viable cells.

Introduction. When conducting technological processes based on the use of yeast, the intensification of the microbial population and/or increasing its productivity development (if yeasts are used as a producer of certain target substances) is the important task.

The traditional approaches to ensuring the specified result are supporting the optimal composition of the nutrient medium, its microbiological purity, rational values of temperature and pH, the use of stimulants/growth promoters. However, at present, when working with well-studied yeast strains, the potential of such approaches is almost exhausted. Genetic modification, which improves the yeast's desired technological characteristics, opens up significant prospects, but the use of genetically modified yeasts and, more generally, GMOs in food production causes a wary attitude among a number of food products consumers.

Because of this, in the last decades research on the possibility of yeast populations development activating by pretreatment with impacts of different types are being conducted. In particular, it can be wave/field effects. The aim of our work was to study the results of the effect of the audible range sound with a fixed wavelength on the technological characteristics of the brewing yeast.

Literature review. Information about the results of the some types of waves and fields impact on different levels of organization objects is quite extensive. Thus, it is reported about the possibility of accelerating the barley grains germination due to pretreatment with ultrasonic waves [1]. Barley certainly belongs to a different level of living matter organization compared to yeast, however, the data presented in the paper prove the possibility of biological objects ultrasonic treatment not only for the purpose of their structures suppression or destruction [2, 3], but, on the contrary, to activate their metabolic processes. The possibility of such treatment effective use, including for the seeds stimulation before sowing, is confirmed by data published in a number of other sources [4-6].

The yeast ultrasonic processing used in alcohol production have been studied, also [7]. It has been established that at constant ultrasound power and frequency, by varying only the duration of exposure, it is possible, by treating the yeast biomass before seeding, to activate the population development, and at the end of the process by repeated (longer) ultrasound treatment to reduce the number of viable cells significantly.

The food production thermotechnical processes in the electromagnetic field of ultra-high frequencies (microwave) are studied. It has been established that the yeast microwave processing efficiency used in the fermented beverages production may be high, but it depends "on the selectivity of the electromagnetic field energy extraction" by the yeast biomass [8]. In order to maximize the yeast enzymes activity during the alcoholic fermentation cycle and the finished product quality, the brewing yeast pressed mass was subjected to heat treatment for $\tau = 6-15$ s in the electromagnetic field of the microwave (frequency 2375 MHz) to a temperature of $283-3080$ K. It is shown that the brewing yeast treatment with microwave range waves increases their fermentation activity by 265% compared with the control and is significantly more efficient than heating in a thermostat, while it has a much shorter duration. It was established experimentally that the microwave electromagnetic field effect enhances the alcoholic fermentation enzymes synthesis, weakens the yeast cells respiratory enzymes synthesis. According to the authors of the work, the developed method can be used in any industry related to fermentation processes [8]. It is important to note that in order to achieve a positive result, careful selection of microwave treatment parameters is necessary, since the same type of effect with other conditions can be used to effectively suppress of microbial, primarily yeast cells development [9].

A method has been developed for treating brewer's yeast, which stipulates exposure to electromagnetic oscillations of the millimeter wavelength range. It is reported that the fermentation time compared with the control decreased 1.3 times, the fermentation activity increased 1.3 times, the concentrations of diacetyl and aldehydes in the green beer of the experimental irradiated variant were about 1.2 times less than in the control one [10]. The method disadvantages include the possibility of irradiating a yeast suspension small amount in one session only, as well as its complexity.

In another research, it was found that after a seven-time (daily, exposure time 2 hours) exposure to electromagnetic radiation with a wavelength of about 6 mm (frequency is about 50 GHz) of a genus *Endomycopsis* fungus, an increase in culture activity was observed by 50%. Similar results were obtained for brewing yeast: exposure to electromagnetic radiation with a wavelength of about 6 mm non-thermal power level resulted in an yeast fermentation activity increase of 1.2-1.5 times compared to the control (non-irradiated) sample. After a tenfold irradiation with electromagnetic radiation with a wavelength of 6.4 mm of a genus *Aspergillus* fungus suspension, an increase in the activity of the culture in 2-2.5 times was observed [11].

At the same time, a method has been developed to effectively suppress the vital various microorganisms activity with pathogenic properties in relation to the human body, based on the object irradiation with electromagnetic radiation with a frequency of 20–95 GHz with a power flux density of not more than $10 \mu\text{W}/\text{cm}^2$ for at least 20 minutes [12].

The microorganisms biological activity changes that were exposed to magnetostatic wave (MSW) radiation with various parameters for 5 to 60 minutes were studied [13]. Dry baker's yeast and *Saccharomyces bayanus* strain LW 185-25 were subjected to irradiation. It was established that during irradiation in one interval of the MSW the yeast biomass increment increases, while in the other interval it decreases. The increase in the biomass volume in comparison with the control (untreated) sample can be as high as 25%, while the decrease can be equal to 15%. The ultrasound multidirectional effects on microbial cells are confirmed by other authors [14].

The literature provides information [15] on the method of accelerating the microorganisms growth and increasing the microbial biomass yield when cultured on ordinary nutrient media by treating the microbial suspension with laser radiation with a certain power, impulse duration and wavelength.

A patent has been issued for [16] a method for producing highly active streptomycetes strains – avermectin producers by irradiating a spore of a *Streptomyces avermitilis* culture at least once with short-impulse X-rays with certain parameters. It can be assumed that with this method of action, it is not the enzyme systems microorganism-producer activation take place, but mutations in which positive changes in the genome are fixed in cell generations, ensure the production of highly active strains.

A method has been developed to activate the wine yeast populations development as a pretreatment with infrasonic oscillations result [17]. For this, a yeast suspension mixture with a sterile wort is treated by vibration action with a frequency of 5-11 Hz with an oscillation amplitude of 4-5 mm for 15-30 minutes at a yeast suspension and wort ratio 1: 40-50, respectively. The source of vibration action is placed in the volume of the mixture at a distance of $1/3 \div 2/3$ from its surface. This provides an increase in the pure yeast culture cells mass and an increase in the number of active (living) cells in the finished yeast starter, allowing to speed up the wort fermentation process, which leads to a decrease in the duration of the winemaking process.

It should be noted also an indirect method – the use of electrochemically activated systems/solutions – which allows to solve such problems as improving the brewing barley quality, activating malt enzymes, the effect on grain microflora [18].

Another way to affects the biochemical and biological objects in order to improve their characteristics is the acoustic treatment by the sound of the audible range.

As a wave, sound is characterized by amplitude and frequency spectrum. Usually, a person hears sounds in the frequency range from 16-20 Hz to 15-20 kHz. Among the audible sounds should also be distinguished phonetic, speech sounds and phonemes (of which oral speech consists) and musical sounds [19]. Published results prove the possibility of changing the biological objects characteristics at various levels of organization as a result of the action of certain musical compositions or simply voiced fragments of the text, individual words [20-22], and these changes in living systems can have as positive and negative character [23]. The musical composition is based on the use of a broadband frequency range, the individual frequencies of which, hypothetically, can coincide with the resonant frequencies of various biological objects, including cells. From our point of view, it is impossible or, at least, extremely difficult to systematize the effect of acoustic vibrations on biological objects by studying the effects of melodies.

The possibility of changing the raw materials technological parameters and semi-products of various, including food, industries with fixed-frequency sound was demonstrated by a number of studies [24-26].

The reasonability of studying the audible range sound effect on the yeast is confirmed, in our opinion, by the research results previously conducted at the Moscow State University of Food Production [27-30]. Based on them, it was concluded that sound processing with frequencies from the range of 20–20,000 Hz provides a significant increase in the target enzymes activity microbial enzyme preparations, hop and light barley malt extractability. Additional confirmation of the yeast activation method perspectivity by sound treatment are data [31], according to which the positive effect was achieved by treating the cell suspension with a sound with frequencies of 20–20,000 Hz in a rotary pulsation apparatus together with the use of the activation medium.

A priori, modern technologies assume the presence of complex process solutions. This applies to the technology of drinks from animal and vegetable raw materials, general and special purpose. Accordingly, there is a need to expand the scope of evaluation criteria of quality [32-41].

It seemed to us expedient to assess the effect on the *Saccharomyces cerevisiae* yeast population, used for the production of bottom-fermenting beer, of the fixed frequency sound of the audible range only.

Methods. Dried yeast *Saccharomyces cerevisiae* species S was used as test objects.

A sterilized 5% sucrose solution was used as a nutrient medium.

The yeast was cultured in flasks of 250 cm³ with 100 cm³ of the nutrient medium statically, without stirring at 26–28 °C.

The development of populations was evaluated by the change in cultures of the yeast cells total titer, the solids content, and by the non-viable cells proportion, also. The controlled characteristics values in the experimental variants were expressed in relation to the control (unprocessed by sound), taken as 100 %.

Dried yeast was processed by sound in a soundproofed cell for 60 min (unless otherwise indicated) at room temperature.

The sound of a certain frequency was generated using a 3-watt PC speaker using the “Generator program”; the waveform was sinusoidal.

In view of the fact that sound was generated in the PC speaker due to electromagnetic oscillations, the acoustically processed object was also subjected to the effects of these electromagnetic oscillations (EMO). In order to evaluate the contribution of the EMO to possible changes in the controlled characteristics of the processed yeast, comparison samples were used, which were similar weights of yeast, which were located at the same distance as in the experimental sample, near the PC speaker with a purposely damaged diffuser that did not generate sound.

The yeast cells total titer was determined by counting in the Gorjaev’s chamber.

Non-viable cells were determined by staining with methylene blue solution (Fink suspension).

The concentration of dry matter (DM) in solutions was determined pycnometrically.

The replication of experiments at all stages of the experiment – not less than 3. The results of experimental studies were processed by methods of mathematical statistics using Student's criterion.

Results. The preliminary acoustic treatment effect on the dried *Saccharomyces cerevisiae* species S brewer's yeast populations development was studied. The acoustic treatment impact on the yeast populations development in the first series of experiments was assessed by the change in dry matter concentration in the nutrient medium, the increase in total yeast cell titer and the non-viable yeast cells proportion.

At the first stage of our research, the problem of determining the presence or absence of the fixed frequencies sound influence from the range of 20–20,000 Hz generated by an acoustic column, as well as electromagnetic oscillations (EMO) arising for the generation of certain frequency sound on the population brewing yeast development in a model nutrient medium (5% sucrose solution) was solved. In case of revealing the existence of such an effect, the goal was to determine the most effective for yeast population activation frequencies. In these experiments, the following calculation was used to assess the change (decrease) in the sugar concentration in the culture medium: the sucrose concentration decreases in the experimental sample (pre-pitching sound processing of yeast) and a reference sample (pre-pitching processing by EMO) for the entire cultivation period (3 days at 25–30 °C) were expressed as a percentage relative to the value of the same indicator in the control (pitching yeast, not subjected to any processing), taken as 100% (table).

Based on the experimental data, a significant dependence of the controlled parameters on the processing of pitching yeast both by sound and electromagnetic oscillations was revealed. Depending on the frequency, the preliminary processing under the experimental conditions led to both intensification and inhibition of the development of the brewing yeast population. The greatest decrease in the sucrose content in the cultivation medium in comparison with the control was recorded in the samples after sound processing with frequencies of 6000, 8000, 9000, 12000, 17000 and, especially, 19000 Hz. The largest increase in total cell titer compared with the control was observed in the experimental samples obtained after exposure to sound with frequencies of 8000, 9000, 12000 and 17000 Hz.

However, at most of the sound frequency indicated values, an increase in the non-viable cells proportion was observed compared to the control. In addition, in the experimental sample obtained after

The effect of sound processing of pitching yeast on the cultural fluid indicators after 3 days of cultivation

Frequency, Hz	The decrease in the concentration of DM, % of the control		The increase in cell titer, % to control		Non-viable cells, % of control	
	Sound	EMO	Sound	EMO	Sound	EMO
20	84.2±2.6	110.5±3.3	111.3±6.2	23.5±2.2	113.6±3.3	179.0±3.1
1000	40.7±1.7	100.0±1.9	56.1±3.1	45.5±3.2	59.2±1.8	111.7±3.3
2000	65.0±2.2	77.5±2.0	105.4±4.8	76.6±3.5	95.6±2.6	89.4±2.4
3000	107.3±3.4	107.3±2.3	111.4±4.1	101.4±5.1	74.3±3.1	72.8±2.6
4000	88.4±3.0	53.6±1.4	86.6±3.4	80.8±3.9	86.0±3.7	89.8±3.3
5000	51.7±2.1	117.2±3.4	117.7±4.4	117.7±4.1	61.0±3.1	57.1±2.1
6000	143.1±4.1	92.2±3.0	84.4±3.7	118.1±4.3	86.7±2.9	97.2±3.2
7000	94.9±2.2	179.5±4.1	76.4±4.3	99.5±3.9	92.0±2.8	85.5±3.4
8000	118.4±5.9	120.4±1.2	145.9±4.4	160.5±5.3	92.0±3.2	113.6±2.7
9000	128.9±4.3	133.3±3.3	133.3±5.9	141.5±5.1	95.6±2.9	83.9±2.7
10000	45.5±0.9	54.6±1.9	79.4±3.7	88.6±3.8	110.4±3.3	108.6±3.1
11000	68.2±1.4	90.9±2.1	115.7±5.0	99.0±3.6	88.8±2.7	93.0±2.9
12000	300.0±4.7	115.8±3.4	142.4±4.8	138.2±4.4	103.8±2.6	97.1±2.8
13000	85.7±1.7	117.9±3.2	119.0±5.2	116.7±4.1	108.9±3.1	115.1±1.9
14000	88.9±2.3	100.0±2.8	113.1±4.1	151.4±4.9	129.6±3.9	109.3±0.7
15000	100.0±1.7	225.0±4.7	92.9±3.2	97.1±2.8	96.2±2.8	101.2±2.2
16000	78.9±2.0	73.7±0.9	86.4±2.7	100.4±3.7	101.8±3.0	95.4±1.9
17000	178.6±3.4	121.4±2.0	123.1±5.6	127.8±4.5	113.1±2.7	105.1±2.4
18000	70.0±1.1	60.0±1.5	93.1±4.9	78.5±3.5	104.3±1.9	101.1±3.6
19000	310.0±4.6	180.0±4.1	80.5±3.7	108.3±4.2	95.1±2.1	98.1±1.8
20000	107.7±3.2	46.2±2.3	93.8±3.6	82.7±3.7	103.4±2.2	101.4±2.6

preliminary sound processing at the frequency of 3000 Hz there was an improvement in all three controlled indicators, although it was not as significant as the increase in individual characteristics of other samples mentioned above. It should be noted that the pitching yeast EMO processing was on average less effective than sound one.

Because of this, at the next stage of work, it was decided to carry out clarifying experiments, the conditions of which were similar to the previous one, except that the cultivation period was 4 days. Besides, it was decided to refuse to set comparison samples (preprocessing by EMO). The value of the DM concentration loss in the experimental sample was expressed as a percentage relative to the value of a similar indicator in control sample on the same day of cultivation, and not at the end of the process. The sound processing was performed at the frequencies of 3000, 8000, 9000, 12000, 17000 and 19000 Hz. The results are shown in figure 1–3.

This series of experiments results, from our point of view, show that the most expedient is the preliminary sound processing of pitching yeast at frequency of 3000 Hz (curve 1). In this case after 4 days of cultivation the most intensive sucrose utilization from the nutrient medium was observed, as well as the smallest non-viable cells proportion, although from the point of view of biomass accumulation, sound effects with frequencies of 8000 and 12000 Hz (curves 2 and 4, respectively). Because of this, it was decided to use the sound frequency equal to 3000 Hz at the next stages of our work as a “starting point” when searching for rational parameters of pitching yeast acoustic processing in order to intensify the development of their population.

To solve the problem, experiments were carried out in which different parameters of acoustic treatment were varied. Under the experimental conditions, the best results were ensured by the sound processing of dry pitching yeast with the following parameters: sound frequency 2765 Hz; processing time 30 minutes; the distance between the processed sample of the yeast and the sound source is 5 cm; the amplitude of sound vibrations is 100%.

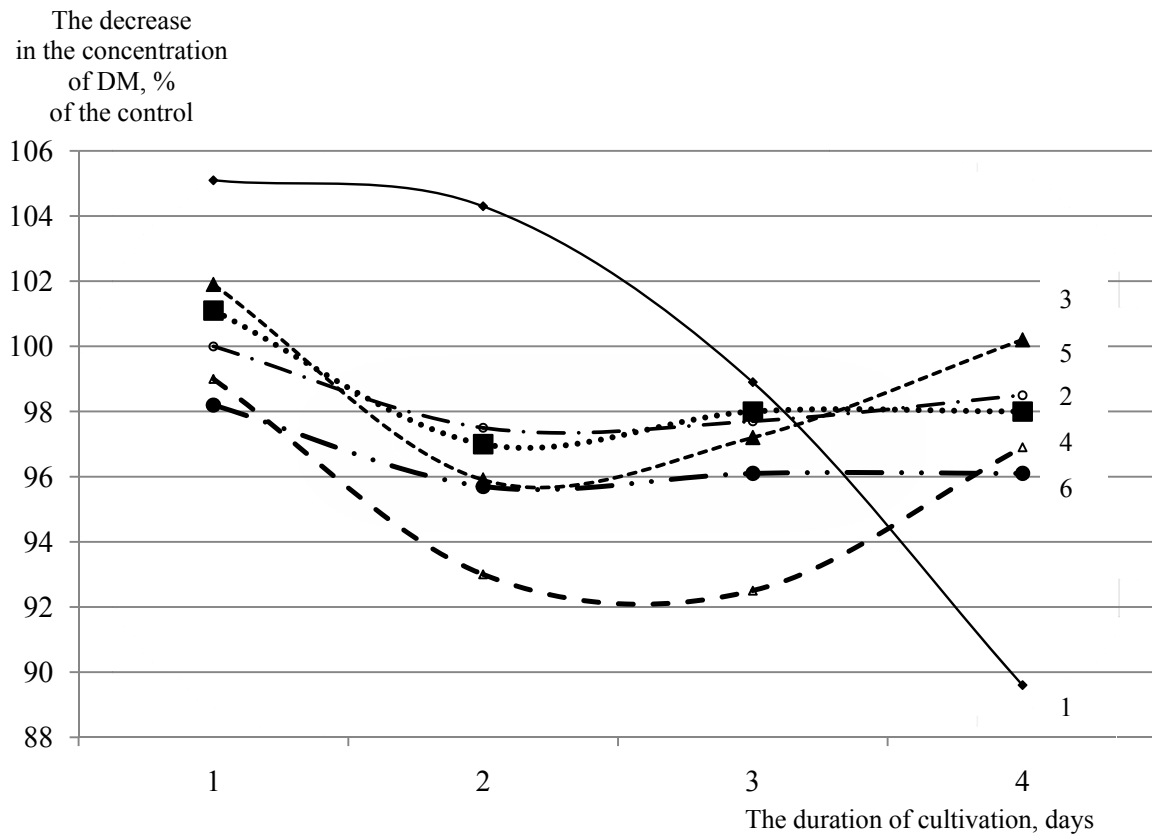


Figure 1 – The effect of processing by the different frequencies sound on the change in the dry matters concentration in the nutrient medium
(sound frequency: 3000 Hz - 1; 8000 Hz - 2; 9000 Hz - 3; 12000 Hz - 4; 17000 Hz - 5; 19000 Hz - 6)

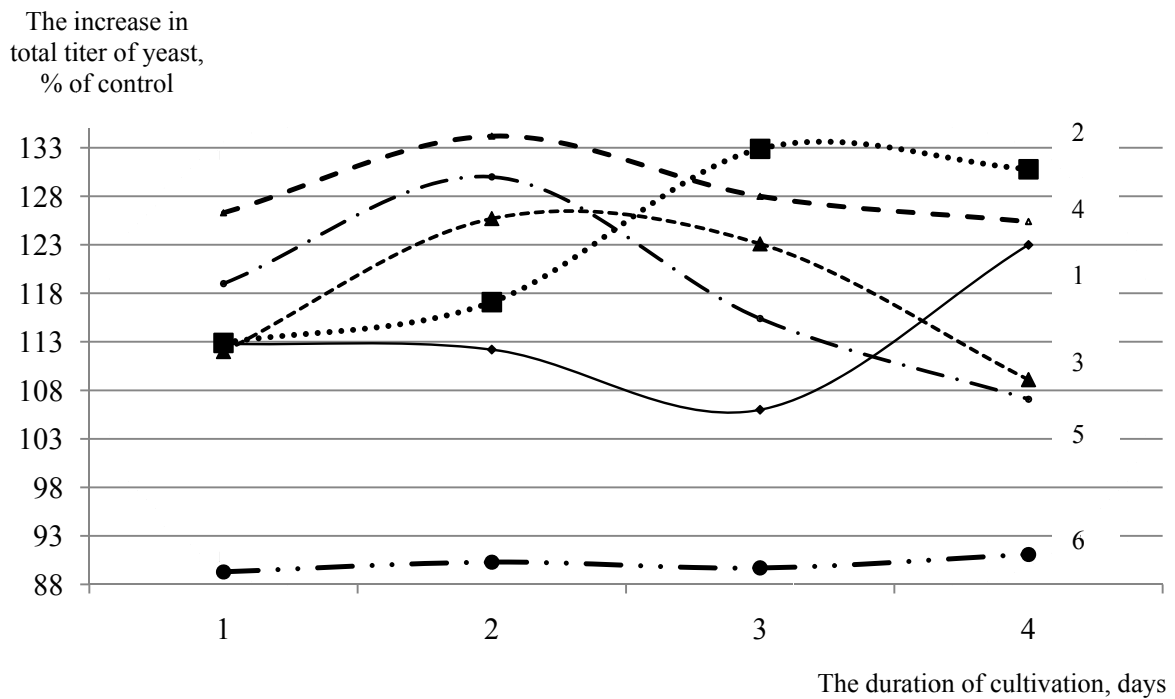


Figure 2 – The effect of processing by the different frequencies sound on the change in the yeast cells total titer increase
(sound frequency: 3000 Hz - 1; 8000 Hz - 2; 9000 Hz - 3; 12000 Hz - 4; 17000 Hz - 5; 19000 Hz - 6)

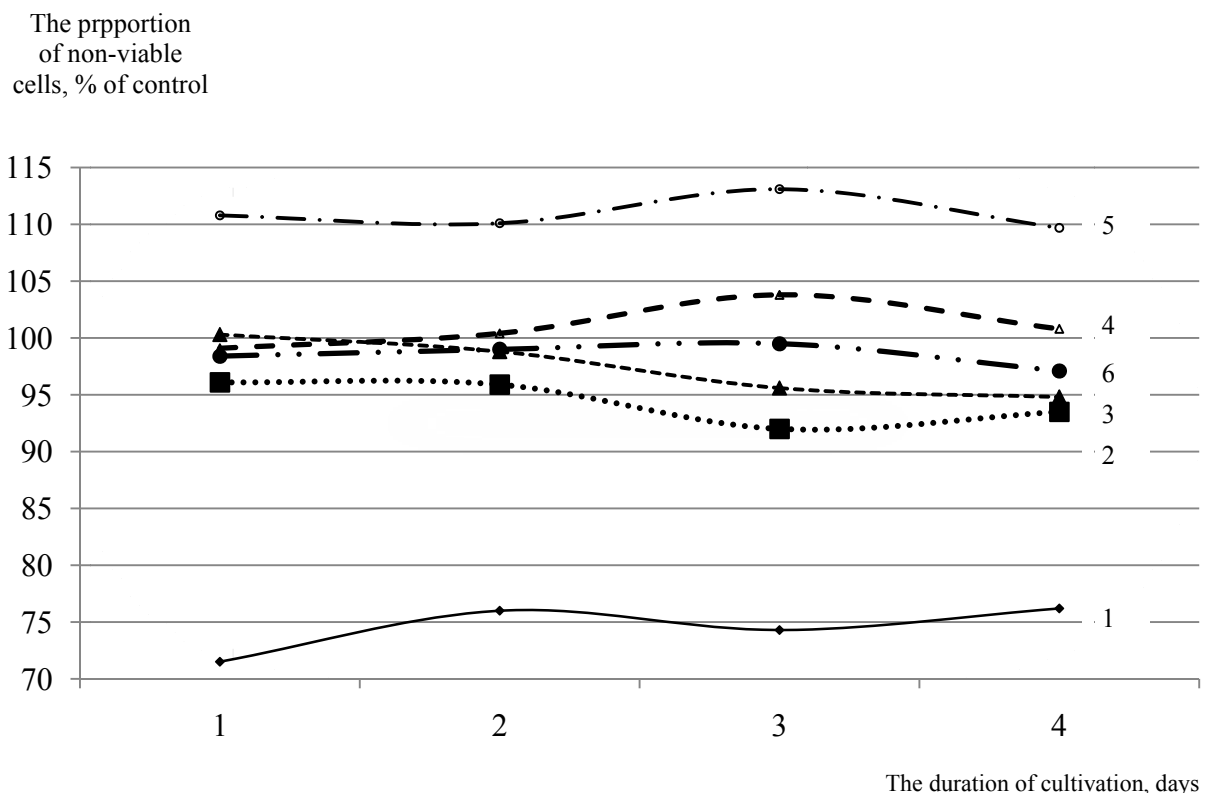


Figure 3 – The effect of processing by the different frequencies sound on the change in the non-viable yeast cells proportion
(sound frequency: 3000 Hz - 1; 8000 Hz - 2; 9000 Hz - 3; 12000 Hz - 4; 17000 Hz - 5; 19000 Hz - 6)

Discussion. Analyzing all the above experimental data, we can make a number of conclusions:

An audible range sound generated by a device for converting electrical signals into acoustic signals and emitting them into the surrounding space, used for yeast processing before introducing them into the nutrient medium, in particular, beer wort, can have both positive and negative effects on the development of a bottom-fermenting yeast population, as well as on the ethanol accumulation in the alcoholic fermentation process; The direction and intensity of influence depends on the sound frequency and some other parameters of acoustic processing.

Electromagnetic oscillations applied to the pitching yeast processing also have a multidirectional effect on the results of cultivation the microbial population, however, for the most part, less pronounced than the audible sound.

The results of the discussed and previous studies, as well as literature information suggest that at least one of the sound influence mechanisms is a change in conformation and, as a consequence, the enzyme molecules activity involved in the yeast metabolic processes, in particular, the alcohol fermentation cycle enzymes.

Acoustic processing parameters that determine its effectiveness in terms of yeast population development activating are the sound frequency and its amplitude, the processing time and the distance from the sound source to the object being processed.

The audible range sound acoustic processing while establishing rational parameters of its implementation can provide both technological and economic effect during yeast generation or at the stage of main fermentation of the brewing industry. It is also of great importance in other fermented beverages technology, including on vegetable raw material beverage [32, 33].

Д. В. Карпенко¹, М. В. Гернет^{1,2}, Е. В. Крюкова¹, И. Н. Грибкова²,
Д. Е. Нурмуханбетова³, Э. К. Асембаева³

¹«Мәскеу мемлекеттік тағам өндірісі университеті»

Федералды мемлекеттік бюджеттік жоғарғы білім беру мекемесі, Мәскеу, Ресей,

²Бүкілресейлік сыра қайнату, алкогольсіз және шарап өнеркәсібі ғылыми-зерттеу институты –
ФМБС филиалы В. М. Горбатов атындағы «Азық-түлік өнімдерінің федералдық ғылыми орталығы» РҒА,
Мәскеу, Ресей,

³Алматы технологиялық университеті, Алматы, Қазақстан

АКУСТИКАЛЫҚ ТЕРБЕЛІСТЕРДІҢ АШЫТҚЫ *Saccharomyces* ТУЫСЫНЫҢ ПОПУЛЯЦИЯСЫНА ӘСЕРІ

Аннотация. Ашытқы популяцияларының қарқынды дамуы азық-түлік және микробиологиялық өндірістердің технологиялық және экономикалық тиімділігін анықтайды. Осыған орай, өндірістік тәжірибеде микробтық биомасса жинақтау үдерістерін күшейтудің көптеген әдістері әзірленді және қолданылды. Әдеби мәліметтерді талдауға биологиялық, биохимиялық немесе басқа табиғат нысандарын белсендіру үшін толқын немесе өріс әсерінің әртүрлі түрлерін қолдану ұсынылады. Дегенмен, тұқымның ашытқыларын белгілі бір жиіліктегі естілетін диапазон дыбысымен алдын ала өңдеу әсері зерттелмеген. Біздің жұмысымыздың мақсаты осы әсерлердің ашытуда сыра ашытқысының популяциясын дамытуға және одан әрі, олардың технологиялық сипаттамаларына әсерін анықтау болды. Ашытқыны естілетін диапазонмен өңдеу үшін акустикалықпен қатар қосымша генерациялайды және электромагниттік ауытқуларға қуаты 3Вт дербес компьютер колонкасы қолданылды. Олардың бақыланатын көрсеткіштерге әсерін ескеру үшін, ашытқылар тек электромагниттік тербелістерге ғана ұшыраған зарарланған диффузоры бар бір бағанды салыстыру нұсқасы қолданылды. Тәжірибелік нұсқаны өңдеу бөлме температурасында дыбыс өткізбейтін ұяшықта жүргізілді. Бақылау ретінде дыбыс және/немесе электромагниттік ауытқуларға ұшырамаған ашытқы пайдаланылды. Акустикалық және электромагниттік тербелістердің ашытқыға әсерін бағалау үшін барлық үш нұсқадағы ашытқы популяциясы – бақылау, тәжірибелік және салыстыру – 25–28 °C температурда 3 күн бойы 5% сахароза ерітіндісінде өңделді. Қоректік ортаға егілгеннен кейін күн сайын, сондай-ақ өсіру аяқталғаннан кейін дереу жалпы жасуша титрі, өлі жасушалардың пайызы және құрғақ заттар концентрациясы анықталды. Зерттеу нәтижесінде акустикалық өңдеудің ашытқы популяцияларын дамытуға айтарлықтай әсері анықталды және дыбыстың жиілігіне байланысты мұндай әсер оң және теріс болуы мүмкін. Электромагниттік тербелістер арқылы өңдеу тек бақыланатын көрсеткіштерге әсерін тигізді, алайда олардың көпшілігі жиілікте және көлемде де, бағытта да дыбысты өңдеуден ерекшеленді. Рационалды көрсеткіштердегі акустикалық әсер технологиялық тұрғыдан ашытуды генерациялау үшін және негізгі ашытудың белсендіруі мүмкін екендігі анықталды.

Түйін сөздер: ашытқыларды дыбысты диапазонмен өңдеу, ашытқыны электромагниттік тербелістермен өңдеу, ашытқы жасушаларының жалпы титерін арттыру, құрғақ заттарды кәдеге жаратуды арттыру, өмірге қабілетті емес жасушалардың санын азайту.

Д. В. Карпенко¹, М. В. Гернет^{1,2}, Е. В. Крюкова¹, И. Н. Грибкова²,
Д. Е. Нурмуханбетова³, Э. К. Асембаева³

¹Федеральное государственное бюджетное образовательное учреждение высшего образования
"Московский государственный университет пищевых производств", Москва, Россия,

²Всероссийский научно-исследовательский институт пивоваренной, безалкогольной и винодельческой
промышленности – филиал Федерального государственного бюджетного научного учреждения
«Федеральный научный центр пищевых систем им. В. М. Горбатова» РАН, Москва, Россия,

³Алматинский технологический университет, Алматы, Казахстан

ВЛИЯНИЕ АКУСТИЧЕСКИХ КОЛЕБАНИЙ НА РАЗВИТИЕ ПОПУЛЯЦИЙ ДРОЖЖЕЙ РОДА *Saccharomyces*

Аннотация. Интенсивное развитие дрожжевых популяций обуславливает технологическую и экономическую эффективность ряда пищевых и микробиологических производств. В силу этого разработано и применяется в промышленной практике большое количество способов интенсификации процессов накопления микробной биомассы. Анализ литературных данных демонстрирует, что для активации объектов биологической, биохимической или иной природы предлагается использование различных типов волновых или полевых воздействий. Однако воздействие предварительной обработки засевных дрожжей звуком слышимого диапазона с фиксированной частотой практически не изучалось. Целью нашей работы было определение такого воздействия на развитие популяций пивных дрожжей низового брожения и, в дальнейшем, их технологические характеристики. Для проведения обработки дрожжей звуком слышимого диапазона использовали

колонку для ПК мощностью 3 Вт, которая помимо акустических, генерировала еще и электромагнитные колебания. Для учета их воздействия на контролируемые показатели использовали вариант сравнения, в котором дрожжи подвергали воздействию только электромагнитных колебаний, для чего использовали такую же колонку с поврежденным диффузором. Обработку опытного варианта проводили в звукоизолированной ячейке при комнатной температуре. В качестве контроля использовали дрожжи, не подвергавшиеся обработке звуком и/или электромагнитными колебаниями. Для оценки влияния акустических и электромагнитных колебаний на дрожжи проводили культивирование дрожжевых популяций всех трех вариантов – контрольного, опытного и сравнения – на 5 %-ном растворе сахарозы в течение 3 суток при 25–28 °С. Сразу после засева питательной среды, каждые сутки, а также по окончании культивирования определяли общий титр клеток, процент мертвых клеток и концентрацию сухих веществ. В результате исследований было выявлено существенное влияние акустической обработки на развитие дрожжевых популяций, причем в зависимости от частоты звука такое воздействие может быть как положительным, так и отрицательным. Обработка только электромагнитными колебаниями оказывала на контролируемые показатели эффект, менее выраженный и при многих частотах отличный от такового при обработке звуком как по величине, так и по направлению. Установлено, что акустическое воздействие при рациональных параметрах может быть технологически целесообразным для дрожжегенерации и для активации главного брожения.

Ключевые слова: обработка дрожжей звуком слышимого диапазона, обработка дрожжей электромагнитными колебаниями, увеличение общего титра клеток дрожжей, интенсификация утилизации сухих веществ, снижение количества нежизнеспособных клеток.

Information about authors:

Karpenko D. V., doctor of technical sciences, docent, professor of the department of technology of fermentation production and winemaking, Federal State Budgetary Institution of Higher Education "Moscow State University of Food Production" Moscow, Russia; doka.65@mail.ru; <https://orcid.org/0000-0002-7885-1150>

Gernet M. V., doctor of technical sciences, professor, leading researcher of the Brewing Department, Federal State Budget Scientific Institution "All-Russian Research Institute of Brewing, Non-Alcoholic and Wine Industry – branch of the Gorbato's Federal Research Center of Food Systems of RAS", Moscow, Russia; institut-beer@mail.ru; <https://orcid.org/0000-0003-0277-7318>

Kryukova E. V., doctor of technical sciences, professor, professor of the department of food safety, Federal State Budgetary Institution of Higher Education "Moscow State University of Food Production" Moscow, Russia; kryukovaev@gmail.com; <https://orcid.org/0000-0001-6858-3618>

Gribkova I. N., Researcher of Brewing department, Federal State Budget Scientific Institution "All-Russian Research Institute of Brewing, Non-Alcoholic and Wine Industry – branch of the Gorbato's Federal Research Center of Food Systems of RAS", Moscow, Russia; institut-beer@mail.ru; <https://orcid.org/0000-0002-4373-5387>

Nurmukhanbetova Dinara Erikovna, candidate of engineering sciences, acting associate professor, Almaty technological university, Department of Food safety and quality; dinar2080@mail.ru; <https://orcid.org/0000-0002-8939-6325>

Assembayeva Elmira Kuandykovna, Master of Technical Sciences, Senior Lecturer, Almaty technological university, Department of Food Biotechnology; elmiraassembayeva@mail.ru; <https://orcid.org/0000-0001-7964-7736>

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Zh. Onglassynov^{1,2}, A. Akylbekova², E. Sotnikov², T. Rakhimov², K. Kanafin², D. Balla³¹Satbayev University, Almaty, Kazakhstan,²KazNRTU named after K. I. Satpayev NPJSC – Ahmetsafin Institute of Hydrogeology and Environmental Geoscience, Almaty, Kazakhstan,³Leibniz Centre for Agricultural Landscape Research, Germany.

E-mail: zhuldyzbek.onlasynov@mail.ru, aigul_igg@mail.ru, sotnikov_yevgeniy@mail.ru, t-rakhimov@mail.ru, km_kanat_2008@mail.ru, balla@zalf.de

**IMPLEMENTATION OF THE ERS FOR YIELD ANALYZING
OF IRRIGATED LANDS OF SOUTH KAZAKHSTAN**

Abstract. Today the agricultural industry of Kazakhstan faces the challenge to make the country enter the list of leaders of agricultural export. Due to the necessity for ensuring food security and competitiveness of domestic farmers in the foreign markets, the Ministry of Agriculture of the Republic of Kazakhstan is going to need more objective information about volumes of crop production. Therefore, Kazakhstan must be very interested in the development of methods to monitor the agricultural production with the use of information from satellite [1].

This article demonstrates the results of the analysis of cotton yield in the irrigated fields of Maktaaraldistrict of Turkestan region of the Republic of Kazakhstan; the analysis has been conducted with the use of the Earth remote sensing data.

Work performed in two stages. At the first stage, field surveys of irrigated tracts were conducted, the state of cotton fields was assessed. At the second stage, a GIS model of irrigated arrays of the Maktaaral district was built, NDVI (Normalized Difference Vegetation Index) was calculated during the vegetation period for the period from 2013 to 2018, NDVI change charts were constructed, data on cotton yield were collected, NDVI dependency graph on yield.

The results of the study showed a high efficiency of applying the methods of remote sensing of the Earth (hereinafter, RSE) in monitoring irrigated agriculture, in the analysis and in the yield forecast with an accuracy of 0.1-0.3 t/ha.

Key words: Maktaaral district, cotton, irrigated lands, NDVI, ERS, yield, GIS, database.

Introduction. The modern space technologies make an important contribution to the development of the agro-industrial complex of the Republic of Kazakhstan. The method of using of the Earth Remote Sensing data to monitor agricultural lands is very relevant for Kazakhstan due to its enormous spaces [2].

One of the most important issues of the Agro-industrial sector of the Republic of Kazakhstan is improvement of yield and competitiveness of agricultural products, including cotton. The soil of the biggest south part of the South Kazakhstan region, where cotton is grown is light sierozem soil [3]. Cotton cultivation has an important role in the economy of the Maktaaral district and in the country's economy. As of 2016, the share of cotton fiber in the export of agricultural crops is 3.8%, but the export of cotton exceeds imports by 21.5% [4].

Cotton fields are located in Maktaaraldistrict of Turkestan region (figure 1). The district center Zhetysay is connected with the villages by asphalt roads. The distance between cotton fields and the regional center Shymkent is about 330 km.

People of different nationalities live in the district. Most of them are the Kazakhs; there are also the Russians, Uzbeks, Tajiks, Ukrainians, and Germans. The district is mainly agricultural. The most developed activities are cotton growing, fruit growing and grape growing.

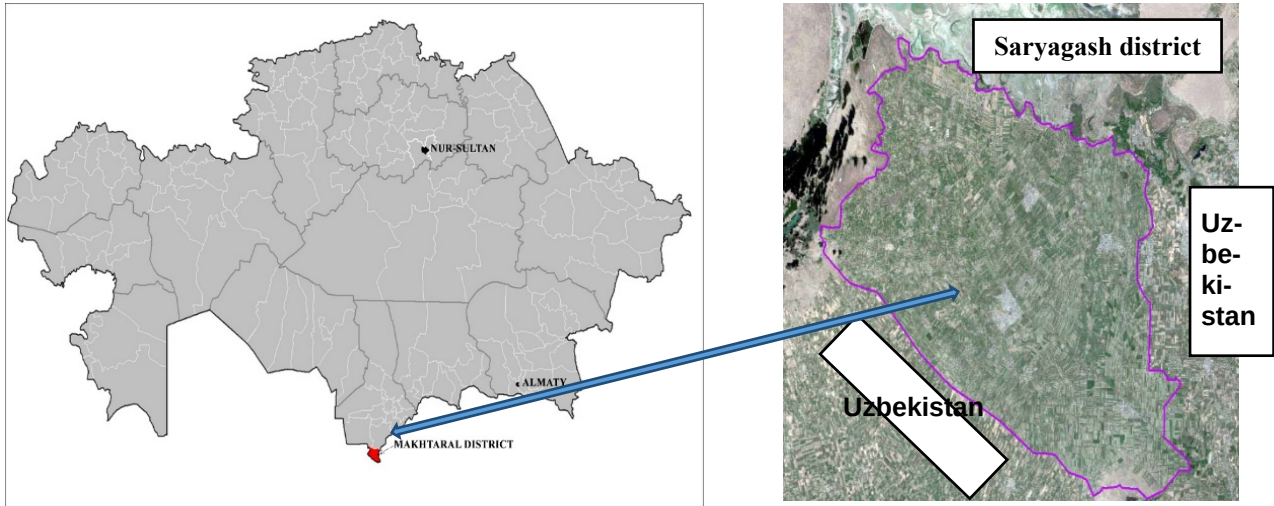


Figure 1 – Location of Maktaaral district on the map of the Republic of Kazakhstan

The climate of the district is characterized by high average annual temperature, relatively small amount of precipitation, low relative humidity of the air. According to long-term observations, the average annual air temperature in the district is $13-14^{\circ}\text{C}$. The lowest temperature is in January (-0.7°C) and the highest is in July ($+26.8^{\circ}\text{C}$). The maximum temperature during winter is $+18-+24^{\circ}\text{C}$. The minimum temperature is -35°C . The annual amount of precipitation is between 279.7 and 306.9 (m/s Maktaaral). The maximum amount of precipitation falls in spring, in March and April. There is almost no precipitation in the warm period from July to October. Air humidity is different during the year. The average absolute humidity is 8.3 mb, the relative humidity is about 79% in February and 42% in July (Maktaaral meteorological station). Wind conditions are relatively stable during the year. There is mainly south-eastern wind. The average annual speed of wind is 1.9 m/s in the western part and 2.5 m/s in the eastern part [5].

Methods. In order to analyze the yield in Maktaaral district, satellite data has been interpreted. The cloudless medium resolution images from archives (Landsat and Sentinel-2) for the vegetation period 2013-2018 have been processed in order to calculate spectral indices and identify changes within the studied district. The licensed software ArcGIS and Geomatica 2016 has been used for processing the ERS data.

In order to interpret and increase the information content of the ERS data, spectral transformations of the original satellite images have been carried out. The atmospheric correction of satellite images was carried out based on the analysis of the spectral profiles of cotton fields on satellite images with the use of spectral libraries; the calibration factors from Landsat metadata for MTL spectral ranges have been taken into account, as well as the estimated information on the azimuth/zenith of the Sun at the time of satellite survey. The matrices of the reflected solar radiation's actual values have been applied for the mathematical analysis, that is, the calculation of indices.

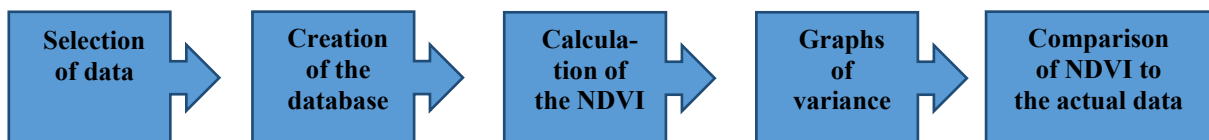


Figure 2 – Procedure for analysis

The following works have been executed in order to analyze the cotton yield in Maktaaral district (figure 2):

1. The medium resolution data from satellites Sentinel – 2 and LandSat – 7, 8 have been selected and downloaded;

2. The database, including vector polygons in ArcGIS as the borders of irrigated fields has been created (figure 3, 4);

3. The NDVI for every polygon for a several-year vegetation period has been calculated; the results of calculation have been included in the database;

4. The graphs of the NDVI variance during the vegetation period have been made (figure 5);

5. The data on yield for several years has been compared to the graphs of the NDVI variance.

Selecting and downloading the medium resolution data from satellites Sentinel – 2 and Landsat – 7, 8.

The data from satellites Landsat 7 and 8 and Sentinel-2 have been used in the experiment. For over 40 years, Landsat program has continuously collected spectral information from the Earth surface. This unique archival data give scientists the opportunity to assess the changes in the Earth's landscape over long periods of time. The Landsat program was created specifically for natural resource monitoring.

The ETM + survey instruments (advanced thematic cartographer) installed on Landsat-7 satellite provides survey of the Earth surface in six channels with Spatial Resolution (SR) 30 m, and panchromatic survey with SR 15 m in the thermal IR channel with SR 60. The swath width is 185 km in all channels. The survey interval is 16 days; the Radiometric Resolution (RR) is 8 bits [6].

The Landsat 8 has two Earth-observing sensors: the multispectral scanner OLI created by Ball Aerospace & Technologies Corporation, and the thermal-imaging infrared sensor (TIRS) created by NASD Goddard Space Flight Center (GSFC). Both sensors are more advanced than the previous Landsat instruments. The Landsat 8 observatory consists of the spacecraft bus and its payload of two Earth-observing sensors. The OLI sensor collects image data for nine short wave spectral channels in a 190-kilometer swath; the SR for all channels is 30 m, except for the 15-meter panchromatic channel [7-9].

Sentinel-2 is a high resolution European multicurrency and multispectral mission which delivers optical images from 13 spectral ranges: four 10-meter wide swaths, six 20-meter wide swaths, three swaths with SR 60 m. The width of the orbital swath is 290 km. Each of the Sentinel-2 satellites weighs approximately 1.2 ton. Both satellites were launched with the European VEGA launcher. The service life of the satellite is 7.25 years, including 3 months of in-orbit commissioning. Batteries and propellants are provided for 12 years of operation, including decommissioning at the end of the service life. Two identical satellites operate simultaneously; they are installed at an angle of 180° to each other, at an average altitude of 786 km in the sun-synchronous orbit [6].

An extensive work with ArcGIS software has been executed to create the vector polygon (figures 3, 4). More than 60,000 vector fields have been created; each of them contains information on geolocation, the field area and calculated indices (figures 3, 4). The database can be expanded significantly; the data on the level of groundwater and its mineralization can be included in the future, as well as the indices describing the water content and soil salinization [10-12].

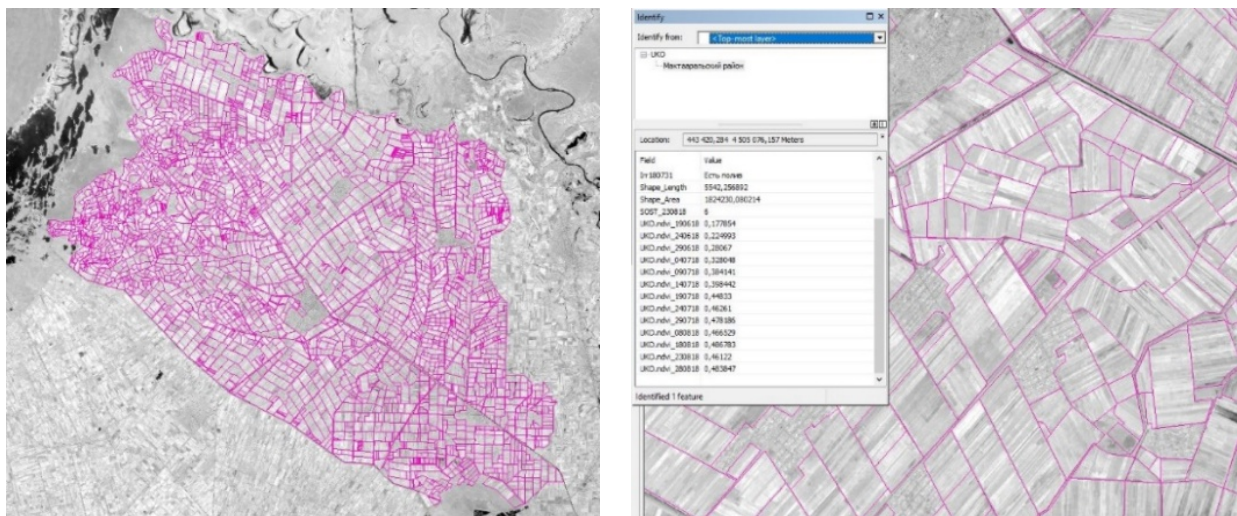


Figure 3 – Vector polygons of irrigated fields

File

View

Tools

Window

Help

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Shape	Area	SOST	Z3081	UKO.ndvi 1995	UKO.ndvi 1996	UKO.ndvi 248618	UKO.ndvi 259818	UKO.ndvi 840718	UKO.ndvi 898718	UKO.ndvi 146718	UKO.ndvi 190718	UKO.ndvi 248718	UKO.ndvi 298718
12829.957487	8		0.211349	0.284268	0.418158	0.55538	0.681404	0.683795	0.55538	0.519238	0.348783		
13032.210586	4		0.380389	0.462294	0.523049	0.555499	0.684212	0.586916	0.534056	0.627365	0.632583		
13186.234237	5		0.302914	0.423438	0.412199	0.432073	0.482751	0.418548	0.421943	0.438718	0.405842		
13881.0568	8		0.41984	0.284811	0.255853	0.319643	0.428126	0.585635	0.580205	0.58857	0.621574		
14396.257927	4		0.347886	0.453877	0.47587	0.5891	0.398198	0.332752	0.449484	0.534793	0.537732		
14598.860868	9		0.331286	0.322018	0.385814	0.478446	0.519055	0.54918	0.588801	0.585183	0.475732		
14821.320194	2		0.197885	0.176688	0.187889	0.178815	0.194653	0.185557	0.194653	0.186221	0.193115		
14878.456236	6		0.17878	0.285388	0.388032	0.546239	0.524775	0.558208	0.529697	0.298151	0.29877		
15086.372085	8		0.676283	0.687581	0.289468	0.259148	0.351629	0.522107	0.665524	0.724787	0.73282		
16471.434336	4		0.204873	0.248454	0.330826	0.284815	0.373699	0.294781	0.317845	0.379953	0.442885		
16583.620971	9		0.23753	0.275299	0.391364	0.352767	0.44159	0.437628	0.481617	0.468736	0.528185		
16787.478288	7		0.547353	0.584885	0.324287	0.315129	0.484449	0.572543	0.632297	0.636886	0.843878		
16851.757811	7		0.286386	0.399189	0.458518	0.480881	0.517608	0.482487	0.53777	0.519532	0.543121		
16898.040352	5		0.47117	0.542178	0.554148	0.562123	0.533311	0.582009	0.583254	0.489429	0.481912		
17598.860849	6		0.232251	0.36331	0.354952	0.387811	0.384119	0.391341	0.397483	0.424789	0.433576		
17853.937232	7		0.499842	0.249382	0.24238	0.350771	0.484196	0.515081	0.562382	0.587889	0.572123		
17883.656287	7		0.358877	0.366535	0.441325	0.438789	0.497286	0.471888	0.582585	0.512051	0.521848		
18046.72187	6		0.352985	0.306674	0.387886	0.47587	0.535491	0.581784	0.604156	0.488757	0.344713		
18274.938881	5		0.125824	0.148612	0.182842	0.217355	0.281313	0.277357	0.301214	0.322864	0.345841		
19523.485918	7		0.480485	0.518842	0.384333	0.372193	0.384208	0.385984	0.428178	0.439885	0.488487		
20288.822834	4		0.444382	0.519583	0.508737	0.322183	0.288739	0.331903	0.338792	0.487745	0.534851		
20348.302271	6		0.23184	0.488324	0.503591	0.530879	0.518157	0.518832	0.428637	0.398841	0.3733		
20642.344184	4		0.318348	0.428447	0.437608	0.438733	0.438736	0.419541	0.458825	0.441818	0.437884		
20786.390557	4		0.377224	0.458055	0.318411	0.348815	0.388251	0.445197	0.472143	0.482741	0.481881		
21296.078917	7		0.485274	0.478919	0.522415	0.517959	0.515129	0.519896	0.572951	0.58863	0.587148		
21488.364231	2		0.278214	0.402817	0.438134	0.543502	0.537591	0.57727	0.464322	0.350186	0.43289		
21821.708244	2		0.478588	0.511881	0.45847	0.424848	0.383816	0.38222	0.385184	0.378718	0.388321		
21728.365553	4		0.362849	0.404862	0.406742	0.42084	0.403557	0.398922	0.385531	0.33639	0.306448		
21878.458889	5		0.188839	0.18385	0.225877	0.244381	0.288883	0.27856	0.288773	0.308574	0.337434		
22388.318087	7		0.330177	0.474	0.522863	0.58794	0.377711	0.298168	0.384956	0.512263	0.593291		
22395.11788	8		0.274889	0.283553	0.287322	0.374208	0.410157	0.45584	0.498884	0.338299	0.331125		
22849.94423	7		0.44428	0.50584	0.523746	0.27328	0.345151	0.487193	0.588829	0.608854	0.589134		
23872.235539	8		0.227786	0.285278	0.32779	0.354358	0.402548	0.424344	0.438802	0.47404	0.485588		
23985.218547	8		0.482879	0.255249	0.247187	0.329288	0.43624	0.588906	0.58308	0.588963	0.588815		
24383.052299	6		0.425723	0.434483	0.458986	0.468548	0.445482	0.152835	0.474855	0.483423	0.48285		
24313.279381	9		0.49387	0.336253	0.272291	0.40838	0.548897	0.618285	0.688385	0.682539	0.65184		

1 out of 2970 Selected

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Figure 4 – Tables of the geodatabase on polygons

At the next stage, the NDVI for each polygon during the several-year vegetation period has been calculated; the results of the calculation have been included in the database. The NDVI is a simple quantitative index of the amount of photosynthetically active biomass which shows the density of vegetation on the given surface area. It is one of the most commonly used solution indices with quantitative estimates of vegetation.

In formula (1), NIR Reflection in the near infrared region of the spectrum (0.7–1.0 μm); RED is reflected in the visible region of the spectrum (0.4–0.7 μm), NDVI is the index of the spectral reflectivity of plants. According to (1), the vegetation density (NDVI) at the remote point of the satellite image is equal to the difference of the intensities of the reflected light in the visible and infrared ranges divided by the sum of their intensities.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

The calculation of the NDVI is based on the two most stable (independent of other factors) parts of the spectral curve of the reflection of plants. In the visible region of the spectrum (0.4–0.7 μm) lies the absorption maximum of solar radiation by chlorophyll of the culture, and in the infrared region (0.7–1.0 μm) there is the region of maximum reflection of the cellular structures of the leaf, that is, high photosynthetic activity (associated, as a rule, with dense vegetation) leads to less reflection in the visible spectrum and more in the infrared. The relationship of these indicators to each other allows you to clearly separate and analyze vegetation from other natural objects, moreover, if you have performed a sub-satellite experiment, you can perform vegetation type recognition. The use of not a simple relationship, but a normalized difference between the minimum and maximum reflections increases the measurement accuracy, reduces the effects of such phenomena as differences in the light of a picture, clouds, haze, radiation absorption by the atmosphere, etc. A standardized continuous gradient or discrete scale is used to display the NDVI index showing values in the range - 1, ..., 0, 0.1, ... 1 in% [13–20].

Results. Figure 5 show the development of the NDVI for Cotton field 1 during the vegetation period of 2018. The peak of the vegetation period of Cotton field 1 is the third decade of August and the first decade of September; the NDVI is 0.49. The NDVI is calculated for every field; the highest values during

the vegetation period 2013-2018 are detected. The data on cotton yield in Maktaaraldistrict during the vegetation period 2013-2018 is collected from EGOV (statistics section). The statistic information is compared to the NDVI, as it is shown on the graph (figure 7). The graph shows the direct correlation between cotton yield and the NDVI.

The experiment carried out within the framework of BioWat project has shown the importance and big potential of the ERS data for analyzing the crop yield. The graph of correlation between the calculated NDVI and the actual data on harvest is linear; its error is 0.1-0.3 t/ha, that confirms a high probability of yield forecast. The obtained results prove that the ERS data can be successfully used not only for monitoring cotton fields, but also for the agriculture in general.

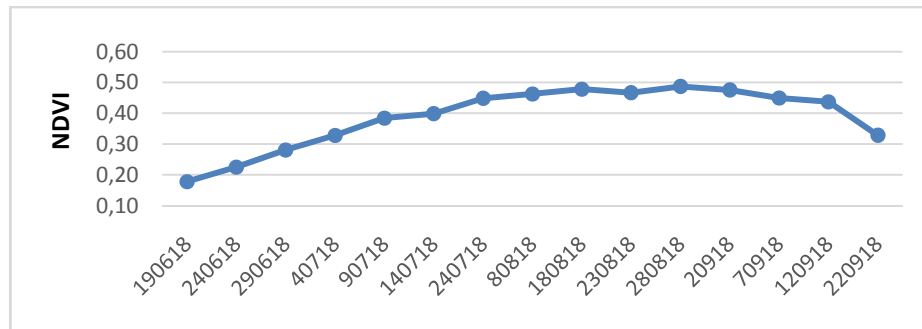


Figure 5 – Graph of the NDVI development for Cotton field 1 during 2018

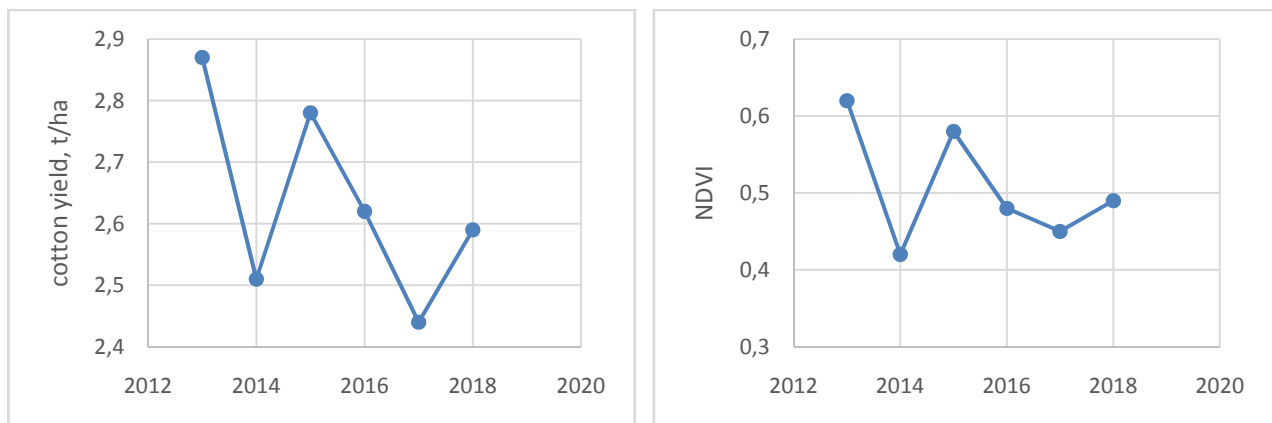


Figure 6 – Graph of cotton yield and NDVI for Cotton field 1 during the period 2013-2018

Moreover, the ERS data can be efficiently used for quick detection and response in case of problems in the irrigated fields. This experiment is important and relevant as this method to monitor the agricultural production can significantly facilitate people's work and contribute to improvement and increase of yield.

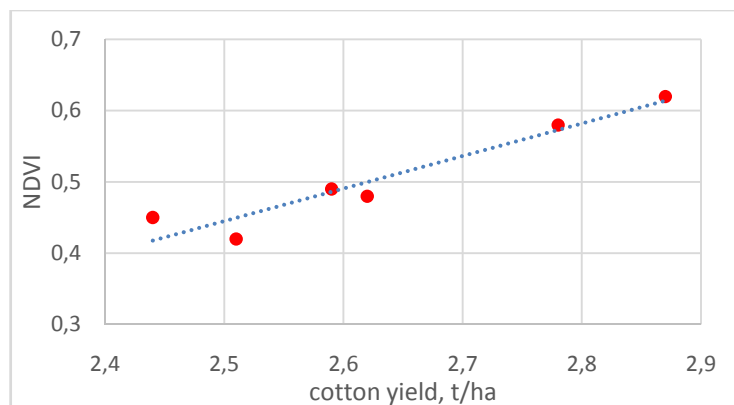


Figure 7 – Graph of correlation between the NDVI of Cotton field 1 and cotton yield

Acknowledgments. This research was financially supported by the German Federal Ministry of Education and Research (BMBF) in frame of the BioWat project. The results of the research can be used in management at different levels of agriculture and can help to improve the condition of agricultural lands. The scope of use of the results of this project is very wide; they can be used by the governments at regional and national levels. The methods used in this project, as well as adequate managerial measures can significantly improve the condition of agricultural lands of the Republic of Kazakhstan and the living conditions of population of Maktaaral district. The results of the research were discussed at the final meeting of the participants of the BioWat project.

**Ж. Ә. Оңласынов^{1,2}, А. Ж. Ақылбекова², Е. В. Сотников²,
Т. А. Рахимов², К. М. Канафин², Д. Балла³**

¹Сәтбаев Университеті, Алматы, Қазақстан,
«Қ. И. Сәтбаев атындағы ҚазҰТЗУ» КЕАҚ –

У. М. Ахмедсафин атындағы гидрогеология және геоэкология институты, Алматы, Қазақстан,

³Лейбниц атындағы агро-ландшафтты зерттеу орталығы, Германия

ЖҚЗ-НЫҢ ОҢТҮСТІК ҚАЗАҚСТАН СУАРМАЛЫ МАССИВТЕРІНІҢ ӨНІМДІЛІГІН САРАПТАУ ҮШІН ҚОЛДАНЫЛУЫ

Аннотация. Бүгінгі таңда ауыл шаруашылық саласына Қазақстанның ауыл шаруашылық өнімдерін экспорттаудағы жетекші мемлекеттердің қатарына кіруін қамтамасыз ету жөнінде мақсат қойылған. Отандық шаруалардың сыртқы нарықтағы бәсекеге қабілеттілігін сақтау және азық-түлік қауіпсіздігін қамтамасыз ету барысында, ҚР Ауыл шаруашылық Министрлігінің ауыл шаруашылық өнімдерін өндіру туралы объективті ақпаратқа мұқтаждығы туындайды. Сондықтан ауыл шаруашылық өндірісін жерсеріктік ақпараттар арқылы қадағалау әдістерін дамытудың Қазақстан үшін маңызы зор.

Мақалада Қазақстан Республикасы, Түркістан облысы, Мақтаарал ауданының суармалы массивтеріндегі мақта өрістерінің өнімділігін, жерді қашықтықтан зондылау деректерінің көмегімен жасалған сараптаманың нәтижелері көрсетілген. Зерттеу жұмыстары екі этапта жүргізілді. Бірінші этапта суармалы массивтердің далалық зерттемелері жүргізілді. Мақта аландарының жағдайы мен орналасу ерекшеліктері тексерілді және бағаланды. Екінші этап зертханада жүргізілді, оның ішінде Мақтаарал ауданының суармалы массивтерінің ГИС моделі құрастырылды. Мақтаарал ауданының территориясының 2013–2018 жылдар аралығында вегетация периодының NDVI – normalized difference vegetation index есептелініп NDVI өзгеріс графигі тұрғызылды. Мақтаарал ауданының мақта өнімділігі туралы ақпарат жиналды. NDVI және өнімділіктің байланыс графигі тұрғызылды.

Зерттеу жұмыстарының нәтижелері суармалы егін шаруашылығының мониторингінде ЖҚЗ-ның жоғарғы тиімділігін, және де өнімділікті 0,1–0,3 т/га дәлдікпен болжамдауға болатындығын көрсетті.

Түйін сөздер: мақтаарал ауданы, мақта, суармалы массивтер, NDVI, ЖҚЗ, өнімділік, ГАЖ, мәліметтер базасы, LandSat, Sentinel-2.

**Ж. А. Оңласынов^{1,2}, А. Ж. Ақылбекова², Е. В. Сотников²,
Т. А. Рахимов², К. М. Канафин², Д. Балла³**

¹Университет Сатпаева, Алматы, Казахстан,

²НАО «КазНИТУ им. К. И. Сатпаева» –

ТОО «Институт гидрогеологии и геоэкологии им. У. М. Ахмедсафина», Алматы, Казахстан,

³Центр агро-ландшафтных исследований им. Лейбница, Германия

ПРИМЕНЕНИЕ ДЗЗ ДЛЯ АНАЛИЗА УРОЖАЙНОСТИ ОРОШАЕМЫХ МАССИВОВ ЮЖНОГО КАЗАХСТАНА

Аннотация. В настоящее время перед сельскохозяйственной отраслью поставлена задача – обеспечить вхождение Казахстана в число стран – Лидеров по экспорту сельхоз культур. В связи с необходимостью обеспечения продовольственной безопасности страны и сохранности конкурентоспособности отечественных земледельцев, на внешних рынках увеличатся потребности Министерства сельского хозяйства РК в объек-

тивной информации об объемах производства сельхоз культур. Поэтому развитие методов контроля над сельскохозяйственным производством с помощью спутниковой информации представляет большой интерес для Казахстана.

В настоящей статье показаны результаты работ по анализу урожайности хлопковых полей орошаемых массивов Мактааральского района Туркестанской области Республики Казахстан, выполненных с применением данных дистанционного зондирования Земли.

Работа проводилась в два этапа. На первом этапе, проведены полевые обследования орошаемых массивов, оценено состояние хлопковых полей. На втором этапе, построена ГИС-модель орошаемых массивов Мактааральского района, вычислены NDVI (Normalized Difference Vegetation Index) в течение вегетационного периода за период времени с 2013 по 2018 годов, построены графики изменения NDVI, собраны данные по урожайности хлопка, построен график зависимости NDVI от урожайности.

Результаты исследования показали высокую эффективность применения методов дистанционного зондирования Земли (далее, ДЗЗ) в мониторинге орошаемого земледельца, в анализе и в прогнозе урожайности с точностью в 0,1–0,3 т/га.

Ключевые слова: Мактааральский район, хлопок, орошаемые массивы, NDVI, ДЗЗ, урожайность, ГИС, база данных.

Information about authors:

Onglassynov Zhuldyzbek Alikhanuli, PhD student and JRoHydrodynamic and geoecological processes modeling laboratory, Satbayev University, «KazNRTU named after K. I. Satpayev»; NPJSC – Ahmetsafin Institute of Hydrogeology and Environmental Geoscience; zhuldyzbek.onlasynov@mail.ru; <https://orcid.org/0000-0002-3587-5996>

Akylbekova Aigul Zhanysbekovna, Scientific secretary, «KazNRTU named after K. I. Satpayev»; NPJSC – Ahmetsafin Institute of Hydrogeology and Environmental Geoscience; aigul_igg@mail.ru; <https://orcid.org/0000-0002-1055-1987>

Sotnikov Yevgeniy Vladimirovich, Researcher of hydrodynamic and geoecological processes modeling laboratory, PhD, «KazNRTU named after K. I. Satpayev»; NPJSC – Ahmetsafin Institute of Hydrogeology and Environmental Geoscience, Kazakhstan; sotnikov_yevgeniy@mail.ru; <https://orcid.org/0000-0002-3542-0983>

Rakhimov Timur Aitkaliyevich, Head of the laboratory of regional hydrogeology and geoecology, PhD; NCJSC "KazNRTU named after K. I. Satpayev" Institute of Hydrogeology and Geoecology named after U.M. Ahmetsafin; t-rakhimov@mail.ru; <https://orcid.org/0000-0002-0976-4643>

Kanafin Kanat Maratovich, Researcher of laboratory of Groundwater resources, PhD, «KazNRTU named after K. I. Satpayev»; NPJSC – Ahmetsafin Institute of Hydrogeology and Environmental Geoscience; km_kanat_2008@mail.ru; <https://orcid.org/0000-0002-8095-5661>

Dagmar Balla, Leibniz Centre for Agricultural Landscape, Germany Ch. R, PhD; balla@zalf.de; <https://orcid.org/0000-0002-9766-8132>

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A. Ye. Vorobev¹, G. P. Metaxa², Ye. M. Bolenov², A. S. Metaxa², Zh.N. Alisheva²¹The Peoples' Friendship University of Russia, Moscow, Russia,²D. A. Kunayev Mining Institute, Almaty, Kazakhstan.E-mail: fogel_al@mail.ru, gmetaksa@mail.ru, ebolenov@mail.ru,
zhannat_86.2007@mail.ru, metaxa_anna@mail.ru**## DIGITIZATION OF THE MINING INDUSTRY. CONCEPT AND MODERN GEOTECHNOLOGY**

Abstract. The current state of digitalization in the mining industry is reflected in international and regional regulations of all technically developed countries. In 2015, in the Russian Federation it was planned to create the first industrial consortium to develop the concept of “smart quarry”. The general initiator of the project was the VIST Group, as well as a number of mining companies in Russia and Kazakhstan. Belarus’s partner is BELAZ, which successfully tested the first unmanned heavy dump truck in history. In the “Smart Quarry” project, an important technological direction is 3D modeling in resource extraction. Here is an interesting example of the Russian company Vizerra, which creates a virtual reality model of a career and an automated control system for mountain transport complexes based on the GLONASS satellite navigation technology and a robotized process control system for open-pit mining. The concept of a “smart” (intellectual) career is also widely developed in other countries where the mining industry has a high value (Australia, Canada, Chile). The Smart Career project was included in the list of AutoNet pilot projects of the National Technology Initiative. In the Republic of Kazakhstan, by the example of processing waste from the Zhezkazgan copper-smelting production, a new geotechnology is being created that assumes one hundred percent digitization of these processes. The combination of the results of experimental studies and implemented developments allows us to predict the successful implementation of digitalization processes in the mining and industrial sector of Kazakhstan. This paper reflects the following features of the digitalization of new geotechnologies developed in the Republic of Kazakhstan.

Keywords: digitalization, geotechnology, leaching, ecology, waste, functional diagram, experiment.

The existing concept of digitalization in the mining industry has a number of significant differences from the developed modern methods of automation of production, working from the industrial power grid.

Using the example of digitalization of the leaching process, it is shown that to implement this concept, an integrated approach to the study and subsequent use of natural mass transfer processes using an autonomous mode of operation is necessary.

A digitalization matrix is proposed for obtaining specified properties when implementing various interaction mechanisms at the phase boundaries. It is shown that the existing system does not possess sufficient knowledge-intensiveness and therefore the digitalization of the mining industry should be carried out taking into account the development of new geotechnologies, providing for an autonomous power supply.

Introduction. The relevance of the work is due to the need to replace unproductive labor with automated 3 D processes. Last year, a representative forum was held in the city of Minsk, which outlined the main priorities in the digitalization of the mining industry. It was shown that the digitalization process is already well underway in many enterprises, covering the logistic, economic and analytical areas [1, 2]. The software is carried out according to the fractal principle with a pyramidal complication depending on the volume of operations performed. According to these conceptual features, particular tasks are solved that do not require scientific content, i.e. It is based on existing technology. A number of processes that

exclude the presence of a person are automated, the development of the information flow depends entirely on the characteristics of the power supply system.

A common disadvantage of the achievements presented in the reports is the complete lack of solutions to environmental problems and social problems associated with the release of a large number of personnel. In addition, the existing restrictions related to the digitization of old technologies cannot provide a breakthrough to new solutions, to new geotechnologies.

In the modern mining industry there are a number of geotechnologies that do not require human presence in the underground space during the mining method of mining. The technologies associated with the processes of cold nuclear fusion (CNF) and other, for example, information technologies are being actively developed. Digitization of future geotechnologies requires a high level of professionalism for the successful solution of the tasks. This paper gives an example of the creation of a new geotechnology for leaching of enrichment wastes, TMT, poor ores and dumps [3, 4]. In this connection, there are problems of studying all the natural processes that accompany this phenomenon. The results of physical modeling showed the feasibility of such processes in real conditions without the use of expensive services of the industrial power grid. In addition, special attention should be paid to the deep study of natural phenomena in order to develop such geotechnologies, in which conditions are created for an autonomous mode of self-feeding and regulation of productivity. In the presented work there is an opportunity to analyze the difference between the concept (lat. – system of understanding) of digitalization, the reliability of which depends on the state of the power unit and the concept of digitalization of the mining industry, which is developed taking into account the influence of the complex interaction of natural factors.

Methods. To solve this problem, physical modeling methods have been used, for which the necessary theoretical substantiations have been created in the form of digitalization matrices for the processes of obtaining specified properties. The advantage of the modeling method created by us is an integrated approach to all the natural phenomena of a real array.

The result of this work is the development of a new project for the restoration of disturbed lands, which provides for the complete digitalization of all processes occurring in natural conditions. The draft sketch being developed has an autonomous power supply, which allows to fully automate the following processes:

- dissolution and sedimentation of minerals;
- their mass transfer depending on the position by countries of the world;
- tidal - tidal effects;
- capillary interactions.

Figure 1 shows the layout of processing nodes in such a project. A distinctive feature of the project is the presence of a bypass channel, a constant water level in which is maintained automatically.

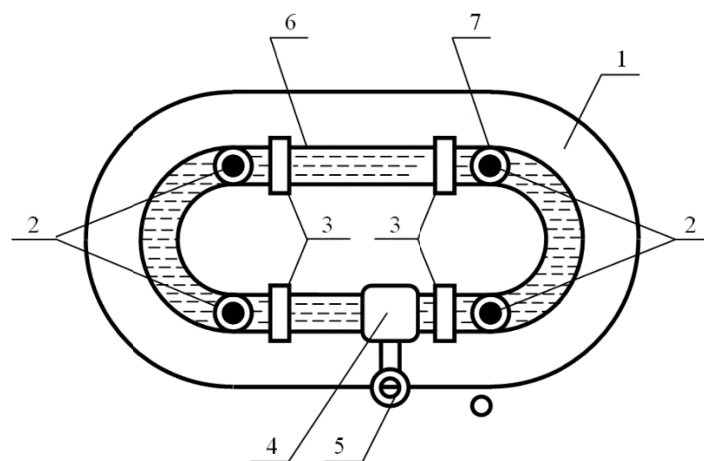


Figure 1 – Scheme of the location of mineral processing units for leaching of minerals:
 1 – polygon array; 2 – collectors (4 pieces); 3 – gateway system elements (4-5 pieces);
 4 – water treatment unit; 5 – well; 6 – polygon bypass channel; 7 – power converter unit (4 pieces)

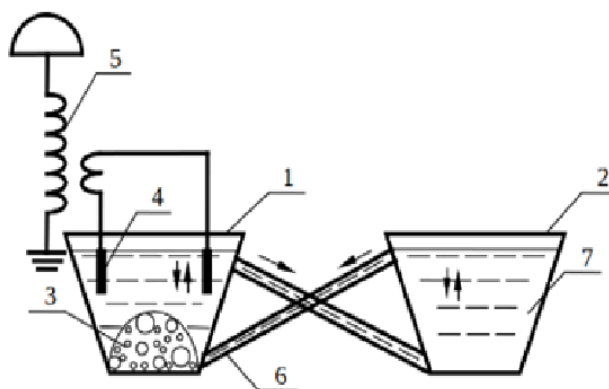


Figure 2 – Functional diagram of the leaching process: 1 – main reactor; 2 – auxiliary reactor; 3 – ore to be processed; 4 – electrodes; 5 – converter; 6 – piping; 7 – productive solution

The functional diagram is shown in Figure 2, it implements the transverse interaction of the following flows:

- concentration ΔC : $\Delta C = C_1 - C_2$, (1)

- capillary: $FT = FH$, (2)

where FT is the force of gravity; FH is the surface tension force;

- convection: $\Delta T = T_1 - T_2$, (3)

- gravitational: $P = mg - ma$, (4)

where P is weight; m - Mass; a - Acceleration; g - Free fall acceleration.

Discussion. For each of the listed mass transfer streams, there are mechanisms developed to control them in the automatic control mode of each process separately and in complex combinations [5]. Physical modeling of these processes was carried out in the laboratory. Pilot – industrial tests were successfully carried out in Zhezkazgan on copper smelting production wastes. The obtained results allow us to predict the economically - beneficial implementation of the development on all types of dumps, poor ores and industrial wastes of existing industries.

Here it should also be noted that according to the concept of M. V. Lomonosov [6] each field is an autonomous reactor, continuously reproducing those obtained minerals, which are due to the geometrical location of the reservoir massif. These problems also require research, although they are related to the solution of problems of cold nuclear fusion (NSF). In this case, it is necessary to know the conditions for focusing incoming external influences.

At the stage of carrying out laboratory work, it is possible to analyze the possibilities of the mechanisms controlling the properties in the reactions taking place at the interface (see table 1).

Table 1 – Matrix of digitalization of the processes of obtaining specified properties at the system output (interaction mechanisms at the interface) (3x3)

Levels of consideration, m	Frequency range, (Hz) c^{-1}			
	Films of liquid metals $10^{-12} - 10^{-15}$	Liquid film $10^{-12} - 10^{-9}$	Films of organic compounds $10^{-9} - 10^{-6}$	Type of controlled process
Lattice $> 10^{-9}$	Elastic and inelastic scattering (exoemission)	Ionization	Radiation - chemical reactions	Intraphase Uniformity
Structural $> 10^{-6}$	Phototransformation	Surface - active processes	Structuring, oxidation, reduction	Concentration disequilibrium
Control method	Heat generation	Sorption, desorption	Polymerization (synthesis, destruction)	Interphase disequilibrium
Levels of consideration, m	Change in contact conditions of heterogeneous phases	Resonance	Capacitive	Method of kinetic correspondences of reactions of actions and response

This table shows the main mechanisms controlling the chemical and physical properties of the processes occurring at the interface, depending on the spatial-temporal parameters of the «impact-response system» [7, 8].

The development of theoretical aspects of the digitalization of the mining industry requires systemic knowledge of the properties of substances for different levels of consideration.

In systematization of knowledge about solid materials, the most significant are the size of their structural elements (spatial characteristic) and the period of their oscillations around the equilibrium position (temporary characteristic). Then, according to the level of significance, the space-time parameters of the influencing medium follow, since the state of the material under external influence depends on the relaxation time. The effect of external power is more dependent on the boundary conditions for the interaction of direct and reverse processes [9–15].

To identify causal relationships when exposed to external sources of variable fields with a solid substance, spatial-temporal parameters affecting the mass transfer, state and boundary conditions of the interacting phases are selected. At the same time, the following distance scales for any level of structures were selected for systematization by spatial attribute:

- macroscopic – near the scale of zero degree, $10^0 \text{ m} \cdot 1 \text{ m}$;
- polycrystalline, 10^{-3} m ;
- monocrystalline, 10^{-6} m ;
- lattice, 10^{-9} m ;
- electronic, 10^{-12} m .

Each model, changing through three orders of distance [7], has a specific leading element of the structure, its own group of relations of the physical model, its own group of mathematical realizations. Each group corresponds to a specific range of vibrations of the elements of the structure, which differs from each other by three orders of magnitude [16–20]. The analysis of causal relationships is performed according to the scheme (table 2) of the dialectical-logical approach to any problem under consideration, i.e. taking into account the categories of single, common and universal for each spatial level (B.A. Koyshibaev).

This scheme contains information for the analysis of cause and effect, taking into account the large-scale (spatial) signs in combination with the time (frequency spectrum) possibilities of manifestation. If the vertical columns arrange the levels of consideration by the scale of the distances, and the horizontal - the vibration frequencies (temporal sign) of the corresponding elements of the structure for each level, then you can systematize all types of mass transfer for solids [21–26]. In addition, for the mathematical implementation it is necessary to take into account the capacitive capabilities in the absorption of a certain type of radiation, which is entirely determined by the state of the material at the moment of radiation. Therefore, there is a need to systematize according to the same signs of solid states (table 3). During the analysis, the dialectical principles developed by BA Koyshibaev were used.

Table 2 – Matrix of system interconnections for the processes of accumulation and discharge of voltages for a solid substance, taking into account the space-time features

Private range, Hz Levels of consideration, m	Oscillation spectrum of electrons, 10^{15} – 10^{12}	Oscillation spectrum of point defects, 10^{12} – 10^9	Oscillation spectrum of linear defects, 10^9 – 10^6	Oscillation spectrum of other discontinuities 10^6 – 10^3
Electronic, 10^{-12}	Contact potential difference	Self diffusion	Polarization	Electroacoustic emission
Lattice, 10^{-9}	ThermoEMF (thermal conductivity)	Diffusion (concentration transfer)	Polymorphic transformations	Martensitic transformations
Structural, 10^{-6}	Thermo Magnetism	Intragranular deformation	Grain boundary deformation	Twinning
Real sample scale, 10^{-3}	Thermoelectro Resilience	Newtonian current	Non-newtonian flow	Superplasticity

Table 3 – The matrix of solid states by space-time basis

Private range, Hz Levels of consideration, m	Oscillation spectrum of electrons, 10^{15} – 10^{12}	Oscillation spectrum of point defects, 10^{12} – 10^9	Oscillation spectrum of linear defects, 10^9 – 10^6	Oscillation spectrum of other discontinuities 10^6 – 10^3
Electronic, 10^{12}	Conductive state	Ionized	Ordered	Scale effects
Lattice, 10^9	Monocrystalline state	Polycrystalline state of solid solutions	Polymorphism (transformation)	Magnetostriction Electrostriction
Structural, 10^6	Amorphous state	Polycrystalline state of mechanical mixes	State of phase boundaries	Shape memory effect, piezo effect
Real sample scale, 10^3	Elastic state	Plastic condition	Hardened, weakened state	Superplasticity, fragility

Thus, the combination of the obtained results of experimental studies and the developed theoretical background for digitalization in the mining industry allows us to draw the following conclusions:

1. The existing concept of digitalization in the mining industry has a number of significant differences from the developed modern methods of automation of production, working from the industrial power grid.

2. Using the example of digitalization of the leaching process, it is shown that to implement this concept, an integrated approach to the study and subsequent use of natural mass transfer processes using an autonomous mode of operation is necessary.

3. A digitalization matrix has been proposed for obtaining given properties when implementing various interaction mechanisms at phase boundaries.

А. Е. Воробьев¹, Г. П. Метакса², Е. М. Боленов², А. С. Метакса², Ж. Н. Алишева²

¹Российский университет дружбы народов, Москва, Россия,

²Д. А. Кунаев атындағы Тау-кен ісі институты, Алматы, Қазақстан

ТАУ-КЕН ӨНЕРКӘСІБІН ЦИФРМЕН ҚАМТАМАСЫЗ ЕТУ. ТҰЖЫРЫМДАМА ЖӘНЕ ҚАЗІРГІ ЗАМАНҒЫ ГЕОТЕХНОЛОГИЯ

Аннотация. Тау-кен өнеркәсібіндегі цифрландырудың ағымдағы жағдайы барлық техникалық дамыған елдердің халықаралық және өңірлік ережелерінде көрініс тапты. 2015 жылы Ресей Федерациясында «ақылды карьер» тұжырымдамасын әзірлеу үшін алғашқы өнеркәсіптік консорциум құру жоспарланған. Жобаның бас демеушісі VIST Group, сондай-ақ Ресей мен Қазақстанның бірқатар тау-кен компаниялары болды. Белоруссияның серіктесі БЕЛАЗ болып табылады, ол тарихтағы бірінші ұшқышсыз ауыр самосвал табысты сыналды. «Smart Quarry» жобасында маңызды технологиялық бағыт ресурстық өндірісте 3D моделдеу болып табылады. Ресейлік компания Vizerra - мансаптың виртуалды нақтылық моделін және ГЛОНАСС спутниктік навигациялық технологияға негізделген тау-кен көлік кешендерін басқарудың автоматтандырылған жүйесін жасайды және ашық карьерді өндіруге арналған роботталған үдерісті басқару жүйесін қызықтырады. "Ақылды" (зияткерлік) мансап тұжырымдамасы өндіруші өнеркәсіп жоғары мәнге ие басқа елдерде де кең дамуға (Австралия, Канада, Чили). "Ақылды мансап" жобасы Ұлттық технологиялық бастаманың "AutoNet" пилоттық жобаларының тізбесіне енді. ҚР-да Жезқазған мыс балқыту өндірісінің қалдықтарын өңдеу мысалында осы процестерді жүз пайыз цифрландыруды болжайтын жаңа геотехнология құрылуда. Тәжірибелік зерттеулер мен енгізілген әзірлемелердің алынған Нәтижелерінің жиынтығы Қазақстанның тау-кен өнеркәсіп саласындағы цифрландыру процестерінің табысты іске асырылуын болжауға мүмкіндік береді. Бұл жұмыста ҚР-да әзірленетін жаңа геотехнологияларды цифрландырудың мынадай ерекшеліктері көрсетілген:

- тау-кен саласындағы цифрландыру тұжырымдамасының өнеркәсіптік электр желісінен жұмыс істейтін өндірістерді автоматтандырудың қазіргі заманғы тәсілдерінен бірқатар елеулі айырмашылығы бар.

- сілтісіздендіру процесін цифрландыру мысалында осы тұжырымдаманы іске асыру үшін пайдаланудың автономды режимін қолдана отырып, массопереностың табиғи процестерін зерттеуге және кейіннен пайдалануға кешенді тәсіл қажет екендігі көрсетілген.

- фазаларды бөлу шекарасында өзара әрекеттесудің әртүрлі механизмдерін іске асыру кезінде берілген қасиеттерді алу үшін цифрландыру матрицасы ұсынылған. Қолданыстағы жүйенің жеткілікті ғылымды қажет сінетіндігі жоқ екендігі көрсетілген, сондықтан тау-кен саласын цифрландыру автономды энергиямен жабдықтауды көздейтін жаңа геотехнологияларды дамытуды ескере отырып жүзеге асырылуы тиіс.

Түйін сөздер: цифрлау, геотехнология, шаймалау, экология, қалдықтар, функционалдық диаграмма, эксперимент.

А. Е. Воробьев¹, Г. П. Метакса², Е. М. Боленов², А. С. Метакса², Ж. Н. Алишева²

¹Российский университет дружбы народов, Москва, Россия,

²Институт горного дела им. Д. А. Кунаева, Алматы, Казахстан

ЦИФРОВИЗАЦИЯ ГОРНОЙ ОТРАСЛИ. КОНЦЕПЦИЯ И СОВРЕМЕННЫЕ ГЕОТЕХНОЛОГИИ

Аннотация. Современное состояние цифровизации в горной отрасли отражено в международных и региональных постановлениях всех технически развитых стран. В 2015 году в РФ планировалось создать первый промышленный консорциум для разработки концепции «умный карьер». Генеральным инициатором проекта выступали Группа ВИСТ, а также ряд горнодобывающих компаний России и Казахстана. Со стороны Беларуси партнером выступает компания БЕЛАЗ, которая успешно провела испытания первого в истории беспилотного большегрузного карьерного самосвала. В проекте «Умный карьер» важным технологическим направлением является 3D-моделирование в добыче ресурсов. Здесь интересен пример российской компании Vizerra, которая создает модель виртуальной реальности карьера и автоматизированной системы управления горно-транспортными комплексами на основе технологий спутниковой навигации ГЛОНАСС и роботизированной системы управления технологическими процессами открытых горных работ. Концепция «умного» (интеллектуального) карьера широко развивается и в других странах, где добывающая промышленность имеет высокое значение (Австралия, Канада, Чили). Проект «Умный карьер» вошел в перечень пилотных проектов «AutoNet» Национальной технологической инициативы. В РК на примере обработки отходов медеплавильного производства Жезказгана создается новая геотехнология предполагающая стопроцентную цифровизацию этих процессов. Совокупность полученных результатов экспериментальных исследований и внедренных разработок позволяет прогнозировать успешную реализацию процессов цифровизации в горно-промышленной отрасли Казахстана. В данной работе отражены следующие особенности цифровизации новых геотехнологий, разрабатываемых в РК:

- существующая концепция цифровизации в горной отрасли имеет ряд существенных отличий от разрабатываемых современных способов автоматизации производств, работающих от промышленной электросети.

- на примере цифровизации процесса выщелачивания показано, что для реализации этой концепции необходим комплексный подход к изучению и последующему использованию природных процессов массопереноса с применением автономного режима эксплуатации.

- предложена матрица цифровизации для получения заданных свойств при реализации различных механизмов взаимодействия на границах раздела фаз. Показано, что существующая система не обладает достаточной наукоемкостью и поэтому цифровизация горной отрасли должна осуществляться с учетом развития новых геотехнологий, предусматривающих автономное энергоснабжение.

Ключевые слова: цифровизация, геотехнология, выщелачивание, экология, отходы, функциональная схема, эксперимент.

Information about authors:

Vorobev A. Ye., Dr. of Sc., professor, The Peoples' Friendship University of Russia; fogel_al@mail.ru; <https://orcid.org/0000-0003-0377-8419>

Metaxa G. P., Dr. of Sc., Head of Laboratory "Physical and technical problems of development of deposits", D. A. Kunayev Mining Institute, Almaty, Kazakhstan; gmetaksa@mail.ru; <https://orcid.org/0000-0001-5271-429X>

Bolenov E. M., Lead Engineer, D. A. Kunayev Mining Institute, Almaty, Kazakhstan; ebolenov@mail.ru; <https://orcid.org/0000-0002-9465-0543>

Alisheva Zh. N., Researcher, D. A. Kunayev Mining Institute, Almaty, Kazakhstan; zhannat_86.2007@mail.ru; <https://orcid.org/0000-0003-0929-4984>

Metaxa A. S., Junior Researcher, D. A. Kunayev Mining Institute, Almaty, Kazakhstan; metaxa_anna@mail.ru; <https://orcid.org/0000-0001-5574-0880>

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L. A. Ismaylova¹, S. Y. Guliyeva²

¹Azerbaijan State Oil and Industry university, Baku, Azerbaijan,

²Institute of Geography named by acad. H. A. Aliyev of ANAS, Baku, Azerbaijan.

E-mail: latifa.ismaylova@gmail.com, selinsevil@gmail.com

MORPHOMETRIC ANALYSIS IN GIS BASED OF RELIEF PARAMETERS MUDFLOW BASINS

Abstract. On based SRTM DEM using GIS technology morphometric analysis of relief Shinchay-Damira-paranchay mudflow basins was performed. With this purpose there were built maps of hypsometry, slopes, aspect, range relief and drainage density, indices, dissection and ruggedness, surface curvature. Also it was analyzed the areal distribution of these parameters by grade.

Now, in connection with development of digital technologies and broad availability of data of remote sensing, detailed assessment of a relief became possible. Application of the digital models of a relief (DMR) considerably simplified the morphometric analysis of a relief.

Obtaining morphometric data in a form and structure of a surface of a relief serves the initial procedure.

Key words: GIS, DEM, morphometric analysis, range relief, SRTM.

Introduction. The drainage basin is the fundamental unit in fluvial geomorphology within which the relationships between landforms and the processes that modify them have been studied. The study of the geometry of the basin and the way in which it changes in response to processes has become a major part of modern geomorphology. Morphometric analysis of a drainage basin is a quantitative description of a basin and an important aspect to know the character of the basin [5].

In geomorphology long ago gained the development "geometrical approach" in studying of a relief. In foreign literature this direction gained development under the name "geomorphometry" [7, 8]. There are also synonyms of this term such as "quantative morphology" (the quantitative morphology), "quantative terrain analysis" (the quantitative analysis of a relief).

The explored region consists of central and east parts of the southern slope of Greater Caucasus and adjacent territories. The area of the explored region is 3220 sq.km (figure 1).

Methodology. As input data for the GIS-analysis of morphometric indexes of relief materials of satellite photos of SRTM are used.

Data of SRTM (Shuttle Radar Topographic Mission) represent the processed results of radar survey of the surface of the globe made from the board of the American Shuttle space ship by the method of radar interferometry, in February 2015. This survey was conducted out almost in all territory and the water area of Earth between 60 ° north lat., 54 ° south lat. by means of the radar SIR-C and X-SAR.

A mathematical basis of the data is the referents-ellipsoid WGS-84 and a projection of GCS_WGS_1984. For SRTM data processing we used the ArcGIS 10.2.1 software package (ESRI, Inc., the USA), the application – Hydro Tools and DEM Tools [1, 9].

The main operations were carried out in the ArcGIS - spatial Analyst applications, 3D analyst and geostatistical Analyst. The Hydro Tools tool model operations of watersheds, reservoirs and drainage network perform functions of processing and preparation of the digital models of a relief (DMR). The DEM Tools applications which contain a number of functions, for calculation of some morphometric indexes was useful to realization in some of operations [3]. The scheme of creation the morphometric maps on the basis of digital models of a relief on ArcGIS (figure 2).

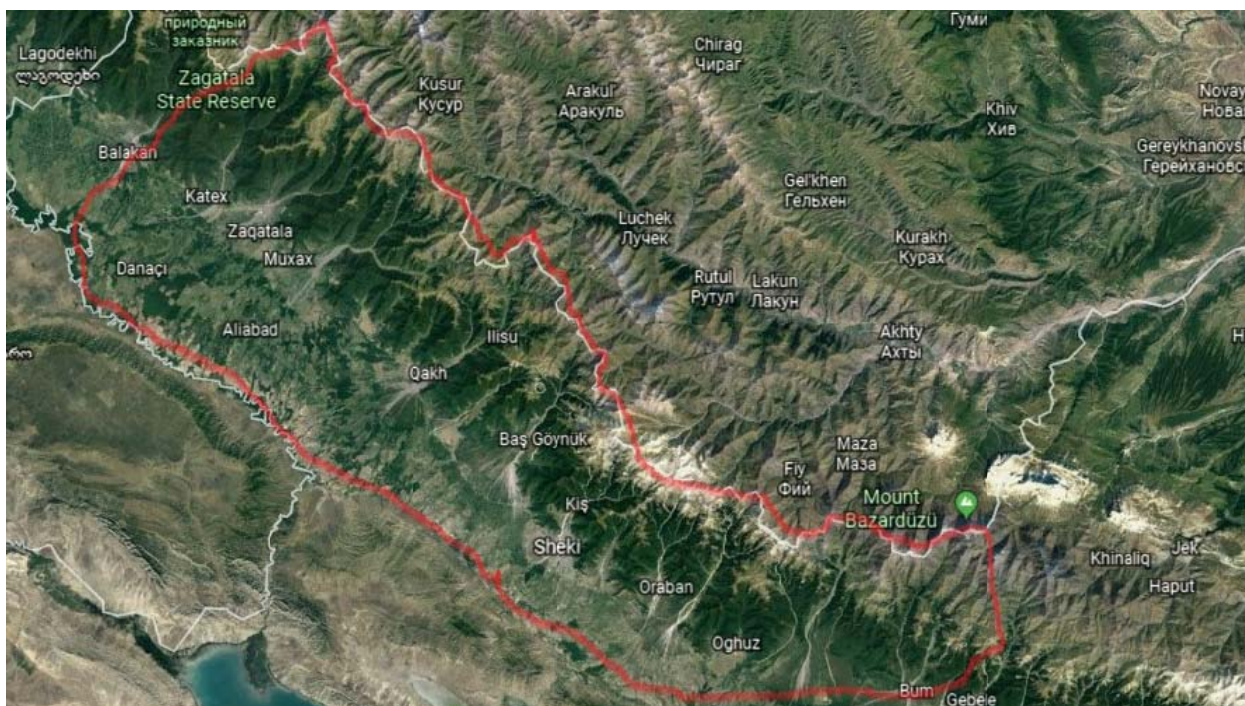


Figure 1 – A geographical location of the explored region

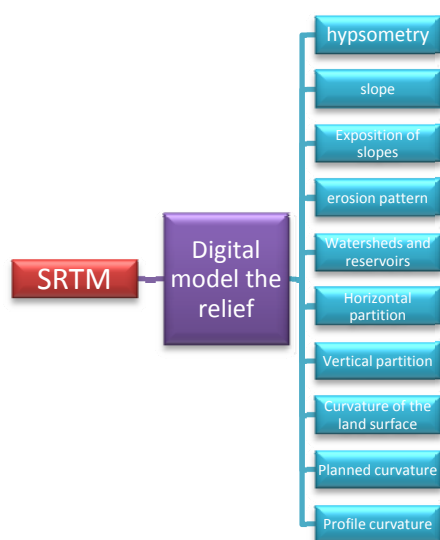


Figure 2 – Scheme of creation of morphometric maps

Discussion of results. For the analysis, we used such classical parameters of morphometry as hypsometry, a surface bias, an exposition of slopes, horizontal and vertical partition, curvature and also, such parameters as the index of partition (dissection index) and the index of ruggedness (ruggedness index).

Hypsometry. The analysis of the Digital model of relief (DMR) shows that absolute heights fluctuate here at 175 to 4147 m. The analysis of the hypsometric map (figure 3) shows that the largest space (54% in the explored region) is occupied by the range of height 175-1000 m (table 1).

Biases of a surface (steepness) and exposition of slopes. Calculations of the biases of a surface it is necessary at assessment of slope processes, in soil erosion calculations, assessment of lands, etc. According to the calculations received from the map (figure 4) slopes with the 10° occupy 49.5% of the total area (table 2). Slopes of more than 10° where slope processes proceed more intensively, is occupied 50.5% of the territory, at the same time the large territory is covered with the slopes by the steepness more than 40° .

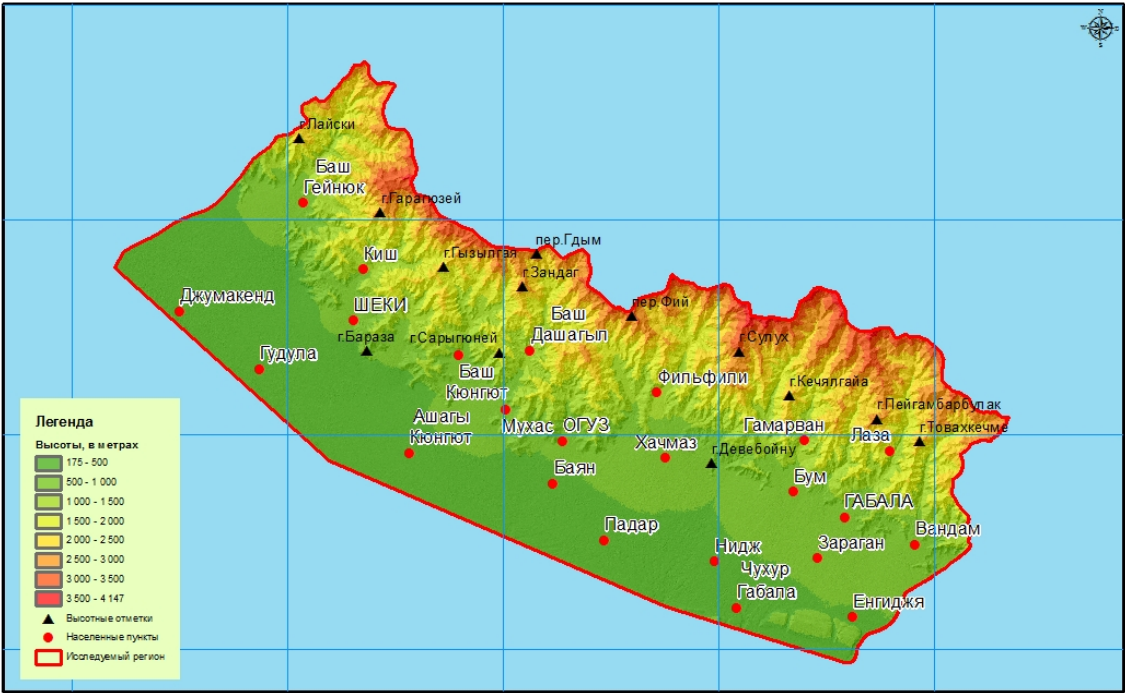
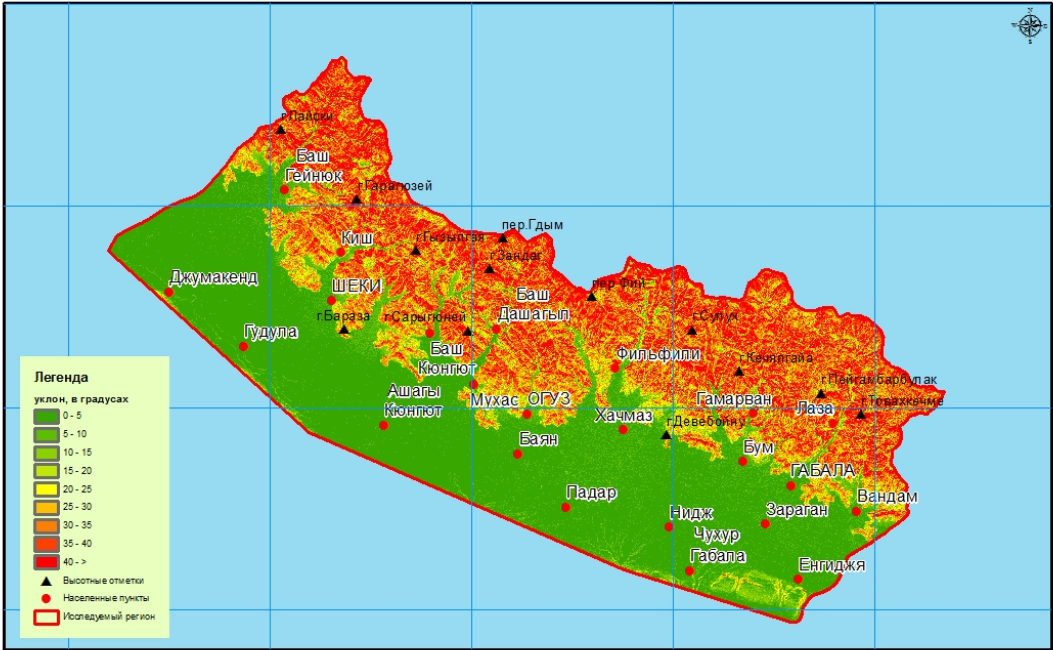


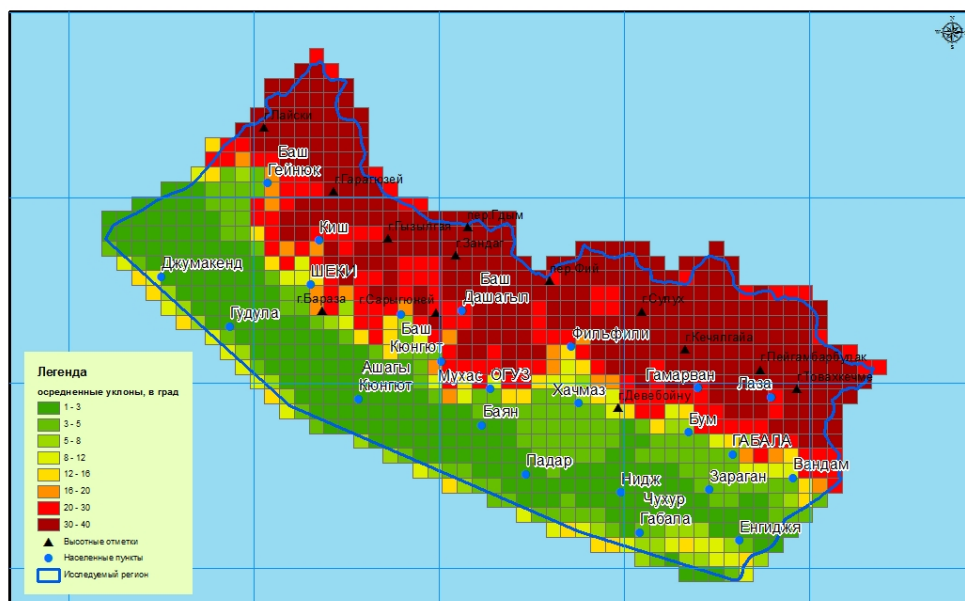
Figure 3 – The hypsometric map of the explored region

Table 1 – Distribution of the total areas on a hypsometry

Hypsometry, m	175–500	500–1000	1000–1500	1500–2000	2000–2500	2500–3000	3000–3500	3500–4147
Area, km ²	1003,385	760,8604	406,5572	391,5357	324,7913	219,8148	100,4427	14,8772
Area, %	31,14	23,61	12,62	12,15	10,08	6,82	3,12	0,46



a)



b)

Figure 4 – The map of slope angles of the explored region received by reference by method (a) and the card of average slope angles received by method of Zone statistics (b)

Table 2 – Distribution of the total areas on slope angles

Angles	0-5°	5-10°	10-15°	15-20°	20-25°	25-30°	30-35°	35-40°	40°->
Area, km ²	1363,24	232,92	103,78	114,93	161,31	233,97	299,97	310,37	399,80
Area, %	42,33	7,23	3,22	3,57	5,01	7,27	9,32	9,64	12,41

The exposition of a slope is one of morphometric characteristics of a relief, characterizing dimensional orientation of the elementary slope (figure 5). It characterizes the slope relation to the multi-scale processes (insolation, gravitation, circulation etc). The exposition can be considered as the direction of a bias [2, 4, 11].

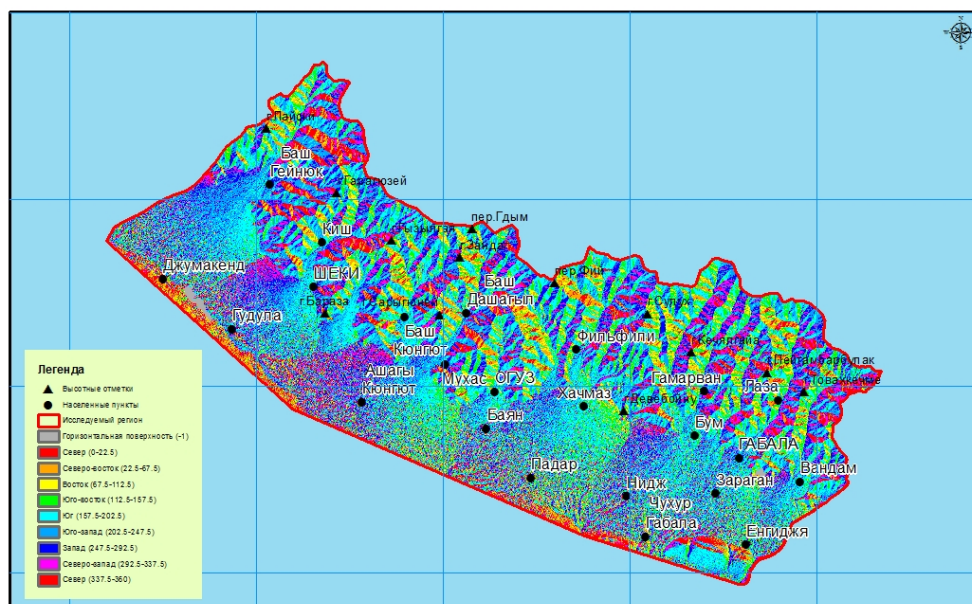


Figure 5 – The map of an exposition of slopes of the explored region

Table 3 – Distribution of the total areas on an exposition of slopes

Exposition	Flatness	North	North-East	East	South-East	South	South-west	West	North-west
Area, km ²	47,29	231,07	193,76	200,83	383,37	762,79	672,10	419,73	309,23
Area, %	1,47	7,18	6,02	6,24	11,91	23,69	20,87	13,03	9,60

As seen from the table, the southern exposition slopes (southern, southern, western, southern and eastern) is composed of half a total of 56.5%. The slopes with anti-polar orientation (northern, southern-western and northern-western) have more than twenty-eight percent of the total area.

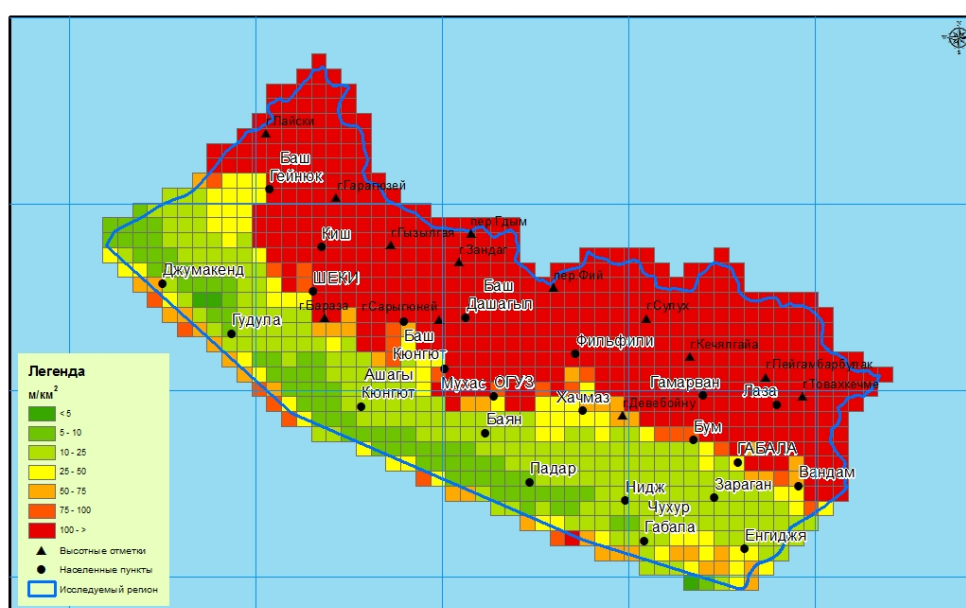


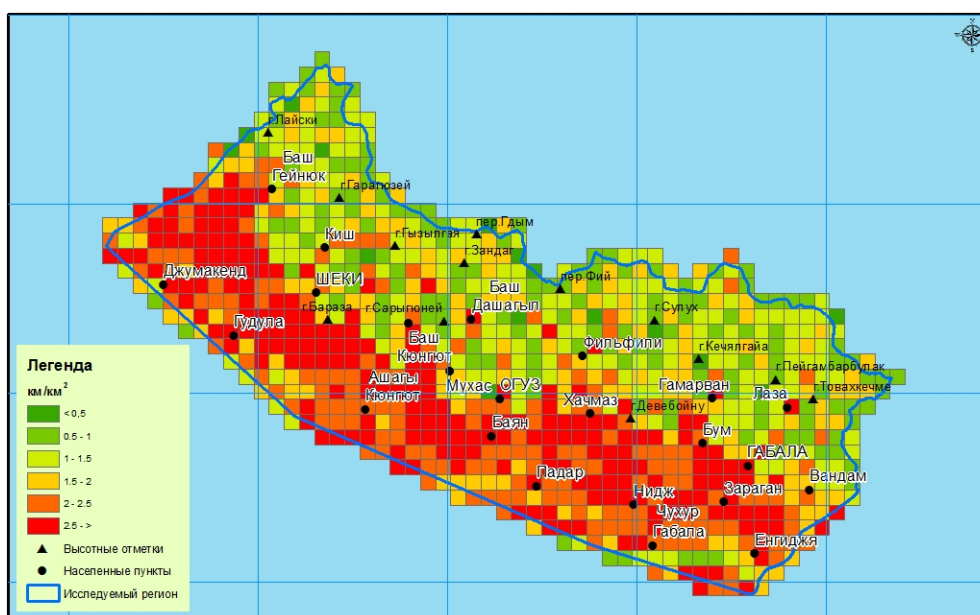
Figure 6 – Map of vertical spreading relief of the region

The erosion network was the base for the calculation horizontally partition. The analysis of the map (figure 7 b) shows that the maximum marks of horizontal partition are found for the Qanix-Ayrichay plain, the least – for water separate zones.

$$DI = \frac{Z_{max} - Z_{min}}{Z_{max}}.$$



a)



b)

Figure 7 – Resistance to CMS Erosion network (a) and map horizontally-distal relief region of the method zonal statistics (b)

Table 4 – Distribution of the total areas by the index of a partition (DI)

Class	DI	Area, km ²	Area, %
Very low	<0,1	1067,583937	33,17
Very low	0,1-0,2	594,9441697	18,49
Temperate	0,2-0,3	1225,437168	38,08
High	0,3-0,4	312,8245578	9,72
Very high	>0,4	17,44357346	0,54

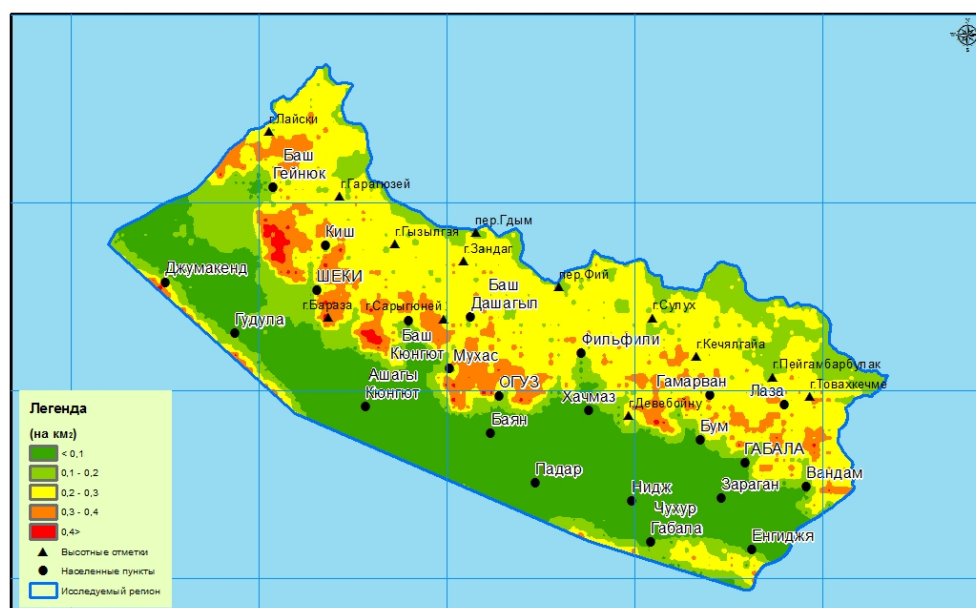


Figure 8 – Distribution of the index of a partition

Ruggedness index. This index describes the complexity and roughness of a land relief. The ruggedness defines extent of crossing of area where the drainage (erosive) network acts as a key parameter. Chorley (1972) developed a formula for this index [9-11]:

$$\frac{\text{Deep partition (m/km}^2\text{)} * \text{horizontal partition (km/km}^2\text{)}}{1000}$$

This index is widely used by scientists in morphological researches for the best comprehension of formation of elements of a relief in the difficult geomorphological conditions [5-8]. Results of the analysis show that the maximum values are partition are observed in mountain and mid-mountain zones of the territory (figure 9).

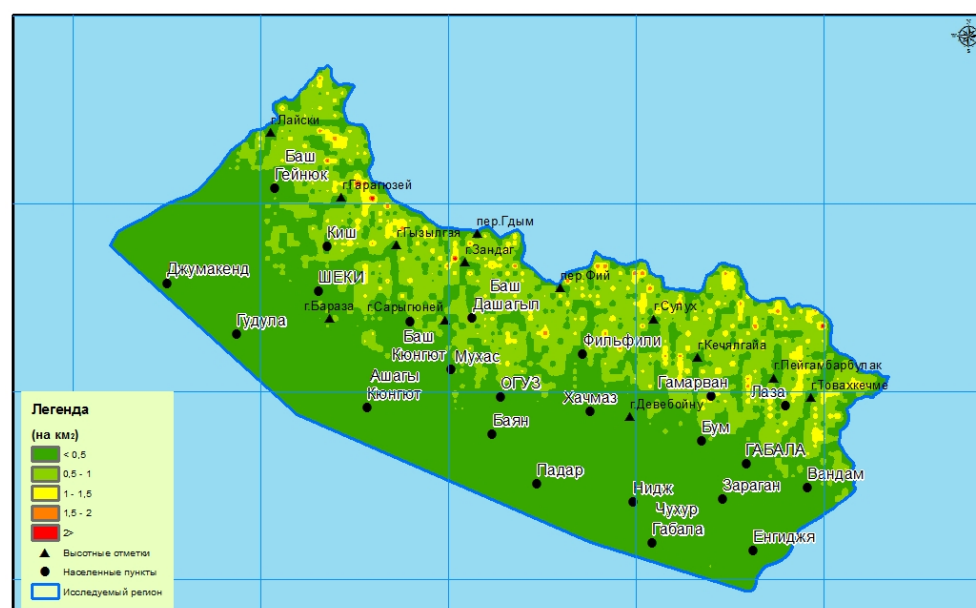


Figure 9 – Distribution of the index of ruggedness

Table 5 – Distribution of the total areas by the index of ruggedness (RI)

Class	RI	Area, km ²	Area, %
Very low	<0,5	2180,205994	67,74
Very low	0,5-1	909,3180482	28,25
Temperate	1-1,5	122,4866082	3,81
High	1,5-2	6,030192299	0,19
Very high	>2	0,481880286	0,01

Conclusions.

1. So, for the first time for the explored territory is carried out the complex morphometric analysis according to the radar interferometric topographic trajectory SRTM, with the software of ArcGIS.

2. On the basis of the created DMR and the modern GIS-technologies are calculated morphometric parameters of a relief. This way allows to carry out the assessment of the modern erosive processes on the quantitative basis and to create a set of geomorphological maps.

3. By means of our research materials is possible to study characteristic of processes of an erosion and accumulation and also assessment of potential stability or tendency to an erosion of various sites of the explored territory.

Л. А. Исмайлова¹, С. Ю. Кулиева²

¹Әзірбайжан мемлекеттік мұнай және өнеркәсіп университеті, Баку, Әзірбайжан,

²География институты ӘУҒА, Баку, Әзірбайжан

ҒАҚ НЕГІЗІНДЕ СЕЛ ҚАУІПІ БАР БАССЕЙНДЕРДІҢ БЕДЕР ПАРАМЕТРЛЕРІН МОРФОМЕТРИЯЛЫҚ ТАЛДАУ

Л. А. Исмайлова¹, С. Ю. Кулиева²

¹Азербайджанский государственный университет нефти и промышленности, Баку, Азербайджан,

²Институт Географии НАНА, Баку, Азербайджан

МОРФОМЕТРИЧЕСКИЙ АНАЛИЗ ПАРАМЕТРОВ РЕЛЬЕФА СЕЛЕОПАСНЫХ БАССЕЙНОВ НА ОСНОВЕ ГИС

Аннотация. На основе цифровой модели рельефа SRTM с помощью ГИС-технологий выполнен морфометрический анализ рельефа селеопасных бассейнов междуречья Шинчай-Дамирапаранчай. С этой целью построены карты гипсометрии, углов наклона, экспозиции, горизонтального и вертикального расчленения, индексов расчлененности и пересеченности, кривизны поверхности. Также проанализировано площадное распространение этих параметров по классам.

Рельеф является одним из основных факторов в дифференциации ландшафтов. В настоящее время, в связи с развитием цифровых технологий и широкой доступностью данных дистанционного зондирования, стала возможным детальная оценка рельефа как ландшафтообразующего фактора. Применение цифровых моделей рельефа (ЦМР) значительно упростило морфометрический анализ рельефа. Именно рельеф и его параметры признаются наиболее важными при выделении ландшафтов.

Получение морфометрических сведений о форме и структуре поверхности рельефа служит начальной процедурой, которая предшествует содержательному исследованию генетических, динамических, временных (т.е. общих геоморфологических) аспектов функционирования рельефа. Преимущество такого подхода заключается в возможности абстрагирования от неопределенности и неоднозначности в геоморфологическом отношении, при этом сосредоточиваясь на анализе морфометрических показателей.

В определении рельефа как объекта исследования геоморфологии существуют 2 основных взгляда. Первый из них рассматривает рельеф как некую совокупность форм земной поверхности, которую можно

описать в виде набора пространственно-координированных высотных отметок (в виде XYZ). Т.е. исследованию подлежат геометрические показатели. Такой подход называется геометрическим. Другая трактовка рельефа учитывает и слагающие его геологические тела. Это значительно усложняет и делает субъективным классификацию форм рельефа.

Ключевые слова: ГИС, ЦМР, морфометрический анализ, расчлененность, SRTM.

Information about authors:

Ismaylova Latifa Arif, PHD, assistant of the department "Industrial safety and labor protection", Azerbaijan State Oil and Industry University; latifa.ismaylova@gmail.com; <https://orcid.org/0000-0002-0254-1746>

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S. B. Mishnev¹, V. G. Berezyuk¹, S. B. Kuzembayev², Y. B. Aimagambetov³,
M. R. Sikhimbayev³, B. N. Absadykov⁴

¹Polytechnical institute of the Siberian federal university, Krasnoyarsk, Russia,

²Sh. Ualikhanov Kokshetau state university, Kokshetau, Kazakhstan,

³Karaganda economic university Kazpotrebsoyuz, Karaganda, Kazakhstan,

⁴A. B. Bekturov institute of chemical sciences, Almaty, Kazakhstan.

E-mail: mishnevs@mail.ru; vberezuk@mail.ru; ksb_mlp@mail.ru;

erkara.aimagambetov@yandex.kz; smurat@yandex.ru; b_absadykov@mail.ru

THE SCIENTIFIC RESEARCHES DIRECTED ON RECEIVING PREPARATIONS FROM THE TEXTURED METAL SHEET WITH THE SET PROPERTIES

Abstract. The process of metal forming is widely used in metallurgy, machine-building and other industries of production of semi-finished and finished products made of ferrous and nonferrous metals and their alloys. From this standpoint, the important value obtains scientific research aimed at designing the properties of metallurgical blank of the machine-building complex. In work short results of a technique of development of laboratory schemes of obtaining the textured metal sheet with anisotropy of physicomechanical properties, on the basis of the principle of symmetrization-dissymmetrization of Shubnikov-Curie method of the differential longitudinal rolling drawing developed are presented. The method is based on the symmetry approach for modeling processes on the basis of the identified relationships between the kinematic factor and the impact that allows to predict the result of processing, and conversely, setting the result, it is possible to design technology.

Keywords: anisotropy, systemmade element, the generating element of symmetry of an elementary field of influence, symmetry texture, quasi-isotropic preform microplastic deformation.

Introduction. In technological processing of preparations by pressure, in particular at the first hot rolling of industrial ingots, results of processes of transcrystallization have essential impact on macro- and a preparation microstructure, and, therefore, and on its quality indicators.

Ways of receiving preparations with the directed crystal structure (texture) are based on management of a ratio of macrostructural zones in system: a peripheral fine-grained zone – column crystals – equal crystals.

On the basis of the principle of symmetrization-dissymmetrization of Shubnikov–Curie [1] authors experimentally, with use of technologies of longitudinal rolling, is reasonable the system method allowing to solve effectively the problems connected as with receiving materials with various on symmetry and size of anisotropy of their physicomechanical properties, and with production of products from them with necessary operational properties [2-6].

Discussed in [2-4] laboratory rolling longitudinal differential scheme do not exhaust all the possible technology for sheet metal with different symmetry of the anisotropy of physical and mechanical properties for this type of treatment. It was considered the most general case of a longitudinal rolling when the work rolls are rotated in opposite directions at the same speed (figure 1a). [2].

In continuation of [3, 5, 6] and the development of the principle of symmetrization-dissymmetrization Shubnikov-Curie [1, 3], the simulation laboratory processing circuitry materials legitimate question becomes the link between the characteristics of the kinematic factor, impact and response, by which is meant any geometric structural, physical and mechanical properties that are sensitive to the effects of rolling.

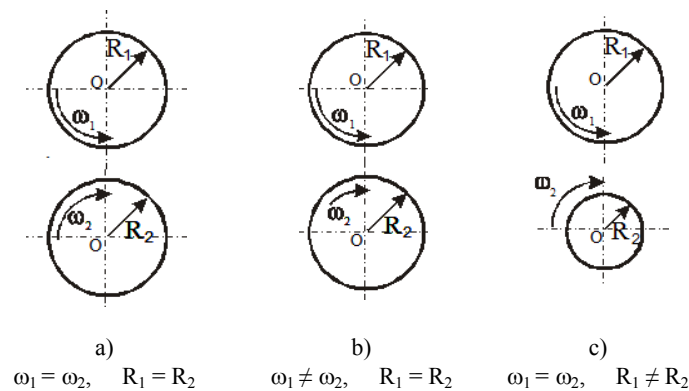


Figure 1 – The geometric interpretation of possible kinematic parameters of laboratory processing circuit materials based on longitudinal rolling

The most interesting from the point of view of the principle of symmetrization-dissymmetrization Shubnikov-Curie, in the development of technologies for the production of sheet metal with different symmetry of the anisotropy of physical and mechanical properties, is rolling, drawing, kinematic parameters of which are presented in figure 1 (b, c).

That's way, in the present study we solve the following problem - find all the laboratory scheme longitudinal differential rolling-drawing, which allow to obtain metal sheets with different symmetries of anisotropy of physical and mechanical properties.

Problem statement and the physical nature of the process. The fundamental difference of rolling-drawing from conventional longitudinal rolling is in the structure of the stress field and, consequently, in the processes occurring in the deformation, which is caused by the kinematic parameters of the working tool and the characteristics of deformation of polycrystalline materials in the area of microplastic deformation [6-15].

We will not consider in detail the processes occurring in the deformation, we note only that the kinematics of the metal flow during rolling, drawing differs from the usual longitudinal rolling in that field strain rates is not symmetrical with respect to a plane lying parallel to the axes of the rolls and equidistant from them.

Determining influence on the symmetry characteristics of the kinematics of rolling provides a working tool – a laboratory rolling mill rolls. Geometrically work roll in a static state is displayed as a resting cylinder and is characterized by symmetry group ∞ / mmm .

The moment of force F , acting on the work roll, and its geometrical interpretation, represented an axial vector, identical in terms of the group transformations, and describe the same symmetry group ∞ / m . Due to the fact that the geometric figures form a heterogeneous system, based on the principle of Curie symmetry kinematic factor of the roll is determined by the intersection of the symmetry groups ∞ / mmm and ∞ / m :

$$G_k = \infty / mmm \cap \infty / m = \infty / m. \quad (1)$$

The system of rolls in a static state is established is described **mmm** symmetry group, i.e. system is symmetrical relative to the three planes of symmetry.

The symmetry group describing said system in a dynamic state is determined based on the generalized principle of symmetry and will look like:

$$G_c = \infty / m \cap \infty / m = m. \quad (2)$$

As seen from the expression, the common element of symmetry is the plane of symmetry **m**, perpendicular to the roll axes and which will determine the symmetry of the system band. Thus, the velocity field of the deformation is not symmetrical about a plane lying parallel to and equidistant from the axes of the rolls.

However, the kinematic factor, in terms of symmetry, only the structural features characteristic of the working body and completely covers the symmetry of impact, which ultimately determines the physical and mechanical properties of the rolled product.

The authors found an association between the kinematic factor and a factor of influence on the basis of the symmetry approach to this kind of treatment [4].

It is known that the influence on the symmetry properties of the crystals can be analyzed: firstly - in crystal symmetry; Second - symmetry of external forces; thirdly - symmetry offset; and fourthly - the symmetry of the physical properties [7, 11-13, 19].

For the polycrystalline materials symmetry analysis it looks not so clear, because of the structural features of the structure of the latter.

The authors of the impact of external forces on the symmetry of the physical properties of polycrystalline materials during their processing is investigated through various schemes of stress-strain state, symmetry-related generating elements of symmetry of the elementary field exposure (*GSEFE*).

Symmetry approach for modeling processes on the basis of the identified relationships between the kinematic factor allows to predict and influence the result of processing [5]. Conversely, setting the result, it is possible to design technology.

Experimental study and discussion of the results. For the production of the original billet was developed [17, 18, 20] technique to obtain quasi-isotropic samples by pressing powders of copper, followed by sintering. We investigated the dependence of the density pycnometric pressing and sintering parameters for sieve № 035-025. The results are shown in figure 2.

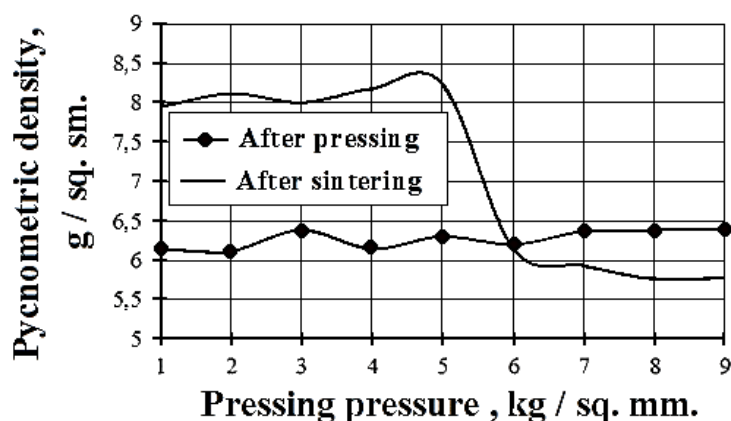


Figure 2 – Depending pycnometric density of modes pressing and sintering copper powder (sieve № 035-025)

As can be seen from the graph, pressing pressure significantly affects the density of the powder, which is explained by the influence of particle shape and external friction of the particles against each other and on the mold surface. However, this small difference of density (less than 10%), strongly influences the subsequent processing. Sintering powders compacted under a pressure of 1 to 5 kg/mm², considerably increases Pycnometric density (about 30%).

At higher pressures, the effect of compression on pycnometric sintering density drops sharply. In powder compacted pressure of about 6 kg/mm², the sintering density does not change substantially. At compaction pressures greater than 6 kg/mm² sinter powder, on the contrary, reduces Pycnometric density. We believe the main reason for this change in the current process of open porosity. As is known, the larger the porosity, the less Pycnometric density of the metal powder. During sintering there is intense release of gases from the fusion of the powder particles and particles in the contact areas. At low compaction pressures many open pores through which gases are emitted to the outside, there is shrinkage of the sample. With increasing pressure, the number of contact points of the particles increases, the gases can not be as freely as before, to come out [16]. Shrinkage decreases Pycnometric density becomes smaller.

When rolling sheets in rolling mills there are vibrations which have impact on decline in quality of hire in the form of superficial defects and a deviation on hire thickness. Frequency of vibrations of rolls depends on the mode of rolling and a condition of the equipment. The schedule of vibration of a working roll when rolling is submitted on figure 3 [8]. As we see, the frequency of vibrations makes about 0,3 Hz with the greatest amplitude of 0,2 mm.

Graphically periodic defects caused by vibrations of rolls can be presented, as shown in figure 4.

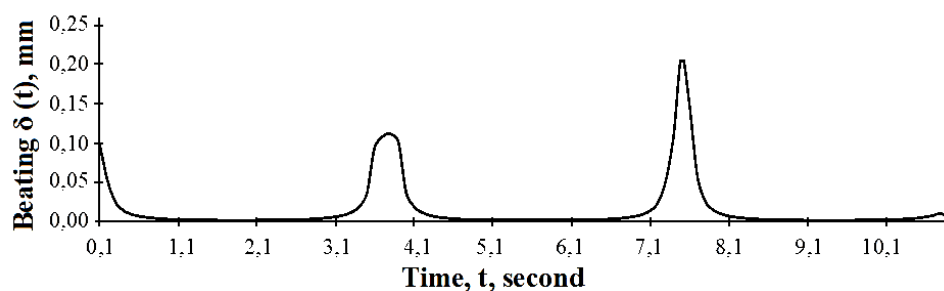


Figure 3 – The schedule of vibration of a working roll when rolling

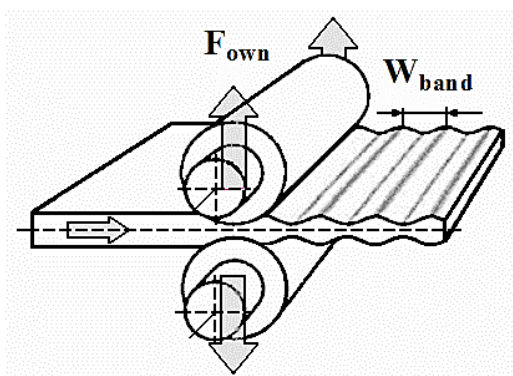


Figure 4 –
The scheme of emergence
of periodic defects of a leaf
as a result of own fluctuations of rolls

For decrease in influence of harmful vibrations on quality of a surface of hire, besides application of the standard actions, application of technologies of differential rolling in two mutually perpendicular directions with the minimum sinking for each tackle is possible, thus mutually perpendicular imposing of periodic defects minimizes their own influence on quality of a surface of a leaf.

Experiments on rolling of samples were made on the laboratory rolling mill of Mario Di Maio 20122 firm (Italy) (figure 5). Diameter of working rolls of 160 mm.



Figure 5 – Laboratory rolling mill

Initial material represented ingots section 60×6 mm and 60 mm long. After rolling the sample turned on 90° round a vertical axis and was repeatedly rolled with the same mode. Sinking of a sample for one tackle made no more than 5%. It is established that when rolling with sinking of 5% of vibration are practically not observed.

The received results of rolling of quasiisotropic preparation are presented in figure 6, 7. They can form the basis for development of laboratory schemes of receiving textures with anisotropy of physico-mechanical properties, various on symmetry, for other types of processing of metal materials.

Figure 6 –
A polar figure {111} from the pressed
copper powder after usual reversible
longitudinal rolling in one direction

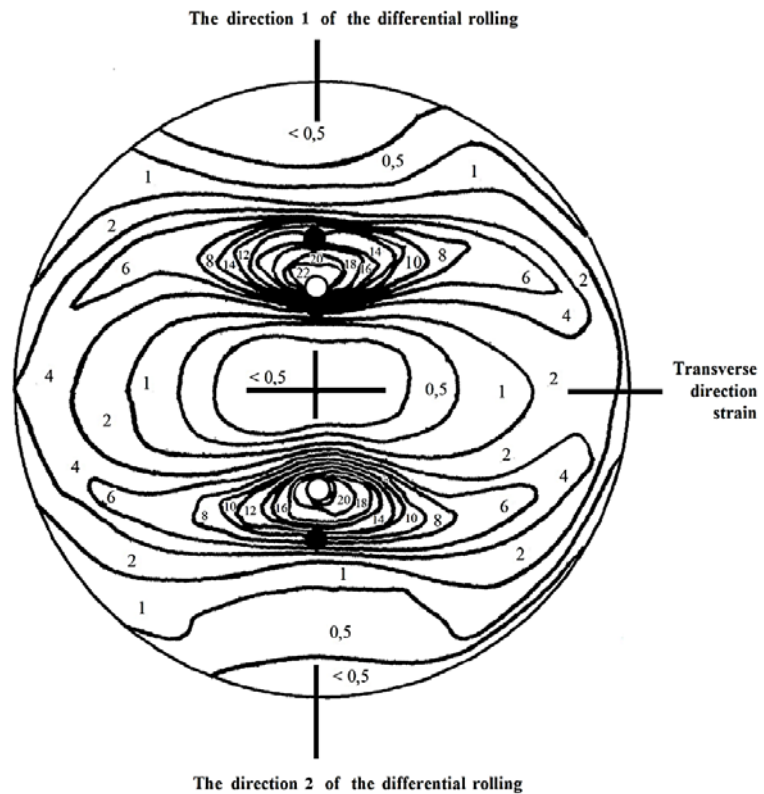
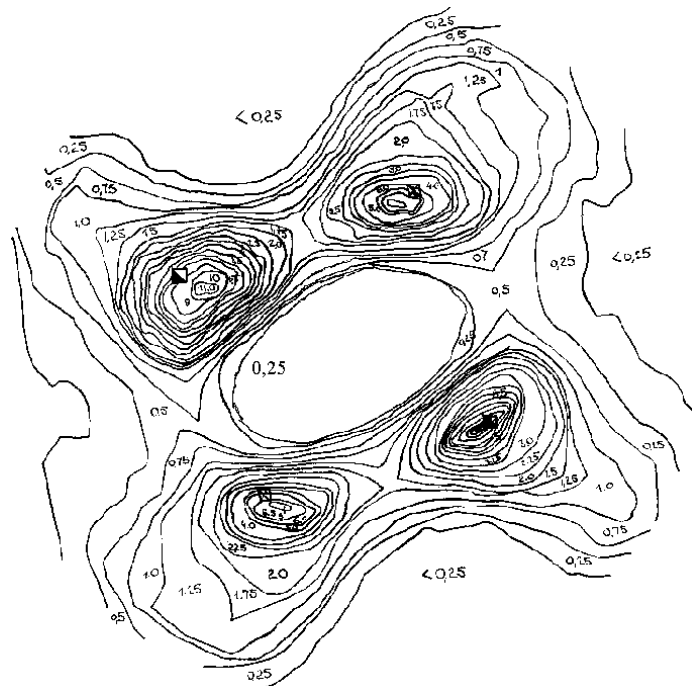


Figure 7 –
A polar figure {111} from the pressed
copper powder after differential reversible
longitudinal rolling in two mutual
and perpendicular directions



Establishment of interrelation between a kinematic factor and a factor of influence was revealed through impact of elements of symmetry on orthogonal system of coordinates. The spatial arrangement initial ($X_3 X_2 X_1$) and shaded ($X_3' X_1' X_2'$) systems of the coordinates connected among themselves by the plane of symmetry of m , perpendicular to a coordinate axis OX_1 is given in figure 8.

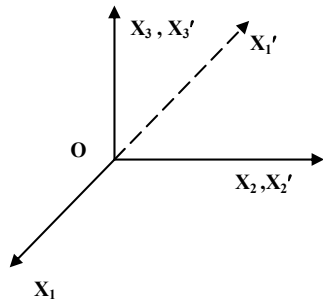


Figure 8 –
The systems of coordinates ($X_1 X_2 X_3$) and ($X_1' X_2' X_3'$),
connected by one plane of symmetry, the perpendicular axis OX_1
coinciding with the coordinate plane ($X_2 O X_3$)

According to the received results of interrelation of systems of coordinates through elements of symmetry identical mathematical images on the basis of tensors of the second rank were described [3].

On the basis of the established interrelations between a kinematic factor and a factor of influence laboratory schemes of processing of metal materials were simulated by the rolling drawing method.

As the instrument of modeling of laboratory schemes of processing of materials by authors the concept a *system creating element* (SKE) is entered.

The symmetry element which is basic at calculation of SKE, we will call *the generating element of symmetry of an elementary field of influence* (GESEFI). Then definition of SKE in a short form will have an appearance: - *it is system which is characterized by such set of elements of symmetry which contains the generating element of symmetry of an elementary field of influence, and their relative positioning determines its level*. Two rules follow from the last point in definition: 1) *each subsequent SKE level contains the previous*; 2) *derivative SKE of the current level can't be SKE of other levels*. We will easily be convinced of it when we analyse SKE of all possible levels and their derivatives for rolling drawing.

As GESEFI for rolling drawing the plane of symmetry of m which also is also its group of symmetry is.

Results of calculation of SKE on levels, for longitudinal rolling drawing, are presented in table (without derivative transformations at each level).

Results of group transformation for SKE in a short form

SKE	SKE in a short form
SKE-1	$G_{c1} = m$
SKE-2	$G_{c2} = m \cap m = mm2$
SKE-3	$G_{c3} = m \cap m = 2$
SKE-4	$G_{c4} = 2 \cap m = 2/m$

The generalized results can be coordinated with the theory of classification of textures by simmet-
rion signs [9, 10]. Owing to lack recently of works on improvement of the system analysis, on the basis
of the generalized principle of symmetry, this method didn't gain wide scientific circulation.

However, at development and addition of basic provisions of the system analysis on the basis of
theoretical and experimental data, the last can be applied to the solution of tasks of design of special
technologies of processing of materials.

Conclusions. At application of technologies of differential rolling mutually perpendicular imposing
of periodic defects minimizes their own influence on quality of a surface of a leaf.

On the basis of the principle of symmetrization-dissimmetrization of Shubnikov-Curie groups of
symmetry of initial (potential) fields of tension of processes of rolling drawing, by means of identical
representation at the geometrical and mathematical levels of geometric-physical parameters of the working
tool are found.

Schemes of processes of rolling drawing in which fields of tension of unilateral and reversed rolling
act as backbone elements are developed.

С. В. Мишнев¹, В. Г. Березюк, С. Б. Кузембаев², Е. Б. Аймагамбетов³,
М. Р. Сихимбаев³, Б. Н. Абсадыков⁴

¹Сібір федералдық университеті, Красноярск, Ресей,

²Ш. Уәлиханов атындағы Көкшетау мемлекеттік университеті, Көкшетау, Қазақстан,

³Қазтұтынуодағы Қарағанды экономикалық университеті, Қарағанды, Қазақстан,

⁴Ө. Б. Бектұров атындағы Химия ғылымдары институты, Алматы, Қазақстан

БЕРІЛГЕН ҚАСИЕТТЕРІМЕН ТЕКСТУРАЛАНЫЛҒАН МЕТАЛ ПАРАҚТАН ДАЙЫНДАМА АЛУҒА АРНАЛҒАН ҒЫЛЫМИ ЗЕРТТЕУЛЕР

Аннотация. Металлургияда, машина жасауда және өнеркәсіптің басқа салаларда қара және түсті металдар мен олардың қорытпаларынан жартылай өнімдер мен дайындамалар өндіру үшін металды қыыммен өңдеу процестері кең қолдануда. Бұл көзқараспен машина жасау кешені үшін металлургиялық дайындаманың қасиеттерін жобалауға бағытталған ғылыми зерттеулер зор маңыз алады. Жұмыста Шубников-Кюри симметриялау-диссимметриялау принципі негізінде зерттеп дайындалған дифференциалдық көлденең илемдеу-тарту әдісімен симметрия бойынша физика-механикалық қасиеттерінің анизотропиясы әртүрлі текстураланған металл парағын алу үшін зертханалық схемаларын жасау әдістемесінің қысқаша нәтижелері берілген. Кинематикалық фактор мен әрекеттің арасында анықталған өзара байланыстар негізінде технологиялық процестер үлгілегендегі симметриялық тәсілдемесі болып әдістеме негізі табылады. Сонымен, технологиялық өңдеудің нәтижесін болжауға мүмкіншілігі пайда болады және керісінше нәтижені белгілеп технологияны жобалау мүмкін.

Түйін сөздер: анизотропия, жүйе құрайтын элемент, әсердің қарапайым өрісі симметриясын тудыратын элемент, текстураның симметриясы, жалған изотропты дайындама, шаңын пластикалық деформациялар.

С. В. Мишнев¹, В. Г. Березюк, С. Б. Кузембаев², Е. Б. Аймагамбетов³,
М. Р. Сихимбаев³, Б. Н. Абсадыков⁴

¹Сибирский федеральный университет, Красноярск, Россия,

²Кокшетауский государственный университет им. Ш. Уалиханова, Кокшетау, Казахстан,

³Карагандинский экономический университет Казпотребсоюза, Караганда, Казахстан,

⁴Институт химических наук им. А. Б. Бектурова, Алматы, Казахстан

НАУЧНЫЕ ИССЛЕДОВАНИЯ, НАПРАВЛЕННЫЕ НА ПОЛУЧЕНИЕ ЗАГОТОВОК ИЗ ТЕКСТУРИРОВАННОГО МЕТАЛЛИЧЕСКОГО ЛИСТА С ЗАДАНЫМИ СВОЙСТВАМИ

Аннотация. Процессы обработки металлов давлением широко используются в металлургии, машиностроении и других отраслях промышленности для производства полуфабрикатов и готовых изделий из черных и цветных металлов, а также и их сплавов. С этих позиций, принципиально важное значение приобретают научные исследования, направленные на проектирование свойств металлургической заготовки для машиностроительного комплекса. В работе представлены краткие результаты методики разработки лабораторных схем получения текстурированного металлического листа с различной по симметрии анизотропией физико-механических свойств, методом дифференциальной продольной прокатки волочением, разработанной на основе принципа симметризации-диссимметризации Шубникова-Кюри. В основе методики лежит симметричный подход при моделировании технологических процессов на основе выявленных взаимосвязей между кинематическим фактором и воздействием, что позволяет прогнозировать результат технологической обработки, и наоборот, задавая результат, можно спроектировать технологию.

Ключевые слова: анизотропия, свойства, прокатка волочением; системообразующий элемент; порождающий элемент симметрии элементарного поля воздействия; симметрия текстур, квазиизотропная заготовка, микропластические деформации.

Information about authors:

Mishnev Sergey Vasilyevich, Candidate of Technical Sciences, Associate Professor, Russian Federation, Krasnoyarsk, Siberian Federal University, Polytechnic Institute, associate professor at the department of 'Mechanical Engineering'; smishnev@sfu-kras.ru; <https://orcid.org/0000-0001-6065-7643>

Berezyuk Vladimir Grigorevich, Candidate of Technical Sciences, Associate Professor, Russian Federation, Krasnoyarsk, Siberian Federal University, Polytechnic Institute, associate professor at the department of 'Materials Science and Technology'; vberezuk@mail.ru; <https://orcid.org/0000-0002-0923-0289>

Kuzembayev Serik Bapaevich, Doctor of technical sciences, docent, the active member of the International Informatization Academy (The diploma No.1833 PK from 06.11.2015), Kazakhstan, Kokshetau, Kokshetau state university named after S. Ualikhanov, professor at the Department of Engineering Technology and Transport; ksb_mlp@mail.ru; <https://orcid.org/0000-0003-2515-6696>

Aimagambetov Yerkara Balkarayevich, Doctor of Economic Sciences, Professor, Academician of IAS HS, Academician of International Economic Academy of Eurasia, Kazakhstan, Karaganda, Rector of Karaganda economic University Kazpotrebsoyuz; erkara.aimagambetov@yandex.kz; <https://orcid.org/0000-0003-1036-4441>

Sikhimbayev Muratbay Ryzdikbayevich, Doctor of Economic Sciences, Professor, the Corresponding member of the Russian Academy of Natural sciences (The diploma No. 4771 from 08.11.2011), Kazakhstan, Karaganda, Karaganda economic university of Kazpotrebsoyuz, professor at the Department of "Ecology and assessment"; smurat@yandex.ru; <https://orcid.org/0000-0002-8763-6145>

Absadykov Bakhyt Narikbayevich, Doctor of Technical Sciences, Professor, the Corresponding member of National Academy of Sciences of the Republic of Kazakhstan, Kazakhstan, Almaty, A. B. Bekturov Institute of Chemical Sciences; b_absadykov@mail.ru; <https://orcid.org/0000-0001-7829-0958>

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R. Khojayev¹, R. Gabaidullin¹, S. Lis², Sh. Shapalov³, N. Akimbekova⁴, G. Ivahnuk⁵¹GeoMark Research Center, Karaganda, Kazakhstan,²The Institute For Comprehensive Development Of Underground Resources LLP, Karaganda, Kazakhstan,³Silkway international university, Shymkent, Kazakhstan,⁴Karaganda state technical university, Karaganda, Kazakhstan,⁵Petersburg state institute of technology (technical university), Saint-Petersburg, Russia.

E-mail: khodzhayev.rustam@bk.ru, gabaydullin.ravgat@bk.ru, lis.sergey.2018@bk.ru, shermahan_1984@mail.ru, nuriya.akimbekova@bk.ru, vakhnyukg@list.ru

WAVE PROPERTIES OF COAL-BEARING STRATA

Abstract. The study was performed in the coal mines of Karaganda coal basin located under the safety pillars and stratum edges. The study comprised of measurements of dimensions of mines located under the safety pillars and edges of above coal strata. The results showed that in all investigated mines the height of mine located under the safety pillar (edge of stratum) varied in a wave pattern. The article summarise the comparative analysis of investigation with the theory predicted laws of wave processes. In the result of the analysis the diffraction features of abutment pressure and the regularities of its propagation under the safety pillars and stratum edges were revealed.

Key words: bearing pressure, the pillar of coal, marginal part of the coal seam, the zone of high rock pressure, interference, diffraction, harmonic process.

Introduction. The actual rock is a multicomponent media formed under the influence of many geological factors. Mechanical features of different rock types vary widely. The processes developed in the rock adjacent to mines and excavations are materially influenced by the stress caused by mining activities and their own mechanical features. It is virtually impossible to take into account all the range of mechanical features of natural soil, and due to that various mechanical models of rock are adopted. These models account for the major substantial features of rock while ignoring minor features. Such substantial features are elasticity, plasticity, frangibility, solidity, isotropism and uniformity of rock. «The real world is so rich in its variety that when we try to invent a model as close to reality as possible we soon are lost in the chase for the most complicated equations consisting of unknown variables following unknown laws. Should we determine these equations they develop in even more complicated ones, ad infinite" - says R. Bellman [1]. The study of the majority of natural phenomena in view of the cause and effect laws is often overwhelmingly complicated, if possible.

Nowadays the problem of finding the laws of organization of physical systems is clearly interdisciplinary; it does not belong to physics, biology, ecology or linguistics itself. The science in the whole range of problems it addresses has come close to understanding of the ways of solution of this problem. It is proven by the existence of a wide variety of science disciplines aimed at finding the laws of organizations of physical systems, though that fact may be hidden beyond apparent variety of theories: dissipative structures, generalized catastrophe, off-balance phase state and bifurcations, irreversible process and structural stability, autowave process and synergetics [2].

Material and methods. Synergetics as a science field is of integrative nature. It combines physics, chemistry, biology, psychology, social studies, astronomy, philosophy and others stating by identification of the laws all of them share. It is an interdisciplinary science, which provides strictly mathematical substantiation of self-organization processes, occurring in open complex nonlinear systems Synergetics deals with the study of systems comprising of subsystems of various nature. It considers how the

interaction of such subsystems leads to the emergence of spatial, temporal and spatial-temporal structures on a macroscopic scale. Thermodynamics of non-equilibrium processes, the theory of random processes, the theory of non-linear oscillations and waves are basis of synergetics.

The world as a whole and every structure of it is a Wave. In other words, not just microscopic objects (traditionally studied in quantum theory), but also each existing thing, all the diversity of the systems of the world, as soon as they are dialectically contradictory, represent the Wave which is a structural resonance of the substrate they're made of, i.e. sort of "interference" of opposites within unity. Physical interference fringe pattern, whether arising as a result of superposition of coherent light, sound or surface waves is just a particular case of the most common resonating principle of the nature, which manifests in interference.

Sources [3, 4] are the studies of wave nature of abutment pressure under safety pillars and stratum edges of coal layers, where the wave nature of distribution of stationary abutment pressure is found. Any wave propagation generates interference and diffraction, so it makes perfect scene to verify the correspondence of wave processes observed in carbonaceous rock to the common oscillatory laws. For instance, diffraction in optics is used to confirm the wave structure of light. Diffraction is defined as the set of facts which are determined by wave nature of light and observed during the propagation of light in a strongly pronounced nonlinear media. In narrower sense it is defined as the bending of waves around the corners of an obstacle or aperture into the region of geometrical shadow of the obstacle. Diffraction is the feature of propagation of waves [5].

Results and discussion. As for the carbonaceous rock the diffraction of rock pressure waves shall take place at the border of the two diverse media: undisturbed rock (elastic medium) and excavated space (nonelastic medium). This is why the coal safety pillar may be considered as a waveguide through which the wave of elastic abutment pressure propagate.

The type of diffraction pattern depends on the value of wave parameter P [6]:

$$P = \frac{\sqrt{\lambda \cdot L}}{a}$$

where a – width of the waveguide, meters; L – the distance from the plane of the waveguide to the observations plane parallel to it, m; λ – wavelength, m.

The excavated space is an obstacle to propagation of such abutment pressure waves, being a kind of screen for such waves. Thus, in relation to rock pressure: a – width of safety pillar B_y , m; L – thickness of inter-stratum space h_m , m; λ – abutment pressure wavelength, equal to the doubled thickness of top rock $2h_{o.k.}$ [4], m. Then the wave parameter equation is:

$$P = \sqrt{\frac{2h_{o.k.} \cdot h_m}{B_y}}$$

$$P = \frac{\sqrt{2h_{o.k.} \cdot h_m}}{B_y}$$

At $P \ll 1$ (wide slot) the intensity distribution on the plane is shown on figure 1. Adjacent to points T_1 и T_2 , located across the edges of the slot it resembles the intensity distribution adjacent to point T_0 , at diffraction on the edge of semi-infinite obstacle (figure 2). The amplitude in point T_0 , located across the edge of the screen is twice less than without the obstacle. The intensity of light is 4 times less, correspondingly. The intensity J of elastic wave is the amount of energy transferred by the wave per unit of time through unit of space perpendicular to direction of propagation [9]. The intensity of sinusoidal wave is proportional to its amplitude squared. With regards to rock pressure waves the amplitude corresponds to the decrease of mine height h subject to pressure.

Let's compare the diffraction pattern on the edge of semi-infinite obstacle (figure 2) and the diffraction pattern of rock pressure on the edge of coal stratum obtained during studies [7] (figures 3 and 4). The study comprised of measurements of dimensions of mines located under the safety pillars and edges of coal strata.

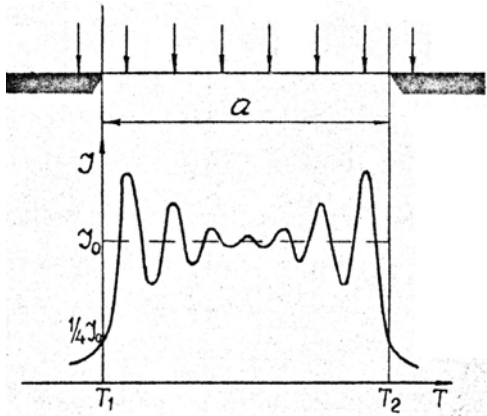


Figure 1 – The intensity distribution of light diffraction on the wide slot at P 1

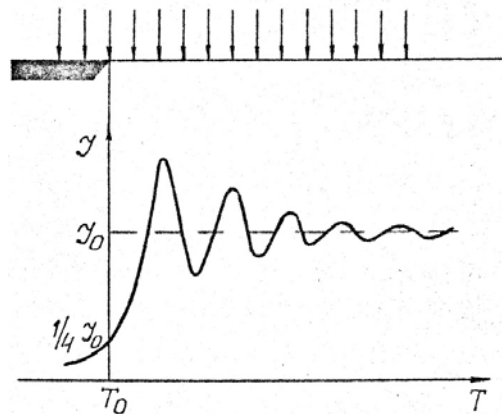


Figure 2 – The intensity distribution of light diffraction on the edge of semi infinite obstacle

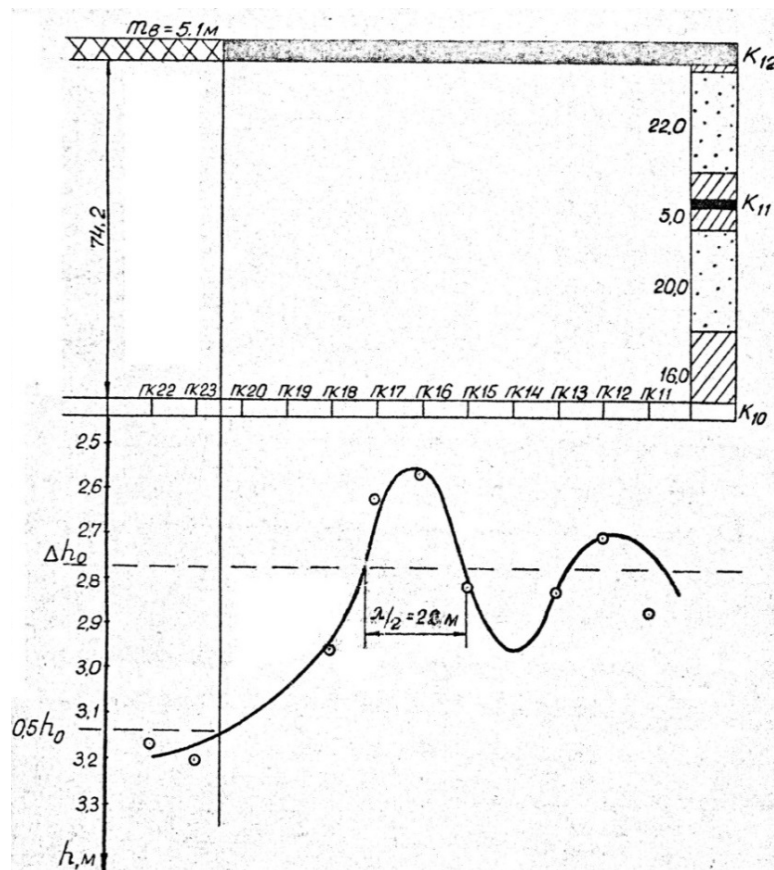


Figure 3 – Observed abutment pressure in the belt entry 42K₁₀-3

The visual resemblance of diffraction patterns is further confirmed by absolute values of deformations of excavations. Thus in the belt entry 42K₁₀-3 having original height $h = 3,5$ m, the axis of abutment pressure wave is located at $h_0 = 2,77$ m, i.e. deformation is $\Delta h_0 = 3,5 - 2,77 = 0,73$ m, and the deformation in the point located under the edge of stratum, $\Delta h_1 = 3,5 - 3,12 = 0,37$ m. So, $\Delta h_1 / \Delta h_0 = 0,51$, i.e. the amplitude in the point located contrary to the edge of the obstacle is twice less than without the obstacle (factoring measurement error). The same applies to the belt entry 45K₁₀-3. Given the original height of excavation $h = 3,635$ m the axis of abutment pressure is located at $h_0 = 3,15$ m, i.e., $\Delta h_0 = 0,485$ m, $\Delta h_1 = 0,245$ m, $\Delta h_1 / \Delta h_0 = 0,5$.

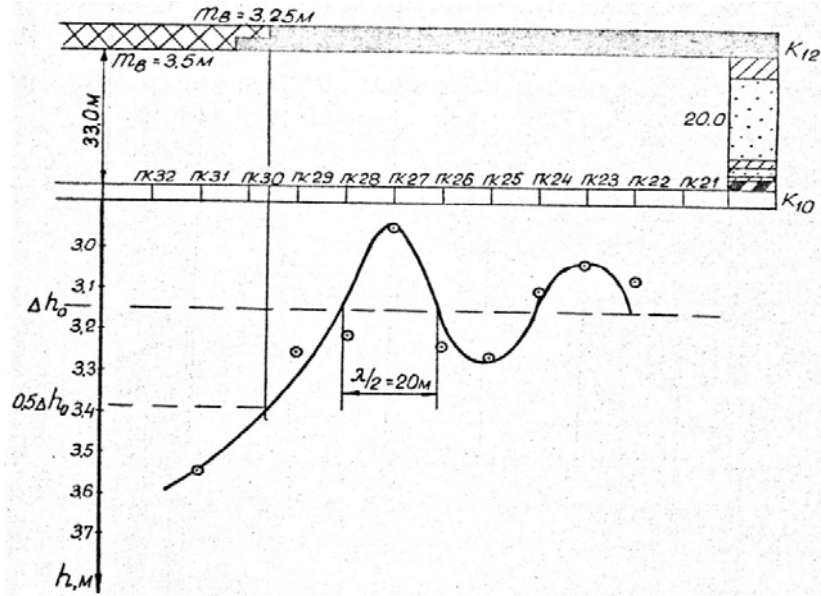


Figure 4 – Observed abutment pressure in belt entry 45K₁₀-3

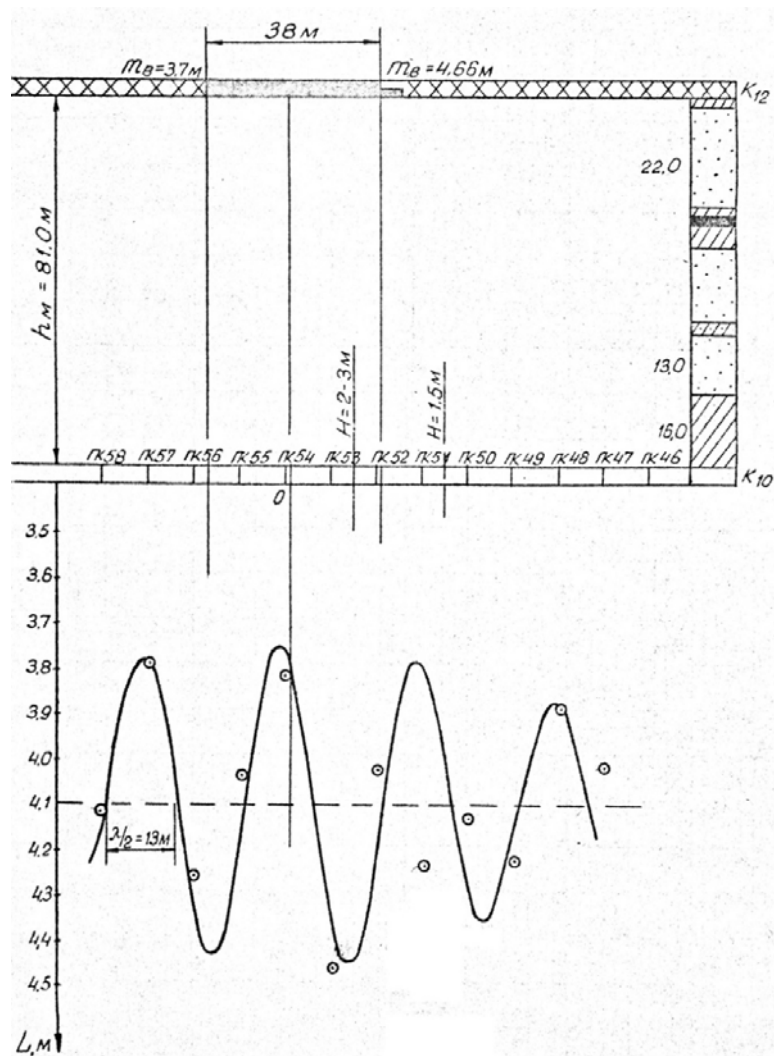


Figure 5 – Observed abutment pressure in the airway 42K₁₀-3

At $P \gg 1$ the oscillations of intensity spread all over the $T_1 - T_2$, which corresponds to the image of the slot in geometrical optics, and is also observed in the area of geometrical shadow (contrary to monotonous decrease adjacent to the edges of the shadow at $P \gg 1$). Depending on the values of P in the middle of diffraction pattern the point O may be either minimum or maximum intensity. When there is an odd number of half wave lengths for point O $(2k + 1) \lambda/2$, the amplitude in point O is less than in the absence of the obstacle. When there is an even number of half wave lengths $(2k) \lambda/2$ – the amplitude in point O is less than in the absence of the obstacle. Refer to figure 5 – the abutment pressure in airway 42K₁₀₋₃ for example. Here, given that wave parameter $P=1.6$, oscillation of abutment pressure are also observed in the geometrical shadow area, though diffraction pattern is distorted by small-scale fluctuations. If the safety pillar is 38 m wide and half wavelength is 13 m, three half-waves fit and, consequently, the amplitude in the center of diffraction pattern O is higher than without the pillar.

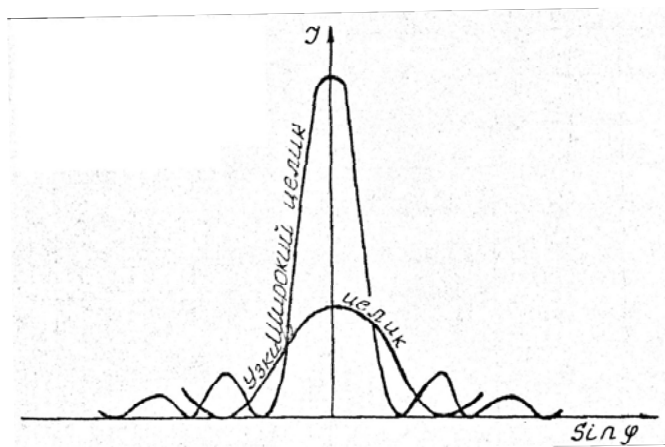


Figure 6 – Diffraction of abutment pressure waves at $P \gg 1$

If $P \gg 1$, the diffraction pattern is similar to that of Fraunhofer diffraction on the same slot (figure 6). The main maximum lies opposite the slot, and is the wider the narrower the slot is. The distance from the center of diffraction pattern to the first maximum increases with the increase of safety pillar width B_y . At this, the central peak gets wider and lower. The intensity decreases going from the center to edges of the plane of observation.

Angle φ between the original direction of the wave and resulting direction is called the diffraction angle. The energy of original wave distributes unevenly in angular space. It is lower at higher diffraction angles.

Conclusions. Thus, the observation of diffraction of abutment pressure waves and their correspondence to common laws of wave propagation confirms its wave nature.

Р. Р. Ходжаев¹, Р. И. Габайдуллин¹, С. Н. Лис², Ш. К. Шапалов³, Н. Н. Акимбекова⁴, Г. К. Ивахнюк⁵

¹«ГеоМарк» ғылыми – инженерлік орталық, Қарағанды, Қазақстан,

²ЖШС «Жер қойнауын кешенді игеру мәселесі институты», Қарағанды, Қазақстан,

³Silkway халықаралық университеті, Шымкент, Қазақстан,

⁴Қарағанды мемлекеттік техникалық университеті, Қарағанды, Қазақстан,

⁵Санкт-Петербург мемлекеттік технологиялық институты (техникалық университет), Санкт-Петербург, Ресей

КОМІР ҚҰРАМДЫ ҚАЛЫҢДЫҚТАРДЫҢ ТОЛҚЫНДЫ ҚАСИЕТТЕРІ

Аннотация. Көмір пластарының жиек бөліктерінде және тіреу астарында орналасқан Қарағанды көмір бассейні көмір шахтасының жер асты өңдеулерінде зерттеулер жүргізілді. Жоғары жатқан көмір пластарының жиек бөліктері мен тіреу астарындағы аймақтарда зерттеу тау-кен өңдеулерін өлшеу арқылы жүргізілді. Жүргізілген зерттеулер нәтижелері көрсеткендей, яғни тіреу астында орналасқан барлық қаралған өңдеулер аймақтарының ұзындығы толқынға ұқсас өзгеріп отырады. Бұл мақалада толқынды үрдістердің таралуының теориялық жағынан қаралған салыстырмалы талдаулардың нәтижелері келтірілді. Жүргізілген талдаулар

нәтижесінде қолдау қысымы мен көмір пластарының жиек бөліктері мен тіреу астарындағы таралу заңдылығының дифракционды қасиеттері анықталды.

Түйін сөздер: қолдау қысымы, көмір тіреулері, көмір пластарының жиек бөліктері, тау-кен қысымының жоғарғы шекарасы, интерференция, дифракция, гармоникалық үрдіс.

Р. Р. Ходжаев¹, Р. И. Габайдуллин¹, С. Н. Лис², Ш. К. Шапалов³, Н. Н. Акимбекова⁴, Г. К. Ивахнюк⁵

¹Научно-инженерный центр «ГеоМарк», Караганда, Казахстан,

²ТОО «Институт проблем комплексного освоения недр», Караганда, Казахстан,

³Международный университет Silkway, Шымкент, Казахстан,

⁴Карагандинский государственный технический университет, Караганда, Казахстан,

⁵Санкт-Петербургский государственный технологический институт (технический университет), Санкт-Петербург, Россия

ВОЛНОВЫЕ СВОЙСТВА УГЛЕНОСНОЙ ТОЛЩИ

Аннотация. Проведены исследования в подземных выработках угольных шахт Карагандинского угольного бассейна, расположенных под целиками и краевыми частями угольных пластов. Исследования проводились путём измерения размеров горных выработок на участках расположенных под целиками и краевыми частями вышележащих угольных пластов. Результаты проведенных исследований показали, что во всех выработках, в которых проводились наблюдения, высота участка выработки, расположенного под целиком (краевой частью) изменяется волнообразно. В статье приводятся результаты сравнительного анализа проведенных наблюдений с теоретическими положениями распространения волновых процессов. В результате проведенного анализа выявлены дифракционные свойства опорного давления и закономерности его распространения под целиками и краевыми частями угольных пластов.

Ключевые слова: опорное давление, целик угля, краевая часть угольного пласта, зона повышенного горного давления, интерференция, дифракция, гармонический процесс.

Information about authors:

Khojaye Rustam, Dr. Eng, GeoMark Research Center, Karaganda, Kazakhstan; khodzhayev.rustam@bk.ru; <https://orcid.org/0000-0002-8499-9012>

Gabaydullin Ravgat, Candidate of Science, GeoMark Research Center, Karaganda, Kazakhstan; gabaydullin.ravgat@bk.ru; <https://orcid.org/0000-0002-8450-2651>

Lis Sergey, Senior Fellow, The Institute For Comprehensive Development Of Underground Resources LLP, Karaganda, Kazakhstan; lis.sergey.2018@bk.ru; <https://orcid.org/0000-0001-6034-5519>

Shapalov Shermakhan, PhD Department of chemistry and biology, Silkway international university, Shymkent, Kazakhstan; shermahan_1984@mail.ru; <https://orcid.org/0000-0002-3015-5965>

Akimbekova Nuriya, candidate of technical science, associate professor, Karaganda state technical university, Karaganda, Kazakhstan; nuriya.akimbekova@bk.ru; <https://orcid.org/0000-0002-8723-1666>

Ivahnuk Gregory, doctor of technical science, professor of St. Petersburg state institute of Technology (Technical University); vakhnyukg@list.ru; <https://orcid.org/0000-0002-3401-158X>

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A. O. Yussupova¹, A. N. Novozhilov¹, T. A. Novozhilov²¹Pavlodar state university, Pavlodar, Kazakhstan,²Omsk state technical university, Russia.

E-mail: aselasp@mail.ru; novozhilova_on@mail.ru; timokvey@mail.ru

MODELING CAPACITANCE OF CAPACITIVE TRANSDUCER

Abstract. The modern circulating electrical machines used to produce electric power and act as drivers are wide spread in electric-power industry. One of the typical mechanical troubles electrical machines encounter is rotor eccentricity. It is usually accompanied by non-uniformity of air gap between stator and rotor and formation of additional magnetic fields in it which leads to deterioration of electromechanical features of electrical machines and increase in electric power loss. With a large displacement of the rotor, the rotor core starts to rub against the stator core. It is accompanied by fairing of cores and overheating. Severe overheat of rotor core can lead to rotor coil burning-out, and overheat of stator core is accompanied by accelerated thermal deterioration of insulation and a subsequent fault in its coil. This can lead to total damage of the machine. Nowadays, rotor eccentricity can be determined by using methods based on measuring values which are caused by additional magnetic fields. However, the sensitivity of the methods mentioned is limited by the need of considering the interferences due to variation of mains settings and loads. In this sense, capacitive sensors used as measuring capacitive transducers are known to be more perspective diagnostic means for determination of rotor eccentricity. However, there are no methods for calculation of parameters of such measuring transducers with complex geometry of electrodes.

The current document features a simple method for calculation of a capacitive transducer with electrodes of various shapes. This method comprises modeling the transducer electro-static field using nets method and calculation of capacitance based on the empirical formula proposed. As an example, the method efficacy is checked by determination of plate capacitor capacitance using the method proposed and classical formula. It was demonstrated that the modeling accuracy did not exceed 5%.

The example included evaluating a capacitance for electrodes with toothed rotor of electrical machines and with different positions of capacitive transducer plates relative to rotor slot opening. This document also contains the principle of forming boundary conditions and electrostatic potential distribution patterns, and the calculation of capacitance.

Key words: diagnostics method, rotor eccentricity, capacitive transducers.

Introduction. In electric-power industry, for example, when diagnosing moving parts of electrical machines (EM) the capacitive transducers (CT) [1-4] are widely used because they provide simple operation and reliable performance. As it is known, changes in transducers capacitance can happen both due to movement of target machine part and its circulation on a shaft. The example [4] shows measuring rotor eccentricity during operation when one of CT electrodes has constant geometrical sizes and the other one represents a circulating toothed rotor core as shown in the figure 1,a: where 1 and 2 – stator and rotor cores; 3 – armature key; 4 – CT electrode; 5 – EM air gap.

Since CT capacitance during rotor circulation changes both because of rotor eccentricity value and open slots of rotor that follow along its electrodes development of methods for diagnosing EM rotor eccentricity is simply impossible without modeling transducer capacitance value depending on the conditions mentioned.

As it is known [5-9], there are many ways that facilitate calculation of capacitor capacitance with various electrode shapes. However, their analysis has shown that it is too difficult to use some of them even equipped with computer technology. Some of them describe only particular cases for electrode surfaces and others cannot provide the required accuracy.

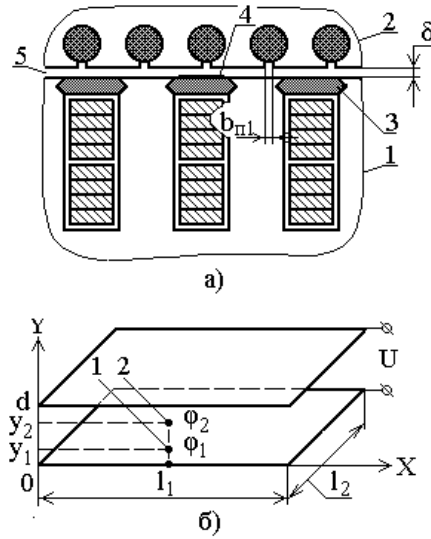


Figure 1 – EM specific design features and calculation diagram

In connection with this, electrical capacitance of two electrodes with various shapes can be calculated the following way.

According to [10-15] electro-static field density in any point between the two electrodes of the capacitor is a constant value. In light of this and the figure 1:

$$E = \frac{U}{d} = \frac{\varphi_2 - \varphi_1}{y_2 - y_1} = \frac{\Delta\varphi}{\Delta y}, \quad (1)$$

where φ_1 and φ_2 - electro-static field potentials in points 1 and 2 with respect to lower capacitor plate; y_1 and y_2 - coordinates y of points 1 and 2; U and d - voltage and the gap between capacitor electrodes.

Then, taking into consideration equation correlations (1) in order to determine the capacitance of air plate capacitor we can use the following empirical dependence:

$$C = \varepsilon_0 l_1 l_2 \frac{\varphi_2 - \varphi_1}{y_2 - y_1} = \varepsilon_0 l_1 l_2 \frac{\Delta\varphi}{\Delta y}, \quad (2)$$

where l_1 and l_2 - breadth and length of capacitor electrodes; ε_0 - electrical permittivity of vacuum.

Since the capacitor electro-static field is potential and there are no free electro-static field sources in it then taking into consideration the diagram in the figure 1 and [13-17] the field can be described by Laplace equation:

$$\partial^2 \varphi / \partial x^2 + \partial^2 \varphi / \partial y^2 = 0. \quad (3)$$

Analysis of [17-20] makes it clear that it is hard or sometimes impossible to get an analytical expression from direct solution of equation (3) with complex electrode shapes whereas the net method provides a simple answer. Here, partial Poisson equations [21-23] (3) for i, k – th node in the figure 2 are replaced by expressions:

$$\frac{\partial^2 \varphi_x}{\partial y^2} \approx \frac{\varphi_{x(i,k+1)} - 2\varphi_{x(i,k)} + \varphi_{x(i,k-1)}}{h^2}, \quad (4)$$

$$\frac{\partial^2 \varphi_x}{\partial z^2} \approx \frac{\varphi_{x(i+1,k)} - 2\varphi_{x(i,k)} + \varphi_{x(i-1,k)}}{h^2}. \quad (5)$$

As a result in i, k – th node electro-static field potential can be described as:

$$\varphi_{x(i,k)} = \frac{1}{4}(\varphi_{x(i+1,k)} + \varphi_{x(i-1,k)} + \varphi_{x(i,k+1)} + \varphi_{x(i,k-1)}) \quad (6)$$

The efficacy of the mathematical model for solution of such issues can be easily demonstrated in an example with determination of capacitance of air plate capacitor [24-25]. According to [10] and the figure 1,6 plate capacitor capacitance is:

$$C = \varepsilon_0 l_1 l_2 / d . \quad (7)$$

When using the net method for modeling electro-static field between MF electrodes the area in question is divided into squares with the help of $k_m + 2$ horizontal and $i_m + 2$ vertical lines as shown in the figure 2 with square side h . When k - th horizontal line crosses i - th vertical line it forms i, k - th node where k_m and i_m - number of nodes in target area in vertical and horizontal direction where electro-static field potential is calculated based on equation (6). In the figure 2 these nodes are located in the area outlined with dotted line. Electrode breadth l_1 of capacitor and distance d between its electrodes on calculation diagram can be described according to:

$$l_1 = x_2 - x_1 \text{ and } d = y_2 - y_1, \quad (8)$$

where x_1, x_2 and y_1, y_2 - coordinates of capacitor electrodes in cells.

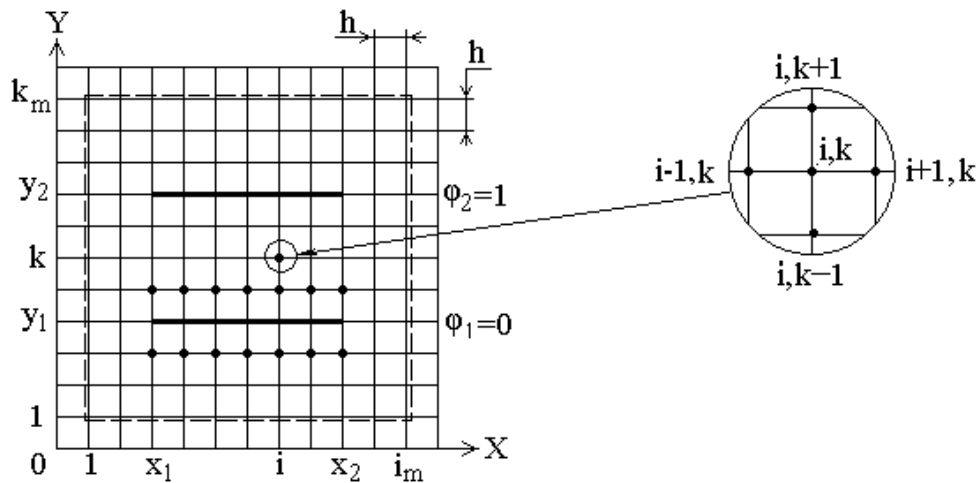


Figure 2 – Calculation diagram

When modeling the electro-static field the upper electrode potential y_2 is assumed to be equal to one and the lower one φ_1 is to zero. After iteration procedure, all nodes with coordinates $k = 0$ and $k = k_m + 1$ are assigned nodes potentials with $k = 1$ and $k = k_m$ and all nodes with coordinates $i = 0$ and $i = i_m + 1$ are assigned nodes potentials with $i = 1$ and $i = i_m$ which is boundary conditions for the given type of task.

Potentials of each node within outlined area are calculated with the help of computer based on iteration method which assumes potential calculation beginning from the left lower corner and then back from the right lower corner of the area. After each iteration procedure boundary conditions are reset again and iteration number is chosen so as to minimize errors.

After calculation of potentials in nodes the capacitor capacitance can be calculated using mathematical expression (2) as

$$C = \varepsilon_0 l_1 l_2 \frac{\sum_{n=1}^N \varphi_n / N - \varphi_1}{h} = \varepsilon_0 l_1 l_2 \frac{\sum_{n=1}^N \varphi_n}{N h}, \quad (9)$$

φ_n - potentials of all nodes adjacent to electrode with $\varphi_1 = 0$; N - number of nodes adjacent to CT electrode with $\varphi_1 = 0$. In the figure 2 all nodes that adjacent to electrode with potential $\varphi_1 = 0$ are marked with dots.

As one can see from the mathematical expression (9) (which defines capacitance through traditional method [10] with constant plate characteristics) the capacitor capacitance depends on the distance between the plates that is determined by air gap which sizes are shown in the table.

EM air gap

Revolutions per minute, rpm	Gap, mm, with engine power, kW					
	Up to 0,2	0,2-1	1-2,5	2,5-5	5-10	10-20
500-1500	0,2	0,25	0,3	0,35	0,4	0,4
3000	0,25	0,3	0,35	0,4	0,5	0,65

If for calculation diagram in the figure 2 we assume $h = 0,01$ m, $k_m = 11$ and $i_m = 11$ cells and coordinates $x_1 = 3$, $x_2 = 9$, $y_1 = 4$, $y_2 = 8$ then potentials modeling results in nodes can be presented as tables shown in the figure 3.

k_m	0.00	0.76	0.77	0.78	0.80	0.80	0.80	0.80	0.78	0.77	0.75	0.74	0.00
	0.76	0.76	0.77	0.78	0.80	0.80	0.80	0.80	0.78	0.77	0.75	0.74	0.74
	0.75	0.75	0.77	0.79	0.80	0.81	0.81	0.80	0.79	0.77	0.74	0.73	0.73
	0.73	0.73	0.76	0.79	0.81	0.82	0.83	0.82	0.80	0.76	0.73	0.71	0.71
	0.67	0.67	0.69	1.00	1.00	1.00	1.00	1.00	1.00	0.70	0.67	0.67	0.67 $\varphi=1$
	0.58	0.58	0.60	0.62	0.66	0.67	0.67	0.67	0.66	0.63	0.61	0.61	0.61
	0.49	0.49	0.48	0.48	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51
	0.39	0.39	0.36	0.34	0.33	0.33	0.33	0.33	0.34	0.38	0.40	0.41	0.41
	0.33	0.33	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.33	0.33	0.33 $\varphi=0$
	0.29	0.29	0.27	0.23	0.19	0.18	0.17	0.18	0.19	0.21	0.24	0.27	0.27
	0.26	0.26	0.25	0.23	0.21	0.19	0.19	0.19	0.20	0.21	0.23	0.25	0.25
1	0.25	0.25	0.24	0.23	0.21	0.20	0.19	0.19	0.20	0.21	0.23	0.24	0.24
	0.00	0.25	0.24	0.23	0.21	0.20	0.19	0.19	0.20	0.21	0.23	0.24	0.00

Figure 3 – Potentials modeling results in nodes of electro-static fields of two-plate electrode

Then, CT capacitance calculated based on mathematical expression (9) using net method amounted to 1.55pf and 1.442pf accordingly. The net method accuracy was 7.001%. Therefore, such method for determination of air CT capacitance is simple and provides sufficient accuracy within the diagnostics system.

Based on the model proposed it is easy to calculate CT capacitance variation of asynchronous motor (AM) rotor with open slots. If we assume CT breadth l_1 , air gap δ and rotor slot opening breadth b_{n1} equal to 5, 3 and 3 cells then potentials modeling results in nodes with CT electrode located above rotor slot opening can be presented as tables shown in the figure 4. Then, CT capacitance was 2.628pf. At the same time when CT electrode was located above the middle rotor tooth the capacity amounted to 2.736pf, as shown in the figure 5.

k_m	$\varphi=0$				$\varphi=1$				$\varphi=0$			
	0.00	0.00	0.00	0.39	1.00	1.00	1.00	1.00	0.42	0.00	0.00	0.00
	0.00	0.00	0.00	0.39	1.00	1.00	1.00	1.00	0.42	0.00	0.00	0.00
	0.12	0.12	0.19	0.32	0.50	0.61	0.64	0.61	0.53	0.38	0.21	0.12
	0.13	0.13	0.17	0.25	0.35	0.42	0.44	0.42	0.36	0.27	0.19	0.14
	0.09	0.09	0.11	0.16	0.22	0.27	0.29	0.27	0.22	0.17	0.13	0.10
	0.00	0.00	0.00	0.00	0.00	0.16	0.18	0.16	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.08	0.10	0.09	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.05	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00

Figure 4 – Potentials modeling results in nodes of electro-static fields of plate electrode and air gap area above AM slot opening

k_m	$\varphi=1$				$\varphi=0$				$\varphi=1$			
	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
0.62	0.62	0.58	0.48	0.30	0.16	0.13	0.15	0.25	0.44	0.59	0.65	0.65
0.41	0.41	0.38	0.32	0.24	0.17	0.14	0.16	0.21	0.30	0.38	0.42	0.42
0.23	0.23	0.22	0.19	0.16	0.13	0.12	0.12	0.14	0.18	0.22	0.24	0.24
0.00	0.00	0.00	0.00	0.00	0.09	0.08	0.08	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.05	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1	$\varphi=0$							$\varphi=0$		i_m	

Figure 5 – Potentials modeling results in nodes of electro-static fields of plate electrode and air gap area above middle tooth of AM rotor

Thus, CT capacitance with AM rotor can be determined the following way:

$$C_{ин} = C_{ин,0} + C_{ин,m} \sin(2\pi f_2 t), \quad (10)$$

where $C_{ин,0}$ and $C_{ин,m}$ - constant component and CT capacitance variable amplitude; $f_2 = nZ_2 / 60$ - CT capacitance variable amplitude frequency; n - rotor rpm; t - time.

According to the net method in the figure 4 capacitance values are $C_{ин,0} = 2.682\text{pf}$ and $C_{ин,m} = 0.054\text{pf}$.

The example mentioned shows it obviously that the method proposed allows simple and quite precise modeling CT capacitance, for example, for diagnosing rotor eccentricity regarding electrode shapes.

А. О. Юсупова¹, А. Н. Новожилов¹, Т. А. Новожилов¹

¹С. Торайғыров атындағы Павлодар мемлекеттік университеті,

²Омбы мемлекеттік университеті, Омбыб Ресей

МОДЕЛЬДЕУ ЭЛЕКТР СЫЙЫМДЫЛЫҒЫН ӨЛШЕУ ТҮРЛЕНДІРГІШ

Аннотация. Қазіргі заманғы айналмалы электр машиналары электр энергетикасында электр энергиясын өндіру үшін және жетек ретінде кеңінен қолданылады. Олардың өзіне тән механикалық зақымдануының бірі ротордың эксцентриситеті болып табылады. Әдетте ол статор мен ротор арасындағы әуе саңылауының біркелкі еместігімен және онда қосымша магниттік өрістердің пайда болуымен сүйемелденеді. Бұл жағдайлардың бәрі электр машиналарының механикалық сипаттамаларын нашарлауына және электр энергиясының шамадан тыс шығындануна әкеледі. Егерде ротордың жылжуы үлкен болса онда роторды өзегі статор өзегін үйкелей бастайды. Бұл өзектердің қызуына әкеп соғады. Ротордың өзегі қатты қызуы ротор орамының балкуына әкеп соғуына мүмкін, ал статордың өзегінің қызуы статор орамының оқшаулағышарының жылулық қартайуын тездетеді кейінен орамдарда қысқа тұйқталалулар болады. Бұл ретте электр машинасы толығымен істен шығады.

Қазіргі уақытта ротордың эксцентриситетін анықтау үшін негізінен қосымша магнит өрістерінің пайда болуынан туындаған шамаларды өлшеуге негізделген әдістер қолданылады. Бірақ олардың сезімталдығы қоректендіруші желінің электр параметрлерінің тербелісінен және жүктемесінен туындаған кедергілерден ауытқудың қажеттілігімен шектеледі. Бұл жағдайда ротордың эксцентриситетін диагностикалау жүйелері үшін өлшеуіш түрлендіргіш ретінде сыйымдылық датчиктерді пайдалану неғұрлым болашағы болып табылады. Алайда электродтардың күрделі формасымен осындай өлшеуіш түрлендіргіштің параметрлерін есептеу әдісі жоқ.

Ұсынылған жұмыста электродтардың еркін формасындағы сыйымдылықты өлшеуіш түрлендіргішті есептеудің қарапайым әдісі ұсынылған, бұл түрлендіргіштің электростатикалық өрісін тор әдісімен модельдеуге және келтірілген эмпирикалық формула бойынша сыйымдылықты есептеуге негізделген. Осы әдістің барабарлығын жазық конденсатордың сыйымдылығын анықтау мысалында тексеру жүзеге асырылды, оның шамасы ұсынылып отырған әдісті пайдалана отырып және классикалық формула бойынша анықталған. Модельдеудің қателігі 5%-дан аспады.

Бұл әдісті қолдану мысалы ретінде электр машина роторының тісті беті бар электродтар үшін сыйымдылықты анықтауына қатысты өлшеуіш түрлендіргіш пластинасының түрлі жағдайларында жүзеге асырылды. Сонымен қатар, шекаралық жағдайларды қалыптастыру принципі және электростатикалық өріс потенциалдарының таралу сұлбасы келтірілген, сондай-ақ сыйымдылықтар есептелген.

Түйіндік сөздер: диагностика әдістемесі, ротордың эксцентриситеті, сыйымдылық өлшеуіш түрлендіргіштер.

А. О. Юсупова¹, А. Н. Новожилов¹, Т. А. Новожилов¹

¹Павлодарский государственный университет им. С. Торайгырова, Павлодар, Казахстан,

²Омский государственный университет, Омск, Россия

МОДЕЛИРОВАНИЕ ЭЛЕКТРИЧЕСКОЙ ЕМКОСТИ ИЗМЕРИТЕЛЬНОГО ПРЕОБРАЗОВАТЕЛЯ

Аннотация. Современные вращающиеся электрические машины широко используются в электроэнергетике для производства электроэнергии и в качестве привода. Одним из их характерных механических повреждений является эксцентриситет ротора. Обычно он сопровождается неравномерностью воздушного зазора между статором и ротором и возникновением в нем дополнительных магнитных полей. Что приводит к ухудшению электромеханических характеристик электрической машины и увеличением потерь электроэнергии. При большом смещении ротора сердечник ротора начинает тереться о сердечник статора. Что сопровождается «заливом» сердечников и их разогревом. Сильный разогрев сердечника ротора может привести к выплавлению обмотки ротора, а разогрев сердечника статора сопровождается ускоренным тепловым старением изоляции и последующим коротким замыканием в ее обмотке. В таких случаях машина может полностью выйти из строя.

В настоящее время для выявления эксцентриситета ротора в основном используются методы, основанные на измерении величин вызванных появлением дополнительных магнитных полей. Однако их чувствительность ограничена необходимостью отстройки от помех, вызванных колебанием электрических параметров питающей сети и нагрузки. В этом отношении более перспективны системы диагностики эксцентриситета ротора, у которых в качестве измерительного преобразователя используются емкостные датчики. Однако метод расчета параметров таких измерительного преобразователя со сложной формой электродов отсутствует.

В предлагаемой работе предложен простой метод расчета емкостного измерительного преобразователя с произвольной формой электродов основанный на моделировании электростатического поля этого преобразователя методом сеток и расчетом емкости по приведенной эмпирической формуле. Осуществлена проверка адекватности этого метода на примере определения емкости плоского конденсатора, величина которого определялась с использованием предлагаемого метода и по классической формуле. Показано, что погрешность моделирования не превысила 5%.

В качестве примера использования этого метода осуществлено определение емкости для электродов с зубчатой поверхностью ротора электрической машины в разных положениях пластины измерительного преобразователя относительно раскрытия паза. Также приведен принцип формирования граничных условий и картины распределения потенциалов электростатического поля, а также рассчитаны емкости.

Ключевые слова: методика диагностики, эксцентриситет ротора, емкостные измерительные преобразователи.

Information about authors:

Yussupova Assel Orazovna, Master of Electric Power Engineering, doctoral candidate of the Department of "Electric Power Engineering" of Pavlodar state university. S. Toraigyrov, Pavlodar, Kazakhstan; aselasp@mail.ru; <https://orcid.org/0000-0001-5516-3024>

Novozhilov Alexander Nikolaevich, doctor of technical sciences, professor (Kazakhstan), professor of the department "Electric power industry" of Pavlodar state university. S. Toraigyrov, Pavlodar, Kazakhstan; novozhilova_on@mail.ru; <https://orcid.org/0000-0001-7530-5034>

Novozhilov Timofey Aleksandrovich, Candidate of Technical Sciences, Associate Professor, Department of "Power supply of industrial enterprises" of Omsk state technical university; timokvey@mail.ru; <https://orcid.org/0000-0003-0293-7852>

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**Kh. R. Sadieva¹, B. K. Massalimova¹, R. D. Abisheva², I. G. Tsoy¹, A. N. Nurlybayeva¹,
A. S. Darmenbayeva¹, L. K. Ybraimzhanova¹, A. A. Bakibaev³, A. K. Sapi¹**

¹M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan,

²South Kazakhstan State pedagogical university, Shymkent, Kazakhstan,

³Tomsk state university, Tomsk, Russia.

E-mail: xalipa71@mail.ru, massalimova15@mail.ru, ard1967@mail.ru, tsoyirinagen@mail.ru,
rustem_ergali@mail.ru, maral88@mail.ru, ybraimzhanova@mail.ru, bakibaev@mail.ru, sapievaaas@mail.ru

PREPARATION OF CARBON NANOCOMPOSITES ON THE BASIS OF SILICON-TIN CONTAINING SUBSTANCES

Abstract. The obtained nanocomposites are tin dioxide nanoparticles immobilized on inorganic polymeric network of silicon dioxide and precipitated carbon. Wherein, silicon dioxide provides high adhesion properties and prevents the aggregation of the crystallites of the composite, and the nano- and microparticles of tin dioxide and carbon predetermine the gas-sensitive properties. The film-forming solutions obtained by sol-gel technology contains tetraethoxysilane, tin salts ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$), silicic acid ($\text{SiO}_2 \cdot n\text{H}_2\text{O}$) and sodium silicate ($\text{Na}_2\text{SiO}_3 \cdot 9\text{H}_2\text{O}$). The resulting solutions have been applied to metal substrates with subsequent heat treatment. The additional introduction of tetraethoxysilane as a source of SiO_2 in solution-sol has made it possible to obtain xerogels of oxide compositions of 5% SnO_2 – 95% SiO_2 , 30% SnO_2 – 70% SiO_2 . The modification of the content of elements shows that the growth of carbon nanoparticles changes the microstructure of the obtained compound.

Key words: nanocomposites, nanoparticles, silicon-tin containing nanotubes.

Introduction. The priority task of the state economic policy and science is the integrated and rational use of mineral raw materials, combating the negative impact of industrial waste and harmful emissions on the environment. With the involvement of phosphate concentrate obtained on the basis of waste into the production of complex mineral fertilizers, an additional 540 thousand tons of highly concentrated fertilizers sold on the international market at a price of at least \$400 per ton can be obtained [1-4].

At the present time, waste stored in the sludge accumulators of the chemical and phosphorous industry under the open air is exposed to wind and water erosion, which creates unfavorable environmental conditions for nearby areas: removal of dust containing silicon oxide from the dried surface of the sludge collector, flushing fluorine-containing salts from the rainwater waters into the underground waters. The second product of waste processing is a cement clinker. The main components of the clinker are calcium oxide (CaO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3), the total content of which reaches 95-97.5%. With the full complex processing of accumulated waste, the ecological problem of environmental pollution with toxic substances will be solved.

Materials obtained on the basis of carbon nanotubes or with the addition of SiO_2 can differ in a wide variety of functional properties. The nanoscale effect of particles of carbon nanotubes is manifested in the unusual properties of materials completely different from the known properties of bulk materials:

- optical, photonic and electronic (glass tubes for optical fibers, color coatings for automotive glasses, photochromic glasses, liquid crystal displays, photonic crystals, solar batteries, gas analyzers, etc.);
- thermal (refractory ceramics, ceramics with low coefficient of thermal expansion, fireproof coatings, thermal insulators);
- mechanical (high-strength polymeric products and ceramics, abrasives, tribological materials);
- chemical (catalysts, membranes, hydrophilic and hydrophobic films, antioxidants);

- biomedical (immobilization of biological molecules, such as proteins, microorganisms, antibacterial substances, biosynthesis, creation of biosensors, removal of toxic organic substances).

The introduction of silica nanoparticles can significantly improve the properties of well-known materials, for example, concrete soil, cement, ceramics, wood.

Methods. Finely divided silica is a light gray or white powder obtained from quartz. It is produced both in Europe and in the USA and it has various product names such as "SSA-1" Halliburton Services "D-66" from "Dowell Schlumberger" or "D-8" from "B.J. Hughes" [5-8].

In the production of glasses, ceramics, mixed inorganic oxides, gels are heated to several hundred degrees to sinter the particles and compress the porous structure to a dense material. In sol-gel technology, the term "sol" refers to colloidal ultradispersed and microheterogeneous systems with a liquid dispersion medium and a solid dispersed phase. Colloidal sols are aggregatively stable disperse systems of various compounds in water (hydrosols of silica, silver, boehmite, titanium dioxide, metal salts), obtained by condensation or dispersive methods. Thus, as a result of the polycondensation of aqueous solutions of silicic acids, silica hydrosols are obtained, which have extremely wide application [9].

According to modern concepts, the formation of a gel begins with the formation of a fractal structure of the sol, the growth of fractal aggregates to the extent that they begin to collide and adhere to each other, as percolation theory (percolation theory) describes. Near the gel point, randomly located neighboring clusters consisting of polymers or aggregates of particles join together to form a single structural grid. The gel point corresponds to the percolation threshold, when a single constricting cluster is formed, as it were spread throughout the volume of the sol [11-13]. After passing the gel point, the sol loses its mobility and gelifies, transforming into a "wet gel", since the liquid phase is retained in the spatial structure. Wet gel usually takes the form of the vessel in which the sol was. The formation of the gel does not stop at the gel point, for some time the aging of the gel occurs. The term "aging gel" reflects structural changes occurring after the gel point in the wet gel. In the resulting product, a single giant cluster coexists with a sol containing many small clusters that continuously join the common core - a giant cluster. In addition, in gels, polycondensation reactions that have not passed to the end in sols can be continued, accompanied by syneresis (release of water); there are also processes of reprecipitation of monomers or oligomers; there are also phase transitions of the "solid-liquid" type, as well as the condensation of the structure [14-17].

The third stage of sol-gel technology is drying, i.e., removing liquid from the spatial structure of the gel, resulting in the formation of a xerogel (dried gel). The xerogel volume is 5-10 times less than the volume of the wet gel. When removing free water from the gel, wetting capillary menisci are formed, which leads to an increase in pressure and cracking of the structure. To reduce the capillary pressure, the gel drying is desirably carried out in a vacuum, in the presence of surfactants (surfactants). Drying in supercritical conditions provided in autoclaves allows obtaining porous aerogels [18-20].

In this scientific work, nanoparticles of silicon oxide with tin chloride and sodium silicates with tin chloride sol-gel method were synthesized. The composition of obtained products was determined by chemical, IR-spectroscopic and microstructural X-ray phase analysis. Growth of nanomaterials was carried out on the carbon nanotube CVD method. The investigated silicon-tin nanostructured vitreous substances were deposited from a carbon nanotube of a columnar shape on a metal substrate using the unique technology of ULVAC JAPAN, Ltd., Japan Manufacturing [8, 13, 21].

Results and discussion. The obtained nanocomposites were investigated by chemical and physico-chemical methods. Table 1 shows the results of the chemical analysis.

Table 1 shows that with increasing solution concentration the silicon content in silicates increases, the chlorine ion decreases, and the content of tin gradually increases. The results obtained make it possible to convert liquid solutions into gel-like liquid glasses, which can be used as semiconductors.

Research on an IR spectrophotometer allows a more accurate determination of the desired components, which gives a huge advantage over the chemical method of analysis of solutions. Figure 1 shows the IR spectra of compounds obtained by mixing 0.1 N Na_2SiO_3 and SnCl_2 . It can be seen that the strongly pronounced peaks in the 767 cm^{-1} region correspond to tin oxide- SnO_2 , in the region of 958 cm^{-1} there correspond silicon oxide- SiO_2 , and also in the region 1153 cm^{-1} and 2667 cm^{-1} , the slopes corresponding to tin oxide - SnO_2 , weakly expressed peak in the region of 4386 cm^{-1} corresponds to sodium oxide - Na_2O .

Figure 2 shows the IR spectra of products obtained from 0.5 N solutions of SnCl_2 and SiO_2 . A strongly pronounced peak in the 802 cm^{-1} region corresponds to silicon oxide- SiO_2 , weakly expressed peaks in

Table 1 – Results of chemical analysis of initial materials

No	Name of composites	Determination of silicon oxide content in silicates by weight method, %	Determination of the chlorine-ion content by a mercurimetric method, %	Determination of sodium content in bulk method, %	Determination of tin content by weight, %	Determination of the refractive index of a solution
1	0,1 n $\text{Na}_2\text{SiO}_3\text{-SnCl}_2$	31,75	17,129	3,68	84,9	1,3342
2	0,3 n $\text{Na}_2\text{SiO}_3\text{-SnCl}_2$	59,33	16,5387	2,17	89,9	1,3354
3	0,5 n $\text{Na}_2\text{SiO}_3\text{-SnCl}_2$	49,36	10,0413	5,43	91	1,3355
4	0,1 n $\text{SiO}_2\text{-SnCl}_2$	44,55	18,9013	1,69	59,2	1,3362
5	0,3 n $\text{SiO}_2\text{-SnCl}_2$	31,247	21,8547	2,5	69,6	1,3378
6	0,5 n $\text{SiO}_2\text{-SnCl}_2$	30,048	15,948	8,9	87	1,3440

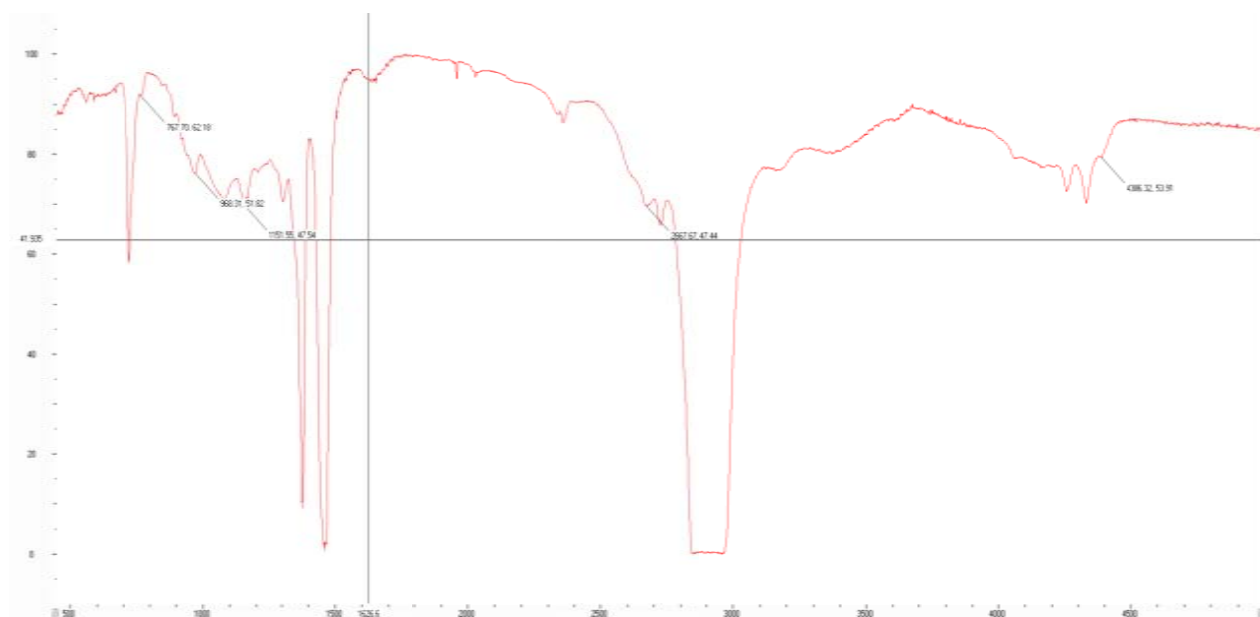


Figure 1 – IR spectra of the resulting compounds of 0.1 N $\text{Na}_2\text{SiO}_3\text{-SnCl}_2$ solution

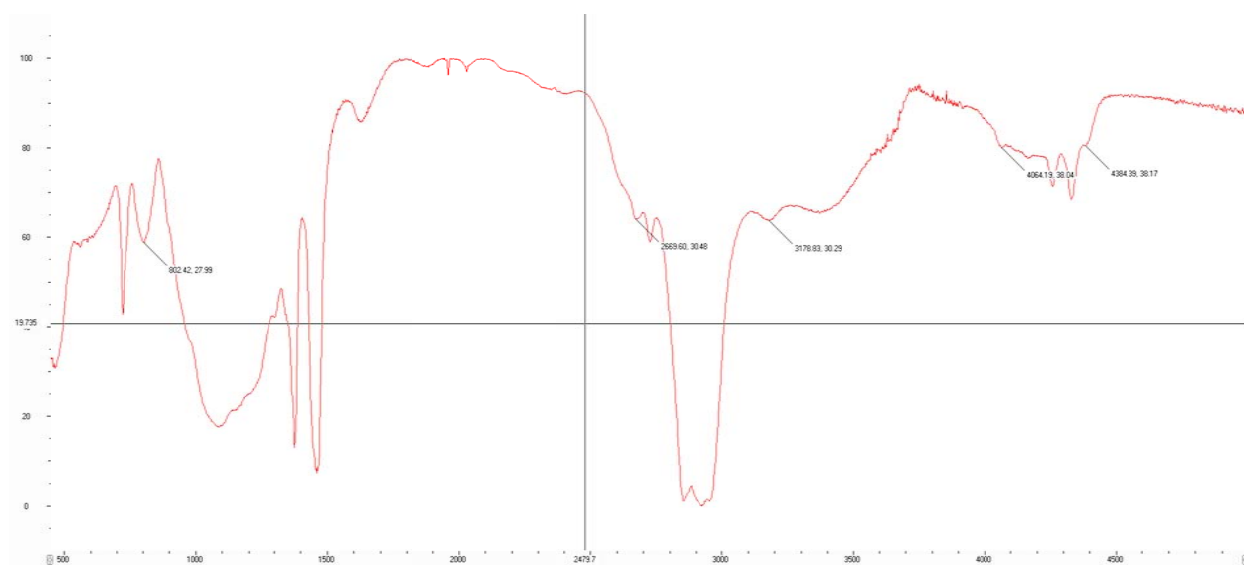


Figure 2 – IR spectra of the resulting compounds of a 0.5 N solution of $\text{SnCl}_2\text{-SiO}_2$

the 2669 and 3178 cm^{-1} region correspond to SnO_2 tin oxide, a weakly pronounced peak at 4064 cm^{-1} corresponds to silicon oxide- SiO_2 .

A scanning electron microscope (SEM) is simpler and more versatile for practical applications. The principle of the JEOL JSM-6490LV raster low-vacuum electron microscope (Japan) is based on the use of certain effects arising from the irradiation of the surface of objects by a finely focused beam of electrons. These effects are the basis for obtaining a variety of information: the relief of the surface of the sample, the chemical composition and the crystallographic orientation of the volumes adjacent to the surface. Electrons emitted by the substance, various kinds of radiation, are captured by special sensors and after amplification are used to control the brightness of the cathode ray tube on which the image is formed. At the same time, a certain point on the screen of the cathode-ray tube corresponds to each point on the surface of the sample [4, 5].

Figure 3 shows microstructure images of products obtained from 0.1 N Na_2SiO_3 and SnCl_2 (initial) (a) and 0.3 N SnCl_2 - SiO_2 solutions (initial) (b).

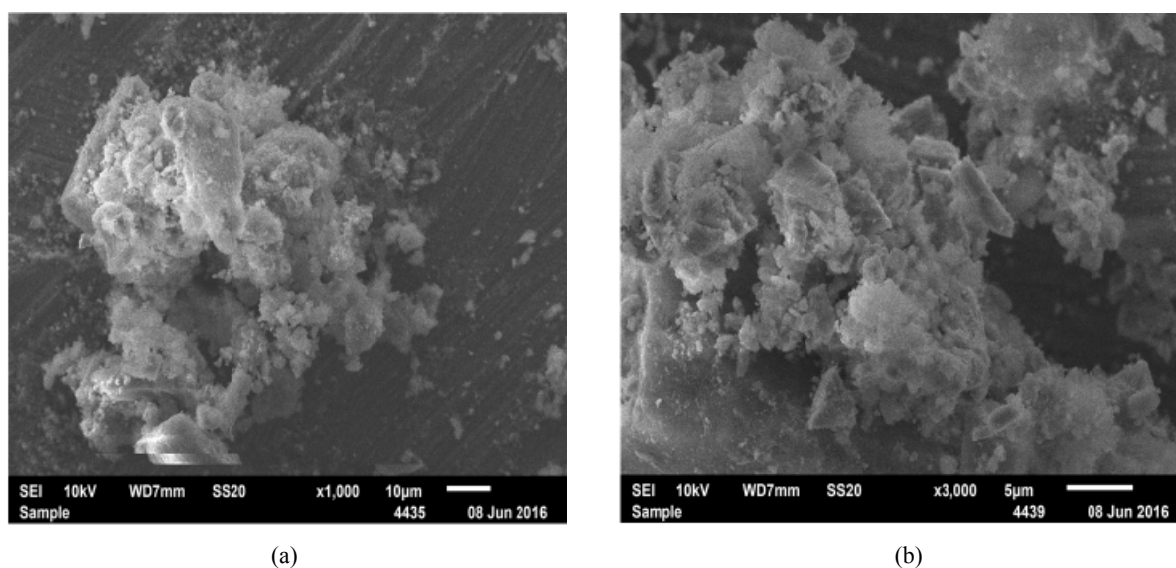


Figure 3 – Microstructure of nanocomposites obtained from Na_2SiO_3 - SnCl_2 (a), microstructure of nanocomposites obtained from SnCl_2 - SiO_2 (b)

Table 2 – Results of X-ray phase analysis of products synthesized from 0,1 N Na_2SiO_3 - SnCl_2 solution

Results of elemental analysis in weight, % ratios									
Range	In stats.	O	Na	Al	Si	S	Cl	Sn	Total
Spectrum 1	Yes	52,57	0,09	0,05	27,65	0,06	0,61	18,97	100
Spectrum 2	Yes	52,57	0,11	0,04	27,55	0,04	0,64	19,05	100
Spectrum 3	Yes	53,14	0,16	0	29,56	0,05	0,69	16,39	100
Average	Yes	52,76	0,12	0,03	28,25	0,05	0,65	18,14	100

Table 3 – Results of X-ray phase analysis of products obtained from 0.3 N SnCl_2 - SiO_2

Results of elemental analysis in weight,% ratios							
Range	In stats.	O	Al	Si	Cl	Sn	Total
Spectrum 1	Yes	41,82	0,12	10,99	4,07	43,01	100
Spectrum 2	Yes	44,17	0,05	15,34	3,62	36,82	100
Spectrum 3	Yes	44,06	0,07	14,39	3,69	37,78	100
Spectrum 4	Yes	41,72	0,04	11,09	4,19	42,95	100
Average		42,94	0,07	12,95	3,89	40,14	100

Table 3 shows that the elemental analysis reduces the oxygen content, the content of tin and silicon increases. The change in the content of elements shows that with the growth of the nanoparticles the microstructure of the obtained compound changes.

In this work, composites based on $\text{SiO}_2\text{-SnCl}_2$ and $\text{Na}_2\text{SiO}_3\text{-SnCl}_2$ with different tin dioxide content were obtained by sol-gel technology on substrates of oxidized single-crystal silicon, further tablets are prepared from the obtained products. The finished tablets allows the carbon deposition in columnar-shaped carbon nanotubes on a metal substrate using the unique technology of ULVAC JAPAN, Ltd. The precursors for the preparation of sols are tetraethoxysilane, five-water tin tetrachloride, ethyl alcohol; the catalyst is hydrochloric acid. The firing was carried out at a temperature of 600 °C.

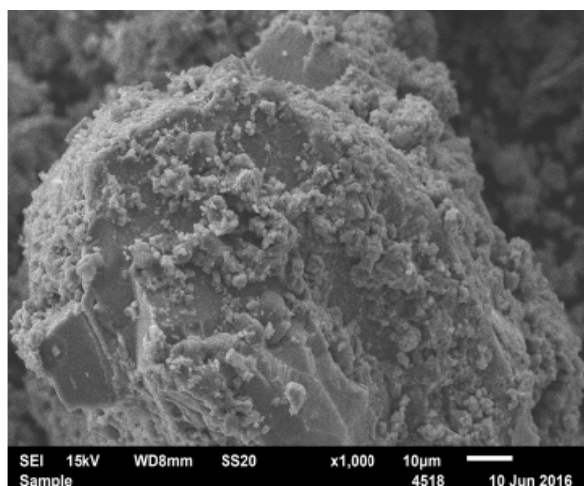


Figure 4 – Microstructure (SEM) of nanocomposites obtained from $\text{Na}_2\text{SiO}_3\text{-SnCl}_2$ compounds after growing nanoparticles on the carbon nanotube CVD methods

Table 4 – Results of X-ray phase analysis after growing a nanoparticle of a carbon nanotube by CVD methods

Results of elemental analysis in weight,% ratios							
Range	O	Na	Al	Si	C	Sn	Total
Spectrum 1	30,17	4,90	0,13	3,97	5,51	55,32	100,00
Spectrum 2	31,60	2,74	0,06	3,96	3,97	57,68	100,00
Spectrum 3	31,07	3,05	0,09	4,20	5,18	56,40	100,00
Average	30,94	3,56	0,09	4,05	4,89	56,47	100,00

Table 4 shows that the elemental analysis reduces the oxygen content, the content of tin and silicon increases, carbon deposits. The change in the content of elements shows that with the growth of carbon nanoparticles, the microstructure of the resulting compounds changes.

From table 5 it is seen that the elemental analysis of the oxygen content decreases, the content of tin and silicon increases, carbon is deposited. The change in the content of elements shows that with the growth of carbon nanoparticles, the microstructure of the resulting compounds changes.

Figures 6 and 7 shows the microstructures of nanocomposites synthesized by the sol-gel method using tin chlorides and sand-like waste, which is accumulated in the fluorine-containing sludge accumulator in the feed phosphate workshop of the Mineral Fertilizers plant in the Taraz city, which contains SiO_2 .

According to the results presented in tables 6 and 7, elemental analysis showed a decrease in the oxygen content, an increase in the content of tin and silicon, and carbon deposition.

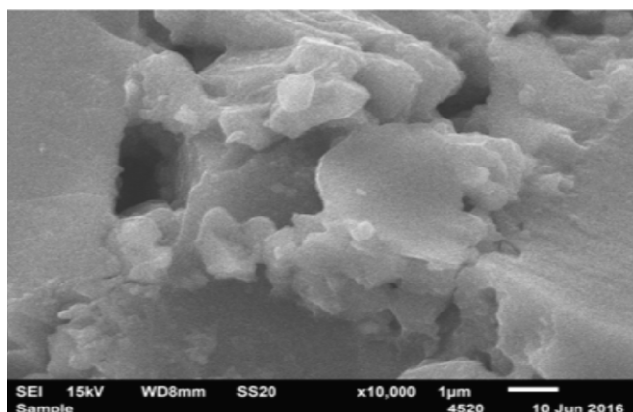


Figure 5 – Microstructure (SEM) of nanocomposites obtained from SiO_2 - SnCl_2 compounds after growing a nanoparticle by a carbon nanotube CVD to methods

Table 5 – Results of X-ray phase analysis after growing nanoparticle carbon nanotube CVD methods

Results of elemental analysis in weight, % ratios							
Range	O	Na	Al	Si	C	Sn	Total
Spectrum 1	29,50	0,50	0,16	2,03	8,40	59,42	100,00
Spectrum 2	29,49	0,47	0,12	2,15	8,60	59,18	100,00
Spectrum 3	29,44	0,52	0,27	2,10	8,63	59,03	100,00
Average	29,48	0,50	0,18	2,09	8,54	59,21	100,00

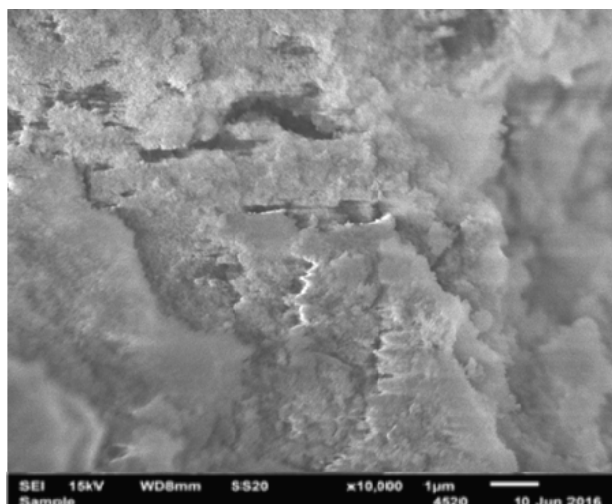
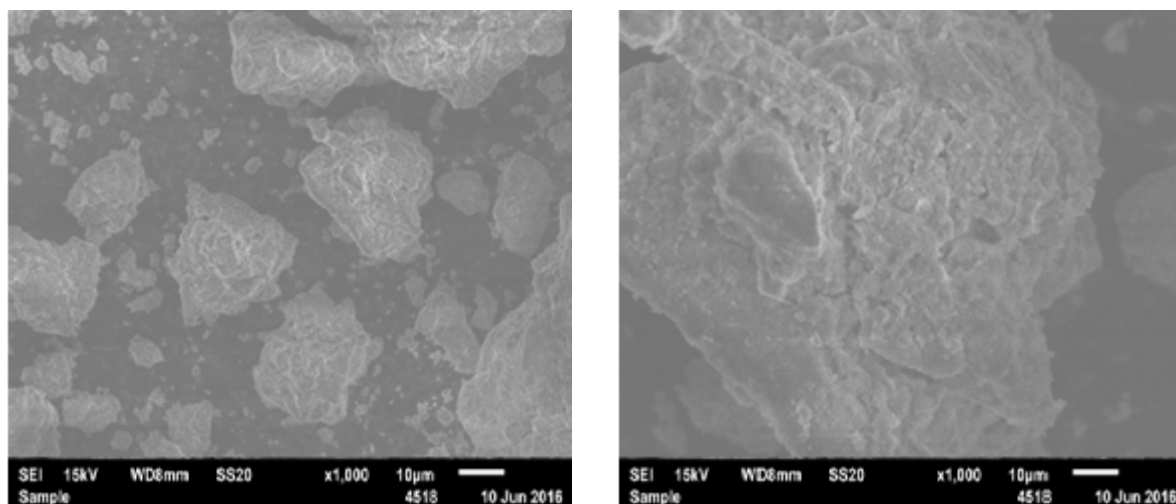


Figure 6 – Microstructure of the obtained products mixture of 1.5 N SnCl_2 solutions and sand waste, in which the composition contains SiO_2 (initial) in SEM - JEOL JSM-6490LV (Japan) low-vacuum electron microscope, 1 nm in volume

Table 6 – Results of X-ray diffraction analysis of the obtained SnCl_2 - SiO_2 starting compounds (from sandy wastes)

Results of elemental analysis in weight,% ratios								
Range	In stats.	O	Al	Si	F	Ca	Sn	Total
Spectrum 1	Yes	31,80	0,12	10,99	0,010	15,00	43,01	100
Spectrum 2	Yes	32,10	0,05	15,34	0,012	15,62	36,82	100
Spectrum 3	Yes	32,06	0,07	14,39	0,013	16,90	37,78	100
Spectrum 4	Yes	32,70	0,04	11,09	0,012	16,25	42,95	100
Average		32,95	0,05	13,95	0,012	15,56	40,14	100



(a) (b)

Figure 7 – Microstructure of nanocomposites obtained from SiO_2 compounds (from sandy wastes) - SnCl_2 after growing a nanoparticle in a carbon nanotube CVD methods, 1 nm (a), microstructure of nanocomposites obtained from SiO_2 compounds (from sandy wastes) - SnCl_2 after growing nanoparticles on a carbon nanotube CVD method (b)

Table 7 – Results of X-ray phase analysis of products obtained from SiO_2 compounds (from sandy wastes) – SnCl_2

Range	In stats.	Results of elemental analysis in weight,% ratios							
		O	Al	Si	F	C	Ca	Sn	Итого
Spectrum 1	Yes	31,80	0,12	10,99	0,010	3,05	15,00	43,01	100
Spectrum 2	Yes	32,10	0,05	15,34	0,012	2,99	15,62	36,82	100
Spectrum 3	Yes	32,06	0,07	14,39	0,013	3,09	16,90	37,78	100
Spectrum 4	Yes	32,70	0,04	11,09	0,012	4,04	16,25	42,95	100
Average		33,95	0,05	12,95	0,012	3,09	15,56	40,14	100

Conclusion. Analysis of the set of experimental data and the results of scanning electron microscopy showed that the sol-gel technology is an effective and promising way to control the nanocrystalline structure of tin dioxide layers.

The change in the content of the elements shows that when the carbon nanoparticles are grown, the microstructure of the obtained compound changes.

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Х. Р. Садиева¹, Б. Қ. Масалимова¹, Р. Дж. Абишева², И. Г. Цой¹,
А. Н. Нурлыбаева¹, А. С. Дарменбаева¹, Л. К. Ыбрайманова¹, А. А. Бакибаев³, А. К. Сапи¹

¹М. Х. Дулати Тараз мемлекеттік университеті, Тараз, Қазақстан,

²Оңтүстік Қазақстан мемлекеттік педагогикалық университеті, Шымкент, Қазақстан,

³Томск мемлекеттік университеті, Томск, Ресей

КРЕМНИЙ-ҚАЛАЙЫҚҰРАМДАС ЗАТТАРДЫҢ НЕГІЗІНДЕ КӨМІРТЕК НАНОКОМПОЗИТТЕРІН АЛУ

Аннотация. Алынған нанокөміртектер кремний диоксиді және тұндырылған көміртегінің бейорганикалық полимерлі торларына иммобилизденген қалайы диоксидінің нанобөлшектері болып табылады. Сондай-ақ, кремний диоксиді жоғары адгезиялық қасиеттерге ие және композиттің кристаллиттерінің агре-

гациялануына жол бермейді, ал қалайы мен көміртегі диоксидінің нано- және микроэлементтері газға сезімтал қасиеттерді алдын ала айқындайды. Золь-гель технологиясымен алынған үлдіртүзгіш ерітінділердің құрамында тетраэтоксисилан, қалайы тұздары ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$), кремний қышқылы ($\text{SiO}_2 \cdot n\text{H}_2\text{O}$) және натрий силикаты ($\text{Na}_2\text{SiO}_3 \cdot 9\text{H}_2\text{O}$) бар. Алынған ерітінділер ары қарай термиялық өңдеу арқылы металл тасымалдағыштың бетіне отырғызылды. Ертіндіге SiO_2 көзі ретінде тетраэтоксисилан ерітінділерін қосымша енгізу $5\% \text{SnO}_2 - 95\% \text{SiO}_2$, $30\% \text{SnO}_2 - 70\% \text{SiO}_2$ құрамдас оксидті ксерогельдерді алуға мүмкіндік берді. Элементтердің құрамын өзгерту көміртегі нанобөлшектерін өсіру кезінде алынған қосылыстың микроқұрылымының өзгеретінін көрсетеді.

Түйін сөздер: нанокөмір, нанобөлшектер, кремний-қалайы нанотүтікшелері.

Х. Р. Садиева¹, Б. К. Масалимова¹, Р. Дж. Абишева², И. Г. Цой¹,
А. Н. Нурлыбаева¹, А. С. Дарменбаева¹, Л. К. Ыбраймжанова¹, А. А. Бакибаев³, А. К. Сапи¹

¹Таразский государственный университет им. М. Х. Дулати, Тараз, Казахстан,

²Южно-Казахстанский государственный педагогический университет, Шымкент, Казахстан,

³Томский государственный университет, Томск, Россия

ПОЛУЧЕНИЕ УГЛЕРОДНЫХ НАНОКОМПОЗИТОВ НА ОСНОВЕ КРЕМНИЙ-ОЛОВОСОДЕРЖАЩИХ ВЕЩЕСТВ

Аннотация. Полученные нанокөмірпредставляют собой наночастицы диоксида олова, иммобилизованные в неорганической полимерной сетке диоксида кремния и осажденного углерода. При этом диоксид кремния обеспечивает высокие адгезионные свойства и предотвращает укрупнение кристаллитов композита, а нано- и микрочастицы диоксида олова и углерода определяют газочувствительные свойства.

Полученные методом золь-гель технологии пленкообразующие растворы содержат тетраэтоксисилан, соли олова ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$), кремниевую кислоту ($\text{SiO}_2 \cdot n\text{H}_2\text{O}$) и кремнекислый натрий ($\text{Na}_2\text{SiO}_3 \cdot 9\text{H}_2\text{O}$). Полученные растворы наносились на металлические подложки с последующей термообработкой. Дополнительное введение в растворы-золи тетраэтоксисилана, как источника SiO_2 , позволило получить ксерогели оксидных составов $5\% \text{масс. SnO}_2 - 95\% \text{масс. SiO}_2$, $30\% \text{масс. SnO}_2 - 70\% \text{масс. SiO}_2$. Изменение содержания элементов показывает, что при наращивании углеродных наночастиц изменяется микроструктура полученных соединений.

Ключевые слова: нанокөмір, наночастицы, кремний-оловосодержащие нанотрубки.

Information about authors:

Sadieva Halipa Ryskulovna, candidate of technical sciences, associated professor of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; xalipa71@mail.ru; <https://orcid.org/0000-0002-8925-8053>

Massalimova Bakytgul Kabykenovna, candidate of chemical sciences, associated professor, manager of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; massalimova15@mail.ru; <https://orcid.org/0000-0003-0135-9712>

Abisheva Roza Dzhanysbekovna, техника ғылымдарының кандидаты. Докторантура және магистратура бөлімінің бастығы, Оңтүстік Қазақстан мемлекеттік педагогикалық университеті, Shymkent, Kazakhstan; ard1967@mail.ru; <https://orcid.org/0000-0002-7056-0420>

Tsoy Irina Gennadievna, candidate of chemical sciences, associated professor of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; tsoyirinagen@mail.ru; <https://orcid.org/0000-0003-1705-6142>

Nurlybayeva Aisha Nurlybayeva, PhD doctor, assistant professor of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; rustem_ergali@mail.ru; <https://orcid.org/0000-0001-9904-9979>

Darmenbayeva Akmaral Sabetbekovna, PhD doctor, senior lecturer of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; maral88@mail.ru; <https://orcid.org/0000-0003-2974-0398>

Ybraimzhanova Laura Kairoldayevna, 2nd year doctoral student of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; ybraimzhanova@mail.ru; <https://orcid.org/0000-0002-2241-6192>

Bakymbayev Abdygali Abdimanapovich, Doctor of Chemical Sciences, Professor, leading researcher of the Laboratory of Catalytic Studies of Tomsk state university, Tomsk, Russia; bakibaev@mail.ru; <https://orcid.org/0000-0002-3335-3166>

Sapi Aruzhan Kanatkyzy, 2nd year student of the department of "Chemistry and chemical technology", M. Kh. Dulaty Taraz state university, Taraz, Kazakhstan; sapievaaas@mail.ru; <https://orcid.org/0000-0001-6487-5023>

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<https://doi.org/10.32014/2019.2518-170X.111>**Y. D. Zhaparkulova¹, K. K. Anuarbekov¹, L. Jurik²**¹Kazakh national agrarian university, Almaty, Kazakhstan,²Slovak university of agriculture in Nitra, Nitra, Slovakia.

E-mail: ermekull@mail.ru, kanat.anuarbekov@kaznau.kz, lubos.jurik@uniag.sk

**ENVIRONMENTAL LOAD NORMA
OF IRRIGATION FIELDS WITH SEWAGE WATER**

Abstract. The article provides materials of field lysimetric studies on the degree of soil purification of wastewater. In order to study the interaction of irrigation wastewater with the soil in the conditions of Almaty region, we carried out field experiments using E. I. Shilova's scoop shape lysimeters.

Keywords: waste water, lysimeters, cleaning, gray soil, ingredients, filtrate.

Introduction. Lysimeters were installed in a hole 1.2 m deep in a previously prepared niche with depth from the surface of the hole wall to a depth of 0,30, 0,60, 0,90 m. The niche free space after installing the lysimeters was tamped with moist soil. The walls of the pit concreted. The filtrate enters the rubber tubes in the vessels (tubes).

On the surface of the lysimeters there is a platform of size 1,00x1,20 m, outlined by a wooden side 0,20 m high.

For irrigation, wastewater from the city of Almaty was used, which is characterized by an alkaline reaction (pH = 7,80), a hydrocarbonate-chloride-sulphate composition with a total mineralization of 0,90–1,10 g/l.

The research results are presented in the table, which show that wastewater, penetrating into the soil, leaves various substances contained in it from top to bottom, that is, soil cleaning takes place. In this case, the degree of wastewater treatment by one or another layer of soil is different in nature and depends primarily on the load rate.

The main wastewater treatment occurs in the soil horizon 0-30 cm. Here, the degree of purification of water-soluble salts reaches 76%, and nitrogen and phosphorus up to 90%. As the load rate increases, it appears to a lesser extent. A high degree of purification is noted in a layer of 0-90 cm with a load of 1000 m³/ha. Bringing the rate of load to 1500 m³/ha slightly reduces the degree of purification in each of the soil layers under consideration. The migration of calcium and magnesium in the underlying layers is not a desirable phenomenon. Their significant migration was established at a one-time irrigation rate of 1,500 m³/ha. Therefore, such a value of a one-time norm for irrigation fields in conditions of dark chestnut soil is not acceptable.

We found that when passing through a certain layer of serozem soils (0,90 m), the wastewater bleached, the amount of all chemical components decreased. Lysimetric waters had no odor, which indicates the cleaning ability of the soil. The final treatment of wastewater does not end at a layer of 0-90 cm. It can be assumed that it will flow in the layer below 0-90 cm and there is such a thickness of the soil layer where the filtrate will be practically clean. Many researchers have argued that at a depth of 1,5 meters, the wastewater is completely free from any impurities, if the irrigation regime is observed [1].

However, in order to protect groundwater from pollution, it is recommended to arrange irrigation fields where groundwater lies at a depth of 3 meters or more. Analyzing the data in the table, it should be noted that the absorption of mineral elements by the soil layer, such as nitrogen, phosphorus, potassium, does not fall below 82-85% even with a load of up to 1500 m³/ha. However, the loss of nitrogen from wastewater increases with increasing irrigation rates. German scientists have shown that with an increase

in the water supply rate, nitrogen absorption by the soil stops: on sandy soils with an increase in water supply from 60 to 150 mm, on sandy soils - up to 400 mm, on clayey - even higher [2].

Apparently, the colloidal composition of the soil is of particular importance for reducing the nitrogen content of wastewater in the process of their purification and use in agriculture.

The main absorption of nitrogen occurs in the upper layers of the soil profile. For example, the absorption of nitrogen to a depth of 30 cm ranged from 40 to 60%, depending on the load norms, and to a depth of 60 cm to 80-87%. Nitrogen uptake will continue. According to I. F. Thomas, it ends at a depth of 3 m [3].

Table 1 – The degree of soil tertiary treatment of wastewater at different load norms (initial water supply)

Indicators	Content of ingredients, mg/l								
	HCO ₃	Cl	SO ₄	Ca	Mg	Na+K	P ₂ O ₅	N	K ₂ O
With a load rate of 600 m ³ /ha									
Sourcewater	480	160	320	80	40	306	11	30	19
In a layer of 0-30 cm									
Filtrate	270	106	118	50	21	160	5	12	3,8
Absorbedin, %	42	34	63	34	47	48	54	60	80
In a layer of 0-60 cm									
Filtrate	114	60	80	35	10	85	2	4	–
Absorbedin, %	76	62	75	56	75	72	81	87	100
With a load rate of 1000 m ³ /ha									
In a layer of 0-30 cm									
Filtrate	240	111	145	60	24	150	6	16	4,8
Absorbedin, %	50	31	55	25	40	51	46	47	75
In a layer of 0-60 cm									
Filtrate	126	80	90	42	12	80	1	6	1
Absorbedin, %	74	50	72	47	70	74	91	80	95
In a layer of 0-90 cm									
Filtrate	91	51	45	29	9	43	–	1	–
Absorbedin, %	81	68	86	64	78	86	100	98	100
With a load rate of 1500 m ³ /ha									
In a layer of 0-30 cm									
Filtrate	280	115	160	30	35	149	6	18	7,2
Absorbedin, %	42	29	50	12	12	51	45	40	62
In a layer of 0-60 cm									
Filtrate	166	96	95	58	16	92	2	6	5,1
Absorbedin, %	75	40	70	28	60	70	82	80	76
In a layer of 0-90 cm									
Filtrate	108	67	90	54	22	86	2	6	0,4
Absorbedin, %	78	58	72	33	45	72	83	81	98

Phosphorus absorption is higher than nitrogen. In 58% of the experimental results showed that the maximum absorption of phosphorus is observed up to a depth of 60 cm. In this layer, depending on the water supply rate, phosphorus absorbed up to 82-91%. Similar trends were noted in the studies of M. Schultz [2].

As it is known, mineral substances such as nitrogen, phosphorus and potassium in waste water are mainly in a dissolved form (nitrogen 85%, phosphorus 50% and potassium 95%). Absorbing in the upper soil layer, they become more accessible to crops.

Calcium absorption by the arable layer of soil 0,30 m did not exceed 37%. With a normal load of 50 mm, and with a load of 150 mm, calcium absorption did not exceed 12%. As the depth of the soil horizons increases, its absorption is somewhat increased. Magnesium has the same pattern, although it is absorbed more than calcium. Apparently they go to the underlying layers of the soil. Therefore, the possible outflow of calcium from the soil must be compensated by liming [4-6].

A number of scientists propose a major role in the significant enrichment of the soil, as noted in our experiments, plays a large absorbing energy of the K-cation, which primarily occupies all the free valences of the surface layers. Huge cations, primarily sodium and calcium, whose absorption energy is much lower than that of potassium, therefore, is carried into the deep layers of the soil.

From the anionic group, the absorption of bicarbonate and carbonate ions is higher than that of chloride.

Although a number of scientists noted that sulphates are mainly absorbed by the deep layers of the soil, in our experiments, a high absorption of sulphate by the upper arable layer of soil is noted. With a water supply rate of 500 m³/ha, the absorbing 63%, with a water supply rate of 1000 m³/ha - 55%, and at a rate of 1500 m³/ha - 50%.

Thus, with an increase in the thickness of the soil layer, the degree of purification increases, and with an increase in the load norm, there is a slight increase in the content of the main components in the lysimetric waters.

When applying the norm of 1500 mm, the degree of purification in the 0-90 cm layer was low and amounted to 16-51%. There is observed the leaching of such an important element as calcium outside the corneal zone of the soil.

The decrease in soil absorption of various ingredients can be explained:

- weakening by the end of the growing season their consumption of plants;
- a decrease in the microbiological activity of gray soils;
- relative “saturation” of the filtering layer with added substances;
- changes in the cation composition of the soil absorbing complex;
- deterioration of the water-physical properties of the upper horizon of the paid soil horizon during irrigation and treatments;
- meteorological conditions and other factors, alone or in combination with causing a change in the sorption properties of the soil. [7,8]

Methods. Factors that are dependent on the treatment of wastewater from soil conditions and water supply rates, as well as the concentration of the ingredient, the temperature of the wastewater and the duration of the intervals between irrigation can be recorded:

$$A = \frac{A_H}{\log \frac{A_0}{A_H}}, \quad (1)$$

where A – degree of purification, %; A_0 – pollution BOD5 (biological oxygen demand), used irrigation water, mg/l; A_H – pollution BOD5 irrigation water after filtration through the soil to a depth of H , mg/l.

For the conditions of gray soils is:

at a rate of 600 m³/ha $A_H = 19,6$

at a rate of 1000 m³/ha $A_H = 28,2$

at a rate of 1500 m³/ha $A_H = 30,6$

Our experimental data showed a high degree of BOD5 purification of a 90 cm soil layer at a load rate of up to 1000 m³/ha. This is of great agricultural importance, since as a result, the accumulation of organic matter significantly increases the fertility of the soil. A further increase in the water supply rate leads to a decrease to 28-52%.

Many researchers believe that the regulation of inter-irrigation periods, which largely determine the use of plants by the introduction of nutrients and their fixation in the soil, can increase the stability of sorption processes in the soil.

In order to prevent the leaching of wastewater ingredients outside the root zone (this not only causes free loss of nutrients, but also the danger of contamination of groundwater), it is necessary to avoid supplying large amounts.

In terms of irrigation with wastewater for environmental safety, an equilibrium should be maintained between the intake of various nutrients from wastewater and their use by plants, which are mainly regulated by inter-irrigation periods.

It is clear from here that the longer the irrigation period is, the higher is the absorption capacity of the soil, and the degree of purification is also meant.

The cleaning properties of gray soils, noted above, takes place only during the period of soil saturation with water. From the moment of their full saturation with water, natural wastewater treatment does not occur and chemical means flowing into the filtrate are subject to the composition of the wastewater.

Based on the data obtained from the lysimetric experience, we were able to identify that the amount of runoff from that other soil profile (H) depends on the applied irrigation norms and it can be expressed:

$$W = \frac{m \cdot \omega}{10000} \cdot (H - h), \quad (2)$$

where W – average runoff, m^3 ; m – irrigation rate per 1 m depth; ω – lysimeter surface area; H – estimated depth of moisture, m; h – the depth of the soil layer through which the filtrate goes.

These data allow carrying out balance calculations of ingredients entering the soil with wastewater (table 2).

Table 2 – Balance calculation of elements of mineral nutrition and water-soluble salts in soil, kg/ha

Indicators	Ingredients, kg			
	N	P ₂ O ₅	K ₂ O	Summa of salts, mg/ha
Irrigation rate, 600 m ³ /ha				
Received with wastewater	18	9,5	11,4	816
Filtrate volume, through 30 cm layer, 450 m ³				
Filtration content	13,5	450	8,55	512
Absorbed in a layer of 0-30 cm	4,5	4,95	2,85	204
Filtrate volume, through 60 cm layer, 240 m ³				
Filtration content	5,2	2,54	4,56	326
Absorbed in a layer of 0-60 cm	12,8	3,0	6,64	490
Filtrate volume, through 90 cm layer, 60 m ³				
Filtration content	1,8	0,00	1,14	61,5
Absorbed in a layer of 0-90 cm	16,2	5,94	10,26	734,4

Results. The overall qualitative and quantitative expression of the processes of absorption and migration of wastewater ingredients introduced into the soil with irrigation water has its own characteristics. The content of ingredients in the filtered and irrigation waters is not identical and is a variable value depending on a number of factors. In quantitative terms, their migration lags behind the rate of moisture filtration: with an increase in the filtration layer. This lag is more pronounced. With increasing irrigation rates, the absorption capacity of the soil is manifested to a lesser extent.

When irrigation of lysimeters with treated wastewater, the predominant part of the nutrients in them absorbs the arable soil horizon and they will be used by plants, the other part accumulates in the lower layers of the soil profile, turning off for a long time from the active circulation of substances in the soil-plant-soil system.

The degree of absorption of the ingredients of sewage gray soils can be adjusted by changing the irrigation regime. According to the results of lysimetric experiments, disposable feed rates of 600–1000 m³/ha turned out to be the most acceptable from the ecological point of view. With this approach, highly efficient wastewater treatment and more complete utilization of nutrients introduced into the soil is achieved.

Е. Д. Жапаркулова¹, Қ. Қ. Ануарбеков¹, Л. Юрик²

¹Қазақ ұлттық аграрлық университеті, Алматы, Қазақстан,

²Нитра Ауылшаруашылығы Словак университеті, Нитра, Словакия

СУАРУ АЛҚАПТАРЫНЫҢ ТӨГІНДІ СУЛАРМЕН СУҒАРУДЫҢ ЭКОЛОГИЯЛЫҚ ЖҮКТЕМЕ НОРМАСЫ

Аннотация. Мақалада төгінді суларды топырақты тазартудың дәрежесін зерттеу бойынша далалық лизиметриялық зерттеулердің материалдары келтіріледі. Суғармалы төгінді сулардың топырақпен өзара байланысын зерттеу мақсатында Алматы облысы жағдайында Е.И.Шиловтың күрек тәрізді формадағы лизиметрлерін қолдану арқылы табиғи тәжірибе жүргізілді.

Түйін сөздер: төгінді сулар, лизиметрлер, тазалау, боз топырақ, ингредиенттер, сүзінді.

Е. Д. Жапаркулова¹, К. К. Ануарбеков¹, Л. Юрик²

¹Казахский национальный аграрный университет, Алматы, Казахстан,

²Словацкий сельскохозяйственный университет в Нитре, Нитра, Словакия

НОРМА ЭКОЛОГИЧЕСКОЙ НАГРУЗКИ ОРОСИТЕЛЬНЫХ ПОЛЕЙ СТОЧНЫМИ ВОДАМИ

Аннотация. В статье приводятся материалы полевых лизиметрических исследований по изучению степени почвенной доочистки сточных вод. В целях изучения взаимодействия оросительных сточных вод с почвой нами в условиях Алматинской области проведены натурные опыты с использованием лизиметров совкообразной формы Е.И.Шиловой.

Ключевые слова: сточные воды, лизиметры, очистка, сероземные почвы, ингредиенты, фильтрат.

Information about authors:

Zhaparkulova Yermekkul, Candidate technical science, assos. Professor of the Department of “Water resources and melioration”, Kazakh national agrarian university, Almaty, Kazakhstan; ermekull@mail.ru; <https://orcid.org/0000-0002-5593-0016>

Anuarbekov Kanat, PhD doctor, senior lecturer of the Department of “Water resources and melioration”, Kazakh national agrarian university, Almaty, Kazakhstan; kanat.anuarbekov@kaznu.kz; <https://orcid.org/0000-0003-0832-6980>

Jurik Lubos, PhD doctor, Slovak university of agriculture in Nitra, Slovakia; lubos.jurik@uniag.sk; <https://orcid.org/0000-0002-4855-7540>

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**Z. B. Karshigina¹, Ye. G. Bochevskaya¹, Z. S. Abisheva^{1,2},
Ata Akcil³, S. M. Kan⁴, M. K. Absametov⁴, S. V. Berstenev⁴**

¹Institute of metallurgy and ore beneficiation, Almaty, Kazakhstan,

²K. I. Satpayev's Kazakh national research technical university, Almaty, Kazakhstan,

³Suleyman Demirel university, Isparta, Turkey,

⁴U. M. Akhmedsavin institute of hydrogeology and geoecology, Almaty, Kazakhstan.

E-mail: zaure_karshiga@mail.ru, elena_bochevskayal@mail.ru, abisheva_z@mail.ru,
ataakcil@sdu.edu.tr, kan-s58@mail.ru, mabsametov@mail.ru, sberstenyov@mail.ru

SORPTION METHODS OF PROCESSING OF HYDROMINERAL LITHIUM RAW MATERIAL OF KAZAKHSTAN

Abstract. In the contemporary world of high technologies lithium (Li) is a key component. Kazakhstan has the required potential for its production. The most attractive raw materials for lithium extraction are natural and saline lake brines. Investigation and search of new technological solutions with the purpose of inclusion thereof in the sphere of lithium-containing hydromineral raw material processing is an important and relevant scientific and technical task. This article provides analysis of the literature data on lithium sorption by organic resins and inorganic sorbents. Generally, cation exchange resins, both in protonated and sodium forms, are mostly used for lithium sorption. They include widespread cationite KU-2-8 or its equivalents. In the investigations on lithium sorption extraction from lithium-containing solutions from amongst of inorganic sorbents mainly manganese, titanium and aluminum based compounds are used. For the static lithium extraction from natural brines we performed sorption using ion-exchange resins: CU-2-8, Purolite C100, Purolite C160S, Purolite S940, Amberlite IR 120, CYBBER CRX 210, and CYBBER CRX 300. It was demonstrated that almost no lithium is sorbed on ionites. Insignificant amount of lithium was extracted on sulphocationite CU-2-8 and made up 0.49%. Investigations were made on natural brines processing using inorganic sorbents (in the form of commercial reagents): aluminum hydroxide, titanium and manganese oxides, and activated carbon. Besides, such inorganic sorbents as aluminum hydroxide, hydrated titanium and manganese oxides were synthesized. It was established that the highest rates were achieved when aluminum hydroxide was used as sorbent, at that lithium extraction made up 21.87%, and on synthesized sorbent – hydrated manganese oxide, where Li extraction reached 20.11%. For lithium extraction from brines inorganic sorbents were chosen as the sorption method using aluminum and/or manganese compounds as sorbents.

Key words: lithium, natural brines, sorption, ion exchange resins, inorganic sorbents, synthesis, extraction.

Introduction. Lithium legitimately can be called the most important element of the modern civilization and technology development. Many lithium compounds and metal itself have become of utmost economic and strategic importance, which resulted in a stable and steady growth of lithium and lithium products output. As forecasted by Goldman Sachs, the lithium demand may triple by 2025 to 570,000 t due to the stable demand by smartphone and electromobile manufacturers. Lithium is already branded “white oil” as Tesla and other automobile companies use it for the manufacture of lithium-ion accumulators. Apart from the accumulators, nowadays it is widely used in the production of glass and ceramics (30%), lubricating materials (11%), metallurgy (4%), as well as in the production of chemicals, pharmaceuticals, rubber, and others [1]. The established global high demand for this metal forces to search new potential sources of its production.

The main sources for lithium production globally are ores, salt lake brines, and a secondary source – dead lithium batteries. Basic studies are currently aimed at development of the efficient technologies of lithium extraction from the said types of raw materials.

For lithium extraction from ores and minerals they use roasting with subsequent leaching, and its extraction from brines includes operations of preconcentration, in other words evaporation, precipitation, adsorption, and ion exchange [2]. For lithium extraction from dead lithium batteries they use leaching with subsequent precipitation, sorption or liquid extraction, electrolysis [3].

Ore processing, especially spodumene, is the most expensive if compared to lithium extraction from brines due to the necessity to use mines, energy consuming preliminary preparation of the ore raw material, and application of the high-temperature opening and subsequent leaching. That is why many spodumene deposits are not producing and not processed now.

Lithium is also present in sea water, but its concentration is too low – about 0.1-0.2 mg/l [4] to be cost-effective. The total amount of metal lithium in sea water (globally) is estimated at ~230 Ht. However, due to the low original concentrations it cannot be considered as a real source of lithium.

Brine sources include lithium detected in the salt water deposits – saline lakes, salt mines, oil field brines, and geothermal brines. Oil brines, which on an industrial scale contain many valuable components, including lithium [5-9], represent subsurface brine reservoirs located with oil. Geothermal brines represent subsurface biologically heated brines, for example, in the Salton Sea, California. Subsurface brines containing lithium make up 66% of global lithium resources and become a dominating raw material for Li_2CO_3 all over the world due to the lower costs compared to production of lithium carbonate of hard ore [10, 11].

While processing hydromineral lithium raw material they use such methods as evaporation and precipitation, offering schemes with the use of extraction, sorption [12-15] and electrolysis [9] processes. This paper describes lithium extraction and concentration methods at natural brines processing using ion-exchange resins and inorganic sorbents.

In the paper [12] for lithium extraction they used resins of nomenclature LSC-100, LSC-500, and D001 with fixed ions $-\text{N}(\text{CH}_2\text{COO}^-)_2$, $-\text{NHCH}_2\text{PO}_3^{2-}$, and $-\text{SO}_3$, accordingly. It is demonstrated that resins LSC-100 and LSC-500 had higher selectivity for lithium extraction with adsorption capacity ≥ 5.5 mmole/g as compared to other alkali metal ions, following the extraction sequence: $\text{Li}^+ \gg \text{K}^+ \sim \text{Rb}^+ \sim \text{Cs}^+$ and $\text{Li}^+ \gg \text{K}^+ > \text{Rb}^+ \sim \text{Cs}^+$, accordingly. The authors explain [12] that strong ligands LSC-100 and LSC-500 are prone to strong complex formation with lithium than any other alkali metals. To the contrary, at sorption with resin D001 there was an inverse extraction trend, where first Cs and later lithium were adsorbed. In the paper [13] for lithium adsorption from synthetic chloride solution they used resin Amberlite IR 120 in sodium and hydrogen forms. The results demonstrated that ion exchange between Li^+ and Na^+ is more favourable if compared to the protonated form. In the ion-exchange method of lithium separation from other alkali metals they use sorption of metal ions on the column filled with cationite CU-2 in N-form and subsequent elution with acid solutions [14]. Lithium ions sorbed on sulphocationite CU-2 with 20% divinylbenzene are the least tightly bonded, desorb at lower saline acid concentration, and elute before ions of Na, K, Rb, and Cs. Sulphocationite KU-2-8, as is known, is an analogue of Amberlite IR 120.

The paper [15] describes studies, where for the selective lithium adsorption they used strongly basic (Dowex MSA-I) and weakly basic (Dowex MWA-I) anion exchangers. Before the contact with the original solution an active chloride form of Dowex MWA-I was transferred to the hydroxide form, while at the time of using Dowex MSA-I change of the active chloride form was not obligatory. Since during the work with Dowex MSA-I the active chloride form of resins was exchanged with AlCl_3 by treatment with a saturated aluminum chloride solution. Thereafter, by the ammonia solution treatment they transferred AlCl_3 to the form of $\text{Al}(\text{OH})_3$, which contacts with brine containing LiCl at $\text{pH} > 6$. Using NaOH instead of solution NH_4OH had an unfavourable effect at resins hydroxylation, since it caused formation of alkali aluminates, which elute AlCl_3 of modified resins. Lithium chloride LiCl was extracted from brine into modified resin as a complex of lithium halogenide with aluminate. Lithium eluting from saturated resin was made using hot water.

There are known methods of lithium extraction by sorption from sea water and brines using different types of adsorbents: inorganic ion exchangers, such as spinel-type manganese oxide, of the aluminum compound demonstrate extremely high selectivity for lithium extraction from sea water [16-19]. Such materials have high adsorption capacity; in alkali media ($\text{pH} \sim 8$) lithium had concentration 400 times higher.

Studies [20] on lithium adsorption on different titanium oxides demonstrated that the structure of Li_2TiO_3 obtained from anatase turned out to be more suitable for lithium extraction than that obtained from rutile. In the paper [21] for lithium adsorption they use activated carbon as an adsorbent.

Lithium adsorption using aluminum salt as an adsorbent ($\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$) was performed at the temperatures of 10 to 30°C. The temperature above 30°C did not have any effect on lithium sorption on $\text{Al}(\text{OH})_3$, which proved that the process is taking place through physical adsorption [22]. The maximum adsorption capacity at pH 9 made up 123 mg/g.

Sorbents obtained on the basis of double compounds of aluminum and lithium $\text{LiCl} \cdot 2\text{Al}(\text{OH})_3 \cdot m\text{H}_2\text{O}$ and stable in brines with low pH level have high rates [23-26]. A distinctive feature of the suggested sorbent is its selectivity, since lithium cannot be replaced by any other element in this compound.

Thus, publications analysis has shown that the problem of lithium extraction from natural brines is relevant. It should be noted that studies are mostly performed at the laboratory level.

The purpose of our work is to choose the most effective sorption method of lithium extraction in the process of natural brine processing in the static conditions using either ion-exchange resins or inorganic sorbents.

Research methodology.

Reagents: saline acid HCl high grade, GOST 3118-77; sodium hydroxide NaOH high grade, GOST 4328-77; aqueous ammonia NH_4OH ultrahigh purity, GOST 24147-80; carbon dioxide in cylinders with 100% concentration; crystalline sodium thiosulfate $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, analytic grade, GOST 27068-86; potassium permanganate 0.1 N, titration standard, TU 6-09-2540-72; aluminum hydroxide $\text{Al}(\text{OH})_3$ analytic grade, GOST 11841-76; manganese dioxide MnO_2 high purity, GOST 4470-79; titanium dioxide TiO_2 grade P-03, GOST **9808-84**, and activated carbon Goldcarb 207C (Altyntau-Kokshetau).

Ionite preparation. Cation exchange resins are produced by the industry in the sodium form. To perform the research cationites were preliminarily transferred to the hydrogen form. Ionite was cleaned from synthesis products and transferred to N-form using the saline acid solution [27]. A definite volume of each ionite previously swollen in distilled water was loaded into the glass columns. Then 5% solution of HCl was flowing through each column at a rate of 3 specific volumes per hour to equal acid concentration at entry and exit. Ionites were washed from acid using distilled water to pH = 6 - 7. Prepared ionites were dried at 50°C to the constant weight.

Sorbent preparation. For the sorbent synthesis they used a pressure tight thermostatically-controlled cell with the capacity of 2 dm³ equipped with a mechanical stirrer 'OST basic' making a fixed number of rotations – 500 rpm. The constant temperature was maintained using a circulation bath LOIP LT-200. For the purpose of aluminate solution carbonization CO_2 was fed through the flowmeter from the cylinders to the distributor placed in the cell. The mixture of titanium dioxide and sodium hydroxide powders was matured in a muffle furnace type SNOL 7.2/1300 for 1 h at 650°C. Synthesized sorbents were washed with distilled water to pH=6 – 7 and dried at 105°C to the constant weight.

Experimental method. Sorption was performed in static conditions at a temperature of 25±5°C. For the purpose of sorption using ion-exchange resins 1 g of each cationite in N-form were placed into the dry flasks with the capacity of 0.5 dm³, 0.2 dm³ of brine was added, and it was placed onto the mixer. Cationites contact with brine was maintained for 28 days.

For the purpose of sorption using inorganic sorbents 10 g of each sorbent were placed into the dry flasks for 2 dm³, 1 dm³ of brine was added, and it was placed onto the mixer. Sorbents contact with brine was maintained for 4 days. Solutions were separated from sorbents using vacuum filtration.

Analysis methods. Natural brines and solutions after sorption were analysed for lithium content. The quantitative content of lithium in the sorbent was determined based on the difference of their content in the original brine and solution after sorption.

Lithium determination was performed by the method of atomic-emission spectroscopy as per NSAM 320Г-90 using a double beam atomic-emission spectrometer Agilent 240FS/AA equipped with an automatic monochromator and control of slit width setting in the flame 'acetylene – air'. The X-ray phase analysis was made using a diffractometer D8 ADVANCE BRUKER AXS GmbH, (Germany) emission of Cu-K α , data base PDF-2 of the International Center for Diffraction Data ICDD (USA).

Results and discussion. Static sorption was performed using natural brine composed of (g/dm³): Na 30.49; Cl⁻ 58.2; Ca 5.37; Mg 1.29 and K 0.68. Concentration of Li was 8.24 mg/dm³. pH of the source brine was 7.

Ion exchange method of lithium extraction from natural brines on synthetic sorbents. Characteristics of ionites used for studying lithium extraction from brines by sorption are shown in table 1.

Table 1 – Characteristics of Cationites

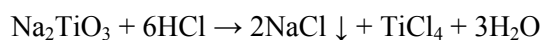
Ionite Name	Ionogenic Group	Physical Structure
CU-2-8	Sulfonic acid $-\text{SO}_3\text{H}$	Gel-like strong-acid ionite
Purolite C100	Sulfonic acid $-\text{SO}_3\text{H}$	Gel-like strong-acid ionite
Purolite C160S	Sulfonic acid $-\text{SO}_3\text{H}$	Macroporous strong-acid ionite
Purolite S940	Amino phosphonic acid $-\text{NHCH}_2\text{PO}(\text{OH})_2$	Macroporous chelating ionite
Amberlite IR 120	Sulfonic acid $-\text{SO}_3\text{H}$	Gel-like strong-acid ionite
CYBBER CRX 210	Iminodiacetic acid $-\text{CH}_2\text{N}(\text{CH}_2\text{COOH})_2$	Macroporous chelating ionite
CYBBER CRX 300	Aminomethylphosphonic acid $-\text{NHCH}_2\text{PO}(\text{OH})_2$	Macroporous weak-acid ionite

As is clear from table 1, we used strong-acid, weak-acid and chelating cationites with a gel-like and macroporous structure as sorbents of the following functional groups: $-\text{SO}_3\text{H}$; $-\text{NHCH}_2\text{PO}(\text{OH})_2$ and $-\text{CH}_2\text{N}(\text{CH}_2\text{COOH})_2$. Ionites have varying selectivity with respect to lithium ion. Carbonaceous and phosphoric-acid cationites, i.e. Purolite S940, CYBBER CRX 210, and CYBBER CRX 300, are more preferable for lithium extraction from brines. However, testing ionites with sulphonic-acid group was of interest for getting fuller information and comparative evaluation. It was established that CU-2-8 was the only sulphocationite that resulted in minor lithium extraction of 0.49%. The sorption results might have been affected by such factors as medium pH, temperature, structure of the resins, and other. Therefore, sorption of lithium from natural brines using cation exchange resins is ineffective.

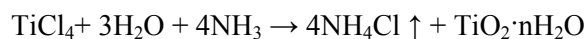
For lithium extraction from natural brines by sorption, inorganic sorbents can be used along with ion-exchange resins. Such inorganic sorbents as aluminum hydroxide, titanium and manganese oxides were synthesized provisionally for the study.

Synthesis of Aluminum Hydroxide $\text{Al}(\text{OH})_3$. At the first stage, a commercial chemical reagent - aluminum hydroxide was leached using NaOH solution under the following conditions maintained: concentration of NaOH was 285 g/dm^3 , the solid to liquid phase ratio was 1:3, temperature was 98°C , and duration was 5 hours. The produced filtered aluminate solution was carbonized with carbon dioxide. Carbonization was performed in polythermal regime with decrease of temperature from 70 to 60°C . Carbon dioxide was flowing through the entire solution volume for 6 hours with constant pulp stirring. Then precipitate of $\text{Al}(\text{OH})_3$ was separated from the stock solution by filtering, elutriated and dried. The X-ray phase analysis of precipitate confirmed production of aluminum hydroxide represented by two phases: gibbsite and bayerite (figure 1).

Synthesis of Titanium Dioxide TiO_2 . To produce hydrated titanium oxide, a mixture of powdered TiO_2 and NaOH was pestled in an agate mortar at a w/w proportion of 1:1.5. Then, the mixture was transferred to alundum pot and kept in a muffle furnace at 650°C for 1 hour to enable a reaction with production of the alloy Na_2TiO_3 . After alloy cooling, we added HCl (1:1) in drops:



SADX'HJGHLThen, after filtering, we added strong solution of ammonia NH_3 in drops to the resulted filtrate, during the procedure white gas NH_4Cl evolved and hydrated titanium oxide was formed:



The X-ray phase analysis of obtained $\text{TiO}_2 \cdot n\text{H}_2\text{O}$ after washing and drying showed that its major phases were hydrated acid oxide $\text{Ti}_4\text{H}_2\text{O}_9 \cdot 1.9\text{H}_2\text{O}$, anatase TiO_2 and brookite TiO_2 .

Synthesis of Manganese Oxide MnO . To synthesize manganese oxide, we added 3.125% $\text{Na}_2\text{S}_2\text{O}_3$ solution to 0.1 N KMnO_4 solution slowly in drops while stirring. This allowed getting a dark-cherry precipitate from the solution. The X-ray phase analysis of the precipitate showed that its major phases were pyrochroite $\text{MnO} \cdot \text{H}_2\text{O}$ and hydrated manganese oxide $\text{Mn}_7\text{O}_{13} \cdot 5\text{H}_2\text{O}$ (figure 2).

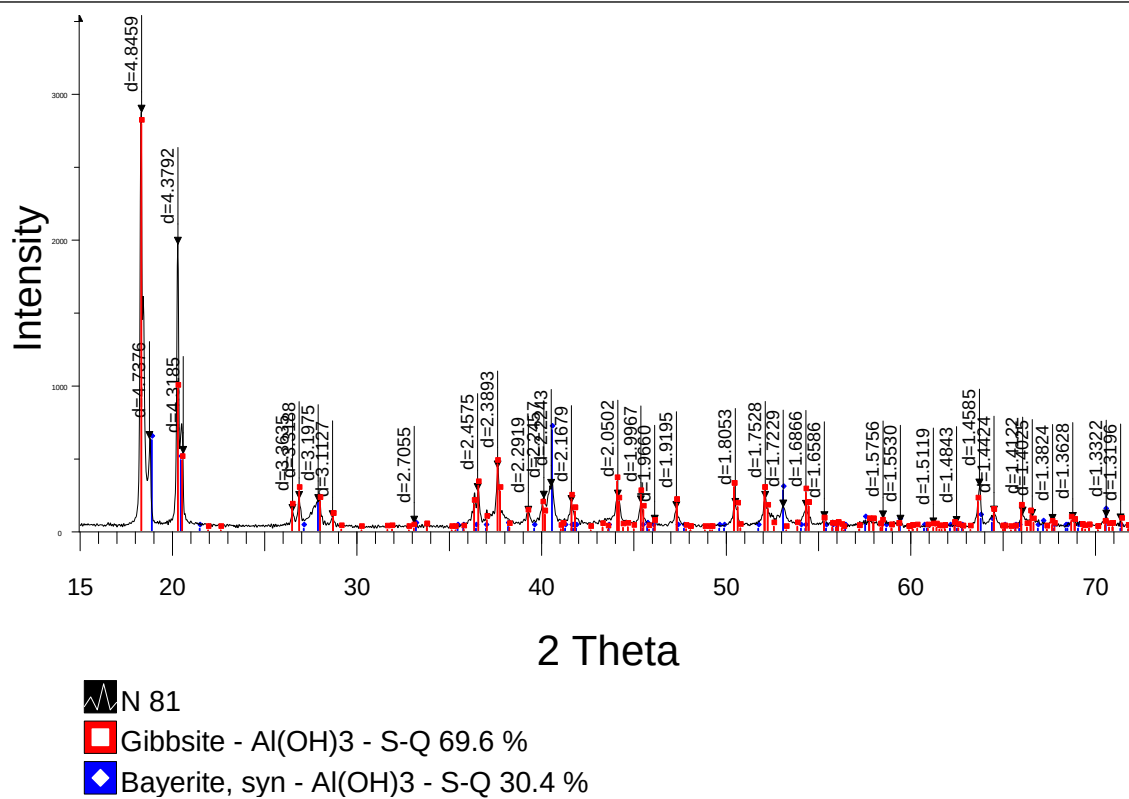


Figure 1 – Diffraction Pattern of Synthesized Aluminum Hydroxide

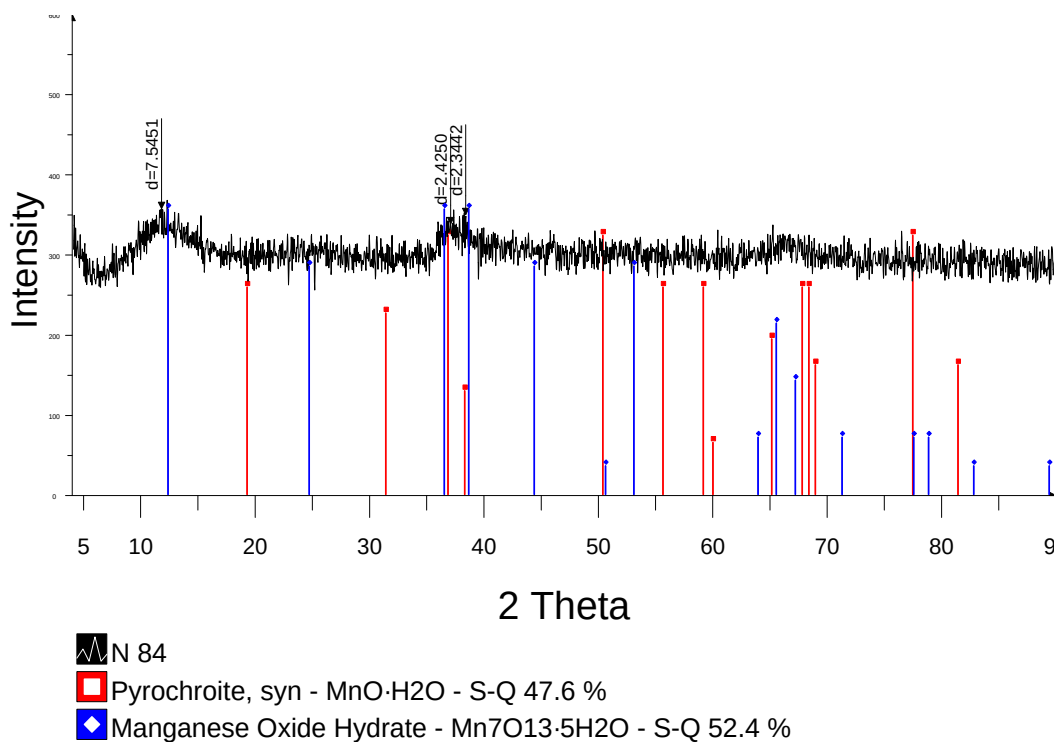


Figure 2 – Diffraction Pattern of Hydrated Manganese Oxide

Lithium Extraction from Natural Brines Using Inorganic Sorbents. Testing of the sorption method for processing brines was investigated using two types of inorganic sorbents: 1) commercial chemical reagents: aluminum hydroxide, titanium and manganese oxides, and activated carbon; 2) sorbents synthesized in laboratory settings. Results of the experiments are presented in table 2.

Table 2 – Sorption of Lithium from Natural Brines Using Inorganic Sorbents

Sorbent	Lithium extraction by sorbent, %	
	Commercial reagent	Synthesized sample
Aluminum hydroxide	21.87	9.13
Titanium oxide	–	–
Manganese oxide	7.85	20.11
Activated carbon	0.97	

As table 2 shows, the highest results of lithium sorption from brines were obtained with commercial aluminum hydroxide used as sorbent, the extraction rate made up 21.87%. The rate of lithium extraction from manganese oxide brine was lower and made up 7.85%. The rate of sorption by activated carbon made up merely 0.97%. Titanium oxide didn't sorb lithium from brine.

The rate of lithium sorption from brines using synthesized sorbents - aluminum hydroxide and hydrated manganese oxide made up 9.13% and 20.11%, respectively. The lithium sorption rates decreased 2.4 times when synthesized aluminum hydroxide was used due to bayerite phase in the synthesized sorbent, according to the X-ray phase analysis results (figure 1). Commercial aluminum hydroxide was entirely represented by a gibbsite phase, which might have a favourable effect on the sorption results. When synthesized manganese oxide was used, the lithium sorption rates were higher than in the previous series of experiments. The phase composition of commercial manganese oxide also differed from the synthesized sorbent. It contained manganese oxide Mn_2O_3 , manganese nsutite $Mn_{1.60}Mn_{0.32}O_{3.10}(OH)_{0.90}$ and hydrated manganese oxide $1.48MnO \cdot 0.15H_2O$. Another factor that might have an effect on the lithium sorption rates was different phase compositions of the sorbents. As the X-ray phase analysis showed, the initial compounds of inorganic sorbents have changed a little after they had been used for lithium sorption due to low rates of lithium sorbed.

Therefore, sorption with the use of inorganic sorbents such as commercial aluminum hydroxide and hydrated manganese oxide may be appropriate for lithium extraction from natural brines.

Conclusion. There is a growing interest to lithium all over the world. Currently, our country does not perform any systematic studies on lithium extraction. Therefore, Kazakhstan, which has lithium resources in natural and saline lake brines, should investigate its raw material sources and develop a technology for Li extraction from such sources. However, composition of natural brines in our country (with an average Li concentration being 0.007-0.012 g/dm³) differs significantly from those in other countries (0.1 g/dm³ Li and higher), and the existing technologies cannot be applied to our natural sources. That's why to involve natural sources of Kazakhstan into the global lithium production new solutions must be found for the effective processing thereof.

It was established that sorption of lithium from natural brines using synthesized ion-exchange resins is ineffective. CU-2-8 was the only ionite resulted in a minor lithium extraction rate (0.49%).

The highest rates were achieved with a commercial reagent aluminum hydroxide (among inorganic sorbents) used as a sorbent (the lithium extraction rate made up 21.87%), and with a synthesized sorbent, hydrated manganese oxide, where the extraction rate reached 20.11%. Differences in the phase compositions of sorbents might have influenced the lithium sorption rates. That was a static sorption, i.e. a one-stage process. In practice, sorption is performed in dynamic conditions, which is more effective as the sorbent is continuously in contact with new portions of the solution flown through it. Therefore, dynamic sorption process may allow increasing the rates of lithium extraction on a sorbent from natural brines to 65-70%.

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**З. Б. Каршигина¹, Е. Г. Бочевская¹, З. С. Абишева^{1,2}, Ата Акчил³,
С. М. Кан⁴, М. К. Абсаметов⁴, С. В. Берстенов⁴**

¹Металлургия және кен байыту институты, Алматы, Қазақстан,

²К. И. Сәтпаев атындағы Қазақ ғылым-зерттеу университеті, Алматы, Қазақстан,

³Сулейман Демирел Университеті, Испарта, Турция,

⁴У. М. Ахмедсафина атындағы гидрогеология және геоэкология институты, Алматы, Қазақстан

ҚАЗАҚСТАННЫҢ ГИДРОМИНЕРАЛДЫ ЛИТИЙЛЫ ШИКІЗАТЫН СОРБЦИЯЛЫҚ ТӘСІЛДЕРІМЕН ҚАЙТА ӨНДЕУІ

Аннотация. Қазіргі әлемдегі жоғары технологиялар литий (Li) басты компоненті болып табылады. Оның өндірісі үшін Қазақстан қажетті әлеуетке ие. Литийді алу үшін ең тартымды шикізатары табиғи тұзды ертітінділер және тұзды көлдер рапы болып табылады. Құрамында литийі бар гидроминералды шикізатын қайта өңдеу саласында, үйлестіру кеңесінің шешімі мақсатында, жаңа технологиялық шешімдерді тарту, зерттеу және іздеу маңызды және өзекті ғылыми-техникалық міндет болып табылады. Мақалада органикалық шайырлармен және органикалық емес сорбенттермен литий сорбциясының әдеби деректер бойынша талдаулар жүргізілді. Әдетте, литийді сорбциялау үшін көбінесе катионоалмастырғыш шайырлары, протонды сияқты, сондай-ақ натрий нысандарында пайдаланылады. Олардың қатарына кіреді таралған катионит КУ-2-8 немесе оның аналогтары. Зерттеуде бейорганикалық сорбенттер қатарындағы, құрамында литийі бар ертітінділерден литийді сорбциямен алуы бойынша, көбінесе марганец, титан және алюминий қосылыстар негізінде пайдаланылады. Табиғи тұзды ертітінділерден біз литийді алу үшін, статикалық жағдайда, сорбциямен ионалмастырғыш шайырларды: КУ-2-8, C100 Purolite, Purolite C160S, Purolite S940, Amberlite IR 120, CYBBER CRX 210 және CYBBER CRX 300 қолдана отырып, жүргізілді. Көрсетілгендей, бұл литий, іс жүзінде ионитерге отырмайды. Шамалы литийді сульфокатионитте КУ-2-8 алуы, бар болғаны 0,49 % құрайды. Табиғи тұзды ертітінділерді қайта өңдеу бойынша, бейорганикалық сорбенттерді (коммерциялық реагенттер түрінде): алюминий гидроксидін, титан оксиді мен марганецті және белсендірілген көмірді қолдана отырып зерттеулер орындалды. Сонымен қатар, осындай бейорганикалық сорбенттер: алюминий гидроксиді, гидратталған титан оксиді және марганец синтезделген. Аса жоғары көрсеткіштер – коммерциялық реагент, алюминий гидроксидін сорбент ретінде пайдаланған кезде орын алуы анықталды, бұл ретте литийді алу 21,87 % құрады, сондай-ақ синтезделген сорбентте – гидратталған марганец оксиді, Li алу 20,11 % құрады. Тұзды ертітінділерден литийді алу үшін, сорбенттер ретінде алюминий және/немесе марганец пайдалана отырып, бейорганикалық сорбенттермен, сорбция тәсілі таңдалды.

Түйін сөздер: литий, табиғи тұзды ертітінділер, сорбция, ионалмастырғыш шайыр, бейорганикалық сорбенттер, синтез, алу.

**З. Б. Каршигина¹, Е. Г. Бочевская¹, З. С. Абишева^{1,2}, Ата Акчил³,
С. М. Кан⁴, М. К. Абсаметов⁴, С. В. Берстенов⁴**

¹Институт металлургии и обогащения, Алматы, Казахстан,

²Казахский научно-исследовательский университет им. К. И. Сатпаева, Алматы, Казахстан,

³Университет Сулеймана Демиреля, Испарта, Турция,

⁴Институт гидрогеологии и геоэкологии им. У. М. Ахмедсафина, Алматы, Казахстан

СОРБЦИОННЫЕ СПОСОБЫ ПЕРЕРАБОТКИ ГИДРОМИНЕРАЛЬНОГО ЛИТИЕВОГО СЫРЬЯ КАЗАХСТАНА

Аннотация. В современном мире высоких технологий литий (Li) является ключевым компонентом. Казахстан обладает необходимым потенциалом для его производства. Наиболее привлекательным сырьем для извлечения лития являются природные рассолы и рапы соляных озер. Исследование и поиск новых технологических решений с целью вовлечения в сферу переработки литийсодержащего гидроминерального сырья является важной и актуальной научно-технической задачей. В статье проведен анализ литературных данных по сорбции лития органическими смолами и неорганическими сорбентами. Как правило, для сорбции лития используются по большей части катионообменные смолы как в протонированной, так и натриевой формах. В их число входит распространенный катионит КУ-2-8 или его аналоги. В исследованиях по сорбционному извлечению лития из литийсодержащих растворов из числа неорганических сорбентов преимущественно используются соединения на основе марганца, титана и алюминия. Нами для извлечения лития из

природных рассолов в статических условиях проведена сорбция с применением ионообменных смол: КУ-2-8, Purolite C100, Purolite C160S, Purolite S940, Amberlite IR 120, CYBBER CRX 210 и CYBBER CRX 300. Показано, что литий практически не сорбируется на ионитах. Незначительное извлечение лития имеет место на сульфокатионите КУ-2-8 и составляет 0,49 %. Выполнены исследования по переработке природных рассолов с применением неорганических сорбентов (в виде коммерческих реагентов): гидроксида алюминия, оксидов титана и марганца, и активированного угля. Кроме того, синтезированы такие неорганические сорбенты как гидроксид алюминия, гидратированные оксиды титана и марганца. Установлено, что наиболее высокие показатели имели место при использовании в качестве сорбента – коммерческого реагента гидроксида алюминия, при этом извлечение лития составило 21,87 %, а также на синтезированном сорбенте – гидратированном оксиде марганца, где извлечение Li достигло 20,11 %. Для извлечения лития из рассолов выбран способ сорбции неорганическими сорбентами с использованием в качестве сорбентов соединений алюминия и/или марганца.

Ключевые слова: литий, природные рассолы, сорбция, ионообменные смолы, неорганические сорбенты, синтез, извлечение.

Information about authors:

Karshigina Zauze Baytasovna, PhD, Leading Researcher, Institute of metallurgy and ore beneficiation, Almaty, Kazakhstan; zauze_karshiga@mail.ru; <http://orcid.org/0000-0002-3025-7363>

Bochevskaya Elena Gennadiyevna, Candidate of Technical Sciences, Associate Professor, Head of the Laboratory of Rare Scattered Metals, Institute of metallurgy and ore beneficiation, Almaty, Kazakhstan; elena_bochevskaya@mail.ru; <http://orcid.org/0000-0001-5413-6446>

Abisheva Zinsh Sadyrovna, D. Scs. (Engineering), Professor, Academician of the National academy of sciences of Kazakhstan, Institute of metallurgy and Ore Beneficiation, Almaty, Kazakhstan; Chief Researcher; Director of Mining and metallurgical institute of K. I. Satpayev's Kazakh National research technical university, Almaty, Kazakhstan; abisheva_z@mail.ru; <http://orcid.org/0000-0002-4506-0694>

Akcil Ata Utku, PhD, full-professor in the Suleyman Demirel University, Head of the MMR&R Research Group, Engineering Faculty, SDU, Isparta, Turkey; ataakcil@sdu.edu.tr; <https://orcid.org/0000-0002-9991-0543>

Kan Sergey Mikhailovich, Candidate of Geological and Mineralogical Sciences, Head of industrial and geothermal waters laboratory, U. M. Akhmedsavin Institute of hydrogeology and geoecology, Almaty, Kazakhstan; kan-s58@mail.ru; <http://orcid.org/0000-0002-2182-0695>

Absametov Malis Kudysovich, Doctor of Geological and Mineralogical Sciences, Professor, Corresponding member of NAS RK, Director of the U. M. Akhmedsavin Institute of hydrogeology and geoecology, Almaty, Kazakhstan; mabsametov@mail.ru; <http://orcid.org/0000-0003-2520-6294>

Berstenev Sergey Vladimirovich, Leading Chemical Engineer, U. M. Akhmedsavin Institute of hydrogeology and geoecology, Almaty, Kazakhstan; sberstenyov@mail.ru; <http://orcid.org/0000-0003-3488-2761>

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**M. Kalimoldayev¹, S. Tynymbayev¹, S. Gnatyuk²,
S. Khokhlov³, M. Magzom¹, Y. Kozhagulov³**

¹Institute of Information and computational technologies, Almaty, Kazakhstan,²National aviation university, Kyiv, Ukraine,³al-Farabi Kazakh national university, Almaty, Kazakhstan.

E-mail: mnk@ipic.kz, s.tynym@mail.ru, s.gnatyuk@nau.edu.ua,

skhokh88@gmail.com, magzomxzn@gmail.com, kazgu.kz@gmail.com

MATRIX MULTIPLIER OF POLYNOMIALS MODULO ANALYSIS STARTING WITH THE LOWER ORDER DIGITS OF THE MULTIPLIER

Abstract. The advantage of an unconventional data encryption system using non-positional polynomial number systems (NPNS), known as polynomial residue number system, is considered. When hardware and software-hardware implementations of cryptosystems based on the NPNS, circuit solutions are needed multipliers of polynomials modulo an irreducible polynomial. In this paper, we present the design of matrix multiplier of polynomials modulo irreducible polynomial. The correct operation of the proposed multiplier is verified by implementing it on the FPGA of the company Xilinx of model Artix 7. In conclusion, a comparative analysis of the matrix multipliers considered is given in terms of time parameters and hardware costs for their implementation.

Keywords: non-positional polynomial number system, partial residual formers, modulo two.

Introduction. The development of information and communication systems increases the need to ensure data protection. At the same time, due to the specifics of the application, restrictions on physical size and power consumption, individual devices have small computational resources [1]. For devices with limited resources, standard cryptographic algorithms may be too complex, too slow, or too energy intensive. The issues of creating and applying methods to improve the efficiency of cryptosystems with hardware implementation remain relevant [2, 3].

Searching for ways to improve the efficiency of software and hardware calculations, methods for detecting and correcting errors and creating highly reliable computer systems, research is being carried out in the field of non-positional notation systems, such as the residual number system (RNS). In the classical positional number system, the value of each digit in the designation of a number depends on its position. In non-positional numeration systems, a large-digit integer in positional notation is represented as a sequence of several positional numbers of small bitness. These numbers are the residues of dividing the original number by moduli of RNS.

The basis for creating the proposed models of cryptosystems [4-9] are non-traditional encryption systems and digital signatures. These systems are developed on the basis of an algebraic approach using non-positional polynomial number systems (NPNS), known as polynomial RNS.

Improving the efficiency of the hardware implementation of these systems is provided by the rules of the NPNS, in which all arithmetic operations can be performed in parallel using the base modules of the NPNS. The features of the NPNS give significant advantages over the positional number system when performing modular operations of addition, subtraction and multiplication. This is especially true if large-digit numbers act as operands [10].

In non-positional cryptosystems, the cryptographic strength of the encryption algorithms and digital signature generation, which is characterized by a complete secret key, is used as a criterion for cryptographic strength. This key depends not only on its length, but also on the selected system of the polynomial bases of the NPNS, as well as on the number of all possible permutations of the bases in the system.

With increasing order of irreducible polynomials with binary coefficients, their number is rapidly growing. In this regard, a wide choice of polynomial bases is possible.

In [4], arithmetic of non-positional number systems with polynomial bases and its applications to problems of increasing reliability were developed. It is shown that the algebra of polynomials over a field modulo an irreducible polynomial over this field is a field and the representation of a polynomial in non-positional form is the only one (an analogue of the Chinese remainder theorem for polynomials). The rules for performing arithmetic operations in the NPNS and restoring a polynomial from its residues are also defined.

The implementation of cryptosystems based on the NPNS can be implemented in software, hardware or software-hardware methods. The main advantage of the software implementation is their flexibility, which makes it possible to quickly rebuild cryptoalgorithms, the main disadvantage is a significantly lower speed compared to the hardware implementation. Software and hardware implementation of cryptosystems combines the advantages of software and hardware implementation. With hardware and software-hardware implementations of cryptosystems based on the NPNS, the central unit is the multipliers of polynomials modulo an irreducible polynomial, where repeated routine calculations are performed on encryption and decryption of data. Therefore, the development of devices for multiplying polynomials modulo an irreducible polynomial is relevant. In such multipliers, the multiplier is full $A(x)$, having degree m , the binary image of which is part of the plaintext, the multiplier is polynomial $B(x)$, having degree m , which is the key for encrypting the polynomial $A(X)$. The module is an irreducible polynomial $P(x)$, which is randomly selected from the set of irreducible polynomials with degree m . After multiplying modulo polynomials, we obtain the polynomial $R(x)$ which is part of the ciphertext.

When decrypted, the polynomial of the ciphertext $R(x)$ acts as a multiplicand, and the multiplier is the reverse key $B^{-1}(x)$. After multiplying $R(x)$ by $B^{-1}(x)$ modulo $P(x)$, we get a part of the plaintext - the polynomial $A(x)$.

There are two ways to multiply polynomials modulo an irreducible polynomial. In the first method of multiplying polynomials, multiplication begins with an analysis of the higher order of the multiplier. At the same time, in each multiplication step, the next partial remainder is shifted one digit to the left. And in the second method, multiplication begins with an analysis of the lower order of the multiplier with a shift of the next partial remainder by one digit towards the older one.

The matrix multiplier of polynomials modulo an irreducible polynomial, where multiplication begins with an analysis of the higher order of the multiplier was considered in [11].

The matrix multiplier scheme of polynomials modulo an irreducible polynomial, where multiplication begins with an analysis of the lower order bits of the multiplier. In the matrix multiplier of polynomials modulo is performed in $N-1$ stages according to the number of digits of the multiplier. Each stage consists of three sub-steps. In the first sub-step, the partial remainder r_i is calculated by modifying twice the previous partial residual $2r_i$ modulo, i.e. $r_i = 2r_{i-1} \bmod P$. In the second sub-step, the partial residues r_i logical are multiplied by the corresponding bits of the b_i of the multiplier, starting with the lower order digit. In the third sub-step, an intermediate residue R_i is formed by modifying the sum $(r_i * b_i) + R_{i-1}$ modulo.

Figure 1 shows a block diagram of the matrix multiplier of polynomials modulo an irreducible polynomial, where multiplication begins with the analysis of the lower digits of the polynomial multiplier with a shift of partial residues by one bit in the direction of the higher digit. The multiplier consists of four blocks: 1 - the block is a block of registers, which includes the register of the module $P(x)$ and the register of the multiplier $B(x)$, the block of the PRS_2 ($PRS_1 \div PRS_{N-1}$), block of circuits AND 3 ($AND_1 \div AND_{N-1}$), block of adders modulo two ($MA_{21} \div MA_{2N-1}$), delay lines 5.

Consider the operation of the device. The signal "START", which is fed into the circuit through input 6 to the register $Pr P(x)$ from input 7, the binary coefficients of the polynomial $P(x)$ are received - the module, and to the register $Pr B(x)$ from input 9, the binary coefficients of the polynomial $B(x)$ is a multiplier. Binary coefficients of the irreducible polynomial $P(x)$ - module from the outputs of the register $P(x)$ are fed to the first inputs of the formers $PRS_1 \div PRS_{N-1}$. The multiplicand $A(x)$ (input 8) with a shift

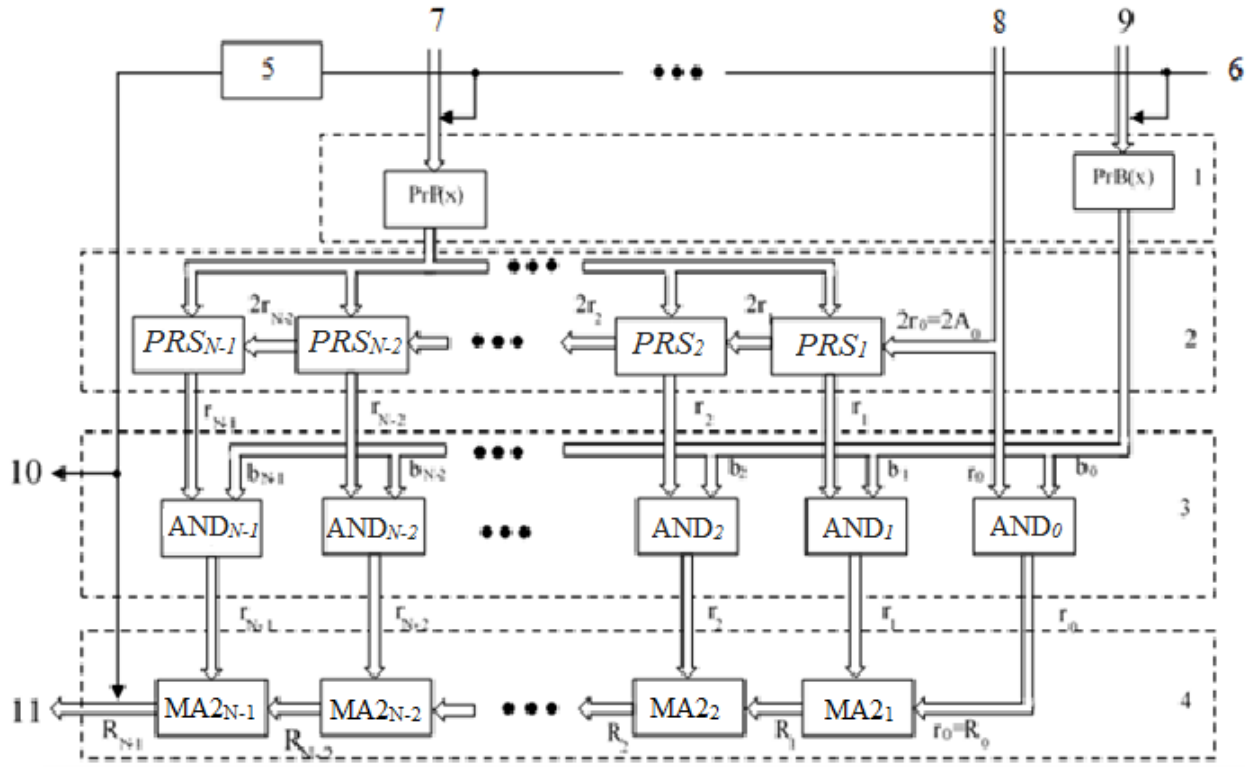


Figure 1 – Block diagram of the matrix multiplier of polynomials modulo an irreducible polynomial, where multiplication begins with the analysis of the lower order of the polynomial – multiplier

by one bit in the direction of the higher discharge, i.e. $2 * A(x) = 2 * r_0$ is fed to the second inputs PRS_i and without shift is transmitted to the information inputs of the AND_0 circuit, the value of the b_0 bit is fed to its control input from the output of the $B(x)$ register. At the outputs of PRS_i , a partial residual $r_1 = 2 * r_0 \bmod P(x)$ is formed, which is fed with a shift by one bit to the second input of the PRS_2 and without a shift is transmitted to the information inputs of the AND_1 circuit, to the control input of which the bit b_1 value is fed from $Pr B(x)$. When $b_1 = 1$, the value of r_1 from the output of AND_1 is transmitted to the first inputs of the adder modulo two $MA2_1$, and the second information inputs of which are fed the value $r_0 = R_0 = A(x)$ and the intermediate balance is formed at the output of the $MA2_1$ by calculating $R_1 = r_1 \oplus r_0$, which is transmitted to the second inputs of the $MA2_2$. The PRS_2 having received the value $2 * r_1$ from the output of the PRS_1 at its output forms a partial residual r_2 , which with a shift of one digit to the left is transmitted to the input of the PRS_3 and without a shift to the information inputs of the AND_2 circuit. To the control input of which is fed bit b_2 from the register $B(x)$. When $b_2 = 1$, the value of r_2 is transmitted to the information inputs of the $MA2_2$, the other information input is supplied with the value R_1 from the outputs of the $MA2_1$ and forms the intermediate remainder R_2 , which is transmitted to the information inputs of the $MA2_3$.

Further, partial residues $r_3, r_4, \dots, r_{N-1}$ and intermediate residues $R_3, R_4, \dots, R_{N-1}$ are formed in the same way. After the formation of the intermediate residue R_{N-1} , the information output $MA2_{N-1}$ forms the result, which by the signal 10 (“end of operation”) outputs it through the output of the device 11.

Figure 2 shows the block diagram of the PRS_i , which consists of a modulo-two adder and an MS multiplexer. The multiplexer, in turn, consists of AND_1, AND_2 schemes and OR scheme. The first partial adder r_{i-1} is fed to the first inputs of the adder with a shift by one bit in the direction of the higher digit, which is equivalent to multiplying r_{i-1} by two. In addition, the value of $2 * r_{i-1}$ is also fed to the information inputs of the AND_1 circuits. The information inputs of the U_2 scheme are fed with the result of the addition of $2 * r_{i-1} \oplus P(x)$. Switching of values $2 * r_{i-1}$ from input AND_1 or AND_2 depends on the values of the most significant digit (S_r) of the value of doubled partial residue $2 * r_{i-1}$. At $S_r=1$, the output of the MS circuit through the AND_2 and OR circuits is the result of the sum modulo two result ($2 * r_{i-1} \oplus P(x)$),

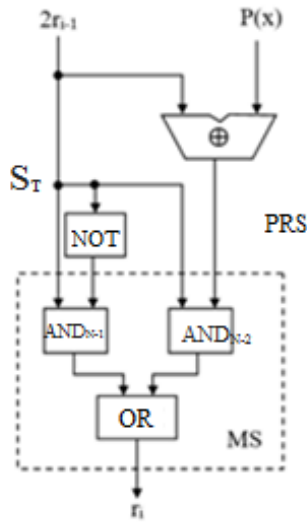


Figure 2 –
The structure of the partial residual shaper

and at $S_T=0$, this signal passing through the inverter is NOT fed to input circuit AND_1 , allowing the passage of the values $2 * r_{i-1}$ to the output MS. Thus, for values of $2 * r_{i-1} < P(x)$ (while $S_T=0$), the output of the PRS circuit produces the value $r_i = 2 * r_{i-1}$, and for values of $2 * r_{i-1} > P(x)$ (at that $S_T=1$) at the output PRS_{N-1} the value $r_i = 2 * r_{i-1} \oplus P(x)$ is shaped.

The $MA2_i$ is an modulo-two n-bit adder, where the operation $R_i = r_i + R_{i-1}$ is performed.

Consider the work of the multiplier on a specific example.

Let $P(x) = x^5 + x^3 + 1$, the binary image of $P(x)$: 101001;

$A(x) = x^4 + x + 1$, binary image $A(x)$: 10011;

$B(x) = x^4 + x^2 + x + 1$, binary image $B(x)$: 10111.

The order of calculation of $R = [A(x) * B(x)] \bmod P(x)$ is given in table.

To implement the above example on programmable logic integrated circuits (FPGA), consider the logical chain of operations performed. The binary image values of the polynomials $A(x)$ and $B(x)$ are fed to the input of the programmable logic integrated circuit. At the output of $MA2_{n-1}$, the result of the multiplication $R=[A(x)*B(x)] \bmod (P(x))$ is formed. The current values of $R_1, R_2 \dots R_{n-2}$ is formed at the outputs of the corresponding adder circuits modulo $MA2_1, MA2_2 \dots MA2_{n-2}$. The first step is set separately, according to the description of the zero stage from Table 1, where r_0 takes the values of the input signal A , also in the $MA2_i$ block, the first value R_0 is equal to r_0 . From the next step, system operations are performed according to the above description, using the modulo multiplier operator. To check the correctness of the proposed algorithm on the integrated circuit, a time diagram was built on the FPGA of the Artix 7 model shown in Figure 3. On the time diagram (figure 3), one can observe the results of the calculation on each clock signal whose numerical values correspond to the values shown in Table 1. The program is written in the Verilog language, consisting of a procedural block, a register (data type) of calculation parameters, a ternary operator, a shift operator, and a continuous assignment operator [12-14].

The number of used FPGA resources of the Artix 7 model does not exceed 1%: the number of registers is 44 out of 126,800, the number of logical cells is 82 out of 63 400. The results obtained confirm the correctness of the proposed algorithm and the proposed theory on the FPGA.

In conclusion, a comparative analysis of the algorithm with a matrix multiplier with the results of [11] was carried out. The comparison is carried out according to the time of multiplication – T_{mult} and the hardware cost Q_{mult} required to build them.

From figure 1, it is easy to determine the components of the circuit from the total delays at which the multiplication time can be determined: $PRS_1 \chi PRS_{N-1} - AND \ AND_{N-1} - MA_{N-1}$. Then the multiplication time can be determined by the following relationship:

$$T_{mult}^{SM} = N - 1 (T_{PRS}) + T_{AND} + T_{MA2} \quad (1)$$

where T_{PRS} is the amount of delay on one partial residual shaper; T_{MA2} – delay time on the adder modulo two; T_{AND} is the delay time in the circuit AND_{N-1} .

Order of calculation of R

Stages	$PRS_i(r_i)$	$b_i * r_i$	$MA2_i(R_i)$
0	$r_0 = 10011$	$b_0 * r_0 = 10011$	$R_0 = r_0 = 10011$
1	$r_1 = 2 r_0 \bmod P(x)$ $2r_0 = 100110$ $\oplus$ $P(x) = 101001$ $r_1 = 001111$	$b_1 * r_1 = 01111$	$R_1 = r_1 \oplus R_0$ $R_0 = 10011$ $\oplus$ $r_1 = 01111$ $R_1 = 11100$
2	$r_2 = 2 r_1 \bmod P(x)$ $2r_1 = 011110$ $\oplus$ $P(x) = 101001$ $r_2 = 011110$	$b_2 * r_2 = 011110$	$R_2 = r_2 \oplus R_1$ $R_1 = 11100$ $\oplus$ $r_2 = 011110$ $R_2 = 00010$
3	$r_3 = 2 r_2 \bmod P(x)$ $2r_2 = 111100$ $\oplus$ $P(x) = 101001$ $r_3 = 010101$	$b_3 * r_2 = 0$	$R_3 = R_2 = 00010$
4	$r_4 = 2 r_3 \bmod P(x)$ $2r_3 = 101010$ $\oplus$ $P(x) = 101001$ $r_4 = 000011$	$b_4 * r_4 = 00011$	$R_4 = r_4 \oplus R_3$ 00011 $\oplus$ 00010 $R = R_4 = 00001$

Check: $(x^4 + x + 1)(x^4 + x^2 + x + 1) = x^8 + x^6 + x^3 + 1$

$$\begin{array}{r}
 x^8 + x^6 + x^3 + 1 \\
 \oplus \\
 x^8 + x^6 + x^3 \\
 \hline
 00001
 \end{array}
 \quad
 \begin{array}{r}
 x^5 + x^3 + 1 \\
 \hline
 x^3
 \end{array}$$

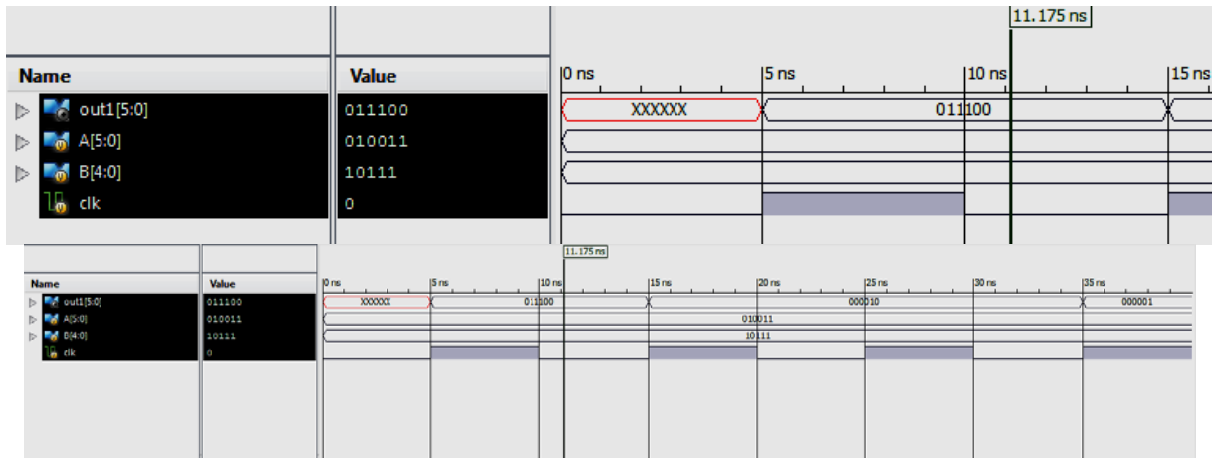


Figure 3 – Timing coding diagram for a 5-bit binary information message in an Artix 7 FPGA

From figure 1, it is also not difficult to determine the ratios, with which you can calculate the hardware cost of the multiplier:

$$Q_{mult}^{SM} = N \cdot I(Q_{PRS} + Q_{MA2}) + N Q_{AND} \quad (2)$$

where Q_{PRS} - the cost of logic circuits for building one partial residual shaper; Q_{MA2} - the cost of logic circuits for building one adder modulo two; $N Q_{AND}$ - the cost of N logic circuits I.

From the matrix multiplier scheme of polynomials modulo an irreducible polynomial, where multiplication begins with an analysis of the most significant bits [10], it is possible to determine the route of the input signal, which determines the maximum delay, i.e. multiplication time of polynomials, where multiplication begins with the analysis of the most significant digit: $AND_0 - MA2_1 - PRS_1 - MA2_2 - PRS_2 \chi MA2_{N-2} - PRS_{N-2} - MA2_{N-1} - PRS_{N-1}$

then:

$$T_{mult}^{BG} = T_{AND} + N-1(T_{MA2} + T_{PRS}) \quad (3)$$

The magnitude of the hardware costs can be determined from the following relationship:

$$Q_{mult}^{BG} = NQ_{AND} + N-1(Q_{MA2} + Q_{PRS}) \quad (4)$$

From relations (2) and (4) it can be seen that the considered matrix multipliers are equal in hardware costs, i.e. $Q_{mult}^{SM} = Q_{mult}^{BG}$ and they differ in speed.

Let us consider in more detail the components of formulas (1) and (2). From figure 2 that

$$T_{PRS} = T_{MA2} + T_{MS}; \text{ in turn, } T_{MA2} = 3 T_{L3} \text{ and } T_{MS} = 2 T_{L3};$$

where, T_{L3} - the delay time on the logical elements AND-NOT, OR-NOT

$$\text{Then } T_{mult}^{SM} = N-1 (3 T_{LE} + 2 T_{LE}) + T_{LE} + 3 T_{LE} = N-1 (5 T_{LE}) + 4 T_{LE} = N 5 T_{LE} - 5 T_{LE} + 4 T_{LE}$$

$$T_{mult}^{SM} \approx N 5 T_{LE}. \quad (5)$$

$$T_{mult}^{BG} = N-1 (8 T_{LE}) + T_{LE} \approx N 7 T_{LE}. \quad (6)$$

From the relation (5) and (6) it is seen that with the same hardware costs of the matrix multiplier polynomials modulo an irreducible polynomial, where multiplication begins with the lower order of the multiplier has a significant advantage in speed.

**М. Н. Калимолдаев¹, С. Т. Тынымбаев¹, С. Гнатюк²,
С. А. Хохлов³, М. М. Мағзом¹, Е. Т. Кожагулов³**

¹Ақпараттық және есептеуіш технологиялар институты, Алматы, Қазақстан,

²Ұлттық авиациялық университеті, Киев, Украина,

³фль-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан

КӨБЕЙТКІШТІҢ КІШІ РАЗРЯДЫНАН БАСТАП ТАЛДАЙТЫН МОДУЛІ БОЙЫНША ПОЛИНОМДАРДЫҢ МАТРИЦАЛЫҚ КӨБЕЙТКІШІ

Аннотация. Қалдықты кластың полиномдық жүйесі ретінде белгілі, есептеудің бейпозициялық полиномдық жүйесін (ЕБПЖ) пайдалану арқылы мәліметтерді шифрлаудың дәстүрлі емес жүйесінің артықшылықтары қарастырылды. ЕБПЖ негізінде криптожүйенің аппараттық және бағдарламалық-аппараттық іске асырылуы кезінде келтірілмейтін полиномның модулі бойынша полиномдардың көбейткіштерінің сұлбалық шешімі қажет. Осы жұмыста мәліметтерді шифрлап және шифрын ашып оқуға мүмкіндік беретін, модулі бойынша полиномдар көбейткішінің матрицалық сұлбасы келтірілген. Ұсынылған көбейткіштің жұмыс істеуінің дұрыстығы Xilinx фирмасының Artix 7 моделі негізіндегі бағдарламаланатын логикалық интегралдық сұлбасында (БЛИС) жүзеге асыру арқылы тексерілді. Қорытындысында қарастырылған матрицалық көбейткіштердің жүзеге асырылуы үшін қажетті аппараттық шығыны және уақыттық параметрлеріне байланысты салыстырмалы талдау келтірілген.

Түйін сөздер: есептеудің бейпозициялық полиномдық жүйесі, жартылай қалдықтарды қалыптастырғыштар, модулі екі бойынша сумматор.

М. Н. Калимолдаев¹, С. Т. Тынымбаев¹, С. Гнатюк², С. А. Хохлов³, М. М. Мағзом¹, Е. Т. Кожугулов³

¹Институт информационных и вычислительных технологий, Алматы, Казахстан,

²Национальный авиационный университет, Киев, Украина,

³Казахский национальный университет им. аль-Фараби, Алматы, Казахстан

МАТРИЧНЫЙ УМНОЖИТЕЛЬ ПОЛИНОМОВ ПО МОДУЛЮ С АНАЛИЗОМ НАЧИНАЯ С МЛАДШИХ РАЗРЯДОВ МНОЖИТЕЛЯ

Аннотация. Рассматривается преимущество нетрадиционной системы шифрования данных с использованием непозиционных полиномиальных систем счисления (НПСС), известный как полиномиальные системы остаточных классов. При аппаратной и программно-аппаратной реализаций криптосистем на базе НПСС необходимы схемные решения умножители полиномов по модулю неприводимого полинома. В данной работе приводится матричная схема умножителя полиномов по модулю, которая позволяет шифровать и расшифровать данных. Правильность функционирования предложенного умножителя проверено путем реализации его на ПЛИС фирмы Xilinx модели Artix 7. В заключении дается сравнительный анализ рассмотренных матричных умножителей с точки зрения временных параметров и аппаратных затрат для их реализации.

Ключевые слова: непозиционная полиномиальная система счисления, формирователи частичных остатков, сумматор по модулю два.

Information about authors:

Kalimoldayev Maksat, Director general of Institute of Information and computational technologies, Doctor of sciences, professor, academician member of the National academy of science of the Republic of Kazakhstan, Almaty, Kazakhstan; mnk@ipic.kz; <https://orcid.org/0000-0003-0025-8880>

Tynymbayev Sakhybay, Chief researcher, Candidate of Technical Sciences, Institute of Information and computational technologies, Almaty, Kazakhstan; s.tynym@mail.ru; <https://orcid.org/0000-0002-9326-9476>

Gnatyuk Sergiy, Doctor of sciences, Associate Professor, Leading Researcher in Cybersecurity R&D Lab, Executive Secretary of Ukrainian Scientific Journal of Information Security, Scientific Adviser of Engineering Academy of Ukraine, IEEE Member, National aviation university, Kyiv, Ukraine; s.gnatyuk@nau.edu.ua; <https://orcid.org/0000-0003-4992-0564>

Khokhlov Serik, Lead researcher, PhD, Lecturer of Department of Physics and Technology, al-Farabi Kazakh national university, Almaty, Kazakhstan; skhokh88@gmail.com; <https://orcid.org/0000-0001-5163-508X>

Magzom Miras – Senior researcher, PhD, Institute of Information and computational technologies, Almaty, Kazakhstan; magzomxzn@gmail.com; <https://orcid.org/0000-0002-9380-1469>

Kozhagulov Yeldos, Lead researcher, PhD, Lecturer of Department of Physics and Technology, al-Farabi Kazakh national university, Almaty, Kazakhstan; kazgu.kz@gmail.com; <https://orcid.org/0000-0001-5714-832X>

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N. A. Amirgaliyev¹, A. S. Madibekov¹, I. Sh. Normatov²

¹Institute of Geography of the Ministry of Education and Science of the Republic of Kazakhstan,
Almaty, Kazakhstan,

²Academy of Sciences of the Republic of Tadzhikistan, Institute of the water problem,
Hydropower engineering and Ecology, Dushanbe, Tajikistan.

E-mail: namirgaliyev@mail.ru, madibekov@mail.ru, inomnor@gmail.com

**ABOUT THE CRITERIA OF ESTIMATION
OF SURFACE WATER QUALITY OF KAZAKHSTAN
ON THE BASIS OF ACCOUNTING OF ITS NATURAL FEATURES**

Abstract. A literature review of the evaluation issues of existed methods and standards regulating the surface waters quality from the scientific and applied points of view is given. The problem of an objective and reliable assessment of the level of influence of anthropogenic factors on the quality of water resources has special relevance in the countries of the Commonwealth of Independent States (CIS). According to the number of leading scientists, mainly from the Russian Federation (RF), one of the significant insufficiency in the assessing of surface waters quality is the applying of uniform values of maximum permissible concentration (MPC) MPC_{sh} and MPC_{fish} established for the entire territory of the former USSR without taking into account the specifics of regional natural conditions and characteristics of water bodies. Within the territory of Kazakhstan the distortion of the actual state of surface water quality is becoming due to the use of the natural concentrations of the main ions and heavy metals in the calculation of the complex water pollution index (CWPI) by the Kazhydromet and not taking into account the wide distribution in the water bodies with brackish waters and ore-bearing areas. The validity of these statements is confirmed by examples from official publications.

According to a common opinion of scientists, it is necessary to proceed the development of regional MPC because some methodological approaches have already appeared. It is recommended to develop a Temporary Methodological Guide for Surface Water Quality Assessment (prior to the establishment of regional water quality indicators) in Kazakhstan, excluding the main water ions from the calculated CWPI indicators, because they are not pollutants but natural components of the water composition.

Key words: surface water quality assessment, standards, regional MPC indicators.

Introduction. Water shortages have long become an acute global problem especially in arid low-water areas. It is no coincidence that in the last century 1981-1990 was proclaimed a decade of drinking water by the United Nations with the slogan "Pure water and acceptable sanitation for all". Considering the further aggravation of water problems in the world the UN proclaimed 2005-2015 as the international decade of action "Water for Life". UN Secretary-General Ban Ki-moon, in his Message on the occasion of World Water Day, noted that water is the key to sustainable development. He also announced the current assessment that by 2030 almost half of the world's population could face water shortages when demand exceeds supply by 40%. The International Year of Cooperation on Water Resources (2013) and World Water Day (22 March) are dedicated to enhancing cooperation and building partnerships at local, national and transboundary levels, to address freshwater issues.

The problem of water is actual in Kazakhstan. Although on its territory there are about 40 thousand rivers, 41 thousand lakes, 210 reservoirs in which about 100 km³ of water are concentrated, and the total surface water resources in the country are 91,3 km³ per year. According to data [1-3], due to economic activities, resources of the river flow of the Republic of Kazakhstan decreased by 23,8 km³/year (by 21%), including transboundary flow - by 15,9 km³/year (by 26%), local runoff - at 7.9 km³/year.

The president of Kazakhstan N.A. Nazarbayev has big concern regarding the water supply problem in Kazakhstan. In his Address, he stressed that by 2050 year Kazakhstan should once and for all solve the water supply problem. Among the ten main challenges of the 21st century, allocated to them for our country, the problem of water shortage is included. He committed to the Government to develop a new water resources policy of the country, study the international best practices in solving water supply problems and change society's way of thinking in the issues of economical usage of water. He also pointed out the need of developing a long-term state program on water in order to solve the problem of providing the drinking water to population by 2020 and irrigation problem by 2040.

The problem of clean water has now become so urgent in many countries that it has already become global and many experts call it "problem number one" for any industrially developed country including ours. Thus, the problem of water can be solved only if its normative quality is ensured.

The toxicological situation is a very tense in the republic. According to available information, improvement of the ecological state of the republic's water bodies should not be expected in the coming years. The revival of industry and agriculture will lead to further intensification of anthropogenic pollution of water bodies. The number of new generation pesticides used in agriculture is increasing year by year. Their impact on the environment remains outside of environmental authority's control.

The continuing anthropogenic pollution of the republic's water basins, both as a transboundary runoff and as a result of the dumping of industrial, agricultural and domestic wastewater in the territory of the republic become the particular concern. Air emissions from industrial and municipal enterprises are also significant sources of pollution not only in the land area, but also in water bodies. All this causes damage to the ecology and economy of Kazakhstan.

Hence, the level of influence of diverse anthropogenic factors on the quality of environment, including water resources, should be assessed objectively and reliably on the basis of perfect methods and criteria developed in accordance with the specific of climatic and other conditions of operating of the country's water bodies. This problem has now become particularly relevant, especially in the CIS countries, due to the fact that on their territory the criterion and standards for assessing the quality of surface waters, developed in the period of the USSR, are used up to now.

The purpose of this work is to show the imperfection of the existed methods for assessing the quality of surface waters in terms of their adaptation to regional conditions and the unreasonableness of the results obtained when using them on the basis of a brief literature review and some results of our own research. The other purpose is to draw the attention of scientists and specialists in the field of control and protection of water resources to the emerging new scientific results in the field of theory and practical approaches to optimize methods for rationing and assessing the quality of surface waters.

Review of scientific literature. According to [4] the control over the content of chemicals in the environment started in 1925 when the first values of the MPC for the air environment of the working area were determined. In 1949 for the first time, some MPCs were set for atmospheric air, and in 1950 for water [4]. I.V. Lukyanenko [5] considers the current understanding of the fishery MPCs and the first-time MPCs for fishery water bodies formed in the 1950s which becomes significant practical achievement of fishery toxicology. They, as it known, were formally approved in 1961 in the "Rules for the protection of surface waters from pollution by sewage".

Currently, the regulation of chemical pollution entry to the surface waters is carried out by two MPC systems: sanitary and hygienic ($MPC_{s.h.}$ - standards for water bodies for domestic and drinking and cultural and public water usage) and fishery (MPC_{fish}) - standards for fishery water reservoirs for the same substances. For a long time these complex experimental works are conducted by medical scientists and biologists disconnected.

According to [6, 7], in the middle 1970s there was an attempt to unify the two active MPC systems, but the opinion of the researchers was divided. Some scientists appeal for merging of two existing MPC systems into one universal one, while others considered it advisable, along with the existing ones, to create another third MPC system aimed at protecting the ecosystems of the reservoir as a whole. It was about the "environmental MPC", i.e. normalization of foreign substances in order to ensure the ecological well-being of the reservoir [8] or, in other words, the "ecological" regulation of pollution or the "environmentally" neutral concentration of pollutants.

That is why there was a need to formulate the problem of ecological water quality criteria and to justify a new view of environmental MPC as the maximum permissible variability of abiotic factors in the aquatic environment [7,9]. This source also emphasizes that the idea of a physiological norm and physiological and biological indicators of the status of hydrobionts, the threshold and critical levels of a particular factor, is highly important during the developing of environmental MPC. Only experiment can evaluate the toxicity of a particular substance or group of substances for fish and other hydrobionts, establish the dependence of the degree of toxicity on concentration and time of action on hydrobionts, establish threshold and maximum permissible concentrations and regulate the supply of these substances to the reservoir. It is impossible to establish the maximum permissible concentration limit for the results of environmental-toxicological studies directly on fishery reservoirs or experimental reservoirs, without taking into account the whole variety of emerging chain changes.

Officially, the current MPC, as a criterion for assessing the degree of contamination of surface waters, is officially defined on the basis of sanitary rules and norms (SanPiN), part "Protection of surface waters from pollution; No. 4630-88, approved in 1988 by the Ministry of Health of the USSR ". They also valid in the territory of the Republic of Kazakhstan in accordance with the order of the head of the Department of sanitary and epidemiological service of the ministry of Health of the Republic of Kazakhstan No. 408 of August 18, 1997. At the same time, there is also a List of MPC_{fish} for water in fishery reservoirs [10].

Both, the sanitary and hygienic rationing system with the use of MPC_{s,h} and the system of fisheries management MPC_{fish}, have for a long time been subjected to justified and fair criticism. In general, similar remarks are stated in the works [11-15] and indicate that the level of accumulation in the reservoir of the substance and products of its biotransformation along the trophic chain, the processes of accumulation of substances in biological objects and bottom sediments is often not taken into account during the establishing process of MPC, t.e. the concentration of substances in the water does not reflect the toxicological load on the ecosystem of the reservoir. The necessity of taking into account the effect on hydrobionts, both the starting compounds and the products of their transformation, is confirmed on the basis of experiments [14], which showed that the interaction of malathion and each of its two hydrolyses was more additive.

According to [16], the existing MPC, especially for sanitary purposes, contain insufficient environmental information. The need to pay special attention to the issue of migration of chemicals on the trophic chains of the aquatic ecosystem and the role of aquatic organisms in the process of self-purification of the reservoir and the formation of water quality was noted. This approach can exclude cases of "false self-purification", when there is no chemical substance in the water (or below the MPC), and a considerable amount of them has been accumulated in hydrobionts.

An analysis of the existing list of MPCs (roughly safe levels of exposure (RSLE)) has shown that more than half of the standardized substances refer to technical products, intermediate products, wastes from various industries, often of undefined composition, various liquid, semi-liquid mixtures that interact with water, connections, and it is practically impossible to verify the compliance of their concentration with the established standards [17]. Hence, the effectiveness of MPC application remains unknown.

The important question is also raised that the normalization of inorganic substances of natural components of the water composition in the MPC_{fish} was performed without taking into account the natural range of concentrations of these substances caused by biogeochemical and climatic factors. For example, the MPC of nitrates is more than 10 times greater than their maximum concentration in unpolluted water bodies and the maximum permissible concentrations of the main ions for low-mineralized water are several times higher while for mineralized waters of steppe and semi desert landscapes it is much lower than the natural concentrations of these ions.

According to [18] ecological water quality standards should be based on ecological criteria for assessing the functioning of aquatic ecosystems and, consequently, should be established on the basis of an analysis of the ecosystem response to external disturbances. As an example, there are significant differences between the content of mineral forms of nitrogen in natural waters, acceptable from hygienic and fishery positions, and those concentrations of these compounds in which "flowering" of water bodies is observed.

The paper [19] draws attention to the fact that the development of standards regulating of levels of water pollution (MPC, RSLE) and maximum permissible level (MPL) of food fish products does not take

into account the possibility of mutagenic and genotoxic action of pollutants and their derivatives. In this regard, the use of a set of simple and reliable methods for testing the genetic hazard of individual representatives of pollutants, their complex mixtures and metabolites in natural waters and fish tissues is recommended for the determination of MPC and MPL.

According to a number of researchers [20-22], the compliance of fishery MPC does not ensure a reduction in the negative impact of pollutants on water bodies and the conservation of natural aquatic ecosystems and the genetic fund of aquatic organisms. It is proposed to include in the normative document of biological indicators in terms of their informativeness and practical applicability, including characterizing the state of groups and communities of aquatic organisms with the identification of basic and additional normalized indicators, as well as methods for their determination for various types of water bodies.

A.G. Kocharyan and etc., in their work [23] formulated the main shortcomings of the water quality assessment system based on MPC, which are given in [24,25], as follows: the MPC ideology is based on the assessment of the effects of substances at the organism level, the transfer of the assessment to the population and ecosystem levels is incorrect. The MPC system does not take into account the entire set of factors acting on the ecosystem of synergism and antagonism of various substances. It does not allow to evaluate the effect of the duration of exposure of elevated and high concentrations of substances on the ecosystem of the reservoir. Many substances identified in wastewater do not have MPC. The MPC system is uniform for the entire territory of Russia, at the same time the vast majority of parameters characterizing both water quality and ecosystem functions have a clearly expressed zonal and regional character.

According to [9,23] the integral biological characteristics can serve as an indicator of the ecological well-being of the aquatic ecosystem – the Shannon biodiversity index and the Woodvissian biotic index, the values of which decrease with water pollution and eutrophication; and the oligochaete index, variability of biomass dynamics and productivity which are increase in the occurrence of mentioned situations. It is also noted that there are close correlation links between the hydrochemical and hydrobiological indicators under these conditions, which makes it possible to compose the regression equations estimating these relationships. The presence of linear relationship between hydrobiological and hydrochemical indicators was revealed by a number of researchers [26, 27]. The use of this approach allows to rank pollutants according to their impact on hydrobiological indicators.

Rumyantsev V.A. and Kryukov LN [28] consider that in order to identify the boundaries between the normal and regressive functioning of water bodies, it is advisable to take into account the possibility of changing from the MPC standards of toxic substances to ecologically permissible levels (EPL) of disturbing effects. The MPC standards are set without taking into account the fact that in natural ecosystems there are no isolated actions of many factors, each of which individually or collectively affects each biological characteristic. Ecological inefficiency of the MPC methodology is overcome in the framework of the biotic concept of environmental control. The work contains an important message that the relevant databases and information systems have been created in the Russian Federation also, methods for bioindication and identification of indices based on saprobity and species structure of hydrobiological communities are developing [29].

One of the important shortcomings of developing of sanitary-hygienic and fishery MPCs is not to take into account local, regional features, i.e. physical, chemical and biological parameters of local water bodies. It is known that these standards regulating water quality was developed in the USSR and recommended in the entire territory. According to the data of [30] a part of the list of substances included in the fishery MPCs was tested on the water of the Western European (Karelia, Baltic, Moscow region) and the East Siberian (Baikal) region of bionts. It was noted in [7] that a big part of work was done by the Leningrad laboratory, i.e. in the same Baltic region.

According to the authors of [31], the application of uniform values throughout the territory of the former USSR, without taking into account the local characteristics of water bodies, is the main shortcoming of the MPC concept. That study presents the results of experiments on the establishment of safe concentrations of a number of metals at various stages of development of rainbow trout with respect to Lithuanian water bodies based on LC_{50} values, the "application factor" and formulas proposed by USEPA [32] taking into account water hardness 2,5-6 (mg-eq/l) for Lithuanian reservoirs. As a result, a concentration of cadmium was 0,001-0,003 mg/l, i.e. below the current MPC (0,005 mg/l),

0,001-0,0127 mg/l for lead was obtained and this is also below the MPC of this element (0,1 mg/l). Only for copper values were close to the experimentally established values.

The development of environmental quality standards that take into account the state and specific features of a specific territory in the Russian Federation is carried out in accordance with the request of President in 2010. As a result of the work on the updating of MPCs and on substances of natural origin an approach of establishing MPC standards on the basis of data on the natural features of the chemical composition of water in water bodies, which is related to the regional natural heterogeneity of the chemical composition of surface waters, was proposed [20]. This approach involves the use of GIS technology to identify areas within which the quality of surface water is determined by natural factors.

Venitsianov E.V. [33] considers that one of the significant shortcomings in the regulatory and legal system of water protection in Russia is a single system for the whole country of the MPC for water objects of fishery use. The development and use of regional water quality standards are stipulated in the Russian Federation water code, however, federal water quality standards are still applying which makes water protection ineffective.

In another work Venitsianov E.V. with co-authors [34] indicate some contradiction when the concentrations of some chemical substances, under which the stability of established biocenoses are ensured, do not correspond to the maximum allowable concentrations for fishery use reservoirs (MPCs), which are the standards for regulating the quality of waters of almost all water bodies of Russia.

Very convincing arguments about the ineffectiveness of MPC_{fish} without taking into account local and regional features of water bodies are given in the work of the Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences [35]. Official sources indicated essential pollution of significant part of the river system in Russian Federation on the basis of an assessment of surface water contamination by the specific combinatorial index of water pollution (CIWP) of Roshydromet. This was explained by the fact that natural concentrations of chemicals were used in the calculation of the CIWP, which exceed the established standards for maximum permissible water levels in the water of the water body, due to their natural content.

Further, there is an explanation about the spatial heterogeneities of the geological structure, landscape-geochemical, soil-geochemical and climatic differentiation of the territory, as well as mineral water outflows and the presence of ore deposits which determine the formation of biogeochemical and hydrogeochemical provinces within its boundaries. The last one are usually characterized by high natural concentrations of normalized chemical elements and substances in the water. The role of climatic features of the territory in the formation of water composition is well known. It defines the sources of feeding and water runoff regime, salinity of soils, composition of soil-forming minerals and other exogenous processes.

An important aspect of this work is also the systematization, analysis and generalization of territory of each of the many basin districts of Russia by the data of general conditions and the main factors for the formation of the chemical composition of surface waters, characteristic pollutants, and the chemical compounds characteristic of the surface waters of that or a different region and positions that require the adjustment of the current standards MPC_{fish} .

It was established by the generalization of the data that the distribution of many chemical compounds that are used to assess the quality of surface waters and the level of their contamination is determined by natural factors and conditions. Basin districts, which require revising of current standards of MPC_{fish} , was identified; also chemical substances, which required regional water quality standard, was identified; and recommendations for special hydrochemical and hydrobiological studies were given.

This study and [17], as well as some other sources, have convincingly shown that due to the imperfection of the MPC_{fish} methodology the list of calculated surface water quality indicators includes the natural concentrations of chemicals, which exceed the MPC_{fish} standards because of the natural features of the territory. This situation is typical and widespread in assessing the quality of surface waters of steppe and semi-arid territories of Kazakhstan and Central Asian countries of the CIS because of using old MPC_{fish} established in USSR.

Discussion. In Kazakhstan the distortion of the actual state of surface water quality is occur due to the use by Kazhydromet the natural concentrations of the main ions of water and heavy metals in calculating CWPI. The increased level of concentrations of these hydrochemical parameters in surface waters

exceeding the MPC_{fish} and MPC_{sh} standards is caused by the fact that the overwhelming majority of lakes (especially large lakes) and rivers in steppe and semidesert area have brackish water. In addition, polymetallic ore deposits are widely distributed in the republic where the waters are characterized by high concentrations of metals. This important factor in the formation of heavy metals in the surface waters of the northern and central regions of Kazakhstan was stated by Konovalov G.S. [36].

It should also be noted that the increased concentration of a number of heavy metals in the water of some artificial objects in the northern regions of Kazakhstan are recorded in the absence of potential sources of pollution [37].

According to studies [38,39], in the reservoirs of the arid territories of Kazakhstan mineralization to the end products of the mass of aquatic and land plants accumulating in them can be an important source of heavy metals such as iron and others.

Below some examples for confirming the facts of distortion of the actual quality of water in some brackish reservoirs of Kazakhstan, which was published in the "Information Bulletins of Kazakhstan" (IB) produced by RSE "Kazhydromet" of the Ministry of Energy of the RK, using the current methods of calculating CWPI, are presented.

The following data are given in the IB for 2015-2017 yy. Jogargy Tobyl (Verkhnetobolskoye) and Vyacheslavskoe reservoirs, built in the upper reaches of the Tobyl and Yesil rivers, i.e. in the non-contaminated background areas, in 2016 and 2017 years was classified as "high level of pollution" due to the concentration of sulfates, magnesium and ammonium nitrogen (which are not contaminants) in water and low concentrations of iron and copper.

The waters of brackish lakes Zerenda, Sabyndykol, Alakol, Zhalanashkol and others also was classified as "highly contaminated" where such natural components of salt composition as sodium, magnesium, chlorides, sulfates are present in concentrations above their own MPC. However, there is no anthropogenic influences to this lakes, therefore, there are some recreation zones function there. And even large recreational zone was created at the Alakol lake due to the healing properties of the salt water composition.

The large fish lake Maibalyk is located near Astana and on this lake there is growing fish farm functioning for more than half a century. However, the water of this brackish lake was classified in the IB Kazhydromet as "extremely highly contaminated". Most importantly in this document for 2015-2017 years, it is stated "pollution of the lake from domestic activities does not occur".

Lakes Ulken Shabakty, Kishi Shabakty, Sulukol, Karasie, Shchuchye are located on the territory of the largest in Shchuchinsk-Burabay resort area. Large financial and labor resources are invested for improvement of tourist attraction and creation of medical institutions of this area. According to the natural and climatic conditions of this territory and the nature of the water regime, some components of the salt composition (magnesium, calcium, sulfates) and zinc exceed the current MPC in the water of these lakes. That is why water quality of these lakes is characterized as "high level contamination" in IB. All of this decrease recreation condition of lakes, as well as the interest and attractiveness of tourists, especially foreign tourists to visit this resort area.

Note that the significant influence of ore zones and soil, climatic, hydro-geological conditions of the central and northern regions of Kazakhstan on the formation of surface water quality was revealed by us on the basis of the results of our own scientific research [40-42]. The methodological incorrectness of accounting for the concentration of the main ions of the salt composition during the assessing the quality of the water resources of brackish reservoirs of steppe and semi-desert regions of the republic was also noted in our previous publications [43, 44].

Thus, there is a certain paradoxical situation, caused by the imperfection of the current methodology for assessing the quality of surface waters, i.e. its inapplicability for water bodies of Kazakhstan with the high mineralization of water. This problem can be solved through the establishment of regional water quality indicators for water bodies in the arid areas of Kazakhstan, where the water with high concentration of ionic components is genetically formed depending on the specific soil, climatic conditions and water regime.

From the above brief overview, it follows that one of the significant disadvantage in assessing the quality of surface waters is the use of uniform values of MPC established for the entire territory of the former USSR without taking into account local characteristics of water bodies [17, 33, 34]. The need for

the development of regional MPC is reasonably recommended even for water bodies in Lithuania [31], the Volga, Azov-Don basins [17, 34, 35] and other regions of the European part of Russia. Although according to [7, 30] the MPC_{fish} were mainly installed on water of Karelia, Baltic, Moscow, Baikal and Leningrad region using a set of local species of hydrobionts. Therefore, of course, the need to develop regional MPCs for water bodies in Kazakhstan with taking into account the natural and climatic features of the territory was faced long ago.

The establishment of regional MPC for all controlled compounds is not an easy task because the methodological approaches to the development of MPC of harmful substances in the water of fishery reservoirs require many experimental toxicology studies on local aquatic organisms and large financial costs. According to [45] the establishment of sanitary and hygienic MPC of one compound for the air of working area takes at least 225 days with a labor intensiveness around 3000 man-days and cost 43 thousand rubles at that times.

It is practically impossible to implement these measures in Kazakhstan at present. To do this it is necessary to carry out extensive preparation of fieldwork methodology, creating an experimental base, human resources development, etc. However, unfortunately the level of development of scientific research in the water toxicology, especially experimental toxicology, is not good enough [46].

However, it must be admitted that the facts of constant biases of the existing state of the quality of water resources of a lot of large, important for the country economy and mostly uncontaminated by anthropogenic pollution water bodies that occurs in official publications of state environmental protection agencies because of wrong methods of water quality assessment of natural conditions of Kazakhstan cannot be accepted. After all, the purity of the surrounding natural environment, including water facilities, and generally favorable environmental conditions of people's living are an important indicator of the level of civilization of the country and comfort of people. Positive results are achieved by great efforts of state bodies, workers and the public. Controlling agencies have to take all possible steps of showing real quality of the reservoirs and make qualified comprehension about the reliability of the provided information.

As a result of all stated above, in our opinion, State environmental protection and control agencies have to develop the temporal methodological guidelines for assessing the quality of surface waters (till to the establishment of regional water quality indicators), with involving the representatives of specialized scientific institutions of the country. This document should specify the real pollutants of surface waters and components of natural origin in the number of controlled indicators.

The research of water quality assessment of individual reservoirs of the republic using existing methods, as well as the analysis of data of the Information Bulletin convince us in advisability of excluding the main ions (Ca, Mg, Na, K, HCO₃, SO₄ and Cl) for majority reservoirs of the RK regardless of whether their concentration exceeds their own MPC or not. The concentration of this group of ions of the salt composition of water in the calculation of CWPI can be taken into account for those water bodies and watercourses where there are sources of pollution with these indicators. For example, the Syr Darya River and some reservoirs in its basin are contaminated by collector-drainage water from irrigated areas saturated with mineral salts.

It should be noted that the problem of establishing regional water quality indicators for Kazakhstan or for its individual territories will be in important issue in the nearest future. Eventually objective and reliable assessment of the quality of the country's water resources will require this kind of knowledge.

As it was mentioned above, this important issue has been studied deeply and systematically by Russian scientists in recent years. The work carried out by scientists from a number of leading scientific centers of the Russian Federation under the leadership of E.V. Venitsianov [34] is extremely valuable in the scientific and practical aspect. The significance of these studies for scientists and specialists of Kazakhstan is lied in the proposed new methodology for the establishing of regional water quality indicators for water bodies in the Upper Kama basin (MPC_{reg}), which is a receiver of industrial wastewater. The methodology takes into account the factors of determining the content of heavy metals in natural waters and its variability in this basin.

This method was implemented in the construction of regional water quality indicators in the Upper Kama basin. In the practical implementation, the authors consider that it is necessary to establish a range of water content of chemical substances, which remains the stability of the functioning of the existing natural hydrobiocenoses. For the Upper Kama basin, the norms of permissible impact (NPI) was developed in accordance with the guidelines [47, 48] and taking into account all mentioned conditions.

The comparison of the norms, established by the method of calculating of NPI, and regional indicators (MPC_{reg}), calculated by the proposed method, revealed a very slight difference (table).

Water quality standards for the Solikamsk-Bereznikovskiy industrial complex (mg/l) [29]

Indicators	MPC_{fish}	MPC of drinking water	Calculation of MPC_{reg}	Calculation by the method of NPI, plots	
				1	2
Iron (total)	0,10	0,3	0,74	0,75	0,52
Manganese	0,01	0,10	0,09	0,10	0,06
Copper	0,001	1,0	0,002	0,002	0,002
Zinc	0,01	1,00	0,01	0,01	0,01

An important result is the fact that for the Kama river the the current standards of MPC_{fish} was smaller than MPC_{reg} for iron in 7,4 times, manganese - 9 times, copper - 2 times. In the reservoirs of Kazakhstan, the difference between the current MPC and MPC_{reg} standards (if any were calculated) would obviously be much higher. That is quite likely if the regional MPC is developed, as it was indicated in [34], based on the background indicators of chemicals composition which are characterized for the region and where ecosystem functions safely for several years. Moreover, background indicators of chemicals in water bodies and watercourses in Kazakhstan are specific in the different soil and climatic regions. For example, these indicators significantly exceed the level of their fisheries MPC for a number of heavy metals in water objects of ore-bearing territories of the republic, which was observed in our studies [40, 42, 49, 50].

Conclusion. The level of influence of anthropogenic factors on the quality of the country's water resources is evaluated not enough objectively and reliably because of using incomplete methods and criterias. According to many scientists, especially from Russian Federation, the main disadvantage of sanitary and hygienic and fishery MPCs is the usage of uniform MPC values established for the entire territory of the former USSR without taking into account regional soil, climatic, hydro-geological conditions and local characteristics of water bodies (physical, chemical and biological parameters).

In Kazakhstan, the distortion of the actual state of surface water quality is mainly caused by using in the calculation of the natural concentrations of main ions and heavy metals in the CWPI by Kazhydromet without taking into account the water salinity level of the steppe territory water bodies, as well as the prevalence of polymetallic ore deposits.

Special attention should be paid to the scientific and methodological development of specialists of the leading scientific institutions of the Russian Federation on the establishment of regional MPCs that can provide an objective assessment of the true state of water quality. The establishment of regional MPCs is extremely necessary for Kazakhstan, but this requires an important preparatory works in the methodology, the establishment of an experimental base, training of specialists, etc. Based on the results of ongoing research and analysis of materials published by Kazhydromet, it is recommended to exclude the main water ions from the calculated parameters of CWPI on the basis that they are not pollutants but the natural components of the water composition.

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Н. А. Амиргалиев¹, А. С. Мадиеков¹, И. Ш. Норматов²

¹ҚР БҒМ География институты, Алматы, Қазақстан,

²Тәжікстан Республикасы Ғылым Академиясы,

Гидроэнергетика және экология су мәселелері институты, Душанбе, Тәжікстан

ҚАЗАҚСТАН ЖЕР БЕТІ СУЛАРЫНЫҢ САПАСЫН ТАБИҒИ ЕРЕКШЕЛІКТЕРІН ЕСКЕРУ НЕГІЗІНДЕ БАҒАЛАУ КРИТЕРИЯЛАРЫ

Аннотация. Жер беті су сапасын бағалау сұрақтарына ғылыми және қолданбалы тұрғыдан әдістер мен нормативтер бойынша әдеби мәліметтерге шолу жасалды. Су ресурстары сапасына антропогенді факторлардың әсер ету дәрежесін объективті және нақты бағалау мәселесі қазіргі уақытта тәуелсіз мемлекеттер достастығындағы (ТМД) елдерде ерекше өзектілікке ие болды.

Бір топ жетекші ғалымдардың пікірлері бойынша су сапасын бағалаудың маңызды кемшіліктерінің бірі, әсіресе Ресей Федерациясы үшін, бұрынғы ССРО бүкіл аумағына бекітілген, аймақтық табиғи жағдайларын және су нысандарының ерекшеліктерін ескермей ШМК_{ст} және ШМК_{бш} бірыңғай көрсеткіштерін қолдану болып табылады. Қазақстан аумағында жер беті сулары сапасының нақты жағдайларының бұрмалануы РМК «Қазгидрометте» судың ластануының кешенді индексі (СЛКИ) негізгі иондар мен ауыр металлдардың табиғи концентрацияларын, аумақта кеңінен таралған тұзды субгендері және рудалы телімдерді ескермей есептеуде болып табылады. Осы тұжырымдардың дәлелдігі ресми басылымдар мысалында көрсетіледі.

Ғалымдардың пікірлері бойынша аймақтық ШМК дайындау қажеттілігі туындады, ол үшін біршама әдістемелік көзқарастар пайда болды. Қазақстанда жер беті су сапасын бағалауда Уақытша әдістемелік құралын (су сапасының аймақтық көрсеткіштерін анықтағанға дейін) өңдеу ұсынылады, ол үшін СЛКИ есептеу көрсеткіштерінің ішінен судың негізгі иондарын алып тастау қажет, өйткені олар ластанушылар емес, ал су құрамының табиғи компоненттері болып табылады.

Түйін сөздер: жер беті су сапасын бағалау, нормативтер, ШМК аймақтық көрсеткіштері.

Н. А. Амиргалиев¹, А. С. Мадиеков², И. Ш. Норматов³

¹Институт географии МОН РК, Алматы, Казахстан,

²Академия наук Республики Таджикистан, Институт водных проблем гидроэнергетики и экологии,
Душанбе, Таджикистан.

О КРИТЕРИЯХ ОЦЕНКИ КАЧЕСТВА ПОВЕРХНОСТНЫХ ВОД КАЗАХСТАНА НА ОСНОВАНИИ УЧЕТА ЕГО ПРИРОДНЫХ ОСОБЕННОСТЕЙ

Аннотация. Приводится обзор литературных сведений по вопросам оценки с научных и прикладных точек зрения существующих методов и нормативов, регламентирующих качество поверхностных вод. Проблема объективной и достоверной оценки уровня влияния антропогенных факторов на качество водных ресурсов приобрела в настоящее время особую актуальность в странах содружества независимых государств (СНГ). Одним из существенных недостатков в оценке качества поверхностных вод, по утверждению целого ряда ведущих ученых, главным образом Российской Федерации (РФ), является применение единых величин ПДК_{ст} и ПДК_{рх} установленных для всей территорий бывшего СССР, без учёта специфики региональных природных условий и характеристик водных объектов. В пределах территории Казахстана искажение фактического состояния качества поверхностных вод происходит из-за использования РГП «Казгидромет» при расчётах комплексного индекса загрязнения воды (КИЗВ) природных концентрации главных ионов и тяжёлых металлов, без учёта широкого распространения на территории водоёмов с соленоватыми водами и рудоносных участков. Обоснованность этих утверждений подтверждается примерами из официальных изданий.

По единому мнению ученых необходимо приступить к разработке региональных ПДК, для реализаций которой уже появились некоторые методические подходы. В Казахстане рекомендуется разработать Временное методическое руководство по оценке качества поверхностных вод (до установления региональных показателей качества вод), исключив из расчётных показателей КИЗВ главные ионы воды, так как они не загрязнители, а природные компоненты состава воды.

Ключевые слова: оценка качества поверхностных вод, нормативы, региональные показатели ПДК.

Information about authors:

Amirgaliev Nariman, Doctor of geography sciences, Professor, Chief researcher of the laboratory of Hydrochemistry and ecological toxicology, Institute of Geography of the Ministry of Education and Science of the Republic of Kazakhstan, Almaty, Kazakhstan; namirgaliev@mail.ru; <https://orcid.org/0000-0002-2664-7473>

Madibekov Azamat, PhD, Head of the Laboratory of Hydrochemistry and Environmental Toxicology, Institute of Geography of the Ministry of Education and Science of the Republic of Kazakhstan, Almaty, Kazakhstan; madibekov@mail.ru; <https://orcid.org/0000-0001-9303-6640>

Normatov Inom, Doctor of chemical sciences, professor, Institute of the Water problems, Hydropower engineering and ecology, Dushanbe, Tajikistan; inomnor@gmail.com

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**Oleksiy Tereshchuk¹, Ihor Korniyenko¹ Sergiy Kryachok¹,
Tetiana Malik², Vadym Belenok³, Irina Skorintseva⁴**

¹Chernihiv national university of technology, Chernihiv, Ukraine,²University of emerging technologies, Kyiv, Ukraine,³National aviation university, Kyiv, Ukraine,⁴Institute of Geography of Ministry of Education and Science, Almaty, Kazakhstan

E-mail: olexter1957@gmail.com, cornel@ukr.net, geodesist2015@gmail.com,

malik.tat@gmail.com, belenok.vadim@gmail.com, skorintseva@mail.ru

RESEARCH OF SYSTEMATIC ERRORS ACCORDING TO THE RESULTS OF PROCESSING SATELLITE OBSERVATIONS BY SOFTWARE COMPLEXES

Abstract. Nowadays, the processing of results of static satellite observations is performed by well-known software complexes.

In order to study and analyze the issues of increasing the accuracy of observations, the full-scale satellite GNSS-measurements were performed at the points of the state geodetic network of the Northern region of Ukraine and the processing of their results was carried out using the OCTAVA and GrafNav/GrafNet software complexes commonly used in the geodetic practice.

As a result of the mathematical processing of observations by the mentioned software processing complexes, the influence of residual systematic errors in the differences of coordinate determinations has been noted. Various criteria have been used to further detect and process them, which made it possible to carry out statistical studies comparing the coordinate definitions of rover points using software systems. This work is devoted to these issues.

The article investigates the differences between geodesic latitudes and heights, which contain systematic errors and mean square errors of the unit of weight for each of the coordinates. It is also stated that there is no correlation between deviations in the plan and the height of coordinate definitions differences depending on the distance to the base station. On the basis of performed statistical researches the method of determination of accuracy of the results processing of GNSS-observations by software complexes on the basis of the method of double non-uniform measurements has been developed.

The methodology is relevant, it is tested based on the results of full-scale GNSS-observations in Chernihiv region and aims at detecting, taking into account and minimizing the residual systematic errors, and will contribute to increasing the accuracy of coordinate support for satellite observations.

Key words: mean square error; systematic error; double homogeneous measurements; software complexes.

Introduction. The dynamics of the development of modern geodetic technologies today is at such a level that scientific research on a given issue should not have inertia. In our opinion, this is relevant in the first place to researches connected with the issues of increasing the accuracy of satellite GNSS-observations, since the impact of residual systematic errors must be detected [1], taken into account and, if possible, minimized. These impacts have been investigated on the basis of the results of full-scale satellite-based GNSS-measurements at the points of the state geodetic network. The processing of their results has been carried out with the use of software complexes commonly used in geodetic practice, which made it possible to investigate the presence of systematic errors in the differences of coordinates of the same rover points.

Detection and accounting of systematic errors are considered in a number of papers. For example, [2] describes the process of diagnosing systematic errors that affect the measurement of angles performed by the tachometer. The diagnosis consists in detecting and identifying the specific components of the instrument errors to exclude them from angular measurements.

Different schools of measurement error theory are compared in the work [3], in particular, different approaches to accounting systematic error in electronic distance measurement (EDM) in the work of Chinese scientists are studied and a new theory of measurement errors is suggested, according to which any error is a bias and obeys the random distribution. The paper refers to the incomprehension of the traditional theory of measurements, proposes a new interpretation of the concept of measurements uncertainty, proposes a unified system of measurement concepts in all disciplines, including geodesy, geomatics, metrology, instrumentation.

The analysis of the latest researches and publications on the issue. Scientists and specialists from universities in Chernihiv, Kyiv and Lviv conducted a GNSS-campaign to investigate the precision of coordinate support in conducting geodetic and land-cadastral works in the Northern region of Ukraine. The research was based on a network of three active permanent GNSS-stations: CNIV-Chernihiv, PRYL-Pryluky, KORP-Korop and rover points.

During the preparation for experimental studies, the reconnaissance of the points of the State geodetic network, most of which were laid down in the 1960s - 1980s, was carried out. Of the 55 surveyed points in the region, 24 points of the first, second and third grades were found.

The conditions of experimental research envisaged the use of the points of the State geodetic network, which are located in an open area with an angle of closure of the horizon of no more than 5 degrees. According to this criterion, 4 points were rejected. Two points could not be reached because of bad weather. Therefore, 16 points of the State geodetic network have been involved in the experimental research [4].

Observations at 16 rover points were performed by six two-frequency GNSS-receivers of the geodetic class LEICA GX1230GG with high-precision antennas AX 1202 OO. The duration of observations at the rover points was at least 2 hours.

Receivers and antennas were located at the reference stations: CNIV – NOVATEL OEMV3 receiver with antenna NOV702GG; KORP – TRIMBLE 400SSI receiver with antenna TRM29659; PRYL – NOVATEL OEMV3 receiver with antenna NOV702GG. Observations at stations CNIV and KORP lasted for 24 hours and at the PRYL station – 18 hours.

For the analysis of the results of observations, there were used: the results of the first and second coordinate solutions for the point; a diagram of satellites radiolabeling and types of received data; change of DOP factors; multi-radiance at the frequency L1 (L2) for the point; the noise level of code observations at the frequency L1 (L2) for the point; noise level of phase observations at the frequency L1 (L2) for the point.

To process the results of satellite GNSS-measurements various software tools were used, such as: BERNES [5], GrafNav / GrafNet [6], OCTAVA [7], GAMIT-GLOBK [8].

The coordinates of the KORP and PRYL stations were determined with respect to the CNIV station using the software complex OCTAVA and BERNES (Switzerland). The coordinates of 16 rover points were defined for the CNIV station using the software complexes OCTAVA and GrafNav / GrafNet software [4].

The analysis of the results of the initial processing of observations at the reference stations showed satisfactory results, and on the rover – the presence of high-level multi-radiance of signals from the GPS/GLONASS satellites and a large number of omissions in the observations at three points. Therefore, we had to reject these results of observations and use data from 13 points in the further processing.

The processing of GNSS data using GrafNav / GrafNet software products is discussed in the works [9-11], with the help of BERNES – in the works [12-14].

Statement of the problem. The main aim of this article is to study the results of coordinate definitions performed at the rover points using the OCTAVA and GrafNav / GrafNet software complexes.

The research included the determination of the presence or absence of a systematic error in the differences of coordinates of the same rover points, defined using the software complexes OCTAVA and GrafNav / GrafNet, and the calculation of the mean square error (MSE) of the unit of weight for each coordinate.

Results. In the table 1 the names of the rover points used during the GNSS-campaign [6], the coordinates of the CNIV (Chernihiv) base station, the coordinates of the rover points and the distance between them and the base station have been listed.

Table 1 – Coordinates of points and distance of rover points from the CNIV (Chernihiv) base station

№	Name	X, m	Y, m	Z, m	S, km
0	CNIV	3397785	2066991	4969812	0
1	BRZN1	3357092	2148092	4963070	90.99
2	BRZN2	3378190	2148723	4948588	86.69
3	BRZN3	3388021	2131603	4949257	68.50
4	CNIV1	3408549	2061735	4964649	13.04
5	CNIV2	3400925	2055021	4972617	12.69
6	CNIV3	3394207	2068124	4971772	4.23
7	KORP2	3358758	2154856	4959069	96.74
8	KOZL1	3458464	2090416	4818201	83.03
9	KOZL2	3450879	2091820	4922895	75.08
10	KOZL3	3459671	2069474	4926158	75.77
11	KORO2	3337328	2164478	4969250	114.71
12	PRYL1	3435179	2170656	4899859	130.53
13	PRYL2	3434959	2165806	4902145	125.40

The distance from the base station to the rover point was determined by the formula

$$S = \sqrt{(X_{CNIV} - X_R)^2 + (Y_{CNIV} - Y_R)^2 + (Z_{CNIV} - Z_R)^2}. \quad (1)$$

Accuracy of determination of the planned position in the static with the help of the receiver LEICA GX1230GG is $m_{PL} = 5 \text{ mm} + 1 \text{ mm/km}$, and the height $m_H = 10 \text{ mm} + 1 \text{ mm/km}$ [15]. Since the distances from the base station to the rover points (see Table 1) were in the range from 4 km to 130 km, it is clear that the accuracy of the planned high-altitude coordinates of the rover points will be different.

At the same time, the coordinates of the rover point determined using the software complex OCTAVA and the software GrafNav/GrafNet will be considered equivalent to each other. In this way, it is necessary to perform processing of double non-uniform measurements.

Let's write the formula of the residual systematic error θ [16]

$$\theta = \frac{\sum_{i=1}^n p_i d_i}{\sum_{i=1}^n p_i}, \quad (2)$$

where p_i – weight of coordinate definitions, d_i – the differences in the coordinates of the rover points obtained using the OCTAVA software complex and the software GrafNav / GrafNet.

Then, the MSE of the unit of weight is determined by the formula (3)

$$\mu = \sqrt{\frac{\sum_{i=1}^n p_i d_i^2}{2n}}, \quad (3)$$

where n – number of rover points equal to 13.

The presence of residual systematic errors in the differences in coordinates is estimated by the criterion [16]

$$|\theta| \leq 0,2\mu. \quad (4)$$

This criterion does not depend on the law of the distribution of differences di and does not require knowledge of the confidence probability, the value of which is necessary to determine the Student's coefficient, or how it is necessary for the implementation of other criteria [17-20].

If inequality (4) is performed, then the residual systematic error in the differences of coordinates is considered significant. Then the differences of coordinates d'_i , free from systematic error, are determined by the formula:

$$d'_i = d_i - \theta, \quad (5)$$

and the MSE of the unit of weight is determined by the formula (6)

$$\mu' = \sqrt{\frac{\sum_{i=1}^n p_i (d'_i)^2}{2(n-1)}}. \quad (6)$$

Control of the definition d'_i is

$$\sum_{i=1}^n p_i d'_i = 0. \quad (7)$$

When calculating the weights of coordinate definitions p_i the following approach has been used. The precision of the point's planned position m_{PL} depends on the accuracy of the definition m_X and m_Y , and is described by the formula [17]

$$m_{PL} = \sqrt{m_X^2 + m_Y^2}. \quad (8)$$

The known value for LEICA GX1230GG receiver is $m_{PL} = 5 \text{ mm} + 1 \text{ mm/km}$ [6], while m_X and m_Y remain unknown. Therefore, in determining the weights p_X and p_Y of measurements, the dependence has been used

$$p_i = \frac{c}{D_i}, \quad (9)$$

where the values of the constant c can be different for each of the coordinate axes, taking into account their independence, D_i – distances from the base station to the rover point on the coordinate axis.

Taking into account the significant distances between the base station and the rover points, and for the purpose of visualizing the values of latitude and longitude differences determined using the OCTAVA software complex and the GrafNav / GrafNet software, the differences and angular distances between the points have been calculated linearly in the form of arcs of meridians and parallels on the surface of a general-Earth ellipsoid for GPS-definitions.

Directions along the meridian of the base station to the north and along its parallel to the east have been selected as coordinate axes.

To determine the arcs of meridians and parallels, in the beginning the first eccentricity of the reference ellipsoid has been calculated using the known formula [21].

$$e^2 = \frac{a^2 - b^2}{a^2}, \quad (10)$$

where a – big and b – small semi-axes of the reference ellipsoid.

The radius of curvature in the Meridian M_i for the mean value of the latitude B_{m_i} of the base station and the rover point i has been determined [21, 22]

$$M_i = \frac{a(1-e^2)}{\sqrt{(1-e^2 \sin^2 B_{m_i})^3}}, \quad (11)$$

and the radius of the curvature in the Prime Vertical N_i for the rover point i

$$N_i = \frac{a}{\sqrt{(1-e^2 \sin^2 B_{m_i})}}. \quad (12)$$

The length of the meridian arc for the latitude difference ΔB° , taken in degrees ΔB° with $\rho^\circ = 57,29578^\circ$ is calculated by the formula

$$D_{M_i} = M_i \frac{\Delta B_i^\circ}{\rho^\circ}. \quad (13)$$

The length of the arc of parallel in the latitude B_i , taken in degrees ΔL° , for the rover point is calculated by the formula

$$D_{P_i} = N_i \cos B_i \frac{\Delta L_i^\circ}{\rho^\circ}. \quad (14)$$

The values of semi-axes of the reference ellipsoid for WGS-84 with accuracy up to meters are accepted $a = 6\,378\,137$ m, $b = 6\,356\,752$ m [21].

Table 2 shows the values of the lengths of arcs of meridians and parallels for the rover points relative to the base station CNIV (Chernihiv), calculated for latitudes and longitudes obtained with the help of GrafNav / GrafNet software. The value of latitudes and longitudes of the points is taken from the work [4].

Table 2 – Determination of the lengths of arcs of meridians and parallels for the rover points relative to the base station CNIV (Chernihiv)

№	B_i°	M_i , m	N_i , m	D_M , km	L_i°	D_P , km	S_i , km
CNIV	51.51893923	–	–	–	31.313601267	–	–
1	51.422055527	6 374 572	6 391 242	10.78	32.613835585	90.35	90.99
2	51.213524898	6 374 458	6 391 204	33.98	32.458711530	79.75	86.69
3	51.223206956	6 374 463	6 391 206	32.90	32.176401375	60.08	68.50
4	51.444486627	6 374 584	6 391 246	8.28	31.168558684	10.08	13.04
5	51.559429634	6 374 647	6 391 267	4.50	31.142512118	11.87	12.70
6	51.547258895	6 374 640	6 391 265	3.15	31.354362172	2.83	4.23
7	51.364139623	6 374 540	6 391 232	17.22	32.682744068	95.20	96.74
8	50.779713015	6 374 220	6 391 125	82.24	31.150220748	11.43	83.03
9	50.846517010	6 374 257	6 391 137	74.81	31.222997234	6.34	75.08
10	50.892885364	6 374 282	6 391 146	69.65	30.886632417	29.84	75.77
11	51.511080326	6 374 621	6 391 259	0.87	32.966068854	114.71	114.71
12	50.519590855	6 374 078	6 391 077	111.18	32.288387392	68.40	130.53
13	50.551914346	6 374 096	6 391 083	107.58	32.232194287	64.43	125.40

To control the calculations, the distances on the ellipsoid from the rover points to the base station have been calculated, which coincided with the ones shown in table. 1. The indicated distances have been calculated according to the formula:

$$S_i = \sqrt{D_{M_i}^2 + D_{P_i}^2}. \quad (15)$$

Further, according to the latitudes and longitudes of the rover points determined using the OCTAVA software complex and the GrafNav/GrafNet software [4], their differences have been calculated firstly at

an angle and next translated linearly as small arcs of meridians and parallels by formulas (13) and (14). The values of the radii of curvature of the meridians and the first vertices for the corresponding rover points have been taken from table 2.

After preparatory calculations, studies have been carried out to detect residual systematic errors in the geodetic coordinates' differences.

By values of arcs of the meridians D_{M_i} for the rover points relative to the base station from table 3 the weights p_i of the rover points have been calculated according to the formula (9) (table 4). The latitude differences ΔB is linearly taken from table 3. It has been found (see table 4) that the residual systematic error is $\theta = +2.3$ mm. By criterion (4), it is significant ($|\theta| = 2.3$ mm; $0.2\mu = 1.4$ mm). Therefore, it has been removed from latitude differences by formula (5) and the MSE of the unit of weight has been calculated by the formula (6), which received $\mu' = 6.1$ mm.

Table 3 – Latitudes and longitudes of rover points identified using the OCTAVA software complex and GrafNav/GrafNet software and their differences

№	$(B_i^{OC})^\circ$	$(B_i^{GN})^\circ$	$\Delta B, \text{ m}$	$(L_i^{OC})^\circ$	$(L_i^{GN})^\circ$	$\Delta L, \text{ m}$
1	51.422055506	51.422055527	-0.0023	32.613834873	32.613835585	-0.0495
2	51.213524891	51.213524898	-0.0008	32.458711464	32.458711530	-0.0046
3	51.223207071	51.223206956	0.0128	32.176401276	32.176401375	-0.0069
4	51.444486643	51.444486627	0.0018	31.168558551	31.168558684	-0.0092
5	51.559429692	51.559429634	0.0065	31.142512154	31.142512118	0.0025
6	51.547258942	51.547258895	0.0052	31.354362278	31.354362172	0.0074
7	51.364139676	51.364139623	0.0059	32.682744036	32.682744068	-0.0022
8	50.779713056	50.779713015	0.0046	31.150220519	31.150220748	-0.0162
9	50.846517209	50.846517010	0.0221	31.222997250	31.222997234	0.0011
10	50.892885403	50.892885364	0.0043	30.886632350	30.886632417	-0.0047
11	51.511080330	51.511080326	0.0004	32.966068758	32.966068854	-0.0067
12	50.519590874	50.519590855	0.0021	32.288387166	32.288387392	-0.0160
13	50.551914377	50.551914346	0.0034	32.232194284	32.232194287	-0.0002

Table 4 – Definition of the systematic error and the MSE of the unit of weight of different latitudes, identified using the OCTAVA software complex and GrafNav/GrafNet software

№	$D_{M_i}, \text{ km}$	p	$\Delta B, \text{ mm}$	$p\Delta B, \text{ mm}$	$p\Delta B^2, \text{ mm}^2$	$\Delta B', \text{ mm}$	$p\Delta B', \text{ mm}$	$p(\Delta B')^2, \text{ mm}^2$
1	10.78	3.71	-2.3	-8.53	19.63	-4.58	-16.98	77.69
2	33.98	1.18	-0.8	-0.94	0.75	-3.08	-3.62	11.14
3	32.90	1.22	12.8	15.56	199.20	10.52	12.80	134.66
4	8.28	4.83	1.8	8.70	15.65	-0.48	-2.30	1.09
5	4.50	8.89	6.5	57.78	375.56	4.22	37.55	158.61
6	3.15	12.70	5.2	66.03	343.37	2.92	37.13	108.58
7	17.22	2.32	5.9	13.70	80.86	3.62	8.42	30.51
8	82.24	0.49	4.6	2.24	10.29	2.32	1.13	2.63
9	74.81	0.53	22.1	11.82	261.15	19.82	10.60	210.13
10	69.65	0.57	4.3	2.47	10.62	2.02	1.16	2.35
11	0.87	45.98	0.4	18.39	7.36	-1.88	-86.24	161.78
12	111.18	0.36	2.1	0.76	1.59	-0.18	-0.06	0.01
13	107.58	0.37	3.4	1.26	4.30	1.12	0.42	0.47
Σ		83.15	66	189.23	1330.31		0	899.66
$c = 40; \theta = +2.28 \text{ mm}; \theta = 2.28 \text{ mm}; 0.2\mu = 1.43 \text{ mm} (\mu = 7.15 \text{ mm}); \mu' = 6.12 \text{ mm}.$								

Table 5 shows the results of calculations of systematic error and the MSE of the unit of weight of the longitudinal differences of the rover points determined using the OCTAVA software complex and the GrafNav/GrafNet software. As can be seen from Table 5, inequality (4) is not satisfied. Therefore, the systematic error $\theta = -0,58$ mm is not significant. The mean square error of the unit of weight of longitudes differences equals $\mu = 12.8$ mm.

Table 5 – Definition of systematic error and the MSE of the unit of weight of the longitudinal differences determined using the OCTAVA software complex and the GrafNav/GrafNet software

№	D_p , km	p	ΔL , mm	$p\Delta L$, mm	$p\Delta L^2$, mm ²
1	90.35	0.55	-49.5	-27.39	1355.98
2	79.75	0.63	-4.6	-2.88	13.27
3	60.08	0.83	-6.9	-5.74	39.62
4	10.08	4.96	-9.2	-45.63	419.84
5	11.87	4.21	2.5	10.53	26.33
6	2.83	17.67	7.4	130.74	967.49
7	95.2	0.53	-2.2	-1.16	2.54
8	11.43	4.37	-16.2	-70.87	1148.03
9	6.34	7.89	1.1	8.68	9.54
10	29.84	1.68	-4.7	-7.88	37.01
11	114.71	0.44	-6.7	-2.92	19.57
12	68.4	0.73	-16.0	-11.70	187.13
13	64.43	0.78	-0.2	-0.16	0.03
Σ		45.26	-105.2	-26.38	4226.39
$c = 50$; $u = -0.58$ mm; $ u = 0.58$ mm; $0.2\mu = 2.55$ mm; $\mu = 12.75$ mm.					

To determine the scales of the differences of geodetic heights of the rover points determined using the OCTAVA software complex and the GrafNav/GrafNet software, the formula has been used

$$p_i = \frac{c}{m_{H_i}^2}, \quad (16)$$

where $m_{H_i} = 10\text{mm} + 1\text{mm} \cdot S_i(\text{km})$ – the MSE of defining heights by the LEICA GX1230GG receiver.

Table 6 – Definition of the systematic error and the MSE of the unit of weight differences of the geodetic heights determined using the OCTAVA software complex and the GrafNav/GrafNet software

№	S_m , km	m_H , mm	p	ΔH , mm	$p\Delta H$, mm	$p\Delta H^2$, mm ²	$\Delta H'$, mm	$p\Delta H'$, mm	$p(\Delta H')^2$, mm ²
1	90.99	100.99	0.87	-30	-26.06	781.84	-25.63	-22.27	570.81
2	86.69	96.69	0.95	-2	-1.90	3.79	2.37	2.24	5.31
3	68.5	78.5	1.44	-26	-37.38	971.94	-21.63	-31.10	672.89
4	13.04	23.04	16.69	1	16.69	16.69	5.37	89.57	480.68
5	12.69	22.69	17.21	1	-189.30	2082.32	-6.63	-114.16	757.26
6	4.23	14.23	43.76	-2	-87.51	175.02	2.37	103.55	245.05
7	96.74	106.74	0.78	-11	-8.55	94.09	-6.63	-5.16	34.22
8	83.03	93.03	1.02	2	2.05	4.09	6.37	6.52	41.49
9	75.08	85.08	1.22	-12	-14.69	176.25	-7.63	-9.34	71.32
10	75.77	85.77	1.20	-16	-19.27	308.32	-11.63	-14.01	163.00
11	114.71	124.71	0.57	-10	-5.70	56.97	-5.63	-3.21	18.08
12	130.53	140.53	0.45	-2	-0.90	1.79	2.37	1.06	2.51
13	125.4	135.4	0.48	-12	-5.80	69.59	-7.63	-3.69	28.16
Σ			86.64	-131	-378.32	4742.73		0	3090.78
$c = 8860$; $\theta = -4.37$ mm; $ u = 4.37$ mm; $0.2\mu = 2.7$ mm ($\mu = 13.51$ mm); $\mu' = 11.35$ mm.									

The results of calculations are given in table 6. The differences of the geodetic heights of the rover points determined using the OCTAVA software complex and the GrafNav/GrafNet software have a residual systematic component $\theta = -4.37$ mm, which by criterion (4) is significant ($|\theta| = 4.37$ mm; $0.2\mu = 2.7$ mm). Therefore, the differences in geodetic heights have been deprived (released) of the systematic component and calculated the MSE of the unit of weight, which was $\mu' = 11.35$ mm.

The general deviations of the planned coordinates Δ_i have been calculated by the formula (15), where: $\Delta_i = S_i$, $D_{M_i} = \Delta B_i$, $D_{P_i} = \Delta L_i$ (table 7). Values ΔB and ΔL are taken from table 4 and table 5 for the corresponding rover points.

Table 7 – The value of the total deviation of the planned coordinates of the rover points

№	1	2	3	4	5	6	7	8	9	10	11	12	13
Δ_i , mm	49.6	4.7	14.5	9.4	7.0	9.0	6.3	16.8	22.1	6.4	6.7	16.1	3.4

Using the values of total deviations and values of distances of rover points from the base station, the graph is built, as shown in figure 1.

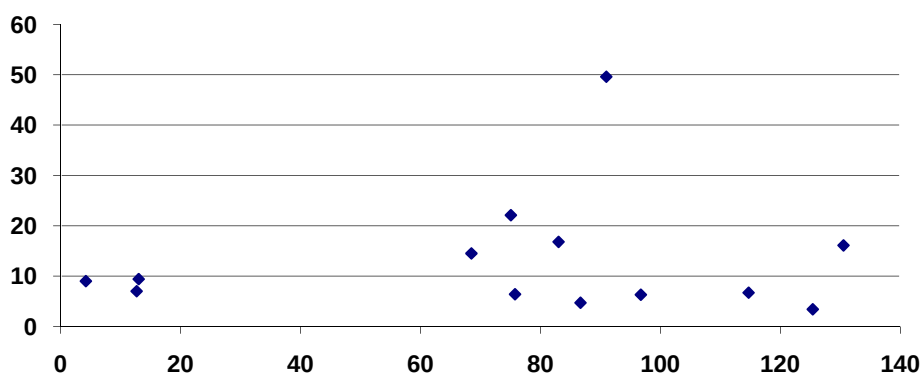


Figure 1 – Distribution of general deviation of planned coordinates depending on the distance of rover points from the base station CNIV

From the graph it is clear that the magnitudes of deviations practically do not correlate with distance. A similar graph is constructed for deviations in the values of the geodetic heights of the rover points calculated using the software complexes OCTAVA and GrafNav / GrafNet, which is depicted in figure 2. Here too, there is no correlation between deviations in height and distance of rover points from the base station

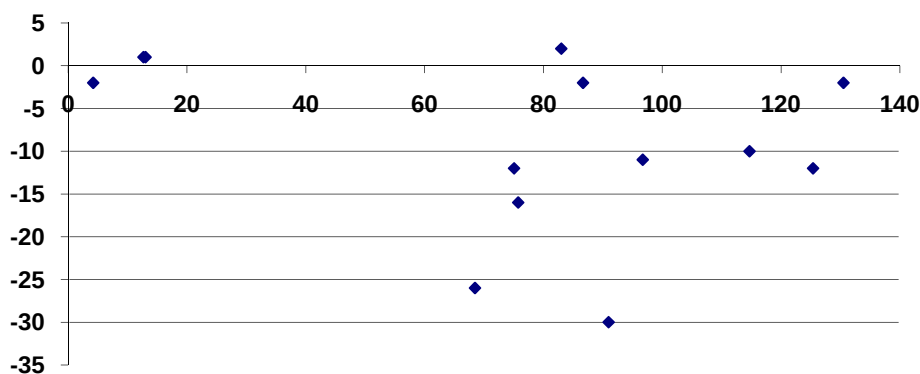


Figure 2 – Distribution of deviations in the values of the geodetic heights of the rover points calculated using the software complexes OCTAVA and GrafNav / GrafNet depending on the distance to the base station CNIV

The next step is to determine the average values of the heights of the rover points and to calculate their accuracy.

The average values of geodetic heights of rover points obtained using the software complexes OCTAVA and GrafNav / GrafNet, are calculated by the formula [17, 19]

$$H_i = \frac{H_i^{OC} + H_i^{GN}}{2}. \quad (13)$$

The weights of the average geodetic heights calculated using the OCTAVA or GrafNav / GrafNet software complex are equal to $\sqrt{2p_i}$. Therefore, the mean square error of geodetic heights, calculated using any of these software complexes, are determined by the formula

$$m_{H_i} = \frac{\mu'}{\sqrt{2p_i}}. \quad (14)$$

The values of the average heights of the rover points and the accuracy of their calculation by the indicated software products are given in the table 8.

Table 8 – Calculation of average values of heights of rover points and their accuracy

№	H_i^{OC} , m	H_i^{GN} , m	H_i , m	$\sqrt{2p_i}$	m_{H_i} , mm	S_i , km
1	141.275	141.305	141.2900	1.31	8.7	90.99
2	165.005	165.007	165.0060	1.38	8.2	86.69
3	158.081	158.107	158.0940	1.70	6.7	68.50
4	170.570	170.569	170.5695	5.78	2.0	13.04
5	179.595	179.606	179.6005	5.87	1.9	12.70
6	175.780	175.782	175.7810	9.36	1.2	4.23
7	167.016	167.027	167.0215	1.25	9.1	96.74
8	148.970	148.968	148.9690	1.43	7.9	83.03
9	146.143	146.155	146.1490	1.56	7.3	75.08
10	155.991	156.007	155.9990	1.55	7.3	75.77
11	152.992	153.002	152.9970	1.07	10.6	114.71
12	156.347	156.349	156.3480	0.95	11.9	130.53
13	157.457	157.469	157.4630	0.98	11.6	125.40

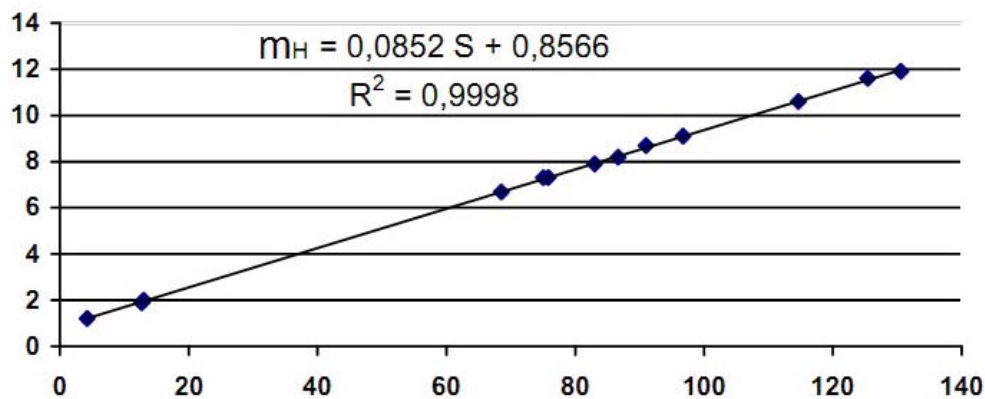


Figure 3 – The graph of dependency of the MSE of the geodesic heights of the rover points calculated using the software complexes OCTAVA or GrafNav / GrafNet, depending on the distance to the base station CNIV (Chernihiv)

Figure 3 shows the graph of dependency of the MSE of the geodesic heights of the rover points calculated using the software complexes OCTAVA or GrafNav / GrafNet, depending on the distance, constructed according to the data of the Table 8. The line of trend of the MSE of geodetic heights is given, with which it is possible to predict the accuracy of calculating the geodetic heights of the rover points using the indicated software products at intermediate rover points, depending on the distance from the base station CNIV (Chernihiv). The accuracy of the approximation is high and is $R^2 = 0.9998$.

The average values B_i of the latitudes of the rover points (table 9) have been defined, calculated using the software complexes OCTAVA and GrafNav / GrafNet, with a correction $-0.5\theta_B^\circ$ for the systematic error $\theta_B = +2.28$ mm (see table 4), which is determined at an angle measure in particles of a degree taking into account the formula (9)

$$\theta_B^\circ = \frac{\theta_B}{M_i} \rho^\circ, \quad (15)$$

Table 9 – Calculation of the mean values of latitudes of rover points and their accuracy

N_i	$(B_i^{OC})^\circ$	$(B_i^{GN})^\circ$	B_i	$\sqrt{2p_i}$	m_{B_i} , mm	D_{M_i} , km
1	51.422055506	51.422055527	51.4220555165	2.72	2.25	10.78
2	51.213524891	51.213524898	51.2135248945	1.54	3.98	33.98
3	51.223207071	51.223206956	51.2232070135	1.56	3.92	32.90
4	51.444486643	51.444486627	51.4444866350	3.11	1.97	8.28
5	51.559429692	51.559429634	51.5594296630	4.22	1.45	4.50
6	51.547258942	51.547258895	51.5472589185	5.04	1.21	3.15
7	51.364139676	51.364139623	51.3641396495	2.15	2.84	17.22
8	50.779713056	50.779713015	50.7797130355	0.99	6.18	82.24
9	50.846517209	50.846517010	50.8465171095	1.03	5.94	74.81
10	50.892885403	50.892885364	50.8928853835	1.07	5.73	69.65
11	51.511080330	51.511080326	51.5110803280	9.59	0.64	0.87
12	50.519590874	50.519590855	50.5195908645	0.85	7.21	111.18
13	50.551914377	50.551914346	50.5519143615	0.86	7.11	107.58
$0.5\theta_B^\circ = (+1.02 \cdot 10^{-10})^\circ$						

The MSE of the latitudinal position of the rover points calculated using the software complexes OCTAVA or GrafNav/GrafNet, is executed using a formula similar to formula (14). These values are linearly determined m_{B_i} in the table 9.

Figure 4 shows the graph of the dependence of the MSE of the geodesic latitudes of the rover points linearly, calculated using the software complexes OCTAVA or GrafNav / GrafNet depending on the distance in the meridional direction relative to the station CNIV (Chernihiv), constructed according to the data of the table 9.

A trend line has been developed, which allows predicting the accuracy of calculating the geodetic latitudes of the rover points using the indicated software products at intermediate rover points, depending on the distance from the base station CNIV (Chernihiv) along the meridian of the point. The accuracy of the approximation is $R^2 = 1$.

The average values L_i of the longitudes of the rover points have been determined, calculated using the software complexes OCTAVA and GrafNav / GrafNet (table 10), the longitudinal values of the mean square error m_{L_i} are calculated using the formula:

$$m_{L_i} = \frac{\mu}{\sqrt{2p_i}}, \quad (16)$$

where $\mu = 12.75$ mm and weights p_i , the values of which are given in the table 5.

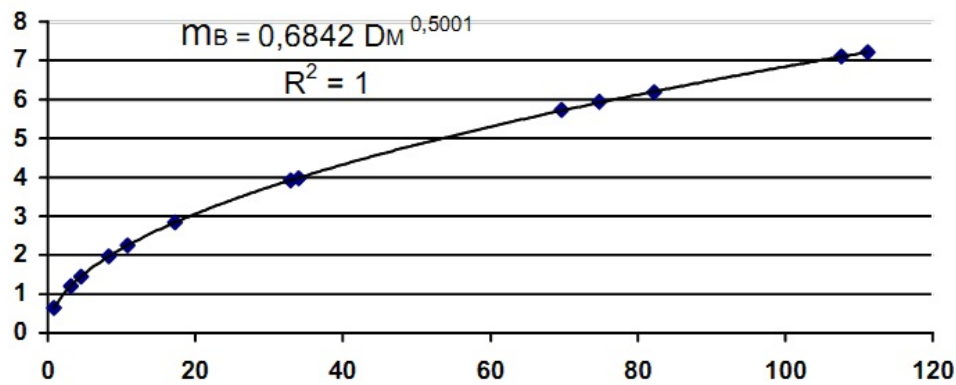


Figure 4 – The graph of the dependence of the MSE of the geodesic latitudes of the rover points linearly, calculated using the software complexes OCTAVA or GrafNav / GrafNet depending on the distance in the meridional direction relative to the station CNIV (Chernihiv)

Table 10 – Calculation of mean values of longitudes of rover points and their accuracy

№	$(L_i^{OC})^\circ$	$(L_i^{GN})^\circ$	L_i	$\sqrt{2p_i}$	m_{L_i} , mm	D_{P_i} , km
1	32.613834873	32.613835585	32.6138352290	1.05	12.2	90.35
2	32.458711464	32.458711530	32.4587114970	1.12	11.4	79.75
3	32.176401276	32.176401375	32.1764013255	1.29	9.9	60.08
4	31.168558551	31.168558684	31.1685586175	3.15	4.0	10.08
5	31.142512154	31.142512118	31.1425121360	2.90	4.4	11.87
6	31.354362278	31.354362172	31.3543622250	5.94	2.1	2.83
7	32.682744036	32.682744068	32.6827440520	1.41	12.4	95.20
8	31.150220519	31.150220748	31.1502206335	2.96	4.3	11.43
9	31.222997250	31.222997234	31.2229972420	3.97	3.2	6.34
10	30.886632350	30.886632417	30.8866323835	1.41	7.0	29.84
11	32.966068758	32.966068854	32.9660688060	0.94	13.6	114.71
12	32.288387166	32.288387392	32.2883872790	1.21	10.6	68.40
13	32.232194284	32.232194287	32.2321942855	1.25	10.2	64.43

Figure 5 shows the graph of dependence of the MSE of the geodetic longitudes of the rover points in the linear measure, calculated using the software complex OCTAVA or the GrafNav/GrafNet software depending on the distance in the parallel direction with respect to the meridian of the station CNIV (Chernihiv), constructed according to the data of the table 9.

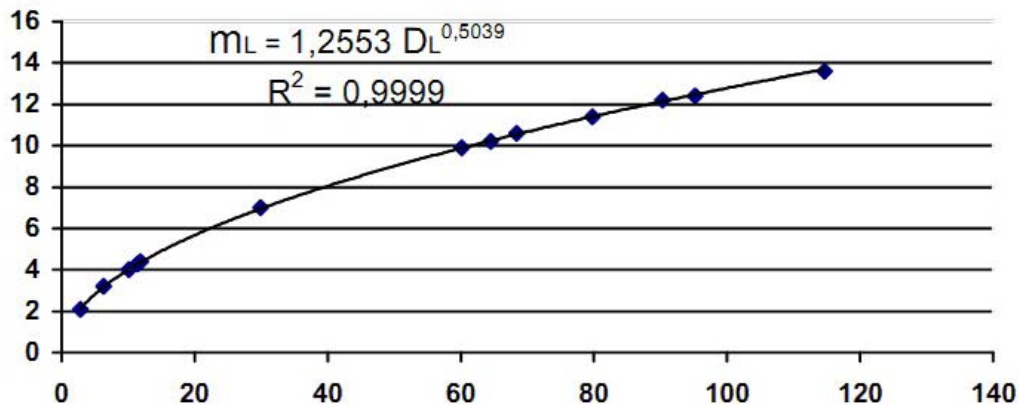


Figure 5 – The graph of dependence of the MSE of the geodetic longitudes of the rover points in the linear measure, calculated using the software complex OCTAVA or the GrafNav / GrafNet software depending on the distance in the parallel direction with respect to the meridian of the station CNIV (Chernihiv)

A trend line has been made that predicts (forecasts) the accuracy of calculating the geodetic longitudes of the rover points, depending on the distance from the meridian of the CNIV base station along the parallel of the rover point. The accuracy of the approximation is $R^2 = 0.9999$.

Using the values of the MSE of the position of points in latitudinal and longitudinal directions, it is possible to construct ellipses of errors of the planned position of the rover points. Figure 6 provides the ellipse of errors of the planned position of the point BRZN3. For intermediate points, it is possible to use the equations of the trend lines, and calculate the lengths of the meridians and parallels by the formulas (13) and (14).

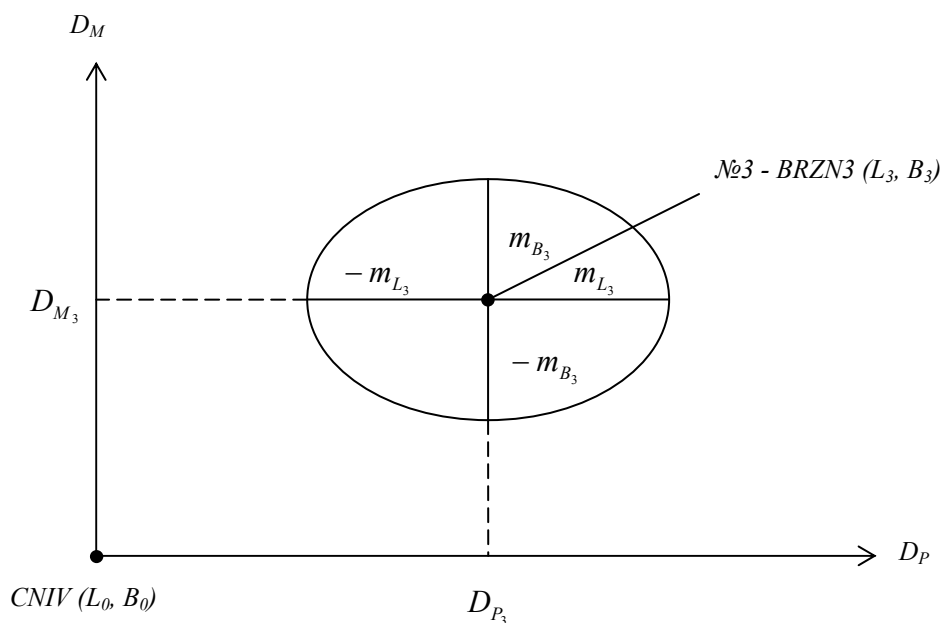


Figure 6 – The ellipse of errors of the planned position of the point BRZN3

Conclusions. According to the results of statistical research of the comparison of coordinate definitions of the rover points using the software complexes OCTAVA and GrafNav / GrafNet, the following conclusions can be drawn:

- the differences between the geodesic latitudes and heights contain systematic errors, which are respectively linearly equal to + 2.3 mm and - 4.4 mm;
- the MSE of the unit of weight for each of the coordinates is for geodetic latitudes, longitudes and heights of 6.1 mm, 12.8 mm and 11.4 mm respectively;
- the greatest differences in geodetic coordinates are determined: in latitude - 22 mm; in longitude - 50 mm; in height - 30 mm;
- it was established that the correlation between the deviations in the plan and in heights of the differences in coordinate definitions, depending on the distance to the base station, is absent;
- a method for determining the accuracy of the processing of GNSS observations by software complexes based on the method of double non-uniform measurements is developed. The method has been tested according to the results of full-scale GNSS-observations in Chernihiv region.

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А. И. Терещук, И. В. Корниенко, С. Д. Крячок,
Т. Н. Малик, В. Ю. Беленок, И. Б. Скоринцева

БАҒДАРЛАМАЛЫҚ ҚАМТАМАСЫЗДАНДЫРУ КЕШЕНІ АРҚЫЛЫ СПУТНИКТІК БАҚЫЛАУДЫ
ӨНДЕУ НӘТИЖЕЛЕРІ БОЙЫНША ЖҮЙЕЛІ ҚАТЕЛЕРДІ ЗЕРТТЕУ

А. И. Терещук¹, И. В. Корниенко¹, С. Д. Крячок¹,
Т. Н. Малик², В. Ю. Беленок³, И. Б. Скоринцева⁴

¹Черниговский национальный технологический университет, Чернигов, Украина,

²Университет новейших технологий, Киев, Украина,

³Национальный авиационный университет, Киев, Украина,

⁴Институт географии Министерства образования и науки, Алматы, Казахстан

ИССЛЕДОВАНИЕ СИСТЕМАТИЧЕСКИХ ПОГРЕШНОСТЕЙ ПО РЕЗУЛЬТАТАМ ОБРАБОТКИ СПУТНИКОВЫХ НАБЛЮДЕНИЙ ПРОГРАММНЫМИ КОМПЛЕКСАМИ

Аннотация. На сегодня обработка результатов статических спутниковых наблюдений выполняется известными программными комплексами.

С целью исследования и анализа вопросов повышения точности наблюдений выполнены натурные спутниковые ГНСС-измерения на пунктах государственной геодезической сети Северного региона Украины и проведена обработка их результатов с применением распространённых в геодезической практике программных комплексов OCTAVA и GrafNav / GrafNet.

По результатам математической обработки наблюдений упомянутыми программными комплексами выявлено влияние остаточных систематических погрешностей в разностях координатных определений. Для их дальнейшего выявления и обработки были применены разные критерии, которые дали возможность провести статистические исследования сравнения координатных определений роверных пунктов с использованием программных комплексов. Этим вопросам посвящена данная работа.

В статье исследованы разности геодезических широт и высот, которые содержат систематические погрешности и средние квадратические погрешности единицы веса по каждой из координат. Установлено также отсутствие корреляции между отклонениями в плане и по высоте разниц координатных определений в зависимости от расстояния до базовой станции. На основе проведённых статистических исследований разработана методика определения точности обработки результатов ГНСС-наблюдений программными комплексами, базируясь на способе двойных неравноточных измерений.

Методика является актуальной, она прошла апробацию по результатам натурных ГНСС-наблюдений в Черниговской области (Украина) и направлена на выявление, учёт и минимизацию остаточных систематических погрешностей и будет способствовать повышению точности координатного обеспечения при спутниковых наблюдениях.

Ключевые слова: средняя квадратическая погрешность; систематическая погрешность; двойные неравноточные измерения; программные комплексы OCTAVA, GrafNav / GrafNet, BERNESE.

Information about authors:

Tereshchuk Oleksiy Ivanovych, Director of Educational-Scientific Institute of Construction, candidate of technical sciences, associate professor, Chernihiv national university of technology, Chernihiv, Ukraine; Olexter1957@gmail.com; <https://orcid.org/0000-0001-6433-9351>

Korniyenko Igor Valentinovich, Deputy Director of Educational-Scientific Institute of Construction, candidate of technical sciences, associate professor, Chernihiv national university of technology, Chernihiv, Ukraine; cornel@ukr.net; <https://orcid.org/0000-0001-9105-0780>

Kryachok Sergiy Dmytrovych, Educational-Scientific Institute of Construction, candidate of technical sciences, associate professor, Chernihiv national university of technology, Chernihiv, Ukraine; geodesist2015@gmail.com; <https://orcid.org/0000-0001-5633-1501>

Malik Tetiana Mykolaivna, candidate of technical sciences, associate professor of Geodesy, Land Management And Ecology Department, University of emerging technologies, Kyiv, Ukraine; malik.tat@gmail.com; <https://orcid.org/0000-0002-1362-8433>

Belenok Vadym Yuriiovich, candidate of physical and mathematical sciences, associate professor of Aerospace Geodesy Department, National aviation university, Kyiv, Ukraine; belenok.vadim@gmail.com; <https://orcid.org/0000-0001-5357-7493>

Skorintseva Irina Borisovna, doctor of geography sciences, associate professor, Institute of Geography of Ministry of Education and Science, Almaty, Kazakhstan; skorintseva@mail.ru; <https://orcid.org/0000-0002-4791-8134>

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**S. Orynbayev¹, E. Amanbayev¹, B. Alimbayev¹,
B. Manapbayev¹, S. Beglerova¹, B. Myktybekov²**

¹Taraz state university after M. Kh. Dulaty, Kazakhstan,²Central Institute of Aviation Engine, Moscow, Russia.

E-mail: seitzhan_74@mail.ru, amanbaev@mail.ru, bazalim@mail.ru,
jiboj@mail.ru, sbeglerova@mail.ru, bahit12@mail.ru

INTERNAL CORROSION PROPAGATION IN CURVED SECTIONS OF STEEL PIPES

Abstract. In the world, the protection of metals from corrosion is one of the urgent problems requiring an integrated approach to their solution. The main task of research in this area is to reduce the economic losses due to corrosion of pipelines, equipment, machinery, structures, machine parts, etc., to increase the reliability of equipment that comes into contact with aggressive media and to preserve the metal stock. Every year around the world there is an increase in the production of metals and the requirements for the conditions of their operation are becoming higher. This is due to the fact that more and more metallic equipment works in aggressive environments. Therefore, the issues of protecting metal equipment from corrosion become more relevant. It is impossible to completely prevent corrosion in metals, but you can find ways to slow down the development of corrosion. For this it is necessary to explore the development of corrosion in metal structures. This article discusses the development of corrosive processes in various parts of the steel pipeline. Studies on the development of corrosion have shown that the development of corrosion on curved sections of steel pipes for various purposes occurs more intensively than on straight sections.

Keywords: corrosion; steel pipes; Lorentz force; internal corrosion.

Introduction. In the history of construction and maintenance of steel pipes, there are accidents and failures due to corrosion damages [1-11]. The problem of corrosion is very urgent and is one of the main factors that cause major catastrophes and accidents on pipelines in various industries.

The main type of corrosion of pipes, which leads to damages, is internal corrosion. Corrosion prevention in steel pipes used in various industrial facilities is in application of insulating coatings both inside the pipes and outside. At that, attention is not paid to the corrosion propagation behavior in the curved sections of steel pipes.

Review. The main internal corrosion studies were carried out in oil and gas and chemical industries, where the transportable medium rapidly leads to the internal corrosion [9-12]. Also, these studies are well developed in the studies of water and heat supply systems [13]. A lot of research has been carried out to this day and being carried out at the moment on the corrosion propagation in these industries, but these results cannot be generalized and used in hydraulic engineering structures due to the difference in the transportable media properties.

In [14] the author studies irrigation pressure pipe systems' life aging by means of forecasting the corrosion propagation danger of metal pipes transporting waste waters. In the work the emphasis is made on waste waters. It does not consider effect of corrosion propagation on the constructional metal pipe features.

The work [15] considers operation conditions of "Astrakhan-Mangyshlak" main internal surface conduit and properties of corrosion formation on it. The corrosion propagates due to water composition, temperature fluctuations and changes along the conduit length. The work does not consider effect of corrosion propagation on the constructional metal pipe features.

The work [16] notes that after long-term operation, localized corrosion damages occur on the oil and gas pipe pitches due to the transportable medium composition and movement influence, which can lead to the pipe rupture.

The works [17-19] present results of experiments on the study of corrosion in the internal cavity of pipes, where the transportable medium flow regime and composition affect the pipe corrosion.

As the review of sources in this direction has shown, investigations of internal corrosion in hydraulic engineering structure pipes have not been adequately conducted, and there are practically no works on the study of the corrosion propagation on the curved sections of steel pipes.

Proposals and differences in methodology. Our investigations [16-20] showed that corrosion propagation occurs more intensively on the curved sections of steel pipes for various purposes than on the straight sections.

We have proposed corrosion propagation mechanism in steel structure elements in aqueous medium taking into account their ferromagnetic properties [18-20]. These studies showed that on the straight sections, ions of the transportable medium attracting by the Lorentz force to the walls of cracks start chemical process of steel elements' corrosion. Existing cracks on the outside are covered with oxide film forming iron hydroxides. Cracks filled with corrosion products on the straight sections are less susceptible to mechanical influences on the transportable medium. Therefore, here the corrosion propagation velocity is less than in the curved sections of steel pipes.

In the curved sections of steel pipes, a centrifugal force acts on moving particles (gases, mechanical impurities, water or other liquids) having a certain mass [21]. In the curved sections the corrosion propagation velocity depends on the liquid motion velocity, on the number of ions, and also on the centrifugal force effect equal to:

$$F = \frac{m \cdot v^2}{R}, \quad (1)$$

where m – particle mass; v – particle motion velocity; R – radius of deformation.

These particles, acting mechanically, open cracks of steel pipes closed by the primary corrosion products and contribute to the further intensive corrosion propagation in them.

In the straight sections the corrosion propagation velocity depends only on the liquid flow velocity and on the number of ions, as $\frac{m \cdot v^2}{R} \rightarrow 0$, at $R = \infty$.

In the curved sections, where the turning angle equal to 90° , the corrosion propagation velocity depends on the liquid flow velocity, on the number of ions, as well as on the kinematic energy action, as $\frac{m \cdot v^2}{R} \rightarrow \max$, at $R \rightarrow 0$. In this situation, the corrosion propagates several times more than in other curved sections, as the liquid motion before the angle changes and the number of ions increases. If previously on the straight sections, ions on the wetted perimeter of the pipe could act on the corrosion propagation velocity, then at turns to 90° , ions on the cross sectional area of the liquid can affect the corrosion propagation velocity.

To test the proposed mechanism for the corrosion propagation, we have conducted experiments to measure thickness of the steel pipes walls on the curved sections. The purpose of the experiment is to determine the turning angles, which have the greatest influence on the corrosion propagation velocity.

To this end, we have developed an apparatus for determining metal corrosion on the curved sections in steel pipes (figure 1). The apparatus consists of a pump welded at various angles of pipes $\varnothing 32 \times 3.0$ in diameter, a filter, an air valve and supports. The apparatus developed by us, where the liquid is circulated by the pump, has sections of steel pipes: straight, curved and with turn by 90° .

The experiment was conducted for one year. As is known, river water, fresh water have very weak ions, therefore, in order to obtain comparatively fast results in the role of a corrosive fluid, we took the salt solution, generally accepted in such experiments (NaCl 3.5%) [9, 23].

It should be noted that in similar works [12, 22], the salt solution (NaCl 3.5%) is used to study the corrosion propagation.



Figure 1 – The distance from the rotation axis to the center of gravity of the current r and peripheral R section

In the work [23], the salt solution (NaCl 3.5%) is also used for the experiment, but the work deals with the corrosion propagation in welded joints of pipes.

The thickness of the steel pipes walls was measured by ultrasonic thickness gage UT-301 according to GOST 28702-90. The converter is of 5B12/2-5.0 MHz type. The main material of the pipe with $\varnothing 32 \times 3.0$ diameter is (Steel 10, GOST 1050-88). When measuring, the “echo” principle is used, i.e. the searcher and receiver are combined in one tester. The activated ultrasonic signals reach the internal pipe surface and are reflected by the receiver, knowing the propagation velocity and the time of passage of ultrasound on the metal, we have determined the wall thickness.

The layout of the measurement points in the apparatus is shown in figure 2. The apparatus is made of a 32 mm pipe, its wall thickness is 3mm, two angles of 90° , one angle is 135° , one angle is 120° , the sharp angle is 35° . The length of the upper pipe is 120 cm, the height is 35 cm, the lower length of the pipe is 36 cm, the angle from this segment is 135° . The apparatus consists of five pipe sections. Its perimeter is 296 cm.

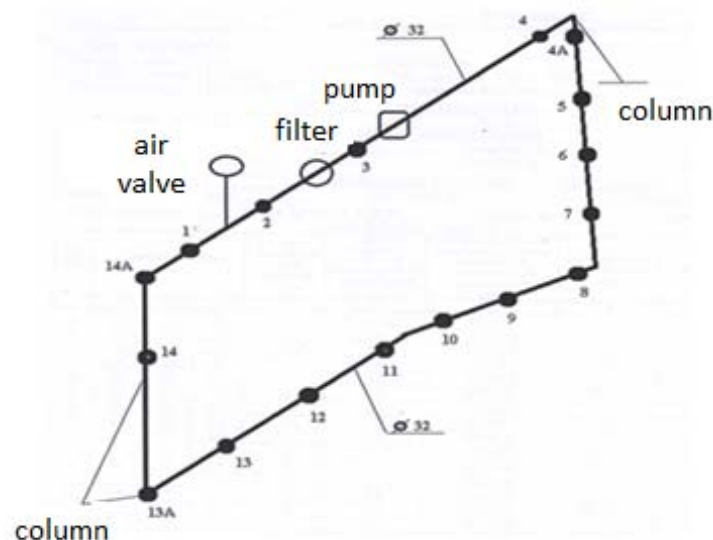


Figure 2 – The layout of the measurement points in the apparatus

Results and discussion. The apparatus was switched on in May 2017. There is a pump in the middle of the upper part that distills the salt solution. The pump is switched on via the time relay, it works continuously for 1 hour, stops for 20 minutes. The thickness of the pipe wall at 17 points was measured after 3 months (table 1), 8 months (table 2) and 1 year (table 3). The thickness of the pipe wall was measured in the laboratory of ultrasonic testing (Testing laboratory of PKF FAN LLP, Taraz, Accreditation certificate N° KZ.I.08.1791).

Table 1 – The results of measuring the thickness of the steel pipes walls subjected to internal corrosion (August, 2017)

N	Measurement value (mm)			Mean value of three measurements (mm)	Thickness of the wall taking into account measurement errors (mm)	Initial thickness of the wall and diameter of measured elements (mm)	Retirement size (mm)	Notice
1	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	pipe
2	3.1	3.0	3.1	3.1	3.0	Ø32x3.0	$\delta = 1.53$	- // -
3	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
4	3.0	3.1	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
4A	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
5	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
6	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
7	3.1	3.0	3.1	3.1	3.0	Ø32x3.0	$\delta = 1.53$	- // -
8	2.7	2.7	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
9	2.7	2.8	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
10	2.9	2.8	2.9	2.9	2.9	Ø32x3.0	$\delta = 1.53$	- // -
11	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
12	3.1	3.0	3.1	3.1	3.0	Ø32x3.0	$\delta = 1.53$	- // -
13	2.7	2.7	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
13A	2.7	2.7	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
14	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
14A	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -

Table 2 – The results of measuring the thickness of the steel pipes walls subjected to internal corrosion (February, 2018)

N	Measurement value (mm)			Mean value of three measurements (mm)	Thickness of the wall taking into account measurement errors (mm)	Initial thickness of the wall and diameter of measured elements (mm)	Retirement size (mm)	Notice
1	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	pipe
2	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
3	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
4	2.9	2.9	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
4A	2.2	2.3	2.2	2.2	2.1	Ø32x3.0	$\delta = 1.53$	- // -
5	2.4	2.3	2.3	2.3	2.2	Ø32x3.0	$\delta = 1.53$	- // -
6	2.9	3.0	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
7	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
8	2.4	2.3	2.4	2.4	2.3	Ø32x3.0	$\delta = 1.91$	- // -
9	2.7	2.8	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.91$	- // -
10	2.8	2.9	2.8	2.8	2.7	Ø32x3.0	$\delta = 1.91$	- // -
11	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.91$	- // -
12	3.0	2.9	3.0	3.0	2.9	Ø32x3.0	$\delta = 1.53$	- // -
13	2.7	2.6	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
13A	2.4	2.5	2.5	2.5	2.4	Ø32x3.0	$\delta = 1.53$	- // -
14	2.4	2.5	2.4	2.4	2.3	Ø32x3.0	$\delta = 1.53$	- // -
14A	2.3	2.3	2.4	2.3	2.2	Ø32x3.0	$\delta = 1.53$	- // -

Table 3 – The results of measuring the thickness of the steel pipes walls subjected to internal corrosion (May, 2018)

N	Measurement value (mm)			Mean value of three measurements (mm)	Thickness of the wall taking into account measurement errors (mm)	Initial thickness of the wall and diameter of measured elements (mm)	Retirement size (mm)	Notice
1	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	pipe
2	2.9	2.9	2.8	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
3	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
4	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
4A	2.2	2.1	2.1	2.1	2.0	Ø32x3.0	$\delta = 1.53$	- // -
5	2.1	2.2	2.2	2.2	2.1	Ø32x3.0	$\delta = 1.53$	- // -
6	2.6	2.7	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
7	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
8	2.4	2.3	2.3	2.3	2.2	Ø32x3.0	$\delta = 1.91$	- // -
9	2.7	2.8	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.91$	- // -
10	2.7	2.7	2.6	2.7	2.6	Ø32x3.0	$\delta = 1.91$	- // -
11	2.8	2.7	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.91$	- // -
12	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
13	2.8	2.7	2.7	2.7	2.6	Ø32x3.0	$\delta = 1.53$	- // -
13A	2.4	2.5	2.4	2.4	2.3	Ø32x3.0	$\delta = 1.53$	- // -
14	2.9	2.8	2.9	2.9	2.8	Ø32x3.0	$\delta = 1.53$	- // -
14A	2.2	2.2	2.3	2.2	2.1	Ø32x3.0	$\delta = 1.53$	- // -

Analysis of tables 1–3 shows that at the points of measurement – N^o. 4A, 8, 13A, 14A, where the turning angles are sharp or equal to 90°, the wall thickness has significantly decreased. This shows that on the curved sections of steel pipes, corrosion propagates more strongly than on the straight sections, which in turn confirms the corrosion propagation mechanism proposed by us.

Corrosion inside steel pipes begins, as we established earlier [21, 22], in the damaged areas. These areas with defects, non-uniformities, dislocations and cracks in steel structures, damage the ferromagnetic properties of steel. They, in turn, damage the domain structure of steel, and between the domains Cl⁻ ions are attracted to the south poles, and Na⁺ ions are attracted to the north poles, and thus corrosion begins, i.e. chemical process.

The pipe thickness in the first section decreased by 0.1 mm at the first measurement and the corrosion propagation velocity was equal to $\frac{0.1}{0.25} = 0.4 \text{ mm / year}$. The corrosion propagation velocity in the second measurement was equal to zero. The corrosion propagation velocity in the third measurement was equal to $\frac{0.1}{0.353} = 0.3 \text{ mm / year}$. The average corrosion propagation velocity in the steel pipes with the straight section was equal to $\frac{0.2}{1} = 0.2 \text{ mm / year}$. After mathematical processing of thickness measure-

ment results, we determined the corrosion propagation velocities in the steel pipes of the experimental apparatus on its straight sections, which are shown in figure 3.

At first straight sections of the steel pipes, the corrosion first developed actively, and then its propagation velocity slowed down. Then after a certain time, the corrosion propagation resumed. The resulting phenomenon is explained by the fact that when the ions passed through the cracks of domains after the first measurement, products of chemical reaction – micelles (chemical corrosion product) [23] formed and filled the cracks of domains, thereby reducing the corrosion propagation velocity.

The average corrosion propagation velocity on the curved sections of the steel pipes of hydraulic engineering structures (figure 4) equal to 0.375 mm/year.

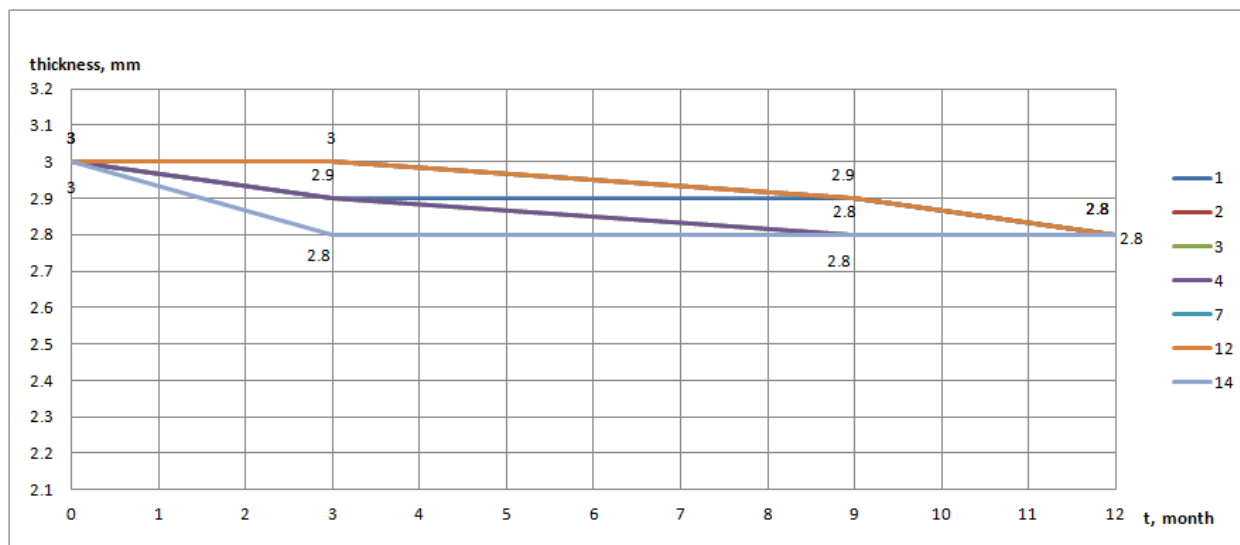


Figure 3 – Dependence of the pipe wall thickness on the residence time in the corrosive medium on the straight sections.
The numbers correspond to the measurement points on the experimental apparatus

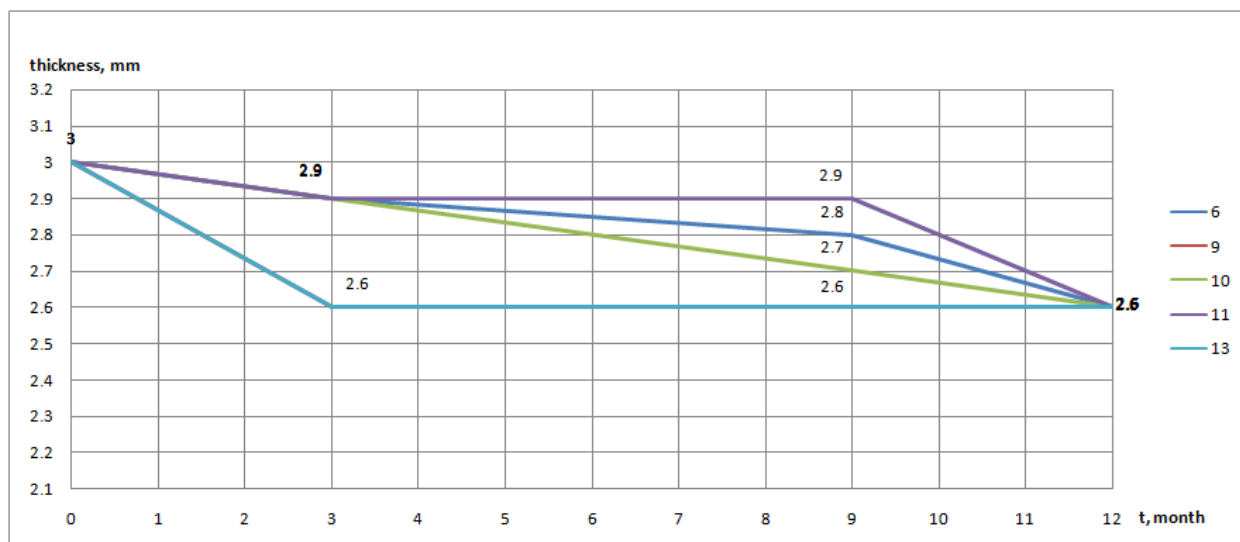


Figure 4 – Dependence of the pipe wall thickness on the residence time in the corrosive medium on the curved sections.
The numbers correspond to the measurement points on the experimental apparatus

The obtained value in comparison with the straight section of the steel pipes increased by 80.5%. This phenomenon is explained by the fact that when turning the steel pipes, the liquid under the action of centrifugal forces hits the walls and wash out the micelles, and therefore the physical process does not stop, affecting the corrosion propagation velocity.

The average corrosion propagation velocity at the turns of the steel pipes of hydraulic engineering structures equal to 90° and is shown in figure 5 and equal to 0.833 mm/year.

The obtained value in comparison with the square section of the steel pipes increased by 416.5%. This phenomenon is explained by the fact that when turning by 90°, the liquid completely breaks its structure, and the number of ions in the liquid increases in proportion to the ratio of the cylinder volume to its perimeter.

Thus, we obtained results showing that location of the steel pipes of hydraulic engineering structures affects the corrosion propagation velocity inside the pipes. This phenomenon was not taken into account when designing the steel pipes of hydraulic engineering structures, and reliability of the steel pipes depends on their location in space. In practice, elements of metal structures are designed to be equal in

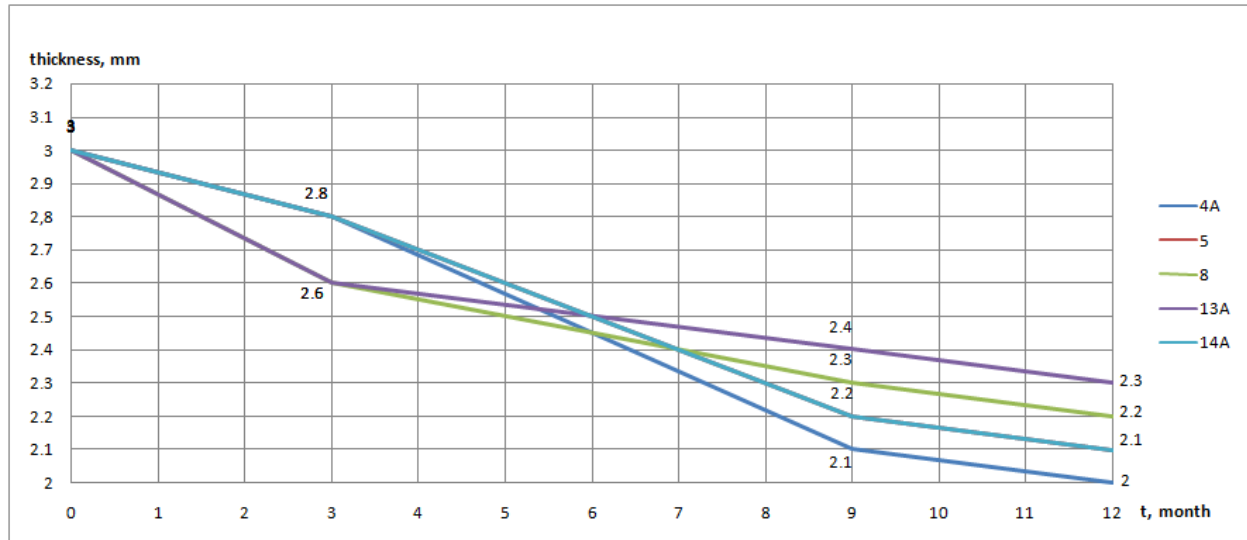


Figure 5 – Dependence of the pipe wall thickness on the residence time in the corrosive medium on the square sections.
The numbers correspond to the measurement points on the experimental apparatus

strength, while elements of metal structures of hydraulic engineering structures should be designed to have the same reliability and ensure trouble-free operation.

Calculation of tubular metal structures of hydraulic engineering structures is carried out according to the well-known formula of Laplace [24]:

$$\frac{\sigma_1}{r_1} + \frac{\sigma_2}{r_2} = pt, \quad (2)$$

where σ_1 - meridian stress; σ_2 - circular stress; r_1 - meridian radius; r_2 - radius of curvature in the circular direction; p - pressure inside the pipe; t - thickness of the pipe walls.

The second component stress acting along the meridian direction is also determined for the pipes by the formula [24]:

$$\sigma_1 = \frac{p}{2t}, \quad (3)$$

The pipes are in a plane stressed state, and the strength is tested by the following formula [24]:

$$\sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2} \leq R_y \frac{\gamma_c}{\gamma_n}, \quad (4)$$

where R_y - design strength of the steel, established by the yield point; γ_c - service factor; γ_n - reliability factor.

The calculation made by this formula does not ensure trouble-free operation of the pipes of hydraulic engineering structures, since it does not take into account the corrosion propagation inside the pipe [25].

Conclusions. The results of the above studies carried out by us in laboratories of M.Kh. Dulati Taraz State University showed that the pipes can lose their performance due to the corrosion. Pipes having turning angles, especially when they turn at the angle of 90°, may lose their trouble-free operation earlier than the pipe sections having straight sections.

To eliminate this phenomenon, it is necessary to take measures ensuring equal reliability of all sections of tubular steel structures of hydraulic engineering structures, thus ensuring their trouble-free operation.

In our opinion, the following measures should be taken:

- thicken pipes at the turning points;
- periodically paint pipes at the turning points;
- use in the turning points of pipes, steel of corrosion-resistant properties grades;
- continue to study the corrosion propagation on the curved sections of the steel pipes.

С. Орынбаев¹, Е. Аманбаев¹, Б. Алимбаев¹, Б. Манапбаев¹, С. Беглерова¹, Б. Мыктыбеков²

¹ М. Х. Дулати атындағы Тараз мемлекеттік университеті, Тараз, Қазақстан,

²Авиациялық мотор құрылысы Орталық институты, Мәскеу, Ресей

БОЛАТ ҚҰБЫРЛАРДЫҢ БҰРЫЛЫСТАРЫНДАҒЫ ІШКІ ТОТЫҒУДЫҢ ДАМУ ЕРЕКШЕЛІКТЕРІ

Аннотация. Дүниежүзінде металлдарды тоттанудан қорғау кешенді шешімдерді талап ететін өзекті мәселелердің бірі. Осы саладағы зерттеулердің басты мақсаты металл құбырларының, жабдықтардың, құрылымдардың машина бөлшектерінің және т.б. механизмдердің тоттығу салдарынан келетін экономикалық шығындарды төмендету, агрессивті ортада жұмыс жасайтын қондырғылардың сенімділігін арттыру және металл қорын сақтау болып табылады. Жыл сайын бүкіл әлемде металдар өндірісінің өсуі байқалады және олардың жұмыс істеуіне талаптар жоғарлауда. Бұл көп металдық жабдықтардың агрессивті орталарда жұмыс жасауында. Сондықтан металл жабдықтарды коррозиядан қорғау мәселелері өзекті болып табылады. Металлдардың тоттануына жол бермеу мүмкін емес, бірақ коррозияның дамуын бәсеңдету жолдарын табуға болады. Ол үшін металл конструкцияларындағы коррозияның дамуын зерттеу қажет. Бұл мақалада болат құбырдың түрлі бөліктеріндегі коррозиялық процестердің дамуы қарастырылады. Коррозияның дамуы туралы зерттеулер түрлі мақсаттағы болат құбырлардың қысық бөліктеріндегі коррозияның түзу бөліктеріне қарағанда қарқынды өсуін көрсетеді.

Түйін сөздер: тоттану, болат құбыр, Лоренц күші, ішкі тоттану.

С. Орынбаев¹, Е. Аманбаев¹, Б. Алимбаев¹, Б. Манапбаев¹, С. Беглерова¹, Б. Мыктыбеков²

¹Таразский государственный университет им. М. Х. Дулати, Тараз, Казахстан,

²Центральный институт авиационного моторостроения, Москва, Россия

ОСОБЕННОСТИ РАЗВИТИЯ ВНУТРЕННЕЙ КОРРОЗИИ НА УГЛАХ ПОВОРОТОВ В СТАЛЬНЫХ ТРУБАХ

Аннотация. В мире защита металлов от коррозии является одной из актуальных проблем, требующих комплексного подхода по их решению. Основная задача исследований в этой сфере – это уменьшение экономических потерь в результате коррозии трубопроводов, оборудования, механизмов, конструкции, деталей машин и т.д., повышение надежности оборудования, которое соприкасается с агрессивной средой и сохранность металлического фонда. С каждым годом во всем мире наблюдается рост производства металлов, и требования к условиям их эксплуатации становятся выше. Это связано с тем, что все больше металлическое оборудование работает в условиях агрессивных сред. Поэтому вопросы защиты металлического оборудования от коррозии становятся более актуальными. Полностью предотвратить коррозионные процессы в металлах невозможно, но можно найти способы замедления развития коррозии. Для этого надо исследовать пути развития коррозии в металлических конструкциях. В данной статье рассматривается развитие коррозионных процессов на различных участках стального трубопровода. Исследования за развитием коррозии показали, что на криволинейных участках стальных труб различного назначения развитие коррозии происходит более интенсивнее, чем на прямолинейных участках.

Ключевые слова: коррозия, стальные трубы, сила Лоренца, внутренняя коррозия.

Information about authors:

Orynbayev Seitzhan, PhD, associate professor of the Department of «Power engineering», M. Kh. Dulaty Taraz state university, Kazakhstan; seitzhan_74@mail.ru; <https://orcid.org/0000-0002-5077-7219>

Amanbayev Erkegali, PhD student, M. Kh. Dulaty Taraz state university, Kazakhstan; amanbaev@mail.ru; <https://orcid.org/0000-0001-8391-8359>

Alimbayev Bazartai, doctor of technical sciences, Professor of the department «Building materials and constructions» M. Kh. Dulaty Taraz state university, Kazakhstan; bazalim@mail.ru; <https://orcid.org/0000-0003-2592-6400>

Manapbayev Bauyrzhan, candidate of technical sciences, associate professor of the Department of «Oil and gas engineering» M. Kh. Dulaty Taraz state university, Kazakhstan; jiboj@mail.ru; <https://orcid.org/0000-0001-9140-178X>

Beglerova Svetlana, candidate of technical sciences, associate professor of the Department of «Applied informatics and programming», M. Kh. Dulaty Taraz state university, Kazakhstan; sbeglerova@mail.ru; <https://orcid.org/0000-0003-2854-7318>

Myktybekov Bahitzhan, candidate of technical sciences, Chief of Sector of «Mathematical Simulation of Life Cycle of Details and Nodes of Aircraft Engines», Central Institute of Aviation Engine, Moscow, Russia; bahit12@mail.ru; <https://orcid.org/0000-0002-5298-7519>

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K. K. Kombayev¹, M. V. Doudkin¹, A. I. Kim¹, M. Mlynczak², B. K. Rakhadilov³

¹D. Serikbayev East Kazakhstan state technical university, Ust-Kamenogorsk, Kazakhstan,

²Wroclaw university of science and technology, Poland,

³S. Amanzholov East Kazakhstan state university, Ust-Kamenogorsk, Kazakhstan

SURFACE HARDENING OF THE ALUMINUM ALLOYS AL3 BY ELECTROLYTIC-PLASMA TREATMENT

Abstract. The article presents the research results of the effect of electrolytic-plasma processing on the structural-phase transformation of aluminum alloy samples. The discharge was ignited from the DC source. When the voltage is switched on, ionization and boiling of the electrolyte occurs. When bubble boiling occurs around the active electrode, large current pulsations are observed. Due to the formation of a gas-vapor jacket and the passage of electric current through it, a low-temperature plasma is formed, which has the characteristic blue color of the glow of the shell around the part. Electric micro-arc plasma is excited on the surface of the product, in which an intense heating of the workpiece occurs from heat generation. After microarc oxidation, the microstructure of quenching and artificial aging in the electrolyte flow is observed on the sample surface. As a result of quenching in the electrolyte stream, solid copper solution in aluminum and pinpoint fine inclusions dissolve from the microplasma temperature, the phases oxidize to form aluminum corundum. X-ray analysis of the samples after electrolytic-plasma processing revealed an increase in the intensity and broadening of the diffraction lines relative to the initial state, which indicates the residual surface stress, which during operation provides an increase in the wear resistance of the part. The average microhardness, after electrolytic-plasma treatment, is 746 MPa, which is about 2.5 times higher than that of the starting material.

Key words: aluminium, electrolyte-plasma treatment, micro-arc oxidization, microstructure.

1. Introduction. As it is known quenching is used for hardening aluminum alloys. Tempering is heating alloy to a temperature at which excessive intermetallic phases completely or predominantly soluble in aluminum. Exposure at this temperature and rapidly cooled to normal temperature allows obtaining a supersaturated solid solution. The heating temperature for quenching is selected depending on the nature of the alloy satisfying the mechanical property requirements for the part. Temperature of quenching alloy system Al-Cu (figure 1) defined by a line abs limiting solubility line passing above for alloys containing less than 5,7% Cu, and below the eutectic line (548 °C) for alloys containing greater amounts of copper [1].

High temperatures cause burnout (melting along the grain boundaries), which leads to cracking, reduced corrosion resistance, mechanical properties and resistance to brittle fracture. Quenching is followed by aging, where the alloy is kept at normal temperature for several days (natural aging) or for 10-24 hours at 150-200 °C elevated temperature (artificial aging) [2].

However, surface oxidized with aging after the quenching, it requires machining and as a result, coatings do not provide high surface wear resistance.

2. Research method. Micro plasma coating is applied to a very narrow range of materials [3]. And overwhelmingly is directed to obtaining a durable and wear resistant oxide layer on the anode surface of aluminum and its alloys [4]. At the same time, the potential of this method has not yet been disclosed, due to the poor knowledge of laws of formation of micro plasma discharges on the surface of the anode and the cathode in different electrolytes and their impact on the structure and properties of the surface of the

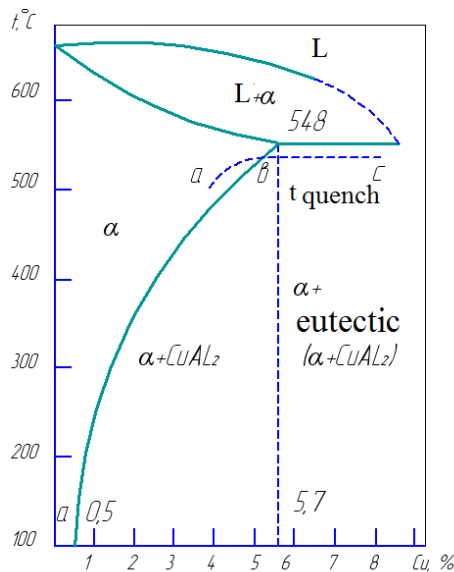


Figure 1 – The phase diagram of Al-Cu: dashed line is quenching temperature

electrodes. To develop the technology of applying various coatings on the surface of the work piece using micro plasma discharges in electrolytes requires studying the patterns of their formation and effects on the surface of the cathode [5]. It is known alternative device for micro-arc oxidation (MAO) wells gear pump housing made of aluminum alloy. The strongest structural hardening of aluminum alloys is shown at micro-arc oxidation [6].

To study the micro-arc oxidation samples measuring $10 \times 10 \times 20$ mm (figure 2) was cut out of aluminum alloy A3 GOST2685-75, diamond disc, 1 mm thick, which is immersed in the coolant. At small cutting speed $n = 350$ r / min, and low load, $m = 250$ g, the sample does not undergo thermal deformation [7].

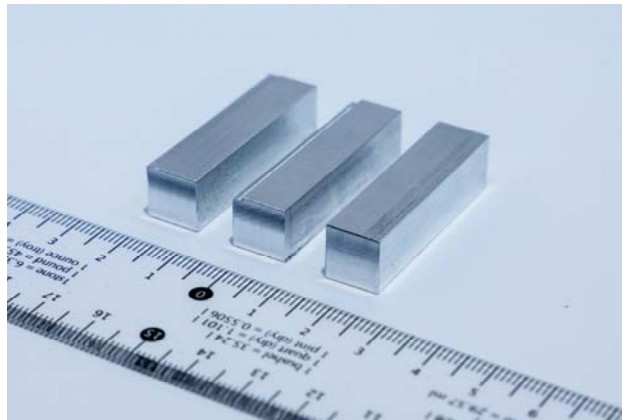


Figure 2 – Pieces for micro arc oxidation

Experimental studies and mechanical tests were carried out in the Regional university laboratory of engineering profile "IRGETAS" D.Serikbaev EKSTU (Ust-Kamenogorsk), Science, and Technology Park "Laboratory of engineering profile". K.I. Satpayev KazNTU (Almaty) [8]. The elemental composition of the aluminum piece was examined in a scanning electron microscope JSM-6390LV - company JEOL (Japan), prefixed energy dispersive microanalysis INCA Energy company «OXFORD Instruments» [9]. Defined elements from boron to uranium. The qualitative and quantitative phase analysis of the structure of aluminium alloy piece was carried out on the X-ray diffractometric DRON-3 in the filtered radiation of a copper anode, as «X'Pert PRO» company «PAN analytical», using Cu-K α radiation [10].

3. Research results and discussion. The discharge was ignited by a constant current source. Scheme of constant current source (figure 3a), which consists of push-button station, the starter, the diode

bridge, throttle, machine, ammeter, voltmeter, and other electrical appliances [11]. Cathode is a piece of aluminum (AL 3: 1,5-3,0 Cu; 0,35-0,6 Mg; 4,5-5,5 Si; 0,6-0,9 Mn), submerged to a depth of 4-6 mm in the electrolyte - 10% aqueous Na_2CO_3 solution [12].

It should be noted that the quality of the surface layer, which was obtained using micro-arc oxidation, depends on the process conditions largely. The power of the spark discharges and accordingly energy impact on reinforcing surface are depending on them. When the voltage is turned on the surface of the exciting electric micro-arc (figure 3b), in which heat comes from the intense heating of the work piece.

As the applied constant voltage smoothly increases the salt is electrolyzing, with this process, according to Ohm's law, amperage increases too (section 0-A, figure 4). For this section: with increasing of the voltage, amperage increases proportionally. With this process electrolyte's temperature is increasing too, which is the consequence of the current passing through the electrolyte.

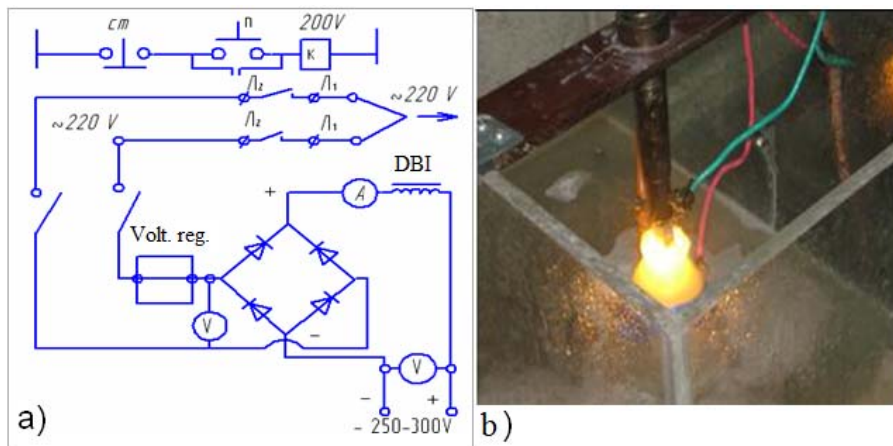


Figure 3 – Scheme of a constant current source for micro arc oxidation of aluminum alloys:
a - electro scheme of constant current source; b - micro arc aluminum oxidation

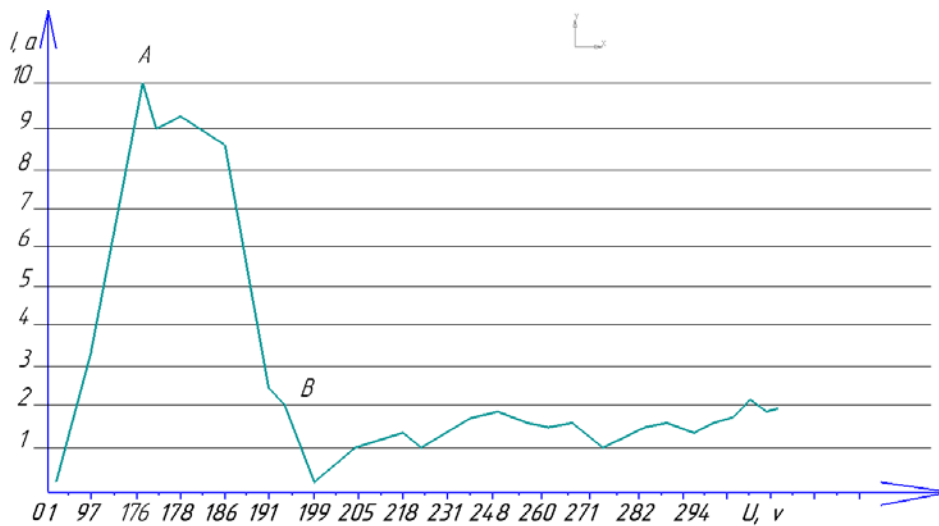


Figure 4 – Voltage-current characteristic of the electrolytium-plasma treatment

After reaching the particular value of voltage (100-180V) on the surface of detail's cathode the electrolyte starts boiling, blisters start actively appear on the surface (nucleate boiling). Nucleate boiling is type of boiling, when detail's temperature is close to the boiling point of water. When this process occurs, the high ripple current around the active electrode is observed. Their amplitude is significantly reduces, when detail heats up to 470°C. With further increasing of rectified voltage film boiling occurs (point A, figure 4), for which it is significant that nucleate boiling is vanishing and quick amperage slump, because

formed gas-steam envelope has higher resistance than liquid electrolyte (section A-B, figure 4). Since gas-steam envelope is less electroconductive, main voltage drop occurs in the zone, where the most heat is released. Because of the forming of gas-steam envelope and current passing through it, low temperature plasma is formed, which has blue envelope glow around the detail. The brighter blue glowing is, the more ions it has, including ion modifiers. With the further increasing of voltage the forming of anomalous discharge is observed.

Experiments have established the optimal modes of micro-arc oxidation of aluminum: voltage $U = 200$ V, the current $I = 10$ A, the heating time $t = 4$ s., quenching time $t = 4$ sec., the total number $n = 15$ cycles [13].

An anode having a disk shape 50 mm diameter, 2 mm thick, with holes drilled $\varnothing 4$ mm 12X18H10T made of stainless steel [14]. Micro arc occurs between the cathode and a liquid electrolyte [15]. Of particular influence on the structural transformation has intermittent fever, when you connect the power supply, which rises above the phase $\alpha \rightarrow L$ -conversion (548°C). After the power supply goes off micro-arcs that provides access to the electrolyte reheat alloy and rapid cooling (quenching).

The aluminum alloy structure present in equilibrium grain which is a solid solution (figure 5 a), which is composed of copper, manganese and magnesium, disperse the inclusion Mg_2Si .

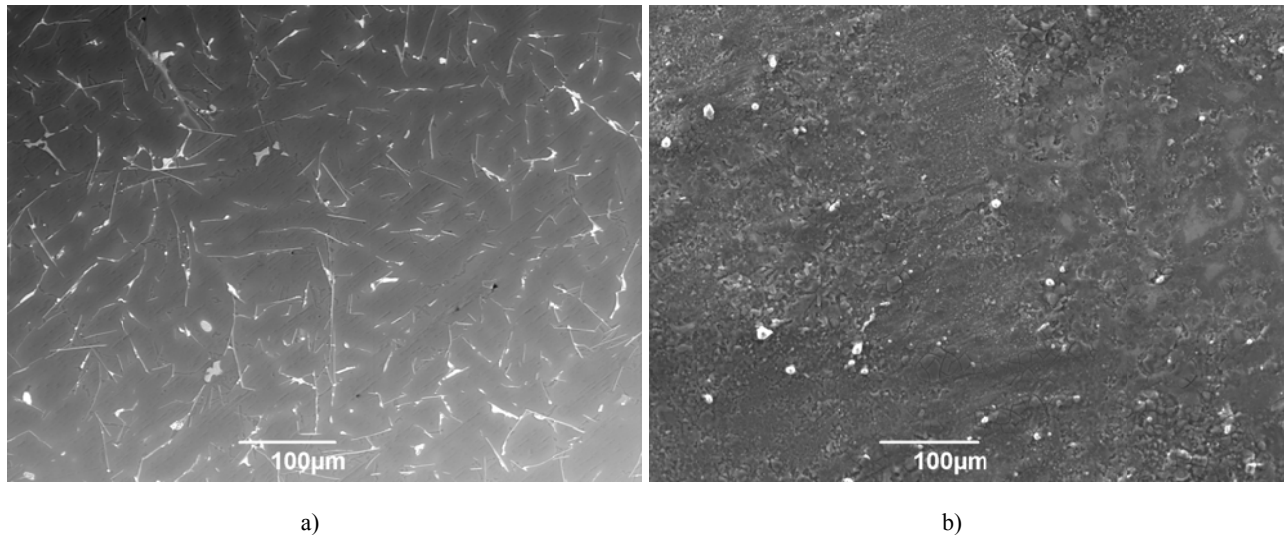


Figure 5 – The microstructure of aluminum alloy AL3:
a - in the initial state; b - after the micro arc oxidation

After the micro-arc oxidation observed microstructure of hardening and artificial aging of the electrolyte stream (figure 5 b). As a result of quenching the solid α - a solution of copper in aluminum and spot finely divided inclusions are dissolved by micro plasma temperatures, these phases are oxidized to form alumina corundum [16]. The results of elemental analysis after the micro-arc oxidation (table 1) indicate the appearance of oxygen and the inclusion of the relevant elements of the reinforcing aluminum alloy. Inclusions were allocated from α -solid solution during artificial aging. After aging, the aluminum surface layer is oxidized. Elements standing out in a dispersed form strengthens the alloy. It can be detected CuAl_2 particles and magnesium particles.

Table 1 – The elemental composition of the aluminum after MAO (to figure 5 b)

Spectrum	O	Na	Al	Si	Cu	Total
Spectrum 1	2.58	–	97.42	–	–	100.00
Spectrum 2	4.95	0.32	93.49	0.76	0.48	100.00

(All results in weight %)

To identify the structural and phase transformations of aluminum as a result of thermal effects micro-arc oxidation held X-ray analysis [17]. X-ray diffraction analysis of samples of aluminum in the initial state and after the delivery of micro-arc oxidation (figure 6) revealed the presence of lines α - phase based on Al.

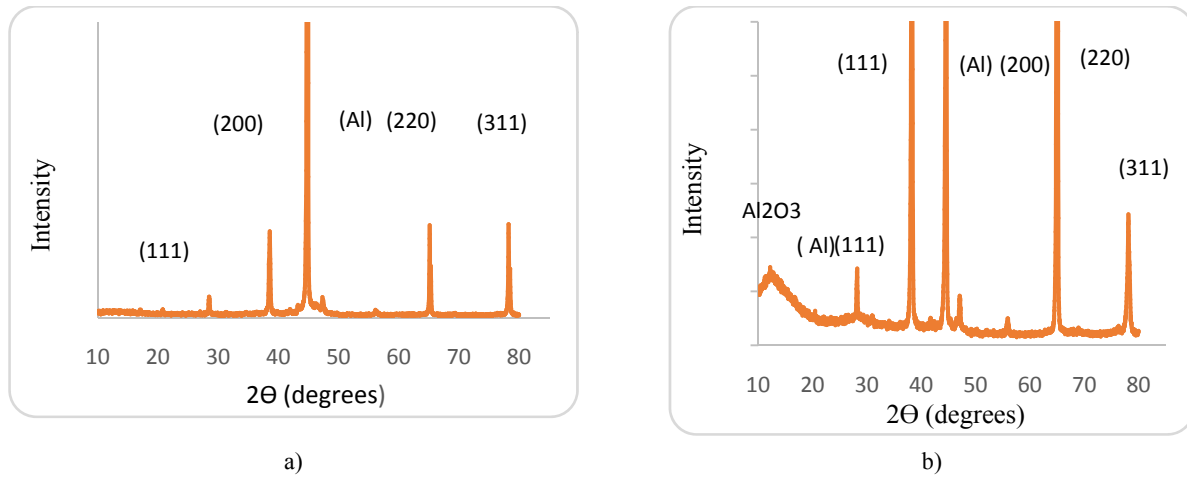


Figure 6 – X-ray diffraction pattern of an aluminum alloy:
a) in the initial state, b) after the micro arc oxidation

After the micro-arc oxidation observed increase in the intensity and broadening of diffraction lines (figure 6 b) with respect to the initial state (figure 6 a), which indicates that the surface of the residual voltage, which is in service enhances the quality of the details. To determine the phase composition of the aluminum alloy sample treated with micro-arc oxidation implemented computerized statistical processing of results [18]. X-ray diffraction analysis of the pieces showed the presence of aluminum oxide phases. The values of the interplanar distances show that the angular position of the diffraction lines of samples does not fully coincide, and their intensity are significantly different (table 2).

Table 2 – phase composition of the aluminum piece after mao

№	I, mm	2 θ , degree	θ , degree	Sin θ	d/n, Å	I, %	d/n, Å	I, %	Hkl	d/n, Å	I, %	Hkl
1	680	38.64	19.32	0.3308	2.330	100	2.338	100.0	111	2.315	45	401
2	56	44.84	22.42	0.3814	2.021	8.0	2.024	47.0	200	2.019	45	112
3	50	65.3	32.65	0.5395	1.429	7.0	1.431	22.0	220	1.426	10	710
4	11	78.42	39.21	0.6322	1.219	2.0	1.221	24.0	311			
5	10	82.58	41.29	0.6599	1.168	1	1.169	7	222			
6	7	112.2	56.1	0.8300	0.929	1	0.929	8	331			
7	7	116.62	58.31	0.8509	0.906	1	0.905	8.0	420			

Notes: I, mm – intensity of diffraction lines; 2 θ – angle according to diffractometer goniometer; θ – angle of diffraction; sin θ – θ angle's sine; d/n, Å – distance between grids of direct diffraction grating hkl; I, % – intensity of diffraction lines in percents; d – interplanar distance; n – order of reflections from the system of grids (hkl); hkl – indices of diffraction lines (Miller Indices).

This may be due to the fact that internal stress arises in the processing of the high temperature of plasma [19]. The sources of stress are the temperature gradients in the cross section; heterogeneity of the chemical composition; structural imperfections; different crystal orientation in space; different specific volume and different coefficients of linear expansion phases [20].

The micro hardness increased in all modes of processing micro-arc oxidation of aluminum alloy. The average micro hardness reached at micro-arc oxidation is 746 MPa (table 3), which is about 2.5 times higher than that of the starting material (figure 7).

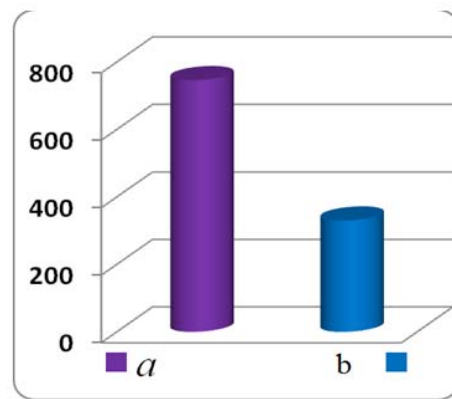


Figure 7 – the average value of micro hardness

Table 3 – Results of micro hardness after MAO

№	z1	z3	z2	z4	zr	zb	z	d	H, MPA	L, mkm	H _{avrg}	H _{avrg} -H	(H _{avrg} -H) ²
1	250	408	172	325	158	153	155.5	34.21	777.56	0	746	-32.06	1027.89
2	250	411	160	320	161	160	160.5	35.31	729.87	100		15.63	244.33
3	250	412	161	320	162	159	160.5	35.31	729.87	200		15.63	244.33
4	250	407	164	322	157	158	157.5	34.65	757.94	300		-12.44	154.71
5	250	405	163	325	155	162	158.5	34.87	748.41	400		-2.90	8.44
6	250	407	160	324	157	164	160.5	35.31	729.87	500		15.63	244.33
7	250	410	160	323	160	163	161.5	35.53	720.86	600		24.64	607.21
8	250	410	163	320	160	157	158.5	34.87	748.41	700		-2.90	8.44
9	250	409	164	318	159	154	156.5	34.43	767.66	800		-22.16	490.87
10	250	408	164	322	158	158	158	34.76	753.15	900		-7.65	58.51
11	250	411	164	322	161	158	159.5	35.09	739.05	1000		6.45	41.61
12	250	410	163	321	160	158	159	34.98	743.71	1100		1.79	3.22
13	250	407	161	320	157	159	158	34.76	753.15	1200		-7.65	58.51
14	250	409	162	324	159	162	160.5	35.31	729.87	1300		15.63	244.33
15	250	408	163	321	158	158	158	34.76	753.15	1400		-7.65	58.51

Notes: z₁, z₃, z₂, z₄, z_r, z_b, z – alculated parameters for determination of imprint's diagonals; d – length of imprint's diagonal of diamond pyramid on the sample's surface, mkm; h, MPa – microhardness value; L, mkm – distance between imprints of diamond pyramid; H_{avrg} – average hardness value; H_{avrg}-H – deviation from average microhardness value; (H_{avrg}-H)² – standard deviation.

After the micro-arc oxidation observed increase in the micro hardness values (figure 7) with respect to the initial state, which certainly improves the performance of aluminum alloy parts [21].

4. Conclusion.

1. Studies show that micro-arc oxidation under certain conditions leads to an increase in the strength properties of aluminum alloys.

2. It is found that the structural phase transformation toughening of aluminum alloys at micro-arc oxidation occurs at significantly lower energy consumption as compared to conventional heat treatment.

3. For hardening an aluminum alloy instead of traditional heat treatment, an alternative electrolytic-plasma hardening technology was proposed. Samples of aluminum alloy AL3 GOST2685-75 were subjected to cyclic heating from the temperature of microplasma and quenched in a stream of electrolyte. Heating, to the temperature of structural phase transformations, occurs at a significantly lower energy consumption compared with traditional heat treatment.

4. Experimentally established the optimal modes of microarc aluminum oxidation: power supply voltage $U = 200$ V, current $I = 10$ A, heating time $t = 2$ sec., Hardening time $t = 24$ sec., The total number of cycles $n = 15$. Pre-established the dependence of the heating temperature on the heating, cooling and voltage times which is expressed by the formula: $T = 4.5 \times t_2 \text{ nag.} + 4.8 \times U - 18 \times t_1$. After microarc oxidation, the microstructure of quenching and artificial aging in the electrolyte flow is observed.

5. As a result of quenching, solid α is a solution of copper in aluminum and dotted fine inclusions dissolving from microplasma temperature, these phases, when oxidized, form aluminum corundum.

6. X-ray analysis of the samples after electrolytic-plasma processing revealed an increase in the intensity and broadening of the diffraction lines relative to the initial state, which indicates the residual surface stress, which during operation provides an increase in the wear resistance of the part.

7. The average microhardness, after electrolytic-plasma treatment, is 746 MPa, which is about 2.5 times higher than that of the starting material.

К. К. Комбаев¹, М. В. Дудкин¹, Ф. И. Ким¹, М. Млынчак², Б. К. Рахадиллов³

¹Д. Серикбаев атындағы Шығыс Қазақстан мемлекеттік техникалық университеті, Өскемен, Қазақстан,

²Вроцлавский атындағы ғылым және технологиялар университеті, Польша,

³С. Аманжолов атындағы Шығыс Қазақстан мемлекеттік университеті, Өскемен, Қазақстан

ЭЛЕКТРЛІ-ПЛАЗМАЛЫҚ ӨНДЕУ КЕЗІНДЕГІ AL3 АЛЮМИНИЙ ҚОРЫТПАЛАРЫН БЕТТІК БЕРІКТЕНДІРУ

Аннотация. Мақалада электролитті-плазмалық өндеудің алюминий қорытпасының үлгілеріне құрылымдық-фазалық өзгеру әсерінің зерттеу нәтижелері келтірілген. Разряд тұрақты ток көрегінен тұтандырылған. Кернеуді қосқан кезде электролиттің қайнауы және иондалуы түзіледі. Көпіршікті қайнау кезінде белсенді электрод айналасында үлкен пульсті ток күштері байқалады. Газ-бұлық өрісінің пайда болу нәтижесінде және ток өту нәтижесінде төмен температуралық плазма түзіледі, ол көк түсті сипатқа ие үлгінің айналасында жалындайды. Бөлшектің бетінде электрлік микроплазма туындайды, жылу бөліну әсерінен дайындама белсенді қызады. Микродоғалық тотығудан кейін үлгінің бетінде шыңдалған микроқұрылым байқалады және электролит ағымында жасанды ескіру жүреді. Электролит ағымында шыңдалу нәтижесінде мыстың алюминидегі α қатты ертідісі және ұсақ түйіршікті қосындылар плазма температурасынан еріп тотығады да, алюминий корундын түзеді. Электролитті плазмалық өндеуден кейінгі бастапқы қалпымен салыстырғанда рентгенқұрылымдық талдау дифракциялық сызықтарының ұлғайуының және созылғанын байқатты. Беткі қабатының ішкі кернеуінің нәтижесі эксплуатациялау кезінде беткі төзімділігін қамтамасыз етеді. Электролитті-плазмалық өндеуден кейін орташа микроқаттылығы 746 МПа құрайды, бастапқы қалпынан 2,5 есеге жоғары.

Түйін сөздер: алюминий, электролиттік-плазмалық өндеу, микроарктік тотықтыру, микроқұрылым.

К. К. Комбаев¹, М. В. Дудкин¹, Ф. И. Ким¹, М. Млынчак², Б. К. Рахадиллов³

¹Восточно-Казахстанский государственный технический университет им. Д. Серикбаева, Усть-Каменогорск, Казахстан,

²Вроцлавский университет науки и технологии, Польша,

³Восточно-казахстанский государственный университет им. С. Аманжолова, Усть-Каменогорск, Казахстан

ПОВЕРХНОСТНАЯ ЗАКАЛКА АЛЮМИНИЕВЫХ СПЛАВОВ AL3 ПРИ ЭЛЕКТРО-ПЛАЗМЕННОЙ ОБРАБОТКЕ

Аннотация. В данной статье приведены результаты исследований влияния электролитно-плазменной обработки на структурно-фазовое превращение образцов алюминиевого сплава. Разряд зажигался от источника постоянного тока. При включении напряжения происходит ионизация и кипение электролита. При возникновении пузырькового кипения вокруг активного электрода наблюдаются большие пульсации силы тока. Вследствие образования газопаровой рубашки и прохождения через нее электрического тока образуется низкотемпературная плазма, которая имеет характерный голубой цвет свечения оболочки вокруг детали. На поверхности изделия возбуждается электрическая микродуговая плазма, в которой от тепловыделения происходит интенсивный разогрев заготовки. После микродугового окисливания на поверхности образца наблюдается микроструктура закалки и искусственного старения в потоке электролита. В результате закалки в потоке электролита, твердый α раствор меди в алюминии и точечные мелкодисперсные включения растворяются от температуры микроплазмы, фазы окисляясь, образуют корунд алюминия. Рентгеноструктурный анализ образцов после электролитно-плазменной обработки выявил увеличение интенсивности и уширение дифракционных линий относительно исходного состояния, что свидетельствует об остаточном напряжении поверхности, которая в процессе эксплуатации обеспечивает повышение износостойкости детали. Средняя микротвердость, после электролитно-плазменной обработки, составляет 746 МПа что примерно в 2,5 раза выше, чем у исходного материала.

Ключевые слова: алюминий, электролитно-плазменная обработка, микродуговое окисление, микро-структура.

Information about authors:

Kombayev Kuat Kurganovich, Candidate of technical sciences, associate professor of the department "Mechanical engineering", D. Serikbayev East Kazakhstan state technical university, Ust-Kamenogorsk, Kazakhstan; kombayev82@mail.ru; <https://orcid.org/0000-0002-3979-6689>

Mikhail Vasilyevich Doudkin, Doctor of technical sciences, professor, dean of the faculty of engineering at D. Serikbayev EKSTU; doudkin@mail.ru; <http://orcid.org/0000-0001-5732-0724>

Kim Alina Igorevna, PhD, associate professor of the department "Technological machines and transport" D. Serikbayev Ekstu; k.a.i.90@mail.ru; <https://orcid.org/0000-0002-9332-4279>

Mlynczak Marek, Hab. Dr., professor of Wroclaw university of science and technology, Poland; mlymar@gmail.com; <https://orcid.org/0000-0002-1134-3477>

Rahadilov Baurzhan Korabayevich, Doctor PhD, head of the National scientific laboratory for collective use of the S. Amanzholov EKSU; rahadilovb@mail.ru; <https://orcid.org/0000-0001-5990-7123>

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Vasyl Popovych, Andriy Voloshchyn

Lviv state university of Life Safety, Lviv, Ukraine.

E-mail: popovich2007@ukr.net

FEATURES OF TEMPERATURE AND HUMIDITY CONDITIONS OF EXTINGUISHING WASTE HEAPS OF COAL MINES IN SPRING

Abstract. Burning of waste heaps of coal mines causes pollution of the environment with toxic gases, increases the temperature of the environment thereby changing the microclimate of the mining area. The purpose of the work is to investigate the temperature and humidity conditions of extinguishing heaps in the spring period in Novovolynsk mining area of Ukraine. The waste heap №1 of mine №9 "Novovolynska" mine were chosen for the research because the combustion processes were observed there in spring.

The following actions are foreseen to implement this goal: to determine the temperature on the surface of the heap and in the places of combustion; to determine relative humidity indicators of the rock at a depth of 5 cm, 30 cm, and 50 cm; to measure the radiation background at the extinguishing heap. The temperature of the surface of the extinguishing heap was determined by the contactless pyrometer NR-1300. Humidity of the rock was measured with a moisture tester MG-44. The radiation background was measured by dosimeter by SOEKS USA, LLC. The software is a package of applications Surfer, MS Excel, MS Visio. Statistical data processing was performed using correlation analysis.

It was found out that: the highest temperature regimes (+ 33-39 °C) was typical for the sites in combustion areas that are located on the middle tier of the southern slope exposure; at a depth of 5 cm the highest humidity was at the foot of the western side of the heap (44.8%); at a depth of 30 cm the highest humidity was at the foot of the western side of the heap (47%); at a depth of 50 cm, the highest humidity was at the foot of the northern side of the heap (55.1%); the highest rates of equivalent radiation dose were observed near the combustion sites of the rock and reached up to 0.18 $\mu\text{Sv} / \text{h}$; the temperature on the surface of the extinguishing heap correlates with a humidity at a depth of 5 cm ($K = -0.58542$), 30 cm ($K = -0.75665$), 50 cm ($K = -0.78303$) and does not depend on the radiation background at all ($K = 0.368116$). With an increase in the rock temperature its moisture decreases and vice versa - at high humidity the temperature of the rock reduces.

Extinguishing heaps are environmentally hazardous as they cause emissions of toxic substances to the environment that do not decrease over the years. Extinguishing heaps due to combustion processes cause the burning of the root system of plants, that leads to the complications of recultivation.

Keywords: waste heap, burning, temperature, environmental safety.

Introduction. Combustion of mines waste heaps causes pollution of the environment with toxic gases, increases the temperature of the environment thereby changing the microclimate of the region [1, 2]. There are numerous scientific works on combustion of waste heaps in the summer and their ecological safety. However, this phenomenon at the initial stage is insufficiently studied.

In the Lviv-Volyn coal basin, which includes the Novovolynsk mining area, rock combustion takes place on operating heaps, heapsof the ChervonogradCentral Mining Enrichment Factory and extinguishing ones [3]. From the point of view of environmental safety, the most dangerous are extinguishing heaps, since combustion processes in them lastfor an average of 20 years and are accompanied by shifts of rock andsubsidences. [4-6]. On the extinguishing heaps vegetation, formed with the participation of zonal vegetation performing aesthetic and buffer functions between combustion products and the environment, develops [7, 8]. Extinguishing heaps are a medium for the development of fungi, invertebrates and some species of animals, which is a positive phenomenon of adaptation of man-made objects to environmental conditions [9].

Investigation of combustion processes on the heaps, where forest vegetation is forming due to natural overgrowing in the spring period, is an up-to-date issue.

Purpose, tasks and methods of research. The purpose of the work is to investigate the temperature and humidity conditions of extinguishing heaps in the spring period in Novovolynsky mining area of Ukraine. The waste heap # 1 of mine №9 "Novovolynska" mine was chosen for the research because the combustion processes were observed there in spring.

The following actions are foreseen to implement this goal:

- to determine the temperature on the surface of the heap and in the places of combustion;
- to determine relative humidity indicators of the rock at a depth of 5 cm, 30 cm and 50 cm;
- to measure the radiation background at the extinguishing heap.

In order to study the temperature and humidity conditions of the heap, 8 study areas were chosen: 1 - at the foot of the northern side of the heap; 2 - on the top of the heap at 59 m; 3 - at the foot of the eastern side of the heap; 4 - at the foot of the western side of the heap; 5, 6, 7 - in the burning places on the southern slope exposition; 8 - at the foot of the south side of the heap. The research was conducted according to approved methods [10-12]. The period of research is April 2017. The average temperature of the environment was +8.1 °C.

The temperature of the surface of the extinguishing heap was determined by the contactless pyrometer NR-1300. Humidity of the rock was measured with a moisture tester MG-44. The radiation background was measured by dosimeter by SOEKS USA, LLC. The software is a package of applications Surfer, MS Excel, MS Visio. Statistical data processing was performed using correlation analysis.

Results and their discussion. Waste heap №1 of the mine №9 "Novovolynska" of the state enterprise "Volynvuhillya" began to operate in 1961, and was completed in 1982.

After the end of waste heap operation, the processes of combustion of the rock refuse are taking place. Intensification of combustion is observed immediately after the snow melting in spring and at the beginning of a fire hazard period. The peak periods of combustion occur in the summer months of July and August. Extremely important is the investigation of temperature and humidity regimes of the waste heap №1 of mine №9 "Novovolynska" in spring, as these regimes directly affect the natural forest-forming processes observed on the surface of the heap and the area of forest re-cultivation in the initial period of plant development. The geometrics of the heap is given in table 1.

Table 1 – Geometric parameters of the waste heap №1 of the mine №9 "Novovolynska"

Parameter	Project	Real situation
Volume, thous. m ³	1430	1050
Height, m	70	59.8
Base area, thous. m ²	61.5	47.1
Pitchangle, degrees	50	40

The control of the thermal condition of the waste heaps is carried out in order to: timely identify the area of self-heating on operating heaps and take measures to prevent self-firing of rocks; evaluation of the effectiveness of measures to reduce the burning rate of waste heaps; obtaining of initial data for the development of projects for the extinguishing or dismantling of waste heaps; determination of the amount of harmful substances released into the atmosphere by the waste heap [12-14].

The average temperature on the surface of the extinct heap at the time of the research was + 18.8 °C. The lowest rates were at the top and at the foot from the south side + 6-8 °C. The highest temperature regimes (+ 33-39 °C) were typical for sections 5, 6, 7 - in combustion areas on the southern slope exposition (figure 1).

In high temperature areas emissions of combustion products from the rock mass were observed. Combustion products of the waste heaps are characterized by high toxicity and the content of hazardous substances and compounds of various origin [15-19].

It should be noted that according to the normative documents of Ukraine, a waste heap is considered to be burning if it has at least one combustion source (regardless of its area) with a rock temperature more than + 80 °C at depths up to 2.5 m. If the heap was non-burning but during the temperature survey at a

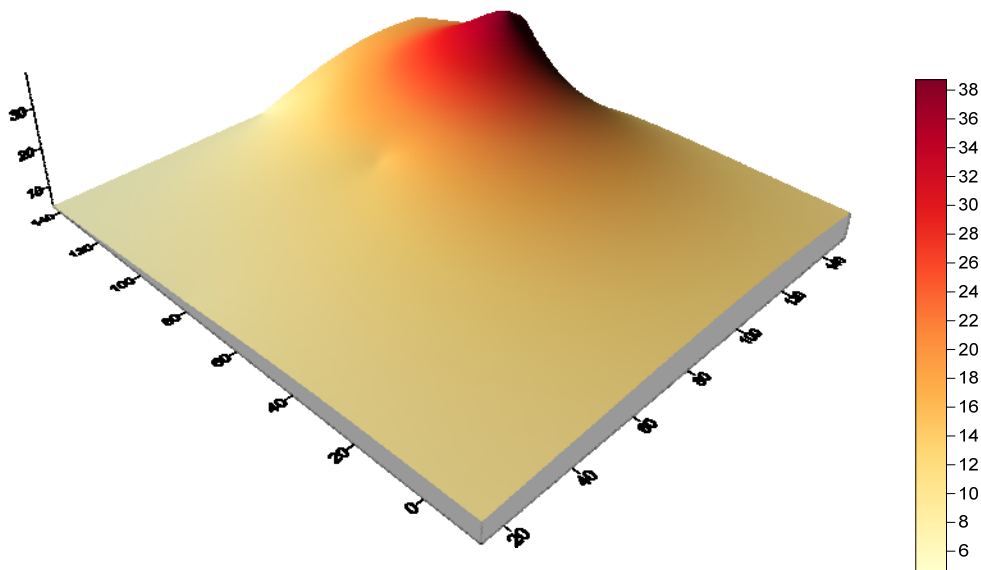


Figure 1 – Temperature profile of the surface of waste heap (°C)

depth of up to 2.5 m a temperature would be more than + 80 °C, and during the next survey it would be the same, then the waste heap is identified as burning, according to the corresponding act [12]. Thus, if in accordance with the regulatory documents the heap is considered to be not burning, the measures for temperature reduce and decommissioning are supposed to be inappropriate (in accordance with the regulatory documents). However, the environmental hazards of such heaps are not less than those with a surface temperature of more than + 80 °C, since emissions of toxic substances to the environment do not decrease over the years. Due to combustion processes extinguishing heaps cause the burnt out of the root system of plants and result in inefficient remediation works.

The humidity measurement of the waste heap was carried out on the same sites at a depth of 5 cm, 30 cm and 50 cm from the surface. It was established that at a depth of 5 cm the highest humidity was at the foot of the western side of the heap (44.8%). The lowest humidity was observed on site 7 where combustion processes were present (16%) (figure 2).

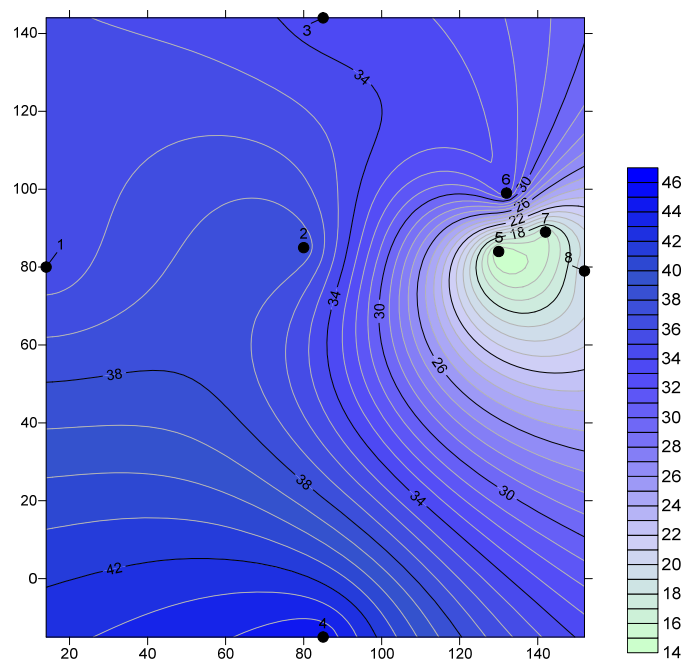


Figure 2 – Humidity of waste heap in the depth of 5 cm from the surface (%)

The same situation with humidity was observed at a depth of 30 cm. The highest humidity was at the foot of the western side of the heap (47%). The lowest humidity was observed at site 7 where combustion processes were present (11.2%) (figure 3).

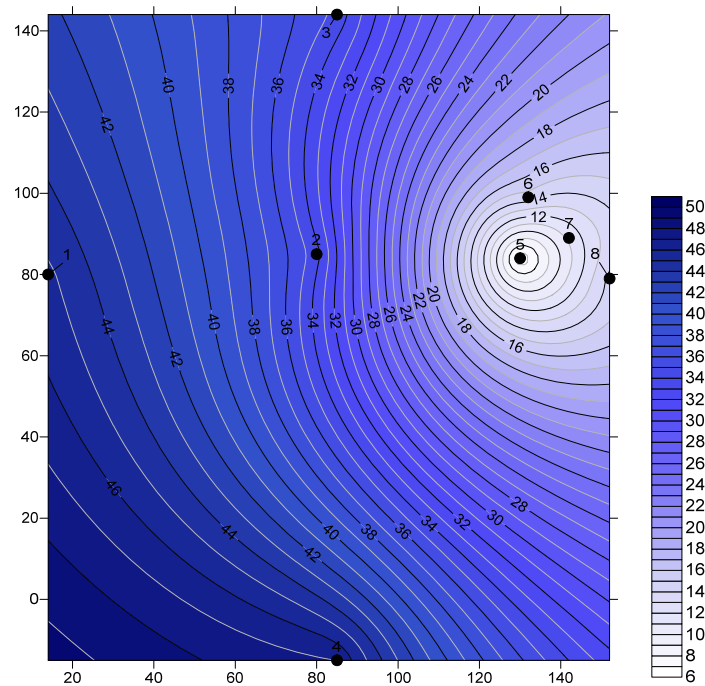


Figure 3 – Humidity of waste heap in the depth of 30 cm from the surface (%)

At a depth of 50 cm, the highest humidity was at the foot of the northern side of the heap (55.1%). In general, high humidity rates on the north side of the waste heaps are caused by low weathering, the lowest influence of solar radiation and initial soil forming processes that cause spontaneous vegetation overgrown. The lowest humidity was observed at site 5 where combustion processes were present (5%) (figure 4).

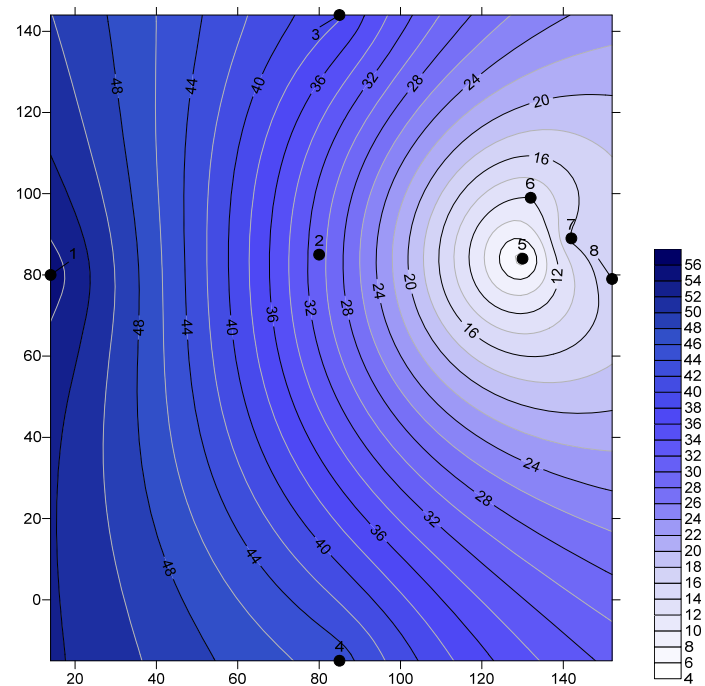


Figure 4 – Humidity of waste heap in the depth of 50 cm from the surface (%)

Some researchers [20, 21] confirm that combustion of the rock refuse causes an increase in the radiation background. Some aspects of the radiation background on coal mine waste heaps were considered in the monograph [22]. It was found that at a level of 15 m from the foot of the heap, the radiation power is much larger than in other areas. The conducted investigation of the radiation background of the heap №1 of mine №9 "Novovolynska" showed that the averaged indicators of the exposure dose rate on the surface of the extinguishing heap are $0.15 \mu\text{Sv/h}$. Indicators of the background radiation do not exceed the permissible norms, which are $0.3 \mu\text{Sv/h}$ [23], but exceed the background values for Novovolynsk ($0.11 \mu\text{Sv/h}$). It should be noted that the highest levels of exposure dose rate were observed near the combustion sites of the heap and were equal to $0.18 \mu\text{Sv/h}$. The lowest rates were stated at the foot of the heap at all sides ($0.14 \mu\text{Sv/h}$). A detailed map of the radiation background of the waste heap is shown in figure 5.

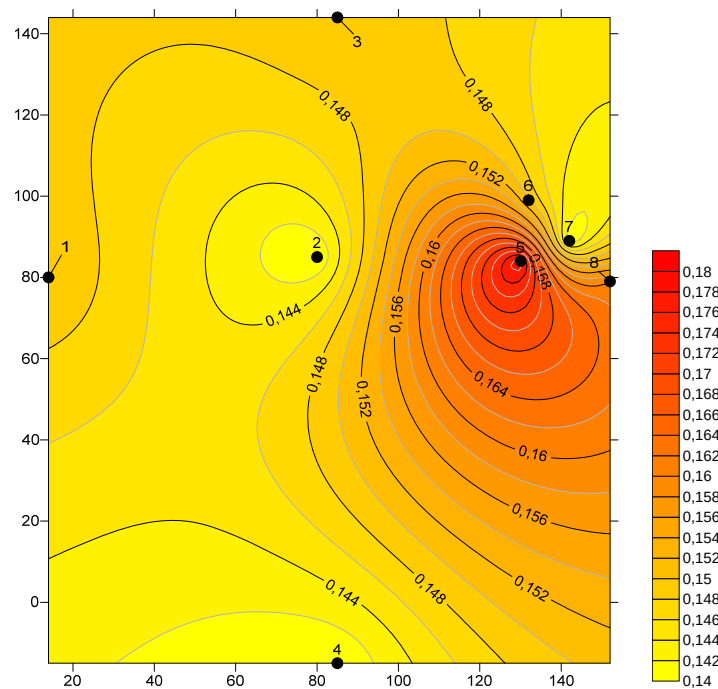


Figure 5 – Exposure dose rate on the surface of waste heap ($\mu\text{Sv/h}$)

Basing on the correlation analysis, we have established the correlation coefficients (K) used for evaluation of the mutual influence of the investigated indicators. It was established that the temperature on the surface of the extinguishing heap is correlated with a humidity at a depth of 5 cm ($K = -0.58542$), 30 cm ($K = -0.75665$), 50 cm ($K = -0.78303$) and does not depend from the radiation background ($K = 0.368116$). With the increase of temperature in the rock, its humidity decreases and vice versa - at high humidity, the temperature of the rock reduces. High positive correlation coefficients are registered for the humidity content at different depths ($K = 0.754308$ - 0.9652). More correlation coefficients are given in table. 2.

Table 2 – Correlation index of the investigated parameters

Indicator	Temperature, °C	Humidity in the depth 5 cm, %	Humidity in the depth 30 cm, %	Humidity in the depth 50 cm, %	Radiation background, $\mu\text{Sv/h}$
Temperature, °C	1				
Humidity in the depth 5 cm, %	-0.58542	1			
Humidity in the depth 30 cm, %	-0.75665	0.879313	1		
Humidity in the depth 50 cm, %	-0.78303	0.754308	0.9652	1	
Radiation background, $\mu\text{Sv/h}$	0.368116	-0.62318	-0.55868	-0.52439	1

Thus, the correlation analysis gave an opportunity to clarify the peculiarities of the mutual influence of the investigated physical indicators on the surface of the extinguishing waste heap.

In order to prevent the dangerous devastation processes on waste heaps, it is necessary to use natural resources rationally, to carry out reclamation, phytomelioration of disturbed lands, to filter out dangerous emissions into the atmosphere, and to waterproof the underground and ground waters [24, 25]. At the same time, measures for soil protection from erosion should be carried out - phased land development, construction of water retaining and catchwater drain facilities, terracing, regrassing and afforestation, and the application of soil protection technologies for the cultivation of crops [26-29].

Conclusions. The investigation of the temperature and humidity conditions of extinguishing heaps in the spring period in Novovolynsk mining area of Ukraine was presented. As an example, the waste heap № 1 of mine №9 "Novovolynska" was chosen.

It was found out that:

- the highest temperature regimes (+ 33-39 °C) was typical for the sites in combustion areas that are located on the middle tier of the southern slope exposure;

- at a depth of 5 cm, the highest humidity was at the foot of the western side of the heap (44.8%). The lowest humidity was observed on the site where combustion processes were present (16%); at a depth of 30 cm the highest humidity was at the foot of the western side of the heap (47%), the lowest humidity was observed on the site where combustion processes were present (11.2%); at a depth of 50 cm, the highest humidity was at the foot of the northern side of the heap (55.1%), the lowest humidity was observed on the site where combustion processes were present (5%);

- the highest rates of equivalent radiation dose were observed near the combustion sites of the rock and reached up to 0.18 $\mu\text{Sv/h}$. The lowest rates were stated at the foot of the heap at all sides (0.14 $\mu\text{Sv/h}$); the averaged indicators of the exposure dose rate on the surface of the extinguishing heap were 0.15 $\mu\text{Sv/h}$.

- the temperature on the surface of the extinguishing heap correlates with a humidity at a depth of 5 cm ($K = -0.58542$), 30 cm ($K = -0.75665$), 50 cm ($K = -0.78303$) and does not depend on the radiation background ($K = 0.368116$). With an increase in the rock temperature its moisture decreases and vice versa - at high humidity the temperature of the rock reduces. High positive correlation coefficients are registered for the humidity content at different depths ($K = 0.754308-0.9652$).

Extinguishing heaps are environmentally hazardous as they cause emissions of toxic substances to the environment that do not decrease over the years. Extinguishing heaps due to combustion processes cause the burning of the root system of plants, that leads to the complications of recultivation.

В. В. Попович, А. И. Волошишин

Львов мемлекеттік тіршілік қауіпсіздігі университеті, Львов, Украина

КӨКТЕМ КЕЗЕҢІ КӨМІР ШАХТАЛАРЫНЫҢ ӨШІП ҚАЛҒАН ТЕРРИКОНЛАРЫНДА ТЕМПЕРАТУРА МЕН ЫЛҒАЛДЫЛЫҚ ЖАҒДАЙЛАРЫ ЕРЕКШЕЛІКТЕРІ

Аннотация. Көмір шахталарының қалдықтарды қоқыстыру улы түтіндер мен газдармен қоршаған ортаның ластануына алып келеді, қоршаған орта температурасын көтереді, сондықтан осылайша тау-кен облысының микроклиматты өзгерту. Жұмыстың мақсаты - қайындағы Нововолинская тау-кен өнеркәсібі аймағында көктемгі кезеңде өшіп қалған терриконларда температуралық және ылғалдылық режимдерін зерттеу. Зерттеу үшін Нововолинская № 9 шахтасының №1 терконы шоғырланған, өйткені көктемде оның үстінде күйдірілген процестер байқалды.

Осы мақсатқа жету үшін мұндай өлшемдерді жасау керек еді: терриконның бетінде және тұқымды жану орындарында температураны орнату; 5 см, 30 см және 50 см тереңдіктегі салыстырмалы жыныстық ылғалдылық көрсеткіштерін белгілеу; қалдықтарды массасының сөну кезінде фон радиациясын өлшеу. Өшіп қалған терриконның тақтасы бетінің температурасы HP-1300 контактісіз пирометрімен орнатылады. Тау жыныстарының қалыптасуы ылғалдылығы MG-44 ылғал өлшеуішімен өлшенді. Радиацияның фоны Soaks экологиялық сынаушымен өлшенді. Бағдарламалық жасақтама - Surfer, MS Excel, MS Visio қосымшалар пакеті. Статистикалық деректерді өңдеу корреляциялық талдау арқылы жүзеге асырылады.

Зерттеу барысында табылды: ең үлкен температура режимдері (+ 33-39 ° C) оңтүстік беткі қабаттың ортаңғы қабатында орналасқан күйдіру орындарындағы аудандармен сипатталды; 5 см тереңдікте, ең жоғарғы ылғалдылық (44,8%) қалдықтардың батыс бөлігінің аяғында болған; 30 см тереңдікте, ең жоғарғы ылғалдылық (47%) қалдықтардың батыс бөлігінің аяғында болған; 50 см тереңдікте, ең жоғарғы ылғалдылық (55,1) қалдықтардың батыс бөлігінің аяғында болған; жоғары қуат фотонды иондаушы сәулеленудің балама дозасы тау жыныстарының жану орындарында байқалды және 0,18 мкЗв / сағ құрады. Әлсіреді теркон бетінің температурасы 5 см ($K = -0,58542$), 30 см ($K = -0,75665$), 50 см ($K = -0,78303$) тереңдікте ылғалды-

лыққа өзара әсер етеді және радиациялық фонға толығымен тәуелсіз ($K = 0.368116$). Тау жыныстарының температурасы артуымен, оның ылғалдылығы азаяды және керісінше - жоғары ылғалдылық кезінде таудың температурасы төмендейді.

Өшіп қалған терриконлар экологиялық қауіпті болып табылады, өйткені қоршаған ортаға улы шығарындылар, ол жылдар бойы азайған жоқ. Өшіп қалған үйіндіжану процестеріне байланысты өсімдіктердің тамыр жүйесі күйіп кетуіне, бұл мелиорациялау асқынулардың туғызады.

Түйін сөздер: террикон, жану күйу өртену, температура, экологиялық қауіп.

В. В. Попович, А. И. Волощишын

Львовский государственный университет безопасности жизнедеятельности, Львов, Украина

ОСОБЕННОСТИ ТЕМПЕРАТУРНЫХ И ВЛАЖНОСТНЫХ РЕЖИМОВ ЗАТУХАЮЩИХ ТЕРРИКОНОВ УГОЛЬНЫХ ШАХТ ВО ВРЕМЯ ВЕСЕННЕГО ПЕРИОДА

Аннотация. Горение породных отвалов угольных шахт приводит к загрязнению окружающей среды токсичными испарениями и газами, повышает температуру окружающей среды тем самым изменяя микроклимат горнодобывающего региона. Цель работы - исследовать температурные и влажностные режимы затухающих терриконов в весенний период в пределах Нововольнского горнопромышленного района Украины. Для исследований выбран террикон №1 шахты №9 «Нововольнская», поскольку на нем наблюдали процессы горения в весенний период.

Для достижения поставленной цели предполагалось: установить температуру на поверхности террикона и в местах горения породы; установить относительные показатели влажности породы на глубине 5 см, 30 см и 50 см; измерить радиационный фон на затухающем терриконе. Температура поверхности угасающего террикона установлена с помощью бесконтактного пирометра НР-1300. Влажность породы измерялась с помощью влагомера МГ-44. Радиационный фон измерялся с помощью экотестера окружающей среды «Soeks». Программное обеспечение - пакет прикладных программ Surfer, MSExcel, MSVisio. Статистическую обработку данных осуществлено с помощью корреляционного анализа.

Установлено, что: повышенными температурными режимами (+33-39°C) характеризовались участки, которые находятся на среднем ярусе южной экспозиции склона; на глубине 5 см самой высокой влажность была у подножия с западной стороны террикона (44,8%); на глубине 30 см самой высокой влажность была у подножия с западной стороны террикона (47%); на глубине 50 см самой высокой влажность была у подножия с северной стороны террикона (55,1%); высокие показатели мощности эквивалентной дозы фотонного ионизирующего излучения наблюдались у мест горения породы и составили 0,18 мкЗв / ч; температура на поверхности затухающего террикона имеет взаимосвязь с влажностью на глубине 5 см ($K = -0,58542$), 30 см ($K = -0,75665$), 50 см ($K = -0,78303$) и совершенно не зависит от радиационного фона ($K = 0,368116$). При повышении температуры породы, ее влажность снижается и наоборот - при высокой влажности температура породы снижается.

Затухающие терриконы являются экологически опасными, поскольку вызывают выбросы токсичных веществ в окружающую среду, которые не снижаются с годами. Затухающие отвалы, вследствие процессов горения, вызывают выгорание корневой системы растений, что вызывает осложнения при проведении рекультивационных работ.

Ключевые слова: террикон, горение, температура, экологическая опасность.

Information about authors:

Popovych Vasyl – Doctor of Technical Sciences, Associate Professor, Head of the Department of ecological safety, Lviv state university of Life Safety, Lviv, Ukraine; popovich2007@ukr.net; <http://orcid.org/0000-0003-2857-0147>

Voloshchyshyn Andriy, regimental commander, Lviv state university of Life Safety, Lviv, Ukraine; voloshichin_25@ukr.net; <http://orcid.org/0000-0003-3174-9965>

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M. Y. Kurbanbayev¹, V. I. Vereshchagin², B. O. Yessimov¹, T. A. Adyrbayeva¹

¹M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan,

²National Research Tomsk polytechnic university, Tomsk, Russia.

E-mail: muk81981@mail.ru, vver@tpu.ru, boyessimov@gmail.com, tatianaadyrbaeva@mail.ru

**MINERAL RAW MATERIALS SELECTION
AND ELECTROTECHNICAL USE PORCELAIN SYNTHESIS**

Abstract. Clay and nonplastic types of raw materials necessary for electrotechnical porcelain synthesis, as well as wollastonite raw materials for additives were considered from among the minerals of the Republic of Kazakhstan; the compositions, properties, phase transformations during heat treatment of kaolins, white-burning refractory clays, quartz sands, feldspars and wollastonites were studied; a technology was developed for obtaining porcelain for electrical insulation with the use of mineralizing additives – wollastonites; porcelain's structure and phase composition formation processes and its mechanical and dielectric properties were studied; optimal ratios of porcelain mixture components and amount of additives needed to improve the porcelain phase formation process by increasing the mullite crystals formation at lower temperatures compared with traditional porcelain were determined; first proved the possibility of obtaining electrotechnical porcelain with high properties from local natural types of mineral raw materials; the developed electrotechnical porcelain technology introduction will allow to solve the import substitution problem.

Key words: electrotechnical porcelain, mineral raw materials, kaolins, clays, feldspars, quartz sands, wollastonite.

Introduction. Electrotechnical porcelain is the main ceramic material used in the production of a wide range of low-voltage and high-voltage insulators [1-5].

In Kazakhstan, electrotechnical porcelain is not produced, and existing factories for production of household items from porcelain that are close to it in terms of composition and technology are mainly focused on imported raw materials. In recent years, there has been a marked depletion of high-quality raw materials for this industry in the CIS countries. At the same time, Kazakhstan has significant industrial reserves of all types of natural mineral raw materials traditionally used in the production of fine ceramics and electrotechnical porcelain.

In the current industrial and economic situation in the Republic of Kazakhstan, one of the country's priority scientific and technical tasks is accelerated development and introduction of the production of modern electrotechnical porcelain insulators based on domestic mineral resources. The solution of this scientific and practical problem is undoubtedly relevant [6].

The purpose of the work is a comprehensive study of promising selected mineral raw material types, development on their basis the mass composition and obtaining import-substituting electrotechnical porcelain.

Materials and methods. The objects of study are kaolins, white-burning clays, quartz sands, feldspars and wollastonites of deposits of the Republic of Kazakhstan; mass compositions developed on their basis; physical and mechanical properties of the synthesized samples.

The basis of scientific research consists of complex chemical, mineralogical, petrographic and electron microscopic studies of raw materials; study of high-temperature phase-structural changes; chemical analyzes of raw materials and porcelain according to the relevant standard requirements; thermal analyzes using NETZSCH STA 449 F3 Jupiter; elemental analysis using X-Supreme 8000 desktop X-ray

fluorescent energy dispersive analyzer; X-ray investigation using DRON-3; electron microscopic studies using JSM-6490LV multipurpose raster microscope (JEOL.Ltd, JAPAN).

Results. Particularly strict requirements are imposed on electrotechnical porcelain in terms of its mechanical strength, breakdown voltage and dielectric losses. These requirements can be satisfied only by dense sintered products with a homogeneous structure and minimum number of pores, obtained on the basis of appropriate types of plastic clay, kaolin, feldspar and silica mineral raw materials with material composition and purity.

The mechanical strength, thermal and chemical resistance of porcelain, including electrotechnical, enhance with increase in the mullite content and improving the glassy phase in it, which is achieved by increasing the kaolin content in the mass [7-9]. The latter at 1000-1200°C decomposes with the release of heat, giving sillimanite at the beginning, and then mullite. These reactions form the basis of all ceramic production with the use of kaolinite.

According to the mineralogical and chemical characteristics, kaolins of one of the large deposits the Soyuznoye, located in the North-Mugodzhzar area, for solving the problems of these studies seem to be the most favorable. The deposit is represented by the trias-Cretaceous areal weathering crust over granites and shales. The kaolin useful stratum consists of dense, block types of white and light gray clays [4]. The averaged results from five chemical analyzes of the samples are as follows: SiO_2 – 59.75%, Al_2O_3 – 28.94%, Fe_2O_3 – 0.47%, TiO_2 – 0.32%, CaO – 1.87%, MgO – 0.73%, K_2O – 0.26%, Na_2O – 0.11%, loss on ignition – 8.53%. According to the mineral composition, kaolins are fairly simple: kaolinite – 71-87%, hydromica – 5-7%, quartz – 6-8% and other – 2-4%.

The enrichment of raw materials in the laboratory under the electrolyte-free wet enrichment scheme provided a noticeable increase in the volume fraction of kaolinite in the raw materials and, accordingly, Al_2O_3 (table 1).

On the X-ray diffraction pattern of enriched kaolins (figure 1), unlike natural ones, diffraction maximums dominate and quartz maximums are weakly expressed.

Table 1 – Chemical composition of the Soyuznoye enriched kaolins

Oxide content, mass percent								Δm_{pr}
SiO_2	Al_2O_3	CaO	MgO	TiO_2	Fe_2O_3	K_2O	Na_2O	
50.94	36.52	0.29	0.08	0.514	–	0.17	–	11.94

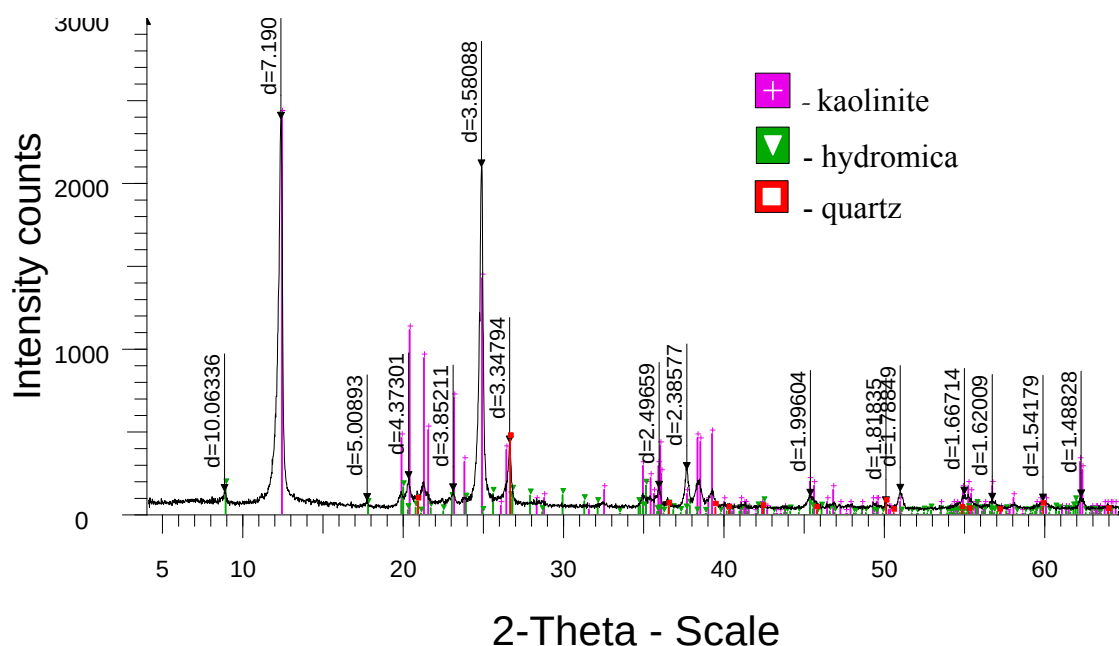


Figure 1 – X-ray diffraction pattern of the Soyuznoye enriched kaolin

The comprehensive studies have shown that the Soyuznoye enriched kaolins are refractory (1690 – 1750°C); the main in the composition (Al_2O_3 – 36,52%) with a very low content of coloring oxides ($\text{Fe}_2\text{O}_3 + \text{TiO}_2$ – 0,514%); kaolinite in the mineral composition; highly dispersed (fractions less than 10 microns – 88.9%); moderate plastic and high-temperature sintering (1400°C). These indicators are fully consistent with the requirements of the State Standard for kaolins for production of electrotechnical porcelain.

In the mass compositions of electrotechnical porcelain, as in other types of fine ceramics, white-burning plastic clays, in addition to kaolin, play an important technological role. The range of functions of such clays includes the forming and molding properties of ceramic masses, mechanical strength in the air-dry state, operational strength and chemical resistance after firing [10-12].

Considerable reserves of white-burning plastic clays are concentrated in the deposits of West, Central and North Kazakhstan. Among them, the Berlinskoye deposit is the most studied and under development, the productive stratum of which is represented by oligocene kaolin clay reservoir. The suitability of its raw materials for production of facing porcelain tiles, chemically resistant bricks, ceramic nozzles and sewer pipes was assessed [13].

In the Berlinskoye enriched clays, kaolinite, montmorillonite, hydromica, and quartz are clearly established (figure 2). Their chemical composition, mass percent: SiO_2 – 49.50; Al_2O_3 – 30.9; Fe_2O_3 – 1.84; TiO_2 – 0.92; CaO – 0.61; MgO – 0.071; K_2O – 0.78; Na_2O – 0.11; SO_3 – 0.021; MnO – 0.008; loss on ignition – 12.87.

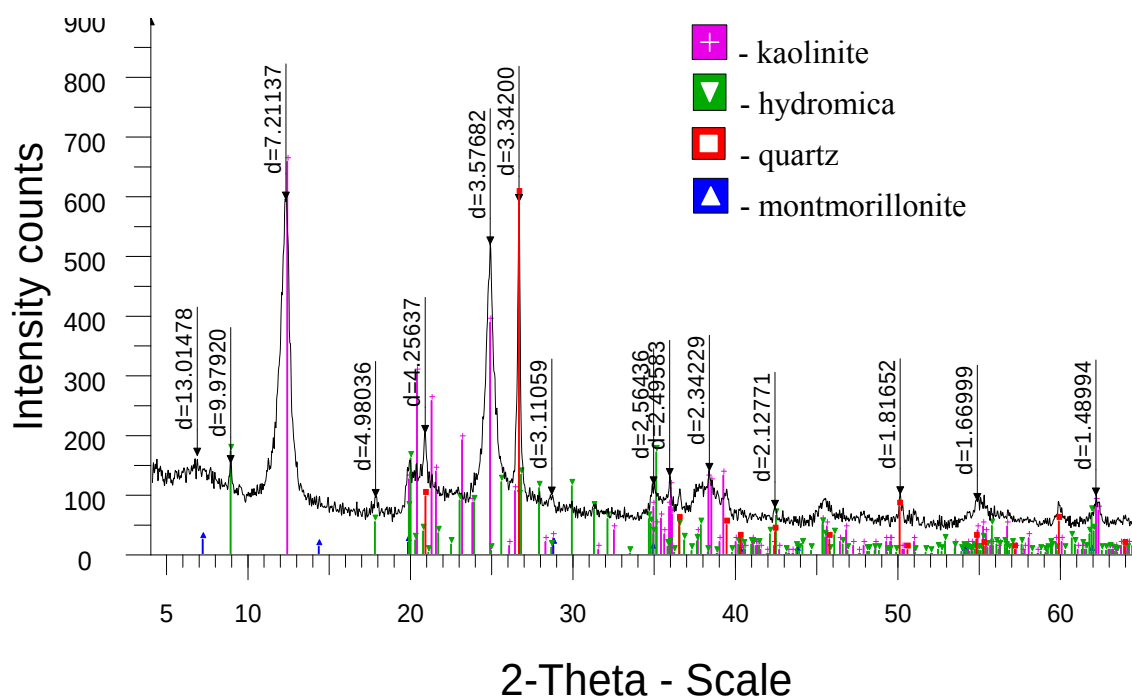


Figure 2 – X-ray diffraction pattern of the Berlinskoye enriched clays

It was established that the Berlinskoye clays after the enrichment are refractory (1630-1790°C); the main in the composition (Al_2O_3 – 32.15%); kaolin-hydromica; medium plastic; medium sintering (1300°C) and highly caking.

Quartz sands from the upper paleogene of the Mugodzhazhar deposit were selected and investigated as an emaciated component responsible for reducing shrinkage and deformation of products.

Earlier laboratory and technological studies have shown that the Mugodzhazhar quartz sands are high grade and meet the requirements for production of white cement, sheet glass and technical glass [14].

The average chemical composition of the Mugodzhazhar sands, mass percent: SiO_2 – 98.07; TiO_2 – 0.05; Al_2O_3 – 0.40; Fe_2O_3 – 0.11; CaO – 0.14; MgO – 0.09; MnO – 0.07; Na_2O – 0.17; K_2O – 0.17. They consist mainly of quartz.

No less responsible is selection of the desired variety of feldspar, introduced as a thickener and fusing agent for formation of the optimal glass phase in the electrochemical porcelain sintering process [15-17].

For this purpose, pegmatite feldspars of the Sarybulak deposit in the area of Mirny village were investigated. The chemical composition, mass percent: SiO_2 – 79; Al_2O_3 – 10.915; Fe_2O_3 – 0.402; TiO_2 – 0.105; CaO – 0.153; MgO – 0.017; K_2O – 5.8; Na_2O – 4.14. The mineral raw materials consist mainly of albite, microcline and less often quartz.

The introduction of various mineralizing additives in the composition of ceramic masses in small quantities leads to improvement in the process of porcelain formation and increase in the appearance of mullite crystals. The latter, in turn, improve the quality characteristics of finished products [18-21].

For the first time, wollastonites of the Upper-Badam deposit were tested as mineralizing additives. The Upper-Badam technological wollastonite sample chemical analysis results, mass percent: SiO_2 – 46.42; Al_2O_3 – 0.11; Fe_2O_3 – 0.53; CaO – 46.09; MgO – 0.5; K_2O – 0.7; Na_2O – 0.20; loss on ignition – 7.73. In the samples studied (figure 3): wollastonite ($d/n = 7.66785$; 5.44570; 4.05062; 3.83412;), calcite ($d/n = 3.83412$; 3.03585; 2.89973; 2.47782;,) and quartz ($d/n = 4.24614$).

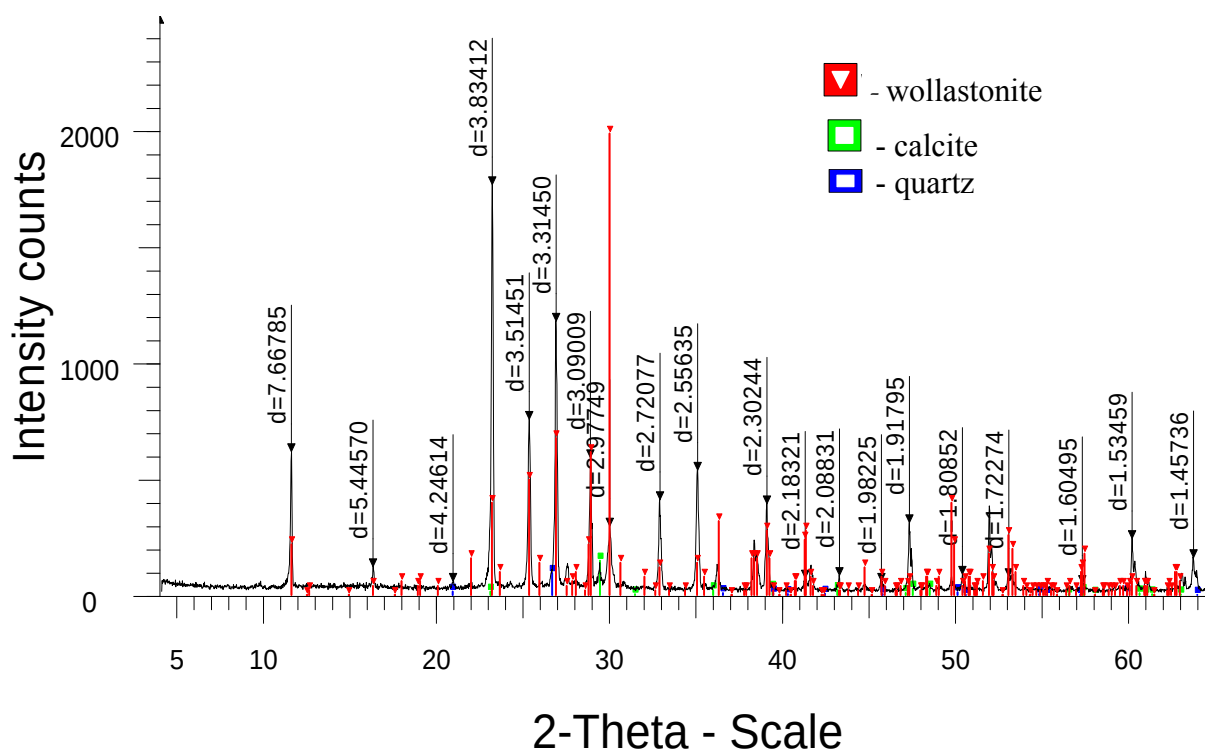


Figure 3 – X-ray diffraction pattern of the Upper-Badam wollastonite

A series of experiments were carried out to find the optimal parameters for synthesizing new porcelain with regard to the results of studying chemical and mineral compositions, technological properties, physicochemical processes and phase transformations during heat treatment of selected domestic kaolin, white-burning clays, quartz sands, feldspars and wollastonites. To determine the role of wollastonite as a mineralizer, compositions with its additives from 1 to 5% were developed.

The samples were made on laboratory equipment using plastic technology. Dried to a residual moisture content of 1%, the test samples were fired at 1280-1320°C.

The analysis of the change in the samples strength depending on the burning temperature (figure 4) shows that when the masses are fired with the wollastonite addition to 2%, a uniform increase in the strength to a temperature of 1250-1300°C is observed. Then, when the temperature rises above 1300°C, it decreases. The strength of ceramic masses with the wollastonite content from 2 to 3% increases to a temperature of 1200°C, but only to values of 50-52 MPa. Then, as well as in the previous masses, a decrease in the strength characteristics is observed. The porcelain samples with the wollastonite addition from 3 to 5% have low strength indicators, so their values are not reflected in the graph.

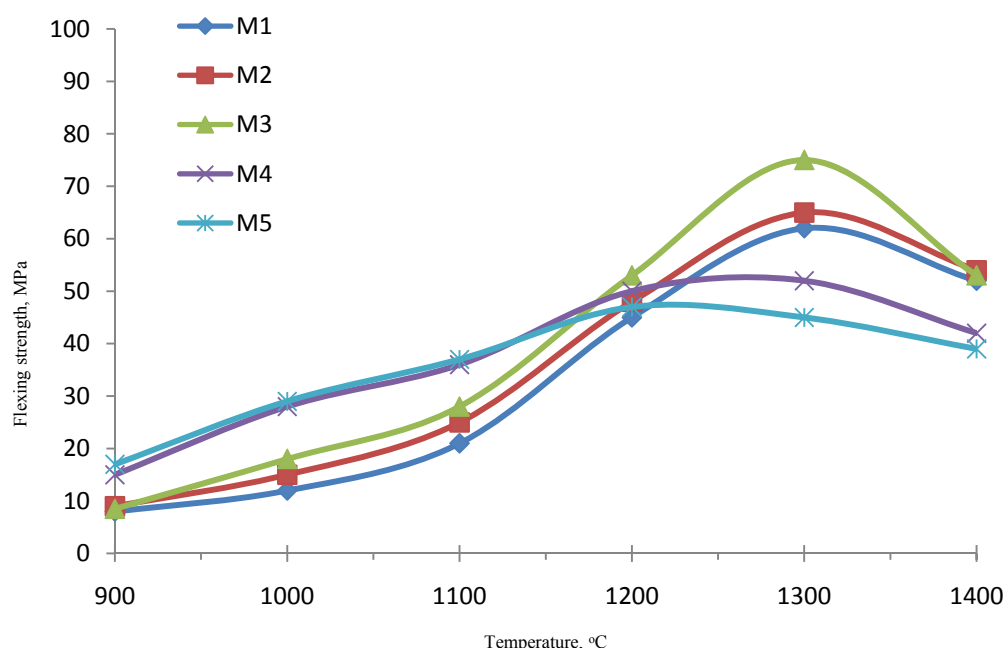


Figure 4 – The change in the porcelain samples strength with various wollastonite content after the firing at various temperatures: M1 – the mass with the wollastonite content up to 1%, M2 – the mass with the wollastonite content up to 1.5%, M3 – the mass with the wollastonite content up to 2%, M4 – the mass with the wollastonite content up to 2.5%, M5 – the mass with the wollastonite content up to 3%

The high strength indexes of the samples based on the masses with the wollastonite up to 2% at a relatively low firing temperature (1290-1300°C) compared with classic porcelain, are explained by the fact that wollastonite in the porcelain mass composition contributes to the formation of a liquid phase with increased reactivity. This accelerates the ceramics structure formation process, increases the content of slow-moving calcium ions in the glass phase.

A higher wollastonite content in the masses – from 2 to 5% narrows the porcelain sintering interval and increases the open porosity degree.

The most favorable ratio of raw components was established: 50-55% clay components (kaolin and clay), 20-25% quartz sands, 25-30% feldspars and 1-2% wollastonite.

The basic properties of optimal composition porcelain samples were determined (table 2).

The crystalline phases of the calcined samples consist of the mullite grains ($d/n = 5.4293; 3.4221; 2.8930; 2.7036; 2.5509; 2.2949; 2.2124; 2.1267; 1.8923; 1.6999; 1.6022; 1.5808$) and quartz ($d/n = 4.2921; 3.3661; 1.8227$).

Table 2 – Physical-mechanical and electrical parameters of the samples

Indexes	Values	Requirements of GOSTs
Fire shrinkage ($t=1350^{\circ}\text{C}$) / full shrinkage, %	8.2 / 13.2	–
Water absorption, %	0.0	0.0
Density, g/cm^3	2.53	2.45
Flexing strength:		
Unglazed sample, MPa	69.7	60
Glazed sample, MPa	75.8	70
Tensile strength:		
Unglazed sample, MPa	31.5	30
Glazed sample, MPa	37.8	35
Electric strength at a frequency of 50 Hz, kV/mm	28.9	25
Dielectric permeability at a frequency of 50 Hz	6.5	From 6 to 7

On the electron micrographs of chipped porcelain mass without wollastonite, it can be seen that the sample has a rather dense structure (figure 5 a, b). The main constant phase in which other phases are dispersed is glass. It is clearly visible how the mullite secretions of various habit sprout from the feldspar glass. There are areas penetrated by large well-developed crystals and areas in which there are their frequent weaves.

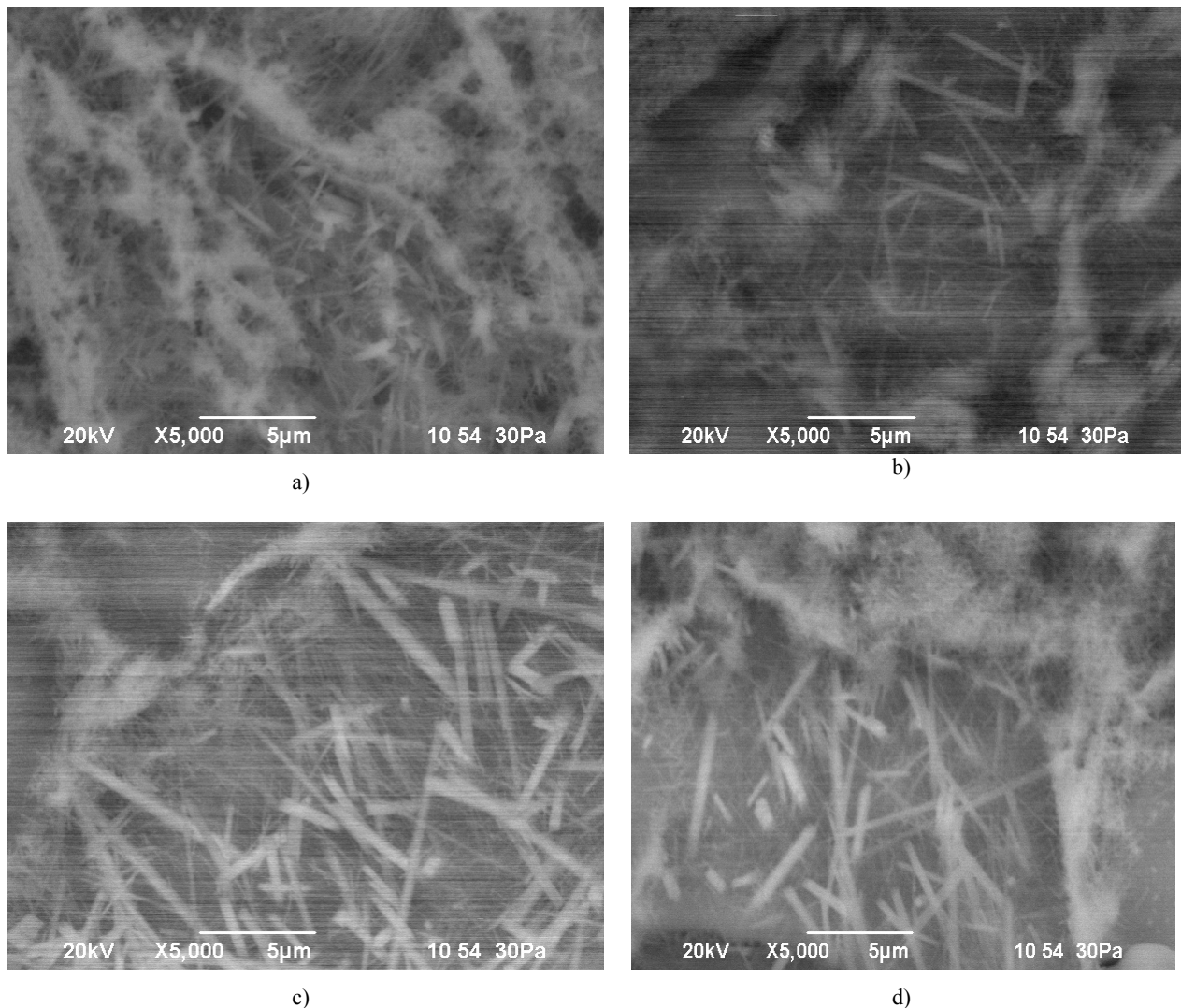


Figure 5 – Electron microscopic photographs of the electrotechnical porcelain without (a, b) and with the addition of wollastonite (c, d)

The structure of pieces of the samples obtained with the wollastonite addition is characterized by a more dense structure and greater mullitization, where pores are practically absent. This is apparently due to the fact that the wollastonite in the porcelain mass composition reduces the liquid phase appearance temperature and changes the structure, as well as the feldspar melt properties. The diffusion processes involving the melt are activated, its dissolving capacity grows. As a result, the amount of dissolved primary mullite increases and its transformation into the crystalline phase in the form of secondary mullite. In the electronic photographs of the structure of the mass samples with the wollastonite content up to 2.5%, these mullite crystals are represented mostly in the feldspathic areas in the form of shagreen and thick felt. In general, the samples based on this mass have a good degree of maturity.

Discussion. The mineralogical and petrographic analysis of the selected raw materials types, experimental and technological studies have shown the possibility of obtaining electrochemical porcelain purely on the basis of domestic mineral raw materials.

The technological scheme has been developed for the production of high-performance electrotechnical porcelain of original composition, where kaolins, white-burning clays, quartz sands, feldspars and wollastonites were used as components.

The electrotechnical porcelain products were synthesized and their decisive physical and mechanical properties were determined. The qualitative characteristics of the developed mass compositions meet the requirements for the porcelain of insulating purpose.

Conclusions. The Soyuznoye kaolins, the Berlinskoye refractory clays, the Mugodzhazhar quartz sands, the Sarybulak feldspars, the Upper-Badam wollastonites fully comply with the requirements set by the State Standards for raw materials for the electrotechnical porcelain production.

The electrotechnical porcelain, produced with the use of plastic and nonplastic raw materials of deposits of the Republic of Kazakhstan, according to its mechanical and electrotechnical properties comply with the requirements of GOST.

The introduction of the developed composition and technology for the electrotechnical porcelain production based on affordable local types of raw materials will provide the creation of domestic production of necessary products and will solve the problem of import substitution.

М. Е. Курбанбаев¹, Б. О. Есимов¹, Т. А. Адырбаева¹, В. И. Верещагин²

¹М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан,

²Ұлттық зерттеу Томск политехникалық университеті, Томск, Ресей

МИНЕРАЛДЫ ШИКІЗАТ ТАҢДАУ ЖӘНЕ ЭЛЕКТРТЕХНИКАЛЫҚ МАҚСАТТАҒЫ ФАРФОР СИНТЕЗІ

Аннотация. Қазақстан Республикасының пайдалы қазбаларынан электртехникалық фарфор синтезіне қажетті сазды, иілгіш емес шикізат түрлері қарастырылды; волластонитті шикізат қоспа ретінде таңдалды; каолиндердің, отқа төзімді саздардың, кварцты құмдардың, дала шпаттарының және волластонитті тау жыныстарының құрамдары, қасиеттері және термиялық өңдеу барысындағы фазалық өзгерістері зерттелді; минералдаушы қоспалар – волластониттер қосылған электроқшаулағыш фарфор технологиясы жасалды; фарфордың фазалық құрамы мен құрылымы түзілу процесстері және оның механикалық және диэлектрлік қасиеттері зерттелді; фарфор массасының компоненттерінің оптимальді қатынасы және фаза түзілу процесін жақсартуға қажетті қоспалар мөлшері анықталды; алғаш рет жергілікті табиғи минералды шикізат түрлерінен жоғары сапалы электртехникалық фарфор алу мүмкіндігі дәлелденді; жасалған электрфарфор технологиясын өндіріске ендіру импорталмастыру проблемасын шешуге мүмкіндік береді.

М. Е. Курбанбаев¹, Б. О. Есимов¹, Т. А. Адырбаева¹, В. И. Верещагин²

¹Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,

²Национальный исследовательский Томский политехнический университет, Томск, Россия

ПОДБОР МИНЕРАЛЬНОГО СЫРЬЯ И СИНТЕЗ ФАРФОРА ЭЛЕКТРОТЕХНИЧЕСКОГО НАЗНАЧЕНИЯ

Аннотация. Из числа полезных ископаемых Республики Казахстан рассмотрены глинистые, непластичные виды сырья, необходимые для синтеза электротехнического фарфора, а также волластонитовое сырьё для добавок; изучены составы, свойства, фазовые превращения при термической обработке каолинов, беложгущихся огнеупорных глин, кварцевых песков, полевых шпатов и волластонитовых пород; разработана технология получения фарфора электроизоляционного назначения с использованием минерализующих добавок – волластонитов; изучены процессы формирования фазового состава и структуры фарфора и его механические и диэлектрические свойства; определены оптимальные соотношения компонентов фарфоровой массы и количества добавок, необходимые для улучшения процесса фазообразования путем увеличения образования кристаллов муллита при более низких температурах по сравнению с традиционным фарфором; впервые доказана возможность получения из местных природных видов минерального сырья электротехнического фарфора с высокими свойствами; внедрение разработанной технологии электрофарфора позволит решить проблему импортозамещения.

Ключевые слова: электротехнический фарфор, минеральное сырьё, каолин, глины, полевые шпаты, кварцевый песок.

Information about authors:

Kurbanbayev Mukhtar Yendibayevich, senior teacher, "Technology of cement, ceramics and glass" chair, M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; muk81981@mail.ru; orcid.org/0000-0003-0626-5934

Vereshchagin Vladimir Ivanovich, Professor, Doctor of Technical Sciences, National Research Tomsk polytechnic university, Tomsk, Russia; vver@tpu.ru

Yessimov Begem Omarovich, Professor, Doctor of Geological and Mineralogical Sciences, "Technology of cement, ceramics and glass" chair, M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; boyessimov@gmail.com; orcid.org/0000-0001-8130-1486

Adyrbayeva Tatyana Amanovna, Candidate of Technical Sciences, associate professor, "Technology of cement, ceramics and glass" chair, M. Auezov South Kazakhstan state university, Shymkent, Kazakhstan; tatianaadyrbaeva@mail.ru; orcid.org/0000-0001-7049-3099

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