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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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MODEL FOR DETERMINING CLASSIFICATION OF FILLING MATERIALS HARDENING

Abstract. This paper presents the model for solving the problem of classification of trajectories of development of states of filling material in the presence of a priori information on the trajectories of processes that have already passed the development of states of the processes. Consideration of the hardening process of stowage material as a chemical-technological process, which can be considered as a multi-parameter dynamic (time) series, allows us to determine the development class of the state of the material based on the classification of the state of the stowage. The proposed approach has established the fundamental possibility of using the proposed methodology to solve the problem of dividing given trajectories represented by time series into classes. It allows us to obtain a model that, according to formal rules, determines the classification of trajectories by sets of heterogeneous features of its state at certain time and improves the reliability of the classification.

Key words: forecasting, filling material, safety, dynamic (time) series, object recognition.

Introduction. Pattern recognition**,** or object classification (observations, phenomena, signals, situations, possesses) is one of the most dynamically developing spheres of applied mathematics and cybernetics which **is** caused by the constant demands of practice as it often faces rather complicated processes and phenomena. An excessive desire for accuracy has begun to exert an influence that negates control theory and system theory, since it leads to the fact that research in this area focuses on those and only those problems that can be precisely solved. Many classes of important problems in which data, goals, and constraints are too complex or poorly defined to allow accurate mathematical analysis, remained and remain aloof only because they cannot be mathematically interpreted [1,2]. The constructed mathematical models were either complex or too simple, which did not allow obtaining acceptable results. Therefore, in some cases, mathematical modeling is an art, and the quality of models largely depends on the intuition, skill and creativity of their developers. One approach to solving this kind of mathematical modeling problem is building recognition systems based on accumulated [3].

In connection with the expansion of the range of practical tasks, the set of heuristic (incorrect) recognition algorithms, the information for which is poorly formalized, is constantly growing. The idea of constructing a unified mathematical theory of incorrect recognition algorithms belongs to Yu. I. Zhuravlev and was developed in his works [4], one of which is “On the algebraic approach to solving recognition or classification problems”. These works give a description of the algorithms for computing estimates and present an algebraic approach to the construction of models of recognition algorithms.

In the framework of estimation calculation algorithms, an approach to solving the problems of determining the states of complex systems in the presence of a priori information about classes is proposed. The paper presents well-grounded algorithms for optimal object recognition.

Given the existence of a priori information about classes, this approach allowed solving a number of problems from a variety of poorly formalizable. But when solving practical problems, it's either impossible to obtain accurate a priori information about classes, or this requires large expenditures of resources, including computational. As a result, the task is to classify objects or observations that do not have the appropriate mathematical apparatus. The forecasting task posed in such a form, which determines the future state of the observed process of the object's functioning on the basis of taking into account information about past states of processes and its current data, belongs to the class of poorly informative dynamic problems.

In this paper, we consider a method with which to solve the problem of constructing a classification of states of dynamic objects in the absence of information about classes.

The aim of this work is to develop and study methods for classifying dynamic objects and determining the states of complex systems, in the absence of a priori information about classes that allow us to determine computational algorithms for optimal classification and forecasting that ensure stability and the required quality of recognition processes.

Since the '80s there have been undertaken attempts of joint image recognition and correlation - regressive analysis consideration for solving problems of various contents [5-11]. It was proposed that for various homogeneous groups the same signs influence on objective function on benchmark figure in varying degrees. Therefore, before appliance of regressive - correlation apparatus analysis it needs on initial stage to divide data on uniform classes and solve objective problem separately for each of the following classes. These attempts where productive due to appliance of image classification methods and they were found implementation in practical tasks - this is problem of classification as needed preliminary stage of statistical processing multidimensional data, it is classification in the tasks of optimal regulation and planning, it's task of classification in problems of forecasting economic - sociological situations or selected indicators and etc.

Successful appliance of image recognition methods in forecasting socio- economical situations problems and separate indicators gave basis to distribute that approach on other areas of knowledge with inclusion of their specific. For that, it was proposed to consider distribution on classes in other moments of time of processes development.

The paper proposes the formalization of the task of classifying the trajectories of development of states of filling materials used in the development of a number of mineral deposits in the presence of a priori information about the trajectories of processes that have already passed the development of states of processes.

This has become possible thanks to the successful use of pattern recognition methods, and the task of dividing trajectories into classes was used in the practical task of classifying dynamic processes as a necessary step in the processing of statistical information from multidimensional data.

Formulation of the problem. In a number of mineral deposits development, systems with stowing are used [12-14].

In mining stowing is defined as filling the goaf with stowing material, which is formed in the entrails of the earth as a result of mineral extraction. Stowing materials can be crushed rock formation, and production wastes. Stowing is solid if all the goaf is filled, and partial when certain parts (as tapes or layers) of it are filled. Depending on the way of transportation and stowage hydraulic, pneumatic, hydro-pneumatic, mechanical, self-flowing and manual are distinguished.

The use of stowing on mining enterprises caused by the process safety of the performance of mining operations, preservation of buildings on the surface of the earth, safety and the environment control, etc. For this purpose, goof is filled with stowing material, which is after reaching a certain state of the material should serve as supporting pillars.

The goals of the use of stowing material depend on the purpose. Stowing is used to control rock pressure, to reduce losses and dilution of extracted minerals in mining, to prevent mine fires, to reduce surface deformations of the earth and to protect the objects on the earth surface from damage, to improve the safety of mining operations, for improving the ventilation of underground workings, to reduce transport costs.

Requirements for filling properties can be different and depend on its purpose. Thus, the requirements for filling used to prevent subsidence of the earth surface and thus the protection of buildings and

structures is much higher and it is especially important to forecast its states of stowing, than in cases when for example, stowing serves as the filler of voids and prevention of ore dilution and loss.

Depending on the purpose and field development systems dry, hydraulic, hardening and other stowing are used. It is reasonable that properties and methods of their creation are different. At hardening stowing binder component is added, that significantly increases the cost of stowing due to the high cost of binding material. This type of stowing greatly exceeds the cost of others and is used in strictly defined cases and only under condition of full recoupment of materials and works on the stowing. This is one of the reasons for considering this type of stowing.

There is a problem of definition of readiness of the state of hardening filling to perform intended functions [12-14].

Based on the above propositions, it can be stated that the determination of the state of the filling is an important and urgent problem, therefore there is a need to develop new ways and methods for determining the states of the technological process [12].

The usual practice of controlling the state of stowing is radiometric monitoring, local destruction methods, impact methods, an acoustic method, a method for measuring material temperature, etc.

The core element of the abovementioned methods is that they require creating individual gradation dependencies based on the results of studies of standard sample cubes made of concrete of the same composition and age as the object under study, the structure, in our case, filling. This directly measures some indirect physical characteristic related to the strength by correlation dependence. To establish this dependence, and, accordingly, to establish the strength of the structure, it is firstly necessary to establish a grading characteristic between strength and some indirect characteristic – temperature, humidity, conductivity, etc.

For that reason bringing durability dependence P array from its indirect characteristics, varying by time, - on basement of methods of least squares constructing dependence of chosen characteristics (temperature, humidity, acoustic parameter, electrical conduction and etc.) in discrete moments of time t_k on time interval $[t_0,t_M]$ with corresponding calculation of statistical parameters - dispersion, correlation coefficient, coefficient of determination and etc.

The values (characteristics) at the moment of time *t*, are taken as the parameters of the dynamic state of the filling at the moment of time *t*.

It should be noted that each characteristic separately determines the state of the filling not completely, but only one side of it, and cannot be an overall assessment of the dynamic state of the process.

Thus, the object of study has a set of the object characteristics, varying in time *t*.

In all cases, forecasting assessment of filling seems necessary to measure at different time points $T = \{t_1,...,t_T\}$ filling parameters characterizing the static state and the dynamics [2].

Below we give a possible way to create an apparatus for processing attributes of any type, and ways to apply this apparatus to the problems of classifying trajectories represented by time series based on the possibility of introducing a distance between different types of vectors.

Formalization of the problem statement. Accepting the approach and denotations from the works of Zhuravlev Yu. I., we give a description of the method for solving the problem of constructing a classification of objects of the same type with different types of variables**.**

Let *R* be the set of all real numbers.

We discredit the attribute space R^N, using the approach proposed in [4], and to characterize the proximity of similarity of vectors R^N we introduce the following evaluations.

We introduce *N* - dimensional vector of weights of variables

$$\overline{w} = \overline{w}(\overline{w}_1, \overline{w}_2,..., \overline{w}_N),\ 0 \le \overline{w}_j \le 1,\ j = 1, N,$$

so $\overline{w}_j$ - is weight of variable *j*.

Let s_p and s_q be two arbitrary points from space R^N. Based on fairly general considerations for the measure of proximity of these two points on *j* - coordinate it's convenient to take some function of the modulus of the difference in the values of this objects' coordinate s_p и s_q:

$$r_j(p,q) = w_j \times f(|t_{pj} - t_{qj}|),$$

where t_{pj} and t_{pj} - j point coordinates s_p and s_q.

We define this object distance function s_p to object s_q on coordinate j.

Following the description of the estimation calculation algorithms, we introduce a numerical N - dimensional vector

$$\bar{\varepsilon} = \bar{\varepsilon}(\varepsilon_1, \varepsilon_2, ..., \varepsilon_N)$$

- vector of threshold estimates by attributes, we explicitly define the distance function of the s_p and object s_q using the following condition

$$r_j(p,q) = \begin{cases} 0, & если \left[t_{pj} - t_{qj}\right] \succ \varepsilon_j \\ w_j, если \left[t_{pj} - t_{qj}\right] \le \varepsilon_j \end{cases}$$

Distance R (p, q) between points s_p and s_q we now define as follows:

$$R(p,q) = \frac{1}{N}\sum_{j=1}^{N} r_j(p,q)$$

Which implies that for any s_p и $s_q \in R^N$ there is an inequality

$$0 \le R(p,q) \le 1.$$

Let us consider the implementation of the trajectory classification method, which is further used by the software module to solve the trajectory classification problem.

Having replaced the objects with descriptions in the form of coordinates by time trajectories, we consider the construction of the question of constructing a classification of trajectories at a given time interval.

Let there be a multitude K^{tr} trajectory at a given time interval.

The idea of the method to construct the desired classification. The threshold value of the distance between the trajectories is set. Then a graph is constructed, the vertices of which are all given trajectories, the vertices are connected by edges, the distances between which do not exceed the threshold value. At a certain threshold value, the graph is divided into separate classes.

Let us consider the implementation of the method for solving the problem of classification of trajectories.

1. The choice of a certain value of ρ as a threshold distance for assessing the proximity of the trajectories to each other;
2. Fixing an arbitrary trajectory $T_r \in K^{rp}$, where K^{rp} – is initially given set of classified trajectories;
3. Find all trajectories that are no more than ρ from the selected trajectory Tr. We get a subset of the trajectories. Let us call it a class K_1.
4. Then, in turn, for each of the trajectories included in the class K_1 with root T_1, using the same rule, we will find neighboring trajectories, we receive the completion of the class K_1.
5. The procedure continues until such a subset of the trajectories K^{tr} is distinguished that none of the trajectories of the class K^1 has close to $K^{tr} \setminus K^1$ trajectories.
6. We accept the formed set of trajectories as a class K_1.
7. We fix a new trajectory from $K^{tr} \setminus K^1$ and in the same way we form a class of trajectories K^2
8. We take the generated set of trajectories as the class of trajectories K^2.
9. We fix a new trajectory from $K^{tr} \setminus K^1 \setminus K^2$ and in the same way we form a class of trajectories K^3, etc.
10. Let q classes of trajectories K^1, K^2, ..., K^q be found. If the combination of the selected classes coincided with the original set of K^{tr} trajectories, then the classification process is completed, otherwise a new class $K_q + 1$ is constructed from the trajectories of the $K^{tr} \setminus K^1 \setminus K^2 ... \setminus K_q$

The resulting classification of the trajectories is declared as required.

The above approach allows setting the classification problem for completely arbitrary objects, the descriptions of which contain signs of a mixed type - quantitative and qualitative.

The proposed classification algorithm can work with information along trajectories represented by heterogeneous signs - of a quality and discrete type.

Conclusions. The proposed approach has established the principal possibility to use the proposed methodology to solve the problem of dividing given trajectories represented by time series into classes. It

allows obtaining a model that, according to formal rules, determines the classification of trajectories by sets of heterogeneous features of its state at certain points in time and improves the reliability of determining the classification.

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ТОЛТЫРЫМ МАТЕРИАЛЫНЫҢ ҚАТАЮ КЛАССИФИКАЦИЯСЫН АНЫҚТАЙТЫН МОДЕЛЬ

Аннотация. Пайдалы қазбалардың бірқатар кен орнын игеру барысында қолданылатын толтырым материал күйінің класын анықтау маңызды және өзекті ғылыми-техникалық мәселе болып саналады, толтырымның оперативті дайындығын анықтау үшін химиялық-технологиялық қатаюдың үдеріс күйін талдау әдістері мен тәсілдерін әзірлеу қажеттілігі туды. Жұмыста материал күйінің алдыңғы даму үдерістері туралы ақпарат болған жағдайда толтырым материал күйінің даму траекториясының классификациясын анықтау мәселесін шешудің әдістемесі берілген.

Ұсынылған әдістеме басқарудың автоматтандырылған жүйесіне жатады және технологиялық үдерісті дискретті уақытша қарауға жол беретін күрделі объектілерді басқаруда пайдаланылуы мүмкін. Әдістеме құру үшін осы объект, жағдай, көпөлшемді динамикалық (уақытша) қатарда ұсынылатын үдерістерді тану және жіктеу әдістері қолданылды. Көппараметрлі динамикалық (уақытша) қатар ретінде қарастыруға болатын толтырым материалының қатаю үдерісін химия-технологиялық процесс ретінде қарастыру әр уақытта бетбелгінің жай-күйін жіктеу негізінде толтырым материал күйінің даму класын анықтауға мүмкіндік береді. Үдеріс күйі даму процесі траекторияларының класы туралы априорлық ақпарат болмаған жағдайда бірнеше пайдалы қазба кен орындарын игеруде қолданылатын толтырым материалдарының жай-күйін дамыту траекториясын жіктеу міндетін формалау ұсынылған. Проблеманы формалау негізінде үдерістердің даму күйінің бұрынғы үдеріс траекторияларының белгісі туралы қолда бар ақпарат бойынша бетбелгі материалы жай-күйінің даму траекторияларын жіктеуді анықтау міндетін шешу әдістемесінің сипаттамасы келтірілген.

Мақалада толтырым материалының жұмысқа дайындығын анықтаудың бұрынғы әдістері келтірілген. Олардың артықшылықтары мен кемшіліктері көрсетілген. Қазіргі әдістердің негізгі кемшілігі – құбылысты толық көрсетпейтін қатаю үдерісінің жеке сипаттау белгілерінің біржақтылығы. Ұсынылған тәсіл көпөлшемді уақыт қатары берілген траекторияларды класқа бөлу мәселесін шешудің жолдарын көрсетеді. Әдістемені қолданудың принципті мүмкіндігін белгілейді, бұл формальды ережелер бойынша оның жай-күйінің түрлі белгілерінің жиынтығы бойынша траекториялардың жіктелуін белгілі бір уақыт мезеті бойынша анықтайды және жіктеуді дұрыс анықтауға мүмкіндік береді.

Көпөлшемді динамикалық (уақытша) қатар түрінде ұсынылған технологиялық үдерісті дискретті қарауға мүмкіндік беретін көптеген күрделі үдерістер үшін қолдану мүмкіндігіне негізделген әдістеменің қамтылу аясының кеңдігін атап өткен жөн. Ұсынылған әдіс қоспа жағдайын бағалау процесін оңтайландырады, дәлдікті арттырады. Тапсырманы шешу әдістемесі бір-бірінен алыс білім салаларында кеңірек қолданыс табады. Жұмыс нәтижелері қоспаны бақылаудың дәстүрлі әдістері бойынша бірқатар артықшылыққа ие және басқа білім саласының өкілдері үшін қызықты.

Түйін сөздер: болжам, бетбелгі материалы, қауіпсіздік, динамикалық (уақытша) қатар, бейнені тану.

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МОДЕЛЬ ОПРЕДЕЛЕНИЯ КЛАССИФИКАЦИИ ПРОЦЕССОВ ТВЕРДЕНИЯ ЗАКЛАДОЧНОГО МАТЕРИАЛА

Аннотация. Определение класса состояний закладочного материала, применяемого при разработке ряда месторождений полезных ископаемых, является важной и актуальной научно-технической проблемой, что вызвало потребность в построении способов и методов анализа состояний химико-технологического процесса твердения для определения эксплуатационной готовности закладки. В данной работе представлена методика решения задачи определения классификации траекторий развития состояний закладочного материала при наличии информации о прошедших ранее процессах развития состояний материала.

Предложенная методика относится к автоматизированным системам управления и может быть использована при управлении сложными объектами, допускающих дискретно временное рассмотрение технологического процесса. Для построения методики были использованы методы распознавания и классификации данных объектов, ситуаций, процессов, представляемых многомерными динамическими (временными) рядами. Рассмотрение процесса твердения закладочного материала как химико-технологического процесса, который можно рассматривать как многопараметрический динамический (временной) ряд позволяет определить класс развития состояния закладочного материала на основе классификации состояния закладки в каждый момент времени. В работе предложена формализация задачи классификации траекторий развития состояний закладочных материалов, применяемых при разработке ряда месторождений полезных ископаемых, при отсутствии априорной информации о классах траекторий уже прошедших процессов развития состояний процессов. На основе проведенной формализации проблемы приведено описание методики решения задачи определения классификации траекторий развития состояний закладочного материала по имеющейся информации о признаках траекторий уже прошедших процессов развития состояний процессов. В статье приведены ранее предложенные методы определения момента эксплуатационной готовности закладочного материала. Показаны их преимущества и недостатки. Основным недостатком существующих методов является односторонность признаков описания процесса твердения в отдельности, что не отражает полную картину происходящего явления и является недопустимым.

Предлагаемый подход установил принципиальную возможность применения предлагаемой методики для решения задачи разбиения заданных траекторий, представленных многомерными временными рядами, на классы, что позволяет получить модель, которая по формальным правилам определяет классификацию траекторий по наборам разнотипных признаков его состояния в определенные моменты времени и позволяет повысить достоверность определения классификации. Хочется отметить широту охвата методики, которая заключается в возможности ее применения для большого множества сложных процессов, позволяющих дискретное рассмотрение технологического процесса, представленных в виде многомерных динамических (временных) рядов. Предложенный способ оптимизирует процесс получения оценки состояния смеси, повышает точность.

Методика решения задачи может найти обширную область применения в достаточно далеких друг от друга областях знаний. Результаты работы имеют ряд преимуществ перед традиционными методами контроля и интересны для других областей знаний.

Ключевые слова: прогноз, закладочный материал, безопасность, динамические (временные) ряды, распознавание образов.

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PREPARING SOLUTIONS BASED ON INDUSTRIAL WASTE FOR FRACTURED SURFACE STRENGTHENING

Abstract. Results of longstanding researches of Satbayev University scientists on the development of modified building materials to strengthen cracked mountain structures based on industrial waste are considered. Industrial processing of technogenic raw materials (enrichment and processing waste, overburden and enclosing rocks), which is similar in composition to natural and used in conventional trend, scarcely different from industrial processing of mineral raw materials. Creation of effective technologies for the processing of technogenic raw materials is an urgent task, which make it possible to obtain competitive products from it for various industries.

Various methods of preparing solutions for strengthening of fractured rocks and building structures are analyzed. Research results of tailings of the Balkhash Mining and Metallurgical Combine and preparing solutions for strengthening fractured rocks and underground mining structures are presented. Rock mass strengthening in cracked areas is achieved by adding substances into the cracks, which after hardening and solidification with rocks, increase its shearing resistance characteristics. The most widespread hardening methods were cementation during mine workings (underground structures) in fractured rocks.

Significance of obtained results for construction industry is in expansion and reproduction of raw material base of building materials industry through the use of Mining and metallurgical complex waste (tailings) and development of resource-saving technologies. Practical significance of work is in the detailed development of modified method for the production of building materials and products.

Key words: field development, mine site, fracturing, cracks, rock mass caving, strengthening, mining waste, building materials, modified solutions.

Introduction. Mining enterprises of Kazakhstan pay special attention to the industrial safety of subsurface development. One of the real examples is geomechanical researches conducted by Satbayev University in the framework of the project "Risk reduction of technogenic disasters by developing innovative management methods" (2015-2017). Currently, within the framework of Project "Innovative methods development for prediction and assessment of rock mass state for the prevention of technogenic nature emergencies" researches on study and ensuring mountain structures stability are conducted by young scientists.

The content of the work. Problems of mine workings stability in fractured rocks are the most hard-solving problems in the construction and operation of mining enterprise. These problems intensely exist in the polymetallic deposits of Kazakhstan: Tekeli, Akzhal, Verkhnekairaktinsky, Karagaylinsky, Tekeli. Ores and enclosing rocks of these deposits are complicated by fractured deformations and make its development more difficult.

Research results of mine workings at the Akzhal mine (at mine site and underground horizons) showed that the largest number of dumps is confined to fractured rocks, and dumps volume is increasing as far as workings' standing. Observations of the mine workings, which were performed on the fractured rocks, revealed that they are stable for a month. After two or three months, pins are formed up to 10-15 cm

in size. Pins and outfalls arise and develop within six months, roof collapses become acquainted in the form of domes. This acutely increases volume and complexity of the tunneling works, as well as the cost of workings fixing and repairing.

Stability of adjacent rock masses is determined by the degree of their fracturing. Strengthening technology of fractured massif should ensure the complete cracks filling in the massif with different composition and securely bind individual structural blocks into a single whole. One of the effective methods to prevent this type of rock deformation is their artificial strengthening which allows to provide the necessary slopes stability of inoperative mine sites and in some cases to prevent possible rock collapse in weakened areas, in others - significantly reduce the volume of overburden operations [1-3].

The most common strengthening method is rock cementation. Such method of ensuring the slopes stability of mine sites is complex task, solution of which should include not only parameters determination of stable slopes, but also their management to achieve the best economic results in the development of natural resources. Use of artificial strengthening of rocks and massifs allows increasing gradient of slope in areas with unstable rocks. Strengthening advisability is established by technical and economic calculations. Strengthening of some areas is achieved with the help of substances that significantly increase its strength characteristics. Adding substance in the massif is made under pressure, using cement solutions, silicates and polymer resins as hardening material, confirmed by publications of leading scientists in the field of mining [4-10].

To prevent the collapse of underground workings (underground structures), passed through fractured rocks, roof timber with metal fencing mesh and shotcreting are used. However, roof rocks cleavage of transport drift and significant rocks destruction indicates that this timber does not solve the problem of stability ensuring of workings and does not prevent deformations development. As a result, after 2-3 years of standing workings, timber are damaged and major repairs are required. Therefore, effective solution of controlling issue on geomechanical properties of rocks is particularly important for adjacent rock mass of mine sites and for underground workings passed through fractured rocks [11-13].

Researches on rock fracturing and methods development of controlling their properties were carried out for the conditions of Akzhal deposit. Analysis of geological conditions of the field and workings condition passed by fractured rocks showed that fracture systems of heavy pitch have great influence on the workings' stability. By nature, cracks vary from smooth, wavy to uneven, splintering. The width of the crack opening does not exceed 3 mm and averages 1.5-1.8 mm. Based on conducted researches on samples of fractured rocks, it was found that rocks have different degrees of fracture. According to the degree of change, they were classified into 3 groups: particularly, highly and partially disturbed (table 1).

Various strength characteristics of fractured rocks predetermine the need for differentiated approach to managing the rocks properties with fracturing intensity.

Table 1 – Classification of rocks, their physical and mechanical properties, structure and texture

№ group	Fracture intensity	Rock characteristics	№ sample	Compres-sion strength on MPa	Rock strength by Proto-diakonov$f$	Srtucture	Texture	Fracture plane state	Fracture positioning
1	Particularly fractured	Quartz-sericite chlorite	9	43,4	3	Small acinose	Fissile	Fracture planes are cragged	Fractures of parallel lamination
			10	44,8	3				
			11	65,5	5				
	Mean value		12	51.2	4				
II	Highly fractured	Sericite-quartz.	2	84	6	Small acinose	Massive	Fracture planes are cragged, hackly	Fractures multioriented
			4	103,6	7				
			14	106,4	8				
	Mean value			62,7	7				
III	Partially fractured	Diorite Quartzite	3	140,0	10	Small acinose	Massive	Fracture planes are cragged, hackly	Fractures multioriented, parallel lamination
			5	154,0	11				
			7	162,4	12				
	Mean value			152,1	11				

For highly fractured rocks with strength factor of 5-8, it is recommended that workings walls be coated with modified concrete in combination with roof timber. Application of waterproofer coat will significantly reduce rock pressure on timber, limit the weathering spread and delamination of overlying layers and prevent properties change of fractured rocks. To study the physical mechanical properties (PMP) of solutions of various compositions, cubic samples of cement and water with modifying additives were prepared in various percentages of cement weight. Research results are shown in figure 1.

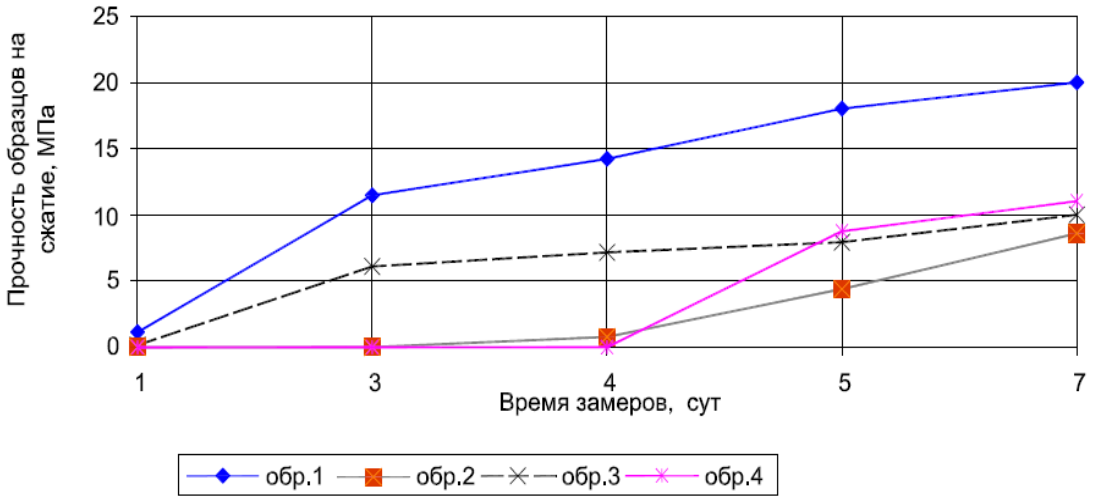

Figure 1 – Change dependency of concrete strength with various additives on time:
1 - Movilita additive; 2 - additive of sodium silicate and calcium chloride;
3 - additive of construction emulsion PVA-M; 4 - addition of high molecular polymer polyacrylamide

For safe deposit development on the underlying horizons, in order to prevent cavings, and also to suppress the dust formation of dumps, insulating solution was developed by our scientists in cooperation with "CelSIM" laboratory, composition of which is given below.

Known solution for strengthening fractured rocks described in the book Pevzner M.E. [14]. It contains cement, water and additive - calcium chloride in the amount of 1-2.2% by weight of cement. Solution has high cost.

Known composition for hardening rocks [15] and contains following components: wt,%

Carbamide resin brand KSM	88-92,
Watersoluble polyester blend	4-6
Aluminum chromophosphate	4-6,

Solution has high cost and must be prepared directly at the well.

We are declaring solution that includes cement, filler and water. The basis of the invention is solution creation for strengthening fractured surfaces, having low cost, sufficient fluidity to fill small cracks and adhesion to rocks, high strength of material obtained and allowing recovering mining waste - concentration plants tailings.

Invention relates to mining and building materials, namely to strengthen rocks with binder solution. Technical result: utilization of mining wastes - concentration plants tailings, achievement of high fluidity of solution, adhesion to rocks and strength of composition obtained.

To achieve this result, composition for strengthening fractured rocks containing cement , filler and water, according the invention results as the filler contains concentration plants tailings and additionally contains Movilite dispersion polymer powder with the following equivalence ratio, wt. %:

Cement	30-35
Concentration plants tailings.	45-50
Movilite dispersion polymer powder	0,8-2
Water other	

Specified equivalence ratio is optimal and obtained experimentally. On the one hand, necessary fluidity of solution and adhesion, and on the other hand, to obtain the material of the necessary strength after setting it with rocks. In each particular case, to select optimal composition of bonding solution, it is necessary to study the physical and chemical composition of tailings of various concentration plants.

For example, Portland cement M 400 of Karaganda cement plant and tailings of the Balkhash mining and metallurgical plant are acceptable for the Akzhal mine and Portland cement of the Shymkent cement plant and tailings of the Akbakay concentration plant itself are acceptable. The X-ray appearance of the Balkhash mining and metallurgical complex tailings (figure 2) shows mainly three components with 4.23 diffraction lines; 3.238; 2,455; 2.28; 2.237; 2.127; 1.977; 1.817; 1,669; 1.658; 1.541; 1.454; 1,388; 1,373, corresponding to quartz.

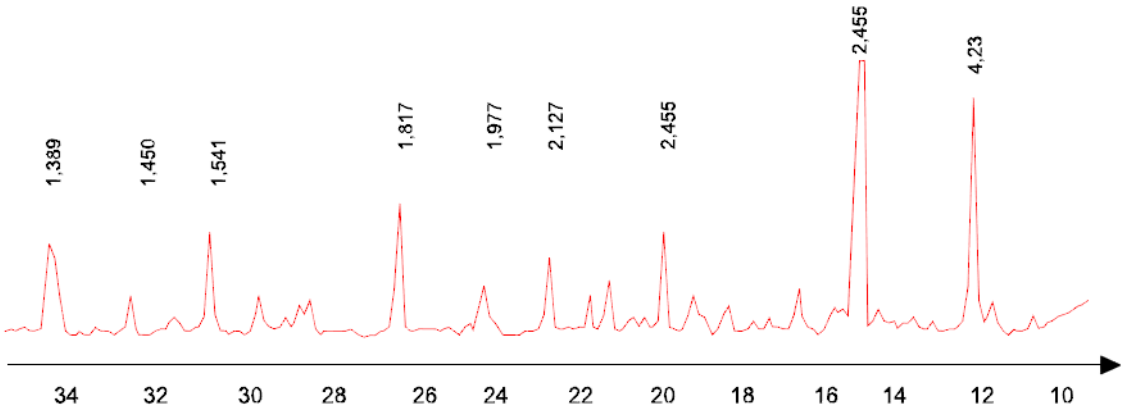

Figure 2 – The X-ray analysis of Balkhash mining and metallurgical complex tailings

After components dosing the cement, tailings and movilit are loaded into concrete mixer and mixed thoroughly. Then add water and mix. Finished composition is delivered by underground workings and pumped into disturbed pillars and roof of the chambers. To determine the strength, 4x4x16 cm samples were molded from the composition and compacted on vibrating plate for 45 sec. After a day, the samples were removed from the molds and stored in humid conditions for 28 days, and then physical and mechanical tests were carried out, results of which are presented in tables 1 and 2.

Table 1 – Physical and mechanical properties of the solution

	Composition of the solution, wt.%			Index			
	Cement	Concentration plants tailings	Movilit	Water	Compressive strength, MPa	Bending strength MPa	Slump, мм
Sample 1	30	50	4	16	32,5	4,7	150
Sample 2	32,5	47,5	3,5	16,5	35,6	5,2	145
Sample 3	35	45	3,0	17,0	37,2	5,8	143

Table 2 – Physical and mechanical properties of the composition

Index	Sample 1	Sample 2	Sample 3
Compressive strength, MPa	22,5	25,6	27,2
Frost resistance, cycles	10	12	15

Technical novelty of the created solution is confirmed by the patent of the Republic of Kazakhstan for the invention [19].

Analysis of mining and construction works showed that acid-resistant cements are the most widely applicable at present, which are obtained by mixing filler with sodium silicate and accelerator of setting and hardening process - calcium chloride of 30% concentration with a density of 1280 kg / m^3. Therefore, liquid sodium silicate with modular number of 2, 5 and density of 1330 kg / m^3 and 1250 kg / m^3 was used to create modified solution. In the course of researches on solutions with high - molecular polymer additives the following polymers were tested: polyvinyl acetate dispersion - PVAD, builder dispersion "Movilit VDM-618". Observations results showed that the best adhesion with humid rocks is achieved in solutions of modified building dispersion "Movilit VDM-618 compositions (see figure 3, lines 1, 5). Therefore, solution modification of construction dispersion "Movilit VDM-618" significantly improves its properties; the set of strength occurs in humid aggressive environment. In addition, "Movilit" building dispersion adding to solution gives the properties of gas and water resistance, resistance to aggressive underground environments. To study adhesion, solution modified with various additives was applied to fractured rocks. Test results are shown in figure 3.

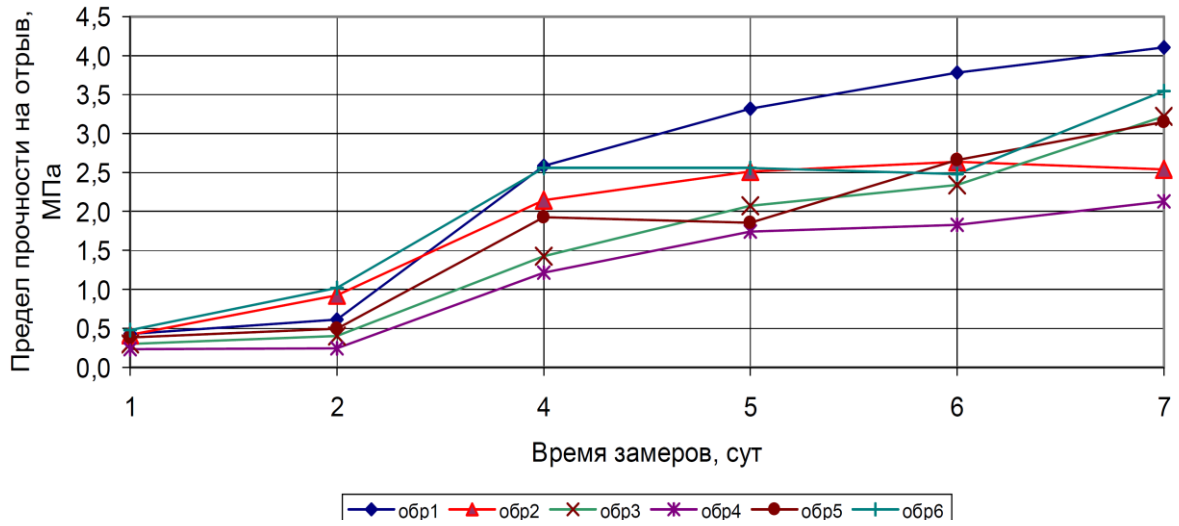

Figure 3 – Influence of time on the adhesion change of modified cementations' compositions with fractured rocks:
1 – with the addition "Movilit VDM-618"- 5% of cement composition;
2 - with the addition of sodium silicate with δ = 1.33 g / cm^3 and m = 2.5 calcium chloride;
3 - with the addition of sodium silicate with δ = 1.25 g / cm^3 and calcium chloride;
4 - with the addition of PVAD; 5– with the addition of PAA

Pilot tests of obtained composition in underground workings of the Akzhal mine showed its sufficient penetrability and rapid polymerization with its own high mechanical properties [20].

Conclusions. Use of concentration plants tailings will contribute to reduce composition cost and increase material strength. With more than 35% increase of cement amount and more than 4% increase super plasticizing additive - composition cost increases. With less than 30% decrease of cement amount and super plasticizing additive less than 3% decrease - strength of the obtained material increases.

Increasing of concentration plants tailings by more than 50% will lead to decrease in the solution fluidity and its adhesion to rocks, and less than 45% decrease will increase the composition cost.

Thus, use of developed solutions allows obtaining the roof with high strength and higher adhesion. It should also be noted that new solution use ensures strengthening of weak sections of open pit sides and underground mining structures and can significantly reduce the damage effect of concentration plants waste on environment.

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ӨНДІРІС ҚАЛДЫҚТАРЫ НЕГІЗІНДЕ ЖАРЫҚШАҚТАЛҒАН БЕТТЕРДІ БЕКІТУ ҮШІН ЕРІТІНДІЛЕР ЖАСАУ

Аннотация. Сәтбаев университеті ғалымдарының өнеркәсіп қалдығы негізінде жарықшақталған тау жыныстарын нығайту үшін жаңартылған құрылыс материалдарын жасау жөніндегі көпжылдық зерттеулерінің нәтижелері қарастырылды.

Табиғи құрамы жағынан жақын техногенді шикізаттарды (байыту қалдығын, аршыма және жанама тау жыныстары) және дәстүрлі бағыттарда пайдаланылатын минералды шикізаттарды өнеркәсіптік қайта өңдеудің айырмашылығы жоқ. Сондықтан, техногендік шикізатты қайта өңдеудің одан өнеркәсіптің түрлі салалары үшін бәсекеге қабілетті өнім алуға мүмкіндік беретін тиімді технологияларын құру бүгінгі күннің маңызды мәселесі болып отыр.

Карьер беткейлерінің құлауы мен шөгуінің алдын алу үшін үлкен массивтердегі тау жыныстарының жасанды түрде беріктігін ұлғайтуға келмесе де, жекелеген беткей деформацияларын және жасанды бекемдеу әдісімен карьер беткейінде опырылудың алдын алу қазіргі таңда отандық және шетелдік карьерлерде қолданылуда. Көптеген карьерлерде жұмыс істемейтін ернеуді түзетін тау жыныстарының құрылымы мен физикалық-механикалық қасиеттері біртексіз болып келеді. Карьер алаңындағы тау жыныстары біртекті болып түзілген күннің өзінде кен орнында, әдетте көптеген тектоникалық бұзылыс аймағы жиі кездеседі.

Тектоникалық бұзылыс аймағы, өз кезегінде өлшемдері мен кеңістікте таралуына байланысты беткейлер мен ернеудің орнықтылығына мейлінше кері әсерін тигізеді. Мұндай жағдайда бекіту арқылы тау жыныстарының үгілуі мен опырылуын баяулатуға, карьер беткейінің опырыла құлауының және тау жыныстарының сырғу беті арқылы жылжуының алдын алуға болады.

Мақалада жарықшақталған карьер беткейі мен құрылыс нысандары қабырғаларын бекіту үшін қажет ерітінділерді алу мүмкіндігі зерттелген. Балқаш тау-кен металлургия комбинатының (БТКМ) байыту қалдықтарын зерттеудің және жарықшақталған тау жыныстары мен құрылыс нысандарын нығайту үшін ерітінділерді алу нәтижелері келтірілген.

Әлсіреген учаскелердегі тау жыныстары массиві мен құрылыс қабырғаларының бекітілуіне, жарықшақтарға арнайы ертінді енгізу арқылы жүзеге асырылады, олар қатайғаннан кейін нысанның жылжу кедергі қабілетін арттырады. Бекемдейтін затты массивке енгізу қысым жасау арқылы жүзеге асады, бекемдейтін материал ретінде цемент ерітінділері, силикаттар және полимерлік материалдар қарастырылған. Бекіту әдістерінің арасында ең көп таралғаны – ол кен қазбаларын (жерасты құрылыстарын) жарышақталған тау жыныстарында жүргізу кезінде цементтеу. Қолдану аясы – қатты жарықшақты үгітілмелі және жартылай жарлыдан бастап ірі тасты құм мен жұмыртастарға дейінгі тау-кен жыныстарының массиві.

Құрылыс индустриясы үшін нәтиже маңызы құрылыс материалдар өнеркәсібінің шикізат базасын кенметаллургия кешен қалдығын (байыту фабрикалары қалдығын) пайдалану және ресурстарды үнемдейтін технологияларды дамыту арқылы құрылыс материалдар өнеркәсібінің шикізат базасын молайту және қайта жаңғырту болып саналады. Жұмыстың практикалық маңыздылығы – құрылыс материалдары мен бұйымдарын өндірудің модификацияланған әдісінің жасалғандығында.

Түйін сөздер: кен орындарын игеру, карьер, бұзылу, жарықшақ, тау-кен массивінің опырылуы, бекіту, тау-кен өндіріс қалдықтары, құрылыс материалдары, ерітінділер.

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СОЗДАНИЕ РАСТВОРОВ НА ОСНОВЕ ОТХОДОВ ПРОИЗВОДСТВА ДЛЯ УКРЕПЛЕНИЯ ТРЕЩИНОВАТЫХ ПОВЕРХНОСТЕЙ

Аннотация. Рассмотрены результаты многлетних исследований ученых Satbayev Unibersitu по вопросам разработки модифицированных строительных материалов для укрепления ослабленных трещинами горных сооружений на основе отходов производства.

Промышленная переработка техногенного сырья (отходы обогащения и переработки, вскрышные и вмещающие породы), близкого по составу к природному и используемого в традиционных направлениях, практически не отличается от промышленной переработки природного минерального сырья. Создание эффективных технологий переработки техногенного сырья, позволяющих получать из него конкурентоспособную продукцию для различных областей промышленности, является актуальной задачей.

Если для предупреждения обрушений и оползней искусственное повышение прочности больших массивов пород практически пока неосуществимо, то предупреждение деформаций отдельных уступов и предотвращение осыпеобразования с поверхности откосов путем искусственного укрепления находит сейчас применение на отечественных и зарубежных карьерах. На большинстве карьеров горные породы, слагающие нерабочие борта, неоднородны по своей структуре и физическим и механическим свойствам. Даже в однородных изверженияхпородах карьерного поля насчитывается множество зон тектонической нарушенности.

В зависимости от их размеров и пространственной ориентации они оказывают более или менее значительное влияние на устойчивость уступов и бортов. С помощью укрепления можно замедлять процессы выветривания и осыпания пород, предупреждать обрушения уступов и осыпание пород с поверхности откосов.

В статье проанализированы различные способы создания растворов для укрепления трещиноватых горных пород и строительных сооружений. Приведены результаты исследования хвостов обогащения Балхашского горно-металлургического комбината (БГМК) и получения растворов для укрепления трещиноватых горных пород и подземных горных сооружений.

Упрочнение массива горных пород на ослабленных участках достигается введением в трещины веществ, которые после отвердевания и схватывания с породой увеличивают ее характеристики сопротивления сдвигу. Введение упрочняющего вещества в массив осуществляется под давлением, а в качестве упрочняющегося материала нами рассматриваются цементные растворы, силикаты и полимерные смолы. Наибольшее распространение среди методов упрочнения получила цементация при проведении горных выработок (подземных сооружений) в трещиноватых породах. Область ее применения – массив, сложенный породами от сильнотрещиноватых скальных и полускальных до крупнозернистых песков и галечников при наличии в породах трещин, обеспечивающих доступ цементного раствора в трещину.

Значимость полученных результатов для строительной отрасли заключается в расширении и воспроизводстве сырьевой базы промышленности строительных материалов за счет использования отходов ГМК (хвостов обогащения) и разработки ресурсосберегающих технологий. Практическое значение работы состоит в том, что детально разработан модифицированный способ производства строительных материалов и изделий.

Ключевые слова: разработка месторождений, карьер, нарушенность, трещины, обрушения горного массива, укрепление, отходов горного производства, строительные материалы, модифицированные растворы.

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ENVIRONMENTAL IMPACTS ASSESSMENT OF TASH BAUXITE MINE IN SEMNAN PROVINCE, NORTHERN IRAN

Abstract. Mineral resources and mining are the pillars of development in any country. Mining development must be performed based on the pillars of sustainable development to prevent the damage to water, soil, air, plants, wildlife and social life of local communities by exploiting valuable minerals and economic development. Lack of attention towards the pillars of sustainable development in the long-term can turn into serious damages to environment and social life of local communities. There would probably be needed to spend multiple times more than the added value earned by the mineral production in order to recompense the environmental and social damages caused by unauthorized mining. Therefore, from the late 2001 the beginning of mining activities in the Bauxite mine of the village of Tash has caused challenges for the environment, natural resources and social issues. Some of the most important of which are loss of water reserves in the region, the pollution of ground and surface waters, soil erosion, susceptibility of the region to dust, loss of vegetation and rangelands, the endangerment of wildlife, flooding due to inappropriate tailings depot. This paper addresses to the causes of these pollutions and how to stop further damages of the process.

Key words: Environment Impact Assessment, Bauxite, Mineral Resources.

Introduction. The future of Bauxite mines in Iran is based on production of 1.5 million tons of Aluminum to 2025 horizon. Lack of the primary substance of this strategic metal is one of the main challenges of the industry. It has led to the import of Alumina powder into the country. More than 500 thousand million tons of Alumina powder was imported during 2017 and around 70 percent of the primary substance of the Aluminum production units of the country are imported. The Bauxite mine of Tash is located in Semnan province, in Shahroud city next to the village of Tash. It is considered one of the Alumina mines of Iran which is working under the supervision of Iranian Mines & Mining Industries Development & Renovation Organization. This company is the only producer of Alumina powder in Iran. The deposit type of this layered mine is a layer of AlOOH ore and the bedrock of Tash is lime and dolomite deposit. 93 bore holes along with 6573 meters of drilling has been done for further discovery studies. The production capacity of this mine is 300 to 400 thousand tons per year and it is 13.13 km^2. 1.4 million tons of Bauxite has been extracted so far. Against this harvest, 1.86 million tons of tailings were harvested. Tailings up to a ratio of 56 to 1 are also possible. This means to hit rock bottom economically. The ultimate volume of tailings dump is also estimated about 62 million tons [Ashofteh et al, 2019].

1. Geology of the area under study. The lenses of Bauxite of Tash are organized based on textural and mineralogical ingredients which are zoned from the bottom to top with lower clayey layer, shale Bauxite unit, hard Bauxite unit and upper clayey layer.

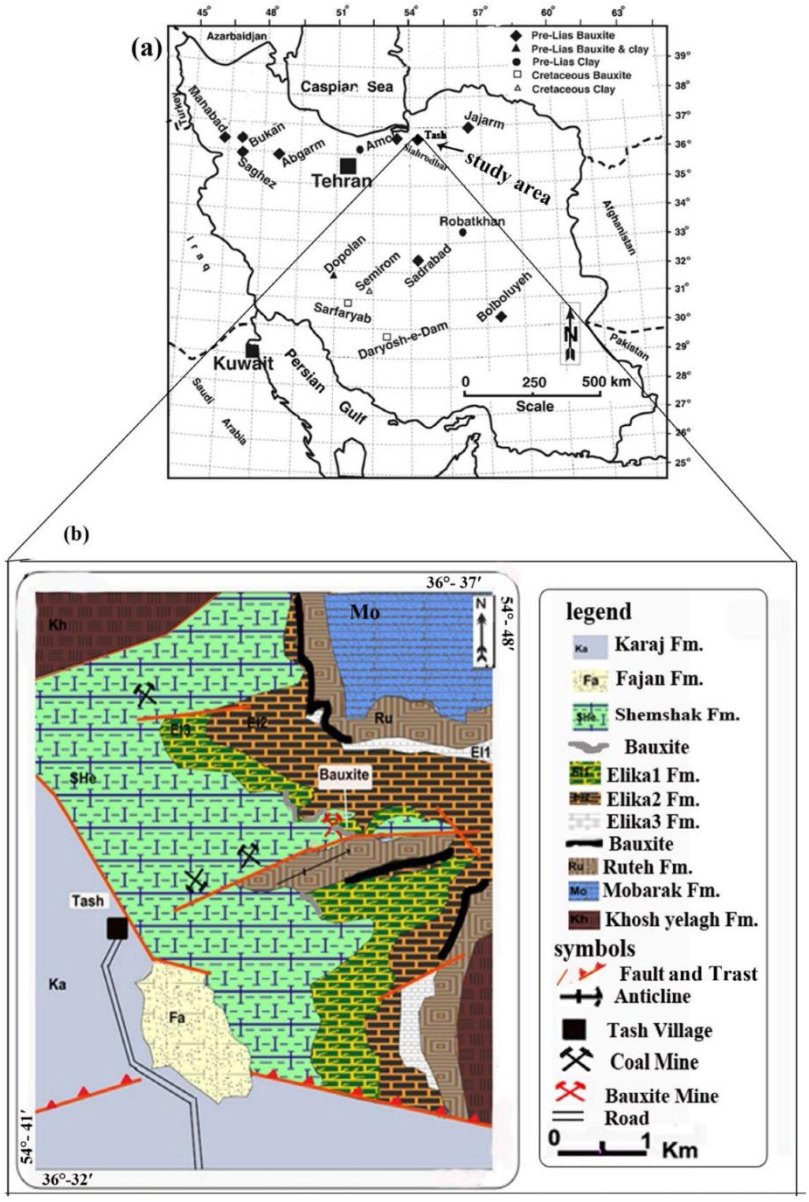

Figure 1 – Map of the geological units of the area under investigation

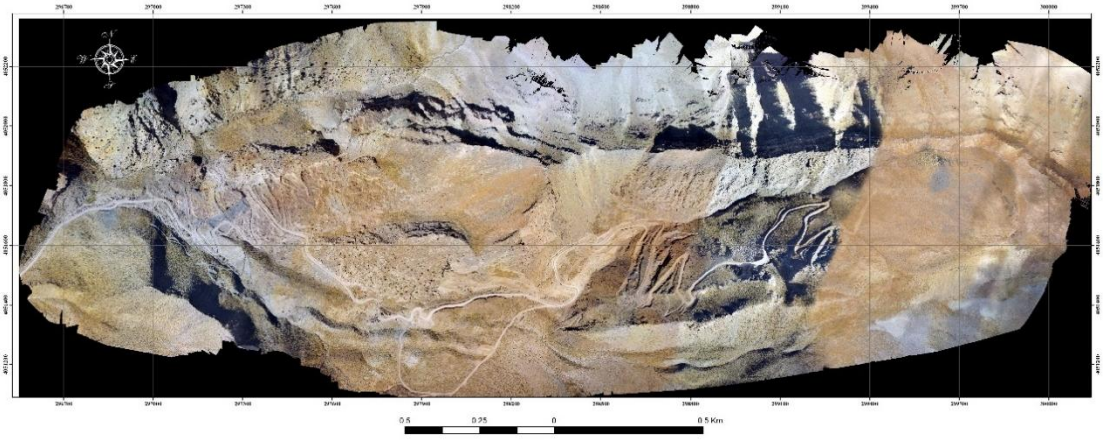

Figure 2 – Satellite image of Tash

1.1. Lower kaolinite layer. This layer is located above the Elika dolomites and under the Bauxite of shale. It is whitish gray and it has 30 to 85 centimeters thickness. The chemical and mineralogical composition of this layer in different parts of the mine is heterogeneous. The main minerals are kaolinite in some parts and in other parts illite and diaspores make up the main ones. This lack of homogeneity is caused by the differences in circumstances in the sediments. This layer is enriched with Bauxite if drainage conditions are appropriate and when the drainage condition is inadequate, clay minerals such as illite and kaolinite are made. This is part of the shale layer that has been separated from the Bauxite by two factors. The first factor is direct contact with carbonate rock which has a totally different condition from shale Bauxite conditions. The other factor is the drainage and fluid motion manner in this layer [Aghanabati, 2006].

1.2. Shale Bauxite unit. This layer is located above the lower kaolinite layer and below the hard Bauxite layer. The thickness of the layer changes based on the sediment's environment. It is mostly 0.5 to 2 meters thick. Shale Bauxite is dark red, brown, usually layered and very fragile. Hematite minerals are often found in the form of nodules. The chemical and mineralogical admixture of this layer mostly shows the enrichment of moving elements such as K, La, Mg, Na, Pb, Rb, Sr and the depletion of elements such as Cr, Ga, Mo, Nb, Th, Zr. This elemental behavior is seen in most karst Bauxite deposits [Nabavi, 1976].

1.3. Hard Bauxite unit. This unit forms the main ore deposit. It is called hard Bauxite, industrial Bauxite, and hard diaspora. It is around 3 to 10 meters thick and is founded in the colors gray, green, red and brown. The Aluminum percentage of this part is very high. It sometimes even goes up to 80 percent. The chemical and mineralogical composition elements reveal the fluctuation of the reductive and oxidizing conditions during the formation of this unit. By the presence of red Bauxite, the oxidation conditions are caused. This process can be ascribed to the exogenous oxidation of iron ores and the formation of secondary iron oxides and hydroxides which is formed in the oxidized environment of the continental margins. In addition to secondary iron ore minerals, anatase, boehmite and diaspora are formed in oxidation conditions in which the admixture of boehmite and hematite reveals the oxidizing and acidic circumstances of the environment. The resuscitation condition is defined with the presence of the green Bauxite enriched with chamosite. The iron needed for these minerals to be made is received from the iron and sulfur oxides of the bacterial revival of the environmental sulfates. Chamosite is formed in low pressure environment with a low pH between 7 to 8 and an Eh higher than -0.2. The amount of active silica is higher in the hard Bauxite than other Bauxite units. This makes problems with Alumina production [Abedini et al, 2019].

1.4. Upper kaolinite unit. This part is hardly found in some parts of the ore under the shales. The chemical and mineralogical admixture of this layer is almost homogenous and mainly made up of kaolinites. It is possible that the Aluminum enriched minerals of this layer be secondary meaning that Aluminum clay minerals including kaolinite and halloysite react and make aluminum minerals because of the similarity of the chemical behavior of Aluminum with silica. New minerals are found in the Bauxites in the kaolinite mettle in the form of veins and membrane. The main part of this layer is destroyed due to erosion. One of the obvious signs of this layer is the presence of concretions and hematite nodules. The separate presence of the Aluminum and iron layers in concretions is the result of subtractive ironing. The formation of concretions is the result of epigenetic processes. The main mineral of nodules are hematite. They are caused by fluctuations in the surface of the ground waters. If there are nucleuses in the centers of the nodules and they also contain concretion circles, they are called pisoid and macro pisoid tissue. If they don't have nucleuses and contain no concretion circles, they are called iron nodules and the texture is called nodular tissue. The low energy level of sediment area and the lack of appropriate nucleuses lead to the formation of this tissue. The existence of concretions and lateritic nodules in the area confirm that the dilution containing silicate gel with other sub-elements along with hematite are shaped in karstic activities [Esmaeili et al, 2010].

Figure 3 – Aerial picture of the Bauxite mine of Tash

2. Geomorphology of the area of study. Mount Shahvar with 4017 meters height is one of the highest mounts of the eastern Alborz mountain which is located in Semnan province. The average height and the maximum mining catchment area 3394 and 3891 meters. One of influential parameter is the vegetation. There are unique varieties in Shahvar region. Onobrychis cornuta and juniperus in the area which grow in steep stopes have an important role in stabilization of the soil and controlling the floods. The areas with steep slopes for example greater than 65 degrees have a very wide mining range. Slope is one of the influential parameters on the amount of runoff, erosion and sedimentation of the basins. The basin slope is also an influential element on the longitudinal slope of the waterways and as a result the energy of surface currents. One of the parameters that affect the surface flow share of total downfall is also the slope. The more is the slope, the less becomes the rally time. Therefore, in steep slope basins, higher discharge can be expected than low slope basins [Abedini et al, 2019].

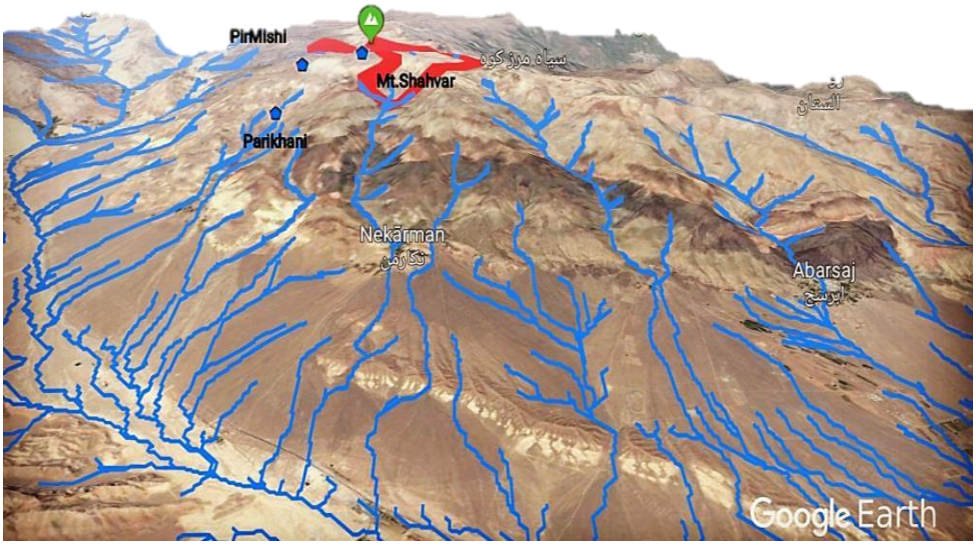

Figure 4 – Basin of Bastam-Shahroud and its gully and river system

3. Environmental issues of Bauxite mining of Tash. One of the most important environmental issues of Bauxite mining of Tash is the disappearance of vegetation, wild life, decrease in animal husbandry.

3.1. Dust creation. Some of the important reasons for the creation of dust and dust in this area are as the following:

Explosions, existence of screeners in the mine, destruction of vegetation, erosion of soil, commuting of the trucks, disposal of tailings and soil, mining machinery activities and incorrect management of waste.

3.2. Threat to groundwater resources. Bastam watershed area is made up of smaller watershed areas which were gathered due to thousands of years of rainfall and storage of rainwater in groundwater aquifers. The entire area of Bastam-Shahroud is made up of storage and and is fed by the reservoir in the basin. The karstic cavities of the limestone in this area are water reservoirs. They are one of the strategic water reserves of Iran. Mining activities specially the explosions has caused a risk of destruction of reservoir rocks of the water resources of the area. Mining is done in the northern borders of the watershed area of Bastam-Shahroud which is next to the watershed of Aliabad in Gorgan. Extensive destruction of the watershed boundary causes the topographic slope to shift northward in the catchment basins. Therefore, the water sheds to the watersheds of Aliabad in Gorgan and as a result the water supply of Shahroud area faces a serious problem. It is possible to extract bauxite from lime formation over 200 million years old up to 800 meters depths. There is a risk of disappearance of water reserves in the area if the open exploitation of the mine continues. Negative influences of mining activities on the water reserves can be stopped by conducting precise studies, banning explosions and gathering extra tails of the mine. Based on the studies conducted, there is 235 million m^3 water in this area which equals the amount of water in the reservoir of the Karaj dam (200 million m^3) which reveals the importance of conservation of this source.

3.3. Pollution of ground waters and surface. There is no proof that confirms the pollution of ground waters and surface with heavy metals like arsenic, plumbum, chromium and nickel but the preliminary studies show that mining activities in the area has caused a rise in the amount of Mg, Al, Si and Na to the density of 1,8 ppm, 273 ppb, 14,9 ppm and 3,5 ppm. Without the mining activities, the densities were 1 ppm, 59 ppb, 0.8 ppm and 0.7 ppm. Based on the declaration of the head of the village of Tash, the amount of water running from Shahvar springs has had a prominent decrease in comparison to the past.

Table 1 – Summery of the data related to Bauxite mine of Tash

Row	Additional Description	Description	Title
1		1986	The first report on the mining potensial
2		2008	Exploratory studies
3		2008	Mineral range registration
4		1300 Hectare	Mineral area
5		2010	Exploration license
6		6573 Meters	Drilling rate for exploration
7		2013	Certificate of discovery
8		2014	Issuance of operating license
9		1,4 Million tons	Mine utilization rate so far
10	The average tailing ratio is 14: 1	1,86 Million tons	The rate of tailings mining so far
11	According to recent studies, it is 8.3 million tons	775 Thousand tons	Total mine storage in license
12	That increased up to 350,000 tons	140 Thousand tons	Annual allowance for mine harvesting
13		300 People	Direct employment in the mine
14		1000-1500 People	Indirect employment in the mine
15		300000 Rial	Cost of exploitation of per ton of Bauxite
16		300000 Rial	Cost of exploitation of per ton of tailings

3.4. Creation of floods due to tailings depot in waterways and valleys and inadequate tailing management. Since the beginning of mining activities in Bauxite mine of Tash, 1400000 tons of Bauxite has been exploited. Against 1860000 million tons of tailings were carried out. Based on previous studies, the amount of dump exploitation in the mine is 14 to 1. The maximum range is 56 to 1 economically. Therefore, during the next years a huge mass of waste (more than 10 million tons) will be created. Inadequate management and lack of a plan to organize this amount of waste is one of the most important challenges of bauxite mine of Tash. Nowadays, tailing dumps are poured into valleys and water ways which leads to high possibilities of flood creations. Floods have caused a lot of trouble in Tash in 2018. Therefore, the most important problems caused are disappearance and destruction of vegetation, blocking the waterways and the threat of destruction of the watershed's border. In other valleys empty of tailing dumps, no flood has happened but in the village flood has happened because of mining depot in the valley and blockage of waterways.

4. Statement of the problem. Water samples of the Tash region were sent to the laboratory of Iran Mineral Processing Research Center and analyzed by the titration method to determine water hardness. The hardness degree of these samples was discovered to be lower than the World Health Organization (WHO) standard. Water hardness was ranked as good adopting Schuler's standard. The TDS parameter was measured by a multimeter to determine water quality. According to the WHO standard, the TDS of all samples except 2W exceeds the standard. The presence of calcareous and marl units as well as long distance passed of water resources can be an explanation for the high TDS. The rise in TDS correlated with mineral activity has resulted in the more dissolution of the material. Assessment of MI and HPI index revealed that all samples were contaminated and non-drinkable. The pH, also known as acidity, is one of the chemical characteristics of water. The "Iran Standard 1053" defines the allowable pH of water between 6.5 and 8.5. The pH measurement of the water samples revealed that their pH concentration ranged from 6 to 8.3. The pH concentration of all samples follows the Iran Standard 1053, but the 2W sample obtained from the contact site of Elika and Shemshak formation has a pH of 6. This shows the influence of Shemshak's coal formation.

4.1. Water quality evaluation based on the Metal Pollution Index. This index is a measure to determine the impacts of heavy metal pollution on water quality. This index was proposed by Tamasi & Cini (2004).

$$MI = \sum_{I}^{N} \left(\frac{ci}{(MAC)i} \right)$$

In which, *Ci* is the concentration of each element in the water and (*MAC*)*i* is the number of the metal element. If *MI*>1, the water is not drinkable. According to this, all samples are consequently contaminated and non-potable. The 2w sample obtained from the Bauxite mine had the highest contamination.

4.2. Water quality evaluation based on the Heavy Metal Pollution Index. This index was proposed by Mohan et al (2008).

$$HPI = \frac{\sum wiqi}{\sum wi} \quad (1)$$

In which, Wi is the weight ratio of the *i*th component, that is calculated by the standard inverse.

$$Wi = 1/Si \quad (2)$$

qi is the quality rate of the *i*th component, that is calculated with the following equation.

$$qi = \sum(Mi(-))/(Si) * 100 \quad (3)$$

In this equation, Mi is the concentration of the *i*th component, and Si is the standard value of the *i*th component. The (–) sign shows the numerical difference of two values, which is neglected. If *HPI*>100, the water is contaminated by heavy metals, and if *HPI* = 100, it is at risk of heavy metal contamination. Ultimately, if it is *HPI*<100, the water is not contaminated by heavy metals.

Table 2 – The concentration of non-metallic cations in water samples

r1	TDS	HCO_3	SO_4	Cl	NO_3	K	Na	Mg	Ca	Sample
0.57	4221	130	19	8	5	1.29	1	22.6	33.9	1
0.72	347	120	22	6	5	1.21	1	18.8	37.9	2
0.68	2727.9	125	25	8	5	1.25	1	20.1	36.2	3
0.72	2463.3	115	22	6	5	1.29	1	19.6	36.9	4
0.75	456	100	33	8	5	1.2	1	19.6	33.3	5
0.70	403.83	110	27	8	5	1.34	1	19.5	36	6
*	600	120	450	250	45	0	200	50	100	WHO

Results. 1. Most samples are higher in TDS than The World International Standard. Rise of TDS in mines can be caused from the mining activities which lead to more dissolution of substances. The existence of lime and marl units as well as long distances to water resources can be a reason for the high TDS.

2. The hardness of the water is rated well based on the Schuler Standard. The hardness in water samples is lower than the WHO standard. The dominant anions and cations are calcium bicarbonate in most samples. Determination of water shows two complexion of calcium bicarbonate and magnesium bicarbonate in the study area. The reservoir is made of calcareous dolomite. Evaluation of ionic index showed that the above index for water samples in the study area is less than one and their class is Na-SO_4.

3. The pH density of the samples differs from 6 to 8.3. The pH value was 1053 Iranian Standard in all samples but the sample taken from the contact site of Elika and Shemshak composition has a pH of 6 which reveals the effect of Shemshak coal composition. Analyze of MI index of all samples are polluted and non-potable. The highest pollution was at the Bauxite mine site. HPI evaluation results revealed that water resources were polluted with heavy metals and were not potable. The highest level of pollution is from northeast of the bauxite mine site.

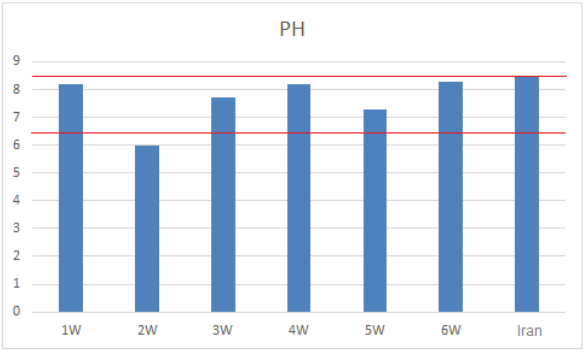

Chart 1 – PH concentration chart of water samples and comparison with Iranian Standard

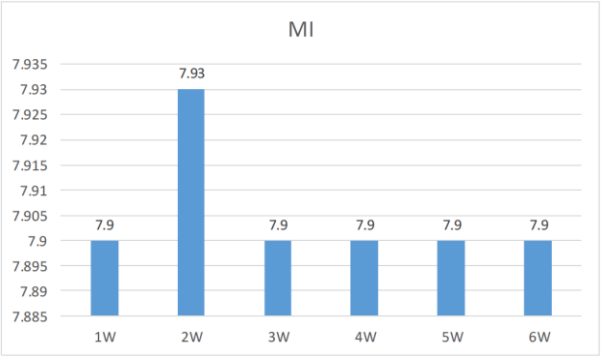

Chart 2 – Diagram of metal index MI water samples

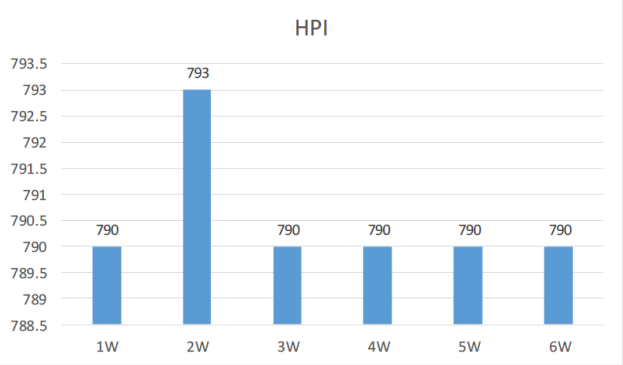

Chart 3 – Diagram of metal index HPI water samples

Suggestions. There are a few suggestions in order to stop more damages and prevent this process.

1. Using sharp drill.
2. Decrease the number of fireworks and work-related scarring.
3. Use of machinery equipped with dust absorption and treatment system.
4. Decrease the slope of the mine dump wall and install drainage covered with clay.
5. Prevention of extraction and loading of bauxite in the area of juniperus.
6. Stopping too much truck traffic or commute back and cleaning the freight root and mulching.
7. Keeping the tailings wet and away from waterways and rivers.
8. On time service of mining equipment and removal of old machinery and collection of burnt oil from the mine.
9. Creation of an artificial channel and lake in downstream to direct floods and build a pipeline to direct surface water.
10. Reconstruction of destroyed areas.

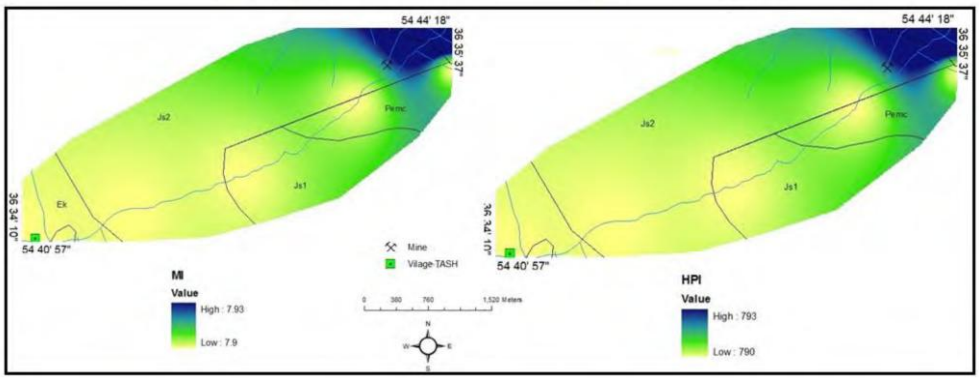

Figure 5 – MI and HP metal index zoning map

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СОЛТҮСТІК ИРАННЫҢ СЕМНАН ПРОВИНЦИЯСЫНДАҒЫ ТАШ БОКСИТ КЕН ОРНЫНЫҢ ҚОРШАҒАН ОРТАҒА ӘСЕРІН БАҒАЛАУ

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ОЦЕНКА ВОЗДЕЙСТВИЯ НА ОКРУЖАЮЩУЮ СРЕДУ МЕСТОРОЖДЕНИЯ БОКСИТОВ ТАШ В ПРОВИНЦИИ СЕМНАН, СЕВЕРНЫЙ ИРАН

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MOBILE COMPOSITE WIND POWER PLANT WITH DIFFUSER

Abstract. This research focuses on the stage of engineering a technical prototype of a composite wind power plant with a diffuser (WPPD). The area of a particular interest in the article is the mathematical aspect of the engineering stage. The article presents a theoretical study as well as experimental and practical data essential to obtain an effective shape of the diffuser. Here are also given engineering calculations and results of patent researches and field tests.

The authors calculate the most rational design parameters capable of ensuring the maximum speed in the area of the blades. This leads to an increase in the generated electricity, since it depends on the speed cubed. The increase in speed is stipulated by the passage of the air flow through the narrow part of the diffuser into the area of expansion and is consistent with the Bernoulli equation. The differential equation relates the flow velocity to the cross-sectional area of the diffuser. It should be noted that its inner part is the surface of rotation of the generatrixes around the axis of the diffuser. The surface shape can be adjusted based on the obtained mathematical calculations. In the research, these curves are described in the form of polynomials of various degrees. After integrating the differential equation for each curve individually the best option is selected. Here is also given an example with a quadratic function, which was experimentally substantiated in earlier researches and is used to compare the effects received from different generators.

The described technology, with account taken of the shape of the generator fairings, contributes to the further improvement of the WPPD. The article serves as the basis for engineering a technical prototype of a mobile composite WPPD.

Key words: wind power plant; composite material; windwheel; diffuser; speed.

Introduction. Economic crises of the past decades have shown that many traditional measures can provide no more a balance between the three pillars of sustainable development: economy, environment, and social sphere. This imbalance urges Kazakhstan to focus more on conceptual studies and related events: researches in the sphere of sustainable energy [1]. Sustainable energy is a sphere of mass application of high technologies; it is a catalyst for extensive social and economic development which provides a higher quality of life and transition of the society to environmentally sound technologies.

During the Astana EXPO – 2017 exhibition, the National Center for State Scientific and Technical Expertise (NCSSTE) held an international forum entitled “Integration of Science and Business”. In his report “Energy of Kazakhstan: Yesterday, Today, Tomorrow”, President of the NCSSTE listed the project described in the present paper among the four best Kazakhstani innovations in the field of green technologies. The project in question is aimed at creating a model prototype of a composite wind power plant with diffuser (WPPD) [2].

Research methods. Engineering and designing of the WPPD technical prototype demanded the usage of theoretical and applied research methods, including resource-saving techniques of processing (composites) CMs [4], tests, and analysis of the influence of the shape of the WPPD units on the amount

of the produced energy [5]. The energy output of the wind turbines grows in proportion to the wind speed cubed. Availability of a diffuser leads to a decrease in pressure in the expanding section, which causes an increase in the air-flow velocity in the convergent section of the diffuser. The process of the flow motion is simulated with the help of the conservation of mass differential equation relating the flow velocity to the cross-sectional area of the diffuser. In order to describe the generatrixes of the inner surface of the diffuser there were used polynomials of various degrees that lead the mass conservation equation to the differential equations with separable variables. The analysis of the results showed that the shape of the generatrix of the construction in question makes no significant effect on the flow velocity increase near the wind wheel. This can also be backed up by the results of some tests of WPPD models carried out by the researchers from Buketov Karaganda State University in 2018.

Subsequent mathematical investigations reveal the influence of the geometric parameters of the fairings on the increase in the air-flow rate by 12-13% [5]. These calculation data are the basis for further experimental design and technological work essential for the creation of a technical prototype in order to obtain acceptable output parameters of the WPPD.

Parameters and advantages of the WPPD. Due to the grants from the Committee of Science of the Republic of Kazakhstan, there were constructed experimental prototypes [3] of a composite WPPD with the following parameters: mass – 95 kg, tower height – 4 m, designed capacity – 1 kW, temperature range – between 50^{o} C below zero to 80^{o} C above zero, material – fiberglass, service age – 20 years. Generation of current begins when the intense wind speeds range from 4 to 25 m/s.

It is worth noting that today there are only 4 or 5 types of wind power plants with diffuser. The states currently engaged in their construction are USA [4], Japan [5,6], UK [7] and Kazakhstan (figure 1).

WPPD in the USA WPPD in Japan WPPD in UK WPPD in Kazakhstan

Figure 1 – Various types of WPPD in the world

WPPDs made outside Kazakhstan are stationary, i.e. they are not mobile. Unlike them, the WPPD in question is mobile. Mobility is achieved due to the smaller size of WPPD compared to the common types of wind turbines. Assembly (and disassembly) of the WPPD in the field conditions takes no more than 2-3 hours and can be carried out by 3 people without any special lifting devices.

Advantages of the described wind power plant include its ease of use, high maintainability, climate resistance, safety of a wide range of applications, quiet operation, low metal consumption, attractive design, lack of radio interference and some others. It is very convenient for those people whose jobs and occupations demand frequent moving: cattle breeders, geologists, tourists, fishermen, rescuers and other consumers, especially those living or working in numerous remote and hard-to-reach locations of Kazakhstan.

The diffuser of the wind turbine in question turns to the wind with its narrow part and increases the speed of the air flow. It also protects the windwheel from the sun, birds, moisture, dust, etc. The WPPD is a reliable, noiseless and environmentally friendly source of energy.

Efficiency of the wind power plant with diffuser. The power of impeller type wind turbines (with horizontal axis of rotation) is calculated according to the formula [8,9]:

$$P = kD^2V^3. \quad (1)$$

D – diameter of the windwheel; V – wind speed; coefficient k depends on air density, wind energy utilization coefficients, transmission mechanism and generator.

Design characteristics of the compact wind turbine. According to formula (1), generation of power by the wind power plant depends on wind speed, diameter, shape and material of the windwheel. Relation

(1) shows that the increase of power is proportional to the squared diameter of the area swept by the windwheel. Thus, for example, if the blade is lengthened by 3 times, then the output power will increase by 9 times. This, certainly, causes a set of problems connected with material requirements, increased construction costs, ensuring strength, stability, etc. In this regard, small scale wind turbines are more reliable.

It seems more preferable to achieve the increase of power capacity by using other multiplicands in (1), since it depends, for instance, on wind speed cubed. This is a more determining factor. Wind speed depends not only on numerous climatic factors, but also on the type of the land surface and height above the ground. Various obstructions on the ground and friction of the lower layers against the earth's surface reduces the speed of the wind flow. Yet, it is at lower heights that turbulence of wind increases. If you take some random fixed place meeting all the necessary wind power plant dimension criteria, you will see that even within its boundaries the wind will frequently change its vector and “diffuse” kinetic energy in different directions [10]. Therefore, it is desirable to have such an air stream in which all particles will move in one specified direction. This can be achieved by ordering motion of particles, for instance, with the help of a horizontal tube or a diffuser. This will make the air flow less turbulent and directed [11] perpendicular to the plane of the windwheel rotation. Remarkably, the efficiency of the latter will increase significantly, especially if a diffuser is used, since the flow speed near the blades is higher compared to the speed outside the diffuser. This, according to formula (1), increases the power considerably. However, in the blades there may also arise significant centrifugal (tensile) stresses proportional to the density of the material and the square of the rotational speed. The increase of angular speed can be compensated by the corresponding decrease in the mass of the windwheel, if modern lightweight materials are used instead of metal.

The urgency of such problems as energy fuel price rises and new ecological requirements became apparent in the late 20th century and coincided in time with the development and production of composites – materials with specified properties. Composite materials are materials formed by means of volumetric coupling of chemically heterogeneous constituents. They combine best properties of their constituents: strength, ductility, wear rate, low density, etc. It is remarkable that the composition itself is distinguished by such properties that none of the components, when taken separately, possesses. The most important of these properties include high specific strength, stiffness of the reinforced structure and the possibility of their variation by choosing particular constituents, modifying the structure, etc. [12].

Wind turbine power output grows proportionally to the cube of wind speed. Availability of the diffuser contributes to the decrease of pressure in its expanding section. This causes an increase in speed of the air flow and kinetic energy in the narrow part of the diffuser [13, 14] where the windwheel is placed (figure 2).

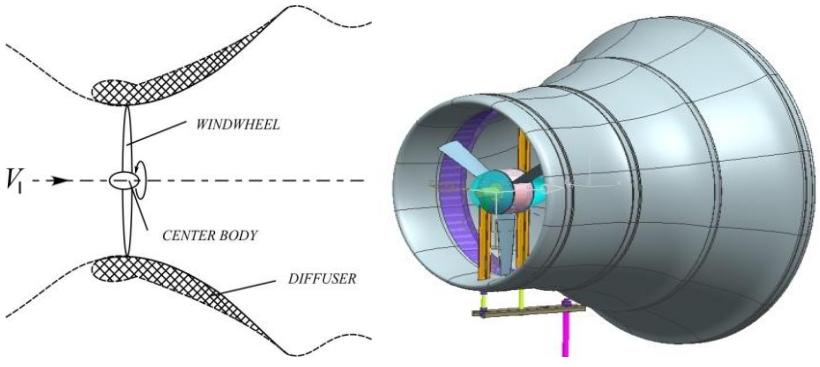


Figure 2 – The main scheme and a model prototype of a windwheel with the diffuser

In a common type of the wind-driven power plant there chiefly interact 2 key parts: its generator and the blade exposed to the unrestricted air environment. Unlike the common type of the wind power plant, the WPPD under consideration has an additional mechanism of interaction: its windwheel and a diffuser in the restricted airflow. This gives rise to a wide range of new theoretical and technical problems and tasks connected with aerodynamics and oscillations, stability and strength, electrodynamics, etc.

Mathematical justification for the use of a diffuser. Without dwelling on the complex mechanisms of the processes inside the diffuser, we shall consider a one-dimensional motion of incompressible fluid (air). To find the simplest analytical dependence of the flow speed distribution along the axis of the diffuser, we shall use the mass conservation equation [15]:

$$\frac{1}{V}\frac{dV}{dx} + \frac{1}{S}\frac{dS}{dx} = 0\ . \qquad (2)$$

The internal generatrixes of the diffuser with an airfoil in its longitudinal section can be described by using a parabola $y=a+bx^2$ in accordance with Figure 3.

Then the cross-sectional area of the rotating body will be: $S = \pi * y^2(x) = \pi(a + bx^2)^2$, if we apply this relation to formula (2), we shall get an ordinary differential equation with separated variables

$$\frac{dV}{V} = -4\frac{bx}{a+bx^2}dx\ .$$

Using the method of separation of variables, the general solution can be presented in the form:

$$V = \frac{c}{(a+bx^2)^2}\ ,$$

where c – the constant of integration.

Using the experimental ratio $V = 1{,}27\ V\infty$ [16], we shall obtain the formula

$$V = \frac{1.27a^2V_\infty}{(a+bx^2)^2}\ ,$$

which, considering the real dimensions of our WPPD: $a=0.5$ m., $b = 0.35$ m, V_∞ - wind speed outside the diffuser.

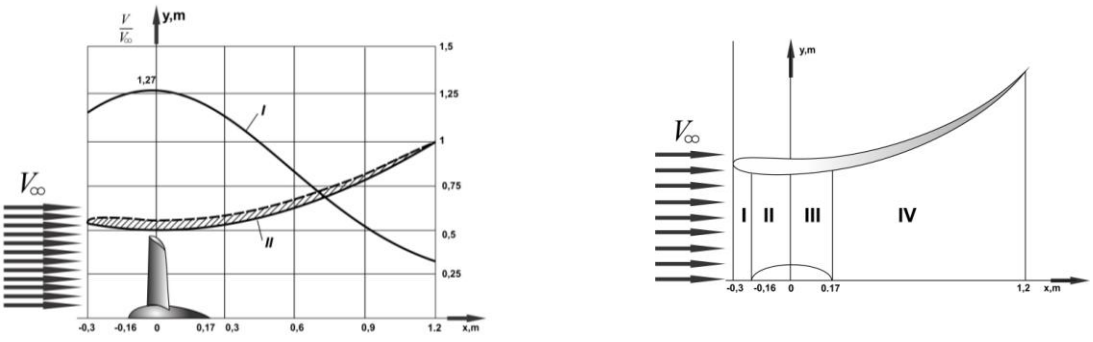
Here: $V_{input} = 1.13\ V_\infty$; $V_{outlet} = 0.32\ V_\infty$.

The obtained speed distribution and diffuser profile are presented in figure 3*a*.

As it was specified above, with the consideration of formula (1), the experimental theoretical relation $V = 1.27\ V\infty$ - requires doubling of the output energy of the wind turbine, such as $1.27^3 = 2.05$.

These calculations are made for the diffuser without taking into account the area of the windwheel.

Air-flow velocity coefficients with the consideration to the wind wheel. If we equip the diffuser with a center body – wind fairings in the form of combined paraboloids of rotation, this can alter the speed profile. To obtain numerical data, the internal content of the diffuser is divided into 4 zones, whose longitudinal section contains flat areas for separate integration. As shown in figure 3*b*, these areas are bounded by curved lines – the generatrixes of the diffuser (on the inside) and the wind turbine fairings. The obtained solutions of the differential equation are consistent at the boundaries of these areas.



a *b*

Figure 3 – *a*) curve I – speed distribution along the diffuser axis;
curve II – inner generatrix of the diffuser profile; *b*) division of the diffuser section into zones

After solving the tasks with the consideration of division into zones, we shall obtain the corresponding profiles of flow speeds, similar to the ones shown in Fig. 3*a*. For different types and sizes of the generator there were obtained the following values of input speed, speed at the output of the diffuser, and speed in the zone of the windwheel:

$$V_{input} = k_1 V_\infty,\ V_{max} = k_2 V_\infty,\ V_{outlet} = k_3\ V_\infty.$$

where $k_1 \epsilon [1.06; 1.1]$, $k_2 \epsilon [1.21; 1.28]$, $k_3 \epsilon [0.29; 0.31]$.

The average value of the wind amplification coefficient k_2 equals to 1.245. This leads to an increase in power by up to 1.93 times.

Results of field tests. The first field tests were carried out on the mobile stand-car "Gazelle" with the WPPD and instruments installed on it. This is an affordable and effective way of testing.

Figure 4 presents the results of testing the first WPPD prototype. The curved lines show that the voltage produced by the WPPD is 1.4-1.5 times higher than that produced by the wind turbines without a diffuser. This means that the diffuser almost doubles the power capacity of the wind power plant.

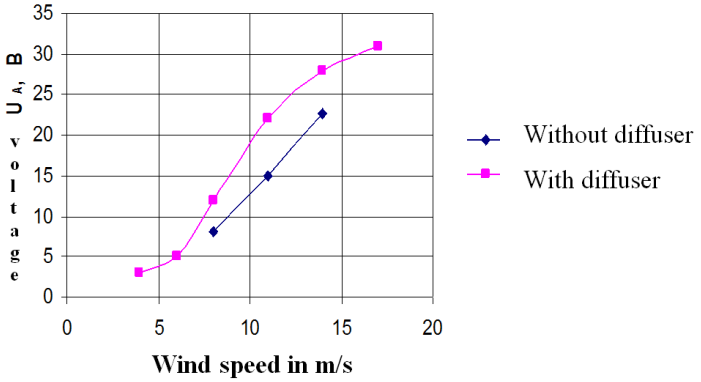


Figure 4 – Voltage U_A dependence on wind speed

These results can be of use when designing other types of WPPD. They can be also helpful for the construction and research of experimental models of wind power plants.

Figure 5 shows the output values of the accumulated at 24 h. capacities P_{24} of the most recent prototypes: WPPD-3 and WPPD-4, constructed in 2014 and 2017 respectively. They differ in weight and other characteristics. It should be noted, that in 2017 there were applied various rotary devices. The test results of 2017 are presented in the form of graphs reflecting operation of WPPD-4(1) and WPPD-4(2) when the electrical load (battery) is connected to it. For comparison, we also show the data for WPPD received earlier in 2014.

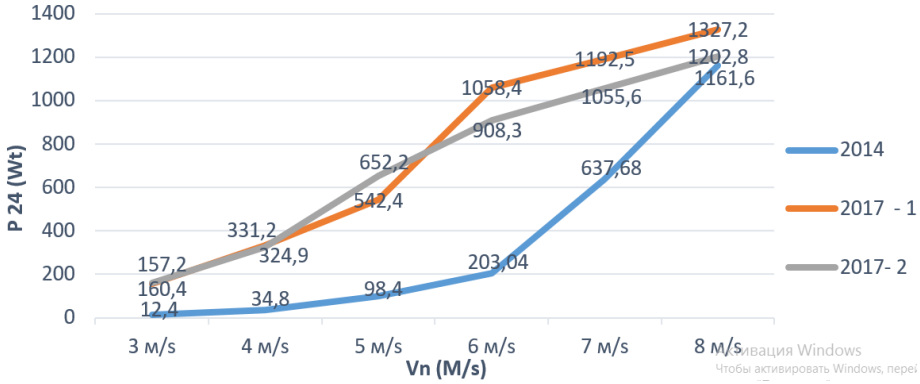


Figure 5 – Graphs of power generated by WPPD-3, WPPD – 4(1) and WPPD – 4(2)

Variability of the values of the wind turbine output parameters in the two graphs above does not exceed 10% at wind speeds of 6-8 m/s. Apparently, the variability is caused by the peculiarities of the rotating device. At speeds of 3 to 6 m/s, the variability is insignificant.

From the comparison of the three curved lines depicted in figure 5, it follows that there is a “band” of numerical values of energy for the 2017 electric generator, whose average points are 5.5 times higher than for the WPPD with an electric generator of 2014.

Conclusion:

1. The work in question helps to design a prototype with competitive parameters which will serve as the basis for small-scale production.

2. In the range of wind speed of 4-7 m/s, the new generator provides a significant increase in the accumulated energy.

3. Rural residents have problems with electricity availability, therefore this issue still remains relevant [8,16,17]. The WPPD in question can solve these problems to some extent.

4. The use of this WPPD will have both economic and environmental effect and provide energy independence at the local levels.

Acknowledgements. This research was financially supported and became possible due to grant given by the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan for the project AP05135906 “Creating a technical prototype of a composite wind power plant with a diffuser” [18].

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ДИФФУЗОРЫ БАР КОМПОЗИЦИЯЛЫҚ МОБИЛЬДІ ЖЕЛЭНЕРГЕТИКАЛЫҚ ҚОНДЫРҒЫ

Аннотация. 2002 жылы облыс әкімдері қатысқан кездесуде мемлекет басшысы ауылдардың мемлекетте өндірілген энергияның 10%-ын ғана тұтынатынын атап өтті. Бұл тек энергетикалық желілердің нашарлығымен қатар көптеген ауылдың қашық орналасуы және халық тығыздығының төмендігіне байланысты деп түсіндірілді. Осы жағдайларды ескере отырып, оларды кез-келген қол жетпейтін жерге оңай жеткізуге болатын автономды энергия көзімен қамтамасыз етуге баса назар аударылды. Сол уақыттан бері 20 шақты жыл өткенімен, ауыл тұрғындарының энергияны тұтыну мөлшері бірнеше есе төмендеп кеткені белгілі болды.

Осы туындап отырған қиындықтан шығу үшін тұтынушыларды электр энергиясының түрлі шағын көзімен қамтамасыз ету қажет. Солардың арасынан күннің, желдің және т.б. орасан табиғи потенциалы қолданылатын, жаңартылатын энергия көзін ерекше атап өтуге болады. Олар адам өмірінің сапасына жақсы әсер ете бере отырып, табиғат пен қоғамның экологиялық тепе-теңдігін бұзбайды. Сонымен бірге, жел энергетикасы бағытын айрықша атап өту қажет, өйткені елдің жел кадастры ауа ағынына қолжетімді екендігін растап отыр. Көптеген сарапшылардың айтуы бойынша далалық жазықтар мен үстірттердің кеңдігі жел энергетикасының дамуына оңтайлы болып саналады.

Отандық ғалымдар энергия тиімділігі мен жергілікті жердегі сапалы қолданысын дәлелдеген жел турбиналарының бірнеше түрін жасап шығаруда. Осы стационар энергомашиналарымен салыстырғанда, зерттелінетін диффузоры бар композиттік желэнергетикалық қондырғы (ДЖЭҚ) жылжымалы болып келеді. Бұл қондырғының жеңіл және берік композициялық материалдан – шыны талшықтан жасалуы оның мобильді болуын қамтамасыз етеді. Сонымен қатар, қолжетімді инженерлік әдістер мен есептеу негізінде дайындалған диффузордың арнайы формасы конструкция дизайнының жаңашылдығын айқындайды.

Мақала диффузоры бар композициялық желэнергетикалық қондырғының (ДЖЭҚ) техникалық прототипін жобалаудың математикалық бөліміне арналған. Жұмыста диффузордың тиімді формасын алу үшін теориялық зерттеу және эксперименталды-тәжірибелік деректер келтірілді. Инженерлік есептеу, жеке ғылыми зерттеулердің, патенттердің және далалық сынақтардың нәтижелері қолданылды.

Қалақ аймағында максималды жылдамдықты қамтамасыз ететін конструкцияның ең ұтымды параметрлері есептеледі. Бұл өндірілетін электр энергиясын арттырады, себебі ол жылдамдықтың үшінші дәрежесіне тәуелді. Жылдамдықтың артуы диффузордың тар бөлігі арқылы оның кеңею аймағына өтуіне негізделген және Бернулли теңдеуіне сәйкес келеді. Дифференциалдық теңдеулер ағынның жылдамдығын диффузор қимасының ауданымен байланыстырады. Сонымен қатар, оның ішкі бөлігі – диффузор осінің айналасындағы түзуші сызықтардың айналу беті. Беттің пішінін алынған математикалық есептеу негізінде реттеуге болады. Бұл қисықтар әртүрлі дәрежедегі полиномдар түрінде сипатталған.

Әрбір сызық үшін айнымалылары ажыратылатын дифференциалдық теңдеу жеке-жеке интегралданады және желаяқ аймағында жел жылдамдығының күшеюі коэффициентінің шамасы бойынша оңтайлы нұсқа таңдалады. Алдыңғы эксперименталды жұмыстарға негізделген және басқа генераторлар әсерімен салыстыру үшін квадраттық функция мысалға келтірілген. Санға дейін жеткізілген аналитикалық шешім жел қондырғысын пайдалану шарттарына барынша жақындатылған сынақтарда дәлелденген. Алынған графиктер өндірілген энергия үшін диффузоры бар композициялық желэнергетикалық қондырғының (ДЖЭҚ) түрлі үлгілерінде қуат өсімін екі және одан да көп есе көрсетеді.

Мақалада соңғы бірнеше жыл бойы әзірленген және жасалған композиттік тәжірибелік үлгілердің әртүрлі нұсқаларын зерттеу нәтижелері көрсетілген. Олар бір-бірінен электрогенераторлардың физика-геометриялық параметрлерімен де, шыны пластиктен жасалған жел илегіштің жиынтықтаушы элементерімен де ерекшеленеді. Заттық сынақ нәтижелерінің ішінде ең тиімді нұсқа ДЖЭҚ - 4 конструкциясы болып саналады. Оған сәйкес материалдар «Астана. ЭКСПО-2017. Болашақ энергиясы» халықаралық мамандандырылған көрмесінде ұсынылған және сарапшылар мен қоғам өкілдерінің қызығушылығын тудырды.

Сонымен қатар, генератордың айналаға ағуын есепке ала отырып, сипатталған әдістеме ДЖЭҚ-ны одан әрі жетілдіру бойынша нәтижелерге әкеледі. Мақала мобильді композициялық ДЖЭҚ-ның техникалық прототипін құру үшін негіз болып саналады.

Түйін сөздер: желэнергетикалық қондырғы, композициялық материал, жел дөңгелегі, диффузор, шыны пластик.

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МОБИЛЬНАЯ КОМПОЗИЦИОННАЯ ВЕТРОЭНЕРГЕТИЧЕСКАЯ УСТАНОВКА С ДИФФУЗОРОМ

Аннотация. Ещё в 2002 году на совещании с руководителями областей Глава государства отметил, что село потребляет лишь 10% электроэнергии, производимой в стране. Это объясняется не только изношенностью энергетических сетей, но и отдаленностью многих аулов, а также малой плотностью населения. Исходя из этого был сделан акцент на обеспечение их автономными источниками энергии, которые легко можно доставить в любой труднодоступный пункт. С тех пор прошло почти 20 лет, а доля потребления электричества сельскими жителями упала в несколько раз.

Для выхода из такого бедственного положения имеет смысл обеспечить потребителей различными малыми источниками электрической энергии. Среди них можно особо выделить возобновляемые источники энергии, которые эффективно используют огромный природный потенциал Солнца, ветра и т.п. Они благотворно влияют на качество жизнедеятельности человека и не разрушают экологическое равновесие природы и общества. При этом можно выделить направление ветроэнергетики, поскольку ветровой кадастр страны подтверждает неисчерпаемость запасов достаточно доступных воздушных потоков. Наличие обширных площадей степных равнин и плоскогорных массивов, как отмечают многие специалисты, благоприятствует развитию ветроэнергетики.

Отечественными учеными разрабатывается несколько видов ветроустановок, которые уже доказали свою энергоэффективность и применимость в соответствующих местностях. В отличие от этих стационарных энергомашин разрабатываемая композиционная ветроэнергетическая установка с диффузором (ВЭУД) – переносная. Её мобильность обусловлена тем, что вся установка изготовлена из легкого и прочного композиционного материала - стеклопластика. При этом новизну конструкции придает особая форма диффузора, которая создана на основе доступных инженерных методов и расчетов.

Статья посвящена математической части этапа проектирования и опытного обоснования технического прототипа композиционной ВЭУД. В работе приводятся теоретическое исследование и экспериментально-практические данные для получения эффективной формы диффузора. Используются инженерные расчёты, результаты собственных научных исследований, патентов и полевых испытаний.

Вычисляются наиболее рациональные параметры конструкции, обеспечивающие максимальную скорость в зоне лопастей. Это приводит к росту вырабатываемой электроэнергии, так как она зависит от

третьей степени скорости. Увеличение скорости обусловлено его прохождением через узкую часть диффузора в зону расширения и соответствует уравнению Бернулли. Дифференциальное уравнение связывает скорость потока и площадь поперечного сечения диффузора. При этом его внутренняя часть есть поверхность вращения образующих линий вокруг оси диффузора. Форма поверхности поддаётся регулированию на основе полученных математических расчетов. Эти кривые описаны в виде полиномов различных степеней.

Дифференциальное уравнение с разделяющимися переменными для каждой линии интегрируется по-отдельности и выбирается оптимальный вариант по величине коэффициента усиления скорости ветра в зоне ветроколеса. Приведён пример с квадратичной функцией, который был экспериментально обоснован в ранних работах и используется здесь для сравнения с эффектами от других генераторов. Аналитическое решение, доведенное до числа, подтверждено на испытаниях, максимально приближенных к условиям эксплуатации ветроустановки. Полученные графики для вырабатываемой энергии на различных образцах ВЭУД демонстрируют прирост мощности в два и более раза.

В статье отражены результаты исследований различных вариантов композитных опытных образцов, разработанных и созданных на протяжении нескольких последних лет. Они отличаются друг от друга как физико-геометрическими параметрами электрогенераторов, так и соответствующими им комплектующими элементами ветроколеса, изготовленных из стеклопластика. Из результатов натурных испытаний следует, что наилучшим вариантом является конструкция ВЭУД-4. Соответствующие ему материалы были представлены на Международной специализированной выставке «Астана.Экспо-2017.Энергия будущего» и вызвали значительный интерес как у экспертов, так и у представителей общественности.

Описанная методика, с учетом также обтекателей генератора, приводит к результатам по дальнейшему совершенствованию ВЭУД. Статья служит основанием для создания технического прототипа мобильной композиционной ВЭУД.

Ключевые слова: ветроэнергетическая установка, композиционный материал, ветроколесо, диффузор, скорость.

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FEATURES OF SEASONAL DYNAMICS OF HAZARDOUS CONSTITUENTS IN WASTEWATER FROM COLLIERY SPOIL HEAPS OF NOVOVOLYNSK MINING AREA

Abstract. Surface run-off is water from rain and snowmelt flowing from the territory of industrial enterprises. The part of surface run-off in the total volume of discharged wastewater from the coal industry is 2%. Their volume depends on the amount of rain and melt water, as well as the size of the sites of industrial enterprises.

The objects of surface run-off contaminants in the Novovolynsk mining area are: outdoor coal and concentrate storages, colliery spoil heaps, sludge and tailings, crushing compartments, storages fuels and lubricants, points of railway cars loading and unloading, cable cars, boiler installations, etc.

On the territory of the Novovolynsk mining area besides the wastewater a huge amount of mining waste is formed. It is stored on flat heaps, adjacent to the area. Coal also accumulates on flat dumps. The surface run-off from the area of the flat heaps may contain chemical compounds. Surface water from the mine area is not purified, although in terms of quality, it is highly polluted. During investigation period the Novovolynsk mining area the storm run-off from their territory contained more than 15,000 mg / ml of suspended substances and up to 500 mg / ml of petroleum products [4].

Spoil heaps are the main sources of surface run-off contamination by suspended solids, mineral salts and heavy metal ions. Thus, the amount of suspended solids in rainwater reaches 12000 mg / l and in meltwater - up to 50,000 mg / l, the total salt content reaches 8000 mg / l. The maximum amount of iron is more than 7550 mg / l. It is found in the meltwater from the spoil heaps of almost all mines in the Novovolynsk mining area. The composition and concentration of pollutants in coal storage water runoff doesn't differ too much from the spoil heaps water run-off. An extremely important factor of man-made impact on the sanitary status of natural water bodies is the pollution of the water-intake areas around coal and mining enterprises by chemical elements, especially during polymetallic ores development [2].

Key words: wastewater, hazardous constituents, colliery spoil heaps, ponds, pollution, organic substance.

Introduction. The development and implementation of effective wastewater treatment methods is an urgent environmental task. There are various methods of wastewater treatment. The most common are: mechanical, physico-chemical, chemical and biological methods. Depending on the hazard level and type of the pollution, wastewater treatment can be carried out by one method or a set of methods (combined method). The purification process involves the treatment of sediment (or excess biomass) and the disinfection of wastewater before discharge. The theoretical basis and problematic features of seasonal dynamics of the content of hazardous components in wastewater from the waste heaps of the coal mines of the Novovolynsk mining area are the subject of research for many scientists [5].

Purpose, tasks and methods of research. In this paper the investigations of content of hazardous components in wastewater from coal mine dumps of the Novovolynsk mining area and the peculiarities of their seasonal dynamics are presented.

Results and their discussion. Rock dumps are the current storage of empty rock – a waste of coal mining technology. Although, when coal was mined manually, the content of empty rock was lower. Mechanized production could either optimize or increase its quantity. Speaking about ecological safety in the process of mine decommissioning, the author tried to build his methods of description, modeling and predicting the ecological status of coal mines [3]. The communication elements listed are directly dependent on the amount of empty rock produced. Thus, based on the annual production of empty rock, new possible remedies should be identified. Quantitative indicators are introduced into the model and the current amount of empty rock per tonne of coal produced is obtained. Improvements of operation could be measured by the reduction in the volume of empty rock per tonne of coal. The immediate positive effects of such an improvement could be the reduction of transport costs, frequency and intensity of dust pollution [10-12].

Maximum admissible concentration of harmful substances in the water is the maximum concentration, which does not have a direct or indirect impact on the health of the population and the next generations, that is determined by modern methods of research with its impact on the human body throughout life and does not impair the hygienic conditions of water. Features of harmful substances manifest in their adverse effect on the processes of natural self-purification of water reservoirs (general sanitary index), organoleptic properties of water (organoleptic index) and population health (sanitary toxicological index), characterized by limiting and threshold concentrations [6]. The admissible threshold harmful concentration by the organoleptic features is the maximum concentration in water at which changes of organoleptic properties of water are acceptable for the population. The admissible threshold harmful concentration of a substance by a general sanitary features is a maximum concentration that does not lead to disfunction of natural self-purification of reservoirs. The admissible limiting harmful concentration by a sanitary toxicological feature is maximum concentration that does not adversely affect the health of the population. The limiting harmful index is one of the indexes of harmfulness that determines the adverse effect of this substance and is characterized by the smallest amount of threshold or subthreshold concentration.

The most important or complicated problem is the protection of surface water from pollution. The following environmental measures are envisaged, namely:

– development of non-waste and anhydrous technologies. Implementation of circulating water supply systems;

– sewage treatment (by bio-plateau method, etc.);

– sewage pumping into deep aquifers;

– treatment and disinfection of surface water used for water supply and other purposes.

The main pollutant of surface water is untreated wastewater. Mechanical purification of industrial wastewater by screening, precipitation and filtration removes more than 90% of insoluble mechanical impurities of different dispersion rate (sand, clay particles, etc.) from industrial waste, more than 60% from domestic waste. Water screens, sand extractor, sand filters, sediment ponds of various types are used for these purposes. Substances floating on the surface of wastewater (oil, resins, fats, polymers) are entraped by oil separator or burned [13-15].

Chemical and physico-chemical treatment methods are most effective for the treatment of industrial wastewater. The main chemical methods include neutralization and oxidation. For neutralization of acids and alkalis special reagents (lime, soda ash, ammonia) are added into the wastewater. Different oxidants (O_3, $KMnO_4$) are used for oxidation. These methods give an opportunity to remove toxic and other components from wastewater. Physical and chemical purification includes:

1. Coagulation - the addition of coagulants (salts of ammonium, iron, copper, sludge waste, etc.) into the wastewater

2. Sorption - the ability of some substances (bentonites, activated carbon, silica gel, peat, etc.) to absorb pollutants. valuable soluble substances can be extracted from the wastewater by sorption and subsequently disposed.

3. Flotation - the blowing of gas through the wastewater. Gas bubbles capture surfactants (oil or other contaminants) when moving upwards [7,8].

The biological (biochemical) method is widely used for the purification of sewage from pulp and paper, oil refining and food processing enterprises. The method is based on the ability of microorganisms

to use organic and some inorganic compounds contained in wastewater (hydrogen sulfide, ammonia, nitrites, sulfides) for their development. Purification is carried out by natural (irrigation fields, filtration fields, biological ponds, bioplato method) and artificial methods (aerotanks, biofilters, circulating oxidation channels).

After screening of the wastewater, a residual matter is formed, which is fermented in concrete tanks and then removed on a sludge site for drying. Dried sludge is usually used as a fertilizer, but in recent years, many harmful substances (namely heavy metals) have been detected in wastewater, which eliminates this method of disposal [17].

The clarified wastewater is purified in aerotanks by special closed tanks, where the oxygen-rich effluents mixed with activated sludge are slowly discharched into the treated water. Active sludge is a mixture of heterotrophic microorganisms and small invertebrates (mold, yeast, aquatic fungi), as well as a solid substrate. It is important to choose the right temperature, pH, additives, mixing conditions, oxidizer (oxygen) to maximize the intensification of hydrobiocenosis [9].

In wastewater treatment systems, the biological method is final stage after which the wastewater can be used in circulating water or discharged into surface water.

In recent years, new effective methods have been actively developed, contributing to the greening of the wastewater treatment process, namely:

– Electrochemical methods are based on the processes of anodic oxidation and cathodic reduction: electrocoagulation and electro-flotation.

– Membrane processes. Ultra filters, electrodialysis.

– Magnetic processing. Improves the flotation of suspended solids.

– Radiation purification of water, gives an opportunity to expose pollutants to oxidation, coagulation and decomposition as soon as possible.

– Ozonation: no hazard substances are formed in wastewater.

– Introduction of new selective types of sorbents for selective recovery of useful components from wastewater for reuse [20-22].

Methane, CO_2, H_2S release during decomposition of organic substances. The energy of this biogas is used for heat and energy production. One promising way to reduce surface water pollution is to pump wastewater into deep aquifers through a system of absorbing wells (underground disposal). Among the water protection issues, one of the most important is the development and implementation of effective methods of disinfecting and purifying surface water used for drinking purposes. Insufficiently treated drinking water is dangerous both from an ecological and social points of view. Beginning from 1896 to the present day, chlorine water disinfection is the most common method. However, the chlorination of water carries a serious risk to human health. Reducing the content of carcinogens in drinking water is possible by replacing primary chlorination by ozonation and UV treatment, as well as by using a non-reagent pre-purification method in biological reactors [23].

Modern technology for the purification of drinking water from petroleum products from surfactants, pesticides, organic and other compounds is based on the use of sorption processes on activated carbon. Agroforestry and hydrotechnical measures are of great importance in protecting surface water from pollutants. Resulting data of Mine #9 of Novovolynsk mining area are presented in table 1.

Table 1 – Resulting data of Mine #9 of Novovolynsk mining area

		Spring		Winter		Autumn		Summer	
Index	*units*		MAC		MAC		MAC		MAC
1	*2*	3	4	5	6	7	8	9	10
Smell at +20 °C	*scores*	0	< 2	0.5	< 2	0	< 2	0	< 2
Transparency	*cm*	5	> 20	28	> 20	40	> 20	30	> 20
pH	*pH units*	7.9	6.5-8.5	5.9	6.5-8.5	6.4	6.5-8.5	6.6	6.5-8.5
Suspended solids	*mg/l*	169	N/A	93	N/A	18.2	N/A		N/A
Dry residues	*mg/l*	2463	<1000	29,2	< 1000	1633	< 1000	770	< 1000
Total hardness	*mg/l*	31.2	< 7.0	0.31	< 7.0	22.5	< 7.0	9.3	< 7.0

Continuation of table 1									
1	2	3	4	5	6	7	8	9	10
Carbonate hardness	*mg/l*	2.5	< 6.5	0.25	< 6.5	3.6	< 6.5	2.9	< 6.5
Hydrocarbonates (HCO3-)	*mg/l*	153	< 300	153	< 300	220	< 300	177	< 300
Chlorides (Cl-)	*mg/l*	43.2	< 250	4.2	< 250	15.8	< 250	54.8	< 250
Sulfates (SO42-)	*mg/l*	1004	< 500	580	< 500	552	< 500	243	< 500
Nitrites (NO2-)	*mg/l*	12.3	< 3.3	0	< 3.3	21.8	< 3.3	18.6	< 3.3
Nitrates (NO3-)	*mg/l*	123.6	< 45	90	< 45	158.3	< 45	88.2	< 45
Phosphates (PO43-)	*mg/l*	1.9	N/A	0	N/A	185.4	N/A	0.3	N/A
Calcium (Ca2+)	*mg/l*	373	N/A	520	N/A	201	N/A	122	N/A
Magnesium (Mg2+)	*mg/l*	153	< 80	0.6	< 80	150	< 80	38.9	< 80
Total Ferrum (Fetot)	*mg/l*	2.5	< 0.3	0.18	< 0.3	0.51	< 0.3	0.1	< 0.3
Ammonium (NH4+)	*mg/l*	1.24	< 2.0	0.15	< 2.0	18.3	< 2.0	2.4	< 2.0
Sodium (Na+) + Potassium (K+)	*mg/l*	199	< 300	5.5	< 300	105.8	< 300	51.1	< 300
Total Dissolved Solids	*mg/l*	2453	N/A	37.8	N/A	1721	N/A	1924	N/A
Chemical oxygen demand	*mgO/l*	15.1	< 5	5.3	< 5	12.6	< 5	21.3	< 5

If we compare the data of mines # 2, # 4, # 9 of Novovolynsk mining area, the results of the researches are almost identical and there is no significant difference between the content of harmful substances in the mines depending on the time of year. For example, we take producing mine # 9 (mines # 2, # 4 are not operating, (figure 1)).

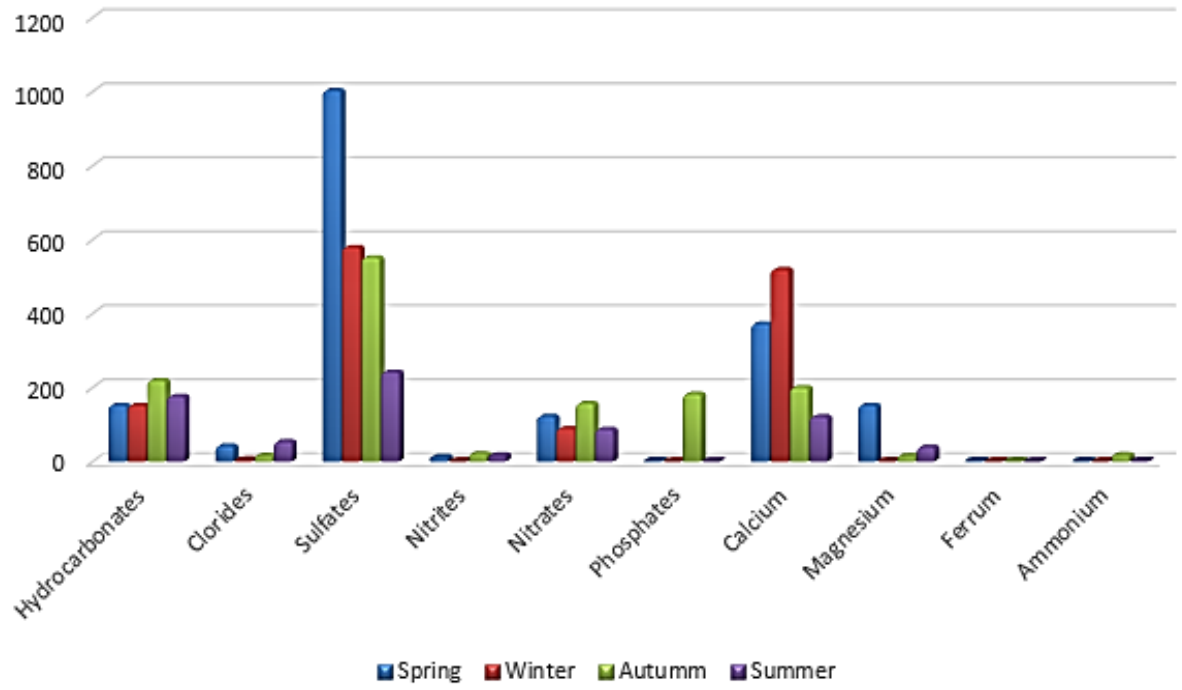

Figure 1 – The seasonal dynamics of the content of hazardous components in the wastewater from the waste heaps of mine № 9 of the Novovolynsk mining area

The aquifer of quaternary sediments is developed in quaternary formations, namely: in loam on watersheds and sandy loam in alluvial deposits in river valleys. Alluvial deposits are of the greatest importance for flooding processes. Are presented in table 2.

Table 2 – The impact of waste heaps

Environmental aspect and sources	Types	Potential impact
Wastewater and discharge of contaminated water, filtrate, drainage and pumped out groundwater Sources: Surface runoff from dumps, the filtrate, surface runoff from devastated lands and objects, discharge of pumped water	Water erosion Chemical contaminants Drainage of acid mine water Drainage of neutral mine water Heavy metals Salinity Soluble or captured resinous coal derivatives	Negative health impacts for people living downstream. Negative impacts on aquatic ecosystems: water turbidity, low dissolved oxygen content as a result of increased biological and chemical oxygen demand, increased toxicity, lower pH, salinity. Reduced municipal water supply. Increased costs for water treatment.

The composition of sediments is mainly represented by a layer of sand or sandy loam with a capacity of 0.5-6.0 m (with a maximum capacity of 16 m). Often there is a stratification. Sometimes at the foot a low-strength layer of gravel or pebble is present.

The coefficient of filtration of loam according to the literature data is more than 0.003-0.17 m/day, sand and sandy loam - 2-5 m/day. According to the pumping on the alluvial horizon, the filtration coefficients vary from 0.35 to 8.68 m/day with an average value of about 3 m/day.

The average value of the horizon's power is 15 m. The horizon is pressureless, not protected by the upper waterproof layer and is fed by precipitation and melt water. The infiltration rate is 607 mm/year on average. Therefore, the amount of infiltration supply to the groundwater, taking into account evaporation (570 mm/year), will be approximately 0.00013 m/day [1,16,24]. Based on the analysis of hydrogeological data in the area, the dynamics of the performance of the coal mines of the Novovolynsk mining area was determined (figure 2).

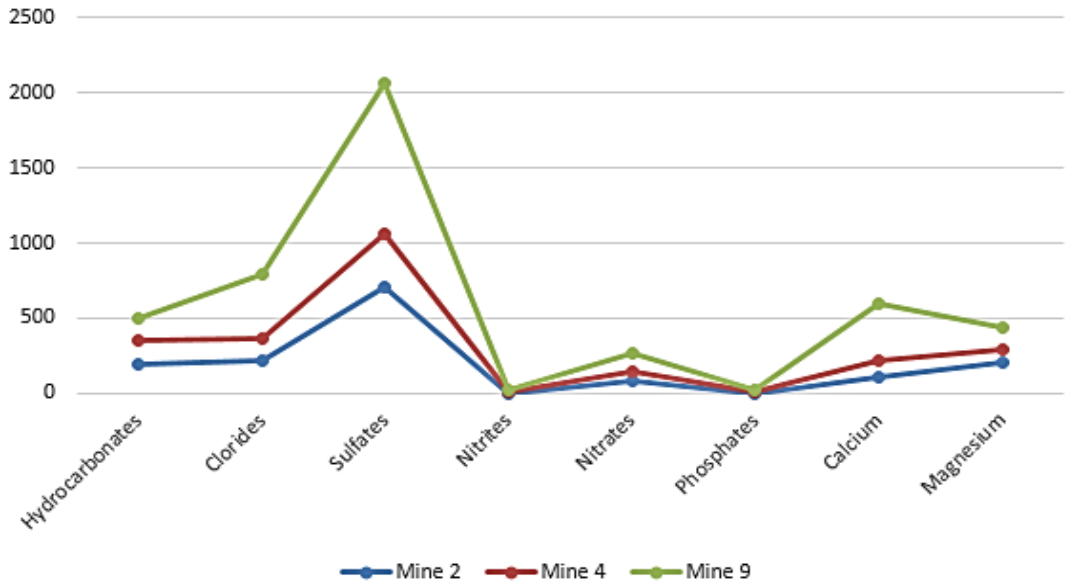

Figure 2 – Resulting data dynamics of mines of Novovolynsk minig area

Conclusions. Chemical and physico-chemical treatment methods are most effective for the treatment of industrial wastewater. The main chemical methods include neutralization and oxidation. To neutralize acids and alkalis, special reagents (lime, soda ash, ammonia) are added into the wastewater. Different oxidants (O_3, $KMnO_4$) are used for oxidation. These methods give an opportunity to remove toxic and other components from wastewater. Basing on the research, there is no significant difference between the

content of harmful substances in mines. Collection, removal, detoxification, recycling and disposal are the main tasks of environmental engineering [25].

In order to investigate the system of environmental safety around the coal mines of the Novovolynsk mining area, a model of the interconnection of environmental and human components is taken. The mentioned system of ecological safety should protect the person from environmental threats caused by anthropogenic factors, in our case - it is coal production. The environment, in the context of environmental safety, means the development of a system of protection of man against man-made factors through environmental management [18,19]. The impact of man-made factors on the environment should be standardized by separate substantiated documents, that is, an integrated indicator should be developed for the total environmental status around the coal mines can be calculated. Considering that long-term production in the country has led to uncompensated, uncontrolled environmental degradation, we consider this environment to be critical. In order to remedy this situation, it is proposed to rehabilitate the coal territories by improving the management system in environmental protection and ecological safety, alongwith timely demineralization, recultivation, vegetative reclamation of disturbed lands and bio-plateaus.

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НОВОВОЛЫН КӨМІР ӨНЕРКӘСІБІ АУДАНЫНЫҢ КӨМІР ШАХТАЛАРЫ ҮЙІНДІЛЕРІНЕН САРҚЫНДЫ СУДАҒЫ ҚАУІПТІ КОМПОНЕНТТЕР ҚҰРАМЫНЫҢ МАУСЫМДЫҚ ДИНАМИКАСЫНЫҢ ЕРЕКШЕЛІГІ

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ОСОБЕННОСТЬ СЕЗОННОЙ ДИНАМИКИ СОДЕРЖАНИЯ ОПАСНЫХ КОМПОНЕНТОВ В СТОЧНЫХ ВОДАХ С ОТВАЛОВ УГОЛЬНЫХ ШАХТ НОВОВОЛЫНСКОГО УГЛЕПРОМЫШЛЕННОГО РАЙОНА

Аннотация. Проблема охраны водных ресурсов от загрязнения неочищенными сточными водами шахт приобрело особую важность, так как предприятия угольной промышленности характеризуются как поставщики большого объема стоков. Шахтные воды, загрязнённые механическими и органическими примесями, отличаются повышенным солесодержанием, что представляет реальную опасность загрязнения поверхностных и подземных вод.

Более 80% общего потребления воды шахтой составляет питьевая вода, используемая для орошения горных выработок, в административно-бытовых комбинатах, котельных, компрессорных, а незначительная часть шахтной воды, что выдается на поверхность, используется для технологических целей в горных выработках. Целесообразным решением данной проблемы является эффективная очистка шахтных вод (методом биоплато), цель которой – пополнение запасов пресной воды, используемой на технологические нужды предприятия, улучшения качества воды перед сбросом в водный объект, а также возможности использования в технологических процессах других отраслей промышленности и сельского хозяйства.

Шахтная вода каждого водоотливного комплекса имеет определенный химический состав. Контролируются основные показатели, регламентируемые для сточных вод угольной промышленности, которые сбрасываются в природные объекты. Это взвешенные вещества, солесодержание, сульфаты, хлориды, нефтепродукты, фенолы, тяжелые металлы и прочее. По своему составу шахтная вода водоотливных комплексов вполне пригодна для технического водоснабжения предприятий, например, металлургических, без дорогостоящей водоподготовки. Использование же шахтной воды для питьевого водоснабжения возможно только в сочетании с предварительной глубокой очисткой, особенно если это вода, откачиваемая водоотливными комплексами с погружными насосами. В такой воде, как правило, превышены предельно

допустимые концентрации железа, марганца. Это связано с геохимическими процессами, происходящими в подземных водных горизонтах после закрытия шахт.

Поверхностные стоки образуются из дождевых и талых вод, стекающих с территории промышленных предприятий. Доля поверхностного стока в общем объеме сбрасываемых сточных вод угольной промышленности составляет 2%. Их количество зависит от объема дождевых и талых вод, а также от величины площадок промышленных предприятий.

Объектами-загрязнителями поверхностного стока на территории Нововолынского углепромышленного района являются: открытые склады угля и концентратов, шахтные породные отвалы, шлам, дробильные отделения, склады горюче-смазочных материалов и фотореагентов, пункты погрузки и разгрузки железнодорожных вагонов, канатные дороги, котельные установки и т.п.

На территории Нововолынского углепромышленного района в качестве отходов производства, кроме сточных вод, образуется большая масса пустой породы. Она складируется на плоских отвалах на примыкающих территориях. На плоских отвалах накапливается также уголь. Порода и уголь в цикле обогащения контактируют с фотореагентами, поэтому ливневые стоки с территории плоских отвалов могут быть загрязнены химическими соединениями. Очистка поверхностных вод с территории шахт не проводится, хотя по качественному составу они относятся к сильнозагрязненным. При обследовании Нововолынского углепромышленного района ливневый сток с территории содержал свыше 15000 мг/дм^3 взвешенных веществ, концентрация фотореагента достигала более 450 мг/дм^3, а нефтепродуктов – 500 мг/дм^3.

Породные отвалы являются основными источниками загрязнения поверхностного стока взвешенными веществами, минеральными солями и ионами тяжелых металлов. Так, количество взвешенных веществ в дождевых водах доходит до 12000 мг/л и в талых – до 50000 мг/л, общее солесодержание достигает 8000 мг/л. Максимальное количество железа составляет более 7550 мг/л. Оно проявляется в талых водах отвалов почти всех шахт Нововолынского углепромышленного района. Стоки угольных складов по составу и концентрации загрязняющих веществ мало отличаются от стоков породных отвалов. Чрезвычайно важным фактором техногенного влияния на санитарное состояние природных водных объектов является загрязнение водосборных территорий химическими элементами вокруг угольных и горнорудных предприятий, особенно при разработке полиметаллических руд.

На основе исследований и анализа сточной воды из технологических отвалов пород шахт мы предложили оптимизационные мероприятия, направленные на улучшение состояния как отдельных компонентов окружающей природной среды, так и целостных природно-хозяйственных систем Нововолынского горнопромышленного района.

Ключевые слова: сточные воды, опасные компоненты, отвалы угольных шахт, водоемы, загрязнения, органические вещества.

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DIGITALIZATION OF TECHNOLOGICAL AND ORGANIZATIONAL PROCESSES OF MINING OPERATIONS DUE TO THE IMPLEMENTATION OF THE INSTALLATION SYSTEM AND ACCOUNTING THE KEY INDICATORS

Abstract. The modern mining industry is full of unique solutions for the implementation of key performance indicators accounting.

The task of the mining enterprise, like any business, is to make a profit.

An important role in assessing the performance of a mining enterprise is played by performance indicators combined into a system called KPI.

The system for setting and recording key indicators developed by specialists from the D.A. Kunaev Institute of Mining

The main task of this system of indicators is to assess the effectiveness of the company, aimed at achieving the main strategic goals and objectives.

Thanks to the system of setting and recording key indicators, it is possible to assess the strengths and weaknesses of the enterprise, as well as understand what factors negatively affect and inhibit the development process.

The use of the system for setting and recording key performance indicators allows:

– To ensure transparency and predictability of technological and organizational processes of the company due to a properly built process of digitalization of the system for setting and recording key indicators.

– To assess the quality of work of each employee / project / company.

– To focus the activities of all departments on priority tasks.

– To form an honest and effective system of staff motivation to achieve super-results.

– To increase the level of responsibility for the result of each employee involved in the project.

– When dismissing or replacing specialists, to use the accumulated information to train new employees in the workplace.

To implement this accounting, in the process of designing the system, universal digital technologies were integrated, which made it possible to keep records of inventories, determine the positioning of personnel, etc.

It should be noted that the project for the implementation of this system in small, medium and large businesses will have its own characteristics and priorities.

Key words: KPI, RFID, tracking, accounting, mathematical model.

Introduction. Trends in technological progress at the present stage of development of mining enterprises are becoming an obvious competitive advantage in this sector. Many companies in the industry are actively purchasing and launching technical solutions at their facilities.

According to the authors, the main disadvantage of Kazakhstan in the global competitive environment is the following:

– Users do not fully use the resource when adapting the solution in production due to the lack of relevant competencies in the field, and the cost of the purchased solution based on the maximum functionality;

– Small companies in this sector cannot afford expensive technologies and, in general, their effectiveness is largely tied to the competencies of the management and management teams;

– Purchased solutions are not compatible and work separately, which often does not bring the expected result, since one decision can affect another, changing their weights.

To implement the existing shortcomings and develop the methodology for setting and recording key performance indicators in a complex of studies within the framework of program-targeted financing at the D.A. Kunaev Mining Institute, a project is being implemented that integrates the work of modern software and hardware solutions and the development of a unique methodology for accounting for key performance indicators and the efficiency of employees and entire departments, expressed in numbers.

To create the basic concept of the methodology for setting and recording key performance indicators and the technical platform within the framework of the project, the following software and hardware tools were identified for use:

– Smart watch with GPS with a sim card slot for tracking and displaying people on the map when performing business operations (going to a quarry, working on road sections and road development schemes, etc.);

– Access control accounting system (office, workshop, garage, warehouse, etc.);

– Software and hardware based on RFID for inventory accounting in the warehouse.

All of these technologies have their own purpose separately in different commercial and domestic conditions. Each software and hardware works according to the manufacturer's unique algorithm and generates data in standard used databases, from which you can take the converted information and use it to create your own mathematical model.

In other words, the developed mathematical model (software and methodological support) for taking into account key performance indicators is a machine interpretation of data from different subsystems, taking into account a unique algorithm for subsequent processing and subsequent storage, as shown schematically in figure 1.

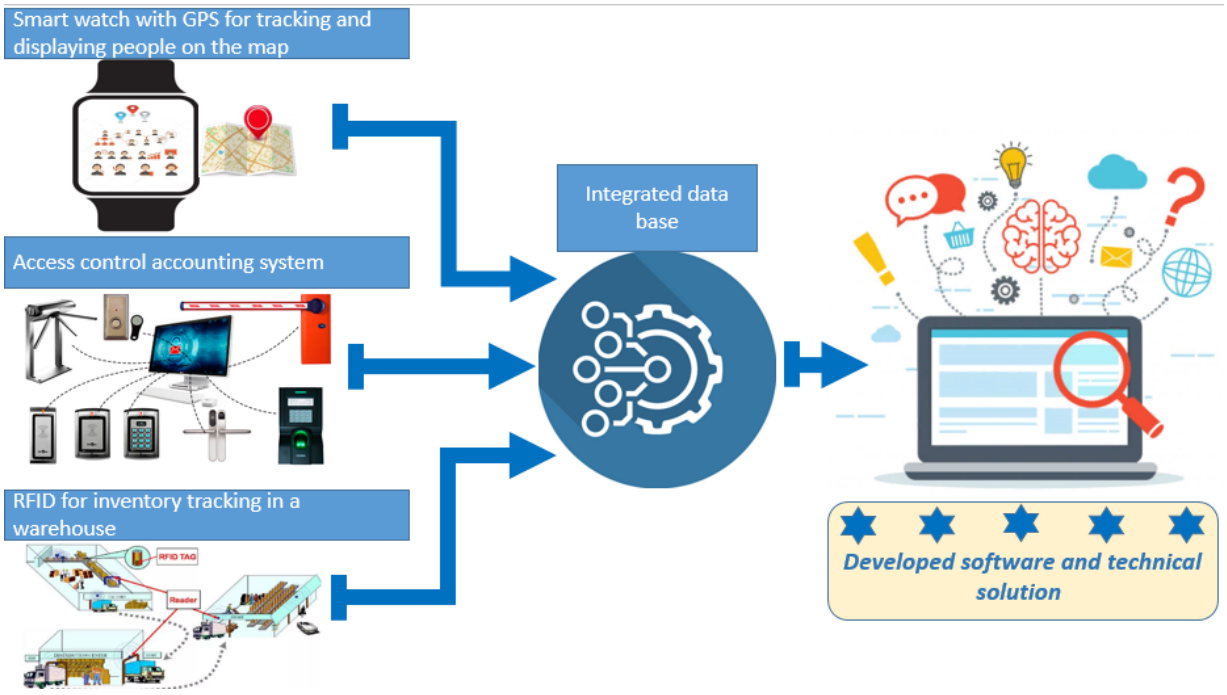

Figure 1 – Representation of data generation from subsystems to the system being developed

For the subsequent creation of a system for setting and recording key performance indicators, as part of an experimental test, a certain amount of information was entered into the system to build a spatial mathematical model of actions.

Intermediate data of the system are employee movement tracks, time tracking when visiting production facilities, goods movement at the enterprise, working time tracking, all kinds of violations and accounting of the main completed and additional tasks formed during the work.

The constant development and division of the obtained data (correct and incorrect actions) when fulfilling the planned tasks of mining during one year, are an introductory and integral part of the tests, since the first received and converted data are a template for the next research period.

When the converted data is generated over a longer period (3 - 5 years) and the list of repetitive commands and tasks is accumulated (the task is repeated, only the values change), the system, according to the algorithm embedded in it, lends itself to machine learning and performs calculations in the relationship of data to various applied tasks.

This approach allows solving complex problems with many input parameters and in practice implements adaptive production control.

At the second stage of testing and development as part of the work on the project, for each specialization in production, the function of accounting for key performance indicators was implemented for testing, the main criterion of which is the implementation of dividing the action into 4 main performance indicators measured in percentage terms, as shown schematically in figure 2.

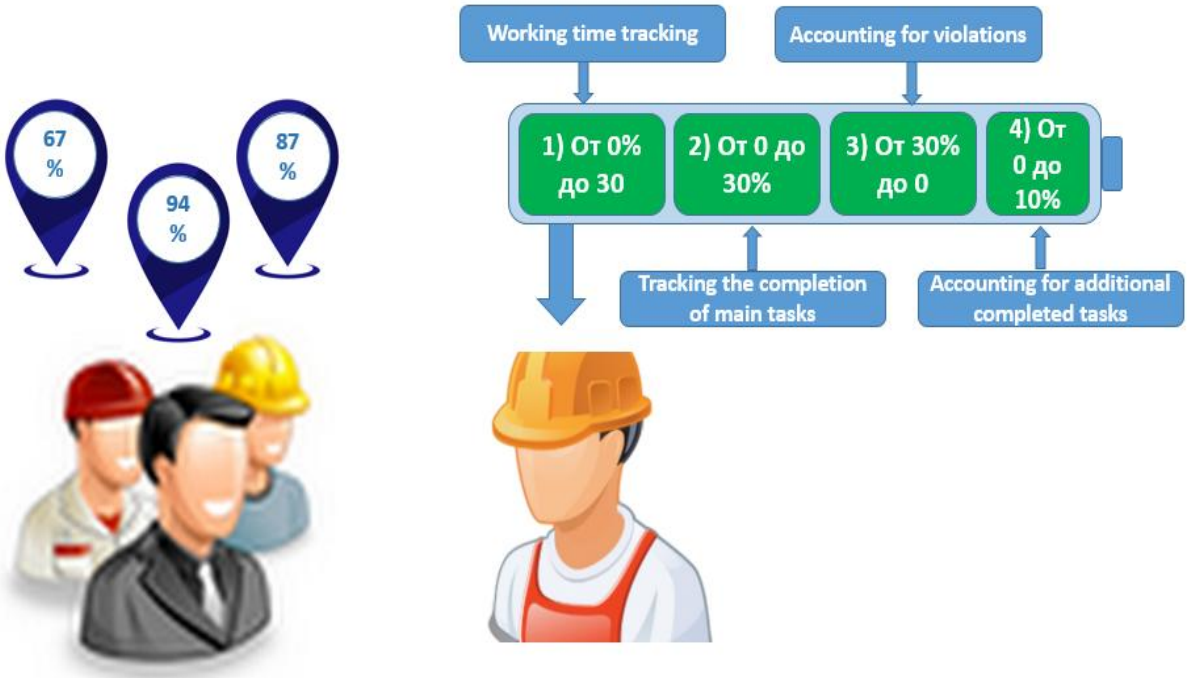

Figure 2 – Representation on the accounting of key performance indicators

The following values are taken into account for the main performance indicators in the system:

1. Accounting for working hours throughout the year - from 0 to 30%.
2. Accounting for the fulfillment of the main tasks of the specialization - from 0 to 30%.
3. Accounting for violations (entering prohibited areas of production, disabling tracking systems, etc.) - from 30 to 0%.
4. Accounting for additional completed tasks - from 0 to 10%.

One of the main advantages of this kind of concept over other algorithms is the ability to consistently train the system (see figure 3). In simple terms, the learning process involves finding new connections between subsystems in interaction with human activities, as well as finding dependencies between the elements of the chain in the solution being developed.

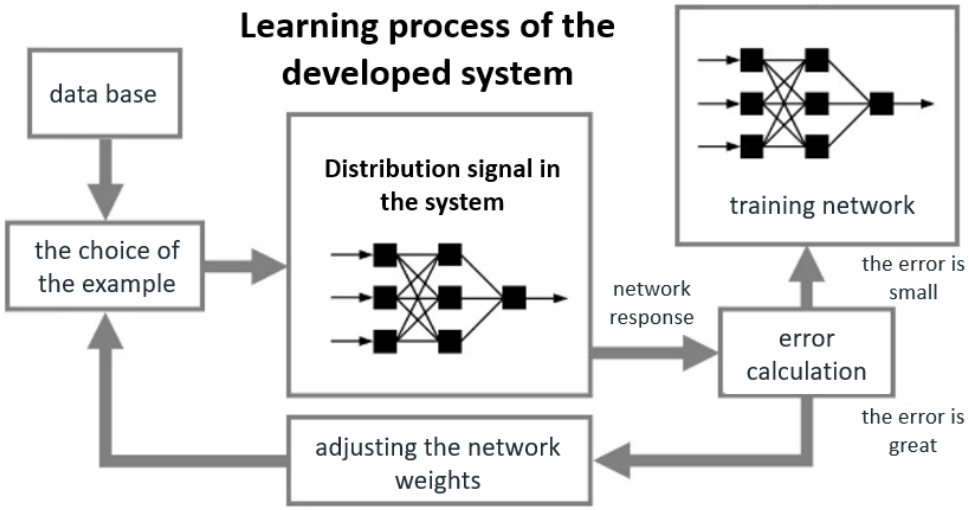

Figure 3 – Schematic description of the system operation algorithm

The software mechanism obtained as part of the work has the ability to take into account the experience in solving complex spatial problems, and the more data suitable for training is accumulated during the operation of the subsystems integrated into the system, as a rule, the best result for the transition to artificial intelligence in production.

Taking into account the existing situation and shortcomings at the mining enterprises of the republic, it is obvious and cost-effective to develop digital technologies in a single center and subsequently use them with maximum efficiency in small and medium-sized enterprises, since the practice of work in this direction shows that the mechanism developed within the framework of the project will allow the state to be guided by the needs and providing the necessary competencies in an important direction that affects the economy and the future development of the potential of the state as a whole.

Thus, for the state to compete in the world market, it is not enough to have only resources, but it is also very important to develop its own competencies, and to have highly intelligent indicative solutions that are used not only in the conditions of domestic production.

In the future, research and development in this area, it is planned to integrate additional subsystems that allow operating the geometric information of a mining enterprise using unmanned aerial vehicles, keeping records of the consumption of electricity, fuel, and the environmental situation in real time.

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НЕГІЗГІ КӨРСЕТКІШТЕРДІ ОРНАТУ МЕН ЕСЕПКЕ АЛУ ЖҮЙЕСІН ЕНГІЗУ АРҚЫЛЫ ТАУ-КЕН ЖӘНЕ ӨНІМДІК ОПЕРАЦИЯСЫНЫҢ ТЕХНОЛОГИЯЛЫҚ ЖӘНЕ ҰЙЫМДАСТЫРУШЫЛЫҚ ҮДЕРІСТЕРІН ЦИФРЛАНДЫРУ

Аннотация. Қазіргі тау-кен өндірісінде тиімділіктің негізгі көрсеткіштерін жүзеге асырудың бірегей шешімдері көп. Кеніш кәсіпорнының міндеті – кез-келген кәсіп секілді пайда табу.

Тау-кен кәсіпорнының жұмысын бағалауда KPI деп аталатын жүйеге қосылған өнімділік көрсеткіштері маңызды рөл атқарады. Негізгі көрсеткіштерді белгілеу және есепке алу жүйесін Д.А. Қонаев атындағы тау-кен институтының мамандары әзірлеген.

Көрсеткіштердің аталған жүйесінің міндеті негізгі стратегиялық мақсаттар мен міндеттерге қол жеткізуге бағытталған компания қызметінің тиімділігін бағалау болып саналады. Көрсеткіштерді белгілеу және тіркеу жүйесінің арқасында кәсіпорынның күшті және әлсіз жағын бағалауға, сондай-ақ қандай факторлардың даму үдерісіне теріс әсер ететінін және бәсеңдететінін түсінуге негіз бар.

Табысты жұмыс істеу үшін негізгі көрсеткішті белгілеу және жазу жүйесі бірқатар іргелі өлшемге негізделуі қажет:

– индикаторлар компания стратегиясын ағымдағы қызметтің қысқамерзімді мақсатына айналдыруы керек;

– индикаторлар компания қызметінің барлық негізгі аспектілерін толық көрсетуі керек;

– индикаторлар саны минималды болуы тиіс;

– индикаторлар мен оларды есептеу тәртібі қоғам қызметкерлеріне түсінікті болуы қажет.

– Тиімділіктің негізгі көрсеткіштерін орнату және жазу үшін жүйені пайдалану жұмыстары төмендегідей мүмкіндік береді:

– орнату жүйесін цифрландыру және негізгі индикаторларды есепке алу үдерісін дұрыс құру арқылы компанияның технологиялық және ұйымдастырушылық үдерістерінің айқындылығы мен болжамын қамтамасыз ету;

– әр қызметкер / жоба / компания жұмысының сапасын бағалау;

– барлық бөлім қызметін басым міндеттерге бағыттау;

– жоғары нәтижеге қол жеткізу үшін қызметкерді ынталандырудың адал және тиімді жүйесін қалыптастыру;

– жобаға қатысқан әрбір қызметкердің нәтижесі үшін жауапкершілік деңгейін арттыру;

– маманды жұмыстан шығарған немесе ауыстырған кезде жинақталған ақпаратты жұмыс орнында жаңа қызметкерлерді оқыту үшін қолдану.

Есепке алу үшін жүйені жобалау барысында әмбебап цифрлық технологиялар интеграцияланған әрі бұл тауарлы-материалдық қордың есебін жүргізуге, қызметкер жағдайын анықтауға және т.б. мүмкіндік береді. Бұл жүйені шағын, орта және ірі бизнеске енгізу жобасы өзіндік сипаттама мен басымдықтарға ие болатындығын атап өткен жөн.

Түйін сөздер: KPI, RFID, бақылау, есепке алу, математикалық модель.

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ОЦИФРОВКА ТЕХНОЛОГИЧЕСКИХ И ОРГАНИЗАЦИОННЫХ ПРОЦЕССОВ ГОРНО-ДОБЫЧНЫХ ОПЕРАЦИЙ ЗА СЧЕТ ВНЕДРЕНИЯ СИСТЕМЫ УСТАНОВКИ И УЧЕТА КЛЮЧЕВЫХ ПОКАЗАТЕЛЕЙ

Аннотация. Современная горнодобывающая отрасль полна уникальных решений по внедрению учета ключевых показателей эффективности. Задача горнодобывающего предприятия, как и любого бизнеса – получение прибыли.

Важную роль в оценке результатов деятельности горнодобывающего предприятия играют показате-ли эффективности, объединенные в систему под названием KPI. Система установки и учета ключевых показателей, разработанная специалистами Д.А. Кунаева Института горного дела.

Основная задача данной системы показателей – оценка эффективности деятельности компании, направленной на достижение основных стратегических целей и задач. Благодаря системе установки и регистрации ключевых показателей можно оценить сильные и слабые стороны предприятия, а также понять, какие факторы негативно влияют и тормозят процесс развития.

Для успешной работы Система установки и регистрации ключевых показателей должна основываться на ряде фундаментальных критериев:

– Индикаторы должны трансформировать стратегию Компании в краткосрочные цели текущей деятельности;

– Показатели должны полностью отражать все ключевые аспекты деятельности Компании;

– Количество индикаторов должно быть минимальным;

– Показатели и порядок их расчета должны быть понятны сотрудникам Компании.

– Использование системы установки и учета ключевых показателей эффективности позволяет:

– Обеспечение прозрачности и предсказуемости технологических и организационных процессов компании за счет правильно выстроенного процесса цифровизации системы установки и учета ключевых показателей.

– Оценка качество работы каждого сотрудника / проекта / компании.

– Сосредоточить деятельность всех подразделений на приоритетных задачах.

– Сформировать честную и эффективную систему мотивации персонала для достижения сверхрезультатов.

– Повышение уровня ответственности за результат каждого сотрудника, задействованного в проекте.

– При увольнении или замене специалистов использовать накопленную информацию для обучения новых сотрудников на рабочем месте.

Для реализации такого учета в процессе проектирования системы были интегрированы универсальные цифровые технологии, позволяющие вести учет материально-производственных запасов, определять позиционирование персонала и т. д. Следует отметить, что проект по внедрению данной системы в малый, средний и крупный бизнес будет иметь свои особенности и приоритеты.

Ключевые слова: KPI, RFID, отслеживание, учет, математическая модель.

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ELEMENTS OF DNA-TECHNOLOGY FORMING QUALITY AND SAFE RAW MATERIALS

Abstract. It is known that cows high milk productivity is associated with decrease in resistance to various diseases, including bovine leukosis, in resistance formation to which the *BoLA-DRB3* gene plays role, whose alleles are associated with resistance (R-alleles *7, *11, *23, *28), sensitivity (S-alleles *8, *16, *22, *24) or are defined as neutral (N) in relation to the disease. Researchers also established association of *BoLA-DRB3*-alleles *8, *11, *23 with an increased milk yield volume, and the *22 allele - with reduced milk yield volume. The aim of research was to study associative communication of servicing bulls *BoLA-DRB3* genotypes groups with their breeding value by female ancestor's dairy productivity indicators. As a result, we studied associative communication of servicing bulls *BoLA-DRB3* genotypes groups with their breeding value by female ancestor's dairy productivity indicators with identification of reduced milk productivity with genetic resistance to bovine leukemia virus infection and bovine leukosis disease relationship, as well as observation of positive correlation between increased milk productivity and genetic predisposition to increased milk yield volumes. The obtained information will be taken into account in breeding during dairy herds reproduction with genetic resistance to bovine leukosis.

Key words: servicing bull, gene, genotype, *BoLA-DRB3*, PCR, SBT, bovine leukosis, milk productivity.

Introduction. The main task in dairy cattle breeding of our country is an objective assessment of genetic potential and improving servicing bull's selection accuracy for herd reproduction, which will serve as a guarantee for industry economic efficiency growth [1-4].

The observed trend towards an increase in cow's milk productivity is closely associated with decrease in resistance to various cattle diseases, which subsequently negatively affects the production process with an increase in output cost [5,6], including due to animals culling and decrease in milk yield average level per herd [7].

In breeding work for formation of highly productive dairy herds populations, screening is carried out for various gene variants of economically significant traits [8-11], including determining resistance to various diseases, including bovine leukosis, the most common in Russian Federation, including Republic of Tatarstan, which is confirmed by studies of causative infection agent - bovine leukemia virus (BLV) [12-15].

The genes of the main histocompatibility complex are considered as a potential molecular marker of cattle resistance to leukosis [16,17], among which *BoLA-DRB3* gene is the most highly polymorphic [18].

Data on *BoLA-DRB3* gene polymorphism [19], which alleles are associated with resistance or susceptibility to bovine leukosis [20,21], make it possible to carry out marker-directed selection in order to obtain disease-resistant animals [22-24].

BoLA-DRB3 gene alleles are divided both into those associated with resistance (R) to bovine leukosis, represented by following alleles: *7, *11, *23, *28, and those related to sensitivity (S): *8, *16, *22, *24 [25], the remaining alleles are defined as neutral (N). Resistance to bovine leukosis is dominant feature, therefore animal carriers of *7, *11, *23 and *28 alleles, even in heterozygous state, will not be susceptible to this disease [26].

Milk, obtained from leukosis dairy cows often leads to decrease in its quality, biological usefulness and safety. At the same time, production of high-quality dairy raw materials is an important task, especially in terms of functional and herodietic dairy products production [27-31].

The researchers also obtained data on different allelic variants of *BoLA-DRB3* gene association directly with milk productivity signs in cattle [32,33]. For example, *BoLA-DRB3* alleles *8, *11 and *23 are associated with increased (I) milk yield, allele *22 - with decreased (D) milk yield.

The aim of this research was to study associative communication of servicing bulls *BoLA-DRB3* genotypes groups with their breeding value by female ancestor's dairy productivity indicators.

Material and research methods. Molecular genetic studies were performed on DNA samples isolated from whole canned blood obtained from 60 servicing bulls of milk production direction, which are cross-breeding and purebred Holstein cattle, belonging to JSC "Head Breeding Enterprise "Elita" of Vysokogorsky District of Republic of Tatarstan. The study was conducted on the basis of interdepartmental laboratory of immunology and biotechnology, Kazan State Academy of Veterinary Medicine named after N.E. Bauman and Research and Production Company "SINTOL" (Moscow).

Nucleic acids were extracted using reagents set for DNA isolation from clinical material "DNA Sorb B" (Central Research Institute of Epidemiology, Russia).

For PCR-amplification of exon 2 locus of *BoLA-DRB3* gene with a length of 319 bp optimized PCR-SBT conditions were used [34] using DRB3FRW (5′-CGCTCCTGTGAYCAGATCTATCC-3′) and DRB3REV (5′-CACCCCCGCGCTCACC-3′) primers and "Encyclo Plus PCR kit" reagent kit (CJSC Evrogen, Russia) under following thermal cycling conditions: preliminary denaturation at 94 °C for 4 minutes; further 40 cycles: denaturation 94 °C - 10 sec., annealing 62 °C - 10 sec., extension 72 °C - 10 sec.; final extension at 72 °C - 5 min.

Electrophoretic detection of resulting PCR fragments was carried out using reagent kit of "EF-genotype 200" (Central Research Institute of Epidemiology) in 2% agarose gel in TBE buffer, containing ethidium bromide, followed by visualization of amplicons in UV-transilluminator (Vilber Lourmat) and fixing result on digital camera (Canon).

For *BoLA* typing by sequencing (SBT), analyzed locus amplicons were sequenced using an "ABI PRISM 3100" genetic analyzer (Applied Biosystems, USA) followed by their alignment in BLAST (https://blast.ncbi.nlm.nih.gov/Blast. cgic) by corresponding partial nucleotide sequences of *BoLA-DRB3* alleles.

The frequency of genotypes occurrence by *BoLA-DRB3* gene was determined by formula [35]:

$$p = \frac{n}{N},$$

where p – genotype frequency; n – number of animal units, having a certain genotype, N – total number of examined animal units.

The calculation of animal unit's frequency alleles was performed according to formula [36]:

$$p = (2N1+N2)/2n,$$

where $N1$ – number of homozygotes for studied allele, $N2$ – number of heterozygotes, n – sample volume.

When studying the associative communication of servicing bulls *BoLA-DRB3* genotypes groups with their breeding value by female ancestor's dairy productivity indicators, were used data on zootechnical and pedigree accounting of researched farm: pedigree cards (form 1-MOL), pedigree certificates and servicing bulls' catalogs.

The PBI is calculated – the parental bull index according to N.A. Kravchenko, 1963 [37] for each bull by milk yield and buttermilk of their female ancestors.

$$PBI = (2M+MM+MF)/4,$$

where *M* – mothers, *MM* – mothers of mothers, *MF* – mothers of fathers.

The results of research were processed by biometric method using computer and Microsoft Excel. The level of their reliability was determined by Student criterion.

Results and discussion. In assessing servicing bulls of milk productivity direction by origin, the indices of breeding bull's evaluation were used. An analysis of parental bull index (PBI) shows the extent to which offspring can transmit signs of milk production (table 1).

In total, typed sample (n=60) of bulls is divided into six associated groups of *BoLA-DRB3* genotypes: S/S – 25, S/N – 14, N/N – 4, R/N – 4, R/S – 11 и R/R – 2 animals.

Table 1 – Evaluation of servicing bulls of different groups of *BoLA-DRB3* genotypes associated with susceptibility or resistance to leukosis, according to indicators of female ancestor's milk productivity

Associated Genotypes Group		Milk productivity indicators		
		milk yield, kg	fat, %	fat, kg
n=60		Mothers (M)		
S/S	25	8561.0±1956.7	3.82±0.19	327.1±77.1
S/N	14	8800±1454.2	3.90±0.13	344.0±64.8
N/N	4	9918±668.5	4.03±0.18	399.8±41.1
R/N	4	8508±1268.8	3.95±0.22	334.3±35.7
R/S	11	8460±1570.5	3.84±0.18	326.6±71
R/R	2	6803±607.4	4.15±0.45	283.3±55.5
n=60		Mothers of mothers (MM)		
S/S	25	7731±2280.7	3.90±0.38	300.2±88.1
S/N	14	6517±1640.6	3.89±0.22	253.9±69.8
N/N	4	8003±2834.5	3.71±0.17	300.2±119.1
R/N	4	7087±1207	3.96±0.11	279.80±41.2
R/S	11	6736±1644.3	3.85±0.42	261.2±78.8
R/R	2	6347±2045	3.80±0	241.2±77.7
n=60		Mothers of fathers (MF)		
S/S	25	10591±3272.7	3.95±0.22	419.4±131.2
S/N	14	9579±1113.6	3.97±0.34	382.6±71.6
N/N	4	13816±2226.5	4.4±0.69	604.9±133.5
R/N	4	11490±2612.5	3.91±0.07	447.3±92.1
R/S	11	10854±3052.7	4.20±0.51	463.1±170.7
R/R	2	9533±951.8	4.16±0.34	395±7.2
n=60		Parental bull index (PBI)		
S/S	25	9251±2530.3	3.87±0.16	358±94.6
S/N	14	8424±995.5	3.91±0.16	329.4±51.2
N/N	4	10414±825.6	4.04±0.19	420.7±47.1
R/N	4	8898±1403	3.94±0.15	350.6±43.4
R/S	11	8628±1505.5	3.93±0.24	339.1±79.7
R/R	2	7371±1052.9	4.06±0.14	299.3±49

Note: R – alleles associated with resistance to leukosis; S – alleles associated with sensitivity to leukosis; N – alleles neutral to bovine leukosis.

According to assessment results of parental bull index (PBI), distribution of genotype groups associated with resistance (R) and/or sensitivity (S) and/or neutral (N) state in relation to bovine leukosis had the following configuration in descending order of values:

for milk yield – N/N>S/S>R/N>R/S>S/N>R/R;
for milk fat content – R/R>N/N>R/N>R/S>S/N>S/S;
for milk fat yield – N/N>S/S>R/N>R/S>S/N>R/R.

Evaluation of bulls by parental index showed that highest milk yield (10,414 kg) and milk fat yield (420.7 kg) were observed in bulls of associated N/N genotypes group, and higher milk fat content had bulls of associated R/R genotypes group (4.06%).

At the same time, the smallest milk yield (7371 kg) and milk fat yield (299.3 kg) were observed in bulls of associated R/R genotype group, and the lowest milk fat content (3.87%) had bulls of associated S/S genotypes group.

A comparative analysis of frequency distribution of *BoLA-DRB3* gene alleles associated with cattle milk productivity signs in researched servicing bulls sample is presented in table 2.

Distribution of presented alleles associated with milk productivity signs in decreasing frequency order of occurrence has following configuration: *8>*22>*23>*11.

Table 2 – Occurrence frequency of *BoLA-DRB3* gene alleles, associated with milk productivity signs in servicing bulls' sample of JSC "Head Breeding Enterprise "Elita" of Vysokogorsky District of Republic of Tatarstan

Allele number	Number of animal-carriers of certain *BoLA-DRB3* alleles		Number of specific alleles	Allele frequency, %
				"Elita" (n=60)
∑	n=110	100 %	n=120	100 %
Alleles, not associated with milk yield level				
∑	75	68.19	83	69.18
I-alleles associated with increased milk yield				
*8 (*1201)	14	12.73	16	13.33
*11 (*0902)	5	4.54	5	4.16
*23 (*2701, *2703)	7	6.36	7	5.83
D-alleles associated with decreased milk yield				
*22 (*1101)	9	8.18	9	7.50

The group of I-alleles associated with an increased milk yield volume is represented by three alleles: *8, *11, *23 with occurrence frequency in range of 4.16–13.33%; at the same time, the allele *11 has the lowest occurrence frequency, the *8 allele is the highest. The total proportion of occurrence frequency of this alleles group was 23.32%, with these alleles' presence in genotype of 22.4% of bulls.

The group of D-alleles associated with reduced milk yield is represented by one *22 allele with occurrence frequency of 7.5%. This allele is present in genotype of 8.18% of bulls.

Evaluation of servicing bulls of different groups of *BoLA-DRB3* genotypes associated with milk productivity signs by female ancestor's indicators of the same name is presented in table 3.

Table 3 – Evaluation of servicing bulls of different groups of *BoLA-DRB3* genotypes associated with milk productivity signs by female ancestor's indicators of the same name

Associated Genotypes Group		Milk productivity indicators		
		milk yield, кг	fat, %	fat, kg
n=60		Mothers (M)		
I/I	5	8545±2381.8	3.85±0.26	329 ±105.9
D/D	–	–	–	–
N/N	32	8817±1568.2	3.87±0.18	341.2±65.6
I/D	3	6943±2103.8	3.79±0.05	263.1±82.3
D/N	5	8990±564.3	3.9±0.05	350.6±25.2
I/N	15	8462±1792.3	3.89±0.25	336.8±71.7

Continuation of table 3

n=60		Mothers of Mothers (MM)		
I/I	5	7829±2748.2	3.92±0.35	306.9±129.1
D/D	–	–	–	–
N/N	32	7035±1983.3	3.82±0.27	268.7±78.2
I/D	3	7255±4002.1	3.92±0.29	284.4±137.4
D/N	5	7735±1990.9	4.02±0.62	310.9±78.29
I/N	15	7129±1584.5	3.93±0.32	279.97±66.2
n=60		Mothers of fathers (MF)		
I/I	5	11379±2288.4	4.54±0.64	516.6±160.9
D/D	–	–	–	–
N/N	32	10826±3049.2	3.97±0.31	429.8±129.7
I/D	3	8433±2225.1	4.1±0.29	345.7±118.7
D/N	5	9537±1656.8	3.9±0.05	371.9±67
I/N	15	10816±2797.6	4.03±0.33	435.9±138.5
n=60		Parental bull index (PBI)		
I/I	5	9075±2262.1	4.04±0.32	366.6±118.42
D/D	–	–	–	–
N/N	32	8874±1662	3.88±0.15	349.6±67.8
I/D	3	7394±2556.9	3.9±0.05	288.4±102.4
D/N	5	8813±867.7	3.93±0.18	345.9±37.5
I/N	15	8717±1480.7	3.94±0.22	343.4±67.3

Note: I – alleles associated with increased milk yield; D – alleles associated with decreased milk yield; N – alleles neutral to milk yield.

The typed sample (n=60) of servicing bulls is represented by five associated groups of BoLA-DRB3 genotypes: I/I - 5, N/N - 32, I/D - 3, D/N - 5, and I/N - 15 animals. Moreover, no bulls of associated D/D genotypes group were revealed in the sample under study (Table 3).

According to assessment results of parental bull index (PBI), distribution of genotype groups associated with an increased and/or decreased milk yield volume and/or their neutral (N) state had the following configuration in decreasing order of indicator values:

for milk yield – I/I>N/N>D/N>I/N>I/D;

for milk fat content – I/I>I/N>D/N>I/D>N/N;

for milk fat yield – I/I>N/N>D/N>I/N>I/D.

Evaluation of bulls by parental index showed that bulls of associated of I/I genotypes group were characterized by highest milk yield (9075 kg), as well as milk fat content (4.04%) and milk fat yield (366.6 kg).

At the same time, the smallest milk yield (7394 kg) and milk fat yield (288.4 kg) were observed in bulls of associated I/D genotypes group, and the lowest milk fat content (3.88%) had bulls of associated N/N genotypes group.

Conclusion. According to research results, it was found that the highest PBI in milk yield and milk fat yield was observed in bulls of associated N/N genotypes group, and milk fat content had bulls of associated R/R genotypes group. The lowest PBI in milk yield and milk fat yield was observed in bulls of associated R/R genotypes group, and in terms of milk fat content - had bulls of associated S/S genotypes group. The distribution of genotypes groups, associated with an increased (I) and/or with decreased (D) milk yield volume and/or their neutral (N) state, in decreasing values order of corresponding indicators, showed that the highest PBI indicator for milk yield, milk fat content and milk fat yield was observed in bulls of associated I/I genotypes group. Thus, by researching associative communication of servicing bulls *BoLA-DRB3* genotypes groups with their breeding value by female ancestor's dairy productivity indicators, a relationship was found between reduced milk productivity and genetic resistance to infection with bovine leukemia virus and bovine leukosis disease, as well as a positive correlation between increased milk production and genetic predisposition to increased milk yield.

Researched associative communication of servicing bulls *BoLA-DRB3* genotypes groups with their breeding value by female ancestor's dairy productivity indicators will be taken into account in breeding work in dairy herd reproduction with genetic resistance to bovine leukosis.

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ДНҚ ЭЛЕМЕНТТЕРІ – ШИКІЗАТ САПАСЫ МЕН ҚАУІПСІЗДІГІ ТЕХНОЛОГИЯСЫН ҚАЛЫПТАСТЫРУ КЕПІЛІ

Аннотация. Сиырдың жоғары сүт өнімділігі түрлі ауруға, соның ішінде ірі қара малының лейкемиясына қарсы тұрақтылықтың төмендеуіне, BoLA-DRB3 генінің рөлі аллельдерінің қарсыласуына байланысты екендігі белгілі (У - аллели *7, *11, *23, *28), сезімталдық (Ч -аллели *7, *11, *23, *28) немесе ауруға қатысты бейтарап (Н) ретінде анықталады. Сондай-ақ BoLA-DRB3 аллельдері * 8, * 11, * 23 сүт шығымының ұлғаюы арқылы және сүт шығымы төмен аллель * 22 арасында байланыс орнатылды. Лейкоз сиырдан алынған сүт көбінесе оның сапасын, биологиялық құндылығы мен қауіпсіздігін төмендетеді. Өндірісте әсіресе функционалды және геродиеталық сүт өнімін алу үшін жоғары сапалы сүт шикізатын қолдану маңызды міндет болып саналады. Жалпы, ірі қара малының лейкемияға төзімділігінің генетикалық маркерлерін скрининг жасау жоғары сапалы және қауіпсіз шикізатты құру үшін ДНҚ технологиясының элементі ретінде орналастырылған. Зерттеудің мақсаты – бұқаның BoLA-DRB3 генотиптік тобының асыл тұқымдық құндылығы арқылы аналық ұрпақтарға жақынырақ келетін тегінің сүт өнімділігі тұрғысынан ассоциативті байланысын зерттеу. Молекулярлық-генетикалық зерттеулер генетикалық және асыл тұқымды ірі қара малдың сүт өнімділігі бағытындағы 60 бұқадан өндірілген, консервіленген қаннан оқшауланған ДНҚ сынамаларында жүргізілді. Нуклеин қышқылын экстракциялау ДНҚ-ны оқшаулауға арналған реагенттер кешені арқылы жүргізілді. Ұзындығы 319 п.н. BoLA-DRB3 генінің экзон 2 локусын ПЦР күшейту үшін оңтайландырылған ПЦР -SBT шарттары DRB3FRW және DRB3REV праймерлері арқылы қолданылды. BoLA-ны жүйелеу (SBT) арқылы енгізу үшін талданған локустың ампликондары генетикалық анализаторға реттелді, содан кейін BoLA-DRB3 аллельдерінің тиісті жартылай нуклеотидтік тізбектерімен теңестірілді. Аналық ұрпақтарға жақын тегінің сүт өнімділігі тұрғысынан BoLA-DRB3 бұқалары генотиптерінің асыл тұқымдық құндылықтарының ассоциативті байланысын зерттеу кезінде зерттелетін шаруашылықтың зоотехникалық және тұқымдық тіркелуі туралы деректерді пайдаландық. Сүт өндіруші бұқаларды тегі бойынша өнімділік бағытын бағалау кезінде бұқалардың асыл тұқымдылығын бағалау көрсеткіштері негізге алынды. Бұқаның аталық-аналық индексін (БАИ) талдау ұрпақтарының сүт өндірудің белгілерін жібере алатындығын көрсетеді. Алынған зерттеу нәтижелері биометриялық әдіспен өңделді. Олардың сенімділігі Стьюденттің өлшемі бойынша анықталды. Зерттеу нәтижелері бойынша, сүт өнімі мен сүт майындағы ең жоғары БАИ мөлшері Н/Н генотиптерінің байланысты топ бұқаларында және У/У генотиптерінің байланысты топ бұқаларындағы сүт майының құрамында екендігі анықталды. Сүт мөлшері мен сүт майының шығымы үшін БАИ ең төмен көрсеткіші У/У генотиптерінің байланысты тобының бұқаларында, ал сүт майының мөлшері бойынша Ч/Ч генотиптерінің байланысты тобының бұқаларында байқалды. Сүт шығымының жоғарылауымен (Ж) және/немесе азайтылған (А) көлемімен және/немесе олардың бейтарап (Н) күйімен байланысты генотиптер тобының таралуы тиісті индикатор мәнінің азаю тәртібімен сүт кірісі, сүт құрамы және БАИ үшін ең жоғары көрсеткіш көрсетті, П/П генотиптерінің қауымдастырылған тобының бұқаларында сүт майының шығымы байқалды. Осылайша, аналық ұрпақтарға жақын тегінің сүт өнімділігі тұрғысынан BoLA-DRB3 бұқалардың генотиптік тобының асыл тұқымдық құндылығымен ассоциативті байланысын зерттей отырып, сүт өнімділігінің азаюы мен ірі қара малдың лейкоз вирусымен инфекцияға генетикалық төзімділігі, сондай-ақ көбею арасындағы оң корреляция арасындағы байланыс анықталды. Ірі қара аналықтардың сүт өнімділігі тұрғысынан BoLA-DRB3 тұқымдық бұқалардың генотиптік тобының зерттелген ассоциативті қатынасы ірі қара малдың лейкемиясына генетикалық төзімділігі бар сүтті табын көбейту барысында асыл тұқымды аналық ұрпақтарға жақын тегінің сүт өнімділігі ескерілетін болады.

Түйін сөздер: өндіруші бұқа, ген, генотип, BoLA-DRB3, ПЦР, SBT, ірі қара мал лейкозы, сүт өнімділігі.

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ЭЛЕМЕНТЫ ДНК-ТЕХНОЛОГИИ ФОРМИРОВАНИЯ КАЧЕСТВЕННОГО И БЕЗОПАСНОГО СЫРЬЯ

Аннотация. Известно, что высокая молочная продуктивность коров связана со снижением резистентности к различным заболеваниям, включая лейкоз крупного рогатого скота, в формировании резистентности к которому играет роль ген *BoLA-DRB3*, чьи аллели ассоциированы с устойчивостью (У-аллели *7, *11, *23, *28), чувствительностью (Ч-аллели *8, *16, *22, *24) или определены как нейтральные (Н) по отношению к заболеванию. Также установлена связь *BoLA-DRB3*-аллелей *8, *11, *23 с повышенным объемом удоев, а аллеля *22 – со сниженным объемом удоев. Полученное от лейкозных коров молоко зачастую приводит к снижению его качества, биологической полноценности и безопасности. При этом производство высококлассного молочного сырья является важнейшей задачей, особенно в части выработки функциональных и геродиетических молочных продуктов. В целом скрининг генетических маркеров устойчивости к лейкозу крупного рогатого скота позиционируется как элемент ДНК-технологии прижизненного формирования качественного и безопасного сырья. Целью настоящего исследования являлось изучение ассоциативной связи групп генотипов *BoLA-DRB3* быков-производителей с их племенной ценностью по показателям молочной продуктивности женских предков. Молекулярно-генетическому исследованию были подвергнуты образцы ДНК, выделенные из цельной консервированной крови, полученной от 60 быков-производителей молочного направления продуктивности, представляющих собой помесный и чистопородный голштинский скот. Экстракцию нуклеиновых кислот осуществляли с применением комплекта реагентов для выделения ДНК. Для ПЦР-амплификации локуса экзона 2 гена *BoLA-DRB3* длиной 319 п.н. применяли оптимизированные условия проведения ПЦР-SBT с использованием праймеров DRB3FRW и DRB3REV. Для *BoLA*-типирования методом секвенирования (SBT) ампликоны анализируемого локуса секвенировали на генетическом анализаторе с последующим их выравниванием с соответствующими частичными нуклеотидными последовательностями *BoLA-DRB3*-аллелей. При изучении ассоциативной связи генотипов по гену *BoLA-DRB3* быков-производителей с их племенной ценностью по показателям молочной продуктивности женских предков использованы данные по зоотехническому и племенному учету исследуемого хозяйства. При оценке быков-производителей молочного направления продуктивности по происхождению использованы индексы племенной оценки быков. Анализ родительского индекса быка (РИБ) показывает степень возможной передачи потомству признаков молочной продуктивности. Полученные результаты исследования обработаны биометрическим методом. Уровень их достоверности определяли по критерию Стьюдента. По результатам проведенного исследования установлено, что наибольший показатель РИБ по удою и выходу молочного жира отмечен у быков ассоциированной группы генотипов Н/Н, а по содержанию молочного жира – у быков ассоциированной группы генотипов У/У. Наименьший показатель РИБ по удою и выходу молочного жира отмечен у быков ассоциированной группы генотипов У/У, а по содержанию молочного жира – у быков ассоциированной группы генотипов Ч/Ч. Распределение же групп генотипов, ассоциированных с повышенным (П) и/или со сниженным (С) объемом удоев и/или их нейтральным (Н) состоянием, в порядке убывания значений соответствующих показателей показало, что наибольший показатель РИБ по удою, содержанию молочного жира и выходу молочного жира отмечен у быков ассоциированной группы генотипов П/П. Таким образом, изучением ассоциативной связи групп генотипов *BoLA-DRB3* быков-производителей с их племенной ценностью по показателям молочной продуктивности женских предков наблюдалась взаимосвязь сниженной молочной продуктивности с генетической резистентностью к инфицированию вирусом бычьего лейкоза и заболеванию лейкозом крупного рогатого скота, а также положительная корреляция между повышенной молочной продуктивностью и генетической предрасположенностью к повышенному объему удоев. Изученная ассоциативная связь групп генотипов *BoLA-DRB3* быков-производителей с их племенной ценностью по показателям молочной продуктивности женских предков будет учитываться в селекционно-племенной работе при воспроизводстве молочного стада с генетической устойчивостью к лейкозу крупного рогатого скота.

Ключевые слова: бык-производитель, ген, генотип, *BoLA-DRB3*, ПЦР, SBT, лейкоз крупного рогатого скота, молочная продуктивность.

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ALIGNING METHOD OF STRUCTURES DURING INSTALLATION IN VERTICAL PLANE

Abstract. This article presents the results of the research methods of structures aligning during installation in the vertical plane. The analysis and research of existing methods of structures alignment in the vertical plane, used in the conditions of enterprises engaged in the installation of metal tanks. The results of the research showed that the applied alignment methods in the vertical plane have some drawbacks, in particular, after aligning, additional calculations are required. And also for alignment of sliding timbering, columns and wall panels use some theodolites, including vertical allotment. Laser devices and theodolites with visual system were also investigated. However, all the methods considered with the use of these devices are quite time-consuming and a significant number of tools and equipment are used. A device is proposed to control the shape and location of flat surfaces using the principle of similarity of triangles allowing obtaining a straight line of intersection of lasers in space parallel to the plumb line. Developed devices are cheap, easy to use and manufacture. With the use of the proposed technique, there is no need to use several working and expensive devices. The developed devices can significantly reduce the alignment time of building structures in the vertical and horizontal planes.

Key words: Alignment design, laser theodolite, laser sights, light spot, laser beam.

Introduction. The development and implementation of advanced methods and technical means of measurement are urgent problems, as the increasing volume and complexity of tasks for the construction of various objects require continuous improvement of geodetic support.

A large number of laser devices are produced to perform engineering and geodetic works, of which theodolites with a visual system are in great demand when reconciling building structures [1-5].

The use of laser theodolite with the beam sweep in the vertical plane allows to determining the position in the plan and the verticality of the structures by the method of lateral leveling. At the same time, continuous geodetic control of the position of the mounted element is provided, and the presence of visible lines and planes formed by the beam and its opening allows for more accurate assembly of structures [6-9].

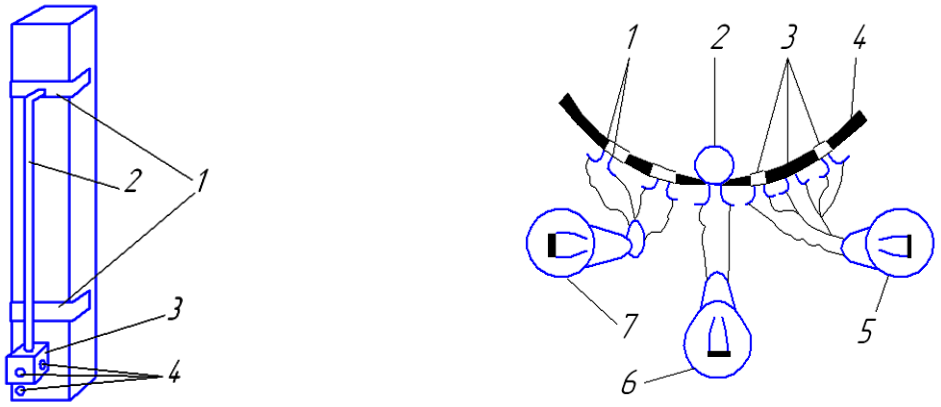
But this method is used mainly for finishing, plumbing and installation of devices indoors [10-12]. For aligning of columns and wall panels of industrial and public buildings it is necessary to use other devices.

In this case, the accuracy of measurements when working with laser devices largely depends on the diameter of the radiation beam, which varies depending on the distance of its propagation. Depending on the distance, the clarity of its contours also changes.

However, the existing methods of structures alignment in the vertical plane have several drawbacks. So, for example, at installation of metal tanks on object "New metallurgy" firm LLP "Ust-Kamenogorsk

installation firm "Imstalkon", made alignment in a vertical plane, thus it was necessary to use special marks and to make additional calculations. To align the sliding formwork, columns and wall panels use multiple theodolites, including the vertical scan.

Traditionally, two theodolites are used when mounting columns (see figure 1) [13-16]. Before installation of columns check their sizes and put the risks facilitating installation of a column in the glass of the base or on heads of subcolumns. The column established in the glass of the base, center to coincidence with risks on the top plane of the base.



а) б)

Figure 1 – Alignment circuit of columns and panels. a) - column alignment with a special device; b) - scheme of operation of the device for aligning of the column

To check the verticality of the column, two theodolites are placed at right angles to the numeric and alphabetic axes of the buildings. In this case, the sighting axis of the theodolite is combined with the risks inflicted on the glass at the bottom of the column, and then, smoothly raising the theodolite pipe, with the risk at the upper end of the column. The distance of the theodolite from the verified column is taken such that at the maximum rise of the pipe the angle of its inclination does not exceed 30-35^{o} [17,18].

A more promising method based on the use of a device with warning lights (Fig. 1, a, b). This device attaches to the verified column through special holders 1. In this case, the rod 2 is parallel to the axis of the column. A device 3 with five warning lights 4 is attached to the rod. Four red light bulbs are located on the side faces of the device, a green lamp-at the bottom. The device has a spherical surface 4 with 3 holes. The metal ball 2, moving on a spherical surface, closes contacts 1 in holes 3 and includes signal lamps.

If the rod occupies a vertical position, the ball is located in the Central hole and includes a signal light 6 green. If the column, and therefore the rod, is inclined, the ball tries to take the lowest position and moves to another hole. In this case, a red light illuminates on the side where the column is tilted upwards. If the column is inclined in a plane perpendicular to the plane of the device, then two red bulbs light up at once. This method significantly reduces labor costs and does not require preliminary marking of the column.

However, all of these methods are quite time-consuming and a significant number of tools and equipment are used.

Proposed reconciliation methods and discussion. The proposed method of reconciliation of structures in the vertical plane allows the use of only one laser theodolite with two sights [19].

The device consists of two sights, which project on the working surface one spot of light in the vertical design plane. The proposed device for controlling the shape and location of flat surfaces (figure 2) includes two lasers 1 and 2 connected by a frame 3, the sides of which are movably connected to each other, for example, by means of hinges, a plumb 4, a counterweight 5, a tripod 6 and a stand 7 with lifting screws 8.

The principle of operation is as follows. Before starting work, the device for controlling the shape and location of flat surfaces is installed in the desired position through a plumb 4, a counterweight 5 and supports 6. Next, using the stand 7 with lifting screws 8, turn the laser 2 to the intersection of two points on the verified plane.

The laser 1 rotates relative to the axis A, forcing the laser 2 to move through the frame 3, while the geometric figure represented by the frame is inverted in the vertical plane, preserving the properties of the original figure (parallelogram), which allows to obtain a laser intersection point moving rectilinearly in the vertical plane, parallel to the vertical side of the frame. If the verified plane deviates from the vertical position, the point will be deformed. Thus, the installer chooses the design. In the other vertical plane (90^o), reconciliation is carried out on the risks on the column or wall panels.

The device allows you to quickly, simply and economically align any flat surface in any direction. To do this, the laser theodolite, mounted on a tripod, must be installed on a construction site with a good outlook (all-round view), to ensure the maximum number of measurements from one Parking lot.

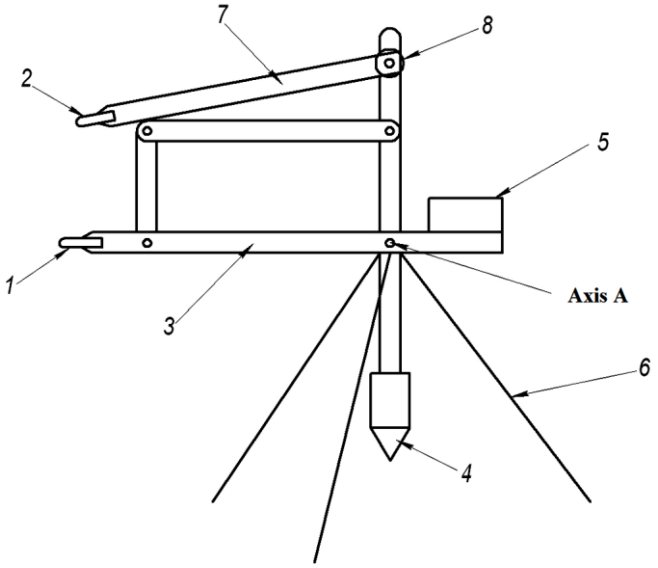


Figure 2 – Device to control the shape and location of flat surfaces: 1 and 2 - laser sights; 3 - frame; 4 - plumb to control the location; 5 - counterweight; 6 - tripod; 7 - stand; 8 - lifting screw

The essence of the reconciliation method is to specify the vertical movement of the light point O_1 in space (figure 3). To do this, it is necessary that when moving the sights at a certain angle in the vertical plane ($\alpha_в$), the sights are rotated in the horizontal plane at a certain angle ($\beta_г$). Rotation of sights is carried out by rotation of micrometric screws, thus both sights turn synchronously thanks to a special worm gear. The intersection of the rays gives a vertical invisible straight line in space.

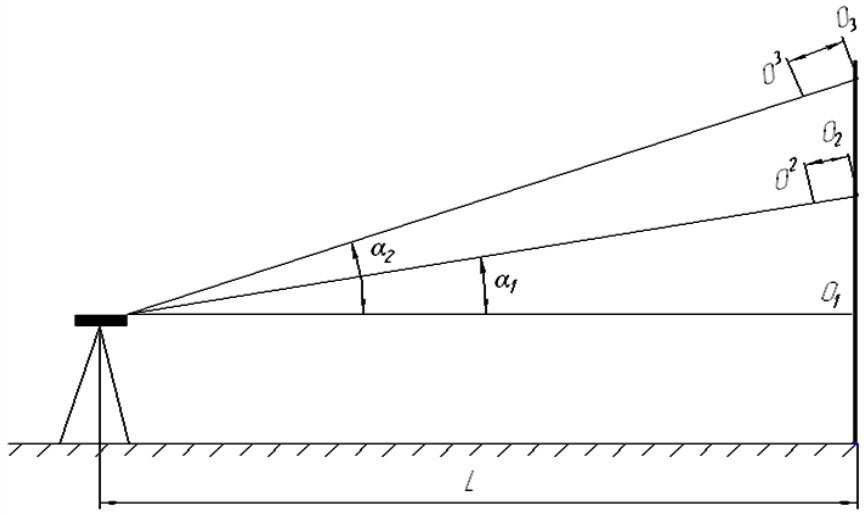


Figure 3 – Determination of the movement of the point of sight in the vertical plane

The displacement of the point O_1 in the vertical plane when rotating the sight angle $\alpha_в$. Where O_2, O_3 - the necessary position of a point when rotating the reticles for aligning structures in the vertical plane; O_2, O_3 - the standard position of the point when you rotate the sight; L - working distance up to mounted structures.

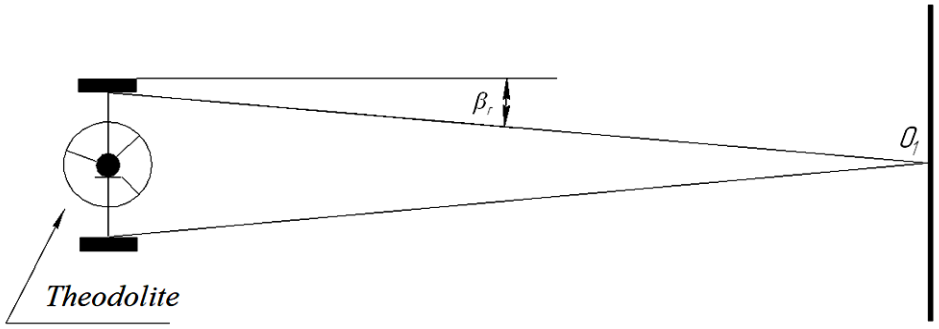


Figure 4 – Determining the movement of the point of sight in the horizontal plane

The circuit shows the required position of the point O_1 in the horizontal plane when turning the sights at an angle $\beta_г$.

A Cam device [20] is also proposed to control the shape and location of flat surfaces (figure 5) including a stand with lifting screws, a tripod, a laser, characterized in that it is provided with a second laser, which the Cam is made with the condition cos β = cos α * R/L, where α is the kinematic rotation angle associated with the first laser shaped Cam, wherein the profile of the shaped first laser, β is the rotation angle of the second laser, R is the distance between the lasers, L is the distance from the first laser to the controlled surface.

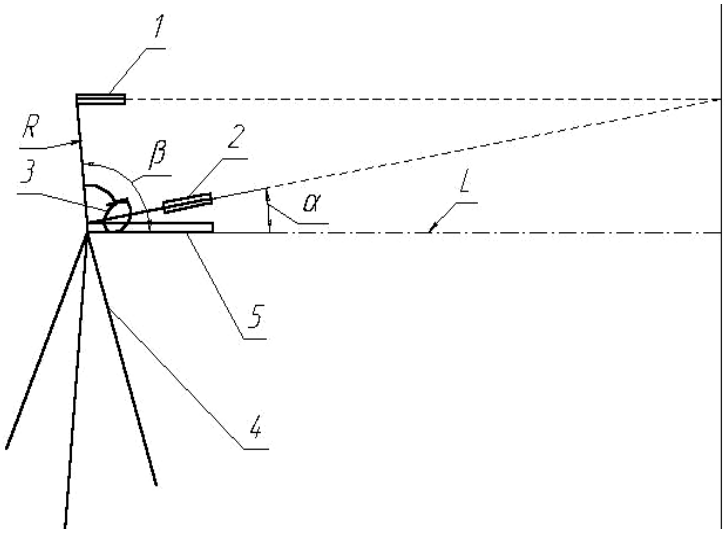


Figure 5 – Cam device for controlling the shape and location of flat surfaces

The proposed Cam device for controlling the shape and location of flat surfaces includes two lasers 1 and 2, connected kinematically to each other by a shaped Cam 3, a tripod 4, a stand with lifting screws 5 to give the necessary position to the two lasers.

The device works as follows. The laser 1 rotates relative to the axis A, forcing through the shaped Cam 3 to move the laser 2, while the intersection of the beams of lasers 1 and 2 will give a point in space, which when moving the laser 2, thanks to the shaped Cam 3, allows you to get a straight line of intersection of lasers in space perpendicular to the stand with the lifting screws 5.

The proposed technique allows the installer to visually observe the beam and make reconciliation directly "under the point" by straightening structures with special mounting tools, which significantly increases the speed of reconciliation of structures during installation.

Conclusions. 1. Existing methods of reconciliation of structures in the vertical plane have some disadvantages: the need to involve several workers and at least two theodolites, or the use of expensive scanners, the complexity, and labor costs of work.

2. A device was developed to control the shape and location of flat surfaces using the principle of similarity of triangles allowing to obtain a straight line of intersection of lasers in space parallel to the plumb line.

3. Designed Cam device for controlling the shape and location of flat surfaces in which the profile of the shaped Cam is made with the condition cos β = cos α * R/L, where α is the rotation angle of the first laser, β is the rotation angle of the second laser, R is the distance between the lasers, L is the distance from the first laser to the controlled surface, which allows to obtain a straight line of intersection of the lasers in space perpendicular to the stand.

4. Developed devices are cheap, easy to use and manufacture.

5. When using this technique, there is no need to use several working and expensive devices.

6. The developed devices can significantly reduce the time of reconciliation of building structures in the vertical and horizontal planes.

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МОНТАЖДАУ БАРЫСЫНДА ТІК ЖАЗЫҚТЫҚТА КОНСТРУКЦИЯЛАРДЫ ТУРАЛАУ ӘДІСІ

Аннотация. Прогрессивті әдістер мен техникалық өлшеу құралдарын әзірлеу және енгізу өзекті мәселе болып саналады, өйткені әртүрлі нысандарды салу жөніндегі міндеттердің көлемі мен күрделілігі геодезиялық қамтамасыз ету құралдарын үнемі жетілдіруді талап етеді.

Инженерлік-геодезиялық жұмыстарды орындау үшін көптеген лазерлік аспаптар шығарылады, оның ішінде визуалды жүйесі бар теодолиттер құрылыс конструкцияларын тексеруде үлкен сұранысқа ие.

Зерттеу нәтижелері көрсеткендей, құрылымдарды тік жазықтықта салыстырудың қолданыстағы тәсілдерінің кемшіліктері бар. Мысалы, «Жаңа металлургия» нысанында металл резервуарларды монтаждау кезінде «Имсталькон» «Өскемен монтаждау фирмасы» ЖШС фирмасы тік жазықтықта тексеру жүргізді, бұл ретте арнайы маркаларды пайдалану және қосымша есептеулер жүргізу қажет болды. Жылжымалы қалып, бағаналарды және қабырға панельдерін салыстырып тексеру үшін бірнеше теодолиттер, соның ішінде тігінен жайылған тесіктер қолданылды. Дәстүрлі түрде колонналарды монтаждау кезінде екі теодолит пайдаланылады. Бағаналарды монтаждау алдында олардың өлшемдері тексеріледі және бағананы іргетастың стаканына немесе баған астының басына орнатуды жеңілдететін қатер еңгізеді. Іргетастың стаканына орнатылған бағананы іргетастың жоғарғы жазықтығында тәуекелмен сәйкес келгенше орталықтандырады.

Тік жазықтықта конструкцияларды салыстыру әдісі ұсынылады, екі визирі бар бір ғана лазерлік теодолитті пайдалануға мүмкіндік береді. Аспап жұмыс бетінде тік жобалық жазықтықта бір жарық дақ жобаланатын екі визирден тұрады. Мақалада тік жазықтықта монтаждау кезінде конструкцияларды туралау тәсілдерін зерттеу нәтижелері келтіріледі.

Металл резервуарларды монтаждаумен айналысатын кәсіпорындарда пайдаланылатын тік жазықтықта конструкцияларды салыстырып тексерудің қолданыстағы тәсілдеріне талдау және зерттеу жүргізілді. Зерттеу нәтижелері тік жазықтықта қолданылатын салыстыру тәсілдерінің кемшіліктері бар екенін көрсетті, атап айтқанда, тексергеннен кейін қосымша есептеу жүргізу талап етіледі. Сондай-ақ, сырғымалы қалып, бағаналарды және қабырға панельдерін салыстырып тексеру үшін бірнеше теодолит, соның ішінде тік жаймасы бар теодолиттер қолданылады.

Сондай-ақ, лазерлік аспаптар мен көрнекі жүйесі бар теодолиттер зерттелді. Алайда осы аспаптарды қолдану арқылы қаралған барлық тәсілдер жеткілікті еңбек сыйымдылығы бар және бұл ретте аспаптар мен жабдықтардың едәуір саны қолданылады. Жазық беттердің орналасуын және пішінін бақылауға арналған құрылғылар ұсынылады. Үшбұрыштардың ұқсастық принципін пайдаланатын кеңістіктегі параллель тіктеуішпен лазердің қиылысуының түзу сызығын алуға мүмкіндік береді. Әзірленген құрылғы арзан әрі қолдану мен жасау жеңіл. Ұсынылған әдістемені қолдану кезінде бірнеше жұмыс және қымбат құрылғыларды іске қосу қажеттілігі жойылады. Әзірленген құрылғы тік және көлденең жазықтықта құрылыс конструкцияларын тексеру уақытын айтарлықтай қысқартуға мүмкіндік береді.

Зерттеу нәтижелері бойынша келесі қорытындылар жасалды:

– құрылымдарды тік жазықтықта салыстырудың қолданыстағы тәсілдерінің кемшіліктері бар: бірнеше жұмыс және кемінде екі теодолитті іске қосу қажеттілігі немесе қымбат тұратын сканерлерді пайдалану, жұмыстың күрделілігі мен еңбек шығыны;

– жазық беттердің орналасуын және пішінін бақылауға арналған құрылғы жасалған, үшбұрыштардың ұқсастық принципін қолдану лазерлердің кеңістіктегі параллель тіктеу сызығын алуға мүмкіндік береді;

– фасонды жұдырықшаның профилі cos β = cos α * R / L шартымен орындалған, мұнда α-бірінші лазердің бұрылу бұрышы, β – екінші лазердің бұрылу бұрышы, R – лазерлер арасындағы қашықтық, L-бірінші лазерден бақыланатын бетке дейінгі қашықтық, бұл перпендикулярлы тұғырық кеңістігіндегі лазердің қиылысу сызығын алуға мүмкіндік береді;

– әзірленген құрылғылар арзан, қолдану және жасау жеңіл;

– осы әдістемені қолдану кезінде бірнеше жұмыс және қымбат құрылғыларды іске қосу қажеттілігі болмайды;

– әзірленген құрылғылар тік және көлденең жазықтықта құрылыс конструкцияларын тексеру уақытын едәуір қысқартуға мүмкіндік береді.

Түйін сөздер: конструкцияларды туралау, лазерлік теодолит, лазерлік визирлер, жарық дақтары, лазерлік сәуле.

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СПОСОБ ВЫВЕРКИ КОНСТРУКЦИЙ ПРИ МОНТАЖЕ В ВЕРТИКАЛЬНОЙ ПЛОСКОСТИ

Аннотация. Разработка и внедрение прогрессивных методов и технических средств измерений являются актуальными проблемами, так как возрастающие объемы и сложность задач по строительству различных объектов требуют постоянного совершенствования средств геодезического обеспечения.

Для выполнения инженерно-геодезических работ выпускается большое количество лазерных приборов, из которых теодолиты с визуальной системой пользуются большим спросом при выверке строительных конструкций. Выполненные исследование показали, что существующие способы выверки конструкций в вертикальной плоскости имеют ряд недостатков. Так, к примеру, при монтаже металлических резервуаров на объекте «Новая металлургия» фирма ТОО «Усть-Каменогорская монтажная фирма «Имсталькон» производила выверку в вертикальной плоскости, при этом необходимо было использовать специальные марки и производить дополнительные расчеты. Для выверки скользящей опалубки, колонн и стеновых панелей используют несколько теодолитов, в том числе с вертикальной разверсткой.

Традиционно при монтаже колонн используют два теодолита. Перед монтажом колонн проверяют их размеры и наносят риски, облегчающие установку колонны в стакан фундамента или на оголовки подколонников. Колонну, установленную в стакан фундамента, центрируют до совпадения рисок с рисками на верхней плоскости фундамента. Предлагается способ выверки конструкций в вертикальной плоскости, который позволяет использовать только один лазерный теодолит с двумя визирами.

Прибор состоит из двух визиров, которые проецируют на рабочей поверхности одно световое пятно в вертикальной проектной плоскости. В данной статье приводятся результаты исследования способов выверки

конструкций при монтаже в вертикальной плоскости. Выполнен анализ и исследование существующих способов выверки конструкций в вертикальной плоскости, используемых в условиях предприятий занимающихся монтажом металлических резервуаров. Результаты исследования показали, что применяемые способы выверки в вертикальной плоскости имеют ряд недостатков, в частности после выверки требуется производить дополнительные расчеты. А также для выверки скользящей опалубки, колонн и стеновых панелей используют несколько теодолитов, в том числе с вертикальной разверсткой.

Также исследованы лазерные приборы и теодолиты с визуальной системой. Однако все рассмотренные способы с применением этих приборов достаточно трудоемки и при этом применяется значительное количество инструментов и оборудования. Предлагаются устройства для контроля формы и расположения плоских поверхностей, использующих принцип подобия треугольников, позволяющий получить прямую линию пересечения лазеров в пространстве параллельную отвесу. Разработанные устройства дешевы, просты в применении и изготовлении. При использовании предлагаемой методики отпадает необходимость задействования нескольких рабочих и дорогостоящих устройств. Разработанные устройства позволяют значительно сократить время выверки строительных конструкций в вертикальной и горизонтальной плоскостях.

По результатам исследования были сделаны следующие выводы:

– существующие способы выверки конструкций в вертикальной плоскости имеют ряд недостатков: необходимость задействования нескольких рабочих и не менее двух теодолитов, либо использование дорогостоящих сканеров, сложность и трудозатратность работ.

– разработано устройство для контроля формы и расположения плоских поверхностей, использующее принцип подобия треугольников, позволяющее получить прямую линию пересечения лазеров в пространстве параллельную отвесу.

– разработано кулачковое устройство для контроля формы и расположения плоских поверхностей, у которого профиль фасонного кулачка выполнен с условием $\cos \beta = \cos \alpha * R/L$, где α – угол поворота первого лазера, β – угол поворота второго лазера, R – расстояние между лазерами, L – расстояние от первого лазера до контролируемой поверхности, что позволяет получить прямую линию пересечения лазеров в пространстве, перпендикулярную подставке.

– разработанные устройства дешевы, просты в применении и изготовлении;

– при использовании данной методики отпадает необходимость задействования нескольких рабочих и дорогостоящих устройств;

– разработанные устройства позволяют значительно сократить время выверки строительных конструкций в вертикальной и горизонтальной плоскостях.

Ключевые слова: выверка конструкции, лазерный теодолит, лазерные визиры, световое пятно, лазерный луч.

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STUDY OF EDGE PROTECTING ANCHORS INFLUENCE ON SOIL HEAVING OF THE MINE WORKING

Abstract. To achieve the objective with the claimed technical result, a method of fastening mine workings of predominantly rectangular cross-sectional shape with anchor bolts was used, while the applied task of reducing the heaving of soil rocks is to increase the efficiency of mine workings by ensuring that the mine workings. Ensuring the possibility of reliable and of good quality fortified rocks along the contour of making within the boundaries of the zone of possible collapse of rocks. The length of the soil anchors did not significantly affect the condition of the soil rocks. Consequently, that on the deformations and stresses both in the lateral and in the soils are not soil, but lateral anchors. The use of these technological developments will reduce the cost of conducting and maintaining workings by 7–10% with soil anchors (reducing maintenance costs by 7–10%) and will provide an economic effect of 10–15 thousand tenge per running meter of output.

Key words: mine working, anchoring technology, soil heaving, roof bolting, side anchors, rock pressure, rock resistance.

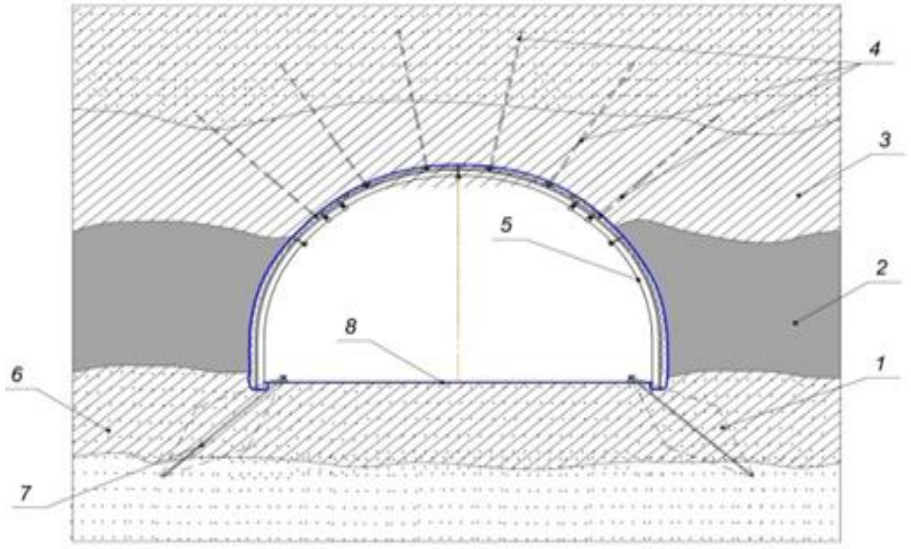
Results of the carried out tests of the effect of soil anchors mounting on the mine working soil rocks heaving. To carry out experimental verification of the roof bolting technology aimed at reducing soil heaving, metal anchors were mounted in the soil along the sides of the workings in sections of 10 m long and gauging stations to control deformations every 5 meters in the experimental section and in adjacent sections of 50 m long each side every 10 m. Surveying services of the mines monitor manifestation of deformations (leveling the soil) twice a week, and when deformations are shown once a week with presenting data of the rock pressure manifestations dynamics.

At the Kazakhstanskaya mine of the Karaganda coal basin, work was done to mount metal anchors into the soil of the gas-drainage drift $322д_7$-з on PK21-22 (section of the UPR-3 advance works). However, the presented working has not yet fallen into the zone of the stoping effect, therefore, intensive heaving of the soil was not observed.

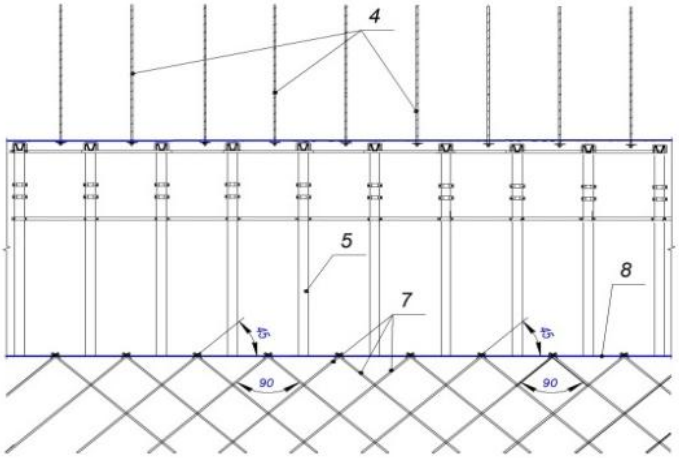
Experimental work was carried out at the Saranskaya mine to strengthen soil rocks in the conveyor drift $52к_7$-з of PK1-PK6 with seven double anchors 1.6 m long in 42 mm diameter holes for six AMK-350 ampoules each. Observations have shown that in this working and in the experimental section heaving of rocks is absent.

Anchors were mounted in the conveyor roadway $22к_{12}$-с in section PK55+3 m along PK56+3 m at the Abayskaya mine to carry out a pilot test aimed at reducing heaving of the soil rocks.

At the Kostenko mine there were mounted soil anchors (figure 1) in the development face of the 4th east conveyor roadway $к_4$ of PK42-PK62, but only at one side of the working. The anchors were mounted at the angle of 45° every 1.0 m, which led to decreasing the convergence of the soil and working sides by 0.6–0.7 m. In order to obtain a greater effect, it is recommended to mount soil anchors at both sides of the working alongside with anchoring the working sides.



a



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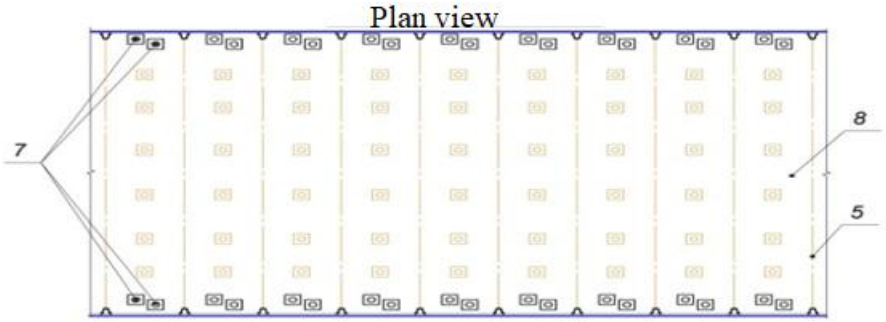


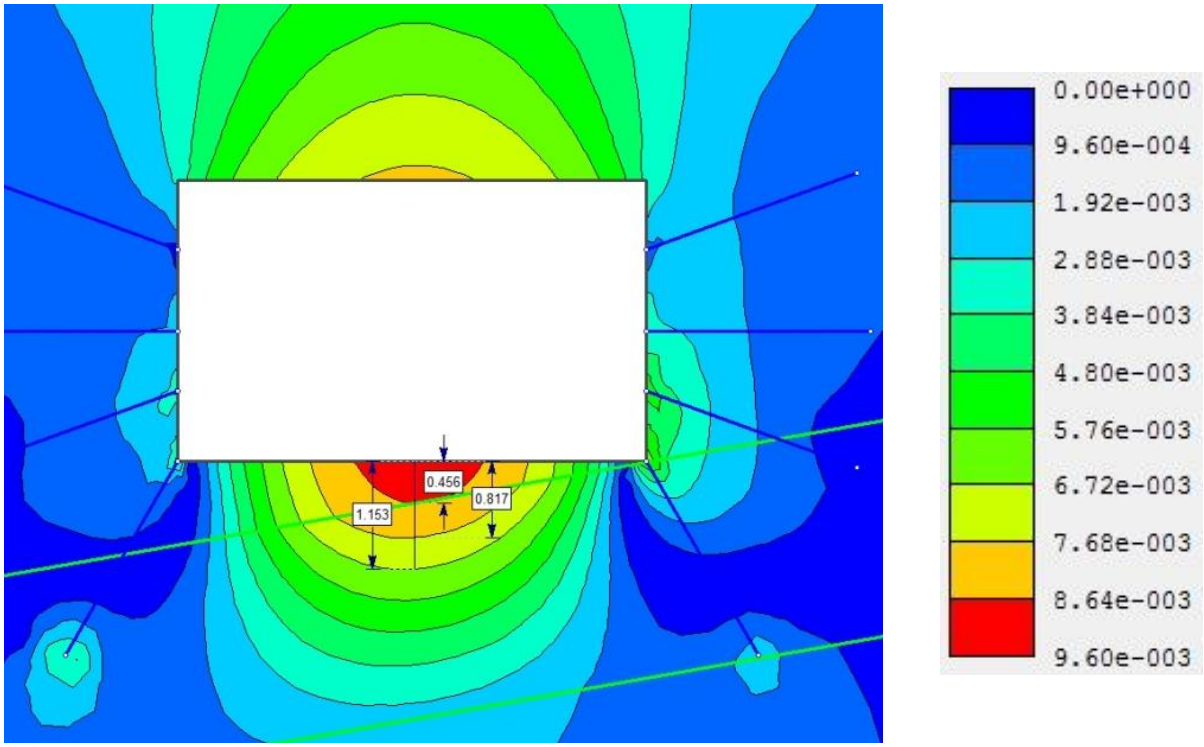
c

a – transverse section (1 – zone of strengthening impact; 2 – coal seam; 3 – rocks of the immediate roof; 4 – roof anchors; 5 – metal-arch support; 6 – soil rocks; 7 – soil anchors; 8 – working soil); b – longitudinal section of the working with soil anchors; c – plan view: scheme of mounting soil anchors relative to the arches of the metal-arch support

Figure 1 – Technological scheme of mounting soil anchors at the Kostenko mine

Analytical modeling of the soil anchors location scheme according to the results of experimental mine observations. Calculations were made using the Flac 2 program [1-6] for various mining conditions of the coal seams development of the Karaganda basin.

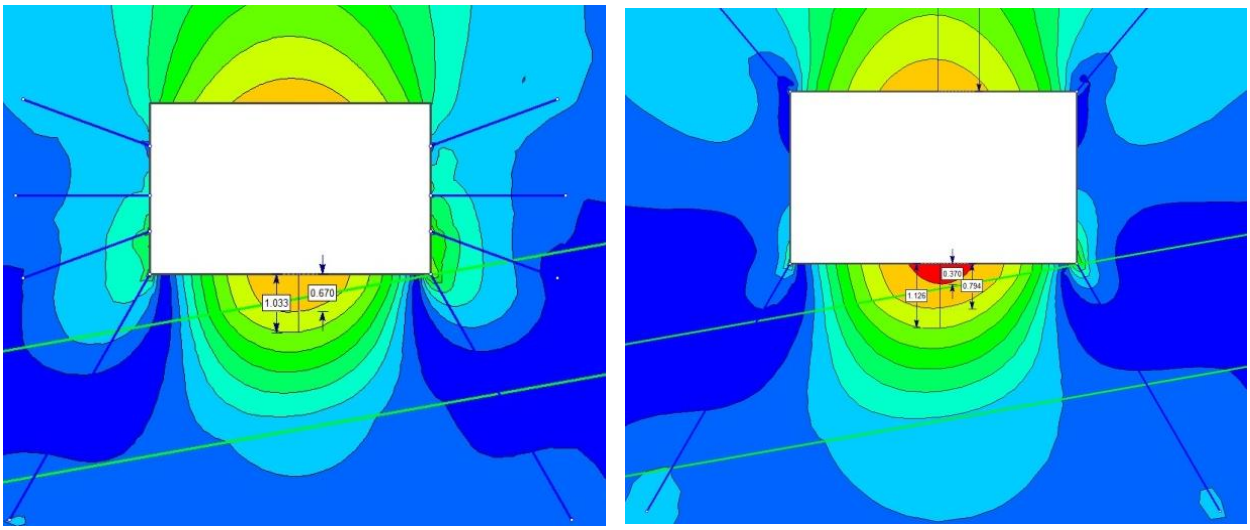
Rectangular and arched sections of the workings were used with soil and corner roofing anchors of various lengths, which allowed analyzing the technological schemes to reduce of mine workings soil rocks heaving (figures 2-5).



A b

a - deformation pattern; b – displacement scale;
red color - the zone of destruction; orange - cracking;
light green - lamination (all three upper zones are zones of unloading);
4, 5 zones of cracking; 6 - zone of microdeformations

Figure 2 - Rectangular cross section of the working with inclined anchors into the soil 2.4 m long



a b

a – into the soil 5.0 m long; b – into the soil and into the roof 5.0 m long

Figure 3 – Rectangular cross section of the working with inclined anchors

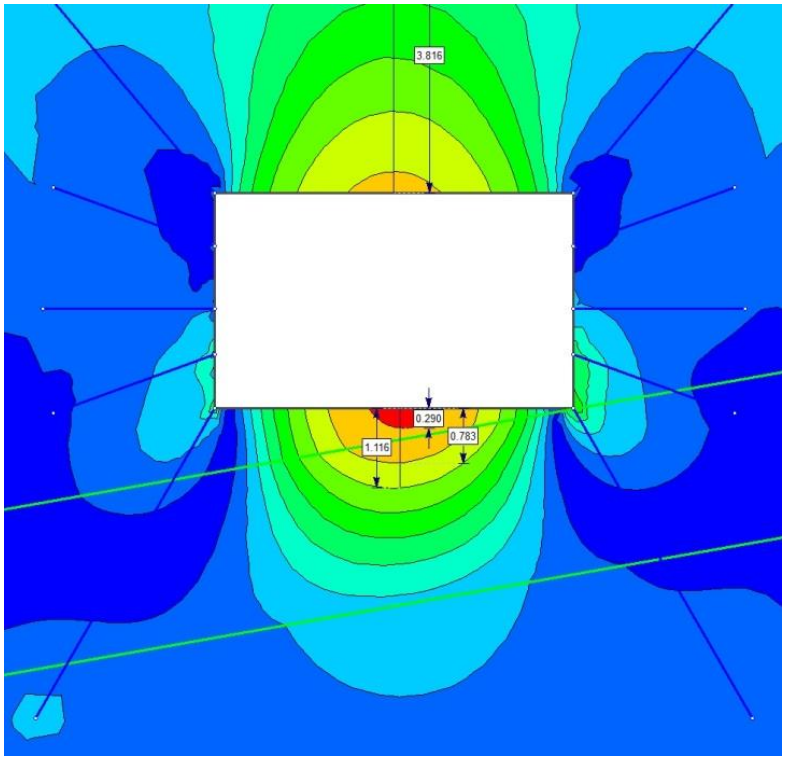
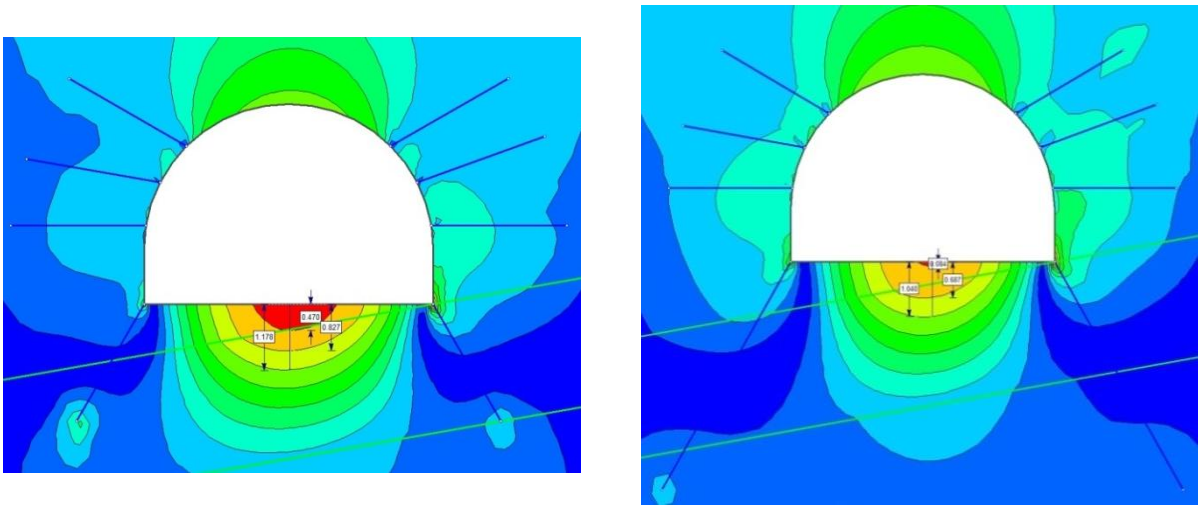


Figure 4 – Rectangular cross section of the working with inclined anchors into the soil and into the roof 5,0 m long alongside with the side anchors



a b

a – 2.4 m long; b – 5.0 m long

Figure 5 – Metal-arch support of the working with inclined anchors into the soil

The analysis of the plots of deformation patterns allows concluding that it is advisable to use a rectangular cross-section of the workings with inclined anchors into the soil 5.0 m long, which ensures the absence of destructive deformations, decreasing degradation (by 20–22 %) and delamination (by 12–14 %) of the soil rocks.

When using a protecting soil anchor system (figure 6), deformations can be reduced by 40–50 % and provide little maintenance of workings according to the stability conditions of the soil rocks of the workings.

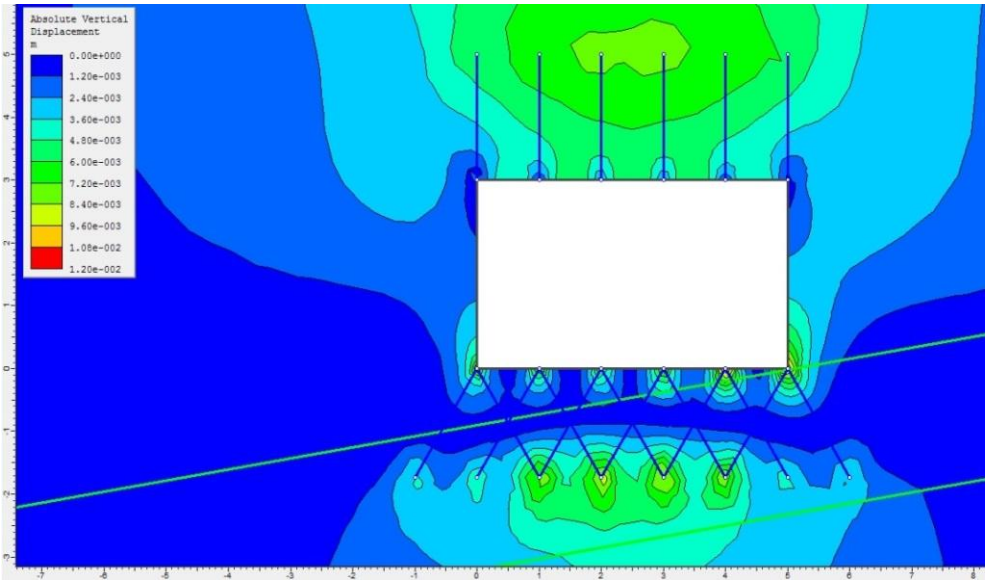
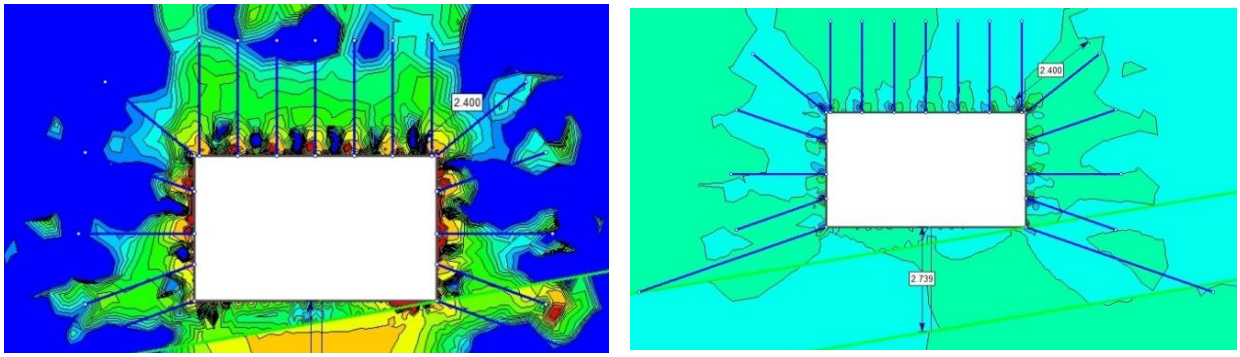


Figure 6 – Technology of soil rock strengthening with a protecting soil system of the roof bolting

Considering that the greatest effect from the strengthening effect was obtained with a rectangular cross section of the mine working, analytical modeling was carried out taking into account presence of the roof bolting and the location of the side anchors according to the combined scheme with their mounting in such a way that the upper side anchor (deep-earth, as a rule) was placed in the zone of the reference pressure beyond the working contour in the enclosing rocks in order to shift the peak of the rock pressure deeper into the massif beyond the zone of propagation the deformations around the working effect zone, while the lower deep-earth anchor was positioned to serve as the protecting zone for spreading and squeezing the wall rocks into the working soil (figure 7) [7-13].



a b

Figure 7 – Development of deformations (a) and tangential stresses (b) in the soil rocks with upper side anchors 2.4 m long and with the soil anchors 5.,0 m long

Applied developments for implementation in production. The applied task of reducing the heaving of soil rocks is to increase the efficiency of supporting mine workings by providing the possibility of reliable and high-quality supporting due to the formation of a zone of strengthened rocks along the contour of the mine working within the boundaries of the zone of possible rock collapse.

Figure 8 shows the general view of the technological scheme of the proposed method, figure 9 shows the modeling of the stress-strain state at the location of the working in a coal seam with different length of soil anchors from 5.0 to 2.4 m.

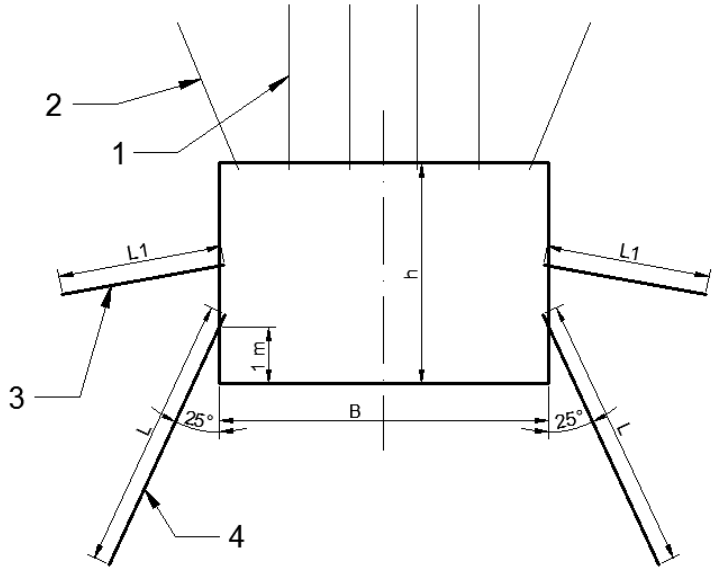


Figure 8 – General view of the technological scheme of the proposed method

To achieve the task with the claimed technical result, when using the method of supporting mine workings of a predominantly rectangular cross-sectional shape with anchor roof bolting, including drilling holes in the roof of the mine in the process of mounting anchors in them, as well as anchors in the side of the mine, the roof of the working in the process of its drilling and mounting anchors 1 in them, simultaneously with drilling inclined holes 2 in the roof of the working there are drilled inclined holes in the sides of the working 3. Next, for strengthening side rocks, in the lower part of the working and strengthening the working soil, at the height of one meter from the working soil there is mounted composite anchor 4 at an angle of 20-25^0 from the working side.

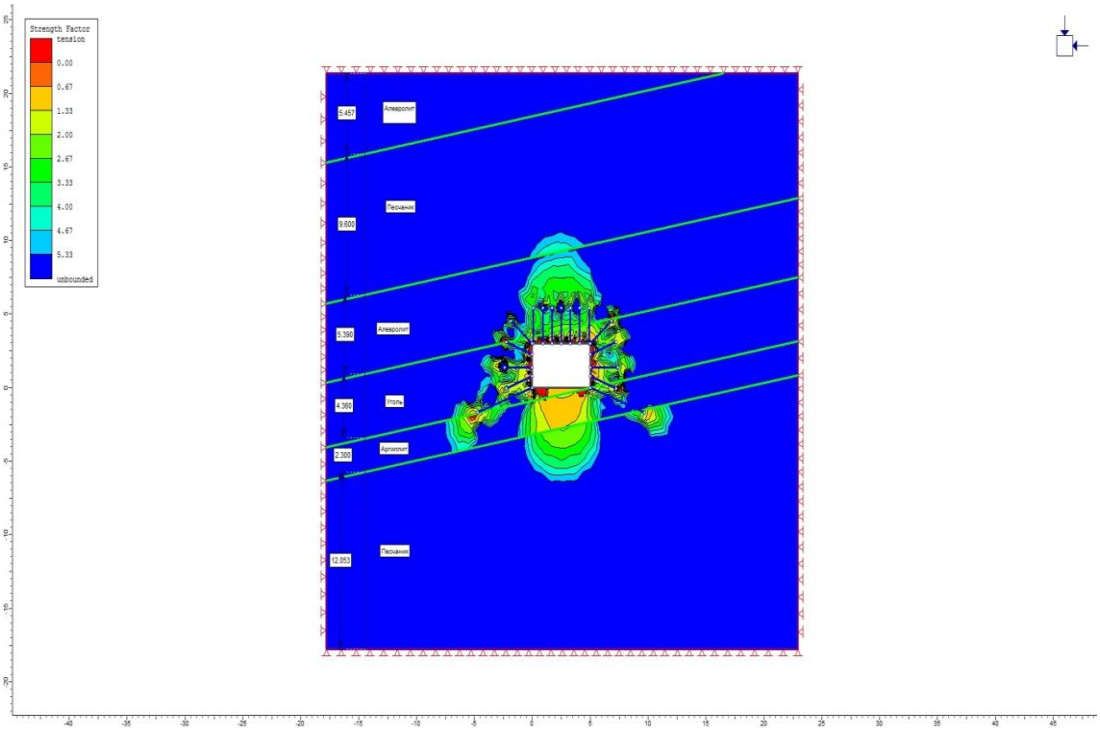


Figure 9 – Simulating the stress-strain state with different working location in the coal seam and with different length of the soil anchors

The technology of the roof bolting provides for its mounting in the direction of the soil along the sides of the mine workings, by drilling inclined holes for composite anchors at the angle of 20-25° to the vertical. The length of the anchors mounted in the side of the working is recommended to be determined by the empirical formula:

$$L=k_f * Bb * H_п /N_п, m,$$

where k_f is an empirical coefficient depending on the shape of the mine working cross section; B_b – the width of mine workings in rough, m; $H_п$ - the probable amount of soil rocks heaving, m; $N_п$ - soil rock compressive strength, MPa.

The height of the hole on the side walls of the working from its soil is 1/3 of the height of the working in the light (h).

There is provided the combination of functions of the mounted side anchors for supporting the sides and preventing the working soil rocks heaving.

The stress-strain state was simulated using the Flac 2 program with the location of the working in the coal seam with different length of soil anchors from 5.0 to 2.4 m (see figure 9) and the presence of side anchors. The length of the soil anchors did not significantly affect the condition of the soil rocks. It should be concluded that deformations and stresses both in the side rocks and in the soil rocks are not affected by the soil but by side anchors.

The technical result which achievement provides a solution to the problem, is expressed in the technology of supporting the working sides and reducing its soil rock heaving.

According to the given information Karaganda basin is divided into 4 zones. Geological and geophysical data were analyzed to perform basin modeling of Karaganda coal basin. In this regard, the basic material was selected, including geological structure [14].

Results. Using the technological developments will reduce the cost of driving and supporting mine workings by 7–10 % with soil anchors (reducing maintenance costs by 7–10 %) and will provide the economic effect of 10–15 thousand tenges per running meter of the working.

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ҚАЗБА ТОПЫРАҚ ЖЫНЫСТАРЫНЫҢ КӨТЕРІЛУІНЕ ШЕКТЕМЕ СЫРТЫНДАҒЫ ҚОРШАУ АНКЕРЛЕРІНІҢ ӘСЕРІН ЗЕРТТЕУ

Аннотация. Тау жыныстарының ісінуін азайтуға бағытталған анкерлі бекіту технологиясына эксперименталды тексеру жүргізу үшін тау жынысына ұзындығы 10 м учаскеде және эксперименталды учаскеде 5 м сайын және әр жағынан ұзындығы 50 м іргелес учаскеде деформацияны бақылау үшін өлшеу станцияларында металл анкерлер орнату бойынша жұмыс жүргізілді.

Қарағанды көмір бассейнінің «Қазақстан» шахтасында ПК21-22 (УПР-3 ұңғымалық жұмыстар учаскесі) 322д7-3 газдренажды штрек жынысында металл анкерлерді орнату бойынша жұмыстар орындалды. Алайда ұсынылған қазба әлі күнге дейін тазарту жұмыстарының әсер ету аймағына түскен жоқ, сондықтан жыныстардың қарқынды ісінуі байқалмады.

«Саран» шахтасында 52к7-3 ПК1-ПК6 конвейерлік штректе әрқайсысы алты АМК-350 ампуласына диаметрі 42 мм теспеге ұзындығы 1,6 м жеті қосарланған анкер бойынша тау жыныстарын нығайту бойынша эксперименталды жұмыстар қолға алынды. Бақылау осы қазбада және эксперименттік учаскеде жыныстардың ісінбегендігін көрсетті.

«Абай» шахтасында тау жыныстарының шоғырлануын төмендетуге бағытталған эксперименталды тексеру жүргізу үшін ПК56+3 м пк55+3 м учаскесінде 22к12-с конвейерлік штректе анкер орнатылған.

Костенк атындағы шахтада ПК42-ПК62 арналған к4 4-шы шығыс конвейерлік штректердің дайындық кенжарына жер қыртысының жамылғысында қазбаның бір жағын ғана қамтитын анкерлер орнатылды. Анкер 1,0 м кейін 45^o бұрышпен қойылып, топырақ конвергенциясы мен қазба бүйірлері 0,6-0,7 м-ге азайды.

Қарағанды бассейнінің көмір қабаттарын әзірлеудің түрлі тау-кен техникалық шарттарына Flac 2 бағдарламасын пайдаланып, есептеулер жүргізілді. Тау-кен қазбалары тау жыныстарының шоғырлануын азайтудың технологиялық сызбасын талдауға мүмкіндік беретін, түрлі ұзындықтағы көмкерілген және бұрыштық шатыр анкерлері негізінде қазбалардың тік бұрышты және аралы қимасы қолданылды.

Тау жыныстарының ісінуін азайту жөніндегі қолданбалы міндет – жыныстардың опырылуы ықтимал аймақ шекара шегінде қазба контуры бойынша бекітілген жыныстар аймағының пайда болуына негізделген қазбаларды сенімді және сапалы бекіту мүмкіндігін қамтамасыз ету есебінен тау-кен қазбаларын бекіту тиімділігін арттыру.

Анкерлік бекітпемен жұмыс істеу технологиясы тау-кен қазба ернеулерінің бойында жыныс бағытында орнатуды, тік бұрыштағы 20-25^{o} құрамдас анкерлер астына көлбеу теспелерді бұрғылауды көздейді. Қазба жағдайына орнатылатын анкерлердің ұзындығын эмпирикалық формула бойынша анықтау жолдары ұсынылады:

$$L=k_f * Bb * H_п /N_п, м$$

мұнда kf - тау-кен қазбасы көлденең қимасының нысанына байланысты эмпирикалық коэффициент; B_b - тау-кен қазбасының ені, м; $H_п$ - тау жыныстары ісінуінің ықтимал шамасы, м; $N_п$ - қысуға топырақ жыныстарының беріктігі, МПа.

Қазбаның бүйір қабырғаларында теспелердің орналасу биіктігі оның жыныстарынан қазбаның жарықта биіктігінің 1/3 бөлігін құрайды (h).

Бүйірлерді бекіту және қазба топырағы жыныстарының шоғырлануын болдырмау бойынша орнатылатын бүйірлік анкерлер функцияларын біріктіру қамтамасыз етіледі.

Көмір қабатындағы қазбаның 5,0-ден 2,4 м-ге дейін әртүрлі ұзындықта орналасқанда және бүйір анкерлер болған кезде Flac 2 бағдарламасын пайдалана отырып, кернеулі-деформацияланған жай-күйі модельдельді. Тау жыныстары күйіне орнатылған анкерлердің ұзындығы айтарлықтай әсер ерпеді. Жыныстарында да, бүйір жыныстарына да табан жыныстарына да бүйір кернеу негізіндегі деформациялар әсер етеді.

Алға қойған міндетті шешуді қамтамасыз ететін техникалық нәтиже қазба ернеулерін бекіту технологиясында және топырақ жыныстарының шоғырлануын азайту барысында көрінеді.

Технологиялық әзірлемелерді қолдану қазбаларды жүргізуге және ұстап тұруға арналған шығындарды 7-10%-ға азайтуға (ұстап тұруға арналған шығындарды 7-10%-ға қысқарту) және жүргізіліп жатқан әзірлеменің қума метріне 10-15 мың теңге экономикалық ықпал етуге мүмкіндік береді.

Түйін сөздер: кен өндіру, анкерлеу технологиясы, топырақты тастау, шатыр болттары, бүйірлік анкерлер, тау жыныстары қысымы, тау жыныстарының кедергісі.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ЗАКОНТУРНЫХ ОГРАЖДАЮЩИХ АНКЕРОВ НА ПОДУТИЕ ПОРОД ПОЧВЫ ВЫРАБОТКИ

Аннотация. Для проведения экспериментальной проверки технологии анкерного крепления, направленной на снижение пучения пород почвы, выполнены работы по установке в почву металлических анкеров вдоль бортов выработок на участках длиной 10 м и замерных станций для контроля деформаций через 5 м на экспериментальном участке и на прилегающих участках длиной 50 м с каждой стороны через 10 м. Маркшейдерские службы шахт производят контроль за проявлением деформаций (нивелировка почвы) два раза в неделю, а при проявлении деформаций один раз в неделю с представлением данных по динамике проявлений горного давления.

На шахте «Казахстанская» Карагандинского угольного бассейна выполнены работы по установке металлических анкеров в почву газодренажного штрека 322д$_7$-з на ПК21-22 (участок проходческих работ УПР-3). Однако представленная выработка до сих пор не попала в зону влияния очистных работ, поэтому интенсивного пучения почвы не наблюдалось.

На шахте «Саранская» проведены экспериментальные работы по упрочнению пород почвы в конвейерном штреке 52к$_7$-з ПК1-ПК6 по семь спаренных анкеров длиной 1,6 м в шпуры диаметром 42 мм на шесть

ампул АМК-350 в каждый. Наблюдения показали, что в данной выработке и на экспериментальном участке пучение пород отсутствует.

На шахте «Абайская» для проведения экспериментальной проверки, направленной на снижение пучения пород почвы установлены анкера на конвейерном штреке $22к_{12}$-с на участке ПК55+3 м по ПК56+3 м.

На шахте им. Костенко произведена установка напочвенных анкеров в подготовительном забое 4-го восточного конвейерного штрека $к_4$ на ПК42-ПК62, но только с одной стороны выработки. Анкера установлены под углом 45^o через 1,0 м, что привело к уменьшению конвергенции почвы и боков выработки на 0,6–0,7м. Рекомендовано с целью получения большего эффекта производить установку напочвенных анкеров с обеих сторон выработки совместно с анкерированием боков выработки.

Произведены расчеты с использованием программы Flac 2 для различных горнотехнических условий разработки угольных пластов Карагандинского бассейна. Применены прямоугольное и арочное сечение выработок с припочвенными и угловыми кровельными анкерами различной длины, позволившими проанализировать технологические схемы снижения пучения пород почвы горных выработок.

Прикладная задача по снижению пучения пород почвы заключается в повышении эффективности крепления горных выработок за счет обеспечения возможности надежного и качественного закрепления выработок, обусловленного образованием зоны укрепленных пород по контуру выработки в пределах границы зоны возможного обрушения пород.

Технология работ анкерной крепью предусматривает ее установку в направлении почвы вдоль бортов горной выработки, забуриванием наклонных шпуров под составные анкеры под углом $20\text{-}25^o$ к вертикали. Длину анкеров, устанавливаемых в борта выработки, рекомендуется определять по эмпирической формуле:

$$L=k_f * Bb * H_п /N_п, м$$

где k_f –эмпирический коэффициент, зависящий от формы поперечного сечения горной выработки; B_b – ширина горной выработки вчерне, м; $H_п$ – вероятная величина пучения пород почвы, м; $N_п$ – прочность пород почвы на сжатие, МПа.

Высота расположения шпуров на боковых стенках выработки от ее почвы составляет 1/3 часть высоты выработки в свету (h).

Обеспечивается совмещение функций устанавливаемых боковых анкеров по креплению боков и предотвращению пучения пород почвы выработки.

Произведено моделирование напряженно-деформированного состояния с использованием программы Flac 2 при расположении выработки в угольном пласте при различной длине припочвенных анкеров от 5,0 до 2,4 м и наличии боковых анкеров. Существенного влияния длина припочвенных анкеров на состояние пород почвы не оказало. Следует сделать вывод о том, что на деформации и напряжения в как боковых, так и в породах почвы оказывают не припочвенные, а боковые анкера.

Технический результат, достижение которого обеспечивает решение поставленной задачи, выражается в технологии крепления бортов выработки и снижении пучения пород ее почвы.

Применение технологических разработок позволит снизить затраты на проведение и поддержание выработок на 7 – 10% с припочвенными анкерами (сокращение затрат на поддержание на 7 – 10%) и позволит получить экономический эффект 10 - 15 тыс. тенге на погонный метр проводимой выработки.

Ключевые слова: горная выработка, технология анкерного крепления, подутие пород почвы, анкерная крепь, боковые анкера, горное давление, устойчивость пород.

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INFLUENCE OF SYSTEM ERRORS IN METEOROLOGICAL SUPPORT ON FLIGHTS SAFETY

Abstract. There are many different systems of interaction in practical aviation activities. In particular, in a system consisting of an operator and a machine there are quite often failures due to errors of designers, operators, manufacturers, maintenance, etc. Errors are usually unintentional: a person performs erroneous actions, considering them as correct or most suitable due to insufficient information, neglect of rules and standards and even due to lack of such.

The specialists of the American corporation Boeing calculated the share of aviation accidents related to incorrect decision-making. It turned out that of all aviation accidents, such incidents account for 75%.

Back in 1990, Professor Reason developed a model describing the causation of an air accident. One of the main elements of this manufacturing system consists of decision-makers, another key element is decision-executors. For top-level decisions and line management actions to be implemented into effective and productive activities carried out directly by pilots and instructors, certain preconditions must be met.

The Rison model explains how people contribute to the disruption of complex, interacting and well-protected systems (such as aviation), resulting in an aviation incident.

This model reveals to us causal relationships that do not directly lead to an accident, but shows that, although there are lots of protection levels between risks and accidents, there are drawbacks in each layer of protection that, in the case of systemic “flaring-out”, can trigger an accident [3].

The drawbacks of one level of protection do not allow realizing the risk, since there are other protections to prevent a single point of failure, but with systemic accumulation of risks, catastrophic consequences are inevitable. This effect is sometimes called the "aggregate action effect." In our work, we tried to investigate the system of unprotected risks that led to disaster.

Key words: Incident, analysis, error, violation, aircraft flight, safety.

Introduction. In order to assess the impact of systemic errors on flight safety, we reviewed the aviation incident and drew some conclusions based on the re-establishment of the situation and the analysis of meteorological conditions during the period under review.

We have studied and analyzed the following materials:

- synoptic maps of weather for 12:00 on 08/09/17;
- ring and micro-ring weather maps for 12:00, 15:00, 18:00, 21:00 08/09/17, 00:00, 03:00 08/10/17;
- maps of absolute baric topography AT-850hPa, AT-700hPa, AT-500hPa for 09. 08 17 deadline 12:00 UTC International Coordinated Time (hereinafter referred to as UTC);
- map of relative baric topography OT-500/1000hPa for 12:00 09.08.17;
- pictures of overcast with the METEOSAT-8 artificial satellite for 00:00, 02:00, 03:00;
- instructions “Aerodrome rules”;
- TIR flight sectors weather forecasts from 00:00 till 06:00 and from 03:00 till 09:00;
- the actual alternate aerodrome weather for the period from 2.30-11.30.
- information about the synoptic situation in the area

- explanatory flight coordinator
- video of the incident

The actual weather data of the airfield were not analyzed, as no observations were recorded.

A DAVIS wireless weather station was installed at the airfield to carry out instrumental meteorological measurements.

Meteorological observations at the airfield were not regularly carried out, the results of observations were not recorded in the weather surveillance log in violation of the Aerodrome rules.

The wind speed and direction sensor of the automatic meteorological complex Davis is installed at a height of 10 meters near the Control Tower (60 cm), above the roof ridge within 60 cm, 560 meters from the end of runway 25 and at a distance of 345 meters from the nearest tree. In fact, the sensor measured the distorted wind flow.

Weather observations were made by the trainee co-coordinator who did not have permission to observe the weather.

The aerodrome is mountainous, the absolute altitude of the aerodrome is 890 meters above sea level. Spurs of mountains are located in the South of the airfield in almost latitudinal direction from West to East. The nearest mountain with a height of 1000 meters is located in the South, 2.8 kilometers from the runway, the mountain with a height of 1940 meters is located in the Southwest 10 kilometers from the runway.

It is known that mountain airfields are located in the zone of influence of local mountain-valley winds (at night the wind comes from the mountains, and during the day into the mountains). However, on the day under consideration, the influence of mountain-valley circulation was not significant due to the presence of a low pressure field and a stationary front in the area of the airfield.

From the climatic characteristics of the airfield it follows that thunderstorm activity is observed from April to September, the maximum frequency of occurrence of thunderstorms occurs in June-July. Thunderstorms are mostly frontal in nature, in the summer near the airfield the south-west direction prevails (45%), in the middle of the day and in the afternoon there is an orographic turbulence.

Analysis of the synoptic situation in the airfield area:

3.00:00 local time.

According to the ring map, the weather was determined by a small-scale baric field of reduced pressure and the stationary tropical front influence with waves. There was observed low-cloudy weather, mild wind 2-3 m/s West and South-East direction, visibility more than 10 km. At the point of observation nearest to the airfield there was a clear sky, wind of the Eastern direction 2 m/s, visibility more than 10 km.

On the surface map for the same period, along the front, the 5-7 octants of cumulonimbus clouds with a lower boundary of 600-1000 m above ground level were noted by separate meteorological stations, visibility more than 10 km, West and South-West winds at a speed of 2-3 m/s. The direction and speed of the leading stream on the barometric topography map of AT500 hPa were 250-270 degrees 15-20 km / h.

05:00 local time.

Weather forecasts for flight areas with a period of 06:00 to 12:00 local time were prepared by the nearest meteorological body. These forecasts were familiarized with all instructor pilots under painting before the flight. The forecasts indicated the presence of a stationary front, turbulence in the 4000-m earth layer and isolated cumulonimbus clouds.

05:44 local time.

There is information from the aircraft board - at a distance of 190 km from Almaty in the sector 275-290 ° there are thunderstorm blips.

The AMC (aeronautical meteorological center) issued a warning on **SIGMET №1** routes from 06:00 to 10:00 in the FIR zone, *masked thunderstorms are predicted with an upper cloud cover up to FL380, with NorthEast displacement at a speed of 20 km / h, intensity – no sig.* These data were not received by the crew.

06:00 local time.

According to the micro-ring map, the wind was southerly 2 m / s, visibility more than 10 km, 6 octants cumulonimbus clouds by 1000-1500 m. That is, in three hours from 03.00 to 06.00 the amount of clouds increased to 6 octants and the ceiling decreased to 1000-1500m, which indicates the frontogenesis

and development of cumulonimbus clouds in the flight area. To the North of the flight area at a distance of about 70 km, a secondary cyclone center (mesocyclone) was formed with a minimum pressure in the center of 1001 hPa. The presence of a secondary mesocyclone center and cumulonimbus clouds fixed by weather stations in the TIR regions could affect the wind mode in the area of the aerodrome.

By the weather stations closest to the airfield the cumulonimbus clouds availability was noted, with a ceiling of 600-1000 m above ground level, visibility is more than 10 km, wind speed is 2-3 m / s, in places with a gain of up to 6-7 m / s SouthWest and Western direction.

07:54 local time.

On AFTN communication, the flight coordinator received a new forecast for TIR flight areas (sectors) from 09:00 to 015:00. In which there were intra-mass thunderstorms, rare cumulonimbus clouds with a ceiling of 1500 m, and an upper cloud cover up to 9,000 m.

09.50´55 local time.

An accident has occurred. The weather conditions indicated by the flight coordinator at the time of the accident from his words) were as follows: wind 260 degrees, speed 4-5 m / s, visibility 10 km, air temperature + 30 °, pressure QNH 1005 hPa. The presence and form of clouds were not indicated.

Based on the analysis of meteorological information, it was found that the meteorological situation in the flight areas of the TIR of Almaty in the period from 06.00 to 09.52 was complicated. During this period, a private cyclone formed, a stationary front was observed, the amount of cumulonimbus cloudiness increased, its lower boundary decreased, retardation layers were observed in the atmosphere, rain (maps) and a chatter (data from the alternate aerodrome) were observed in the area.

The most characteristic synoptic situations and conditions under which wind shear occurs include: the development of convective clouds, the passage of atmospheric fronts, the formation of delayed inversion and isothermal layers, all these factors took place during the period under review, except for that the relief features played a role, namely, proximity mountain range.

All this provoked the development of cumulonimbus clouds in the stationary front zone, which led to the appearance of wind shears, and a flurry arose at the surface of the earth.

Judging by the recording from the video in the aerodrome area, about 8 cumulonimbus cloud points were observed in accordance with figure 1, 2. In the upper left corner of the recording, clouds with a dark lower edge is recorded. When analyzing the weather using video materials, the height of the ceiling was determined using the Google Earth Pro program and photo materials from the scene. It was established that the height of the ceiling in the area of the aerodrome was supposedly about 600 m.

Figure 1 – Weather conditions in the area of the aerodrome during take-off

Figure 2 – Cumulonimbus cloud cover at the aerodrome after the accident

The direction of the wind, in accordance with the spread of burning traces, at the crash area was 200-230 ° in accordance with figure 3.

Figure 3 – Calculation of the direction of the wind from the traces of burning vegetation at the place of aircraft crash landing

The wind speed at the airport during the incident was determined by recording surveillance cameras using the Beaufort scale. At 9.46 local time, the wind force was 5.3 - 7.4 m / s, after a second it reached a force of 12.5 - 19.2 m / s.

Recording a video camera at this time captures the swaying of trees near the ground, a little later the swaying of aircraft in the parking lot and dust breakdowns, which confirms the presence of a flurry, which is shown in figures 4, 5 and 6.

Figure 4 – Deterioration of visibility, increased wind and dust disruptions at the aerodrome

Figure 5 – Deterioration of visibility, increased wind and dust disruptions at the aerodrome

Figure 6 – Smoke propagation and vibration of aircraft parked due to the effects of wind after an accident at an aerodrome

A flurry was limited in space and lasted for 2-3 minutes, and was recorded on the camcorder for about two minutes.

Figure 7 – Weather conditions at the aerodrome after an accident

It was found that the PIC received a forecast for the sectors in printed form, signed by the coordinator and intern of the aerodrome before the start of flights, and within 3 hours performed flights with cadets without requesting the actual weather at the aerodrome from the TIR dispatcher.

In conditions of complex orography and in the presence of a stationary front, forced air lift increased the vertical component and made an additional contribution to thermal convection and intensified the cloud-forming process in the morning. The presence of a stationary front, cumulonimbus clouds and retaining layers in the atmosphere, as well as the terrain, contributed to the formation of wind shears in a layer of 50-100 m and a flurry near the ground surface, which affected the flight of the aircraft.

During the last flight, the aircraft should take a right turn after takeoff, but instead, the aircraft turned left and the aircraft began to lose altitude with the air currents accompanying the development of convective cloud cover.

The crew tried to correct the situation, but the descending air currents did not allow this and the aircraft crashed. The direction of the air flow confirms the direction of the smoke from the explosion of the aircraft, which is shown in photo 6.

In that way, several system errors led to the aviation accident:

- Lack of proper organization of flight support;
- No qualified weather observation;
- No consideration of the influence of orography on the development of convective clouds;
- Absence of weather analysis and forecasts by the aircraft commander and unjustified decision-making for departure.

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МЕТЕОРОЛОГИЯЛЫҚ ҚАМТАМАСЫЗ ЕТУДЕГІ ЖҮЙЕЛІК ҚАТЕЛІКТЕРДІҢ ҰШУ ҚАУІПСІЗДІГІНЕ ӘСЕРІ

Аннотация. Тәжірибелік авиация қызметінде түрлі өзара әрекет ету жүйесі бар. Атап айтқанда, оператор мен машинадан тұратын жүйеде дизайнер, оператор, өндірушінің, техникалық қызмет көрсетудің және т.б. қателіктеріне байланысты сәтсіздік жиі кездеседі. Қателіктер, әдетте, байқаусызда орын алады, мысалы, адам қате әрекеттерді орындайды, ақпараттың жеткіліксіздігі, ережелер мен стандарттардың ескерілмеуі, тіпті оның жоқтығына байланысты дұрыс немесе ең қолайлы деп бағалайды. Азаматтық авиацияға авиация қызметкерінің топтық қызметі тән. Кең мағынада алғанда, топ дегеніміз – жалпы қажеттіліктерді қанағаттандыру және ортақ мақсаттарға жету үшін адамдардың бірлестігі [1]. Ұшу және ұшу экипаждары, тасымалдау

қызметін немесе әуе қозғалысының диспетчерлерін ауыстыру, сондай-ақ техникалық (өндірістік) команда – бұлардың барлығы құрамы мен қатынастары белгіленген ережелер мен келісімдермен анықталатын типтік формальды шағын мүшелік топтар. Жауапты шешім қабылдаған кезде оның жеке немесе топ құрамында болғаны, сондай-ақ қандай факторлардың әсерінен және осы шешімнің негізінде қабылданғаны маңызды.

Американдық Boeing корпорациясы мамандарының ойынша, авиациялық оқиғалар дұрыс шешімді қабылдамағанда орын алады деп санайды. Осындай авиациялық оқиғалар барлық оқиғалардың 75%-ын құрайды екен. Бұдан басқа, олардың 58%-ы әуе кемесі экипажының әуе немесе жер бетіндегі жағдайды дұрыс бағаламауы тиіс. Ұшуларды дайындау және жүргізу жағдайында ақпарат алмасу – ұшқыштар мен әуе қозғалысына қызмет көрсету органдарымен хабар алмасуды жүргізетін және оларды нақты мәнмәтінде немесе жағдайда, ұшуды қауіпсіз тиімді және үнемді жүргізу үшін түсіндіретін динамикалық және қайтымсыз үдеріс, бұл ұшқышқа ұшуға қандай да бір шешім қабылдау үшін негіз бен ұшуды жоспарлау мүмкіндігін береді.

1990 жылы профессор Ризон авиациялық оқиғаның себеп-салдарын сипаттайтын модельді әзірледі. Профессор Ризон авиациялық саланы күрделі өндірістік жүйе ретінде қарастырады. Бұл жүйенің негізгі элементтерінің бірі шешім қабылдайтын тұлғалардан тұрады, басқа негізгі элемент жоғары эшелонның шешімі мен желілік басшылықтың іс-әрекеттері тікелей пилоттар мен нұсқаушылар жүзеге асыратын тиімді және өнімді қызметке жүзеге асыру үшін белгілі бір алдын ала шарттар орындалуы тиіс шешімді орындайтын адамдар.

Ризонның моделі адамдар күрделі, өзара қарым-қатынас жасайтын және жақсы қорғалған жүйелердің (авиация сияқты) жұмыс істеу қабілетінің бұзылуына қалай ықпал ететінін түсіндіреді, соның нәтижесінде авиациялық оқиға орын алады.

Бұл модель апатқа тікелей әкелмейтін себептік қатынастарды ашады, бірақ қауіп пен жазатайым оқиғалар арасындағы қорғаныс деңгейі көп болғанымен, қорғаудың әр қабатында кемшіліктер бар, олар жүйелік «теңестіру» жағдайында авария тудыруы мүмкін [3].

Аталған модель қауіп-қатерді талдау және басқару кезінде қолданылады және ұшуды жоспарлау, ұйымдастыру және өткізу барысында, сонымен қатар авиациялық қауіпсіздік, инженерлік қамтамасыз ету және т.б. ескерілуі керек. Кез келген салада қолданылатын болса, бірдей нәтиже береді: көптеген жүйелік емес бұзушылықтар қауіп-қатердің жинақталуымен оқыс оқиғаларға және төтенше жағдайларға әкеледі. Себеп жүйелерді бір-біріне қыстырылған бірнеше швейцар ірімшігімен салыстырады, мұнда қауіптің шындыққа айналу қаупі түрлі деңгейлер мен қорғаныс түрлері арқылы төмендетіледі, олар бір-бірінің үстіне «қабатталады», бірақ егер «тесіктер» сәйкес келсе, олар оқыс оқиғаларға әкеледі. Қорғанудың бір деңгейінің кемшіліктері қауіп-қатерді іске асыруға мүмкіндік бермейді, өйткені бас тартудың бірыңғай нүктесін болдырмау үшін басқа да қорғаныстар бар, бірақ қауіп-қатер жүйелі түрде жою кезінде апатты салдары сөзсіз болады. Бұл әсер кейде «жиынтық әсер» деп аталады. Жұмысымызда біз апатқа әкеп соқтырған қорғалмаған қауіп-қатер жүйесін зерттеуге тырыстық.

Түйін сөздер: апат, талдау, қате, бұзушылық, ұшақтың ұшуы, қауіпсіздік.

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ВЛИЯНИЕ СИСТЕМНЫХ ОШИБОК В МЕТЕОРОЛОГИЧЕСКОМ ОБЕСПЕЧЕНИИ БЕЗОПАСНОСТИ ПОЛЕТОВ

Аннотация. В практической авиационной деятельности существует насколько различных систем взаимодействия. В частности, в системе, состоящей из оператора и машины, довольно часто отмечаются сбои из-за ошибок проектировщиков, операторов, изготовителей, техобслуживания и т.п. Ошибки, как правило, непреднамеренны: человек выполняет ошибочные действия, расценивая их как верные или наиболее подходящие в силу недостаточности информации, пренебрежения правилами и стандартами и даже в силу отсутствия таковых. Для гражданской авиации групповая деятельность авиационного персонала очень характерна. В широком значении слова группа – это объединение людей для удовлетворения общих потребностей и для достижения общих целей [1]. Летный и кабинный экипажи, смена службы перевозок или диспетчеров УВД, а также техническая (производственная) бригада - всё это типичные формальные малые группы, членство, состав и взаимоотношения в которых определяются установленными предписаниями и договоренностями. При принятии ответственного решения важно, происходит ли оно индивидуально или в составе группы, а также под влиянием каких факторов и на основе чего принимается данное решение.

Специалисты американской корпорации Boeing просчитали долю авиационных происшествий, связанных с неправильным принятием решения. Оказалось, что из всех авиационных происшествий такие проис-

шествия составляют 75%. Кроме того, из них 58% процентов занимает неверная оценка воздушной или наземной обстановки экипажем воздушного судна. Обмен информацией в условиях подготовки и проведения полетов – это динамичный и необратимый процесс, при помощи которого пилоты и органы обслуживания воздушного движения производят обмен сообщениями и интерпретируют их в конкретном контексте или ситуациях для безопасного эффективного и экономичного производства полетов, что в конце концов дает пилоту основание для принятия того или иного решения на вылет и возможность планирования всего полета.

Еще в 1990 году профессором Ризоном была разработана модель, описывающая причинную обусловленность авиационного происшествия. Профессор Ризон рассматривает авиационную отрасль как сложную производственную систему. Один из основных элементов этой системы состоит из лиц, принимающих решения, другим ключевым элементом являются лица, выполняющие решения, для того чтобы решения высшего эшелона и действия линейного руководства были претворены в эффективную и продуктивную деятельность, осуществляемую непосредственно пилотами и инструкторами, должны выполняться определенные предварительные условия.

Модель Ризона поясняет, каким образом люди способствуют нарушению работоспособности сложных, взаимодействующих и хорошо защищенных систем (таких как авиация), в результате чего происходит авиационное происшествие.

Данная модель раскрывает перед нами причинно-следственные связи, не ведущие непосредственно к происшествию, а показывает, что, хотя между рисками и несчастными случаями лежит много уровней защиты, в каждом слое защиты есть те недостатки, которые, в случае системного «выравнивания», могут спровоцировать аварию[3].

Эта модель используется при анализе рисков и управлении рисками и должна учитываться при планировании, организации и проведении полетов, а также в авиационной безопасности, инженерном обеспечении и т.п. Используемая в любой отрасли, она дает один и тот же результат на выходе: многие несистемные нарушения ведут при накоплении рисков к происшествиям и, что крайне опасно, к катастрофам. Ризон сравнивает системы с несколькими кусочками швейцарского сыра, сложенными рядом друг с другом, в которых риск того, что угроза станет реальностью, смягчается различными уровнями и типами защиты, которые «наслоены» друг на друга, но при совпадении «дырок» ведут к происшествиям. Недостатки одного уровня защиты не позволяют реализовать риск, поскольку существуют и другие защиты для предотвращения единой точки отказа, но при системном накоплении рисков катастрофические последствия неизбежны. Этот эффект иногда называют «эффект совокупного действия». В нашей работе мы попытались исследовать систему незащищенных рисков, приведшую к катастрофе.

Ключевые слова: происшествие, анализ, ошибка, нарушение, полет воздушного судна , безопасность.

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COMPARATIVE ANALYSIS OF LOW TEMPERATURE RESISTANCE FOR NANOCARBON AND OTHER BITUMENS

Abstract. A comparative analysis of the low temperature resistance for a nanocarbon bitumen and other 30 neat and modified bitumens has been performed in the work. The stiffness at the temperatures of -24°C, -30°C and -36°C under technical system Superpave has been accepted as an indicator of low temperature resistance of the bitumens. The stiffness of the bitumens has been determined on a bending beam rheometer (standard ASTM D 6648-08). Before testing the bitumens have been subjected to the double artificial aging: short-term aging – under standard AASHTO T 240-13 and long-term aging – under standard ASTM D 6521-08.

The nanocarbon bitumen has been prepared in the laboratory of the Kazakhstan Highway Research Institute (KazdorNII) with the use of a road bitumen of the grade BND 70/100 produced by the Pavlodar petrochemical plant (PNHZ) and a nanocarbon powder (2% by weight) manufactured from a coal rock of the deposit "Saryadyr" "Corporation "ON-Olzha" LLP, Akmola region, Kazakhstan). The nanocarbon powder (150-200 nm) has been manufactured by three-stage size reduction of the coal rock: I – a mechanical dispergator (up to 2-3 mm), II – an aerodynamic mill (up to 20 mcm), III – a reactor with a rotating electromagnetic field.

The neat bitumens of the grades BND 50/70, BND 70/100, BND 100/130 have been produced by the plants of Kazakhstan and Russia; they satisfy the requirements of the standard ST RK 1373-2013. The modified bitumens have been prepared in the laboratory of KazdorNII with the use of the neat bitumens, 7 types of the polymers, crumb rubber and polyphosphoric acid and they satisfy the requirements of the standard ST RK 2534-2014.

It has been determined that the nanocarbon bitumen is one of the most resistant at the low temperatures: -24°C, -30°C and -36°C.

Key words: bitumens, nanocarbon powder, polymers, bending beam rheometer, stiffness.

1. Introduction. It is known that the climate of Kazakhstan is a sharp continental one, and to provide a reliable operation of highways with the asphalt concrete pavements in such climatic conditions it is required to improve both high temperature and low temperature characteristics of the road bitumens [1-5]. One of the widely used methods for the increase of operational characteristics of the road bitumens is their modification with the polymer additives [1-3, 6-8]. The works [9-12] show an efficient alternative method for the essential increase of the low temperature characteristics of the road bitumens – their modification with nanocarbon powder manufactured from the local coal rock. The increase of the low temperature resistance of the nanocarbon bitumen has been explained on the basis of electromagnetic theory [13,14] and quantum physics [15]. The works [16,17] demonstrate the increased standard characteristics of a nanoasphalt concrete of the type B prepared with the use of the nanocarbon bitumen in comparison with the main types of the road asphalt concretes used in the world.

This article is a continuation of our works mentioned above and it contains the results of the comparative analysis for the low temperature resistance of the nanocarbon bitumen and other 30 neat and modified bitumens.

2. Materials and methods

2.1. Bitumens. 11 neat and 10 modified bitumens which satisfy the requirements of the standards ST RK 1373-2013 and ST RK 2534-2014 have been accepted for the research. Data regarding the tested bitumens and their abbreviations are represented in table 1. More detailed information about bitumens and their modification one can obtain in the works [7,18].

Data regarding the tests of the neat and the modified bitumens

Serial №	Name of a plant	Grade of a bitumen	Name of a modifier	Amount of a modifier, %	Abbreviation
1	Pavlodar petrochemical plant (Pavlodar city, Kazakhstan)	BND 70/100	–	–	PNHZ_70-100
2		BND 70/100	nanocarbon	2.0	PNHZ_70-100+ nano
3		BND 100/130	–	–	PNHZ_100-130
4		BND 100/130	Elvaloy 4170	1.4	PNHZ_100-130+ Elvaloy1
5		BND 100/130	Elvaloy AM	2.0	PNHZ_100-130+ Elvaloy2
6		BND 100/130	Kraton	4.0	PNHZ_100-130+ Kraton
7		BND 100/130	Calprene 501	4.0	PNHZ_100-130+ Calprene
8		BND 100/130	Butonal NS 198	3.0	PNHZ_100-130+ Butonal
9		BND 100/130	SBS (L 30-01 A)	3.0	PNHZ_100-130 + SBS
10		BND 100/130	KUMHO KTP	3.0	PNHZ_100-130+ KUMHO3
11		BND 100/130	KUMHO KTP	6.0	PNHZ_100-130+ KUMHO6
12		BND 100/130	Crumb rubber	10	PNHZ_100-130+ PK10
13		БНД 100/130	Crumb rubber	15	PNHZ_100-130+ PK15
14	Caspi Bitum (Aktau city, Kazakhstan)	BND 50/70	–	–	CB_50-70
15		BND 70/100	–	–	CB_70-100
16		BND 100/130	–	–	CB_100-130
17	Asfaltobeton-1 (Almaty city, Kazakhstan)	BND 70/100	–	–	AB1_70-100
18		BND 100/130	–	–	AB1_100-130
19	Omsk petroleum processing plant (Omsk city, Russia)	BND 70/100	–	–	ONPZ_70-100
20	(Ufa city, Bashkortostan, Russia)	BND 50/70	–	–	SU_50-70
21	Gazpromneft-Bitum Kazakhstan (Shymkent city, Kazakhstan)	BND 70/100	–	–	GPN_70-100
22		BND 100/130	–	–	GPN_100-130
23		BND 100/130	Elvaloy 4170	1.4	GPN_100-130+ Elvaloy
24		BND 100/130	Kraton	4.5	GPN_100-130+ Kraton
25		BND 100/130	Calprene 501	4.5	GPN_100-130+ Calprene
26		BND 100/130	Butonal NS 198	3.5	GPN_100-130+ Butonal
27		BND 100/130	SBS (L 30-01 A)	3.0	GPN_100-130+ SBS
28		BND 100/130	Elvaloy 4170 PPA	1.3 0.02	GPN_100-130+ Elvaloy+PPA
29	Gazpromneft-Bitum Kazakhstan (Shymkent city, Kazakhstan)	BND 100/130	Calprene 501 PPA	4.0 0.02	GPN_100-130+ Calprene+PPA
30		BND 100/130	Butonal NS 198 PPA	3.0 0.02	GPN_100-130+ Butonal+PPA
31		BND 100/130	Kraton PPA	4.0 0.02	GPN_100-130+ Kraton+PPA

2.2. Nanocarbon powder. A nanocarbon powder (150-200 nm) has been manufactured from a coal rock of the deposit "Saryadyr" ("Corporation "ON-Olzha" LLP, Akmola region, Kazakhstan) by three-stage size reduction. More detailed information about manufacturing the nanocarbon powder and nanocarbon bitumen is given in the works [9,12].

2.3. Bending beam rheometer. The stiffness determined on a bending beam rheometer (BBR) under the standard ASTM D 5548-08 has been accepted as the characteristics of the low temperature resistance of the bitumens. Before testing the bitumens have been subjected to the double artificial aging: short-term aging – under the standard AASHTO T 240-13 and long-term aging – under the standard ASTM D 6521-08.

3. Results and discussion. Figures 1-3 represent the bar graphs for the stiffness values of the bitumens at the temperatures of -24°C, -30°C and -36°C. The stiffness values of the bitumens have been determined on BBR at the load duration of 60 seconds as it is required by the Technical system Superpave [4,5]. As it is known, under the Technical system Superpave the maximum permitted value for the stiffness of the bitumens at the low temperatures should not exceed 300 MPa.

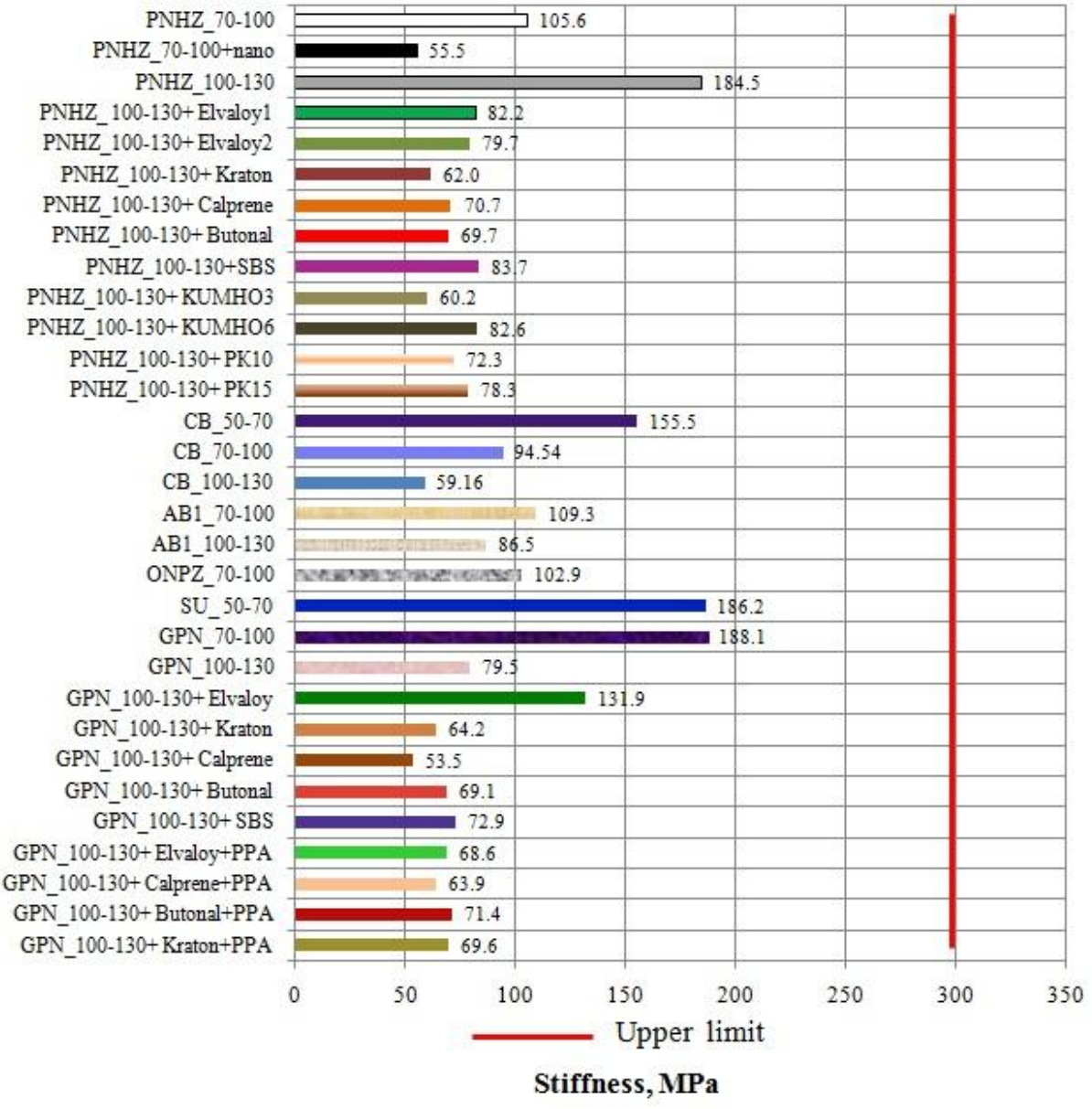

Figure 1 – Stiffness of the bitumens at the temperature of -24˚C

All the tested bitumens have the stiffness considerably lower than 300 MPa at the temperature of -24°C (figure 1). The prevailing part of the bitumens has the stiffness lower than 100 MPa. The nanocarbon bitumen (the bitumen of the grade BND 70/100+nanocarbon) is practically the most resistant one.

Three neat bitumens (Ufa bitumen and Aktau bitumen of the grade BND 50/70 and Pavlodar bitumen of the grade 100/130) are not resistant at the temperature of -30°C (figure 2). Other bitumens except for Shymkent neat bitumen of the grade BND 70/100 and Pavlodar bitumen of the grade BND 100/130+Elvaloy 4170 have the stiffness lower than 200 MPa. The nanocarbon bitumen (S=152.8 MPa) is among the most resistant ones.

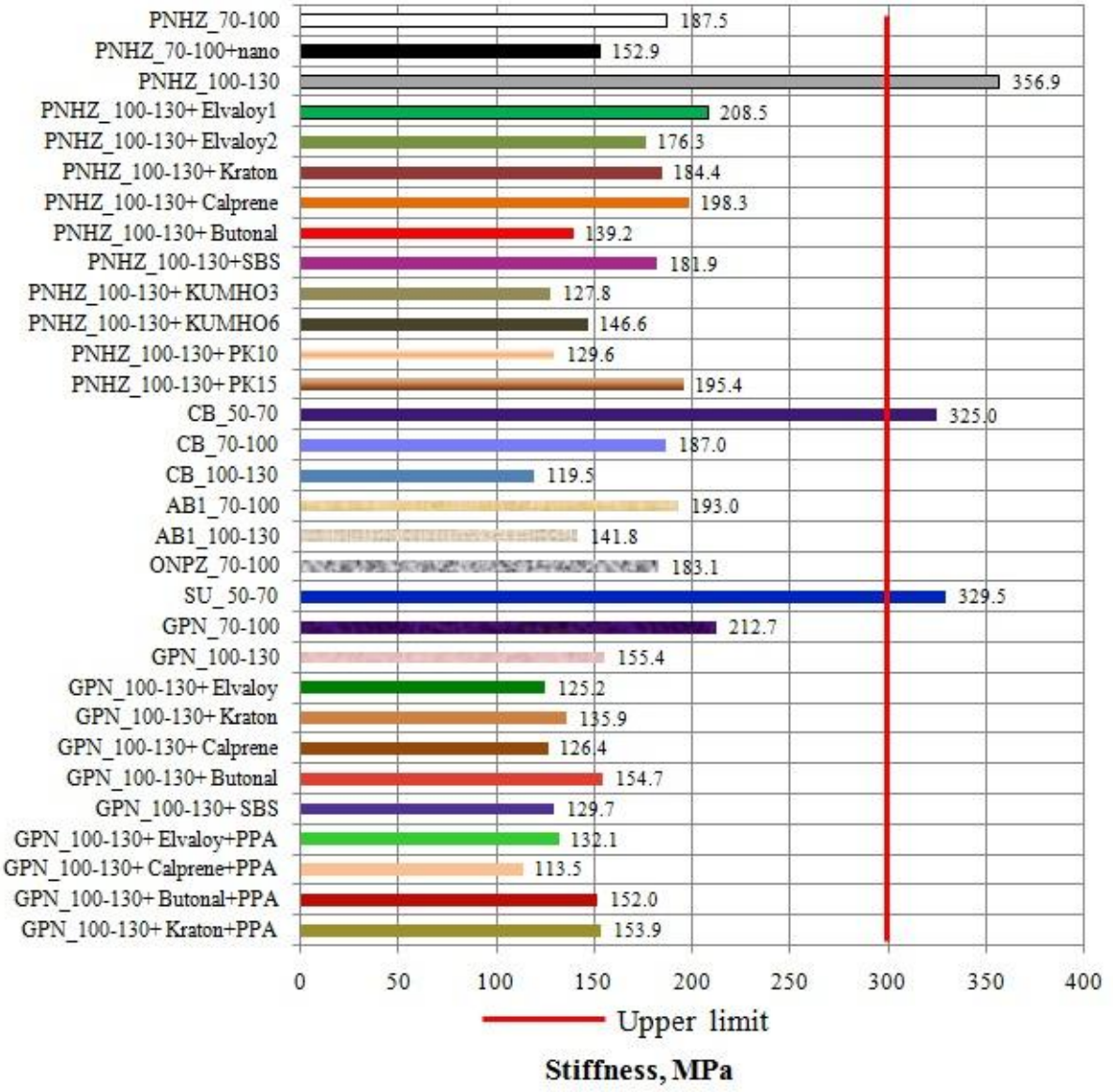

Figure 2 – Stiffness of the bitumens at the temperature of -30˚C

21 bitumens from the tested ones do not satisfy the requirements at the temperature of -36°C (figure 3). Not only the neat bitumens, but also some modified bitumens are included into the number. 5 bitumens included into the number (Aktau bitumen, Omsk bitumen and Shymkent bitumen of the grade BND 70/100, Shymkent bitumen of the grade BND 100/130 and the same bitumen modified with the polymer Butonal) have shown the stiffness higher than 400 MPa and 2 more bitumens (the neat bitumens of the grade BND 50/70 of the Ufa plant and Aktau plant) have the stiffness higher than 550 MPa. And at this low temperature the nanocarbon bitumen is one of the most resistant.

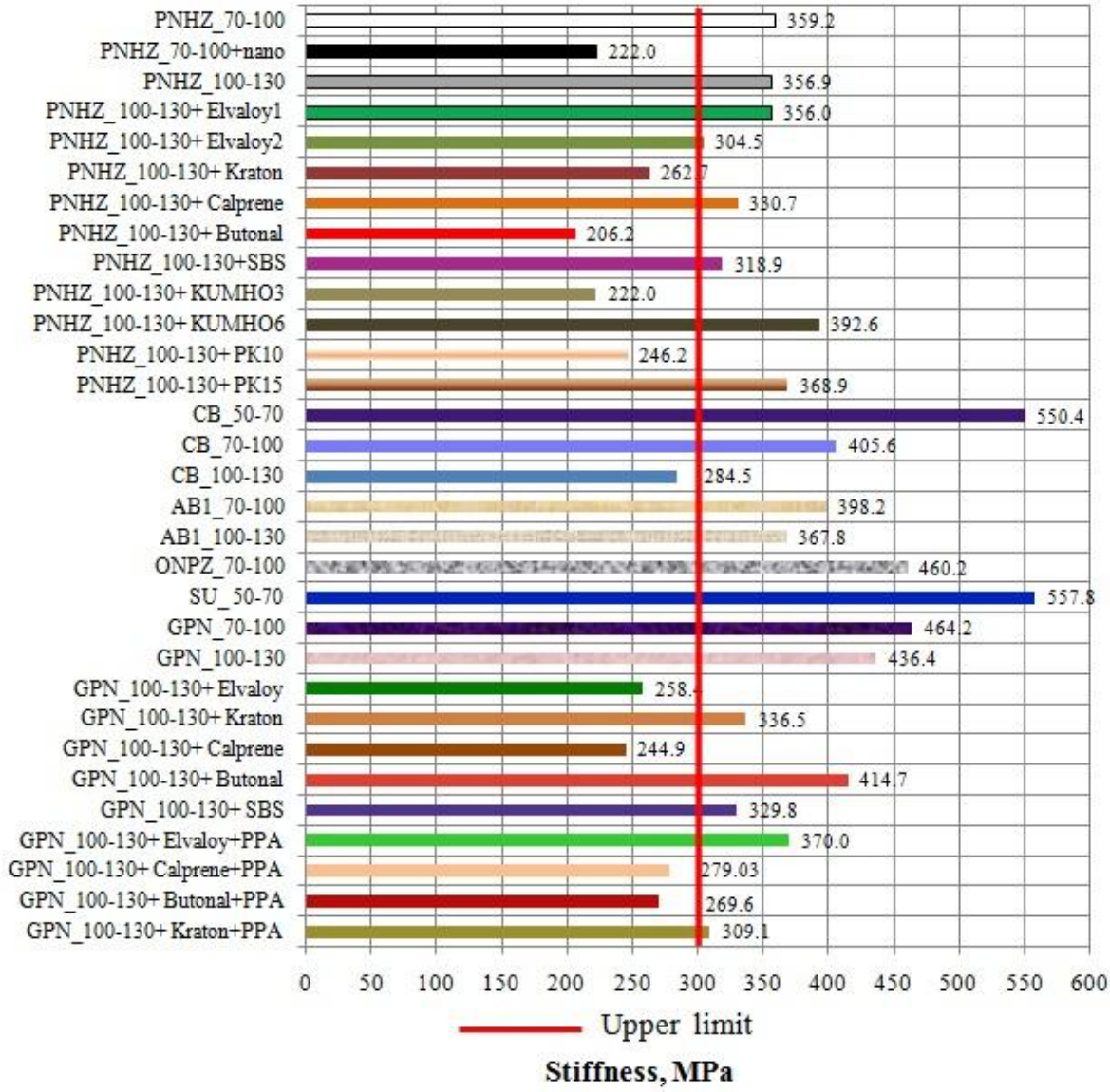

Figure 3 – Stiffness of the bitumens at the temperature of -36 ˚C

Conclusion. The results of the comparative analysis for the stiffness of a nanocarbon bitumen and other 30 neat and modified bitumens at the temperatures of -24°C, -30°C and -36°C have shown that the nanocarbon bitumen is one of the most resistant at all the considered temperatures.

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НАНОКӨМІРТЕК ЖӘНЕ БАСҚА БИТУМДАРДЫҢ ТӨМЕНГІ ТЕМПЕРАТУРАЛЫҚ ОРНЫҚТЫЛЫҒЫН САЛЫСТЫРМАЛЫ ТАЛДАУ

Аннотация. Мақалада нанокөміртек битумның және басқа 30 таза және модификацияланған битумның төменгі температуралық орнықтылығына салыстырмалы талдау жасалған. Битумдардың төменгі темпе-

ратуралық орнықтылығының көрсеткіші ретінде Superpave техникалық жүйесі бойынша -24 °С, -30 °С және -36 °С температурадағы қаттылық қабылданды. Битумдардың қаттылығы ASTM D 6648-08 стандарты бойынша иілігіш білікті реометрде (BBR) анықталды. Сынақтан бұрын битумдар екі сатылы жасанды ескіруден (AASHTO T240-13 стандарты бойынша қысқа мерзімде ескіруден және ASTM D 6521-08 стандарты бойынша ұзақмерзімді ескіру) өтті.

Нанокөміртек битум Қазақстан жол ғылыми-зерттеу институтының (ҚазжолҒЗИ) зертханасында Павлодар мұнай-химия зауыты (ПМХЗ) өндірген МЖБ 70/100 маркалы жол битумын және «Сарыадыр» кен орнының («ОН-Олжа» корпорациясы» ЖШС, Ақмола облысы, Қазақстан) көмір тау жынысынан алынған нанокөміртек ұнтағын пайдалану негізінде дайындалды. Нанокөміртек ұнтағы (150-200 мм) көмір тау жынысын үш сатылы ұнтақтау әдісімен алынды: I механикалық диспергатор (2-3 мм-ге дейін); II аэродинамикалық диірмен (2-3 мм-ге дейін); III айналма магнит өрісті реактор.

МЖБ 50/70, МЖБ 70/100, МЖБ 100/130 маркалы таза битумдар Қазақстан мен Ресей зауыттарында өндірілді және ҚР СТ 1373-2013 стандартының талаптарын қанағаттандырады. Модификацияланған битумдар ҚазжолҒЗИ зертханасында таза битумдарды, 7 түрлі полимерді, резеңке ұнтақтын және полифосфор қышқылын пайдалану негізінде дайындалды және ҚР СТ 2534-2014 стандартының талаптарын қанағаттандырады.

Мақалада орындалған салыстырмалы талдау нәтижесінде төмендегілер анықталды:

1) -24 °С температурада барлық сынақтан өткен битумдардың қаттылығы 300 МПа-дан әлдеқайда жоғары. Битумдардың көп бөлігінің қаттылығы 100 МПа-дан төмен. Нанокөміртек битум (МЖБ 70/100 маркалы битум+наноұнтақ) практикалық тұрғыдан аса тұрақты екендігі анықталды.

2) -30 °С температурада үш таза битум (МЖБ 50/700 маркалы Уфа және ақтау битумдары және МЖБ 100/130 маркалы Павлодар битумы) тұрақты емес. Шымкенттің МЖБ 70/100 маркалы таза битумы мен Павлодардың Elvaloy 4170 полимері қосылған МЖБ 100/130 маркалы битумынан басқа битумдардың қаттылығы 200 МПа-дан төмен. Нанокөміртек битум (S=152,8 МПа) аса тұрақты битумдардың қатарына жатады.

3) -36 °С температурада сынақтан өткен битумдардың 21-і қойылатын талаптарды қанағаттандырмайды. Олардың қатарында тек таза битумдар ғана емес, модификацияланған битумдар да бар. Олардың 5-еуі (Ақтаудың, Омбының және Шымкенттің МЖБ 70/100 маркалы битумдары, Шымкенттің МЖБ 100/130 маркалы битумы және Butonal полимерімен модификацияланған осы битум) 400 МПа-дан жоғары қаттылық көрсетті және тағы 2-інің (Уфа және Ақтау зауыттарының МЖБ 50/70 маркалы битумдары) қаттылығы 550 МПа-дан жоғары. Осы төменгі температурада да нанокөміртек битумы аса тұрақты битумдардың бірі екендігі айқындалды.

Сонымен, нанокөміртек битумы мен әлемде жол құрылысында пайдаланылатын басқа да 30 таза және модификацияланған битумдардың -24 °С, -30 °С және -36 °С температуралардағы қаттылығын салыстырмалы талдау нанокөміртек битумының барлық қарастырылған температурадағы аса тұрақты битумдардың бірі екендігін көрсетті.

Түйін сөздер: битумдар, нанокөміртек ұнтағы, полимерлер, иілгіш білікті реометр, қаттылық.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ НИЗКОТЕМПЕРАТУРНОЙ УСТОЙЧИВОСТИ НАНОУГЛЕРОДНОГО И ДРУГИХ БИТУМОВ

Аннотация. В настоящей работе выполнен сравнительный анализ низкотемпературной устойчивости наноуглеродного битума и других 30 чистых и модифицировынных битумов. В качестве показателя низкотемпературной устойчивости битумов принята жесткость при температурах -24 °С, -30 °С и -36 °С по технической системе Superpave. Жесткость битумов определена на реометре с изгибаемой балкой (стандарт ASTM D 6648-08). Перед испытанием битумы были подвержены двойному искусственному старению: кратковременному - по стандарту AASHTO T 240-13 и длительному - по стандарту ASTM D 6521-08.

Наноуглеродный битум был приготовлен в лаборатории Казахстанского дорожного научно-исследовательского института (КаздорНИИ) с использованием дорожного битума марки БНД 70/100, произ-веденного Павлодарским нефтехимическим заводом (ПНХЗ), и наноуглеродного порошка (2% по массе), полученной из угольной породы месторождения «Сарыадыр» (ТОО «Корпорация «ОН-Олжа», Акмолинская область,

Казахстан). Наноуглеродный порошок (150-200 нм) получен путем трехстадийного измельчения угольной пароды: I - механический диспергатор (до 2-3 мм), II - аэродинамическая мельница (до 20 мкм), III - реактор с вращающимся магнитным полем.

Чистые битумы марок БНД 50/70, БНД 70/100, БНД 100/130 были произведены заводами Казахстана и России, удовлетворяют требованиям стандарта СТ РК 1373-2013. Модифицированные битумы были приготовлены в лаборатории КаздорНИИ с использованием чистых битумов, 7 видов полимеров, резиновой крошки и полифосфорной кислоты и удовлетворяют требованиям стандарта СТ РК 2534-2014.

В результате выполненного сравнительного анализа было установлено, что:

1) При температуре -24 °С все испытанные битумы имеют жесткость, значительно ниже 300 МПа. Преобладающая часть битумов имеет жесткость ниже 100 МПа. Наноуглеродный битум (битум марки БНД 70/100+наноуглерод) является практически самым устойчивым.

2) При температуре -30 °С три чистых битума (Уфимский и Актауский битумы марки БНД 50/70 и Павлодарский битум марки БНД 100/130) не устойчивы. Остальные битумы, за исключением Шымкентского чистого битума марки БНД 70/100 и Павлодарского битума марки БНД 100/130+Elvaloy 4170, имеют жесткость ниже 200 МПа. Наноуглеродный битум (S=152,8 МПа) относится к числу наиболее устойчивых.

3) При температуре -36 °С 21 битум из испытанных не удовлетворяют предъявляемым требованиям. В их числе не только чистые, но и некоторые модифицированные битумы. 5 из них (Актауский, Омский и Шымкентский битумы марки БНД 70/100, Шымкентский битум марки БНД 100/130 и этот же битум, модифицированный полимером Butonal) показали жесткость выше 400 МПа и еще 2 (чистые битумы марки БНД 50/70 Уфимского и Актауского заводов) имеют жесткость выше 550 МПа. И при этой низкой температуре наноуглеродный битум является одним из самых устойчивых.

Таким образом, сравнительный анализ жесткости наноуглеродного битума и других 30 чистых и модифицированных битумов, применяемых в дорожном строительстве во многих странах мира, при температурах -24 °С, -30 °С и -36 °С показали, что наноуглеродный битум является одним из наиболее устойчивых при всех рассмотренных низких температурах.

Ключевые слова: битумы, наноуглеродный порошок, полимеры, реометр с изгибаемой балкой, жесткость.

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INTEGRATED STUDY OF THE EFFICIENCY OF GRINDING MATERIAL IN AN IMPACT-CENTRIFUGAL MILL

Abstract. Grinding processes, which are very common and occurring in almost any industry and agriculture, require large energy costs and are associated with irretrievable losses due to wear of working units of grinders. It is generally recognized that reduction in specific energy costs is possible when using mills in which grinding will be carried out mainly due to the impact loading of a material. The results of studies of a single impact grinding of materials with various physical and mechanical properties, depending on the impact velocity and design features of a grinder in an impact-centrifugal mill, are presented. Experimental dependences of impact-centrifugal grinding are presented. Graphic dependences of the median particle mass distribution of a ground material depending on the number of blades are obtained. The number of blades for a given rotor diameter (0.4 m) was 4, 6, 8, 12 pcs. The graph shows that when grinding chalk, the number of blades does not significantly affect the quality of grinding. When grinding sylvinite and in particular gypsum stone with an increase in the number of blades to 8, the grinding fineness improves, i.e., the median particle size decreases, however, with a further increase in the number of blades, the dispersed composition of the products remains almost constant. The analysis of known data on the theory of impact grinding is given, on the basis of which the principles of creating new energy-efficient machines for grinding materials, in particular to reduce energy costs, were formed.

Key words: impact loading of a material, impact-centrifugal mill, critical fracture initiation velocity, fractional composition, particle mass distribution median.

Introduction. Grinding processes are widespread in all industries, including agriculture. The grinding process requires high energy costs and is associated with an irretrievable loss due to wear of working units of grinders. The drive power of mills in cement production is measured in thousands of kilowatts. In a number of works [1], it is noted that about 10% of the world's electricity and several million tons of high-grade steel are consumed for grinding, and even more [2-5] according to statistics from the US mining and processing industry. The high energy costs are explained not only by the large volumes of processed materials, but also by the fact that the machines used for grinding, especially for grinding, are characterized by extremely low efficiency [6].

It is generally recognized that reduction in specific energy costs [7,8] is possible when using mills in which grinding will be carried out mainly due to the impact loading of a material. It was established by experiments that the average work of grinding by impact is approximately 42% of the work of grinding by crushing. Upon impact, the compressive force arises in a certain section so quickly that a crack is formed before the equilibrium energy distribution necessary for breaking is established in the particle [9].

To reduce energy costs, optimal impact loading of the material to be ground should be ensured with minimal effort and a high degree of fracture in one working cycle, avoiding excessive overgrinding. Therefore, a very important characteristic of the impact grinding process is the critical fracture velocity ($V_{кр}$), i.e. the velocity of impact loading of the material particle at which its ensured fracture begins. This indicator ($V_{кр}$) will determine the minimum rotor velocity with hammers or blades in almost all designs of impact-centrifugal grinders. Practically all researchers working in the field of impact grinding were

involved in theoretical and experimental studies to determine the critical fracture initiation velocity ($V_{кр}$). Today, a large number of mathematical dependences are known to determine $V_{кр}$, for example, the formula of Academician V.P. Goryachkin [10] and Professor G.I. Pokrovskiy [11]:

$$V_{kp} = \sqrt{\frac{E}{\rho}} \cdot \frac{\sigma_p}{E} \quad (1)$$

A different theoretical approach showed a similar dependence in collaboration with Academician of the Ukrainian Academy of Sciences V.N. Poturaev [12]; dependences proposed by V.P. Romandin [13], P.M. Sidenko [14], E. Reiners [15] do not differ significantly.

Since the critical velocity ($V_{кр}$) at which the fracturing impact begins depends, first of all, on the mechanical properties and density of a piece of material, all of the above dependences can be represented in general form:

$$V_{кр} = f(\sigma_p, E, \rho_м) \quad (2)$$

However, the experimental results for determination of $V_{кр}$ given in [10] show that the actual critical velocity is several times higher than that obtained from the theoretical dependences given in the above works.

In the works of V.A. Bauman [16], B.V. Klushantsev [17], in the formulas for determination of $V_{кр}$, the size of the initial material fed to grinding is additionally taken into account. All researchers agree that the determining factors are the mechanical properties and density of the material, however the design parameters of the grinder, which should be taken into account on the basis of experimental studies, also have a significant effect [18-22].

The dispersed composition of the material crushed by impact loading will also depend on its mechanical and physical properties, to a large extent on the velocity of impact loading and the design features of the grinder [19,20]. Therefore, specific dependences for determining the critical velocity ($V_{кр}$), as well as the dispersed composition of the grinding products should be found experimentally.

To study the process of single impact grinding, an experimental plant of the impact-centrifugal mill was used. The analysis of the fractional composition of grinding products was carried out using the method of mechanical classification (sieving) on sieves. At the first stage of experimental studies, the process of single impact grinding was studied. The studies were carried out on the experimental plant shown in figure 1.

The main unit of the plant is the impact-centrifugal mill, consisting of the cylindrical body 1 coated inside by the rods 2. The cover 3 with the bearing unit 4 and the shaft 5 in the center for rotation of the disk 6 with the blades 7 is attached to the upper part of the body. The shaft 5 is driven with V-belt transmission from the electric motor 8. The disk rotation velocity was varied over a wide range by changing the motor velocity using a high-frequency controller (inverter). The initial material for grinding in the mill was fed from the hopper 9 by the screw feeder 10. The screw was driven from the electric motor 11 through the reductor-regulator 12, which made it easy to control the amount of material fed to the mill. In addition to the material, air entered the mill through the holes 13 in the cover 3. The conical collector 14 is attached to the lower part of the mill, where the ground material is poured and periodically removed through the shutter 15 from the mill. Air from the mill was removed through the tube section 16 ending with the filter sleeve 17. The studies were carried out using the reflective rods 2 of square cross section with a side of 14 mm “option a” and a round “option b” with a diameter of 14 mm. The diameter of the working disk at the ends of the blades was 0.4 m.

As the material for the experimental studies there were used: lime granules after the furnace, with the size of $(2 – 8) \cdot 10^{-3}$ m; gypsum stone with the particle size of $(2 – 10) \cdot 10^{-3}$ m; chalk with the particle size of $(2 – 10) \cdot 10^{-3}$ m; sylvinite with the particle size of $(2 – 15) \cdot 10^{-3}$ m; ammonium sulfate crystals with the particle size of $(2 – 8) \cdot 10^{-3}$ m; grains of wheat and barley; ammophos granules with the particle size of $(2 – 5) \cdot 10^{-3}$ m; pyrolysis products of rubber products $(2 – 5) \cdot 10^{-3}$ m; oil coke $(2 – 5) \cdot 10^{-3}$ m.

After each of the experiments, the analysis was carried out according to the fractional composition of grinding products. Currently, a large number of methods and their modifications are known for determining the dispersed composition of both dusts and ground materials [22].

The simplest and sufficiently accurate method is the method of mechanical classification (sieving) on sieves. For the experimental studies of the fractional composition of grinding products, the authors used a set of standard sieves with a minimum hole size of 0.063 mm and a maximum of 4 mm.

For a graphic representation of the material's fractional composition, a distribution function $D_{(\delta)}$ is taken expressed as a percentage of the mass of all particles which diameter is less than the holes of this sieve to the total mass of the analyzed material.

The results of experimental studies of the fractional composition of products of grinding lime, chalk, gypsum stone, sylvinite, ammonium sulfate, ammophos, solid pyrolysis products of rubber products, oil coke and barley grain are shown in the graph (figure 2).

The fractional distribution curves shown in the graph were obtained at the rotor velocity of 2900 rpm, which corresponds to a tangential velocity at the ends of the blades of 60.7 m/s and an optimal loading on the initial material of 460-520 kg/h with the particle size of 3-8 mm. It can be seen from the graph that under the impact-centrifugal loading, lime granules and chalk particles are most finely ground. The high grinding degree of these materials is explained by the fact that they consist of tiny crystals, the bond between which is much weaker than the bond between crystals of other substances, for example, gypsum stone. Between the crystals of gypsum stone, the bond is stronger, as evidenced by the grinding results. The barley grains are ground much worse than all, this is due primarily to the fact that the grain is enveloped outside with several layers of a strong and elastic shell. It should be noted that of all the grain crops ground in the experimental plant (barley, rye, wheat, peas), barley was the most durable.

The graph (Fig. 3.) shows the fractional composition curves of products of grinding gypsum stone and pyrolysis products. The graph shows that with an increase in the loading, the dispersed composition of the grinding products worsens and with an increase in the loading on the mill more than 760 kg/h, the decrease in the quality of grinding is more noticeable. However, the fractional composition of the pyrolysis products varies slightly with increasing productivity. This is due to the high fragility of the material.

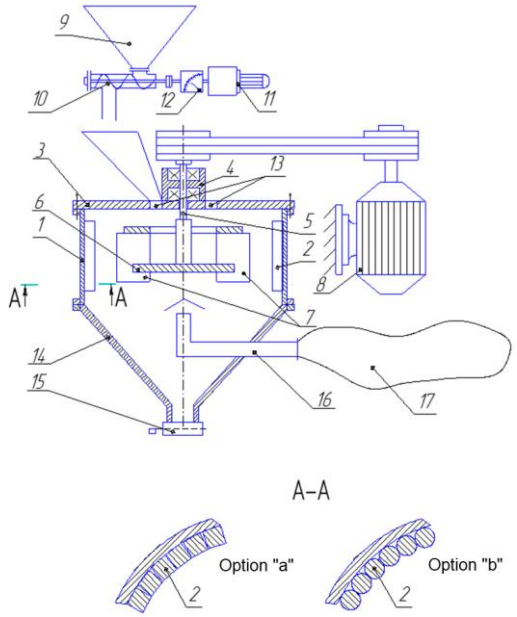

Figure 1 – Scheme of the plant for the study of impact-centrifugal mill. 1 – mill body; 2 – reflective rods; 3 – cover; 4 – bearing unit; 5 – shaft; 6 – disk; 7 – blades; 8, 11 – electric motor; 9 – hopper; 10 – feeder; 12 – reductor-regulator; 13 – holes; 14 – collector; 15 – shutter; 16 – tube section; 17 – filter sleeve

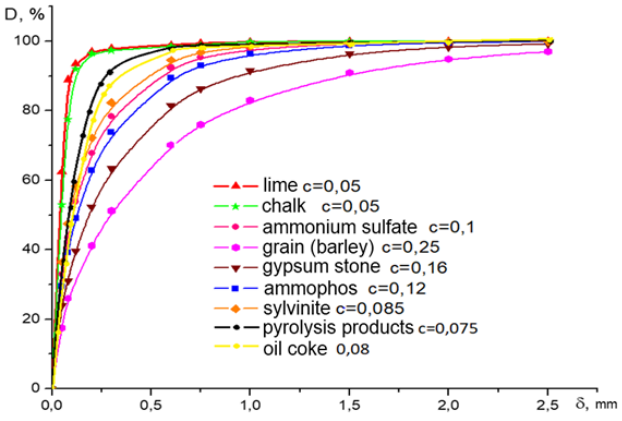

Figure 2 – Fractional composition of products of impact-centrifugal grinding of materials with various strength characteristics. G = 460-520 kg/h, n = 2900 rpm

The influence of the rotor velocity on the quality of grinding products was also carried out when grinding sylvinite, gypsum stone, grain and oil coke. The studies were carried out at the rotor velocity of 750, 940, 1450 and 2900 rpm with a loading of 480 kg/h for gypsum stone and 60 kg/h for oil coke. The results of studies presented in Figure 4 were obtained by grinding gypsum stone (curves 1-4) and oil coke (curves 5-8). The graph shows that the rotor velocity is one of the main factors determining the fineness of grinding material. In addition to the influence of the material's mechanical properties, rotor velocity and loading, geometrical parameters of impact-centrifugal grinders were studied on the quality of grinding materials.

In the course of further studies, the optimal number of rotor blades and their height were determined. Figure 5 shows graphic dependences of the median particle mass distribution of the ground material depending on the number of blades. The number of blades for a given rotor diameter (0.4 m) was 4, 6, 8, 12 pcs. The graph shows that when grinding chalk, the number of blades does not significantly affect the quality of grinding. When grinding sylvinite and in particular gypsum stone with an increase in the number of blades to 8, the grinding fineness improves, i.e., the median particle size decreases, however, with a further increase in the number of blades, the dispersed composition of the products remains almost constant. This is explained by the fact that the granules of lime and chalk have low mechanical strength, and they are ground to small particles immediately after the first impact, as for sylvinite and gypsum stone, then at the first impact the material breaks up into small and large particles. Larger particles bounce off the rods and are again thrown onto the rods. Naturally, the more blades, the more particles fall under the impact of the blades, and naturally their grinding will continue to a certain fineness.

In addition to laboratory studies on the influence of the number of blades, surveys of industrial mills with a diameter of 0.6 and 0.8 meters were carried out. Based on the results of all these studies, the recommended number of rotor blades with acceptable accuracy can be found from the known dependence recommended for determining the number of impeller blades of centrifugal fans:

$$z = 4{,}3\,\frac{j+1}{j-1} \tag{3}$$

where $j = \frac{D_2}{D_1}$; D_1 – rotor diameter along the inner edge of the blades; D_2 – rotor diameter at the ends of the blades. The value of j should be taken within j = 1.4-3.

The influence of the blades' height on the quality of grinding the material was carried out when it changed from 0.04 to 0.12 m. Sylvinite and gypsum stone were used as the ground material, the material loading was 480 kg/h, and the rotor velocity was 1450 rpm. For both materials, increasing the height of the blades from 0.04 to 0.08 meters significantly improves the grinding quality, which is shown in figure 6. However, a further increase in the height does not significantly affect the grinding quality.

It should be borne in mind that increasing the height of the blades leads to an increase in air flow through the mill, which leads to additional energy consumption for the idle mill drive. However, many researchers note [14,16] that the optimal air flow through the mill allows to cool its working elements, quickly remove ground material from the grinding zone and thereby increase the efficiency of grinding material [7].

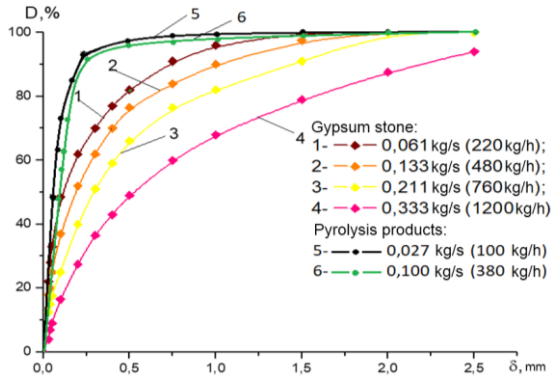

Figure 3 – Fractional composition of products of impact-centrifugal grinding of gypsum stone at various productivity n=2900 rpm

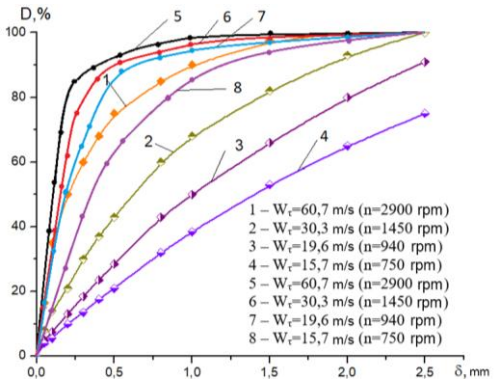

Figure 4 – Fractional composition of products of impact-centrifugal grinding of gypsum stone and oil coke at various rotor velocities

Based on laboratory studies and industrial tests, the height of the blades should be taken as:

$$h_2 = 0{,}2D_2 \tag{4}$$

The influence of the gap between the reflective rods and the ends of the rotor blades is presented in the form of a graph in figure 7 obtained when grinding grain (curve 1) and gypsum stone (curve 2). The graph shows that with an increase in the gap, the grinding quality worsens. This is explained by the fact that both materials with the rotor velocity of n=1450 rpm are difficult to grind, and numerous impacts are

required to obtain a thin product. However, with an increase in the gap, the possibility of repeated contact with the blades decreases. At the same time, with a decrease in the gap, a number of negative phenomena are also observed, namely, the specific energy consumption increases and intense wear of the edges of the blades is observed. Based on laboratory tests and industrial implementation, the gap between the reflective rods and blades should be taken for small mills with a diameter of up to 0.5 meters in the range of 5-8 mm for larger mills up to 15 mm.

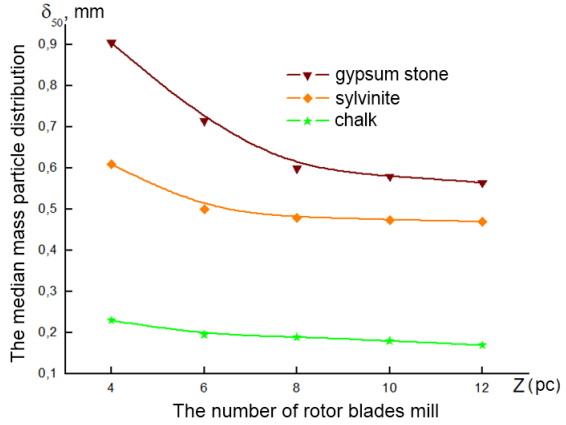

Figure 5 – Dependence of the median particle mass distribution during impact-centrifugal grinding on the number of rotor blades. G=480 kg/h, n=1450 rpm

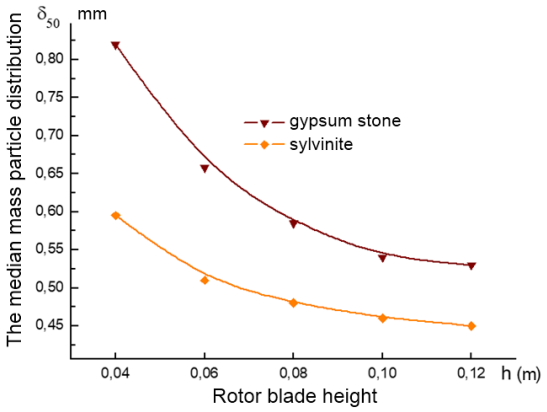

Figure 6 – Dependence of the median particle mass distribution during impact-centrifugal grinding on the blades' height. G=480 kg/h, n=1450 rpm

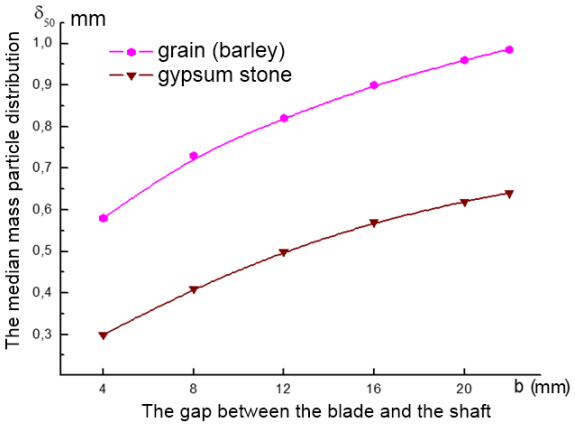

Figure 7 – Dependence of the median particle mass distribution during impact-centrifugal grinding on the size of the gap between the ends of the rotor blades and reflective rods. G=480 kg/h, n=1450 rpm

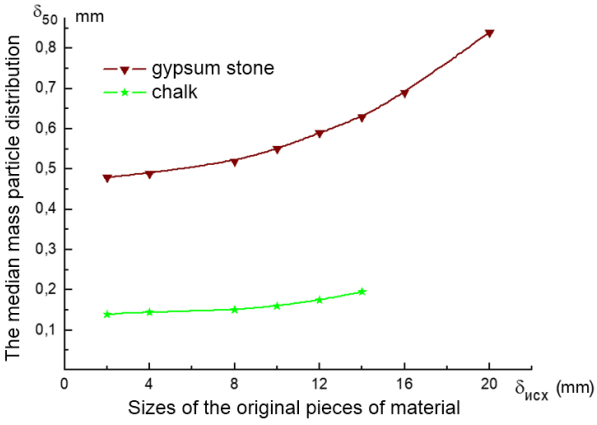

Figure 8 – Dependence of the median particle mass distribution during impact-centrifugal grinding on the size of the initial pieces of material. G=480 kg/h, n=1450 rpm

The influence of the size of the initial material pieces on the grinding quality was carried out by grinding chalk, gypsum stone and sylvinite. The results of studies are presented in the graph in figure 8. The particle size in the study varied from 2 to 20 mm.

The graph shows that when grinding chalk, which strength is not large, the particle size of the initial material has practically no effect on the grinding fineness. At the same time, sylvinite and gypsum stone, with an increase in size, are ground somewhat worse, this is due to the fact that their strength is much higher and for fine grinding of such materials it is necessary to increase the velocity of impact loading and provide conditions for multiple impact.

Most researchers [22] believe that the Rosin – Rammler equation gives the best fit of the mathematical description to the experimental data of the grinding products.

The Rosin-Rammler formula has the following form

$$R_{(\delta)} = 100 \cdot e^{-b\delta^n} \quad \text{or} \quad D_{(\delta)} = 100\,(1 - e^{-b\delta^n}) \tag{5}$$

where *b* and *n* – empirical constants.

Since the physical and mechanical properties of the material, the rotor velocity, and the mill productivity will affect the dispersed composition of the materials being ground, the Rosin-Rammler formula is somewhat modified by introducing an additional parameter δ_{50} to take these parameters into account, after which it takes the following form:

$$R_{(\delta)} = 100 \cdot e^{-b\left(\frac{\delta}{\delta_{50}}\right)^n} \quad \text{or} \quad D_{(\delta)} = 100 \cdot \left[1 - e^{-b\left(\frac{\delta}{\delta_{50}}\right)^n}\right] \tag{6}$$

where δ_{50} – particle mass distribution median, i.e., the particle size at which the mass of all particles is smaller or larger than 50%.

The influence of the material's physical and mechanical properties both on the grinding quality and on the material's critical fracture initiation velocity according to theoretical concepts should be sought in the form of the relationship:

$$\delta_{50} = k \frac{\sigma_p}{\sqrt{E \cdot \rho_м}} \tag{7}$$

The influence of the rotor velocity is most conveniently expressed through the tangential rotor velocity at the ends of the blades. Then the empirical equation for determining the median particle mass distribution will have the following form:

$$\delta_{50} = k \frac{\sigma_p}{\sqrt{E\rho_м}} V_\tau^l G^m \tag{8}$$

where *k, l, m* – constants determined on the basis of the experimental data shown in figures 2-4; V_τ – tangential rotor velocity at the ends of the blades, (m/s); *G* – productivity of the mill, (kg/s).

However, for many materials that were ground, data on the tensile strength σ_p and elastic modulus *E* are absent in the reference literature. P.M. Sidenko [14] explains this by the fact that there are a lot of factors influencing the mechanical strength of materials and, in the first place, on σ_p and *E*, and besides, they are variable. Therefore, to calculate the grinding efficiency, it is necessary to use "grinding coefficient". It is determined experimentally and its value is available in the relevant literature. Considering the above, in the formula (8), the expression taking into account the physical and mechanical properties of the material was replaced by the coefficient *c*, which takes into account primarily the strength properties of the material and was found on the basis of experimental data for each ground material. When processing the experimental data, the values of the exponents *l* and *m* and the coefficient *k* in the equation 8 were determined. Ultimately, the equation for determining the particle mass distribution median has the following form

$$\delta_{50} = 2{,}71 C V_\tau^{-1{,}42} G \tag{9}$$

The value *c* for the ground materials has the following value: grain (barley) *C*=0.25, lime and chalk *C*=0.05, crystals of ammonium sulfate *C*=0.1, ammophos *C*=0.12, gypsum stone *C*=0.16, sylvinite *C*=0.08, oil coke *C*=0.08, solid pyrolysis products of rubber products *C*=0.075.

When processing the experimental data, the values of the empirical constants *b*=0.68 and *n*=0.75 were determined in the Rosin-Rammler formula and then it has the final form:

$$D_{(\delta)} = 100\left[1 - e^{-0{,}68\left(\frac{\delta}{\delta_{50}}\right)^{0{,}75}}\right] \tag{10}$$

In determining the critical velocity, the fracture initiation, taking into account the data of various authors, for example [15], was taken to be the velocity when the initial material was split into pieces, the largest of which is equal to the half of the initial.

The studies were carried out on the experimental plant (figure 1). The change in the rotor velocity was controlled using a high-frequency controller. The experiments were carried out on gypsum stone, sylvinite, granules of lime and grain. The size of the initial particles was close to 6 mm. When the plant was operating with the certain rotor velocity, ten pieces of the initial material were fed to the grinding. After the grinding, the mill turned off, the shutter opened, and visual observation, as well as sieving on the laboratory sieves, determined the size of the ground material. When the maximum size of the ground particles was very close to the half of the initial, the experiments on this material were terminated.

The full material velocity was calculated by solving numerically the differential equations of particle motion in the mill rotor [22]. The processing of the experimental data showed that there is a clear relationship between the coefficient *c* and the critical velocity, which is understandable since it takes into account the strength properties of the material and then:

$$V_{кр} = 224 \cdot C \quad (11)$$

Thus, the critical velocity for the materials will be as follows: grain (barley) $V_{кр}$ = 56 m/s, ammophos $V_{кр}$ = 29 m/s, lime $V_{кр}$ = 11,2 m/s, crystals of ammonium sulfate $V_{кр}$ = 22,4 m/s, gypsum stone $V_{кр}$ = 39 m/s, sylvinite $V_{кр}$ = 19 m/s, solid pyrolysis products of rubber products $V_{кр}$ = 16.8 m/s, oil coke $V_{кр}$ = 17.92 m/s.

In addition to the mill design developed and studied by the authors, other industrial impact grinders, for example, hammer and ball industrial, have found wide application in industry. In particular, it is known that in a hammer mill no more than 17% of energy is spent on grain grinding by impact, and the rest is spent on grinding by abrasion. Therefore, when developing new mill designs, it is necessary to strive for the grinding process to be carried out mainly due to the impact, and for this purpose it is necessary to study the impact phenomenon itself.

Conclusions. 1. The experimental studies on the impact-centrifugal grinding of the materials were carried out taking into account their physical and mechanical properties, impact loading velocity, productivity and geometrical parameters of the grinder.

2. The processing of the experimental studies allowed to determine the optimal geometrical parameters of impact centrifugal grinders and, based on the Rosin-Rammler formula, obtain the mathematical dependence describing the dispersed composition of the grinding products depending on the physical and mechanical properties of the material, the impact loading velocity, and the grinder performance.

3. Based on the experimental studies and the processing of the experimental data, the mathematical dependences were obtained for calculating the productivity and the dispersed composition of the grinding products in impact-centrifugal mills.

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ЕКПІНДІ ОРТАДАН ТЕПКІШ ДИІРМЕНДЕ МАТЕРИАЛДЫ ҰСАҚТАУ ТИІМДІЛІГІН КЕШЕНДІ ЗЕРТТЕУ

Аннотация. Өнеркәсіп пен ауыл шаруашылығының кез келген саласында кең таралған ұсақтау үдерісі ірі энергетикалық шығынды талап етеді және ұсатқыш жұмыс тораптарының тозуына байланысты қайтарымсыз шығынға ұшыратады. Жалпы энергия шығыны диірменді пайдалану барысында азаюы мүмкін, онда ұсақтау негізінен материалды соққымен жүктеу есебінен жүзеге асырылады. Жұмыста екпінді ортадан тепкіш диірменді зерттеу бойынша қондырғы сұлбасы берілген. Тәжірибелік зерттеу үшін келесі материалдар пайдаланылды: пештен кейінгі әк түйіршігі, өлшемі (2-8)·10^{-3} м; бөлшек өлшемі (2-10)·10^{-3} м гипс тасы; бөлшек өлшемі (2-10)·10^{-3} м бор; бөлшек өлшемі (2-15)·10^{-3} м сильвинит; бөлшек өлшемі (2-8)·10^{-3} м аммоний сульфатының кристалдары; бидай мен арпа дәні; бөлшек өлшемі (2-5)·10^{-3} м аммофос түйіршіктері; бөлшек өлшемі (2-5) •10^{-3} м резеңке техникалық; бұйымдардың пиролиз өнімдері (2–5) ·10^{-3} м; мұнай коксы соққылы жүктеу жылдамдығына және екпінді ортадан тепкіш диірменде ұсақтағыштың конструктивтік ерекшеліктеріне байланысты түрлі физикалық және механикалық қасиеттері бар материалдарды бір рет соққылы ұсақтау үдерісін зерттеу нәтижелері келтірілген. Екпінді ортадан тепкіш ұнтақтаудың тәжірибелік тәуелділігі ұсынылған. Қалақ санына байланысты ұсақталған материал бөлшектер массасының медиандық таралуының графикалық тәуелділігі алынды. Ротордың осы диаметріне арналған күрек саны (0,4 м) 4, 6, 8, 12 дананы құрады. Кестеде көрсетілгендей, бұл сәтте майдалау бор саны жауырын аса әсер етпейтін сапасы тартылған. Сильвинитті ұсақтауда және әсіресе гипс тасын қалақ санының 8 тоннаға дейін ұлғаю арқылы жақсартылады, яғни бөлшектердің мыс мөлшері азаяды, алайда қалақ санының одан әрі ұлғаюында өнімнің дисперсиялық құрамы іс жүзінде тұрақты болып қалады. Ұрмалы ұсақтау теориясы бойынша белгілі деректерге

талдау жасалды, соның негізінде материалдарды ұсақтау үшін, атап айтқанда, энергия шығынын азайту үшін жаңа энерготиімді машиналарды құру принциптері қалыптасты. Жүргізілген талдау негізінде екпінді ортадан тепкіш диірменнің құрылымы әзірленді. Ұсақталатын материал ретінде сильвинит және гипс тасы пайдаланылды, материал бойынша жүктеме 480 кг/с, ротордың айналу жылдамдығы 1450 айн/мин болды. Ұсақталатын материал ретінде сильвинит және гипс тасы пайдаланылды, материал бойынша жүктеме 480 кг/с, ротордың айналу жылдамдығы 1450 айн/мин болды. Алайда ұнтақтау сапасына биіктікті одан әрі ұлғайту аса әсер етпейді.

Түйін сөздер: материалды соққымен жүктеу, екпінді ортадан тепкіш диірмен, жойылу басының күрделі жылдамдығы, фракциялық құрамындағы бөлшектер массасының таралу медианы.

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КОМПЛЕКСНОЕ ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ ИЗМЕЛЬЧЕНИЯ МАТЕРИАЛА В УДАРНО-ЦЕНТРОБЕЖНОЙ МЕЛЬНИЦЕ

Аннотация. Процессы измельчения, являющиеся весьма распространенными и встречающимися практически в любой отросли промышленности и сельском хозяйстве, требуют больших энергетических затрат и сопряжены с безвозвратными потерями в связи с износом рабочих узлов измельчителей. Обще- признано, что снижение удельных затрат энергии возможно при использовании мельниц, в которых измельчение будет осуществляться в основном за счет ударного нагружения материала. В работе представлена схема установки по исследованию ударно-центробежной мельницы. В качестве материала для экспериментальных исследований использовались: гранулы извести после печи, размером $(2 – 8)\cdot10^{-3}$ м; гипсовый камень с размером частиц $(2 – 10)\cdot10^{-3}$ м; мел с размером частиц $(2 – 10)\cdot10^{-3}$ м; сильвинит с размером частиц $(2 – 15)\cdot10^{-3}$ м; кристаллы сульфата аммония с размером частиц $(2 – 8)\cdot10^{-3}$ м;зерно пшеницы и ячменя; гранулы аммофоса с размером частиц $(2 – 5)\cdot10^{-3}$ м; продукты пиролиза резинотехнических изделий $(2 – 5)\cdot10^{-3}$ м; нефтяной кокс Приведены результаты исследований процесса однократного ударного измельчения материалов различных физических и механических свойств в зависимости от скорости ударного нагружения и конструктивных особенностей измельчителя в ударно-центробежной мельнице. Представлены экспериментальные зависимости ударно-центробежного измельчения. Получены графические зависимости медианного распределения массы частиц измельченного материала в зависимости от числа лопаток. Число лопаток для данного диаметра ротора (0,4 м) составляло 4, 6, 8, 12 шт. Из графика видно, что при измельчении мела число лопаток не оказывает существенного влияния на качество помола. При измельчении сильвинита и в особенности гипсового камня с увеличением числа лопаток до 8 тонина помола улучшается, то есть медианный размер частиц уменьшается, однако при дальнейшем увеличении числа лопастей дисперсный состав продуктов остается практически постоянным. Дан анализ известным данным по теории ударного измельчения, на основании которых были сформированы принципы создания новых энергоэффективных машин для измельчения материалов, в частности для снижения энергозатрат. Исходя из проведенного анализа, была разработана конструкция ударно-центробежной мельницы. Влияние высоты лопаток на качество измельчения материала проводилось при ее изменении от 0,04 до 0,12 м. В качестве измельчаемого материала использовались сильвинит и гипсовый камень, нагрузка по материалу составляла 480 кг/ч, скорость вращения ротора – 1450 об/мин. Для обоих материалов увеличение высоты лопаток от 0,04 до 0,08 метра значительно улучшает качество помола, что изображено на рисунке 6. Однако дальнейшее увеличение высоты на качество помола существенного влияния не оказывает. Влияние высоты лопаток на качество измельчения материала проводилось при ее изменении от 0,04 до 0,12 м. В качестве измельчаемого материала использовались сильвинит и гипсовый камень, нагрузка по материалу составляла 480 кг/ч, скорость вращения ротора 1450 об/мин. Для обоих материалов увеличение высоты лопаток от 0,04 до 0,08 метра значительно улучшает качество помола. Однако дальнейшее увеличение высоты на качество помола существенного влияния не оказывает.

Ключевые слова: ударное нагружение материала, ударно-центробежная мельница, критическая скорость начала разрушения, фракционный состав медиана, распределение массы частиц.

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MONITORING OF DISPLACEMENTS OF OBJECTS OF TERRESTRIAL SURFACES BY INTERFEROMETRY METHOD

Abstract. Geomechanical monitoring is a system of observations of the state of the geological environment, the processes of displacement of rocks and the earth's surface, geomechanical and hydrodynamic processes in a rock mass, interpretation of the results of observations, the formation of judgments about the state of the rock mass as a whole and the forecast of parameters of stable slopes.

To determine the displacement of the earth's crust of the Akbakay field, the technology of terrestrial radar interferometry was used. Which is used by only a few research institutes and organizations in the world.

In satellite radar interferometry, the promptness to obtain an actual spatial information about the Earth's surface is an important requirement for modern Earth remote sensing data, along with high spatial resolution, as well as geometric accuracy. The operational efficiency is one of the main advantages of radar systems for remote sensing of the Earth or a system of instruments synthesized by radar.

Geomechanical monitoring and research on geodynamic polygons reveal wide opportunities for studying vertical movements of the earth's crust.

In this work, the most important point is the scanning of the terrain and objects around the scanner standing point, i.e. Scanning special marks with the maximum resolution, which allows you to get a cloud of points.

Key words: Geomechanical monitoring, Space monitoring, geodynamic polygon, crustal movements, remote sensing of the Earth, interferometry, artificial earth satellite, rapper, digital model.

Introduction. On the territory of the Republic of Kazakhstan, developed and further developing industry sufficient number of such man-made systems and ties with this in parallel, the question of man-made disasters is raised. The increase in various risks are given a lot of attention everywhere, as evidenced by the increased number of risks. publications on the subject, including in mining countries. [1].

President Of The Republic Of Kazakhstan N. A. Nazarbayev in the missive to the people "The way of Kazakhstan-2050" within the framework of the program of industrial-innovative development set a task to create a leading school in the field of effective deposits development in The Nazarbayev University and signed convention. This vision of the head of State shows the importance of the mining industry in the further development of the country. With increasing depth of mining safe mining operations have the influence of the movement of rocks and the earth's surface, mountain pressure and mountain shocks.

Besides, at reconstruction of old mines development of temporarily left Tselikov, especially during transition from open to underground methods of working out, questions of movement rocks and protection facilities are becoming important for many mining enterprises'. The complexity of these issues lies in the fact that many of them is necessary to solve during the design and construction of mining enterprises, when there are often no reliable data on the deposits nature and the parameters of the process of moving rocks. It was during this period set the borders project of threat zones of displacement, choose the Foundation place of the mine shafts,construction of industrial facilities and residential settlements, expect safety pillars or provide other measures for the protection of buildings and mountain productions'.

At present, has formed two main areas, which are under being a study of this issue: mining pressure and the actual displacement of the mountain rocks and the earth's surface. In the first direction are studied mainly conditions stability, deformation and displacement of rocks surrounding In the second direction, the earth's surface and intermediate displacement are studied the strata of rocks with the aim of establishing the measures for the protection of buildings and in e workings from the harmful effects of underground mining. Studies in this case are carried out mainly by setting instrumental observations of the earth's surface displacement.

The results of observations on the gold deposits of Kazakhstan has repeatedly were used at drawing up Instructions on protection of constructions for fields with unexplored nature of the movement of rocks. Later in Kazakhstan was held a monitoring of the displacement of KazNTU – on ore deposits as a result of which a number of Instructions on protection were made facilities for various mines. In this regard, the scientific works of the above-mentioned scientists re analyzed, taken into account the results of large-scale studies on the problem of studying the process of development of ore deposits, including the open-underground method of development. One of them is the research carried out at the mine Akbakay [2].

Initial data and research methods. The rapid development of science and technology the past 10-15 years, led to the birth a new method for determining the coordinates in geodesy and surveying - satellite system. The use of the satellite system for geomechanical monitoring is based on three the main directions. The first direction is connected with the construction and reconstruction of support structures surveying networks on the earth's surface and areas of open mining. The second direction-the implementation of surveying surveys surface and communications in the fields of downhole production of hydrocarbons, open mine excavations, dumps, tailings, as well as filming engineering constructions'.

Conducting geodetic observations is based on a system of constant base stations.

They collect GPS information- receivers or GNSS receivers and the Rover in RTK mode (the actual time) is introduced amendments. Geodetic works on supervision are carried out by means of mobile (temporary) base and permanent base stations [1].

Results of the study and discussion. Based on the GPS measurements surveying service to the mine Abai were provided with reference points (earlier and new) whose coordinates are determined with high accuracy [Sultanguzin U.M., Aubakirov T.O., Musabaev T.A i dr. Kosmicheskie issledovanija v Kazahstane, Almaty: ROND, 2002]. The scheme of location of strong points and shooting on the field "." is shown in figure 1 and coordinates in table 1.

1. Using the results of satellite definitions in the field of geodesy is not ends, because with each passing day, improved technology and equipment, accordingly, the scope of their use is expanding. [11]

The emergence in recent times of surveying and geodetic practice of modern devices, in the form of 3D scanners, allows you to study in detail the elements of occurrence surfaces of attenuations and inaccessible locations. In the conduct of geomechanical monitoring, the study of vertical and horizontal the earth surface displacement finds wide applicable scope radar interferometry method. Currently, there are two methods of radar interferometry: satellite and ground. In satellite radar interferometry, the efficiency of obtaining the actual spatial information about the earth's surface is an important requirement, applied to modern data of remote sensing of the Earth (remote sensing), along with high spatial resolution as well as geometric accuracy. Exactly efficiency is one of the main advantages of radar systems of remote sensing or synthesized radar equipment (SAR) systems [4]. Thanks to the microwave radio band used in radar, the data serve as a unique source information about the earth's surface. Space radar monitoring of subsidence, caused by the development of deposits, successfully carried out abroad and in Kazakhstan.

In the fields of geodetic observations are carried out twice a year (spring and in autumn) and additional seismological measurements are carried out. For obtaining reliable data must be carried out simultaneously with geodetic observations in monitoring mode space radar interferometric survey areas of deposits, which allows to regularly receive the field of displacement of the earth surfaces with high precision [21].

The main methods of carrying out geomechanical observations on the Akbakay field were:

1. Geomechanical monitoring;
2. Space interferometric monitoring;
3. Instrumental monitoring.

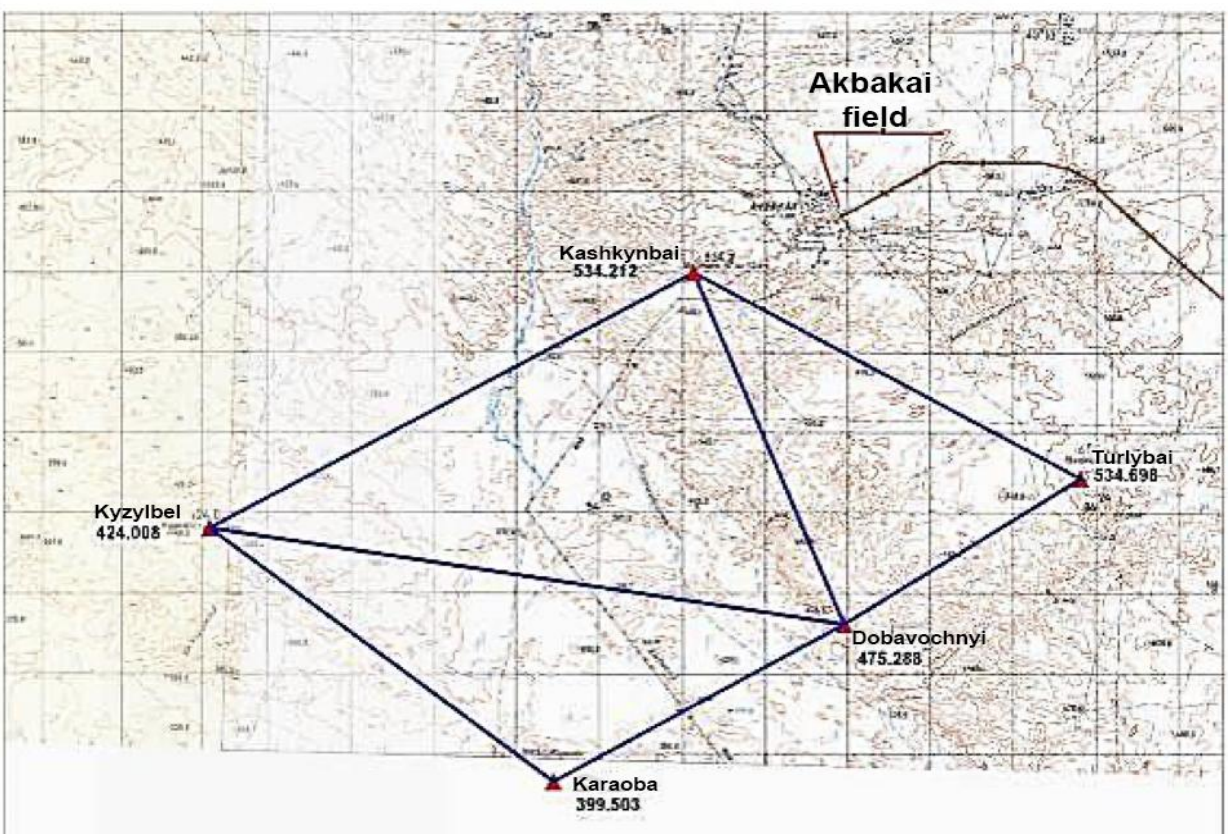

Figure 1 – Location outline of geodetic network points and survey points

The Catalogue of coordinates points

Points	Coordinates		
	X	Y	H
Turlybai	4993455,446	323687,609	534,698
Kashkynbai	4998214,446	314456,909	534,212
Kyzylbel	4991708,246	302559,769	424,008
Karaoba	4985882,546	310687,379	399,503
Dobavochnyi	4989490,346	317564,379	475,288

Recently the increasing distribution for determination of vertical and horizontal displacements of the land surface is received by methods of the space radar interferometry (SRI) in which amplitude and a phase, the radio signal reflected from a surface is fixed.

The basic advantage of a space radar interferometry before other methods of vertical and planned deformations monitoring of the land surface consists in direct measurement of the diversity in a relief which occurred for the period between two (three, four) space shootings occurring at different times.

The file of shifts received as a result of interferometric processing displays the happened changes of the studied land surface relief resulted from various natural and technogenic processes.

The interferometric technique of land surface motions monitoring assumes existence of couple of SAR the images removed from two relatives, but the parallel orbits of the spacecraft carried on time, locally.

Each radar image of interferometric couple (or chain) contains an amplitude and phase layer. The amplitude layer is more suitable for the visual analysis. The resulting phase F, received during interferometric processing of phase layers images of interferometric couple, consists of the following components [10]:

$$F = F_{topo} + F_{def} + F_{atm} + F_n$$

where: F_{topo} – phase incursion due to survey of a topography under two different corners; F_{def} – phase incursion due to surface shift during the period between shootings; F_{atm} – phase incursion due to lengths distinction of optical paths because of refraction in the environment of a signal distribution; F_n – phase variations as a result of electromagnetic noise.

For interferofram creation on couple of radar space pictures the license software products (Gamma, D-InSAR (ERDAS), PhotomodRadar, SARscape (Envi), etc) allowing to create high-precision and multi-scale digital models of a relief and also a number of the specialized maps displaying the quantitative and qualitative information about stability of the land surface.

As a result of the carried-out surveys there was created a shifts map of the land surface of the Akbakaysky mine territory on which there was registrated shifts of soils and grounds in a sag trough up to 5 cm (figure 2).

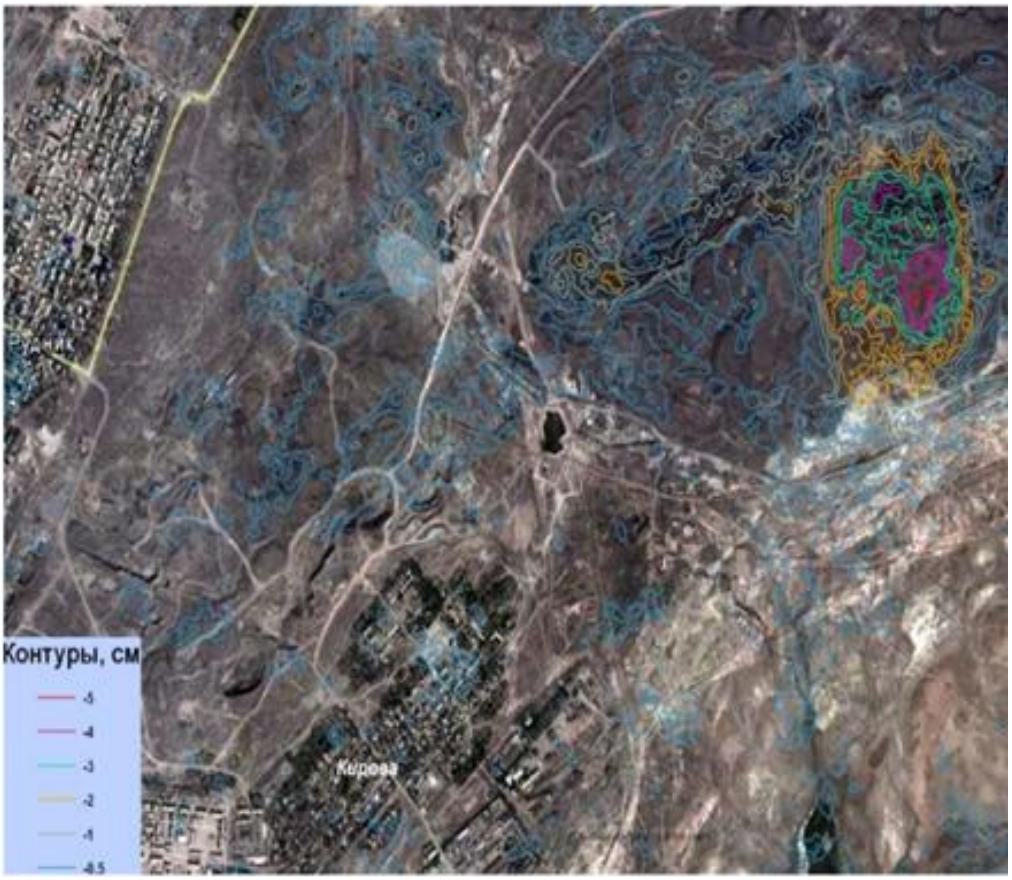

Figure 2 – Map of the land surface of the Akbakay mine territory
on which there was registrated

Based on the processing of radar images obtained by the space Agency from artificial earth satellites (ISZ), defined vertical movement of the territory the object and the assessment of its state (figure 3).

Figure 3 – Space the field "Akbakay" used in interferometry

Radar interferometry makes it possible to work with data obtained by remote sensing, creation of three-dimensional models, sections and profiles of terrain According to the results of space radar observations, a number of local foci were established sedimentation of the earth's surface over areas of underground mining. Currently on this areas of land being land-based observations. Such geomechanical observations and researches on geodynamic polygons opens wide opportunities to study the vertical movements of the earth's crust. The advantages of space monitoring are, first of all, its greater productivity compared with traditional geodetic survey. Cosmic monitoring shows in advance of settling of a surface over the developed space (coverage area up to 3000 sq.km). The method does not require large economic costs, no need for field surveying work. Radar images obtained from ISS depending on the type of spacecraft change within 11 to 45 days (figure 4).

Figure 4 – Space image of "Akbakay" field received from LandSat satellite

There are two types (seismic and cosmic) of monitioring Seismic monitoring can provide information that is short-term harbinger of the impending destruction of rocks in local areas. Space monitoring provides information on long-term processes, flowing both in the local areas of observation and in a large area. The that way, they complement each other [3].

The shift (sag) zone of the land surface received on the technology using data of the radar spacecraft TerraSAR-X having high spatial resolution has more detailed parts and more precisely displays trough contours

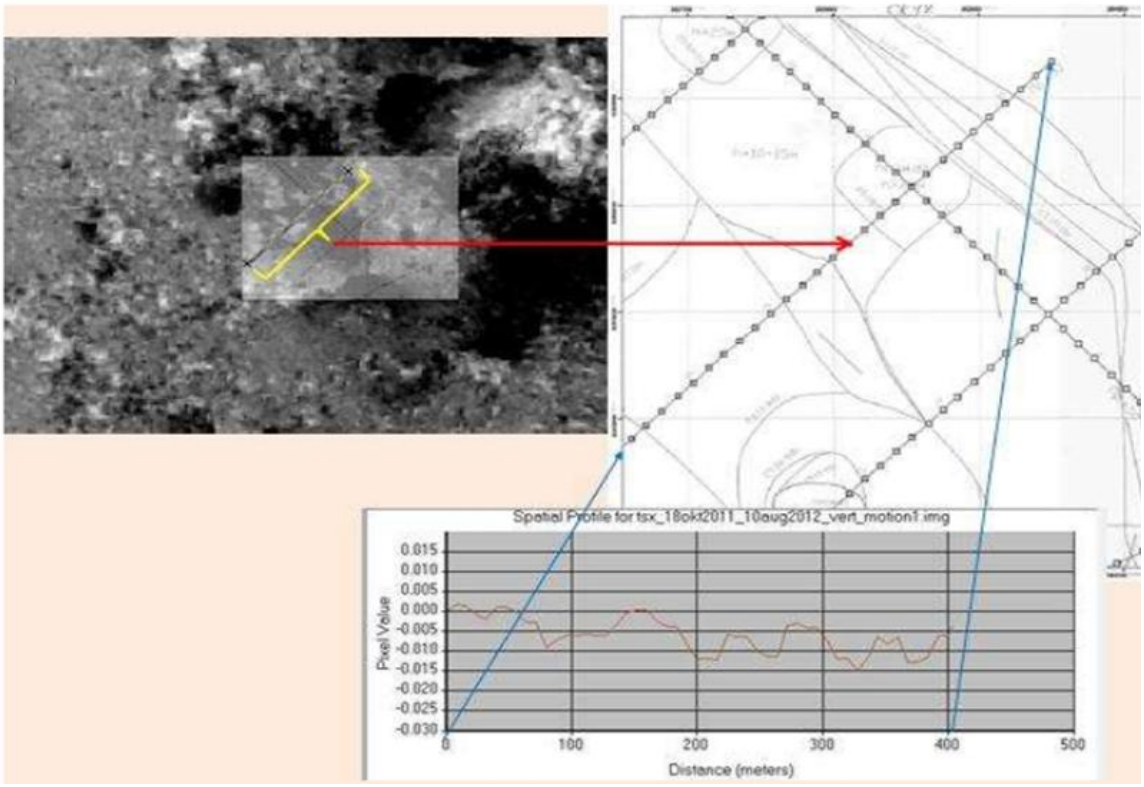

Figure 5 – Comparison of results lifting of the land surface, received by method of a differential interferometry and land measurements

The comparative analysis of differential interferometry results and comparison of the results of the land surface lifting received by a differential interferometry method with data of surveying measurements during 2011-2016 on a profile showed rather high correlation. There is a arrangement scheme of a profile on the resulting map of shifts received from interferometric measurements and size of shifts along this profile in the (Figure 5).

According to interferometric measurements in a reference point point 27, absolute value of the land surface sag was 0.8 cm since October, 2014 till August, 2015, and on land measurements this value is equal to 1 cm.

Summary. The third direction is the implementation of a systematic surveying observations of the earth's surface displacement and deformations of building elements and constructions'. Currently, GPS-monitoring is successfully conducted on a number of large enterprises of mining complex of the Republic of Kazakhstan. In General, in the process of the providing the region with basic stations and adjustment of "permanent" strong points call out a number of difficulties. Therefore, the geodynamic polygons and mines to conduct geomechanical monitoring using modern surveying instruments, new technologies and software product.

Cooperation with geodetic observations is also useful when identified the areas vulnerable to subsidence of the ground surface, and required more precision observations with real-time results, since space data monitoring require longer processing times. The main advantage is the possibility space-based

monitoring coverage of significant areas. At the field Aqbaqay observation station is about 500 frames. Shooting is carried out one once a year at every point where the rapper is laid. In the best case manage to hold 2 measurements per year on all lines and thus obtain information on offsets from interval 1 year 6 months. During this time, the collapse may develop, and it is impossible predict. According to the results of space radar surveys, data on the earth's displacements the surfaces are delivered to us every month.

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ЖЕР БЕТІНДЕГІ ОБЪЕКТІНІҢ ЖЫЛЖУЫН ИНТЕРФЕРОМЕТРИЯЛЫҚ ӘДІСПЕН МОНИТОРИНГТЕУ

Аннотация. Геомеханикалық мониторинг жүргізу – геологиялық орта жағдайын бақылау жүйесі, тау жынысы мен жер бетінің жылжу үдерістері, тау жыныстары массивіндегі геомеханикалық және геодинамикалық үдерістер, орындалған бақылау интерпретациясы, жалпы массив жағдайын топтастыру және берік кемер параметрлерін болжау.

Ақбақай кен орнындағы жер қыртысының жылжу жағдайын анықтау үшін жердегі радар интерферометриясы қолданылады. Бұл технологиясы әлемдегі бірнеше ғылыми-зерттеу институттары мен ұйымдары ғана қолданады.

Спутниктік радарлы интерферометрияда ағымдағы жердің беті жайлы кеңістіктік ақпарат алудың жылдамдығы, сонымен қатар кеңістіктік ажыратымдылық мен геометриялық дәлдік – жерді қашықтықтан зондтауға қойылатын маңызды талап. Жерді қашықтықтан зондтау немесе синтезделген радарлы аппараттық жүйедегі радиолокациялық жүйе артықшылықтарының бірі жылдамдық болып саналады.

Геомеханикалық мониторинг және геодинамикалық полигондар жөніндегі зерттеулер жер қыртысының тік қозғалысын зерттеу үшін мол мүмкіндік береді.

Жұмыстың маңызды қыры – сканер айналасында тұрған жер мен объектілерді сканерлеу. Арнайы маркаларды жоғары дәлдікпен сканерлеу нүкте бұлтын алуға мүмкіндік береді. Жер қыртысының жылжу жағдайын анықтау үшін жердегі радарлы интерферометрия қолдану технологиясын әлемдегі бірнеше ғылыми-зерттеу институттары мен ұйымдары ғана қолданады.

Жерсеріктік радарлы интерферометрияда жербеті туралы өзекті кеңістіктік ақпаратты алу жеделдігі жоғары кеңістіктік ажыратымдықпен, сондай-ақ геометриялық дәлдікпен қатар жерді қашықтықтан зондтаудың қазіргі заманғы деректеріне қойылатын маңызды талап болып саналады. Дәл осы шапшаңдық жерді қашықтан зондтаудың радиолокациялық жүйесінің немесе жүйенің синтезделген радар аппаратурасының негізгі артықшылықтарының бірі болып саналады.

Геомеханикалық мониторинг және геодинамикалық полигондардағы зерттеулер жер қыртысының тік қозғалысын зерттеуге мол мүмкіндік береді. Радиолокацияда қолданылатын микротолқынды радиодиапазон арқасында деректер жер беті туралы бірегей ақпарат көзі болып саналады. Кен орындарын игеруден туған отырыстардың ғарыштық радиолокациялық мониторингі шетелде және Қазақстанда табысты жүзеге асырылады.

Кен орындарында геодезиялық бақылау жылына екі рет (көктемде және күзде) жүргізіледі және қосымша сейсмологиялық өлшемдер жүргізіледі. Сенімді деректерді алу үшін геодезиялық бақылаумен бір уақытта жоғары дәлдікпен жер бетінің жылжу алаңын тұрақты алуға мүмкіндік беретін кен орындары аумағының ғарыштық радиолокациялы интерферометриялық түсірілімін мониторингтік режимде жүргізу қажет.

Жердің жасанды серіктерінен (ЖҚЗ) ғарыш агенттігі арқылы алынған радарлық суреттерді өңдеу негізінде объект аумағының тік жылжығаны анықталды және оның жай-күйіне баға берілді.

Радарлық интерферометрия ЖҚЗ алынған мәліметтермен жұмыс істеуге, үшөлшемді модельдерді, тіліктер мен жергілікті жер профильдерін құруға мүмкіндік береді. Ғарыштық радарлы бақылау нәтижелері бойынша жер беті жерасты өндіру учаскелерінің үстінен бірқатар шөккен жергілікті ошағы белгіленген. Қазіргі уақытта осы учаскеде жер бетіне бақылау жүргізілуде. Геодинамикалық полигондардағы мұндай геомеханикалық бақылау мен зерттеулер жер қыртысының тік қозғалысын зерттеуге жағдай тудырады.

Ғарыштық мониторинг артықшылықтары, ең алдымен, дәстүрлі геодезиялық түсіріліммен салыстырғанда өнімді болып келеді. Ғарыш мониторингі игерілген кеңістік үстінде (аумақты 3000 шаршы метрге дейін қамту) жердің алдын ала шөккенін көрсетеді. Әдіс үлкен экономикалық шығынды талап етпейді, далалық геодезиялық жұмыстарға қажеттілік жоқ.

Түйін сөздер: геомеханикалық мониторинг, ғарыштық мониторинг, геодинамикалық полигон, жер қыртысының қозғалысы, жерді қашықтықтан зондтау, интерферометрия, жердің жасанды серігі, репер, сандық модель.

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МОНИТОРИНГ СДВИЖЕНИЙ ОБЪЕКТОВ ЗЕМНОЙ ПОВЕРХНОСТИ ИНТЕРФЕРОМЕТРИЧЕСКИМ МЕТОДОМ

Аннотация. Геомеханический мониторинг – это система наблюдений состояния геологической среды, процессов сдвижения горных пород и земной поверхности, геомеханических и гидродинамических процессов в массиве горных пород, интерпретация результатов наблюдений, формирование суждения о состоянии массива в целом и прогноз параметров устойчивых откосов.

Для определения сдвижения земной коры месторождения Акбакай применялась технология наземной радарной интерферометрии, которая применяется только несколькими научно-исследовательскими институтами и организациями в мире.

В спутниковой радарной интерферометрии оперативность получения актуальной пространственной информации о земной поверхности является важным требованием, предъявляемым к современным данным дистанционного зондирования Земли, наряду с высоким пространственным разрешением, а также геометрической точностью. Именно оперативность является одним из основных преимуществ радиолокационных систем дистанционного зондирования Земли или синтезированный радар системой аппаратур.

Геомеханические мониторинги и исследования на геодинамических полигонах раскрывают широкие возможности изучения вертикальных движений земной коры.

В этой работе самым ключевым моментом является сканирование местности и объектов вокруг точки стояния сканера, т.е. сканирование специальных марок с максимальным разрешением, что позволяет получить облака точек. Технология применения наземной радарной интерферометрии для определения сдвижения земной коры применяется только несколькими научно-исследовательскими институтами и организациями в мире.

В спутниковой радарной интерферометрии оперативность получения актуальной пространственной информации о земной поверхности является важным требованием, предъявляемым к современным данным дистанционного зондирования Земли, наряду с высоким пространственным разрешением, а также геометрической точностью. Именно оперативность является одним из основных преимуществ радиолокационных систем дистанционного зондирования Земли или синтезированной радар аппаратурой систем.

Геомеханические мониторинги и исследования на геодинамических полигонах раскрывает широкие возможности изучению вертикальных движений земной коры. Благодаря микроволновому радиодиапазону, используемому в радиолокации, данные служат источником уникальной информации о земной поверхности. Космический радиолокационный мониторинг просадок, вызванных разработкой месторождений, успешно осуществляется за рубежом и в Казахстане.

На месторождениях геодезические наблюдения ведутся два раза в год (весной и осенью) и проводятся дополнительные сейсмологические измерения. Для получения надежных данных необходимо одновременно с геодезическими наблюдениями вести в мониторинговом режиме космическую радиолокационную интерферометрическую съемку территорий месторождений, позволяющую регулярно получать поле смещений земной поверхности с высокой точностью.

На основе обработки радарных снимков, полученных космическим агентством из искусственных спутников Земли (ИСЗ), определены вертикальные сдвижения территории объекта и дана оценка ее состоянию.

Радарная интерферометрия создает возможность работать данными, полученных ДЗЗ, создания трехмерных моделей, разрезов и профилей местности. По результатам космических радарных наблюдений

установлен ряд локальных очагов оседаний земной поверхности над участками подземной добычи. В настоящее время на этом участке местности ведутся наземные наблюдения. Такие геомеханические наблюдения и исследования на геодинамических полигонах раскрывает широкие возможности изучению вертикальных движений земной коры.

Преимущества космического мониторинга состоят, прежде всего, в его большей производительности по сравнению с традиционной геодезической съёмкой. Космический мониторинг показывает заблаговременно оседания поверхности над выработанным пространством (охват территории до 3000 кв.м.). Метод не требует больших экономических затрат, нет необходимости в полевых геодезических работах.

Ключевые слова: геомеханический мониторинг, космический мониторинг, геодинамический полигон, движения земной коры, дистанционного зондирования Земли, интерферометрия, искусственный спутник Земли, репер, цифровой модель.

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MATHEMATICAL MODELING FORECASTING OF CONSEQUENCES OF DAMAGE BREAKTHROUGH

Abstract. The article is devoted to the development of a mathematical model for preventing a breakthrough of a dam and predict its possible consequences. In this work, the task of developing a single integrated approach to ensuring the safe operation of hydraulic structures, based on the notification of interested bodies in real time, was solved. A mathematical model of the state of the reservoir is developed, on the basis of which a hardware-software complex for operational notification of interested organizations (akimats) and local emergency departments is implemented. A mathematical model of predicting the consequences of a dam break is proposed. An algorithm for calculating the maximum level of the breakout wave has been formulated, taking into account many parameters of the hydraulic structures. The convergence of the developed algorithm in the form of a theorem has been proved. This method has a large practical focus, compared with existing formulas.

The Java language implements a hardware-software complex (PAC) for predicting the effects of a dam break, consisting of the following modules: 1) a module for receiving and transmitting current information about the water level, humidity and temperature on the crest of the dam; 2) a module for processing constant and operational information about the threat of dam breakthrough (server); 3) a module for predicting the effects of a dam break. Based on the solution of the model problem, the effectiveness of the developed hardware-software complex is shown. The practical basis for the model task was the events that took place in Kyzylagash village of Almaty region of the Republic of Kazakhstan.

Key words: mathematical modeling, flooding, dam, breach, breakthrough waves, water resources, water level, hydraulic structure, hardware-software complex.

Introduction. According to the report of the UN Commission, the damage from natural disasters, in particular floods, has only increased over the years, and economic losses from the consequences of floods lead to a decrease in gross domestic product. Over the past century, more than a thousand cases of destruction of hydraulic structures have occurred in the world, the causes of which, among the meteorological phenomena, were factors of a geological and geophysical nature.

Thus, the St. Francis dam in California was built 70 km from Los Angeles in the San Francisco canyon in order to accumulate water for its subsequent distribution through the Los Angeles water supply system. Under a wave wall of 40 m, all living things and buildings were destroyed. The valley was flooded for 80 km. More than 600 people died during this flood. The second example in Italy in 1963, a mountain massif collapsed in the Vayont reservoir, resulting in ~ 25 million tons of water overflowed through the dam, creating waves in the Piave river valley with a height of 70 m. 4 villages were destroyed, 4,400 people were killed [1-3].

The accident at the Sayano-Shushenskaya hydroelectric station was a man-made disaster that occurred on August 17, 2009. As a result of the accident, 75 people died, the equipment and the equipment and premises of the station were seriously damaged [4-6].

In Kazakhstan, the construction of many hydraulic structures was carried out in the 60-80s of the last century. Their survey today shows that the actual depreciation is more than 60%, the reliability and safety of strategically important hydraulic structures are sharply reduced [7-9].

The long service life and reduction in the last 20 years of funding for operating expenses, current and capital repairs, as well as the influence of climatic and seismic factors gradually lead to moral and physical deterioration of the entire complex of hydraulic structures. There are also objects located close to hazardous industries [10-12].

The tragic events in the spring of 2010 in the Almaty region and 2014 in the Karaganda region with human casualties and destruction, as well as floods in other regions of Kazakhstan, served as a serious lesson to prevent similar situations in the future. It is necessary to develop recommendations on equipping the hydraulic structures with modern monitoring systems, equipment and means to improve operational safety. Also, the recent events of May 1, 2020 on the breakthrough of the dam of the Sardobin reservoir (capacity of 922 million m3) in neighboring Uzbekistan led to the flooding of 4 villages in the Turkestan region of Kazakhstan. As a result, 620 houses were damaged and the region's agriculture was severely economically damaged [13, 14].

In this regard, research on the development of a mathematical model of dam breakout and the prediction of its consequences is relevant.

Mathematical model for predicting the consequences of a dam breakout. Catastrophic flooding, which is the result of a hydrodynamic accident, consists in the rapid flooding of the area by a breakout wave. Hydraulic structures can be breached due to natural forces (earthquake, hurricane, landslide, etc.), structural defects, violations of operating rules, impact of floods, destruction of the dam base, etc. During the breakthrough of the hydraulic structures, a gap (closure channel, passage) is formed, through which the water flows from the upper downstream to the lower one and the formation of a breakthrough wave. Breakthrough wave is the main striking factor of this type of accident, characterized by wave height and speed [15, 16].

In [17], it was found that the following hydroelectric complex parameters and the conditions of propagation of a breakthrough wave in the downstream most significantly affect the h_{max} values: reservoir volume before the accident (W_{water}), reservoir depth at the dam before the accident (H_0), roughness of the upstream wall (n_0), the amount of opening of the gap (B_{gap}), water flow in the downstream of the hydroelectric facility before the accident (Q_0), the distance from the damsite to the observation site (L). The dependence of the maximum flooding depth on the main influencing factors was obtained and presented in general form by the expression:

$$h_{max} = 2{,}51\frac{H_0^{0,98} n_0^{0,02} Q_0^{0,05}}{W_{water}^{0,05} L^{0,13}} \quad (1)$$

The limits of applicability of formula (1) are indicated: reservoir volume (W_{water}) – from 50 to 5000 thousand m^3; depth of water upstream of the dam (H_0) – from 2 to 20 m; water flow in the downstream of the hydraulic facility before the accident (Q_0) – from 1 to 100 m^3/s; reservoir length – from 0.8 to 2 km, if there is no backup from the downstream hydraulic structures; distance from the dam site to the considered section (L) from 0.5 to 50 km; roughness (n_0) from 0.02 to 0.2.

In addition, the formula (1) has the following disadvantages:

1) missing parameter –the amount of opening of the gap (B_{gap}),

2) the volume of the reservoir before the accident (W_{water}) is placed in the denominator, which leads to a contradiction to the basics of hydrology – "a larger volume of reservoir filling leads to a decrease in the breakthrough wave".

In [18], due to the limitations of the applicability of the formula (1), it was proposed to use the dependence (2) proposed by V.I. Volkov to determine the maximum depth of flooding:

$$h_{max} = 0{,}34 H_0 \left(\frac{L}{H_0}\right)^{-0,13} \quad (2)$$

As a disadvantage of the formula (2), it should be noted that it does not use such important parameters of the hydraulic structures as the reservoir volume before the accident (W_{water}), the amount of opening of the gap (B_{gap}). This fact greatly narrows the applicability of this formula.

To correct these shortcomings, the article proposes the following approach.

The maximum depth h_{max} is sought in the form

$$h_{max} = \alpha_0 B_{gap}^{\alpha_1} H_0^{\alpha_2} W_{water}^{\alpha_3} L^{-\alpha_4} \quad (3)$$

In the formula (3) all the coefficients $\boldsymbol{\alpha_i > 0, i = \overline{0,4}}$.

Let n = 4 be the number of information parameters of hydraulic structures that affect the size of the breakthrough wave; $x = (x_0, \dots, x_n)$ – the vector whose components characterize the hydraulic structures.

For the convenience of further calculations, we will accept

$$y = h_{max};\ x_0 = 1,\ x_1 = B_{gap};\ x_2 = H_0;\ x_3 = W_{water};\ x_4 = L.$$

We introduce the following designations:

m– the number of versions (situations); X_{ij} – the value of the i-th parameter in the j-th version, where $i = \overline{0,n}$, $j = \overline{1,m}$.

Y_j – maximum breakthrough wave depth in the j –th situation, where $j = \overline{1,m}$.

Then formula (3) can be rewritten in the form:

$$Y = \alpha_0 * \left(\prod_{k=1}^{3} x_k^{\alpha_k}\right) * x_4^{-\alpha_4} \quad (4)$$

Formula (4) corresponds to the optimization problem, where the coefficients α_k, are unknown, which determine the influence of the k–th information parameter on the overall result.

We will take the logarithm of the expression (4):

$$ln(Y) = \alpha_0 + \sum_{k=1}^{3} \alpha_k ln(x_k) - \alpha_4 ln(x_4) \quad (5)$$

The coefficients $\alpha_k$can be found from the minimum condition for the functional

$$S = \sum_{j=1}^{m} \left(ln(Y_j) - \alpha_0 - \sum_{k=1}^{3} \alpha_k ln(X_{kj}) + \alpha_4 ln(X_{4j})\right)^2 \quad (6)$$

We introduce the set

$$A = \{0 \le \alpha_i \le 10\} \quad (7)$$

It is easy to show that A is a convex closed set in R^m space.

The algorithm for finding the coefficients of functional (6).

Step 1. The minimum of functional (6) is found by the least square method, by reducing to a system of linear algebraic equations of the form

$$C\beta = d,$$

where C – (n+1)*(n+1) – the matrix, $d - (n + 1) -$ the vector made up of values

$$ln(Y_j), ln(X_{kj}), k = \overline{0,n}, j = \overline{1,m}.$$

If all elements of the vector $\beta_i > 0$,$= \overline{0,n}$, then we take $\alpha_i = \beta_i$, $i = \overline{0,n}$ and go to step 5.

Step 2. Denote by α_i^n the n-th approximation for calculating the coefficient α_i.

As a zero approximation, we select

$$\alpha_i^0 = \begin{cases} \beta_i, if \beta_i > 0 \\ \varepsilon, if \beta_i \le 0 \end{cases}.$$

Here $\varepsilon > 0$ – is a sufficiently small number.

Step 3. The minimum of the functional (6) is defined on the set (7).

Let's build an iterative process

$$\alpha_i^{n+1} = \Pi_A \left(\alpha_i^n - \gamma_n S'(\alpha_i^n)\right) \quad (8)$$

Here Π_A – projection operator onto the set A. The coefficients $\gamma_n \geq 0$, the determine the step length at the n-th stage, can be found from the condition

$$S(\quad \alpha_i^n - \gamma_n S'(\alpha_i^n)) = \min_{\gamma \in R} S\left(\alpha_i^n - \gamma S'\left(\alpha_i^{k,n}\right)\right)$$

or in the process of splitting the step.

Step 4. Discrepancy is sought $r = min_i\left(abs\left(\alpha_i^{n+1} - \alpha_i^n\right)\right)$.

If $r < \varepsilon$, then go to step 5. Otherwise, increase the iteration number and go to step 2.

Step 5. Algorithm completion.

The convergence of the proposed algorithm is provided by the following theorem.

Theorem 1. Let the set A be convex and closed. Then the sequence $\{\alpha_i^n\}$, defined by the formula (8) converges to the solution of the problem of minimizing the functional (6) on the set (7).

Proof. Since the set A is convex and closed, the functional (6) is convex and differentiable, then any limit point of the sequence $\{\alpha_i^n\}$ is the minimum point [19].

Based on the available information about the breakthroughs, 30 versions of parametric data were prepared. Based on this information, the following formula is obtained:

$$\mathrm{h_{max}} = 1{,}34 * H_0^{0,55} B_{gap}^{0,32} W_0^{0,04} L^{-1,4} \qquad (9)$$

In the formula (9), the volume of the reservoir (W_{water}) is measured in millions of m^3; the water depth in the upstream wall of the dam (H_0) is in m;the amount of opening of the gap (B_{gap}) – in m; the distance from the dam site to the observation site (L) - in km.

Model problem. All further calculations simulate the events that took place in the village of Kyzylagash of Almaty region on March 11 and 12, 2010. The 45-meter-high dam was designed to store 42 million cubic meters of water. On the night of March 10, the water level reached 30 million cubic meters. The next day, in the afternoon or in the evening, I can not say the exact time, the water level exceeded 40 million cubic meters. In other words, 15-16 million cubic meters of water was added to the Kyzylagash reservoir in 15-16 hours. The dam broke on March 11 at 10.30 p.m. Two hours later, the water gushed towards the village of Kyzylagash. The wave width of the mudflow was 1.6 kilometers, and the height was 3 to 4 meters. According to official figures, most of the village was severely damaged. 70% of the village of Kyzylagash was destroyed. The tragedy in Kyzylagash claimed the lives of 44 people.

Results. Based on the mathematical forecasting model, the situation for March 11-12, 2010 in the village of Kyzylagash was simulated. Table presents the chronicle of events. The first two columns provide information about the date and time. Information in columns 3 through 5 is obtained in automated mode. Based on the above proposed mathematical model, calculations were performed on the level of safety, reservoir occupancy and the expected overflow time over the dam crest (columns 6-8).

In the 6th column, the following security level encoding is adopted: 1 - low; 2 - safe; 3 - alarming; 4 – catastrophic.

The simulation results of a dam break

Date	Time	Waterlevel (m)	Temperature	Precipitation	Securitylevel	Water volume (cbm)	Time to overflow (hour)
1	2	3	4	5	6	7	8
11/03/2010	10.00	15	12		2	30 000,0	
	10.30	14.75	12		2	30 250,0	
	11.00	14.5	13		2	30 500,0	
	11.30	14.25	13		3	30 750,0	14.25
	12.00	14	13		3	31 000,0	14
	12.30	13.75	14		3	31 250,0	13.75
	13.00	13.5	14		3	31 500,0	13.50
	13.30	13.25	14		3	31 750,0	14.25

Table continuation

1	2	3	4	5	6	7	8
	14.00	13	15		3	32 000,0	13
	14.30	12.75	15		3	32 250,0	12.75
	15.00	12.5	15		3	32 500,0	12.50
	15.30	12.25	14	rain	3	32 750,0	11.75
	16.00	12	14	rain	3	33 000,0	11
	16.30	11.25	14	rain	3	33 750,0	10.25
	17.00	10.5	13	rain	3	34 500,0	9.30
	17.30	9.75	13	rain	3	35 250,0	8.75
	18.00	9	13	rain	3	36 000,0	8
	18.30	8.25	13	rain	3	36 750,0	7.25
	19.00	7.5	12	rain	3	37 500,0	6.50
	19.30	6.75	12	rain	3	38 250,0	5.75
	20.00	6	11	rain	3	39 000,0	5
	20.30	5.25	11	rain	3	39 750,0	4.25
	21.00	4.5	10	rain	4	40 500,0	3.50
	21.30	3,75	10	rain	4	41 250,0	3
	22.00	3	9		4	42 000,0	2.50
	22.30	2,5	9		4	42 500,0	2
	23.00	2	9		4	43 000,0	1.50
	23.30	1,5	8		4	43 500,0	1
12/03/2010	00.00	1	8		4	44 000,0	0.50
	00.30	0,5	7		4	44 500,0	0
	01.00	0	7		4	45 000,0	0
	01.30	0	6		4		

Figure 1 shows an hourly chart of the reservoir occupancy. As can be seen from table 1 and the graph in figure 1, the akimat (local administrations) and emergency authorities would have been alerted at 21.00 on March 11. According to the forecast time was still 3.5 hours before the tragedy. Victims could have been avoided.

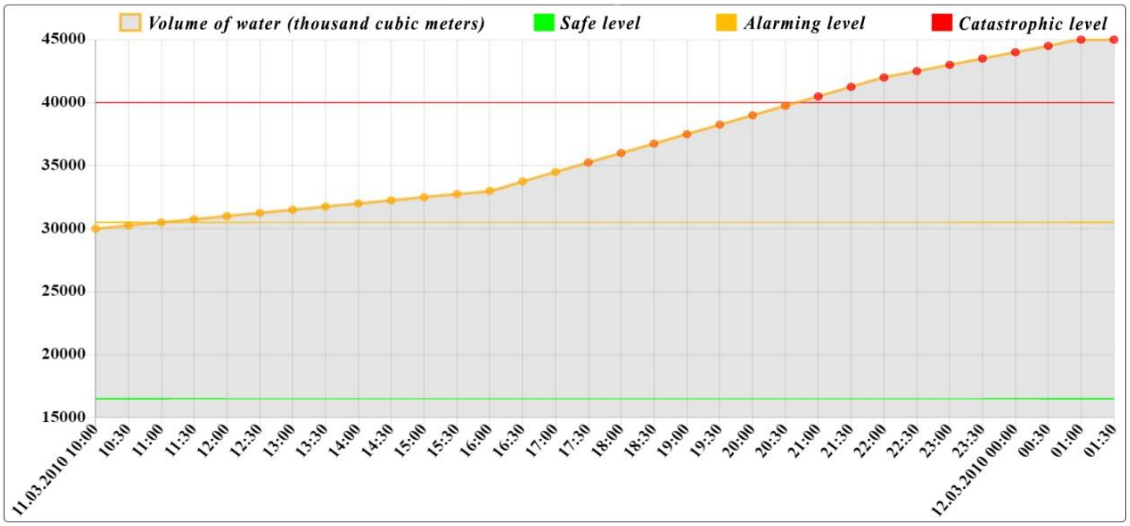

Figure 1 – Graph of fillability of a reservoir

Based on the formula (9), the situation was simulated in Kyzylagash village. Figure 2 shows a kilometer-long graph of the passage of a breakthrough wave.

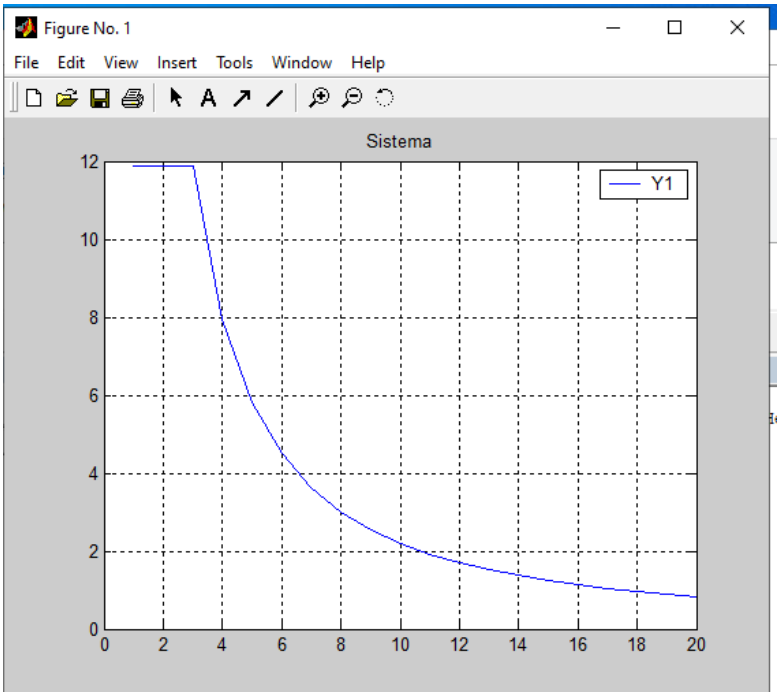

Figure 2 – Graph of maximum breakthrough wave in Kyzylagash village

As can be seen from the Figure, the wave of breakthrough came to Kyzylagash village reached a height of 4.5 meters. In Eginsu village, 16 km from the dam, the wave reached a height of about one meter.

Conclusion. This article has developed a mathematical model of monitoring the state of the reservoir and predicting the consequences of a dam break.

The model problem (events that took place in Kyzylagash village of the Almaty region of the Republic of Kazakhstan) shows the effectiveness of the developed mathematical model of predicting the consequences of a dam break.

The tragic events in the spring of 2010 in the Almaty region and in 2014 in the Karaganda region with human casualties and destruction, as well as floods in other regions of Kazakhstan, served as a serious lesson to prevent similar situations in the future. It is necessary to develop recommendations on equipping hydraulic structures with modern control and measuring devices, equipment and means to improve the safety of operation.

The practical significance of the work is to develop a system that provides current and forecast information that contributes to the correctness of decision-making at the territorial or republican level.

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БӨГЕТ БҰЗЫЛЫСЫНЫҢ САЛДАРЫН БОЛЖАУДЫҢ МАТЕМАТИКАЛЫҚ МОДЕЛІ

Аннотация. Мақала бөгеттің бұзылуына жол бермеу және оның ықтимал салдарын болжаудың математикалық моделін жасауға арналған. Осылайша қолданыстағы әртүрлі әдістерді талдау негізінде гидродинамикалық апатты төтенше жағдай ретінде болжау әдістерін жасау үшін зерттеудің мақсаты мен негізгі міндеттері тұжырымдалды. Бұл жұмыста шешімнің қолданыстағы әдістеріне талдау және зерттеу мақсаттарына тұжырым жасалды. Мәселе талданып және оны шешу барысында туындауы ықтимал негізгі проблемалар анықталған. Мәселенің жалпы сипаттамасы және зерттеу мақсаттарының тұжырымдамасы келтірілген. Сипатталған әдістердің артықшылықтары мен кемшіліктері көрсетілген. Математикалық модельдеудің заманауи технологияларын және есептеу нәтижелерін географиялық ақпараттық жүйеде көрсетумен қатар бөгет бұзылысының математикалық моделін зерттеумен есептеу тәжірибесін қолдана отырып, кешенді талдаудың, табиғи және техногендік сипаттағы төтенше жағдай салдарын болжаудың белгілі әдістеріне салыстырмалы талдау жасалды.

Климаттық мәліметтерді таратуға арналған автономды микрокомпьютерлік жүйе жасалды, нақты уақыт режимінде серпінді толқын факторларын болжау мәселесінің жалпы сипаттамасы мен міндеті келтірілген. Жерсеріктік деректерді беру жүйесінің дербес электрмен жабдықтау жүйесіне келесі энергияны пайдалану үшін энергия өндіруге және жинақтауға кіретін жабдықтар кешені кіреді. Су деңгейі өлшеу жабдықтары әртүрлі болуы мүмкін. Жүйе қызметін қамтамасыз ету үшін өлшеу құралдары деректерді берудің ішкі жүйесімен және электрмен жабдықтау жүйесімен байланыстырылады. Көрсетілген жүйелерді біріктіру орналасуы күрделі өзен көліндегі су деңгейін бақылауға мүмкіндік береді. Су деңгейін өлшейтін жабдық түрлі кезеңдік сенсорлардан мәліметтерді алуы керек. Жиналған мәліметтер ситуациялық орталықтарға жіберіліп, арнайы қызметтер ықтимал су тасқыны мен су тасқынын болжау, су шығынын есептеу және басқа мақсаттар үшін пайдаланады.

Бөгеттердің сипаттамалары, микропроцессорлық технологияны қолдануға негізделген қазіргі заманғы басқару жүйелерінің мүмкіндіктері талданады.

Су қоймасының жағдайын бақылаудың математикалық моделі жасалды, оның негізінде мүдделі ұйымдарды (әкімдіктер) және жергілікті төтенше жағдай бөлімдерін жедел хабарлау үшін аппараттық-бағдарламалық кешен енгізілді. Талдау келесідей қорытынды жасауға мүмкіндік береді: мүмкін гидродинамикалық апат салдарын болжаудың ұтымды әдісі – аналитикалық модельдерге негізделген қолданыстағы модельдеу бағдарламалық құралын пайдалану.

Математикалық модельдеу мен есептеу экспериментінің заманауи технологияларын пайдалана отырып, табиғи техногендік сипаттағы төтенше жағдай салдарын кешенді талдау, модельдеу және болжаудың белгілі әдістеріне салыстырмалы талдау жүргізіліп, нәтижелерді геоақпараттық жүйеде көрсете отырып және бөгет бұзылысының математикалық моделіне зерттеу жүргізілді. Тасқынның салдарын болжаудың түрлі математикалық модельдері, әдістері мен алгоритмдері сипатталған.

Бөгет бұзылысының әсерін болжаудың математикалық моделі ұсынылған. Гидравликалық құрылымдардың көптеген параметрлерін ескере отырып, серпінді толқынның максималды деңгейін есептеу алгоритмі тұжырымдалған. Әзірленген алгоритмнің теорема түріндегі жинақтылығы дәлелденді. Бұл әдіс қолданыстағы формулалармен салыстырғанда үлкен практикалық бағытқа ие.

Java тілі бөгет бұзылысының әсерін болжауға арналған бағдарламалық-аппараттық кешенді (БАК) жүзеге асырды. Ол келесі модульдерден тұрады:

1) бөгет бағанасындағы су деңгейі, ылғалдылығы мен температурасы туралы ағымдағы ақпаратты алуға және жіберуге арналған модуль;

2) бөгеттің бұзылу қаупі туралы тұрақты және жедел ақпаратты өңдеуге арналған модуль (сервер);

3) бөгет бұзылысының әсерін болжауға арналған модуль.

Модельдік есепті шешудің негізінде әзірленген аппараттық-бағдарламалық кешеннің тиімділігі көрсетілген. Модельдік есептің практикалық негізі ретінде Қазақстан Республикасы Алматы облысының Қызылағаш ауылында болған апатты оқиға алынды.

Түйін сөздер: математикалық модельдеу, су басу, бөгет, бұзу, серпінді толқындар, су ресурстары, су деңгейі, гидротехникалық құрылым, аппараттық-бағдарламалық кешен.

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПРОГНОЗИРОВАНИЯ ПОСЛЕДСТВИЙ ПРОРЫВА ДАМБЫ

Аннотация. Статья посвящена разработке математической модели предупреждения прорыва плотины и прогнозированию возможных его последствий. Таким образом, на основании проведенного анализа различных существующих методов были сформулированы цель и основные задачи исследований, направленных на разработку методики прогнозирования гидродинамической аварии как чрезвычайной ситуации. В данном исследований проведен анализ существующих методов решений и формулировка задач исследования. Проанализирована задача и выявлены основные проблемы, которые могут возникнуть в ходе ее решения. Приведена общая характеристика проблемы и постановка задач исследования. Выделены достоинства и недостатки описанных методов. Выполнен сравнительный анализ известных методов для комплексного анализа, прогнозирования последствий чрезвычайных ситуаций природного и техногенного характера с применением современных технологий математического моделирования и вычислительного эксперимента с отображением результатов в географической информационной системе и исследование математической модели прорыва дамбы.

Разработана автономная микрокомпьютерная система передачи климатических данных, приведена общая характеристика и постановка задачи прогнозирования факторов прорывных волн в реальном масштабе времени. Автономная подсистема энергоснабжения для спутниковых систем передачи данных включает в себя комплекс оборудования, функции которого заключаются в выработке и накоплении энергии для последующего его использования в целях обеспечения электропитания оборудования передачи данных. Оборудование измерений уровня воды может быть различным. Для обеспечения функционирования системы измерительное оборудование будет сопрягаться с подсистемой передачи данных и подсистемой энергообеспечения. Сопряжение указанных систем позволит осуществлять мониторинг уровня воды в моренных озерах, расположение которых является крайне труднодоступным. Технические средства, измеряющие уровень воды, должны быть способны получать данные с датчиков с различной периодичностью. Накапливаемые данные будут передаваться в ситуационные центры и использоваться специальными службами для прогнозирования возможных паводков и наводнений, подсчета расхода воды и в прочих целях.

Проанализированы характеристики плотин, возможности современных систем контроля, основанных на применение микропроцессорной техники.

Разработана математическая модель мониторинга состояния водохранилища, на основе которой реализован аппаратно-программный комплекс оперативного оповещения заинтересованных организаций (акиматов) и местных подразделений ЧС. Проведённый анализ позволяет сделать следующие выводы: рациональным способом прогнозирования последствий возможных гидродинамических аварий является применение существующих имитационных программных инструментов на основе аналитических моделей.

Выполнен сравнительный анализ известных методов для комплексного анализа, моделирования и прогнозирования последствий ЧС природного техногенного характера с применением современных технологий математического моделирования и вычислительного эксперимента с отображением результатов в географической информационной системе и исследование математической модели прорыва дамбы. Описаны различные математические модели, методы и алгоритмы для прогнозирования последствий наводнений.

Предложена математическая модель прогнозирования последствий прорыва плотины. Сформулирован алгоритм вычисления максимального уровня волны прорыва, учитывающий множество параметров гидротехнических сооружений. Доказана сходимость разработанного алгоритма в виде теоремы. Данный метод имеет большую практическую направленность по сравнению с имеющимися формулами.

На языке Java реализован аппаратно-программный комплекс мониторинга и прогнозирования последствий прорыва плотины, состоящий из следующих модулей: 1) модуль получения и передачи текущей информации об уровне воды, влажности и температуры на гребне плотины; 2) модуль обработки постоянной и оперативной информации об угрозе прорыва плотины (сервер); 3) модуль прогнозирования последствий прорыва плотины.

На основе решения модельной задачи показана эффективность разработанной программы. Практической основой для модельной задача послужили события, произошедшие в с.Кызылагаш Алматинской области Республики Казахстан.

Ключевые слова: математическое моделирование, наводнение, плотина, проран, волны прорыва, водные ресурсы, уровень воды, гидротехническое сооружение, программно-аппаратный комплекс.

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DEVELOPMENT OF THE TECHNOLOGICAL PROCESS OF ROLLING BARS IN THE NEW DESIGN RADIAL SHEAR MILL BY USING PHYSICAL MODELING

Abstract. A new design radial shear mill (RSM) which allows us obtaining high quality rods and wires by combining rolling and pressing is presented in this article. Physical modeling of the technological process of rolling rods and wires at RSM with various processing modes was performed by using STD 812 torsion plastometer.

The change in the structure of aluminum alloy A5083 during multi-stage compression at various temperatures and strain rates is described with a single position. The impact of temperature-deformation processing conditions on the microstructure and micro-hardness of aluminum alloy A5083 while rolling at RSM is analyzed. Kinetics of growth and grain grinding are considered; the conditions for forming the fine-grained structure are mentioned. It is established that in the deformation temperature range of 200 ÷ 300 °C and strain rates of 1.0 and 30 s^{-1}, dynamic and static recrystallization proceeds in the structure of the aluminum alloy A5083, depending on the temperature-deformation processing conditions. In the article, it is proved that it is necessary to perform rolling of the workpieces on a RSM at a rolling temperature of 280-320 °C in order to ensure a fine-grained structure in bars out of A5083 alloy.

Key words: tensile torsion, torsion, experiment, structure, grains, mill, rolls, hardening, softening, recrystallization.

Introduction. Nowadays, it is common that various industries produce a certain amount of press products out of non-ferrous metals and alloys with small geometric dimensions (various profiles, rods, pipes, wires, etc.). With the purpose of producing such types of products, most of the technically developed countries produce and implement radial-shear rolling (RSP) [1,2], methods of continuous pressing of a new generation of Conform, Extrolling, Linex, as well as the methods of continuous casting, rolling and pressing of Castex and Caster [3-5] at a good scientific level. Furthermore, it should be noted that the equipment used in these technological processes own high mobility, flexibility, and relatively high productivity while manufacturing products of various nomenclatures despite the large number of changes in the technological process.

According to the authors of the article [6-9], a well-studied continuous process is the method of combined rolling and pressing (CRP). This opinion occurred due to the fact that the development of CRP installations with an optimal design and testing of rational modes of manufacturing bars and profiles out of non-ferrous metals and alloys were performed by studying this method in laboratory and industrial conditions. It should be noted that it is advantageous to use a continuous combined process of casting, rolling and pressing in the production [10-13] in order to decrease the number of metallurgical processes and reduce energy costs. Later, these methods might become innovative processes in mini-factories for the production of small batches of press products.

Thus, the analysis of technological processes of manufacturing press products indicated that they are effective according to both technological and economic indicators. However, most of the above mentioned

methods were not used and implemented properly in the industry, since the proposed technical solutions did not provide the industry with a stable process and did not create the necessary pressure for extruding the metal. At the same time, powerful shear deformations of the metal are not developed along the section of the workpiece, and, consequently, does not create conditions for a good investigation of the metal structure and for its property improvement.

It is known [14-17] that a set of experimental and industrial studies is required in order to develop a technology with the optimal temperature-deformation processing intervals. In this case, a certain amount of time is spent and certain materials are consumed. Therefore, for developing a technological process it is necessary to study and investigate various processing modes by using physical modeling and find rational modes that make it possible to manufacture products with a fine-grained structure as well as with high mechanical properties. The implementation of physical modeling can minimize the resource and time costs of the study in a significant way. Subsequently, physical modeling allows us to determine the rational temperature-deformation modes of rolling and pressing by a resource-saving way.

The objective set in our work was to develop a rational technology for hot pressing of rods out of aluminum alloy on a new design radial-shear mill (RSM) by using physical modeling.

Materials and methods of research. In this article, a new design of RSM was presented [18]. At this mill, the combination of hot screw rolling and pressing produces metal rods of small diameters or wire with a fine-grained structure.

Physical modeling was used for developing a rational technology for the hot deformation of rods and wires on a new design radial-shear mill. Operations of torsion and tensile torsion were implemented for physical modeling due to the fact that combined rolling and pressing processes in the proposed mill is carried out by rotational-translational movement of the workpiece. The impact of the temperature-strain parameters of the above mentioned combined process on the evolution of the grain structure of the aluminum alloy A5083 was investigated by using these operations.

STD 812 torsion plastometer was implemented for the physical modeling of hot plastic deformation of rods and wires on a new design radial-shear mill [19,20]. The samples were heated in an inductor. Aluminum alloy A5083 was chosen as the workpiece material. With the purpose of producing samples with a homogeneous and relatively coarse-grained structure, the initial bar stock with a diameter of 10 mm was subjected to homogenization annealing at the temperature of 470 °C and kept in this position for 30 hours.

In the manufacture of bars and wires at radial-shear mill, the main changing technological parameter is regarded to be the feed angle and the rolling angle. These indicators affect both speed and degree of deformation, as well as the processing temperature. Therefore, samples with the size of Ø16 × 210 mm manufactured out of annealed rods (length of the deformation zone is 60 mm) were deformed by torsion and tensile torsion at various strain rates. Testing procedure of the samples was carried out in vacuum. The samples were heated until the temperature reached 200, 300, and 400 °C at a rate of 5 °C/s and kept at this temperature for 250 s, then they were tested at a strain rate of 1.0 and 30 s^{-1}. After deformation, the samples were cooled at a rate of 20 °/s.

A universal microscope Neophot 32 (Karl Zeiss, Jena) (Germany) was used for conducting metallographic analysis. The Neophot 32 microscope is designed for metallographic microscopy and for making photographs.

The measurement of micro-hardness of the samples was performed according to the Vickers HV method on an automated micro-hardness tester of the American company INSTRON at a working load of 2.942 H and holding time of 10 seconds at the particular load.

Results and discussions. In this article, the obtained image of the microstructure of aluminum alloy A5083 in the cross section of the deformed rod was presented and demonstrated in Figures 1-4.

Based on the study of the microstructures of aluminum alloy A5083, it was established that:

- the initial structure has relatively unevenly distributed large grains with an average size of ~ 368 microns;

- samples deformed by the torsion with a strain rate of 1 s^{-1} at temperatures of 200 °C had a relatively coarse-grained structure in the central and surface zones of the sample (figure 1, a, b). The average grain size varied from 163 microns to 315 microns;

- an increase in the strain rate to 30 s^{-1} at a testing temperature of 200 °C led to an intensive decrease in grain sizes in the surface zone of the workpiece, while it had a relatively coarse-grained structure in the

central zone (figure 1, c,d). In these cases, the average grain size in the surface zone was 52 μm, and 253 μm in the central layers;

- torsion of the samples with a strain rate of 1 s^{-1} at a temperature of 300 °C also led to the formation of a different-grain structure (figure 2, a,b). The average grain size in the surface zone was 28 μm, and 57 μm in the central layers;

- testing the samples at the temperature of 300 °C, but with a strain rate of 30 s^{-1}, also contributed to the formation of a relatively different-grain structure (figure 2, c, d) with a change in the average grain size from 34 μm (surface zone) to 69 μm (central zone);

- deformation of samples at the temperature of 400 °C and with a strain rate of 1 and 30 s^{-1} led to the formation of a relatively coarse-grained structure (figure 3, a, b) with a range of grain sizes ranging from 263–271 μm (surface layer of the sample) and 293–302 μm (central zone of the sample);

- deformation of samples by the tensile torsion at the temperature of 200 °C with a strain rate of 1 s^{-1} led to the formation of a homogeneous and relatively coarse-grained structure with an average grain size of 62 μm (figure 4, a);

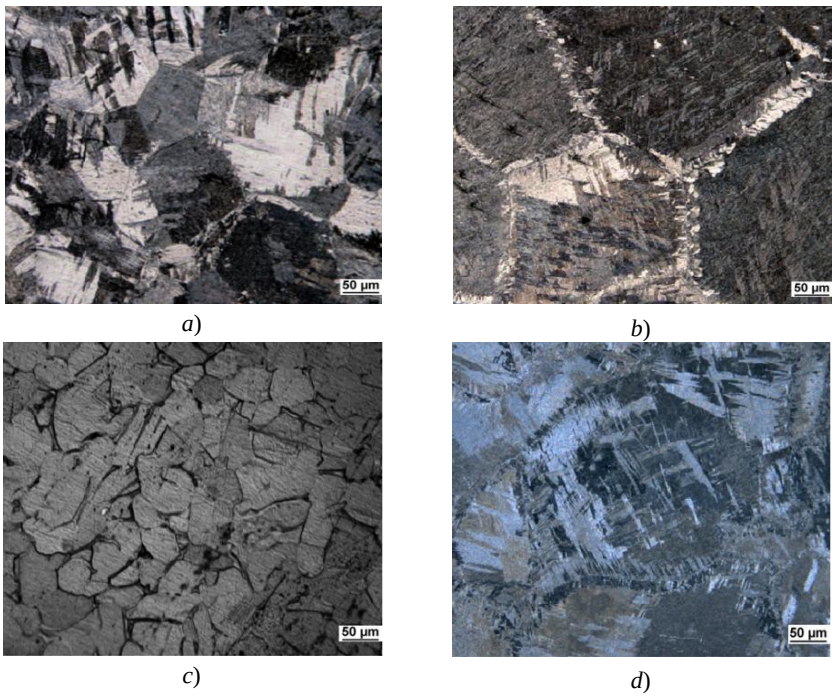
- an increase in the temperature to 200 °C and deformation at a speed of 30 s^{-1} made it possible to obtain a homogeneous and relatively fine-grained structure over the entire cross section of sample which is under testing with a grain size of 73 μm (figure 4, b);

- tensile torsion with a strain rate of 1 s^{-1} allowed us to obtain more homogeneous and relatively fine-grained structure in samples deformed at a temperature of 300 °C a with a grain size of 36 μm (figure 4, c);

- twisting tension at a temperature of 300 °C and deformation at the rate of 30 s^{-1} resulted in a homogeneous and relatively fine-grained structure over the entire cross section of the sample under testing. In this case, the average grain size was 18 μm (figure 4, d);

- tension with a torsion at the temperature of 400 °C and strain rates of 1 and 30 s^{-1} led to the formation of a relatively homogeneous and coarse-grained structure with a range of grain sizes from 182 - 211 μm across the sample cross section (figure 4, d).

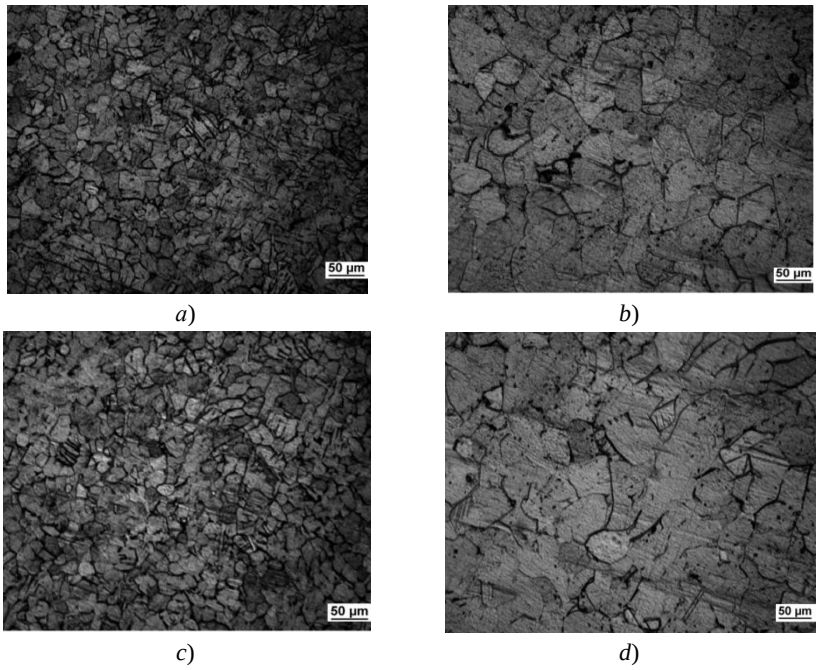
By comparing the obtained images of the structures, it can be seen that the strain by the torsion did not allow us to obtain a homogeneous refinement of the structure in the cross section of the rod. In the majority of cases, there are areas with a fine-grained structure in the surface layer of the sample, and larger grains which are visible in the central zones. We believe that the reason behind fragmentation of surface zones and preservation of coarse-grained structure in the center of the workpiece is the concentration of deformation degree in the surface zone of the workpiece during the deformation of sample by torsion.



a) *b*)

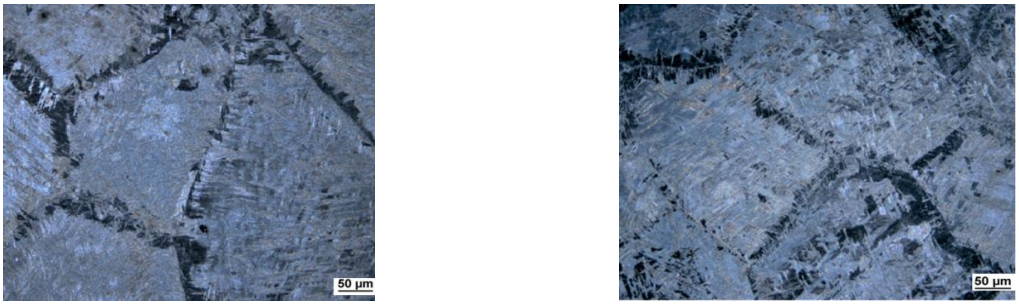
c) *d*)

Figure 1 – Microstructure of the surface and central zones of samples deformed by the torsion at the temperature of 200 °C. *a* - surface zone, 1 s^{-1}; *b* - central zone, 1 s^{-1}; *c* - surface zone, 30 s^{-1}; *d* - central zone, 30 s^{-1}



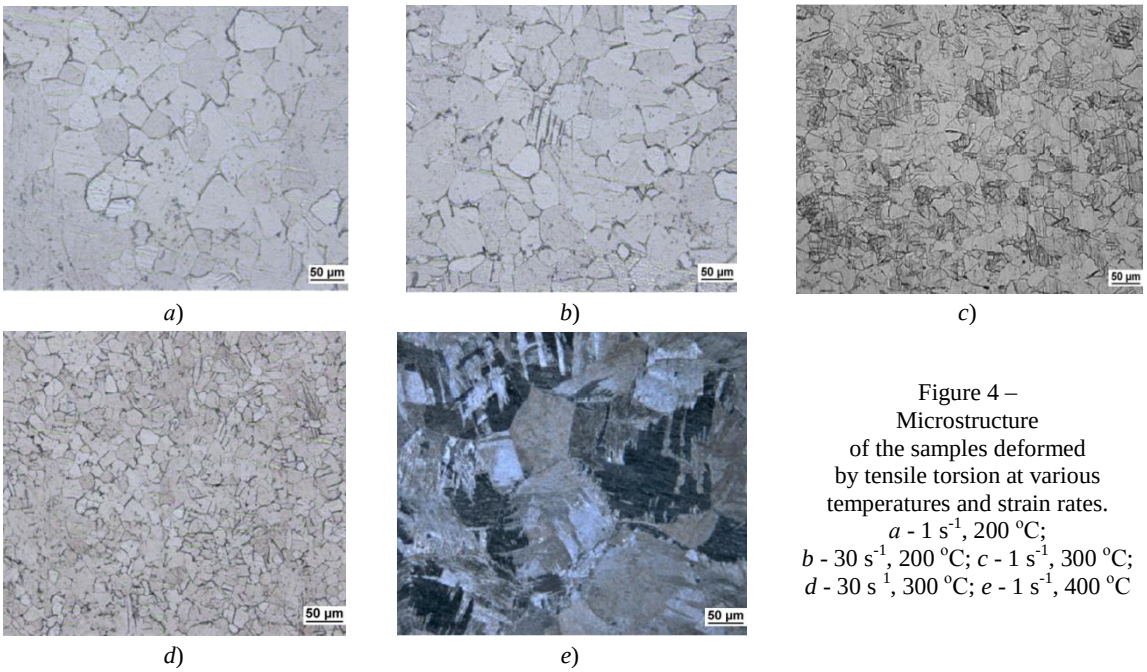
a) *b*) *c*) *d*)

Figure 2 – Microstructure of the surface and central zones of samples deformed by the torsion at the temperature of 300 °C. *a* - surface zone, 1 s^{-1}; *b* - central zone, 1 s^{-1}; *c* - surface zone, 30 s^{-1}; *d* - central zone, 30 s^{-1}



a) *b*)

Figure 3 – Microstructure of the surface and central zones of samples deformed by torsion with a strain rate of 1 s^{-1} (a) and 30 s^{-1} (b) at the temperature of 400 °C



a) *b*) *c*) *d*) *e*)

Figure 4 – Microstructure of the samples deformed by tensile torsion at various temperatures and strain rates. *a* - 1 s^{-1}, 200 ^{o}C; *b* - 30 s^{-1}, 200 ^{o}C; *c* - 1 s^{-1}, 300 ^{o}C; *d* - 30 s^{1}, 300 ^{o}C; *e* - 1 s^{-1}, 400 ^{o}C

It should be noted that such a difference in the formation of structures is particularly evident when samples are deformed by torsion with a strain rate of 1 s^{-1} at a testing temperature of 200 °C. The results of the experiment indicated that torsion of the samples under demonstrated temperature-strain conditions leads to a small thermal effect of plastic deformation. The temperature of the working part of the sample increases by 250 °C while compared to its initial temperature.

The results of metallographic studies indicated that hardening and softening processes take place mainly by the return and polygonization mechanism during a rise in temperature in the structure of the central zone of the sample. At the initial stage of deformation, a dynamic return occurs in the metal structure of the workpiece, and polygonization occurs with a continuous increase in stresses. Furthermore, unsteady polygonization takes place in the metal structure. Due to the unsteady process of polygonization in the metal structure, unequal grains and subgrains are formed in the sample with relatively large sizes. It should be noted that this temperature-velocity condition of deformation provides unsteady dynamic recrystallization taking place on the surface of the sample and structure which is formed with an average grain size.

The above mentioned research results indicate that structure is formed during the deformation of samples by torsion with temperature-speed conditions both at the temperature of 200 °C with a strain rate of 30 s^{-1}, and at the temperature of 300 °C with strain rates of 1 and 30 s^{-1} according to the above-described law. However, torsion of the sample at the temperature of 200 °C with a strain rate of 30 s^{-1} led to the greatest thermal effect of plastic deformation. The maximum temperature recorded in the working area of the sample was 530 °C. Based on these data, it can be noted that the temperature of the working area of the sample was increased by 330 °C. Such increase in temperature led to the occurrence of steady-state polygonization and recrystallization in the structure of the central and surface zones of the sample, respectively. We believe that the established polygonization and recrystallization took place in the structure of the central and surface zones of the sample in the case of torsional stress at a temperature of 300 °C with strain rates of 1 and 30 s^{-1} respectively. The occurrence of established polygonization and recrystallization at these temperature-strain rate deformations led to the formation of fine-grained structure in the surface zone of the workpiece and a medium-grained structure in the central zone of the workpiece.

It should be noted that the samples deformed by tensile torsion with a strain rate of 1 and 30 s^{-1} received a relatively large fragmentation of grains. Therefore, the microstructure of samples deformed by this type of deformation at the temperature of 200 and 300 °C has more finer-grained structure in comparison with samples deformed by torsion under the same temperature and speed conditions of testing. The reason behind the greater fragmentation of grains when tensile torsion is applied to the sample is the action on the rod of the torsion and additional tensile stress. The actions of such complex stress state lead to a more uniform distribution of the degree of deformation. It is known that a uniform distribution of the deformation degree leads to the formation of a homogeneous structure in the metal.

By analyzing the above mentioned data, it becomes clear that, regardless of the applied load, an increase in the testing temperature up to 400 °C leads to the formation of a coarse-grained structure due to the occurrence of secondary (collective) recrystallization.

Investigation of the micro-hardness of A5083 aluminum alloy deformed by the torsion and tensile torsion indicated that the hardness of the material in the surface layer is higher than on the rod axis. At the same time, the study of the laws of the distribution of micro-hardness in the cross section of samples deformed by the torsion or tensile torsion at various temperatures and strain rates indicated that the smaller the size of the fragmented grains of the structure, the greater the micro-hardness of the metal. Conversely, the larger the grain size, the lower the micro-hardness of the sample.

It should be noted that deformation of samples by the torsion or tensile torsion at the temperature of 400 °C led to the decrease in micro-hardness over the entire cross section of the sample, which is associated with the passage of secondary (collective) recrystallization in the metal structure.

Based on the obtained results, it can be concluded that the rolling should be carried out in the temperature range of 280 - 320 °C with a strain rate of 1 – 30 s^{-1} in order to obtain a fine-grained structure in bars or wires out of aluminum alloy A5083, deformed on a RSM of a new design. Furthermore, in the proposed mill, it is necessary to produce a load conducive to develop tensile or compressive torsion in the deformation zone. The load which facilitates deformation of the workpiece with the tensile torsion can be created by installing a coiler in front of the die. At the same time, the load allowing the workpiece being

deformed by compressive torsion can be produced by increasing the flow velocity of the rolled metal in the rolls, i.e. by backing up the metal in front of the matrix.

Conclusion. The combination of rolling and pressing on a new design radial-shear mill allows us to obtain uniform micro-hardness and fine-grained structure over the entire cross section of a cylindrical workpiece in the case of production of load contributing to the development of tensile or compressive torsion in the deformation zone.

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ҚҰРЫЛЫМЫ ЖАҢА РАДИАЛЬДЫ-ЫҒЫСТЫРУ ОРНАҒЫНДА ШЫБЫҚ ИЛЕМДЕУДІҢ ТЕХНОЛОГИЯЛЫҚ ҮДЕРІСІН ФИЗИКАЛЫҚ МОДЕЛЬДЕУ АРҚЫЛЫ ЖАСАУ

Аннотация. Мақалада құрылымы жаңа радиалды-ығыстыру орнағы (РЫО) ұсынылған. Шыбықтар мен сымтемірлерді баспақтау үшін қолданылатын радиальды-ығыстыру орнағы басты жетектен, жұмысшы қапастан, пішінбілік торабынан және баспақ-ұяқалыбынан тұрады. РЫО-ның үш пішінбілігі бар жұмысшы қапасы тұғырдың ішіне орналастырған. Осы тұғырдың ойығына 120^{o} бұрышпен жұмысшы пішінбіліктердің торабы жинақталған. Жұмысшы пішінбіліктер жастыққа жинақталған. Пішінбіліктерге айналу моменті біліктер арқылы электрқозғылтқыштардан беріледі. Осы орнақтың пішінбіліктері дайындаманы қарпитын және жаншитын толқынды-консуты бөлімге және мөлшерлейтін бөлімге иемденген. Толқынды-консуты бөлімнің шығыңқы және ойыңқы жерлері бұрандалы сызықпен орындалғаны жайында айта кеткен жөн. Осы кезде шығыңқы және ойыңқы жерлердің геометриялық өлшемі илемдеу бағытына қарай біртіндеп азаяды. Осы орнақта илемдеу мен баспақтауды біріктіру жолымен жоғары сапалы шыбықтар мен сымдарды алуға болады. STD 812 торсионды пластометрін қолдана отырып, РЫО шыбықтар мен сымдарды түрлі режимдермен өңдеудің технологиялық үдерісі физикалық модельдеу арқылы жасалды. Мақалада нақты позициямен түрлі температурада көптеген деформация жылдамдығымен А5083 алюминий қорытпасынан жасалған дайындаманы көпсатылы жаншығанда қорытпа құрылымындағы түйіршіктер өлшемінің өзгеру заңдылығы сипатталған. РЫО-да А5083 алюминий қорытпасынан жасалған шыбықтарды илемдеген кезде осы қорытпаның микроқұрылымына температура-деформацияның өңдеу режімі қандай заңдылықпен әсер ететіндігі талданған. Құрылым түйіршіктерінің өсуі мен майдалау кинетикасы жұмыста қарастырылған, ұсақ түйіршікті құрылымның қалыптасу жағдайы көрсетілген. 200-300 °С деформация температурасы мен 1,0 және 30 $с^{-1}$ деформация жылдамдығы диапазонында А5083 алюминий қорытпасынан жасалған шыбықты илемдегенде, температура-деформациялық өңдеу режіміне байланысты шыбық құрылымында динамикалық және статикалық қайта кристалданатыны анықталды. Жұмыста А5083 алюминий қорытпасынан жасалған шыбықта ұсақ түйіршігі құрылымды алу үшін оның дайындамасын РЫО-да 280-320 °С температура аралығында илемдеу қажеттігі дәлелденді. Осы жұмыста түрлі температура мен деформация жылдамдығы аралығында үлгілерді бұрау немесе созып бұраумен деформацияланғанда олардың көлденең қимасында микроқаттылықтың таралу заңдылықтары зерттелді. Металл құрылымның бөлшектелген түйіршіктерінің мөлшері неғұрлым кіші болса, металл микроқаттылығы да соғұрлым жоғары болатындығы мақалада көрсетілді. Жұмыста А5083 қорытпасынан жасалған бұйымдарда ұсақтүйіршікті құрылымды алуды қамтамасыз ету үшін оларды 280-320 ° С температура аралығында РЫО-да деформациялау қажеттілігі дәлелденді.

Түйін сөздер: созып бұрау, бұрау, тәжірибе, құрылым, түйіршік, орнақ, пішінбілік, беріктік, беріксіздік, қайтакристалдану, полигондау.

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РАЗРАБОТКА ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ПРОКАТКИ ПРУТКОВ НА РАДИАЛЬНО-СДВИГОВОМ СТАНЕ НОВОЙ КОНСТРУКЦИИ С ПОМОЩЬЮ ФИЗИЧЕСКОГО МОДЕЛИРОВАНИЯ

Аннотация. В данной статье предложен радиально-сдвиговый стан (РСС) новой конструкции, позволяющий совмещением прокатки и прессования получать прутки и проволоку высокого качества. РСС для прессования прутков и проволоки содержит главный привод, рабочую клеть, валковый узел и пресс-матрицу. Трехвалковая рабочая клеть РСС состоит из станины, в расточках которой через 120° смонтированы узлы рабочих валков. Рабочие валки смонтированы на подушках. Крутящий момент к валкам передается через шпиндели от электродвигателей. Валки данного стана имеют волнисто-конусообразные участки захвата и обжатия и калибрующий участок. Заметим, что выступы и впадины волнисто-конусообразных участков выполнены по винтовой линии. При этом геометрические размеры выступов и впадин постепенно уменьшаются в направлении прокатки. С использованием торсионного пластометра STD 812 произведено физическое моделирование технологического процесса прокатки прутков и проволоки на РСС новой конструкции с различными режимами обработки. С единой позиции описано изменение структуры алюминиевого сплава А5083 при многоступенчатом обжатии при различных температурах и скоростях деформирования. Проанализировано влияние температурно-деформационных режимов обработки на микроструктуру алюминиевого сплава А5083 при прокатке на РСС. Рассмотрена кинетика роста и измельчения зерен, отмечены условия образования мелкозернистой структуры. Установлено, что в диапазоне температур деформаций 200 ÷ 300 ^{o}C и скоростях деформации 1,0 и 30 c^{-1} в структуре алюминиевого сплава А5083 протекает динамическая и статическая рекристаллизация в зависимости от температурно-деформационных режимов обработки. В работе доказано, что для обеспечения мелкозернистой структуры прокатку заготовки из сплава А5083 на РСС необходимо производить при температуре прокатки 280-320°С. В работе изучены закономерности распределения микротвердости в поперечном сечении образцов, деформированных кручением или растягивающим кручением при различных температурах и скоростях деформации. Показано, что чем меньше размер фрагментированных зерен структуры, тем больше микротвердость металла. В работе доказано, что для обеспечения мелкозернистой структуры в прутках из сплава А5083 необходимо прокатку заготовок производить на РСС при температуре прокатки 280-320 °С.

Ключевые слова: растягивающее кручение, кручение, эксперимент, структура, зерна, стан, валки упрочнение, разупрочнение, рекристаллизация.

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CHANGES IN THE COMPOSITION AND PROPERTIES OF THE HOST ROCKS OF COAL DEPOSITS IN YAKUTIA UNDER THE INFLUENCE OF CRYOGENESIS

Abstract. The results of laboratory tests carried out on rock samples of the Kharbalakhskoye coalfield located in Central Yakutia revealed significant secondary changes having taken place in the host rocks containing the coal. Evidently, under transformation processes, it is not only the composition of the rocks that had changed, but also the nature of structural bonds that have a great influence on their physical and mechanical properties. Thus, the ultimate strength values of coal-containing sandstone and siltstone samples under uniaxial compression vary from 20 to 30 MPa, while under uniaxial tension, the ultimate strength values range from 6 to 10 MPa. These relatively low numerical values pertaining to the physicomechanical properties of rocks, which are generally atypical for long-flame coal deposits, are almost 50% lower than those of analogous rocks hosting other coal deposits in Russia. It is considered that the mechanical strength properties of the rocks of the Kharbalakhskoye field are due to significant cryogenic processes. A comparative analysis of the properties of core samples obtained from boreholes drilled in 2019 with samples from a quarry obtained several decades ago reveals signs of transformation of rocks in the Kharbalakhskoye field due to phase transitions of freezing and thawing water.

Key words: coal, Yakutia, cryogenesis, physical and mechanical properties, Harbalakhskoye deposit, host rocks, material composition.

Introduction. In the mining industry, ensuring the stability of pit walls is a very important issue. In turn, the stability of inclined technogenic landforms largely depends on the cryogenic predisposition of constituent rock strata [1] (in this work, cryogenesis is understood as a set of processes associated with phase transitions of water resulting from freezing and thawing [2]). Insufficient attention paid to factors determining the nature and intensity of cryogenesis in the design of mining facilities leads to the development of undesirable processes that complicate mining operations and reduce their safety level [3-8].

In order to obtain quantitative characteristics of the influence of cryogenesis on the technological elements of the open pit mine, taking the timing of its impact into account, studies were carried out on the physicomechanical properties (PMS) of carbon-bearing rocks of the Lensky coal basin. The object of the study was the pit wall of the Kharbalakhsky open pit mine, which has played a significant role in the mining activities of Central Yakutia in its more than 55 years of operation since the discover of the deposit in 1962.

The Kharbalakhskoye coal deposit is located in the central part of the Lower Aldan coal-bearing region of the Lena basin in the Sakha Republic (Yakutia) (figures 1, 2, 3). In orographic terms, the deposit area is confined to the flat plain of the Lena-Amginsky interfluve and characterised by a weak dissection of the relief.

Figure 1 – Main coal basins of the Russian Federation (infographic with vip.karelia.pro)

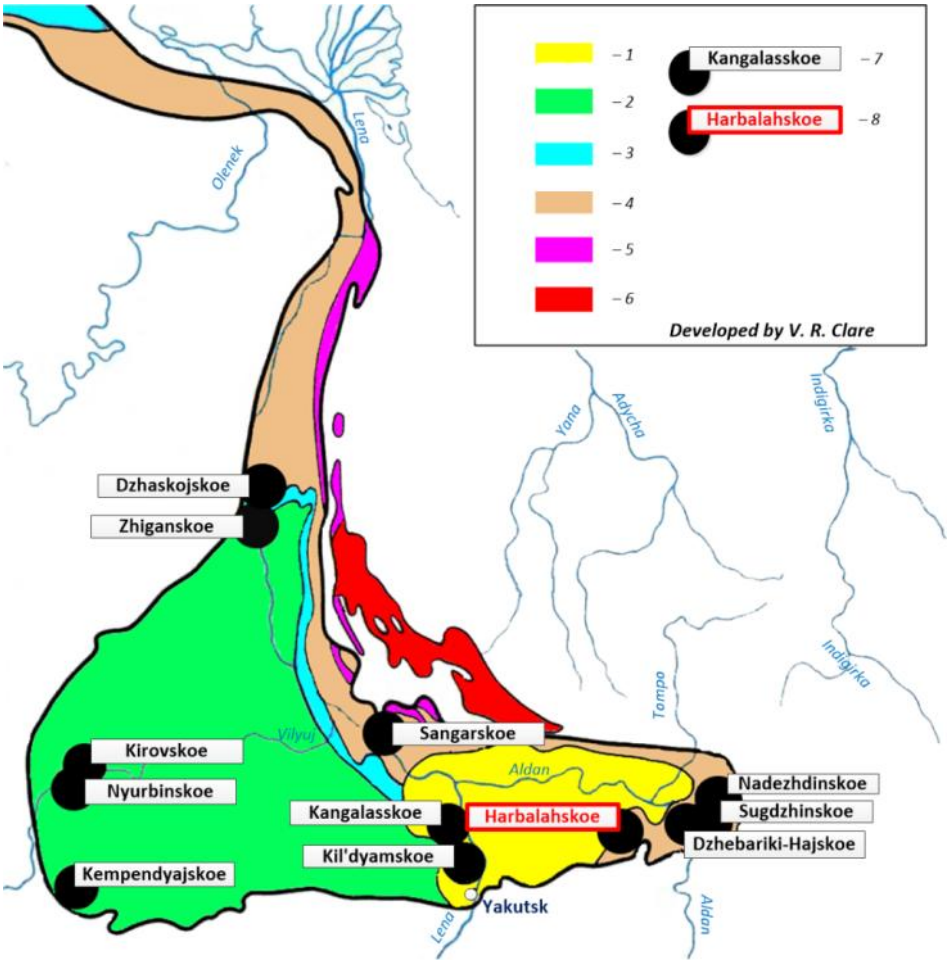

Figure 2 – Area of distribution of coal deposits of the Lensky basin showing coals of various technological groups. Legend. Brown coal: 1 – grade B_1; 2 – grade B_2; 3 – grade B_3. Coal: 4 – grade D – G; 5 – grade G–OS; 6 - grade T. 7 – coal mining enterprises; 8 – *Harbalakh* open-pit mine.

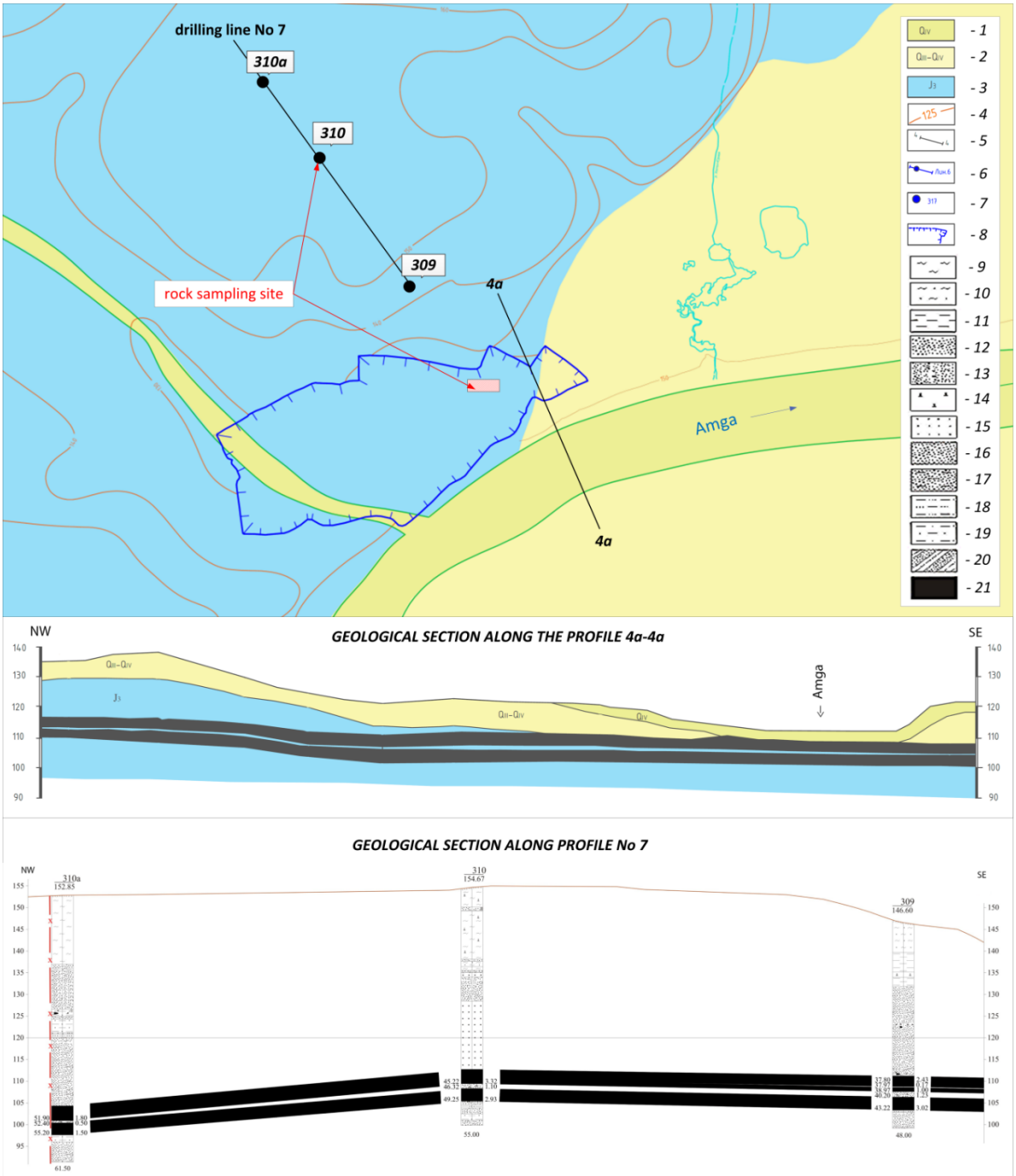

Figure 3 – Geological scheme of the site. Legend: 1 – alluvial floodplain and riverbed – sand, pebble; 2 - Sartang horizon – alluvium of the I-floodplain terrace – pebbles, sands, sandy loam, loam; 3 – Upper Jurassic deposits – sandstones, siltstones; 4 – contour; 5 – line of geological section; 6 – line of geological section of the works of 2019; 7 – wells drilled in 2019; 8 – boundaries of the investigated quarry; 9 – loam; 10 – sandy loam; 11 – clay; 12 – sand; 13 – sand-gravel mixture; 14 – ice; 15 – medium-grained sandstone; 16 – fine-grained sandstone; 17 – fine-grained sandstone; 18 – coarse siltstone; 19 – siltstone; 20 – intercalation of lithological differences; 21 – coal.

Absolute elevations range from 110 to 147 m. The climate of the deposit area is characterised as extremely continental. The average annual air temperature is minus 10 °C. The absolute minimum air temperature is minus 66 °C, while the absolute maximum is plus 38 °C.

The average number of days with frost is 240, while the frost-free period falls within the range of 120-125 days. The last frosts are observed at the end of May, with negative temperatures starting to appear at the end of August.

The geological structure of the region is characterised by terrigenous Jurassic deposits, which are represented by the alternation of sandstones, siltstones (aleurolites) and mudstones (argillites) (see figure 3). The total thickness of the deposits is 225-270 m. The deposits are overlain by loose Quaternary formations. One coal seam, extending to 10.4 m, was identified in the sediments of the Upper Jurassic upper sub-formation within the Kharbalakhskoye deposit. This coal seam is divided into two bands, with the thickness of the upper band varying between 1.45 m and 5.40 m, while the lower band has a thickness of between 1.66 m and 5.56 m. The rocky intercalation separating the seam into bands is typically composed of sandstone or, less frequently, coarse siltstone. The depth of the intercalation varies from 0.15-0.20 to 3.5-5.21 m. The top of the seam is overlain by medium- and fine-grained sandstones. This soil is composed of fine-grained sandstones and coarse siltstone. Fault tectonics in the area of work are represented by infrequent nonsinusoidal in-situ shear zones. In general, the deposit is characterised by a fairly uncomplicated geological structure [9].

Research methods. In 2019, in order to clarify the PMS and the material composition of the host rocks, as well as to study the main mining-geological and engineering-geological conditions, boreholes up to 62.0 m deep were drilled at the Kharbalakhskoye coal deposit (see Figure 3). In the process of carrying out work on the boreholes, carbon-bearing rocks represented by Jurassic deposits comprising heterogeneous sandstones and siltstones were tested.

Laboratory tests were performed on a recently-obtained rock core in order to determine the following characteristics: density; porosity; humidity; tensile strength under uniaxial compression and uniaxial tension; acoustic properties (propagation velocity of longitudinal and transverse waves in a rock sample); Poisson's ratio; and Young's modulus of elasticity. The determination of these rock indicators was carried out in accordance with the requirements established by state standards of the Russian Federation (GOSTs: 12071-2014; 21153.7-75; 21153.2-84; 21153.3-85; 24941-81; 5180-2015; 1248-2010, etc.).

When examining the specificity of material transformations of rocks during cryogenesis, chemical-analytical studies are typically carried out [10-13]. However, the analysis of changes in the chemical composition of rocks does not fully characterise the conversion of their mineral composition and fails to completely take into account the effect of structural transforming processes, which are of great importance for sedimentary rocks [14]. A satisfactory understanding of the relationship between changes in the composition and PMS of rocks informs their mineralogical and petrographic study. According to the authors, this approach gives the most accurate results by identifying the most complete range of possible reasons for their change as well as providing a forecast of further possible changes in the rocks. Thus, in addition to defining the PMS, laboratory work included mineralogical and petrographic studies.

The effect of cryogenesis on rocks was estimated from sandstone samples taken from borehole No. 310, which was drilled in 2019, as well as from the pit wall (opening date 1962), located 750 m from the borehole. Samples from the borehole were correlated with the corresponding section of the pit wall.

Results. The main results for determining the PMS of rocks from the borehole core and the pit wall of the Kharbalakhskoye field are shown in table.

The density of rocks from borehole cores at natural humidity is in the range from 1.99 to 2.37 g/cm^3; the tensile strength of siltstone under uniaxial compression is about 20 MPa, while for sandstone it varies from 21.2 MPa to 31.4 MPa. The uniaxial tensile strength of the host rocks of the considered field typically does not exceed 10 MPa. At the same time, sandstone samples taken from the quarry showed a 20–27% decrease in uniaxial compression strength, a 16% decrease in density and an increase in porosity coefficient of 25-32% as compared to fresh samples from borehole 310.

The results of mineralogical and petrographic studies of sandstones from the bore hole and pit wall allowed the following main transformational mechanisms to be identified (figure 4):

1) hydromicasation, which is caused by the decomposition of feldspars, fragments of aluminosilicate rocks and clay cement, and is accompanied by a general softening of the rock mass;

2) carbonation, accompanied by the formation of ankerite with grain sizes <0.01 mm and calcite;

3) ironisation due to surface oxidation of carbonates containing iron (ankerite and siderite) and layered silicates (chlorite and biotites).

PMS of rock samples taken from a borehole core of (2019) and the pit wall (opened 1962) of the Kharbalakhskoye field

No. in order	Borehole number	Rock stratum	Sampling interval, m		ρ	K_P	Vp	Vs	μ	E	$\sigma_{compress}$	σ_p
			from	to								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	310A	Sandstone, fine-grained	40.0	45.0	2.15	3.10	3.66	2.03	0.27	2268.3	27.2	9.5
2	310A	Siltstone	55.2	56.8	2.17	1.39	3.42	1.95	0.26	2084.6	21.6	6.5
3	310A	Sandstone, fine-grained	56.8	60.2	1.99	3.16	3.76	2.12	0.27	2283.1	26.1	8.4
4	310	Sandstone, very fine-grained	22.0	23.5	2.07	2.28	3.47	1.96	0.27	2032.6	29.5	8.6
5	310	Sandstone, medium-grained	34.8	36.5	2.12	2.75	3.68	2.04	0.28	2291.6	24.9	8.9
6	309	Sandstone, fine-grained	14.5	30.3	2.37	3.50	3.78	2.09	0.28	2654.6	31.4	14.3
7	309	Sandstone, fine-grained	44.0	16.5	2.10	7.26	3.09	1.75	0.26	1671.3	21.2	9.8
8	open pit mine	Sandstone, very fine-grained	22.0	23.5	1.87	5.1	–	–	–	–	20.3	6.1
9	open pit mine	Sandstone, medium-grained	34.8	36.5	1.82	6.3	–	–	–	–	18.2	5.5

Table legend: ρ – rock density at natural humidity, g / cm³; K_P – porosity,%; V_P – propagation velocity of elastic longitudinal waves in a rock sample, km / s; V_S – propagation velocity of elastic transverse waves in a rock sample, km/s; μ – Poisson's ratio; E – Young's modulus, MPa; $\sigma_{compress}$ – ultimate strength under uniaxial compression, MPa; σ_p – ultimate strength under uniaxial tension, MPa; f/g – fine-grained; vf/g – very fine-grained; m/g – medium-grained.

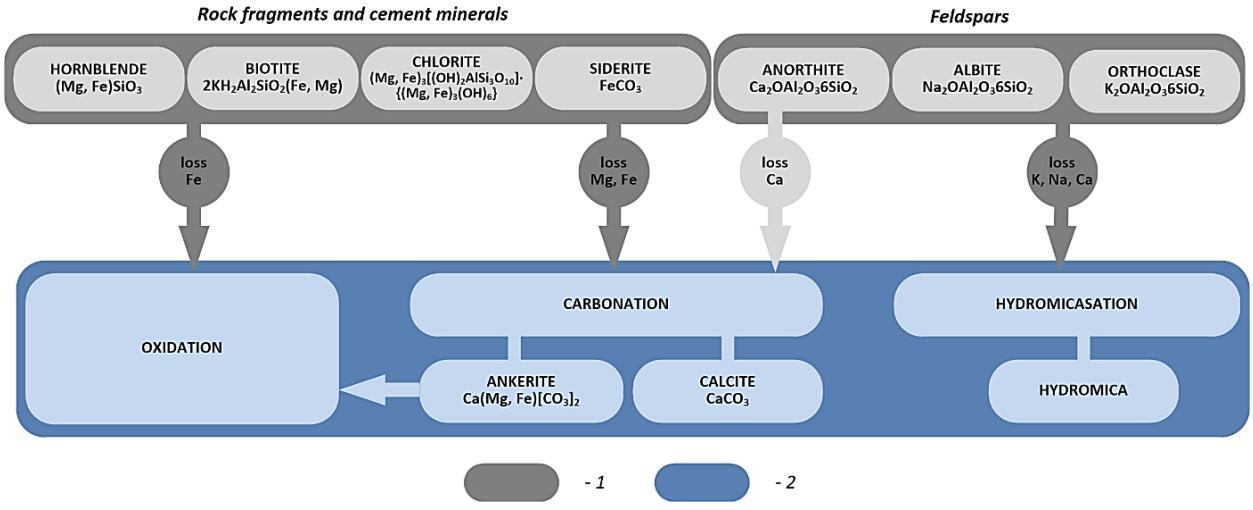

Figure 4 – Scheme of mineralogical-petrographic transformations of sandstones of the Kharbalakhsky coal deposit.
1 – composition of sandstones from borehole 310; *2* – composition of sandstones from the quarry after 57 years of exposure to cryogenesis

In the mineralogical and petrographic study of sandstone samples taken from the pit wall, deformations of individual fragments of quartz grains and feldspars (crushing, fracturing), as well as plastic damage to materials were identified taking the form of clastic defectiveness and recrystallisation of carbonate grains. All of these deformational distortions are evidently the result not only of lithostatic pressure, temperature and hydration mechanisms of weathering, but are also due to cryohydration during the phase transition of water into ice at the stage of seasonal freezing of rocks.

The influence of cryogenesis on sandstones in the natural mass revealed by the borehole is broadly similar to the effects observed in the same rocks that make up the pit walls.

Common signs are the staged nature of weathering and uneven nature of its manifestation, as well as the mineralogical identity of the neoplasms, including the formation of hydromica with an admixture of ancherite, kaolinite, calcite and iron hydroxides. The main difference between the transformations of sandstones from the quarry consists in their greater intensity, especially in terms of carbonation, as well as the completeness of the manifested processes of the selected mechanisms.

We note that similar mechanisms for the transformation of host rocks subjected to cryogenesis have been established for other coal deposits in Yakutia. In particular, studies of the mineralogical and petrographic composition of the Jurassic sandstones of the Neryungri coal deposit in South Yakutia led to the conclusion that the transformation of the mineral part of sandstones during cryogenesis is expressed in a change in the PMS of the rocks composing the massif, whose nature depends on the leading role of one of the above mechanisms [14].

Conclusions. The high intensity of changes in the initial properties of sandstones in the studied region over a relatively short period of time appears to be due to processes of cryogenesis. Moreover, the degree of change in the properties of coal-bearing rocks is determined by the duration of cryogenic impact. Thus, no forecast of the stability of manmade gradients, cut slopes and pit walls can be sufficiently substantiated without a detailed study of cryogenesis processes. To date, there is still a significant lag in the study of the theory of weathering processes on which basis methods for their assessment can be developed. Although the processes of cryogenesis in temperate climates have been studied for several decades, methods and approaches for areas of permafrost distribution are under development. Hardly any work has been carried out to describe the mechanisms (mineralogical, structural, including the nature of water migration and ice formation) and material transformations that occur during phase transitions of water, i.e. freezing and thawing.

According to the authors, the establishment of features of regional cryogenesis is universal in nature and can be applicable to solving a wide range of tasks in assessing and predicting the degree of cryogenic transformation of rocks having various structural components.

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КРИОГЕНЕЗ ӘСЕРІНЕН ЯКУТИЯ КӨМІР КЕН ОРЫНДАРЫНЫҢ СЫЙЫМДЫ ЖЫНЫСТАРЫНЫҢ ҚҰРАМЫ МЕН ҚАСИЕТТЕРІНІҢ ӨЗГЕРУІ

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ИЗМЕНЕНИЕ СОСТАВА И СВОЙСТВ ВМЕЩАЮЩИХ ПОРОД УГОЛЬНЫХ МЕСТОРОЖДЕНИЙ ЯКУТИИ ПОД ВОЗДЕЙСТВИЕМ КРИОГЕНЕЗА

Аннотация. По результатам лабораторных испытаний проб горных пород месторождения угля «Харбалахское», расположенного в Центральной Якутии, установлено, что вторичные изменения в горных породах, вмещающих угли, являются весьма существенными. В процессе преобразования изменился не только состав пород, но и характер структурных связей, оказавших большое влияние на их физико-механи-

ческие свойства. Так, значения предела прочности при одноосном сжатии образцов песчаника и алевролита, вмещающих угли, изменяются от 20 до 30 МПа, при одноосном растяжении – от 6 до 10 МПа. Данные числовые значения физико-механических свойств пород относительно низки и, в целом, не типичны для месторождений длиннопламенных углей. Прочностные свойства вмещающих пород почти наполовину ниже по сравнению с аналогичными породами других месторождений угля в России. Вероятно, на прочностные свойства пород Харбалахского месторождения существенное влияние оказали процессы криогенеза. Проведенный сравнительный анализ свойств керна из скважин, пробуренных в 2019 г., с пробами из карьера, вскрытого несколько десятилетий назад, обнаруживает признаки преобразования пород Харбалахского месторождения, обусловленного фазовыми переходами воды, промерзанием и оттаиванием.

Петрографо-минералогические исследования позволили выделить следующие основные механизмы изменения пород: 1) гидрослютизация, которая обусловлена разложением полевых шпатов, обломков алюмосиликатных пород и глинистого цемента, данный механизм сопровождается общим разупрочнением скального массива; 2) карбонатизация, сопровождающаяся образованием анкерита и кальцита; 3) ожелезнение, обусловленное поверхностным окислением карбонатов содержащих железо (анкерита и сидерита) и слоистых силикатов (хлорита и биотитов). Аналогичные механизмы преобразования вмещающих пород, подвергшихся криогенезу, установлены и для других угольных месторождений Якутии, в частности, Южной Якутии.

При минералого-петрографическом исследовании образцов горных пород, отобранных с борта карьера, идентифицировались деформации отдельных обломков зерен кварца и полевых шпатов (дробление, трещиноватость), а также признаки обломочной дефектности и перекристаллизации зерен карбонатов. Все эти деформационные «искажения», по-видимому, являются результатом литостатического давления, температурного и гидратного механизмов выветривания, а также обусловлены криогидратной природой в процессе фазового перехода воды в лед на стадии сезонного промерзания пород.

Во влиянии криогенеза на песчаники в естественном массиве, вскрытого скважиной, и таких же породах, слагающих стенки карьерного уступа, обнаружилось много сходного. Общими признаками являются стадийный характер выветривания, неравномерный характер его проявления, минералогическая индивидуальность новообразований. Отличие преобразований песчаников из карьера выражается в большей их интенсивности, особенно карбонатизации, и полноте проявлений выделенных механизмов.

Таким образом, высокая интенсивность изменения первоначальных свойств песчаников в исследуемом регионе за относительно короткий период времени обусловлена процессами криогенеза. Причем степень изменения свойств углевмещающих пород определяется сроком его воздействия. В связи с чем, прогноз устойчивости искусственных склонов, откосов выемок и бортов карьеров не может быть достаточно обоснован без детального изучения процессов криогенеза. На сегодняшний день все еще имеется существенное отставание в изучении теории процессов выветривания и в разработке методик их оценки. Если процессы криогенеза в условиях умеренного климата изучаются несколько десятилетий, то для районов распространения многолетней мерзлоты методы и подходы находятся в стадии разработки. Практически никогда не проводятся работы по описанию механизмов (минералогических, структурных, в том числе характер миграции воды и льдообразования) и вещественных преобразований, возникающих при фазовых переходах воды, промерзании и оттаиванием. По мнению авторов, установление особенностей регионального криогенеза имеет универсальный характер и может быть применимо для решения широкого спектра задач при оценке и прогнозе степени криогенной трансформации пород с различными структурными связями.

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Ключевые слова: уголь, Якутия, криогенез, физико-механические свойства, месторождение Харбалахское, вмещающие горные породы, вещественный состав.

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GEOMORPHOLOGICAL ANALYSIS OF THE ILI RIVER BASIN CATCHMENT AREA FOR INTEGRATED DEVELOPMENT

Abstract. Based on long-term informational and analytical materials of the World Meteorological Organization (WMO), the Weather and Climate reference portal and stationary meteorological stations of the RSE Kazhydromet located in the catchments of the Ili River basin, which cover the Almaty region (Narynkol, Tekes, Sumbe, Dobyn, Aydarly, Kapshagay, Usharal, Bakanas, Kokzhide, Kuigan) of the Republic of Kazakhstan, Xinjiang Uygur Autonomous Region (Tekes, Xinyuan, Tokkuztara, Yamata, Kuldzh) of the People's Republic of China and using the law of geographic vertical zoning, the energy resources of river basins and groundwater, the climatic potential of natural systems that characterize the heat and moisture supply of natural landscapes and ecological and hydrogeochemical indicators showing the direction and intensity of the hydrogeochemical process on a spatial scale, which allowed for geomorphological zoning, are determined catchments of the Ili river basin, characterizing the natural functions of the river basin, to have runoff and environment formation, which are the basis for environmental management and environmental engineering.

Key words: climate, nature, resources, river, pool, environment, landscape, catchment, system, heat, moisture, security, potential, process, nature management, environmental management, function.

Relevance. The general current situation of the catchment of the basin of the transboundary Ili River, located on the territory of the People's Republic of China and the Republic of Kazakhstan, is characterized by a rather intense geoecological state. This situation is caused by the progressive involvement and development of the natural resource potential of vast territories (in our case, watersheds), the increase in technogenic impact on them and the disruption of the relationship between natural components in geosystems and in the human-nature system.

Therefore, to solve the geoecological problems of the watersheds of the transboundary river basin, it is necessary to consider and study them in the form of geosystems of a certain rank, including an interdependent set of components and developing as a whole on the basis of geomorphological schematization, describing the main processes of the functioning of watersheds with a possibly large set of parameters that take into account changes in the components of geosystems catchment areas.

The main natural function of the river basin is, firstly, drainage, secondly, peculiar combined geosystems (the principle of unification here is the unity of hydrogeochemical flows having one object for their discharge) and, thirdly, this is a spatial basis for nature management (allocation of land for various purposes) and environmental management, that is, objects of a comprehensive arrangement of their watersheds.

With a comprehensive arrangement of the catchments of the river basin, the catenary approach is the basis of the geomorphological schematization of the catena, which consists of four facies with different altitudinal positions. The eluvial facies represents a hill near the dividing line, the transeluvial facies represent the slope to the inflection point, the transaccumulative facies represent the slope after the

inflection point, and the supersquale is the lowland of the floodplain terraces. The floodplains of the rivers, despite their significance, were not considered in the work. The transeluvial and transaccumulative facies form the transit facies of the slope, and the supequal facies adjoins the watercourse.

Purpose of the study – based on geomorphological schematization of catchments of river basins using the catenary approach, zoning of the landscape system of catchments of the Ili River basin to identify regional differences and the need to accurately determine their economic and economic capabilities.

Object of study - The Ili River, which originates in the Central Tien Shan on the territory of the People's Republic of China (PRC) after the confluence of three tributaries - the rivers Kash, Kunes and Tekes, with the latter having a large tributary - the Koksu River and its flow formation zone (Halyktau and Narat) is characterized by the largest layer of precipitation - more than 1300 mm / year. The sources of the Tekes river are located on the territory of Kazakhstan on the Muzart glaciers and their length is 438 km, the catchment area is 28100 km^2 (within the Republic of Kazakhstan, respectively, 218 km and 4250 km^2). The river, high in the upper reaches, at the intersection of the Tekes Depression loses a significant part of its flow for water consumption in the branches of the economy, but after the confluence of the tributaries Kokpak, Bayankol, Narynkol, which feed on meltwater from the Khan-Tengri glaciers, the water content of the river increases significantly. Then it flows through the territory of the People's Republic of China (East Turkestan), where it merges with the Kunes and Kash rivers, and at the 250-th km from their confluence enters the territory of Kazakhstan with the Ili river with many waters. After exiting the Kapshagai Gorge, the Ili River flows through the deserted Balkash plain to Lake Balkhash. Downstream the riverbed is unstable, replete with elders and islets. When it flows into the lake, the river forms a delta with an area of about 9000 km^2, which is divided into three systems of branches - Topar, Ili and Zhideli [1].

Research Methods and Materials. The work used information and analytical materials of the World Meteorological Organization (WMO), the reference and information portal «Weather and Climate» and stationary meteorological stations of the RSE «Kazhydromet» located in the catchments of the Ili River basin, which cover the Almaty region (Narynkol, Tekes, Sumbe, Dobyn, Aydarly, Kapshagay, Usharal, Bakanas, Kokzhide, Kuigan) of the Republic of Kazakhstan, Xinjiang Uygur Autonomous Region (Tekes, Xinyuan, Tokkuztara, Yamata, Kulja) of the People's Republic of China [2]

By the methodology of the comprehensive arrangement of the catchments of river basins, given the multidimensional nature of the problem, the whole set of methodological approaches that exist in environmental management, that is, the geosystem and catenary approaches, has been adopted.

The catenary approach is the basis of the geomorphological schematization of catenas when substantiating the need for a comprehensive arrangement of catchments of river basins [3,4,5].

In the geomorphological schematization of landscape catenas of catchment areas, in order to justify the need to equip river basins, each catchment within the same physical and geographical area is represented by a catena consisting of four facies with different altitude positions, determined by the depth of the relief: eluvial, transit, superaqual and subaquatic. If the watersheds have extended slopes, the transit facies is divided into the transeluvial and transaccumulative facies [5].

Thus, the basis of geomorphological schematization of watershed landscapes based on the geosystem approach, based on the excess of the earth's surface over the watercourse, makes it possible to more objectively differentiate the zones of facies locations.

However, in the quantitative description of the hydrogeochemical processes of catchments of river basins, the main integral factor is the energy of the groundwater flow, that is, the speed of their movement, the mass of water, depending on the thickness of the aquifer, filtration energy, and evaporation energy, which are not taken into account when using the excess of the earth's surface over the watercourse as a criterion for geomorphological schematization of river basins, i.e Δ_i and ΔH characterize the excess of the earth's surface over the watercourse, then you can imagine the energy or work performed by the flow of groundwater in the following form [4]: $\Delta E = A_i = m_i \cdot \mathrm{g} \cdot \Delta H = m_i \cdot \mathrm{g} \cdot \Delta_i$, where ΔE – change in energy at the site *dx*, kJ; A_i – work performed in an elementary volume by the flow of groundwater in the area *dx*, kJ; m_i – groundwater mass; Δ_i и ΔH – height exceeding the Earth's surface above the bank of the watercourse, m.

Construct geomorphological circuit landscape catenas possible using hydrogeochemical potential groundwater flow river basin ($\bar{M}$), characterizing work ($\bar{A}_n$),committed by a liquid in the process of precipitation to the ratio of the concentration of soil solution ($\bar{C}_n$),that is, they can be considered as the ability of the soil cover to be released from readily soluble salts from the upper to the lower reaches of the river basins: $\bar{M} = \bar{A}_n / \bar{C}_n$, where: $\bar{M}$ – hydrogeochemical potential of river basins; $\bar{A}_n$ – work performed in an elementary volume by the flow of infiltration water in the soil layer of river basins; $\bar{C}^*$ – average salt concentration in groundwater flow [4]: *г*

$$\bar{A}_n = O_c / \left[\frac{R}{L} - (1-t)\frac{R}{L}(1-\bar{\Delta})\right],\ \bar{C}^* = \left[C_o + (1-t)\frac{R}{L}(1-\bar{\Delta}) \cdot C_г / O_c\right] / C_{доп},$$

where: R – radiation balance; O_c – precipitation; L – latent heat of vaporization; C_o – initial concentration of soil solution in the soil layer; - permissible concentration of salts in the soil solution, which corresponds to the parameter of non-saline soils; $C_г$ – salt concentration in groundwater; $(1 - t)$ – infiltration action time ($t = T/365$), T – duration of the biological active period; $\bar{\Delta} = \Delta/\Delta_{kp}$, Δ – groundwater depth: Δ_{kp} – critical groundwater depth.

Research results. For the geomorphological zoning of the watershed territories of the Ili River basin, a catenary approach was used, which involves a geomorphological schematization of landscape catenas of the watersheds of river basins characterizing landscapes in the mountain class (eluvial facies), piedmont landscape subclass (transelyuvial facies), foothill plain landscape subclass (transaccus) flat class of landscapes (super-aquatic and sub-aquatic facies).

Based on the above methodological approach, the energies and work performed by the groundwater flow in the catchments of the Ili River basin are determined (table 1).

Table 1 – Energy resources of the catchments of the Ili River basin

Natural and climatic zones		Weather stations	The absolute height of the earth's surface, m	ΔH, m	Groundwater flow energy, kJ	
landscape class	facies				A_i	$\sum A_i$
Mount	Eluvial	Basuarkor	4059,0	–	–	–
		Narynkol	1806,0	1797,0	17628,6	31961,3
		Tekes	1766,0	40,0	392,4	14333,3
Piedmont	Trans-eluvial	Sumbe	1232,0	534,0	5238,5	13940,3
		Tekes (China)	1203,0	29,0	284,5	8701,8
		Xinyuan (China)	947,0	256,0	2511,4	8417,3
		Tokkuztara (China)	773,0	174,0	1707,0	5905,9
Piedmont lowland	Trans accumulative	Yamato (China)	723,0	50,0	490,5	4198,9
		Gulja (China)	663,0	60,0	588,6	3708,4
		Kokdala (China)	627,0	36,0	353,2	3119,8
		Dubyn	596,0	31,0	304,1	2766,6
		Aydarly	576,0	20,0	196,2	2462,5
		Kapshagay	540,0	36,0	353,2	2266,3
Plain	Super aqual	Ili	490,0	50,0	490,5	1913,1
		Bakbakty	459,0	31,0	304,1	1422,6
		Usharal	397,0	62,0	608,2	1118,5
		Bakanas	396,0	1,0	9,8	510,3
		Akdala	390,0	6,0	58,9	500,5
		Akkol	384,0	6,0	58,9	441,6
	Subaquatic	Araltobe	357,0	27,0	264,9	382,7
		Kokzhide	350,0	7,0	68,7	117,8
		Kuigan	345,0	5,0	49,1	49,1

As can be seen from table 2, in the catchment areas of the Ili River basin in the territory of the Raiymbek district of Almaty region, that is, the zone of runoff formation, where the mountain class of landscapes with eluvial facies is located, has rather high energy resources of river basins and groundwater, which are 23259.5 kJ. At the same time, in the watershed territories of the Ili River basin, which pass through the borders of the Xinjiang Uygur Autonomous Region of the People's Republic of China, are located in the piedmont class of landscapes with transeluvial facies, the energy resources of river basins and groundwater are reduced to 8034.4 kJ. The energy resources of river basins and groundwater in the foothill lowland class of landscapes with a transaccumulative facies of catchments of the Ili River basin, which cover part of the territory of the Xinjiang Uygur Autonomous Region of the People's Republic of China and the Uyghur District of the Almaty Region of the Republic of Kazakhstan, amount to 2285.8 kJ. At the same time, in the territories of the catchment part of the Republic of Kazakhstan, covering from the Dobyn hydrological post to the city of Kapshagai, it amounts to 500.3 kJ, that is, the energy resources of the river basin and groundwater are sharply reduced. In the territories of the flat class of landscapes with superaqual facies, covering the Ili and Balkhash districts of the Almaty region, the energy resources of the river basin and groundwater are reduced to 1530.3.1 kJ, and in the zone of the subaquatic facies it decreases sharply to 333.6 kJ.

Thus, in accordance with the principle of geographical zonality existing in energy and groundwaters, from 31,961.3 to 49.1 thousand catchment areas of the Ili River basin (table 2).

Table 2 – Geomorphological schematization of landscape catenas in the catchment areas of the Ili River basin according to the energy resources of the river basin and groundwater

Natural and climatic zones		Geomorphological indicator	
Landscape class	Facies	The absolute height of the earth's surface, m	Groundwater flow energy, kJ
Mount	Eluvial	<1800	<175000
Piedmont	Trans-eluvial	800-1800	8000-17500
Piedmont lowland	Trans accumulative	540-800	5500-8000
Plain	Super aqual	350-540	3500-5500
	Subaquatic	>350	>3500

The natural heat and moisture supply of the active surface is the most important constituent element of the complex of natural productive forces, that is, natural landscapes that are actively involved in the biological process in general and in the formation of natural-technogenic complexes, especially the catchments of river basins [6,7,8].

Based on the long-term information and analytical materials of the located meteorological stations in the catchments of the Ili River basin, their average long-term energy resources and natural and climatic potentials are determined, that is (table 2): the sum of the air temperature for the biologically active period of the year ($\sum t,°C$), amount of precipitation (O_c, mm), evaporation level (E_o, mm), and photosynthetically active radiation (R, kJ/cm^2) (table 3).

As can be seen from table 3, the energy resources of the watersheds of the Ili River basin from the mountainous class of landscapes (eluvial facies) to the plain class of landscapes (subaquatic) increase, the sum of the biological active air temperature from 2338.0 to 3800.0 ° C, volatility from 844, 0 to 1472.0 mm and the radiation balance from 134.0 to 182.0 kJ / cm^2, and precipitation decreases from 433.0 to 144.0 mm. Under these conditions, landscape-geochemical catenes are formed in the catchment areas of the river basin, that is, the simplest cascade landscape-geochemical system, characterized by the intensity of hydrogeochemical flows, which largely depend on their energy resources.

Table 3 – Natural and energy resources of the catchments of the Ili River basin

Natural and climatic zones (landscape class, facies)	Weather stations	Absolute height (*H*), m	Natural and climatic indicators			
			O_c, mm	$\sum t$, ℃	E_o, mm	*R*, kJ/cm^2
Mountain class of landscapes (eluvial facies)	Narynkol	1806,0	433,0	2805,0	1001,0	149,0
	Tekes	1766,0	421,0	2338,0	844,0	134,0
Piedmont subclass of landscapes (transeluvial facies)	Sumbe	1232,0	377,0	3074,0	1122,0	158,0
	Tekes (China)	1203,0	259,0	3100,0	954,0	159,0
	Tokkuztara (China)	773,0	248,0	3579,0	894,0	175,0
Piedmont lowland subclass of landscapes (trans accumulative facies)	Yamato (China)	723,0	252,0	3130,0	1269,0	162,0
	Gulja (China)	663,0	248,0	3800,0	1284,0	182,0
	Zharkent	641,0	213,0	3950,0	1661,0	187,0
	Dobyn	596,0	226,0	4100,0	1748,0	192,0
	Aydarly	576,0	364,0	4305,0	1247,0	199,0
	Kapshagay	540,0	370,0	3750,0	1528,0	180,0
Plain class of landscapes (superaqual facies)	Usharal	397,0	354,0	3622,0	1168,0	176,0
	Bakanas	396,0	273,0	3700,0	1527,0	179,0
Plain class of landscapes (subaquatic)	Kokzhide	350,0	224,0	3700,0	1474,0	179,0
	Kuigan	345,0	144,0	3800,0	1472,0	182,0

At the same time, the energy resources of river basins and groundwaters of the natural system are additionally characterized by hydrogeochemical processes of groundwater, which are characterized by ecological and hydrogeochemical parameters of landscape of river basins, which are extremely important in the ecological and hydrogeochemical zoning of landscape and geographical zones and water management assessment of catchments of the Ili River basin (table 4).

Table 4 – Environmental-hydrogeochemical indicator of the landscape system of the catchment area of the Ili River basin

Natural and climatic zones (landscape class, facies)	Weather stations	*H*, m	Indicators					
			C_o, g/l	C_e, g/l	Δ, m	$\bar{A}_n$	$\bar{C}^*$	$\bar{M}$
Mountain class of landscapes (eluvial facies)	Basuarkor	4059,0	0.30	1.00	10.0	0,73	0,60	1,21
	Narynkol	1806,0	0,30	1,00	10,0	0,79	0,60	1,32
	Tekes	1766,0	0,30	1,00	10,0	0,60	0,60	1,00
Piedmont subclass of landscapes (transeluvial facies)	Sumbe	1232,0	0.40	1.20	10.0	0.60	0,80	0,75
	Tekes (China)	1203,0	0.40	1.30	10.0	0.41	0,80	0,51
	Tokkuztara (China)	773,0	0,40	1,30	10,0	0,35	0,80	0,44
Piedmont lowland subclass of landscapes (trans accumulative facies)	Yamato (China)	723,0	0.50	1.50	6.0	0.39	1,00	0.39
	Gulja (China)	663,0	0.50	1.50	6.0	0.29	1,00	0.29
	Zharkent	641,0	0,50	1,50	6,0	0,34	1,00	0,34
	Dobyn	596,0	0,50	1,50	6,0	0,29	1,00	0,29
	Aydarly	576,0	0,50	1,50	6,0	0,46	1,00	0,46
	Kapshagay	540,0	0,50	1,50	6,0	0,51	1,00	0,51
Plain class of landscapes (superaqual facies)	Usharal	397,0	0,90	3,50	3,0	0,50	1,50	0,33
	Bakanas	396,0	0,90	3,50	3,0	0,38	2,50	0,25
Plain class of landscapes (subaquatic)	Kokzhide	350,0	1,50	6,00	3,0	0,31	1,80	0,17
	Kuigan	345,0	1,50	6,00	3,0	0,20	1,80	0,13

In this case, the work, as can be seen from table 4, performed in an elementary volume by a flow of infiltration water in the soil layer ($\bar{A}_n$) from the mountain side (eluvial facies) to the lowland (subaquatic) zones gradually decreases from 0.73 to 0.20, and the average salt concentration in surface water - soil – "groundwater" system ($\bar{C}^*$), on the contrary, increases from 0.60 to 1.20. Consequently, the ecological-hydrogeochemical potential or soil-reclamation indicator of the landscape ($\bar{M}$), obeying the law of vertical zonality, decreases from 1.21 to 0.13, which characterizes a saline collection basin in the area of hydrogeochemical flow stacking. This regularity shows the available possibilities for the formation of hydrogeochemical processes in the catchment areas of the Ili River basin, which are damaged by the spread in the flat class of landscape with superaqual and suaqual facies, where salinization of soils with low ecological productivity are widespread [57], which are estimated using integrated criteria for environmental and climatic productivity natural landscapes (table 5):

- humidification coefficient ($K_y = O_c / E_o$), where O_c – precipitation, mm; E_o – volatility over the biological active period of the year, mm: $E_o = 0.0018 \cdot (25 + t)^2(100 - a)$, where t – is the average monthly temperature °C; a – monthly average relative humidity, % [9];

- dryness index ($\bar{R} = R/LO_c$, where L – specific heat of vaporization, assumed constant and equal to 2,5 kJ/cm^2); R – photosynthetically active radiation, kJ/cm^2[10]: $R = 13.39 + 0.0079 \cdot \sum t > 10$℃, here $\sum t$, ℃ – the sum of the air temperature for the biological active period of the year [11].

At the same time, under natural conditions, the formation of landscape hydrogeochemical facies largely depends on the heat and moisture supply of the catchment areas of the Ili River basin, since the natural humidity coefficient decreases from 0.50 from the mountain class of landscapes (eluvial facies) to the Plain class of landscapes (subaquatic) to 0.10, and the "dryness index", which characterizes the degree of balance of moisture and heat, rises from 1,273 to 5,056, which show the presence of sufficiently high energy resources.

Table 5 – Geomorphological schematization of landscape catenas of catchments of the Ili River basin

Humidity zones	Indicators of heat and moisture			The absolute height of the earth's surface, m	Administrative districts
	Weather stations	K_y	$\bar{R}$		
Mountain class of landscapes (eluvial facies)					
Wet mountain	Narynkol	0,43	1,370	1806,0	Raiymbek
	Tekes	0,50	1,273	1766,0	
Piedmont subclass of landscapes (transeluvial facies)					
Arid mountain	Sumbe	0,34	1,676	1232,0	Raiymbek
	Tekes (China)	0,27	2,456	1203,0	Ili Kazakh Autonomous Prefecture
	Tokkuztara (China)	0,29	2,822	773,0	
Piedmont lowland subclass of landscapes (trans accumulative facies)					
Arid piedmont	Yamato (China)	0,20	2,571	723,0	Ili Kazakh Autonomous Prefecture
	Gulja (China)	0,19	2,935	663,0	
	Zharkent	0,13	3,510	641,0	Panfilov
	Dobyn	0,13	3,398	596,0	Uigur
	Aydarly	0,29	2,187	576,0	Kerbulak
	Kapshagay	0,24	1,946	540,0	Kapshagay city
Plain class of landscapes (superaqual facies)					
Arid plain	Usharal	0,30	1,988	397,0	Ili
	Bakanas	0,18	2,622	396,0	Balkhash
Plain class of landscapes (subaquatic)					
Very arid desert	Kokzhide	0,15	3,200	350,0	Balkhash
	Kuigan	0,10	5,056	345,0	

Thus, using the laws of geographic vertical zonality, the energy resources of river basins and groundwater, the climatic potential of natural systems characterizing the heat and moisture supply of natural landscapes, and ecological and hydrogeochemical indicators showing the direction and intensity of the hydrogeochemical process on a spatial scale, which allowed geomorphological zoning of catchments of the Ili River basin, characterizing the nature valued functions of the river basin, ie runoff and environment formation and is a basis for environmental management and environmental engineering (table 5).

Thus, based on the geomorphological schematization of the catchments of the transboundary Ili river, based on the drainage of river basins as a thermodynamic system, the boundary of which coincides with the altitudinal zonality, it is possible to assess changes in the hydrological, ecological, soil, and ecological-hydrogeochemical regime of landscape systems taking into account natural and territorial differences as performing important environment formation or environmental functions.

Conclusions. Based on long-term informational and analytical materials of the World Meteorological Organization (WMO), the Weather and Climate reference portal and stationary meteorological stations of the RSE Kazhydromet, located in the catchments of the Ili River basin, which cover the Almaty region (Narynkol, Tekes, Sumbe, Dobyn, Aydarly, Kapshagay, Usharal, Bakanas, Kokzhide, Kuigan) of the Republic of Kazakhstan, Xinjiang Uygur Autonomous Region (Tekes, Xinyuan, Tokkuztara, Yamata, Kuldzh) of the People's Republic of China and using the law of geographic vertical zoning, the energy resources of river basins and groundwater, the climatic potential of natural systems that characterize the heat and moisture supply of natural landscapes and ecological and hydrogeochemical indicators showing the direction and intensity of the hydrogeochemical process on a spatial scale, which allowed for geomorphological zoning, are determined catchments of the Ili river basin, characterizing the natural functions of the river basin, to have runoff and environment formation, which are the basis for environmental management and environmental engineering.

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КЕШЕНДІ ҮЙЛЕСТІРУ ҮШІН ІЛЕ ӨЗЕНІНІҢ СУ ЖИНАУ АЛАБЫН ГЕОМОРФОЛОГИЯЛЫҚ ТАЛДАУ

Аннотация. Қазақстан Республикасы Алматы облысының (Нарынқол, Текес, Сүмбе, Добын, Айдарлы, Қапшағай, Үшарал, Бақанас, Кокжиде, Құйған) және Қытай Халық Республикасының Синьцзян-Ұйғыр автономиялық ауданының аймағын қамтитын Іле өзенінің су жинау алабына орналасқан «Қазгидромет» РМӨ-нің тұрақты метеорологиялық бекеттерінің және Әлемдік метеорологиялық ұжымның (ӘМҰ) «Ауа-райы және климат» анықтамалық-ақпараттық жүйесінің көпжылдық мәліметі негізінде және географиялық тік белдеу заңын пайдалана отырып, өзен алабының және жерасты суы ағынының энергетикалық ресурстары, табиғи жүйенің табиғи-климаттық потенциалын сипаттайтын табиғи ландшафттардың ылғалмен қамтамасыз етілу көрсеткіштері, гидрогеохимиялық үдерістер бағытын және қарқынын бейнелейтін уақыт-кеңістік масштабындағы экологиялық-гидрогеохимиялық көрсеткіштері анықталды, ал ол оның нәтижесі өзен алабының табиғи қызметін сипатайтын Іле өзенінің су жинау алабында геоморфологиялық ауданды жүргізуге мүмкіндік берді, яғни оның су ағынын және ортаны құрушы қасиеті, табиғатты пайдалану және табиғаты үйлестірудің негізі болып саналады.

Іле өзенінің су жинау алабы аймағының табиғи энергетикалық ресурстары ландшафтардың таулы топтарынан (элювиалдық фациядан) ландшафттардың жазықтық тобына (субаквальдық фацияға) қарай өседі, яғни биологиялық белсенді ауа температурасының жиынтығы 2338,0 ^{o}С-тан 3800,0 ^{o}С-қа, буланудың шамасы 844,0 мм-ден 1472,0 мм-ге және радиациялық теңгерме 134,0 кДж/см^2-тан 182,0 кДж/см^2-қа дейін, ал атмосфералық жауын-шашын шамасы 433,0 мм-ден 144,0 мм-ге дейін төмендейді және осы жағдайға тән ландшафттық-геохимиялық катен, яғни геохимиялық ағын қарқыны арқылы ерекшеленетін, географиялық аймақтық (белдеулік) заңдылығына байланысты сатыланған ландшафттық-геохимиялық жүйе пайда болады және көптеген жағдайда жерасты суы ағынының энергетикалық қуаты соған байланысты болғандықтан, оның сандық шамасы элювиалдық фациядан субаквальдық фацияға қарай 31961,3 кДж-дан 49,1 кДж-ға дейін біртіндеп төмендейді, ал ол өзен аймағын геоморфологиялық желілеуге мүмкіндік береді.

Сонымен, табиғи ортаның нақтыланған көлемдегі топырақ қабатындағы сүзілген су ағынының атқаратын жұмысын ($\bar{A}_n$) таулы (элювиалдық фациядан) жазықтық (субаквалдық фацияға) аймаққа қарай 0,73-тен 0,20 -ға дейін төмендесе, «жер беті суы-топырақ-жерасты суы» жүйесіндегі су ағынының орташа тұздылығы 0,60-тан 1,80-ге дейін өседі. Сондықтан, географиялық аймақтық (белдеулік) заңдылығына байланысты экологиялық-гидрогеохимиялық немесе топырақ-мелиоративтік көрсеткіш ($\bar{M}$) 1,21-ден 0,11-ге дейін төмендейді, ал ол гидрогеохимиялық ағынның қорлану аймағында тұз жиналатын алаптың қалыптасатынын сипаттайды, яғни бұл заңдылық Іле өзеннің су жинау алабының аймағындағы гидрогеохимиялық үдерістердің қалыптасу мүмкіншілігіне байланысты, оның жазықтық аймағында супераквалдық және суаквалдық фациялардың таралуына дәлел бола алады.

Сонымен қатар, табиғи жағдайдағы ландшафттық-гидрогеохимиялық фацияларының қалыптасуына Іле өзенінің су жинау алабының жылу және ылғалмен қамтамасыз ету дәрежесіне тікелей байланысты, себебі ландшафттардың таулы топтарынан (элювиалдық фациядан) ландшафттардың жазық топтарына (субаквалдық фацияға) қарай табиғи ылғалдану көрсеткіші 0,50-ден 0,10-ға дейін төмендей бастайды, ал жылу және ылғалдың теңгермелік дәрежесін сипатайтын «құрғақшылық белгісі» 1,273- тен 5,056-ға дейін жоғарылайды, ал бұдай жағдай аймақтың энергетикалық ресурстарының өте жоғары екендігін көрсетеді.

Сонымен, өте маңызды ортаны құрушы және экологиялық қызмет атқаратын өзеннің су жинау алабы су ағынының қалыптасу жағдайын термодинамикалық жүйе ретінде қарастыра отырып, шекаралық Іле өзенінің су жинау алабын геоморфологиялық желілеу негізінде және аймақ шекарасының биік белдеулікке сай келуі, оның ландшафт жүйесінің гидрологиялық, экологиялық-топырақ және экологиялық-гидрогеохимиялық тәртібінің өзгеруін, табиғи-аймақ өзгешілігін ескере отырып бағалауға мүмкіндік береді.

Түйін сөздер: климат, табиғат, қор, өзен, алап, орта, ландшафт, су жинау, жүйе, жылу, ылғал, қамтамасыз ету, потенциал, үдеріс, табиғатты пайдалану, табиғат үйлестіру, қызмет.

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ГЕОМОРФОЛОГИЧЕСКИЙ АНАЛИЗ ВОДОСБОРА БАССЕЙНА РЕКИ ИЛИ ДЛЯ КОМПЛЕКСНОГО ОБУСТРОЙСТВА

Аннотация. На основе многолетних информационно-аналитических материалов Всемирной метеорологической организации (ВМО), справочно-информационного портала «Погода и климат» и стационарных метеорологических станций РГП «Казгидромет», расположенных в водосборах бассейна реки Или, которые охватывают Алматинскую область (Нарынкол, Текес, Сумбе, Добын, Айдарлы, Капшагай, Ушарал, Баканас, Кокжиде, Куйган) Республики Казахстан, Синьцзян-Уйгурский автономный район (Текес, Синьюань, Токкузтара, Ямату, Кульджа) Китайской Народной Республики и с использованием закона географической вертикальной зональности, определены энергетические ресурсы речных бассейнов и подземных вод, природно-климатического потенциала природных систем, характеризующих тепло- и влагообеспеченности естественных ландшафтов и эколого-гидрогеохимических показателей, показывающих направленность и интенсивность гидрогеохимического процесса в пространственном масштабе, которые позволили провести геоморфологическое районирование водосборов бассейна реки Или, характеризующих природные функции речного бассейна, то есть стокообразование и средообразование, являющихся базисом для природопользования и природообустройства.

Природные энергетические ресурсы территории водосборов бассейна реки Или от горного класса ландшафтов (элювиальная фация) в сторону равнинного класса ландшафтов (субаквальная) повышается, то есть сумма биологической активной температуры воздуха от 2338,0 до 3800,0 ^{o}С, испаряемость от 844,0 до 1472,0 мм и радиационный баланс от 134,0 до 182,0 кДж/см^2, а атмосферные осадки уменьшаются от 433,0 до 144,0 мм и в этих условиях в водосборных территориях речного бассейна формируется ландшафтно-геохимические катены, простейшая каскадная ландшафтно-геохимическая система, отличающаяся интенсивностью гидрогеохимических потоков, которые во многом зависят от их энергетических ресурсов подземных вод, подчиняющихся от закона географической зональности, от элювиальной до субаквальной фации постепенно уменьшается от 31961,3 кДж до 49,1 кДж, что дает возможность на их основании производить геоморфологическую схематизацию ландшафтных катенов водосборной территории бассейна реки Или.

При этом работа, совершаемая в элементарном объеме потоком инфильтрационных вод в почвенном слое ($\bar{A}_n$) от стороны горных (элювиальная фация) к равнинным (субаквальная) зонам, постепенно уменьшается от 0,73 до 0,20, а средняя концентрация солей в системе «поверхностная вода - почва - грунтовая вода» ($\bar{C}^*$), наоборот, увеличивается от 0,60 до 1,80. Следовательно, эколого-гидрогеохимический потенциал

или почвенно-мелиоративный показатель ландшафта ($\bar{M}$), подчиняясь закону вертикальной зональности, уменьшается от 1,21 до 0,11, что характеризует в области магазинирования гидрогеохимического потока формируется солесборный бассейн, то есть эта закономерность показывает имеющиеся возможности формирования гидрогеохимических процессов в территориях водосбора бассейна реки Или, что повреждаются распространением в равнинном классе ландшафта с супераквальной и суаквальной фациями.

При этом в естественных условиях формирования ландшафтно-гидрогеохимических фаций во многом зависят от тепло- и влагообеспеченности территорий водосборов бассейна реки Или, так как от горного класса ландшафтов (элювиальная фация) до равнинного класса ландшафтов (субаквальная) коэффициент естественного увлажнения уменьшается от 0,50 до 0,10, а «индекс сухости», характеризующий степень сбалансированности влаги и тепла, повышается от 1,273 до 5,056, которые показывают наличие достаточно высоких энергетических ресурсов.

Таким образом, на основе геоморфологической схематизации водосборов трансграничной реки Или, базирующейся на положениях стокообразования речных бассейнов как термодинамической системы, граница которых совпадает с высотной поясностью, позволяют оценить изменения гидрологического, эколого-почвенного и эколого-гидрогеохимического режима ландшафтных систем с учетом природно-территориальных различий как выполняющие важные средообразующие или экологические функции.

Ключевые слова: климат, природа, ресурсы, река, бассейн, среда, ландшафт, водосбор, система, тепло, влага, обеспеченность, потенциал, процесс, природопользование, природообустройство, функция.

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POSSIBILITY OF VORTEX SEPARATION EJECTOR APPLICATION IN THE COLLECTION AND SEPARATION OF GAS

Abstract. The article analyzes the experimental and pilot ejector installations and shows shortcomings in their work with two-phase flows. Association of high and low pressure gas flows with a conventional choke device leads to a significant loss of flow energy of high pressure gas. This union of gas flows of high and low pressures, also limits the selection of gas from wells with low wellhead pressure and the combined gas stream in this case becomes a low-pressure, so transporting it over long distances becomes impossible. Thus, new design of the vortex and separation ejector for the improvement of technological processes is proposed.

Its design and principle of operation are described. The proposed ejector consists of a feed chamber with a tangential inlet of the passive flow, and a tangential exit of the liquid phase, mixing chamber and diffuser.

The possibility of implementing it at the same time in the ejection and low-temperature gas separation processes were considered. The advantages of the ejector are shown. Due to the cold created by very low temperature in the proposed vortex ejector it is possible to carry out the process of static low-temperature gas separation simultaneously with the process of ejection. The use of this small-sized ejector instead of compressor installations on limited areas of offshore platforms, bushes and flyovers is especially expedient and advantageous.

The vortex ejector is simple in design and can be made out of the factory by forces of the manufacturers themselves from tube elements.

Key words: pressure, temperature, flow velocity, nozzle, adiabatic expansion, flow, energy, vortex flow.

Introduction. In the operation of gas condensate fields in the technological scheme of collection and preparation of gas to transport gas-liquid flows with different (high and low) pressures appear. In some cases, because of the inability to dispose of these low-pressure gas streams with a high content of gasoline fractions, they are useless burned in flares or released into the atmosphere. With the aim of increasing the pressure of low-pressure gases requires the construction of a compressor station, which is not always profitable with a techno-economic point of view.

Vortex tubes of small diameters ($D_t \leq 30$ mm), working with air flow at low pressures, have found their industrial application in the field of aviation, refrigeration, air conditioning, instrumentation, measuring equipment and others.

However, vortex tubes, like other jet devices (ejectors, turbo-expanders), have not found their wide industrial application and have remained at the experimental and pilot stage in the field of high pressure and gas processing practices. There are several reasons for this. Firstly, in the technical literature, vortex tubes have an opinion that they, as a transformer (converter) of energy, have a low performance index due to the need for a high initial gas pressure. Secondly, it is difficult to carry out laboratory and bench tests of large vortex tubes with high flow rates and initial gas pressures that simulate field and factory conditions. In addition, there is currently no reliable theoretical basis and universally accepted methods for technological and structural calculations of vortex tubes in the widely changing thermodynamic conditions of field and factory practice. Heating half of the total flow in a vortex tube is also considered a vulnerable factor when used in a low-temperature gas separation unit (LTS) installation.

At the same time, the presence of "free" natural high reservoir pressures in gas condensate fields and the need for rational use of the energy of these pressures cast aside the opinion of the low efficiency of vortex tubes. It should be noted that the "hot stream" in the vortex tube can form at low initial pressures at the inlet of the pipe, and at higher initial pressures at the inlet of the vortex pipe, the temperature of the hot stream is equal to the initial temperature of the total flow at the inlet of the vortex pipe. At higher initial gas pressures at the inlet of the pipe, the so-called "hot flow" of the vortex tube may have a negative temperature. In this case, a strongly cooled dry (central) stream and a moderately cooled and supersaturated vapor of heavy hydrocarbons and water (peripheral) stream will leave the vortex tube. The decrease in the temperature of the "hot stream" is explained by the fact that the total vortex temperature effect is the algebraic sum of the Rank effect and the usual throttling $[(\Delta T)_{Total} = (\Delta T)_{Rank} \pm \beta_{throttling}]$. When determining the total vortex effect by the "hot flow", the value of the integral throttling effect $(\beta_{throttling})$ gets a negative value.

It should also be noted that by cooling a hot pipe with an external source of cold (water or another cooling agent), it is possible to increase the proportion of cold flow

(μ = 0.8-0.9). This situation (the use of a non-adiabatic vortex tube) increases the cooling capacity and thereby increases the possibility of the use of vortex tubes in LTS installations (figure 1).

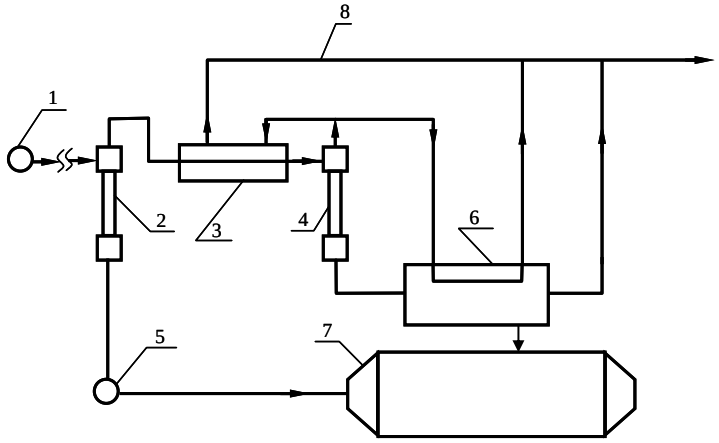

Figure 1 – Schematic diagram of the low-temperature separation of natural gas using vortex tubes
1 - well; 2 - the first vortex tube; 3 - heat exchanger; 4 - the second vortex tube; 5 - blockhouse;
6 - separator-heat exchanger; 7 - capacity for liquid; 8 - dry gas reservoir

Thus, the technological need to reduce wellhead pressure during the operation of gas condensate wells to the pressure of apron gas pipelines, the simultaneous cooling and separation of gas in small vortex tubes without rotating metal elements, makes it possible to rationally use the pressure energy of the gas flow during its expansion and significantly reduce the specific consumption of metal. The throughput of a vortex tube with a diameter of 60 mm at a critical expiration of a gas stream with an initial pressure of 100 kgf / sm^2 is approximately 350 thousand nm^3 / day. The mass of such a vortex tube is about 4550 kg. In the separation mode of operation (μ = 0.6), this jet apparatus can carry out gas separation in an amount of: $0.6 \cdot 350000 = 210000 nm^3 / day$. A comparison of the mass of the vortex tube and the amount of treated gas shows a very low specific metal consumption for separating gas in the vortex tubes.

This article proposes a model of a vortex separation ejector for collecting and separating produced gas.

Methodology. Association of high and low pressure gas flows with a conventional choke device leads to a significant loss of flow energy of high pressure gas. This union of gas flows of high and low pressures, also limits the selection of gas from wells with low wellhead pressure and the combined gas stream in this case becomes a low-pressure, so transporting it over long distances becomes impossible.

In the case of high-pressure gas stream in the field scheme of gas collection is much beneficial the use of ejector units in exchange for the construction of the compressor station. From oilfield practices there are known some results of experimental and experimental-industrial tests of straight ejector installations in technological scheme of the high and low pressure gas flows' collection [1]. However,

these ejector installations is not found wide industrial application in field practice, and remained at the stage of experimental work for the following reasons:

- The lack of reliable calculation methods of the ejection for not-separated gas-liquid flows' process;
- Violation of the optimal operation mode of straight ejector installations in the presence of a liquid phase in active (high-pressure) and passive (low-pressure) gas flows;
- the need to implement the process of active and passive gas-liquid flows separation before entering them into the ejector unit;
- difficulty controls work of straight ejector installations, as in the case of change of initial parameters of active and passive flows, you often need to change all the transverse dimensions of the ejector units elements (i.e., dimensions of cross sections of the nozzles, chambers and displacement diffusers);
- presence of a liquid phase in the active and passive flow leads to a large hydraulic resistance, loss of energy pressure, the emergence of a "flooding" regime in existing ejector systems;
- Appearance of the liquid in the gas enter to those set, also dramatically affects the main indicators, including the coefficient of efficiency and coefficient of ejection.

Considering mentioned above drawbacks in operation and design of the existing straight ejector units upon their work with two-phase flow, the authors have developed a new design of vortex separation ejector (figure 2) that performs simultaneously two functions in the collection and preparation of gas for transport:

- Ejecting and increase of the passive flow pressure;
- Implementation of the active and passive flow separation together in the vortex ejector [2].

The proposed ejector consists of a feed chamber with a tangential inlet of the passive flow, and a tangential exit of the liquid phase, mixing chamber with a tangential nozzle for active flow input, the diaphragm installed between the receiving and mixing chambers to enter the passive flow in the chamber of the displacement, diffuser with a rectifier of common flow and tank for collecting liquid.

The principle of operation of the proposed ejector is as follows. Passive two-phase flow, coming through the tangential inlet to the receiving chamber, makes in it a rotational movement. The free liquid phase of the flow due to centrifugal force is forced out to the walls of the inlet chamber and through a tangential exit pipe is drained into a tank for collecting liquid. After separation, the rotating passive gas flow through the central hole of the diaphragm and enters into the mixing chamber, where through the tangential inlet nozzle the active two-phase flow enters too. Here the flow is also subjected to rotational movement. In this case, in the mixing chamber is a joint rotational movement of active and passive flows in the form of a "vortex inside another vortex", that is, in this camera continues the rotary motion of the passive flow inside rotating active flow. There is a separation of combined flows, and selected liquid phase through a tangential outlet of the mixing chamber is drained into a tubular container for collecting liquid. Then mixed combined separated flow in the diffuser straightening and raising its pressure, shell out of the vortex ejector.

Note that the active flow passing through tangential nozzle is subjected to adiabatic expansion in which the flow becomes very low static (local) temperature.

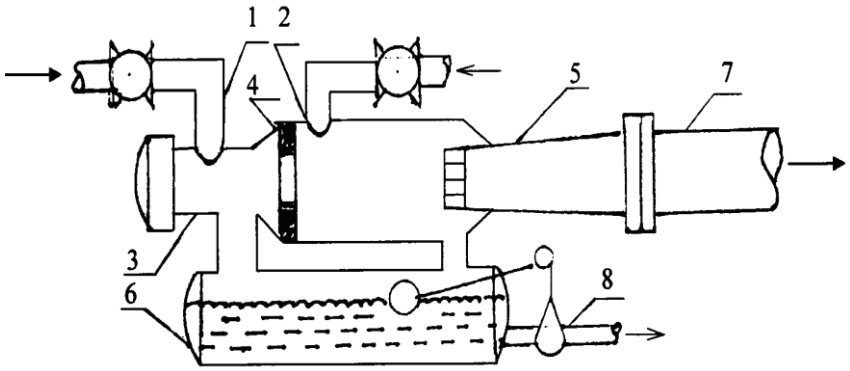

Figure 2 – Vortex separation ejector 1 - input passive flow; 2 - input of the active stream; 3 - receiving chamber; 4 - mixing chamber with a diaphragm; 5 - diffuser with a rectifier; 6 - tube fluid container; 7- gas line; 8 - fluid line

However, measurement of this low static temperature with a thermometer is almost impossible, since in this case the movement of the thermometer with the same speed at which the moving stream of gas is necessary. But, despite that this temperature is not subject to direct measurement, however, due to the cold created by this very low temperature in the proposed vortex ejector it is possible to carry out the process of static low-temperature gas separation simultaneously with the process of ejection.

The static temperature of a moving gas stream can be determined using the dependences of the adiabatic expansion of the gas. In the critical mode of the gas stream outflow through the nozzle (i.e., at the maximum flow rate of the active stream), the temperature ratio in front of the nozzle (T_0) and in the mixing chamber (T_{cr}) is equal to: $\frac{T_0}{T_{cr}} = \frac{k+1}{2}$, here k is the adiabatic index (for natural gases, k = 1.3). In this mode, the pressure ratio in front of the nozzle (P_0) and in the mixing chamber (P_{cr}) is equal to:

$$\frac{P_0}{P_{cr}} = \left[\frac{k+1}{2}\right]^{\frac{k}{k-1}}$$

For natural gases, these ratios are equal:

$$\frac{T_0}{T_{cr}} = \frac{1.3+1}{2} = 1.15$$

$$\frac{P_0}{P_{cr}} = \left[\frac{1.15+1}{2}\right]^{\frac{1.3}{1.3-1}} = 1.83$$

Temperature ($\Delta T_{cr} = T_0 - T_{cr}$) and pressure ($\Delta P_{cr} = P_0 - P_{cr}$) differences for this mode for natural gases will be:

$$\Delta T_{cr} = T_0 - \frac{T_0}{1.15} = T_0\left(\frac{0.15}{1.15}\right) = 0{,}13T_0 \qquad \Delta T_{cr} = 0.13T_0$$

$$\Delta P_{cr} = P_0 - \frac{P_0}{1.83} = T_0\left(\frac{0.83}{1.83}\right) = 0{,}454P_0 \qquad \Delta P_{cr} = 0.454P_0$$

In the proposed vortex ejector, the critical static temperature (T_{cr}) corresponds to the separation temperature (T_{sep}) of the total mixed flow in the mixing chamber ($T_{cr} = T_{sep}$) and can be determined in the critical mode of the flow of the active stream depending on the initial temperature (stagnation temperature) of the active stream ($T_{cr} = \frac{T_0}{1.15}$).

Results. The table shows the calculation results for the determination of critical temperatures (T_{cr}).

Temperature differences ($\Delta T_{cr} = T_0 - T_{cr}$) and coefficients $\alpha_s = \frac{\Delta T_{cr}}{\Delta P_{cr}}$ in the critical flow of the active stream at initial pressures and temperatures equal to $P_0 = 6.0 \div 10.0 MPa$ and $T_0 = 273 \div 313 K$.

Table 1- Calculation results for gas flow cooling during adiabatic gas expansion under critical outflow conditions for various initial pressures and temperatures

T_o, K	T_{cr}, K	$\Delta T_{cr} = T_o - T_{cr}$, K	P_o / P_{cr}, (MPa / MPa)				
			6.0/3.28	7.0/3.23	8.04/4.37	9.0/4.92	10.0/5.46
			$\Delta P_{cr} = P_o - P_{cr}$				
			2.72	3.17	3.63	4.08	4.54
			$\alpha_s = \Delta T_{cr} / \Delta P_{cr}$ (K / MPa)				
273	237	36	13.2	11.3	9.9	8.8	7.9
283	246	37	13.6	11.7	10.2	9.1	8.1
293	255	38	13.9	12.0	10.5	9.3	8.4
303	263	39	14.3	12.3	10.7	9.6	8.6
313	272	40.7	14.9	12.8	11.2	9.9	8.9

Analysis of table data shows that in the adiabatic expansion of the gas committed at the critical gas outflow with increasing initial temperature (T_0) increases the difference in critical temperature $\Delta T_{cr} = T_0 - T_{cr}$and the coefficient $\alpha_s = \frac{\Delta T_{cr}}{\Delta P_{cr}}$. This ratio also increases at lower values of ΔP_{cr} in case when $\Delta T = const$.

In the considered coefficient α_s [as an indicator of the degree of cooling efficiency during iso-entropic (*s* = *const*) expansion of the gas flow] equal to:

α_s = 7.9-14.9°C/MPa, whereas under these conditions, the corresponding ratio of the throttling process (i.e. constant enthalpy *i* = *const*) equal $\alpha_i = 3 - 4.5℃/MPa$ This means that under these conditions the process of iso-entropic gas expansion from the point of view of obtaining a cold at a lower temperature, significantly effective (2.5-2.7 times) than the gas throttling process, applicable in existing low-temperature gas separation units.

It should be noted that the mode of operation of the vortex ejector can be likened to the mode of operation of the turbine expander only with the difference of absence of rotating parts (wheels, bearings) in vortex ejector. In this ejector the rotation of the high circumferential and angular velocities is exposed to the gas stream. Therefore, in this case, unlike the wheel of the turbine expander, the gas vortex rotates with a significantly higher number of revolutions, which allows the low-temperature separation process more effectively, so this process can co-administer at lower static temperatures of the gas streams. Despite the fact that this static low temperature cannot be directly measured, it really exists and can be successfully used in the proposed vortex ejector for low-temperature gas separation. Its value, as has already been said, can be determined by calculation and confirmed by measuring the temperature of the dew point of the gas at the outlet of this ejector using a moisture meter.

Thus, in the proposed vortex ejector, it is possible to combine the processes of ejection and gas separation. The use of this small-sized ejector instead of compressor units on limited areas of offshore platforms and overpasses is especially expedient and advantageous.

The vortex ejector is simple in design and can be made out of the factory by forces of the manufacturers themselves from tube elements. Its work is easily regulated by changing the initial parameters of the initial gas flows. In this case, it is enough to replace the dimensions of the nozzle cross sections and the diameter of the diaphragm for the passive flow to enter the mixing chamber.

Conclusions. 1. The reasons that delay the widespread use of existing rectilinear ejector installations in technological schemes for gas collection are indicated;

2. The presence of a free liquid phase in the composition of the active and passive flows impairs the reliability of the results of technological and mechanical calculations for the design of existing rectilinear ejector installations;

3. The presence of fluid in rectilinear ejector installations increases the hydraulic resistance in them, leads to a loss of pressure energy and violates their optimal mode of operation;

4. In the proposed vortex separation ejector, the above-mentioned disadvantages of existing ejector installations are eliminated and pressure energy is rationally used.

5. In the vortex ejector, the processes of ejection and gas separation occur simultaneously;

6. Low-temperature gas separation in a vortex ejector occurs at low static temperatures obtained due to high gas flow rates during adiabatic expansion of gases;

7. The advantages of vortex separation ejector using in the technological scheme of collecting and preparing gas for transport are indicated.

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ГАЗДЫ ЖИНАУ ЖӘНЕ АЖЫРАТУ ҮДЕРІСІНДЕ ҚҰЙЫНДЫ ЭЖЕКТОРДЫ ҚОЛДАНУ МҮМКІНДІГІ

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ВОЗМОЖНОСТЬ ПРИМЕНЕНИЯ ВИХРЕВОГО ЭЖЕКТОРА В ПРОЦЕССАХ СБОРА И СЕПАРАЦИИ ГАЗА

Аннотация. В статье проанализирована работа опытно и опытно-промышленных эжекторных установок, указаны недостатки в их работе с двухфазными потоками. Объединение газовых потоков высокого и низкого давлений посредством стандартного штуцера приводит к значительным потерям энергии газа высокого давления. Также такое объединение потоков газа низкого и высокого давлений ограничивает отбор газа из скважин с низким устьевым давлением и совмещенный поток в этом случае имеет низкое значение давления, что делает невозможным его транспорт на большие расстояния. В связи с этим, для усовершенствования технологических процессов предлагается вихревой и сепарационный эжектор.

Описаны его конструкция и принцип работы. Предлагаемый эжектор состоит из приемной камеры, камеры смешения с тангенциальным соплом для входа активного потока, диафрагмы, установленной между приемной и смесительной камерами для входа пассивного потока в камеры смещения, диффузора.

Были показаны возможности одновременного применения предложенного эжектора в процессах низкотемпературной сепарации газа и эжекции. Отмечены преимущества этого эжектора. Ввиду холода, создаваемого очень низкой температурой, в разработанной схеме предложена одновременная реализация вышеуказанных технологических процессов. Использование этого малогабаритного эжектора, вместо компрессорных установок на ограниченных участках морских платформ, кустов и эстакад является особенно целесообразным и выгодным.

Следует учесть также то, что в вихревых трубах сепарационная скорость газа значительно (в сотни раз) больше, чем в современных сепарационных аппаратах, что позволяет осуществить обработку большого количества газа в весьма малогабаритных вихревых трубах.

Учитывая ограниченность рабочих площадей эстакад и индивидуальных морских оснований, авторами предложена технологическая схема обработки газа с применением совместно трубного сепаратора и новой конструкции вихревой трубы, расположенных на дне моря**.**

Вихревой эжектор прост по конструкции и может быть изготовлен на заводе силами самих производителей из трубчатых элементов.

Ключевые слова: давление, температура, скорость потока, сопло, адиабатическое расширение, поток, энергия, вихревое течение.

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STUDY OF MINING-GEOLOGICAL CHARACTERISTICS OF URANIUM DEPOSITS OF KAZAKHSTAN FOR DEVELOPMENT BY UNDERGROUND WELL LEACHING

Abstract. Existing traditional uranium mining technologies have major drawbacks, do not meet the requirements of a market economy, are ineffective, require the use of a large number of expensive injection and pumping wells, low leaching rates, require a large consumption of chemical reagent, sulfuric acid (to produce 1 ton of uranium concentrate requires a flow of 100 tons sulfuric acid). Here, a productive solution refers to a chemical solution containing the concentration of the leached therein of various useful components (metals), including uranium, dissolved therein.

In the practice of exploitation of hydrogenous uranium deposits, the arrangement of technological wells has been adopted: linear (or in-line), areal (or cellular) and combined.

Our proposed innovative technology for the exploitation of hydrogenous uranium deposits will be developed on the principle of piston wells using the effect of activation of a chemical solution supplied to the array of a hydrogenated uranium layer for leaching and other useful components. In the process of activation, the chemical solution is heated to t = 70 ° C, the water in the solution becomes a good solvent. Pumping wells are used as piston wells without changing the design, i.e. pumping wells are also used as injection wells.

This article presents the mining and geological characteristics of technogenic uranium deposits in Kazakhstan. The basis of the raw material base of Kazakhstan's uranium is exogenous type deposits, combined into a subgroup called “infiltration”. Uranium infiltration deposits are formed by groundwater associated with regional formation zones and zones of soil-layer oxidation. The development and implementation of the method of underground well leaching of uranium (UWL) is one of the most important scientific and technical achievements of the mining industry. The main advantages of the underground leaching method compared to traditional mining methods of developing deposits are as follows: the possibility of involving poor and off-balance ores in deposits with complex geological and hydrogeological conditions, but with large reserves of uranium; Significant reduction in capital investments and terms of commissioning deposits; improving working conditions, reducing the number of miners and increasing labor productivity by 2.5-3.5 times; reducing the negative impact of uranium mining on the environment.

Key words: uranium, deposit, exploration, borehole underground leaching, industrial assessment.

Introduction. The Republic of Kazakhstan has the world's largest raw material base of proven industrial reserves of uranium. Explored reserves in Kazakhstan total about 1 million. 560 thousand tons uranium. The presence in Kazakhstan of significant reserves, well-explored deposits of uranium, developed mining and processing capacities of uranium, as well as the current situation on the world uranium market, determine the prospects for the development of the uranium mining industry in Kazakhstan. The basis of the raw material base of Kazakhstan's uranium is exogenous type deposits, combined into a subgroup called “infiltration”. Uranium infiltration deposits are formed by groundwater associated with regional formation zones and zones of soil-layer oxidation.

Development of infiltration uranium deposits was started in Kazakhstan from the 70s of the last century. By the mid-80s, Kazakhstan already provided about 40% of the uranium needs of the former USSR. To develop the deposits, a new method of uranium mining was used at that time - the method of underground leaching through a system of wells drilled from the surface, which consists in transferring uranium to solution at the place of natural ore occurrence.

The development and implementation of the method of underground well leaching of uranium (UWL) is one of the most important scientific and technical achievements of the mining industry. The main advantages of the underground leaching method compared to traditional mining methods of field development are as follows:

- the possibility of involving in the exploitation of poor and off-balance ores of deposits with complex geological and hydrogeological conditions of occurrence, but with large reserves of uranium;
- significant reduction in capital investments and terms of commissioning;
- improving working conditions, reducing the number of miners and increasing labor productivity by 2.5-3.5 times;
- reducing the negative impact of uranium mining on the environment.

Methods. The basis for the development and implementation in practice of uranium mining of the method of underground borehole leaching were achievements in the field of geological exploration and industrial assessment, epigenetic deposits of regional zones of reservoir and soil oxidation, achievements in the field of hydrodynamics, geochemistry, hydrometallurgy.

Underground leaching technology can rightfully be attributed to the revolutionary technology that has changed the conditions and economics of uranium production.

The successful solution of the complex of technical problems in the development of the underground leaching method of uranium was associated with the development and implementation of special technical means and technologies for the construction and operation of wells, instrumentation, as well as with the development and industrial development in the hydrometallurgy of uranium sorption-desorption technology using ion-exchange resins.

Over the past years, collectives of Kazakhstani uranium mining enterprises have done a great job to improve the technology of uranium mining, increase labor productivity, reduce production costs, and automate production processes. Considerable work has been done in the field of drilling and equipment of wells, improving the means of raising productive solutions, devices for their sorption-desorption redistribution.

New deposits are involved in commercial exploitation, including those with complex geological and hydrogeological conditions, characterized by weakly permeable areas with high carbonate content, filtration heterogeneity, unstable spatial arrangement of ore bodies in ore-bearing horizons and large depths of their occurrence, lack of reliable water confines, etc. Expanding the boundaries of the application of the underground borehole leaching method of uranium requires further improvement of this progressive mining method and determines its high science intensity.

Based on modern achievements of geotechnological science and practice, the development of uranium mining by the method of downhole leaching goes along the path of introducing computer-aided mining technology based on the complete automation of all production processes; optimization of opening, preparation and mining schemes; the introduction and development of new technical means for the construction and development of wells, new structural materials; reducing the cost of solvents, ion exchange resins; the introduction of electrodialysis plants, sorption-desorption concentration apparatuses such as SDK, polymer washing liquids, hydraulic fracturing and hydraulic washing of formations, new methods of electro-ultrasonic intensification of leaching and redistribution of productive solutions; the introduction of effective methods for monitoring the hydro-geochemical parameters of underground leaching sites and environmental rehabilitation of waste.

The social significance of introducing the method of downhole leaching into uranium mining practice is extremely great. Fundamentally, for the better, the nature of the work of miners and the radiation safety of the work have changed.

A further increase in uranium production, based on the introduction of the latest scientific and technical achievements in the practice of developing infiltration deposits, will allow Kazakhstan to take a leading place among the world's uranium producers.

Results. About 25% of the world reliably explored uranium reserves are concentrated in the bowels of Kazakhstan. Total reserves and resources are estimated at 1560 thousand tons of uranium, including category reserves ($B+C_1+C_2$) of 928 thousand tons.

A unique feature of the republic's uranium reserves is that about 75% of them are concentrated in deposits associated with regional zones of formation oxidation. This type of field is not widespread in the world and is being developed by the most progressive, relatively cheap and environmentally preferable method of underground well leaching. (UWL).

Geological and industrial types of Kazakhstani uranium deposits: deposits of regional zones of reservoir oxidation; deposits of soil-bed oxidation zones; organogenic phosphate deposits; vein stockwork deposits.

Kazakhstan uranium deposits associated with regional formation oxidation zones are formed in the Shu-Sarysuyskaya and Syr-Darya depressions of the platform cover of the northern part of the Tien Shan uranium megawatch (Northern, Eastern and Western group of deposits).

Deposits associated with zones of soil-layer oxidation are developed in the Ili River basin, outside the zone of activity of industrial enterprises and in the Akmola region of Northern Kazakhstan.

Uranium deposits suitable for mining with sulfuric acid leaching through a system of wells drilled from the surface belong to the subgroup of infiltration (hydrogen). These deposits are the basis of the raw material base of the uranium industry of Kazakhstan and are concentrated in the Shu-Sarysuyskaya (Mynkuduk, Inkai, Budenovskoye, Zhalpak, Sholak-Espe, Uvanas, Moinkum, Kanzhugan) and Syrdarya (Irkol, Karamurun, Kharasan, Zarechnoye, Asarchik Kyl, Zha , Chayan, Lunar) uranium ore provinces.

The largest of the deposits of the soil-formation oxidation zone and promising for development is the Semizbay deposit.

The development of vein stockwork type deposits is, in principle, possible with a minimum level of profitability, subject to selective mining of rich areas in combination with heap leaching. The scale of this direction of production directly depends on the situation on the natural uranium market.

The development of deposits of organogenic phosphate type is not profitable and is possible only with the integrated extraction and marketing of uranium, scandium, rare earths, sulfur sulfide and phosphorus pentoxide. However, global market demand for these types of products is still limited.

A prerequisite for the implementation of underground leaching technology should be good permeability of the medium containing uranium mineralization for the solution. With sufficiently good permeability indicators, even deposits of poor uranium ores prove to be profitable for mining. Each uranium deposit is always individual in its natural features, the technical and economic indicators of the exploitation of deposits by underground leaching depend on these features. Moreover, the feasibility of using underground leaching technology for mining a particular uranium deposit is based on the parameters of two factors: the possible volume of uranium production per unit time and the possible cost of producing a unit of uranium.

The average concentration of uranium in the productive solutions depends on the productivity of the ore-bearing stratum and the effective thickness of the ore-bearing rocks involved in the leaching process.

The reagent consumption for underground leaching of uranium depends on the reagent capacity of ore-bearing rocks, the type and nature of uranium mineralization, rock carbonate, productivity and effective thickness of formations, hydrodynamic conditions for pumping solutions through ore-bearing strata.

In the practice of underground leaching of uranium, the specific consumption of the reagent is 50-150 kg per 1 kg of metal, which is due to the reaction of the acid with other minerals and the spreading of solutions. Carbonates almost completely react with acid (1 kg of sulfuric acid is consumed per 1 kg of $CaCO_3$), minerals of oxide iron, less intensely ferrous iron and some aluminosilicates (up to 10%) dissolve well (40-50%) [1,2].

At the stage of formation acidification, the reagent (sulfuric acid) consumption is usually 8-10 g / l for ores with high carbonate content and 20-30 g / l for non-carbonate ores. At the leaching stage, the concentration of sulfuric acid in working solutions ranges from 8 to 15 g / l.

Productivity in productive solutions is determined by the total production rate of pumping wells, and the metal yield in solutions by its concentration in solutions. The degree of uranium extraction from the

bowels depends on many natural factors, geotechnological parameters of the deposits of the deposit and technological indicators of the leaching process. The ratio of liquid to solid L:S is determined by the ratio of the volume of pumped solutions through the ore-bearing formation to the volume of the rock mass of the formation [4].

The solution to the question of determining the degree of suitability of a uranium deposit for mining by underground sulfuric acid leaching in each particular case, first of all, should be based on a study of the geotechnological parameters of the deposits. In this case, the development of a geotechnological classification of the suitability of the field for sulfuric acid underground leaching through a system of wells drilled from the surface acquires practical significance [5,6].

When constructing the classification, the basis can be taken of general geotechnological features that apply to all infiltration deposits and particular parameters of these features that characterize one or another degree of suitability of the deposit for sulfuric acid underground leaching of uranium.

The developed classification is given in table 1. The classification allows, according to existing field exploration data, an aggregate assessment of the degree (class) of suitability of a deposit (deposit) for underground leaching of uranium.

Table 1 – Classification of signs of suitability of uranium deposits for sulfuric acid leaching

Geotechnological features of uranium deposits	Suitability of the deposit for sulfuric acid leaching of uranium according to parameters of geotechnological features		
	High (1st class fitness)	Sufficient (2nd class of suitability)	Low (3rd class fitness)
1. The length of ore deposits, km	> 1,0 – 2,0	1,0 – 2,0	< 1,0
2. Depth width, km	50-100	30-50	< 10
3. Depth of mineralization, m	100 - 200	200 – 400	> 400
4. Mineralization power, M	> 3 – 5	3 – 5	< 1,0
5. The content of clay-silt fractions, %	< 20	20 - 30	> 30
6. Uranium content in ore, %	> 0,05 – 0,1	0,05 – 0,1	<0,05
7. Content CO_2, %		1,0 – 2,0	> 2,0
8. Type of ore mineralization: Activation energy, E, kJ / mol; The order of the reaction of sulfuric acid leaching, α	Oxide < 10 > 0,3	Mixed 10 – 20 0,25 – 0,3	Coffinite > 20 0,25
9. Ore productivity, kg/m^2	> 5,0	3,0 – 5,0	< 3,0 - 1,0
10. Groundwater level, m	< 50	Up to 50	> 50
11. Groundwater pressure on the horizon roof, m	> 50	Up to 50	< 50
12. The oxygen content in formation water, mg/l	8-10	5-6	< 5
13. The ratio of iron ions in produced water	$Fe^{3+} > Fe^{2+}$	$Fe^{3+} = Fe^{2+}$	$Fe^{3+} < Fe^{2+}$
14. The filtration coefficient of ore-bearing rocks, KF, m/day	> 1,0	1,0 – 0,5	< 0,5
15. The rate of filtration apisotropy of the productive horizon	< 0,1	0,1 – 0,3	0,7 – 1,0

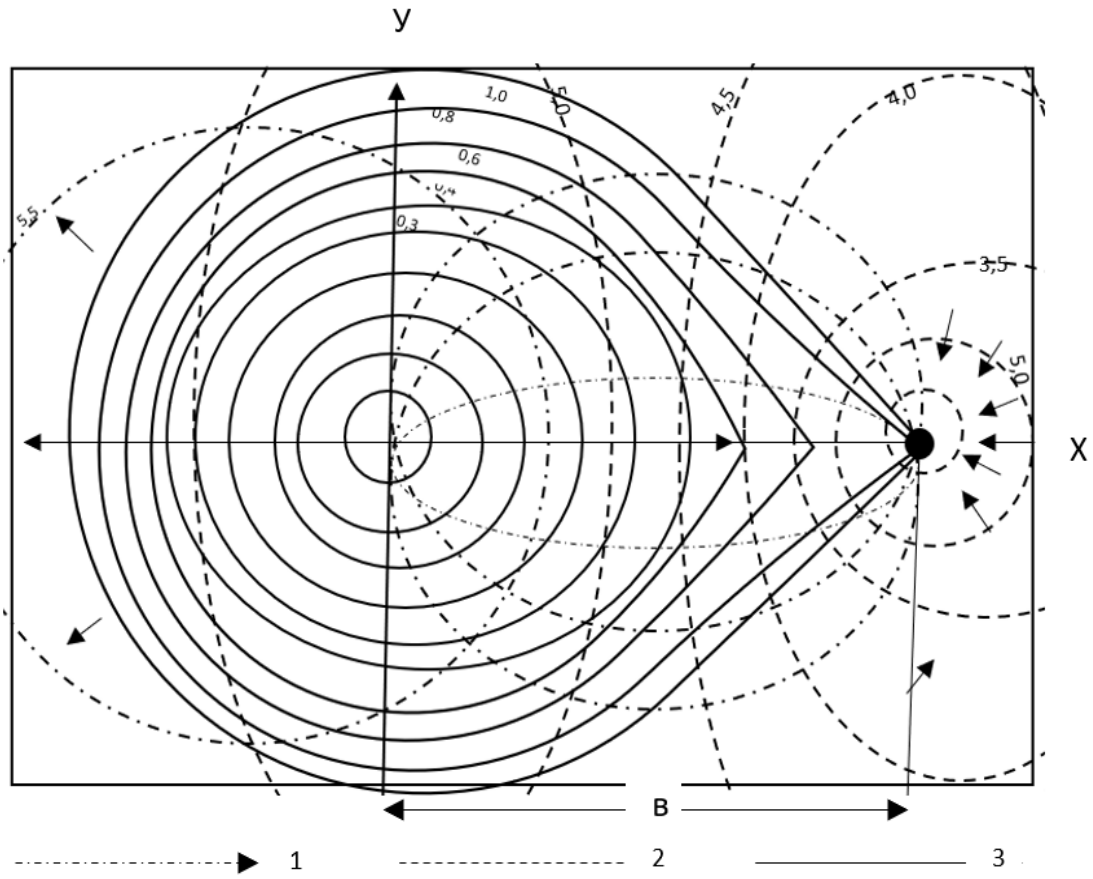
The analysis of table 1 shows that the parameters of geotechnological features can have a significant impact on the conditions and indicators of leaching of uranium.

Depending on the parameters of geotechnological features of the fields, each of the fields selected for leaching can be classified as high, sufficient and low suitability for sulfuric acid leaching through a system of wells drilled from the surface.

During the operation of two equally-produced wells (pumping-out), a sufficiently high rate of movement of the solution is ensured, however, the leaching process is carried out with significant spreading of the solutions outside the zone of interaction of the wells. Working solutions are almost always diluted with produced water, but this does not affect the amount of uranium removed and the effluent, since a decrease in concentration corresponds to the same increase in the flow rate (volume) of the pumped liquid. The true concentrations of uranium and solvent in the leach solutions are equal to their values in the pumped liquid, multiplied by the unbalance coefficient. The dilution ratio of solutions is equal to the unbalance coefficient. In practice, due to the need to maintain a balance of pumped and injected solutions, it is rather difficult to reliably determine the contours of the leached volume. For this, hydrodynamic grids obtained in various ways (electro-analog modeling, calculations, etc.) are used with the results of laboratory or experimental work on metal extraction superimposed on them.

Figure shows the grid current of the solution and the position of the boundaries of its distribution with a linear (in-line) arrangement of technological wells [2-5].

In this case, leaching occurs in a linear section limited by a pair of technological wells.



The grid current of the solution and the position of the boundaries of its distribution during the operation of two wells in an unlimited aquifer. 1- streamlines; 2 - equal pressure lines (numbers indicate filtration resistance); 3 - the boundaries of the distribution of the leach solution (the numbers show the dimensionless relative time the solutions reach the boundaries)

The accumulated experience in the exploitation of deposits of zones of formation oxidation allows us to group natural geological and hydrogeological factors and the conditions of occurrence of deposits in favorable and unfavorable conditions for the use of underground downhole leaching of uranium (table 2).

Table 2 – Geological and hydrogeological factors and conditions determining the operating conditions of uranium deposits by underground leaching

Natural factors determining the in-situ leaching process	The conditions of operation of the deposit by underground leaching method	
	favorable	unfavorable
1. Mineralization position in the ore-bearing aquifer	Compact, there are no barren interbeds inside the ore deposit	Complex, with frequent alternation of mineralization and barren rocks in the aquifer
2. Lithological and filtrational features of the ore-bearing aquifer section	Mineralization uniformity, low thickness (up to 20 m) of the aquifer, filtration uniformity of rocks	Mineralization heterogeneity, increased thickness (over 20 m) of barren aquifers, the possibility of spreading and dilution of productive solutions
3. Tectonic environment in the ore zone	Faults and vertical displacements of the ore zone are absent; formation hydrodynamics is stable	The presence of faults and displacements along the faults of mineralization and aquifers, a complex hydrodynamic situation, which makes it difficult to control the process of leaching of uranium
4. The presence of water storage	Apertures are available; ore bearing aquifers are located between mature aquifers	There are no mature aquifers; there are hydrodynamic windows between productive and barren aquifers
5. The composition of ore-bearing rocks	Quite homogeneous, mainly quartz-silicate, easily soluble ballast impurities are absent, low content of clay particles, carbonates, sulfides.	High content of harmful readily soluble compounds, carbonates, phosphates, sulfides, the presence of clay minerals of the montmorillonite group
6. Explosiveness of mineral forms of uranium	Easy opening with slightly acidic aqueous solutions, low acid consumption	High persistence of mineral forms of uranium by dissolution with acid solutions, the need for oxidizing agents, high acid consumption
7. Ore Productivity	High enough (more than 4-5 kg /m^2)	Low (1-3 kg/m^2)
8. The ratio of productivity to the effective power of the ore-bearing horizon	From 1: 5 to 1:10, allows you to maintain a high concentration of uranium in solutions	More than 1:10, has a negative effect on the concentration of uranium in solutions
9. Achieved in exploration flow rates of pumping wells	2 to 5 l / s or more	Less than 2 l / s
10. Form of deposits	Elongated wide deposits with good permeability of ore-bearing rocks	Irregular complex shape with low permeability of ore-bearing rocks

The data in tables 1 and 2, the data can be used in the evaluation of deposits for the use of underground borehole leaching [6-10].

Discussion. The developed classification system for signs of the suitability of infiltration uranium deposits for leaching is recommended for use in the design of PSV technology in Kazakhstan deposits. The possibility and effectiveness of applying the technology of underground leaching of uranium with sulfuric acid solutions through a system of wells drilled from the surface is determined by a combination of a number of geotechnological and economic factors and parameters [11].

The determining factors and parameters for the use of underground leaching of uranium include the availability of reserves for the organization of work on UWL; parameters of water cut and permeability of ore-bearing rocks; mineralization depth; type of ore mineralization; the material composition of ore-bearing rocks; parameters of carbonate and sulfuric acid solubility of minerals; parameters of occurrence and groundwater pressure; presence of water storage; expected uranium mining costs. The degree of suitability of the field for efficient exploitation by underground leaching depends on specific combinations of parameters of natural and production conditions [12-22].

Based on the results of this work, an assessment was made of the existing technology for exploitation of hydrogenic uranium deposits in Kazakhstan to select the object of study; an analysis is made of existing

production technologies for the exploitation of hydrogenous uranium deposits that do not meet the requirements of a market economy: low labor productivity, high cost per unit of production; a comparative analysis of boreholes with the main technical facilities providing the injection of a chemical or biochemical solution was made; An alternative method for supplying chemical solutions to an array of hydrogenous uranium reservoir has been developed; losses and dilution of chemical solutions are determined.

The work was performed according to the results of study No. AP05130987 "Development of innovative technology for exploitation of hydrogen deposits of uranium for industrial and energy development of the contra"

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КЕН ОРНЫН ЖЕРАСТЫ ҰҢҒЫЛАП ШАЙМАЛАУ ӘДІСІМЕН ИГЕРУ ҮШІН ҚАЗАҚСТАННЫҢ УРАН КЕН ОРЫНДАРЫНЫҢ ТАУ-КЕН-ГЕОЛОГИЯЛЫҚ СИПАТТАМАЛАРЫН ЗЕРТТЕУ

Аннотация. Уран өндірудің дәстүрлі технологияларының едәуір кемшіліктері бар, нарықтық экономика талаптарына жауап бермейді, тиімділігі аз, қымбат тұратын құю-сору ұңғымаларын көп қолдануды талап етеді, сілтілеудің төмен қарқындылығы химиялық реагент пен күкірт қышқылының көп мөлшердегі шығынын қажет етеді (1 т уран концентратын алу үшін 100 т күкірт қышқыл шығыны). Мұндағы өнімді ерітінді – ерітілген сілтісізденген түрлі пайдалы компоненттердің (металдар), оның ішінде уран концентрациясын қамтитын химиялық ерітінді.

Уранның гидрогенді кен орындарын пайдалану тәжірибесінде технологиялық ұңғымалардың орналасу схемасы қабылданған: желілік (немесе қатар), алаңдық (немесе ұяшық) және құрама болып саналады.

Біз ұсынатын гидрогенді уран кен орындарын пайдаланудың инновациялық технологиясы оны сілтісіздендіру және басқа да пайдалы компоненттер үшін уранның гидрогенді қабат массивіне берілетін химиялық ерітіндіні белсендіру әсерін қолдана отырып, поршеньді ұңғымалардың жұмыс істеу қағидатында әзірленеді. Белсендіру үдерісінде химиялық ерітінді t = 70 ° C дейін қызады, ерітіндідегі су жақсы еріткішке айналады. Сорғыш құдық конструкцияны өзгертпестен поршеньдік ұңғылар ретінде пайдаланады, яғни айдау ұңғымалары сору ұңғымалары ретінде де қолданылады.

Мақалада Қазақстанның техногендік уран кен орындарының тау-геологиялық сипаттамасы берілген. Қазақстандық уранның шикізат базасының негізін «инфильтрациялық» деп аталатын кіші топқа біріктірілген экзогендік үлгідегі кен орындары құрайды. Уранның инфильтрациялық кен орындары қабатты өңірлік және топырақтық-қабаттық тотығу аймақтарымен байланысты жерасты суы негізінде қалыптасқан. Уранды жерасты ұңғылап шаймалау әдісін әзірлеу және енгізу тау-кен өнеркәсібінің маңызды ғылыми-техникалық жетістіктеріне жатады. Жерасты сілтісіздендіру әдісінің дәстүрлі кен орындарын игеру әдістерімен салыстырғанда мынадай артықшылығы бар: күрделі геологиялық-гидрогеологиялық жағдайда ірі уран қоры бар кен орындарын нашар және баланстан тыс кен орындарын пайдалануға тарту мүмкіндігі; күрделі салым және кен орындарын пайдалануға беру мерзімін едәуір қысқарту; еңбек жағдайын жақсарту, тау-кен жұмысшылар санын қысқарту және еңбек өнімділігін 2,5-3,5 есе арттыру; уран өндірудің қоршаған ортаға теріс әсерін азайту болып саналады.

Түйін сөздер: уран, кен орны, геологиялық барлау, ұңғымалық жерасты шаймалау, өнеркәсіптік бағалау.

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ИЗУЧЕНИЕ ГОРНО-ГЕОЛОГИЧЕСКИХ ХАРАКТЕРИСТИК УРАНОВЫХ МЕСТОРОЖДЕНИЙ КАЗАХСТАНА ДЛЯ РАЗРАБОТКИ МЕТОДОМ ПОДЗЕМНОГО СКВАЖИННОГО ВЫЩЕЛАЧИВАНИЯ

Аннотация. Существующие традиционные технологии добычи урана обладают большими недостатками, не отвечают требованиям рыночной экономики, малоэффективны, требуют применения большого количества дорогостоящих закачных и откачных скважин, большого расхода химического реагента, серной кислоты (для получения 1 т концентрата урана требуется расход 100 т серной кислоты), отличаются низкой интенсивностью выщелачивания. Здесь под продуктивным раствором понимается химический раствор, содержащий концентрацию растворенных там выщелоченных различных полезных компонентов (металлов), в том числе урана.

В практике эксплуатации гидрогенных месторождений урана приняты схемы расположения технологических скважин: линейные (или рядные), площадные (или ячеистые) и комбинированные.

Предлагаемая нами инновационная технология эксплуатации гидрогенных урановых месторождений будет разработана на принципе работ поршневых скважин с применением эффекта активации химического раствора, подаваемого в массив гидрогенного пласта урана для его выщелачивания и других полезных компонентов. В процессе активации химический раствор подогревается до t = 70ºС, вода в растворе становится хорошим растворителем. В качестве поршневых скважин применяются откачные скважины без изменения конструктивного оформления, т.е. откачные скважины используют и как закачные скважины.

В этой статье даны горно-геологические характеристики техногенных урановых месторождений Казахстана. Основу сырьевой базы казахстанского урана составляют месторождения экзогенного типа, объединенные в подгруппу, получившую название «инфильтрационного». Инфильтрационные месторождения урана сформированы подземными водами, связанными с региональными зонами пластового и зонами грунтово-пластового окисления. Разработка и внедрение метода подземного скважинного выщелачивания урана (ПСВ) относится к важнейшим научно-техническим достижениям горнодобывающей промышленности. Основные преимущества метода подземного выщелачивания по сравнению с традиционными горными способами разработки месторождений заключаются в следующем: возможность вовлечения в эксплуатацию бедных и забалансовых руд месторождений со сложными геолого-гидрогеологическими условиями залегания, но имеющими крупные запасы урана; значительное сокращение капитальных вложений и сроков ввода месторождений в эксплуатацию; улучшение условий труда, сокращение численности горнорабочих и повышение производительности труда в 2,5-3,5 раза; уменьшение отрицательного воздействия уранодобычи на окружающую среду.

Ключевые слова: уран, месторождение, геологоразведка, скважинное подземное выщелачивание, промышленная оценка.

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GEOLOGICAL STRUCTURE OF SOILS AND RICE YIELD IN THE ILI RIVER BASIN

Abstract. Rice irrigation systems in Kazakhstan are located on river terraces and levees of the Syr Darya, Ile, and Karatal rivers' basins. The geological structure and lithological composition of soils in the aeration zone is characterized by a wide variety, differing in soil fertility, mechanical composition, water and physical properties, water availability and salinity. Alluvial-meadow and takyr soils consist of light and heavy loam, sandy loam, and clay [1,2,3].

Melioration errors of the rice irrigation systems, built in the period from 60s to 80s of the last century, can be described by the fact that the *Kubanskaya* rice sowing map was built on all soils of river terraces and river banks, with the same parameters of irrigation and drainage, with the share of rice 57.5% and 63% [4].

At the rice irrigation systems, where the geological structure and lithological composition of the aeration zone soils correspond to the irrigation and drainage parameters of the *Kubanskaya* rice sowing map, the soil fertility and ameliorative status of irrigated land has remained high for many decades. The salt content in the 100 cm soil layer is 0.3-0.4%; in the autumn-winter period ground water is at a depth of 2.0-2.5 m, its mineralization is 5-7 g/l. During the rice irrigation period, ground water does not connect with the water of rice paddies, and the filtration of water from rice paddies is permitted and comprises 12 – 17 mm/day. Rice is grown without flow and discharge of water from rice paddies, the irrigation rate is 21,400 m^3/ha, and the yield is 5.2 t/ha.

At the rice irrigation systems, where the geological structure and lithological composition of the soil in the aeration zone does not correspond to the irrigation and drainage parameters of the *Kubanskaya* rice sowing map, the land is saline. During the rice irrigation period, the ground water connects with the water on the rice paddies. On these paddies, due to the convective diffusion of salts from the soil and from ground water, water salinity increases and reaches the critical threshold of toxicity of 2.5 g/l [5]. It is necessary to discharge water to reduce the salinity of water on the rice paddies, which is followed by flooding of water from the irrigation channel. The irrigation rate is 23,500 m^3/ha, and the yield is 4.7 t/ha.

Key words: Geology, soil cover, lithology, aeration zone, takyrs, mineralization, water availability, salinity, ricesystems, water-salt balance, rice, yield.

Introduction. The impact of geological structure of the soil on the yield of rice study was carried out empiricallyon the field of 155 hectares of "Birlik" farm. The mineralization rate of water layer as well as observations on rice growth and productivity have been carried out on 20 paddies during rice irrigation period. On two rice paddies (10 and 11) with the area of 6.8 ha, the soil is highly saline with a salt content in the soil of the aeration zone of more than 1.0%. Upon reaching a critical threshold of toxicity and water salinity layer in rice paddies, water from paddies is discharged and paddies are flooded to the same level with water from an irrigation channel. On the other rice paddies (the remaining 18), with the overall area of 48.2 hectares, the soil is slightly saline with a salt content of up to 0.3%. On the remaining 100 ha paddy field, the rice is cultivated according to the existing recommendations [8].

Results. On saline soils of rice paddies 10 and 11, the irrigation rate is 23,488 m^3/ha, the yield is 4.7 t/ha. Discharge (change) of water from rice fields during the irrigation period is carried out twice: the

first is during stem extension of the rice plants when the salinity of the water layer in rice paddy is 2.5 g/l and the second time is during flowering period; the volume of water discharge is 2,297 m^3/ha. On slightly-saline lands of 18 rice paddies, the salinity level of the water layer in the rice paddies during the irrigation period did not exceed 1.0 g/l and water was not discharged from the paddies, the irrigation rate of rice constituted 21,346 m^3/ha, while the yield was 5.2 t/ha (table 1).

Table 1 –Rice irrigation technique

№	Rice vegetation stages and their duration	Rice irrigation regime on saline soils	Water supply m^3/h	Rice irrigation regime on low saline soils	Water supply m^3/h
1	2	3	4	5	6
1	Sprouting 05.V-15.V	Flooding and maintenance of 10 cm water layer	6,559	Flooding of the paddy fields by 10 cm	5,780
2	Emerging crops 16.V-31.V	Maintenance of 8 - 10 cm water layer	3,170	Intermittent flooding by 5-6 cm	3,070
3	Tillering 01.VI-30.VI	Maintenance of 5 cm water layer	2,609	Maintenance of 5 cm water layer	2,510
4	Booting 01.VII-25.VII	01-02.VII Increase of water layer up to 12 cm	820	Increase and maintenance of 12 cm water layer	790
		03-22. VII Maintenance of the water layer	3,270	Maintenance of 12 cm water layer	4,100
		23-24. VII Discharge of the water layer from paddy due to mineralization increase up to 2.5 g/l	1,200		
		24-25. VII Flooding of paddy with 12 cm water layer			
5	Heading - blooming 26.VII-10.VIII	26. VII-08.VIII Maintenance of 12 cm water layer	2,510	Maintenance of 12 cm water layer	2,866
		9-10.VIII Discharge of the water from paddy due to mineralization increase up to 2.5 g/l			
6	Milk – waxed ripeness 11.VIII-28.VIII	11-12. VIII Flooding of paddy fields to 12 cm	1,200	Maintenance of 12 cm water layer	2,230
		13-28.VIII Maintenance of 12 cm water layer	2,150		
7	Full ripeness of rice grain 29.VIII-08. IX	29. VIII Discontinue water supply	–	Discontinue water supply	–
8	Total		23,488		21,346
9	Rice yield, t/ha	4.7		5.2	

Hydro module of initial flooding of the paddy fields is equal to 6,4 – 7,8 l/s·h, during maintenance of the water layer period – 1.9-4.6 l/s·h.

When rice yield is 5.2 c/h, the total evaporation during irrigation period (evaporation plus transpiration) is 9,860 m^3/h. An intensity of the evaporation in irrigation period depends on vegetation phase. The highest value of the evaporation occurs in the booting phase – 158 m^3/h per day [9,10,11].

Total evaporation value, which includes transpiration and filtration is 17,710 m^3/h, which is lower than the water consumption norm set by spillways at 3,679 m^3/g. Such water volume is consumed for soil saturation of aeration zone and side filtration to adjoining territory of the paddy fields [12,13].

In water balance, water supply to the paddy fields during irrigation period to the low saline soils without water discharge is 21,396 m^3/h, to the saline soils with water discharge is 23,488 m^3/h, additional supply from the ground waters and atmospheric precipitations are 1,340 m^3/h and 2,670 m^3/h respectively. In consumption side of the water balance, total evaporation is equal to 9,860 m^3/h, filtration and drainage run-offs are 7,850 m^3/h, ground water outflow from the paddy fields is 1,180 m^3/h, and 1,490 m^3/h.

Discharge run-off from the paddy fields in which mineralization of the water layer exceeded acceptable limits, it is 2,800 m^3/h. On the rice system, the water balance is steadily maintained, the sum of the components of the supply part of the water balance is equal to the consumption, the balance discrepancy is 5.5-5.6% (table 2).

Table 2 – Water balance of the paddy fields of Agrofirm «Birlik» experimental field

№	Name	Low saline soils, paddy fields without water discharge	Saline soils, paddy fields with water discharge
1	2	3	4
Supply side			
1	Water supply from channel	21,396	23,488
2	Precipitations	1,200	1,200
3	Ground water inflow	140	1470
	Total	22,736	26,158
Consumption side			
1	Soil saturation	2,700	2,700
2	Total evaporation and transpiration	9,860	9,860
3	Filtration and drainage run-off	7,850	7,850
4	Discharge run-off	–	2,800
5	Ground water outflow	1,180	1,490
	Total	21,590	24,700
	Discrepancy	1,270	1,474
		5.5%	5.6%

The salinity balance of Agrofirm «Birlik» of the Akdaly rice system demonstrates that soil desalination of aeration zone occurs during rice cultivation at the rice fields. Salt discharge from aeration zone of 0-160 cm from the paddy without water discharge in irrigation period is 36.4 t/h, on saline soils with water discharge in irrigation period is 29.9 t/h. Salt discharge prevails over entry to the paddy fields without water discharge up to 4.7 t/h, on saltine soils with water discharge 2.6 t/h, discrepancy is 4.0% and 1.3% (table 3).

Table 3 – Salinity balance at the paddy fields of Agrofirm «Birlik» experimental field of the Akdaly rice system, t/h

Elements of Salt Balance	On low saline soils, paddy fields without water discharge during irrigation period	On paddy fields with water discharge during irrigation period
S_1 – salt reserves of aeration zone before rice crop	112.6	229.8
S_2 – salt entry with irrigation water	12.2	12.8
S_3 – salt entry from ground water	1.2	1.4
TOTAL	126.0	244.0
S_4 – salt reserves of aeration zone after rice harvesting	76.2	199.9
S_5 – salt discharge by filtration run-off S_6 – salt discharge by discharge run-off	49.1	38.1 5.2
S_7 – salt discharge by drainage run-off and ground water outflow	5.4	2.8
TOTAL	130.7	246.6
Balance	- 4.7	- 2.6
Discrepancy, %	- 4.0	- 1.3

The rice growing technique, which is taking into account the geological structure and lithological composition of soils in the aeration zone of rice paddies, affects the critical threshold indicators of the mineralization of the water layer on rice paddies and provides: profit of 33,250 tenge/ha and increases profitability by 18.6% on saline lands; on slightly saline lands profit is 49,256 tenge/ha and profitability by 22.2%. Reduction of non-productive loss of irrigation water on the area of 55 hectares is 3,945 m^3/ha; rice yield increases by 0.6 t/ha, efficiency of rice production by 20,137 tenge/ha, profitability by 10.7% (table 4).

Table 4 – Rice cultivation economic efficiency of irrigation technique based on critical threshold values of water layer mineralization in the paddy fields

Indicators	Rice irrigation technique during irrigation period		Weighted average value	At remaining production cooperative of Agrofirm «Birlik»	A difference in comparison with cooperative
	Low saline soils without water discharge	Saline soils with water discharge			
Area, hectares	48.2	6.8	55	100	
Rice yield, t /h	52.4	47.2	51.8	46,0	5.8
Irrigation rate, m^3/ t	21,396	23,488	21,655	25,600	- 3,945
Water consumption, m^3/c	408	499	418	556	- 138
Product prime cost, KZT/ t	5,060	5,307	5,154	5,810	- 656
Profit, KZT/h	49,256	33,250	47,277	27,140	20,137
Efficiency, %	22.2	18.6	21.7	11.0	10.7

Conclusions. The geological structure and lithological composition of soils in the aeration zone of the Akdala rice system affects the degree of soil salinity, water consumption rates and rice yield. In comparison with slightly and moderately saline soils, on saline soilsthe irrigation rate of rice is higher by 2,800 m^3/ha, whilethe rice yield is lower by 0.5 t/ha. On the saline lands of the Akdala rice system, water is discharged from rice paddies twice during the irrigation period, once in July and the second time in August. Saline lands of rice systems, where itis necessary to be discharge(change) water during the irrigation period, account for 11% of the irrigated area, while other 89% of the irrigated land area is slightly and moderately saline, and there is no need to discharge water during the irrigation period [5, 14, 15].

The introducing of the proposed technique for rice irrigation, which is taking into account the thresholds of critical indicators of the water layer mineralization of the rice paddies will increase the additional harvest of shaly rice from the Akdala rice system by 6.0 thousand tons, and will save water resources by 40 million m^3 per year. On the rice irrigation systems of Kazakhstan, these indicators will comprise 43.5 thousand tons and 296 million m^3 of saved water respectively.

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ІЛЕ ӨЗЕН БАССЕЙНІ ТОПЫРАҒЫНЫҢ ГЕОЛОГИЯЛЫҚ ҚҰРЫЛЫМЫ ЖӘНЕ КҮРІШ ӨНІМІ

Аннотация. Қазақстандағы күріш суару жүйесі Сырдария, Іле және Қаратал өзені бассейнінің террассасы мен сағасында орналасқан. Аэрация аймағы топырағының геологиялық құрылымы мен литологиялық құрамы топырақ құнарлылығы, механикалық құрамы, су-физикалық қасиеттері, су өткізгіштігі мен тұздылығы арқылы ерекшеленеді. Аллювиалды шалғынды және тақыр топырағы жеңіл және ауыр саздақтан, құмдақ саздан және саздан тұрады [1,2,3].

Өткен ғасырдың 60-80-жылдары салынған күріш суару жүйесіндегі мелиоративті кемшіліктер өзен террассасы мен жағалауындағы топырақтың аэрация аймағының геологиялық құрылымы, литологиялық құрамымен ерекшеленетін, біркұрылымды «Кубанская» күріш картасы, суару және дренаждың бірдей

параметрімен салынғаны және күріштің ауыспалы егістік схемалары 7 және 9 күріштің үлесі сәйкесінше 57,5% және 63% құрайды [4].

Күріш суғару жүйесін пайдалану кезінде «Кубанская» күріш картасы топырақ қасиеттерін сақтаған топырақта, күріштің жетекші дақылдарын суарудың бұзылуы жағдайында, күріштің өнімділігі мен күріш дақылдарының ауысуы көптеген ондаған жылдар бойы жоғары болып келді, күріш 6,0 тонна./га және одан да көп, жоңышқа 18,0 т / га құрғақ массаға дейін жетеді. Күріштің суару нормасы жобалық ауқымда 22-23 мың $м^3$/га құрайды. Жетекші күріш дақылдарын суарудың арқасында топырақ қасиеттері бұзылады, өнімділігі төмен жердің буферлік қабілеті екінші реттік тұзданады, күріш өнімділігі 3,5 т / га, жоңышқа 6,0-8,0 т/га. Күріштің суару нормасы 28 мың $м^3$/га және одан да көп, жердің тозу үдерісі және ауылшаруашылығы мақсатында пайдаланудан шығып қалған [5].

Жалпы ауданның 220 мың га, Сырдария өзені бассейніндегі Қызылорда күріш суару жүйесіндегі өнімі аз жерлер 40 мың га құрайды. Іле өзені бассейніндегі Ақдала массиві 8 мың га, Қызылорда күріш суару жүйесіндегі 20 мың га және Ақдала массивіндегі 6 мың га тозған жер екінші рет тұзданғандықтан, ауылшаруашылығы мақсатында пайдаланудан шығып қалған [6].

«Кубанская» күріш картасы жеті және тоғыз танапты ауыспалы егістікте күріш өнімділігі 50-60 ц/га болатын аэрация аймағы топырағының геологиялық құрылымы мен литологиялық құрамы жеңіл саздауыт топырағымен, құмды саздақ қабаттан тұрады. Жері тұздырақ, 100 см топырақ қабатында 0,3-0,4% тұзды болып келеді. Күзгі, қысқы кезеңде жерасты суы 2,0-2,5 м тереңдікте, олардың минералдануы 5-7 г/л құрайды. Күрішті суару кезеңінде жерасты суы күріш егісінің суымен қосылмайды, күріш егісінен судың сүзулуі бос және тәулігіне 12-17 мм құрайды. Сүзулудің арқасында күріш атызындағы су жаңарады, топырақтың тамыр қабатынан микроорганизм қалдығы мен тұз алынады. Дренаж ағыны секундына 0,57 л/га көрсетеді. Күріш ағынсыз және күріш атызынан су ағызылмай өсіріледі.

Күріш суару жүйесінің өнімі аз жерде аэрация аймағы топырағының геологиялық құрылымы мен литологиялық құрамы ауыр саздауыт пен саз балшықты саздақтан тұрады. Жері тұзды, 100 см топырақ қабатында 0,7-0,9% тұз кездеседі. Күзгі, қысқы кезеңде жерасты суы 1,2-1,5 м тереңдікте, ал минералдануы 12-15 г/л құрайды. Күрішті суару барысында жерасты суының күріш атызындағы сумен араласып, күріш атызындағы судың сүзілуі тәулігіне 0-3 мм, дренажағы 0,12 л / сағ. болады. Бұл жерде топырақ пен жерасты суы тұзының конвективті диффузиясына байланысты күріш атызындағы су көбірек минералданады және уыттылық шекті деңгейіне 2,5 г/л жетеді [7,8]. Судың минералдануын азайту үшін суару каналынан суды ағызу қажет, кейіннен суару каналынан су толтырады. Бұл жердегі күріш дақылының жеті және тоғыз танапты ауыспалы егіске арнап «Кубанская» күріш картасының құрылымын өзгерту керек, оның жобалық 350-400 м орнына 60 м қашықтықта жасау қажет. «Кубанская» күріш картасының 60 м дрен арақашықтығы дренажды ағынын 0,37 л/с.га. қамтамасыз етеді, топырақтың қайта тұздану жағдайының алдын алады [5,6,7].

Түйін сөздер: геология, топырақ жамылғысы, литология, аэрация аймағы, тақыр, минералдану, су өткізгіштік, тұздылық, күріш жүйесі, су, тұз балансы, күріш, өнімділік.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ ПОЧВОГРУНТОВ И УРОЖАЙНОСТЬ РИСА БАССЕЙНА Р. ИЛЕ

Аннотация. Рисовые оросительные системы Казахстана расположены на речных террасах и прирусловых валах в бассейнах рек Сырдарьи, Иле, Каратал. Геологическое строение и литологический состав почвогрунтов зоны аэрации характеризуется большим разнообразием, отличающихся по плодородию почв, механическому составу, водно-физическим свойствам, водопроводимости и степени засоления. Почвы аллювиально-луговые и такырные состоят из легких и тяжелых суглинков, супесей, глины [1,2,3].

Ошибки мелиорации рисовых оросительных систем, построенные в 60-70-80 годы прошлого столетия, состоят в том, что на всех почвогрунтах, речных террасах и прирусловых валах, отличающиеся по геологическому строению и литологическому составу зоны аэрации была построена рисовая карта «Кубанская» одной конструкции, с одинаковыми параметрами орошения и дренажа и схемами рисовых севооборотов 7 и 9 полные, с долей участия риса соответственно 57,5% и 63% [4].

В процессе эксплуатации рисовых оросительных систем выяснилось, что на почвогрунтах, где рисовая карта «Кубанская» способна сохранять свойство почв, в условиях действующих возмущений от поливов ведущей культуры риса, урожайность риса и культуру рисового севооборота многие десятилетия остается

высокой, риса – 6,0 т/га и более, люцерны – до 18,0 т/га сухой массы. Оросительная норма риса – в пределах проектной 22-23 тыс.м^3/га. На почвогрунтах, где за счет полива ведущей культуры риса нарушаются свойства почв, их буферность земли низкопродуктивные подвержены вторичному засолению, урожайность риса не превышает 3,5 т/га, люцерны – 6,0-8,0 т/га. Оросительная норма риса 28 тыс.м^3/га и выше, происходит деградация земель и выход из сельхозоборота [5]. Из общей площади 220 тыс.га низкопродуктивные земли на Кызылординской рисовой оросительной системе в бассейне р.Сырдарьи составляют 40 тыс.га, на Акдалинской в бассейне р.Иле – 8 тыс.га, деградированные земли на Кызылординской рисовой оросительной системе, вышедшие из сельхозоборота по причине вторичного засоления , 20 тыс.га и 6 тыс.га – на Акдалинской [6].

Геологическое строение и литологический состав почвогрунтов зоны аэрации, где рисовая карта «Кубанская» обеспечивает урожайность риса 50-60 ц/га в семипольном и девятипольном севооборотах, представлен почвами легкими суглинками, суглинками с прослойками супеси. Земли слабозасоленные, с содержанием солей в 100 см слое почв 0,3-0,4%. В осенне-зимний период грунтовые воды находятся на глубине 2,0-2,5 м при их минерализации 5-7 г/л. В период полива риса грунтовые воды не смыкаются с водой рисовых чеков, фильтрация воды из рисовых чеков свободная и составляет 12 – 17 мм/сут. За счет фильтрации происходит обновление воды в рисовых чеках, вынос солей и продуктов жизнедеятельности микроорганизмов из корнеобитаемого слоя почв. Дренажный сток составляет 0,57 л/с.га. Рис выращивается без проточности и сбросов воды из рисовых чеков.

На низкопродуктивных землях рисовой оросительной системы геологическое строение и литологический состав почвогрунтов зоны аэрации представлен тяжелыми суглинками, суглинками с прослойками глины. Земли засоленные, с содержанием солей в 100 см слое почв 0,7-0,9%. В осенне-зимний период грунтовые воды находятся на глубине 1,2-1,5 м, минерализация их 12-15 г/л. В период полива риса грунтовые воды смыкаются с водой рисовых чеков, фильтрация воды из рисовых чеков составляет 0-3 мм/сут, дренажный сток – 0,12 л/с.га. На этих землях за счет конвективной диффузии солей из почвы и от грунтовых вод увеличивается минерализация воды в рисовых чеках и достигает критического порога токсичности 2,5 г/л [7,8]. Для снижения минерализации воды в чеках необходимо производить сбросы воды с последующего затопления из оросительного канала. Для семипольного и девятипольного рисовых севооборотов на этих землях необходимо изменить конструкцию рисовой карты «Кубанская», выполнить расстоянием 60 м вместо 350-400 м проектной. Рисовая карта «Кубанская» с междренным расстоянием 60 м обеспечит дренажный сток 0,37 л/с.га, предотвратит вторичное засоление почв [5,6,7].

Ключевые слова: геология, почвенный покров, литология, зона аэрации, такыры, минерализация, водопроводимость, засоление, рисовые системы, водно-солевой баланс, рис, урожайность.

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URANIUM AND OTHER TOXIC ELEMENTS IN TRANSBOUNDARY WATERS NEAR KAMYSHANOVSKY DEPOSIT

Abstract. The paper is devoted to revealing the signs of negative impact from the territory of the Kamyshanovskoye deposit (Kyrgyzstan) on the level of contamination with uranium and other hazardous elements in transboundary water bodies, in the first place in the Shu River. For this, six control points along the irrigation canal at this territory were chosen together with 9 control points along the Shu river within the area. The elemental composition of water samples was studied employing MS-ICP and OES-ICP; concentration values of 22 elements were determined. The calculations were performed based on the obtained contents of toxic elements of the 1st and 2nd classes. Corresponding sanitary standards exceed the corresponding values by 1.5 – 6.7 times. At that, uranium makes the main contribution to the toxicity level of the studied water in the Shu River (46%) and in the canal (61%). The toxicity of the water canal is for ~3 times higher than that of the Shu River. The highest toxicity indicator was found in the water delivered to the agricultural irrigation at the territory of the Kamyshanovskoye deposit. This peculiarity and the obtained data may be of interest to the Ministry of Agriculture of the Kyrgyz Republic.

The distribution of chemical elements in water along the irrigation canal and along the Shu River bed was studied. It is established that the canal water do not become contaminated with toxic elements while passing through the deposit lands. It was established in the 3 control points of the Shu River that an increase (by 28 – 130%) in the concentration of Ca, Ni, Li, Sr, U, Mg, Cr, Ba over their concentrations at the control points is higher upstream of this river. The results obtained convincingly indicate the presence of a serious influence of the Kamyshanovskoye deposit territory on the Shu River contamination with these elements. It is unlikely that such significant contamination is caused by the irrigation system discharge waters. One of the possible mechanisms of water contamination in the Shu River in its segment may be the entry of groundwater in contact with the ore body of this deposit.

Key words: uranium deposit, transboundary waters, toxic elements.

Introduction. The uranium deposit Kamyshanovskoye is located on the territory of Kyrgyzstan 45 km from Bishkek and in the immediate vicinity of the border with Kazakhstan. It has been revealed exploring this deposit that uranium is concentrated (up to 0.1%) mainly in peat and silt-peat deposits. Uranium-bearing peat also contains the following chemical elements (including the toxic ones): Mo, Cu, Zn, V, As – n·(0.1-0.01)%; Pb, Co, Ni, Sc, Ga – n·0.001% [1].

In the southern part of this field, the village of Kamyshanovka with a population of about 2.5 thousand people is located. The local population is mainly engaged in cattle breeding and cultivation of vegetables and grain crops. These agricultural works are carried out practically on the entire territory of the field. A complex densely interwoven irrigation system has been created for watering the cultivated products. Water, which is a mixture of many water sources, enters this system through a special hydro-canal. Ultimately, the waters of this system, including all return water from the irrigation fields, are discharged into the riverbed of the Shu River flowing in the northern part of the field along the Kyrgyzstan-Kazakhstan border.

Since virtually any mineral exploration activity or industrial development of mineral deposits affects the environment [2,3], al-Farabi KazNU studied the radionuclide composition and the presence forms of uranium in peat samples from the Kamyshanovskoye deposit and soil taken near the residential village of the same name.

The revealed specific activity of ^{238}U in the studied soil significantly (for about 10 times) exceeded the background value of its activity for the region. This indicates a technogenic impact from the uranium mine. It was also shown that the main part (more than 90%) of uranium contained in the studied soil and peat samples is in geochemically mobile forms [4, 5]. Uranium in such forms, under the influence of various natural factors (rain, wind), can migrate to local water sources and spread over considerable distances. Thus, the situation on the territory of the Kamyshanovskoye deposit, located in close proximity to the transboundary Shu River, represents a potential danger of contamination of this river with uranium (and, possibly, with other toxic elements).

Given the above, we set up a task to study the elemental composition of water samples taken in the Shu River and the hydro-canal in the territory of the Kamyshanovskoye deposit. The purpose of this study is to identify the signs of the negative impact of the above (or other) factors on the contamination with uranium and other toxic elements (TE) of the waters of these transboundary objects, in the first place of the Shu River.

Field work and methods of research. Field work was based on the experience gained in our previous studies of radiation and environmental conditions in the Syr Darya river basin within the framework of the international project "Navruz" (Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan) [6].

Water was sampled as shown in figure 1 from 6 control points (CH-1 – CH-6) along one of the irrigation canals and at 9 control points along the Shu River (SH-1 – SH-9). The vast majority of these samples (14 out of 15) were taken on the territory of Kyrgyzstan. In Kazakhstan, only 1 water sample was taken at the control point (CP) SH-9.

Figure 1 – Water sampling points in the territory of the Kamyshanovskoye field

At each control point, water was sampled at least in 5 points in compliance with the State Standard RK GOST R 51592-2003. So, places free of algae and floating debris were chosen. A water sampling container was immersed to a depth of 50 cm below the surface. The combined 0.25 l water sample was filtered through 0.3 μm membrane filters, preserved at the rate of 3 ml of concentrated HNO_3 per 1 l, and hermetically packed in plastic bottles.

Inductively coupled plasma mass and optical emission spectrometry (MS-ICP, OES-ICP) were used to determine the elemental composition of the taken water samples. MS-ICP analysis was performed at the ELAN-9000 inductively coupled plasma quadrupole mass spectrometer PerkinElmer SCIEX. The OES-ICP analysis was performed on an OPTIMA-8000 inductively coupled plasma optical emission spectrometer, manufactured by PerkinElmer Inc. Each device is equipped with a computer workstation and specialized software. All analyses were carried out according to the standard method "ISO 17294-2.

Part 2: determination of 62 elements." Prior to each measurement series, the sensitivity and stability of the spectrometer system (instrument tuning) was checked using specially prepared (based on standard samples) solutions. Upon obtaining the calibration curves, blank solutions and natural water samples were measured, both initial and (if necessary) diluted 1/10, 1/100, etc. The isotopes for measurement (in the case of IC-ICP) and the emission lines (in the case of OES-ICP) were selected based on a compromising criterion assuring acceptable detection sensitivity, minimal spectral noise and low background. The technique allows to determine concentrations of many elements with the detection thresholds from 0.1 to 10 $\mu g \cdot kg^{-1}$.

The presented technique was tested on various standard samples and has been successfully used in monitoring the transboundary rivers of Kazakhstan and studying the environmental situation in the basins of the most contaminate water objects [6-8].

Results and their discussion. The methods of MS-ICP and OES-ICP were used to study the elemental composition of water samples taken at all 15 CPs. The concentration values (or their threshold values) were determined for the following 27 elements: Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, Hg, K, La, Li, Mg, Mn, Mo, Ni, Pb, Sb, Sr, Th, U, V. Preliminary analysis of the obtained data showed that the contents of Ag, Be, Cd, Hg and Th in all the studied water samples were below the detection thresholds of the employed analysis methods and the corresponding clark values (world average) for drinking water [9].

Table 1 shows the intervals of the concentration values for the remaining 22 elements and the average values of their concentrations in water at the studied sections of the Shu River and the canal. The table also presents the clark values for all elements, as well as the maximum allowable concentrations values set by WHO (MAC_{WHO}) [10] and (additionally) by Kyrgyz Republic (MAC_{KR}) [11] for drinking water. It should be noted that the values of the MAC_{KR} for Al, Co and Li coincide with the relevant standards set by the Republic of Kazakhstan (MAC_{RK}) [12].

Table 1 – The concentrations of chemical elements in water samples taken along the Shu river and the canal, $\mu g \cdot kg^{-1}$

Element	Object				clark [9]	MAC_{WHO} [10], MAC_{KR} [11]
	The canal		Shu River			
	Range	Average	Range	Average		
Al	103 - 179	146±32	35.9 – 88.0	75.4±24.0	50.0	*500*
As	2.45 - 4.50	3.35±0.79	1.70 - 2.13	1.93±0.11	0.20	10.0
B	232 - 452	312±95	60.9 - 149	91.6±30.5	50.0	2,400
Ba	30.2 - 58.1	40.4±12.1	29.3 - 82.3	62.6±15.7	60.0	700
Ca, %	62.3 - 90.1	73.6±11.5	37.1 - 77.0	57.5±10.4	13.4	–
Ce	0.37 - 0.55	0.46±0.09	0.17 - 0.30	0.26±0.07	0.06	–
Co	0.41 - 0.58	0.47±0.07	0.23 - 0.30	0.25±0.02	0.20	*100*
Cr	2.45 - 8.64	4.84±2.42	1.62 - 4.09	2.29±0.67	1.00	50.0
Cu	1.15 - 2.49	1.82±0.59	1.31 - 3.03	2.59±1.87	1.50	2,000
Fe	82.0 - 163	116±43	43.6 – 61.4	58.8±9.6	40.0	2,000
K, %	2.58 - 4.33	3.53±0.74	1.52 - 2.97	2.56±0.44	1.30	–
La	0.19 - 0.28	0.24±0.05	0.14 - 0.19	0.17±0.05	0.04	–
Li	18.3 - 42.8	26.6±11.2	4.93 - 11.4	8.03±1.87	2.50	*30.0*
Mg, %	31.1 - 59.5	40.4±11.4	12.2 - 24.8	17.8±4.4	3.35	–
Mn	5.22 - 16.6	10.6±6.1	3.99 - 10.6	9.13±3.39	8.20	400
Mo	9.09 – 14.7	10.5±2.2	4.92 - 5.76	5.30±0.24	0.50	70.0
Ni	6.16 - 8.60	6.92±0.98	4.15 - 6.58	5.19±0.58	0.50	70.0
Pb	0.40 – 0.62	0.51±0.08	0.30 - 0.60	0.49±0.11	0.10	10.0
Sb	1.06 - 1.84	1.34±0.35	<0.30 - 0.75	0.69±0.21	1.00	20.0
Sr	1107 - 2025	1392±358	529 - 905	650±124	60.0	–
U	82.6 - 114	99.0±14	17.4 - 31.1	24.3±4.7	0.24	30.0
V	7.83 - 14.2	10.4±3.1	2.08 - 2.43	2.19±0.11	1.00	–

The data presented in table 1 indicate that the average concentration of the vast majority of the studied elements (with the exception of Ba and Sb) in the waters taken in the Shu River and in the canal are higher (for many, are substantially higher) than their corresponding clark values. Also, for many of these elements (with the exception of Ba and Cu), the concentrations in the canal are noticeably (for 1.5 – 4 times) higher than those in the river. As it has been mentioned above, the water of the irrigation system on the territory of the Kamyshanovskoye deposit flows into the Shu riverbed. This imposes the risk of the Shu water contamination with chemical elements contained in significant concentrations in these wastewaters. The highest contamination danger exists due to the significant contents of uranium (U is a chemical element of the 1st hazard class), certain elements of the 2nd hazard class (Al, As, B, Li, Mo, and Sr), and salts of calcium, potassium, magnesium.

Table 2 show the calculated values of the total chemical toxicity (the limiting indicator of the harmful effects, K_{LHI}, the limiting hazard indicator) of water at all CPs along the canal and the Shu River. The calculations are performed in accordance with the following expression

$$K_{LHI} = \sum_{i=1}^{n} C_i * \mathrm{MAC}^1$$

where C_i – is the concentration of the elements of the Hazard class 1 or 2. At that, we considered a limited list of elements (those with significant concentrations at all 15 CPs) of the 1st and 2nd hazard classes: Al, As, B, Ba, Li, Mo, Pb, Sr, U. This indicator for drinking water, following the Sanitary Rules of the Republic of Kazakhstan, should not exceed 1.0 [12].

Table 2 – The values of the limiting hazard indicator K_{LHI} for the water samples taken at the control points in the canal and in the Shu River

Sample code	$C_i \cdot MAC_i^{-1}$									
	Al	As	B	Ba	Li	Mo	Pb	Sr	U	K_{LHI}
Canal										
CH-1	0.36	0.39	0.19	0.08	1.43	0.21	0.04	0.29	3.66	6.65
CH-2	0.34	0.32	0.17	0.07	1.25	0.15	0.05	0.22	3.80	6.37
CH-3	0.32	0.25	0.12	0.04	0.68	0.14	0.05	0.18	3.55	5.33
CH-4	0.31	0.28	0.11	0.04	0.67	0.14	0.06	0.18	3.24	5.02
CH-5	0.21	0.32	0.10	0.05	0.61	0.14	0.06	0.16	2.81	4.45
CH-6	0.22	0.45	0.10	0.06	0.69	0.13	0.05	0.17	2.75	4.62
Shu River										
SH-1	0.18	0.21	0.03	0.11	0.23	0.07	0.08	0.08	0.58	1.57
SH-2	0.17	0.20	0.03	0.11	0.24	0.07	0.04	0.08	0.59	1.53
SH-3	0.18	0.20	0.03	0.12	0.24	0.07	0.06	0.08	0.61	1.59
SH-4	0.17	0.20	0.03	0.11	0.25	0.07	0.05	0.08	0.60	1.56
SH-5	0.16	0.21	0.06	0.09	0.38	0.08	0.05	0.13	0.91	2.07
SH-6	0.09	0.18	0.06	0.09	0.37	0.08	0.06	0.12	1.03	2.08
SH-7	0.08	0.18	0.06	0.08	0.35	0.08	0.05	0.12	1.04	2.04
SH-8	0.07	0.17	0.03	0.04	0.16	0.08	0.03	0.08	0.94	1.60
SH-9	0.08	0.18	0.03	0.05	0.19	0.08	0.03	0.08	0.99	1.71
MAC_{WHO}, MAC_{KR}, $\mu g \cdot l^{-1}$	500	10	2,400	700	*30*	70	10	*7,000*	30	

The data presented in table 2 indicate that all the studied waters are characterized by the K_{LHI} values exceeding the sanitary standard of 1.0. At that, the main contribution to the toxicity of the studied waters is made by uranium (an element of the 1st class of chemical hazard): in the Shu River – for 46%, in the canal – 61%. It should also be noted that the toxicity of the cannel waters is significantly (~3 times) higher than that of the river waters (the average value of the K_{LHI} indicator for the canal waters is 5.41 ± 0.91, for the waters of the Shu River – 1.75 ± 0.24). The highest value of this indicator ($K_{LHI} = 6.65$) was found for

water at KP SN-1. This means that water significantly contaminated with toxic elements is supplied to the irrigation system of the agricultural fields on the territory of the Kamyshanovskoye deposit. We believe that this feature and the data obtained may be of interest to the Ministry of Agriculture of the Kyrgyz Republic.

The distribution histograms were made to study the distribution of the studied elements in the waters of the irrigation canal (laid through separate sections of the uranium-bearing peat deposits) and in the waters of the Shu River. Some of them are shown in figure 2 below.

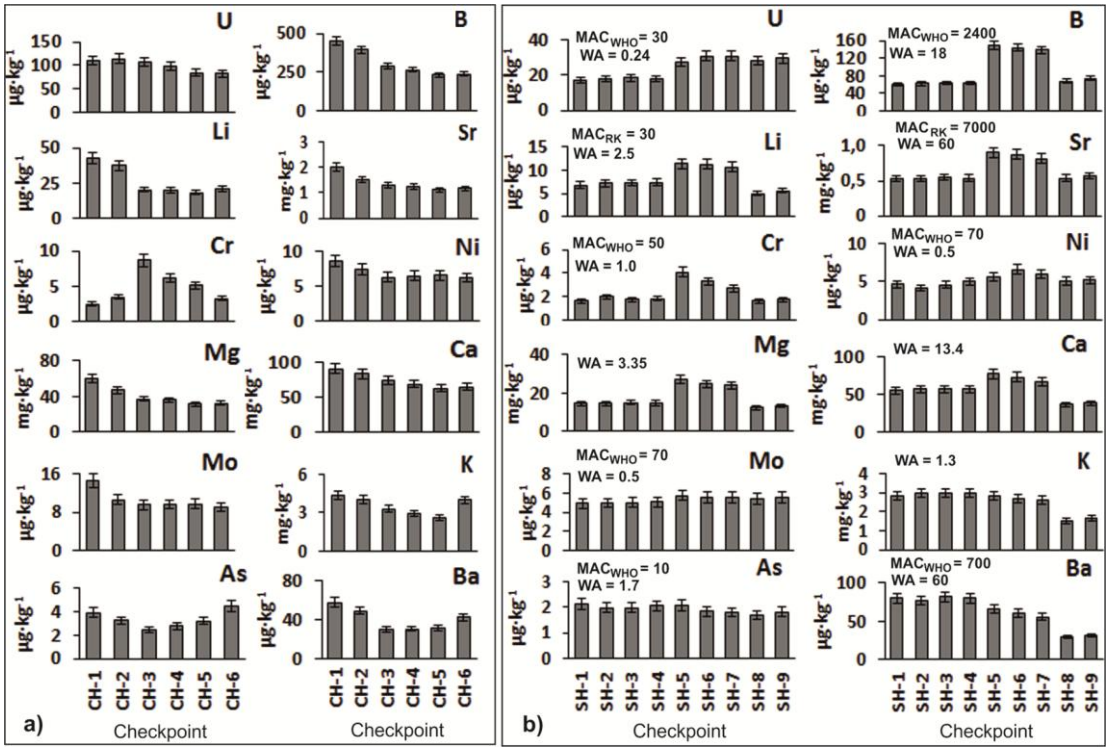

Figure 2 – Distribution of individual elements in the waters along the canal (a) and the Shu river (b)

It follows from figure 2a that the passage of the canal waters through the field does not ultimately lead to their enrichment with the elements presented. Moreover, the concentrations of most of them (U, B, Li, Sr, Ni, Mg, Ca, Mo) in the water at CH-5 are noticeably lower than those at CH-1. At the same time, one should pay attention to the sharp increase in the concentration of Cr in the canal water at the CP CH-3 (probably, due to a local contamination spot), as well as the increased contents of K, As, Ba in the water at the CP CH-6. Additional research is needed to clarify this pattern. It is common for all elements at figure 2b that their concentrations in the Shu River are evenly distributed in the waters taken upstream from the territory of the Kamyshanovskoye deposit at the following CPs: SH-1, SH-2, SH-3, SH-4. Further, their distribution in the waters of this river downstream differs markedly. In accordance with the main objective of this study, the distribution of U, B, Li, Sr, Cr, Ni, Mg, and Ca is of primary interest. The concentrations of each of these elements in water increase sharply (for most of them) or smoothly (for Ni) at SH-5 and remains elevated at the next two CPs SH-6 and CH-7. The excess of the average concentration in waters at these three CPs of each of these elements over the average value of its concentration in waters at the previous 4 CPs has the following value, %: Ca – 28, Ni – 30, Li – 55, Sr – 61, U – 66, Mg – 71, Cr – 86, B – 130. The presented results convincingly indicate the presence of a serious influence of the Kamyshanovskoye deposit territory on the river contamination with these elements. It is unlikely that such significant contamination is caused by wastewater from the irrigation system. This conclusion is supported by the comparison of the concentrations of these elements in the river at the CPs SH-8 and SH-9, in the interval between which the waters of the studied canal flow into this river. An increase in the concentration of these elements in the water on this segment of the Shu River is negligible and ranges from 2.5% (Ni) to 13% (Li). One of the possible mechanisms of water contamination in the Shu River in

its segment (SH-5 to SH-7) may be the entry of groundwater in contact with the ore body of this deposit. It should also be added that the revealed contamination with TE, Ca and Mg of the Shu River water is limited to the river section from the CP SH-5 to the CP SH-7. At SH-8, a sharp decrease (with the exception of U) of the concentration of these elements in water is observed. A more detailed study is needed in this place, on a segment of the river from SH-7 to SH-8, to clarify the essence of this phenomenon and its profoundness.

Conclusions. As a result of the present study, the factors of serious environmental concern were identified on the territory of the Kamyshanovskoye uranium deposit. Specific measures are required to clarify their nature and degree of danger to the environment and the health of the local population.

It has been established that the water used for irrigation of agricultural fields in this territory is significantly contaminated with uranium in concentrations of more than 3 times higher than the maximal permissible level for drinking water (MPA_{WHO} = 30 $\mu g \cdot kg^{-1}$) and with other toxic elements. It is necessary to carry out specific studies to reveal the degree of these elements transition to the farmed agricultural products.

It was also established that the concentration of uranium and other TEs in the water of the Shu River in its section located near the ore bodies of this deposit significantly exceed their levels in the upstream waters of this river. The discussed here possible mechanisms of the identified contamination is hypothetical. In order to identify a real source and reveal the mechanism of this contamination, it is necessary to carry out a more detailed study on this section of the deposit territory and the adjacent section of the Shu River.

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КАМЫШАНОВСКОЕ КЕН ОРНЫ МАҢЫНДАҒЫ ТРАНСШЕКАРАЛЫҚ СУДАҒЫ УРАН ЖӘНЕ БАСҚА ДА УЫТТЫ ЭЛЕМЕНТТЕР

Аннотация. Камышановское уран кен орны Қырғызстан аумағында Бішкек қаласынан 45 шақырым қашықта және Қазақстан шекарасына тікелей жақын орналасқан. Бұл кен орнын барлау нәтижесінде уран негізінен шымтезекте және лайлы-шымтезекті шөгіндіде шоғырланғаны (0.1% дейін) анықталды. Сондай-ақ уранды шымтезек құрамында келесі химиялық элементтер (оған қоса уытты) бар: Mo, Cu, Zn, V, As - n·(0.1-0.01)%; Pb, Co, Ni, Sc, Ga - n·0.001%.

Аталмыш кен орны аумағының оңтүстік бөлігінде 2.5~ мыңға жуық халқы бар Камышановка кенті орналасқан. Бұл кент тұрғындары негізінен мал шаруашылығымен, сондай-ақ көгөніс, дәнді дақыл өсірумен айналысады. Бұл ауылшаруашылық жұмыстары іс жүзінде кен орнының барлық аумағында жүзеге асырылады. Өсірілген өнімді суғару үшін бір-бірімен тығыз байланысты суару жүйесі құрылған. Бұл жүйеге су арнайы су арнасы арқылы келеді. Аталған жүйенің суы, оған қоса суармалы алқаптардан кері келетін барлық су, ақыр соңында, Қырғызстан-Қазақстан шекарасы бойындағы кен орнының солтүстік бөлігі арқылы ағып жатқан Шу өзені арнасына жіберіледі.

Әл-Фараби атындағы ҚазҰУ-да Камышановское кен орнынан алынған шымтезек үлгілеріндегі уранның радионуклидтік құрамын және орналасу пішінін, сондай-ақ аттас кенттің жанынан іріктеліп алынған топырақты зерделеу бойынша жұмыстар орындалды. Зерттелген топырақтағы ^{238}U меншікті активтілігі оның аталмыш аймақтағы активтілігінің аялық мәнінен едәуір (шамамен 10 есе) асатыны анықталды. Бұл уран кенішінің техногендік ықпал ететінін көрсетеді. Сондай-ақ, зерттелген топырақ пен шымтезек үлгілеріндегі уранның негізгі бөлігі (90%-тен астамы) геохимиялық-мобильді пішінде екендігі көрсетілген. Осындай

пішіндердегі уран әртүрлі табиғи факторлардың (жаңбыр, жел) әсерінен жергілікті су көзіне көшуі және едәуір қашықтыққа таралуы мүмкін. Осылайша трансшекаралық Шу өзеніне жақын жерде орналасқан Камышановское кен орны аумағындағы жағдай осы өзеннің уранмен (мүмкін басқа да уытты элементтермен) ықтимал ластану қаупін төндіреді.

Мақала трансшекаралық су объектілері суының, бірінші кезекте Шу өзенінің уранмен және басқа да уытты элементтермен ластану деңгейіне Камышановское уран кен орны аумағының теріс әсер ету белгілерін анықтауға арналған. Ол үшін осы аумақты суармалау жүйесі арнасының бойындағы 6 бақылау пунктінен, сондай-ақ осы мекенде ағып өтетін Шу өзені арнасының бойындағы 9 бақылау пунктінен су сынамалары іріктеліп алынды. Іріктеліп алынған су сынамаларының элементтік құрамы MS-ICP және OES-ICP әдістерімен зерделенді. 22 элементтің концентрация мәні анықталды. Қауіптілігі 1-ші және 2-топтағы уытты элементтердің мөлшері туралы алынған деректердің негізінде барлық зерделенген судың қосынды химиялық уыттылығының мәніне есептеу жүргізілді. Есептеу нәтижелері осы параметрдің барлық алынған мәні тиісті санитарлық нормативтен 1.5-6.7 есе асатынын көрсетті. Бұл ретте, зерделенген судың уыттылық деңгейіне уранның қосатын үлесі зор: Шу өзенінде - 46%, арнада – 61%. Арна суының уыттылығы Шу өзеніне қарағанда едәуір (~ 3 есе) жоғары. Камышановское кен орны аумағындағы ауыл шаруашылығы алқаптарын суару жүйесіне түсетін судың уыттылық көрсеткіші ең жоғары мәнге ие болды. Осы ерекшелік және алынған деректер ҚР Ауыл шаруашылығы министрлігінің қызығушылығын тудыруы мүмкін.

Химиялық элементтердің суландыру каналы мен Шу өзені арнасында таралу жағдайы зерделенді. Канал суының кен орны аумағы арқылы ағуы олардың уытты элементтермен ластамайтыны анықталды. Кенді шоғыр жанында орналасқан Шу өзені суының үш бақылау пунктінде Ca, Ni, Li, Sr, U, Mg, Cr, Ba концентрациясының осы өзен ағысының жоғарғы бөлігінде орналасқан бақылау пункттеріндегі олардың концентрациясынан едәуір жоғарылағаны (28-130%-ға) анықталды. Алынған нәтижелер Шу өзенінің осы элементтермен ластану деңгейіне Камышановское кен орны аумағының едәуір әсер ететіндігін нақты дәлелдеді. Мұндай айтарлықтай ластанудың суландыру жүйесінің ағынды суынан туындау ықтималдығы аз. Бұл жерде Шу өзенін ластайтын ықтимал механизмдердің бірі оның арнасы арқылы аталмыш кен орнының кенді шоғырымен түйісетін жерасты суының өткенінен болуы мүмін.

Түйін сөздер: уран кен орны, трансшекаралық су, уытты элементтер.

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УРАН И ДРУГИЕ ТОКСИЧНЫЕ ЭЛЕМЕНТЫ В ТРАНСГРАНИЧНЫХ ВОДАХ БЛИЗ МЕСТОРОЖДЕНИЯ КАМЫШАНОВСКОЕ

Аннотация. Месторождение урана Камышановское расположено на территории Кыргызстана в 45 км от г. Бишкек и в непосредственной близости от границы с Казахстаном. В результате разведки этого месторождения установлено, что уран сконцентрирован (до 0.1%), в основном, в торфах и илово-торфяных отложениях. Ураноносные торфы содержат также следующие химические элементы (включая токсичные): Mo, Cu, Zn, V, As - n·(0.1-0.01)%; Pb, Co, Ni, Sc, Ga - n·0.001%.

В южной части территории этого месторождения расположен поселок Камышановка с населением ~2.5 тыс. человек. Жители этого поселка, в основном, занимаются скотоводством, а также выращиванием овощей и зерновых культур. Эти сельскохозяйственные работы проводятся практически на всей территории месторождения. Для полива выращиваемой продукции создана сложная густопереплетённая система орошения. Вода поступает в эту систему по специальному гидроканалу. Воды этой системы, включая все обратные воды с полей орошения, в конечном итоге, сбрасываются в русло р. Шу, протекающей в северной части месторождения вдоль границы Кыргызстан – Казахстан.

В КазНУ им. аль-Фараби выполнены работы по изучению радионуклидного состава и форм нахождения урана в образцах торфа с месторождения Камышановское и почвы, отобранной возле одноименного жилого поселка. Установлено, что удельная активность ^{238}U в изученной почве существенно (примерно в 10 раз) превышает фоновое значение её активности в данном регионе. Это свидетельствует о техногенном влиянии со стороны уранового рудника. Показано также, что основная часть (более 90 %) урана, содержащегося в изученных образцах почвы и торфа, находится в геохимически-мобильных формах. Уран, находящийся в

таких формах, под воздействием различных природных факторов (дождь, ветер), может мигрировать в местные водные источники и распространяться на значительные расстояния. Таким образом, ситуация на территории месторождения Камышановское, расположенной в непосредственной близости от трансграничной р. Шу, представляет потенциальную опасность загрязнения этой реки ураном (возможно, и другими токсичными элементами).

Статья посвящена выявлению признаков негативного влияния территории месторождения урана Камышановское на уровень загрязненности ураном и другими токсичными элементами вод трансграничных водных объектов, в первую очередь – р. Шу. Для этого были отобраны пробы воды на 6-ти контрольных пунктах вдоль канала оросительной системы этой территории, а также на 9-ти контрольных пунктах вдоль русла р. Шу, протекающей в этой местности. Элементный состав отобранных проб воды изучен методами MS-ICP и OES-ICP. Определены значения концентрации 22-х элементов. На основе полученных данных о содержании токсичных элементов 1-го и 2-го классов опасности выполнены расчеты значений суммарной химической токсичности всех изученных вод. Результаты расчетов показали, что все полученные значения этого параметра превышают соответствующий санитарный норматив в 1.5-6.7 раз. При этом основной вклад в уровень токсичности изученных вод вносит уран: в р. Шу – 46%, в канале – 61%. Токсичность вод канала существенно (~ в 3 раза) выше, чем р. Шу. Наиболее высокое значение показателя токсичности установлено для воды, поступающей в систему орошения сельскохозяйственных полей на территории месторождения Камышановское. Эта особенность и полученные данные могут представлять интерес для Министерства сельского хозяйства КР.

Изучено распределение химических элементов в водах вдоль оросительного канала и вдоль русла р. Шу. Установлено, что протекание вод канала через территорию месторождения не приводит к их загрязнению токсичными элементами. В водах р. Шу на трех контрольных пунктах, находящихся близ рудных залежей, установлено значительное повышение (на 28-130%) концентрации Ca, Ni, Li, Sr, U, Mg, Cr, Ba относительно их концентрации на контрольных пунктах, расположенных выше по течению этой реки. Полученные результаты убедительно свидетельствуют о наличии серьезного влияния территории месторождения Камышановское на уровень загрязненности р. Шу этими элементами. Маловероятно, чтобы такое значительное загрязнение было вызвано стоками вод оросительной системы. Одним из возможных механизмов такого загрязнения р. Шу на этом месте может являться поступление в её русло подземных вод, контактирующих с рудными залежами этого месторождения.

Ключевые слова: месторождение урана, трансграничные воды, токсичные элементы.

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MODELING THE INFLUENCE OF THE ARTICLE DEVICE ON DYNAMIC INDICATORS OF FREIGHT WAGONS

Abstract. The article investigates the dynamic performance of a freight car with an articulation device - model SAC-1 RUS. As a criterion for assessing dynamic indicators, the acceleration of the car body and the dynamic deflections of the "spring-truck" system were selected, which characterize the ride and loss of stability of the car when it goes off the rails on various irregularities of the track.

When an articulated car moves along different path irregularities, the acceleration that occurs at various points along the length of the car is not the same. In compiling the system of differential equations of motion of the "spring - truck" system, the Lagrange equation of the second kind was used as the mathematical apparatus.

The body acceleration and the dynamic deflections of the springs were chosen as the criteria for assessing the running properties of the cars. The first characterizes the smoothness of the carriage, and the second characterizes the stability of the wheel, i.e. wheel derailment. It is known that the magnitude of the acceleration at different points along the length of the car is not the same, since the value of the vertical acceleration of bouncing is influenced by the vertical oscillations of the body's galloping. Therefore, when solving the system of differential equations, the body accelerations were determined at two points: above the center plates of the bogies and the center plate of the device for articulating freight cars or above the wheelsets, that is, in the places where acceleration sensors are installed during full-scale tests of cars.

Based on the analysis of the results obtained, it was revealed that articulated cars: exclude the possibility of relative vertical displacements of adjacent cars, with other equal dynamic parameters; lead to a noticeable deterioration in driving properties, accompanied by an increase in the value of vertical acceleration of the body. The values of accelerations and dynamic deflections of an articulated car are 6% higher than those of a four-axle freight car. The vertical acceleration of the front and rear of an articulated car is 30% greater than that of a typical car. Outside the critical speed for an articulated car, the value of vertical dynamic deflections significantly decreases in the case of an isolated irregularity with a length of 6 m or less.

Key words: articulated car, acceleration of the body, dynamic deflection, ride, articulation, unevenness of the path.

In 2019, a model articulated gondola car of increased payload capacity manufactured by Tikhvin Car-Building Plant JSC appeared on the CIS market. This gondola car model has a number of technical advantages, firstly, it improves transportation efficiency, and secondly, it provides a significant increase in the throughput of the railway network. Freight wagons should possess not only effective technical and economic characteristics, but also increased driving characteristics, stability and reliability. Therefore, it becomes necessary to conduct deep theoretical studies in order to determine the optimal dynamic performance of a freight car with an articulation device. Problems related to the study of the effective dynamic parameters of an articulated car taking into account the unevenness of the track are one of the urgent problems of transport technology and traffic safety in railway transport.

The aim of this work is to develop a mathematical model of a freight car with an articulation device that adequately describes the smoothness and stability of the car with various irregularities in the track, as

well as to give an objective assessment of the dynamic performance of an articulated car based on the solution of differential equations of motion.

In the works of Russian scientists [1-3], the results of a study of the dynamic loading of a freight car on modernized bogies of increased carrying capacity are presented, where the maximum acceleration of the car body from the speed of movement, in an empty state, is determined.

A characteristic element of a modern wagon is a device for articulating freight wagons, which is supported by a biaxial trolley (see figure 1). Wagon sections connected by a device for articulating freight wagons of the SAC-1 RUS brand allow their mutual rotation in the horizontal and vertical plane. The device is designed to connect two successive sections of the carriage with support on one common trolley.

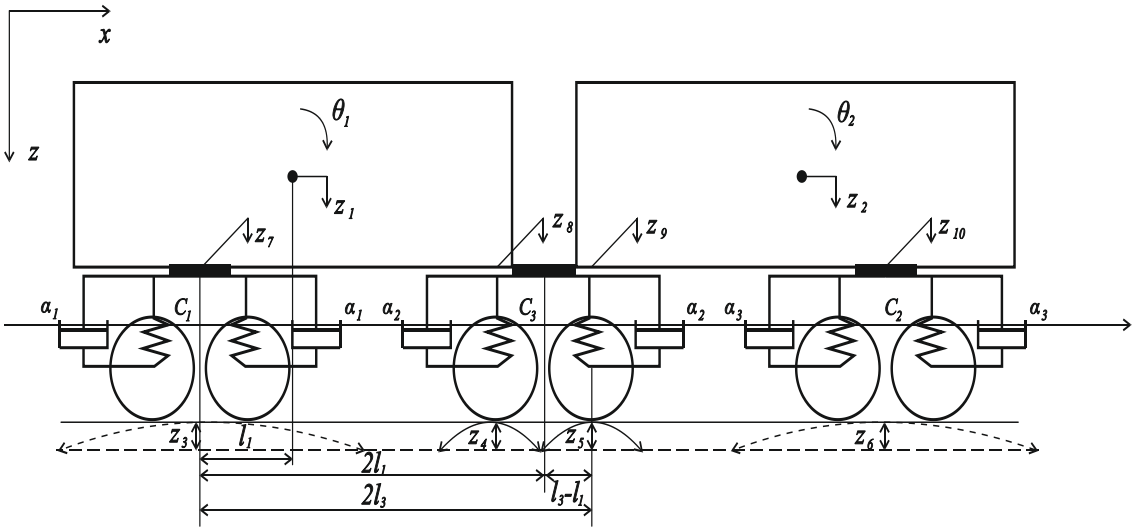

Figure 1 – Design diagram of an articulated wagon

The rotation of the sections of the car relative to the three coordinate axes is due to the presence of a spherical hinge in the structure. Consider the oscillations of an articulated car when moving along various irregularities of the path. Two types of bumps were considered, namely, periodic and isolated bumps at various lengths. Suppose that the car body is supported through the Fridays and the Friday of the articulation device on three trolleys with ordinary spring suspension. The rigidity of the carriage structure and the absorbing apparatus are taken into account through the rigidity of the articulation device, i.e. averaged stiffness is taken.

When studying plane vertical vibrations, an articulated car is considered as a special case of a generalized mechanical system, the mathematical model of which is defined as follows: an articulated car is a flat oscillatory system with degrees of freedom; suspension elements are characterized by independent parameters, i.e. mass and moment of inertia about the coordinate axes.

We assume that the wheelsets rotate relative to their own axes Oy and there is no translational movement relative to the side beams of the carts. The vertical movements of the two-part body are z_1 and z_2, respectively, and the galloping angles are - θ_1 and θ_2. The generalized coordinates are: z_2, θ_1 and θ_2.

The vertical displacement of the body z_1 is determined through the generalization of the coordinates using the expression [4]:

$$z_1 = z_2 - l_3(\theta_1 + \theta_2).$$

The positive directions of the displacements z_1, z_2 and the galloping angles θ_1, θ_2 are shown by arrows, the symbols z_3, z_5, z_6 are the irregularities of the path (see figure 1).

The movement of an articulated freight car along an absolutely rigid path is given by the second-order Lagrange equation

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial \Pi}{\partial q_i} + \frac{\partial \Phi}{\partial \dot{q}_i} = Q_i, \quad (1)$$

where T - is the kinetic energy, Π - is potential energy, Φ - is the dissipative function, q_i - is the generalized coordinate, $\dot{q}_i$ - is the generalized speed, $Q_i -$ is the generalized force corresponding to the generalized coordinate q_i. The dissipative function, kinetic and potential energy are defined below by the relations

$$\Phi = \alpha_1\left[\dot{z}_2 - l_3\left(\dot{\Theta}_1 + \dot{\Theta}_2\right) - l_1\dot{\Theta}_1 - \dot{z_3}\right]^2 + \alpha_2\left(\dot{z}_2 - l_1\dot{\Theta}_2 - \dot{z_5}\right)^2 + \alpha_3\left(\dot{z}_2 - l_1\dot{\Theta}_2 - \dot{z_6}\right)^2, \quad (2)$$

$$T = \frac{1}{2}I_{oy}\dot{\theta}_1^2 + \frac{1}{2}I_{oy}\dot{\theta}_2^2 + \frac{1}{2}m\left[\dot{z}_2 - l_3\left(\dot{\theta}_1 + \dot{\theta}_2\right)\right]^2 + \frac{1}{2}m\dot{z}_2^2\,, \quad (3)$$

$$\Pi = c_1[z_2 - l_3(\theta_1 + \theta_2) - l_1\theta_1 - z_3]^2 + c_2(z_2 - l_1\theta_2 - z_5)^2 + c_3(z_2 - l_1\theta_2 - z_6)^2\,. \quad (4)$$

In expressions (2 - 4): I_{oy}- the central moment of inertia of the body; c_1, c_2, c_3 - stiffness of one spring set in kg/cm; α_1, α_2, α_3– resistance coefficients of one hydraulic damper in kg·sec/cm.

To derive a system of differential equations of motion of an articulated car, we substitute relations (2-4) into equation (1), then after some transformations we obtain a system of differential equations in the form [5]:

$$\left.\begin{gathered}
\left(I_{oy} + ml_3^2\right)\ddot{\theta}_1 + ml_3^2\ddot{\theta}_2 - ml_3\ddot{z}_2 + 2\alpha_1(l_1 + l_3)^2\theta_1 + 2\alpha_1 l_3(l_1 + l_3)\dot{\theta}_2 - 2\alpha_1\dot{(l_1 + l_3)}\dot{z}_2 + \\
+2c_1(l_1 + l_3)^2\theta_1 + 2c_1 l_3(l_1 + l_3)\theta_2 - 2c_1(l_1 + l_2)z_2 = -2\alpha_1(l_1 + l_3)\dot{z}_3 - 2c_1(l_1 + l_3)z_3; \\
ml_3^2\ddot{\theta} + \left(I_{oy} + ml_3^2\right)\ddot{\theta}_2 - ml_3\ddot{z}_2 + 2\alpha_1 l_3(l_1 + l_3)\dot{\theta}_1 + (2\alpha_1 l_3^2 + 2\alpha_2 l_1^2 + 2\alpha_3 l_1^2)\dot{\theta}_2 + \\
+(-2\alpha_1 l_3 + 2\alpha_2 l_1 + 2\alpha_3 l_1)\dot{z_2} + 2c_1 l_3(l_1 + l_3)\theta_1 + (2c_1 l_3^2 + 2c_2 l_1^2 + 2c_3 l_1^2)\theta_2 + \\
+(2c_1 l_3 - 2c_2 l_1 + 2c_3 l_1)z_2 = -2\alpha_1 l_3\dot{z}_3 - 2\alpha_2 l_1\dot{z}_5 + 2\alpha_3 l_1\dot{z}_6 - 2c_1 l_3\dot{z}_3 - 2c_2 l_1\dot{z}_5 + 2c_3 l_1\dot{z}_6; \\
-ml_3\ddot{\theta}_1 - ml_3\ddot{\theta}_2 + 2m\ddot{z}_2 - 2\alpha_1(l_1 + l_3)\theta_1 + (-2\alpha_1 l_3 - 2\alpha_2 l_1 + 2\alpha_3 l_1)\ddot{\theta}_2 + \\
+(2\alpha_1 + 2\alpha_2 + 2\alpha_3)\ddot{z}_2 - 2c_1(l_1 + l_3)\theta_1 + (-2c_1 l_3 - 2c_2 l_1 + 2c_3 l_1)\theta_2 + \\
+(2c_1 + 2c_2 + 2c_3)z_2 = 2\alpha_1\dot{z}_3 + 2\alpha_2\dot{z}_5 + 2\alpha_3\dot{z}_5 + 2\alpha_3\dot{z}_6 + 2c_1\dot{z}_3 + 2c_{\,2}\dot{z}_5 + 2c_3\dot{z}_6;
\end{gathered}\right\} \quad (5)$$

Solving the system of differential equations (5) with respect to the highest derivatives, we obtain:

$$\left.\begin{aligned}
\ddot{\theta}_1 &= \frac{ml_1l_3^2 + 2I_{oy}l_1 + I_{oy}l_3}{2I_{oy}\left(I_{oy} + ml_3^2\right)}F_1 - \frac{l_3\left(ml_1l_3 + I_{oy}\right)}{2I_{oy}\left(I_{oy} + ml_3^2\right)}F_2 + \frac{l_3\left(ml_1l_3 - I_{oy}\right)}{2I_{oy}\left(I_{oy} + ml_3^2\right)}F_3, \\
\ddot{\theta}_2 &= \frac{l_3\left(I_{oy} - ml_1l_3\right)}{2I_{oy}\left(I_{oy} + ml_3^2\right)}F_1 + \frac{I_{oy}(2l_1 - l_3) + ml_1l_3^2}{2I_{oy}\left(I_{oy} + ml_3^2\right)}F_2 - \frac{I_{oy}(2l_1 + l_3) + ml_1l_3^2}{2I_{oy}\left(I_{oy} + ml_3^2\right)}F_3, \\
\ddot{z}_2 &= \frac{ml_1l_3 - I_{oy}}{2m\left(I_{oy} + ml_3^2\right)}F_1 + \frac{ml_1l_3 - 2ml_3^2 - I_{oy}}{2m\left(I_{oy} + ml_3^2\right)}F_2 - \frac{ml_1l_3 + 2ml_3^2 + I_{oy}}{2m\left(I_{oy} + ml_3^2\right)}F_3,
\end{aligned}\right\} \quad (6)$$

where:

$$F_1 = [z_2 - (l_1 + l_3)\theta_1 - l_3\theta_2 - z_2]2c_1 + \left[\dot{z}_2 - (l_1 + l_3)\dot{\theta}_1 - l_3\dot{\theta}_2 - \dot{z}_2\right]2\alpha_1;$$

$$F_2 = (z_2 - l_1\theta_2 - z_5)2c_2 + \left(\dot{z}_2 - l_1\dot{\theta}_2 - z_5\right)2\alpha_2;$$

$$F_3 = (z_2 + l_1\theta_2 - z_6)2c_3^{'} + \left(\dot{z}_2 + l_1\dot{\theta}_2 - z_6\right)2\alpha_3.$$

Based on a comparison of the structural elements of the articulated and typical carriage, the following geometric and mechanical characteristics were adopted: body length -19.540m, body height - 3.2m, width -3.0m, weight -42t and the total static deflection at full load is 45mm. The parameters included in equations (5-6) take the following values: m = 39542 kg, l_1 = 5.21 m, l_3 = 6.38 m, $I_{oy} = 183\cdot 10^4$ kg·m^2, c_1=c_3=394 Kg/cm, c_2=380 Kg/cm, α_1=α_2=26 Kg/cm, α_3= 44 Kg/cm [6].

As criteria for assessing the running properties of cars, body accelerations and dynamic spring deflections were selected. The former characterizes the smooth running of the car, and the latter the stability of the wheel, i.e. wheel derailment [7]. It is known that the magnitude of the acceleration at different points along the length of the car is not the same, since the vertical vibrations of galloping of the body contribute to the value of the vertical acceleration of bouncing. Therefore, when solving the differential equations of motion, the accelerations of the body were determined at two points: above the Fridays of the trolleys and the Friday of the device for articulating freight wagons or above the wheelsets, that is, in places where acceleration sensors are installed during field tests of wagons. The depth of the

roughness of the path, that is, the double amplitude of the sinusoid or the vertical distance between the lower and upper points of the roughness is denoted by z_i (where i=3,4,5,6), which is 1 cm.

Figure 2 shows graphs of the dependence of the acceleration $\ddot{z}$ of the rear of the car on the speed of movement in the case of isolated bumps, respectively, with a length of 6, 12.5 and 25 m. Curves 1, 2 and 3 correspond to path irregularities of 6, 12.5 and 25 m in length. The acceleration value of an articulated wagon is 30% greater than that of a four-axle freight wagon.

Figure 3 shows the graphs of the dynamic deflections of the rear spring sets z_∂ depending on the speed of movement in the case of an isolated roughness, respectively, with a length of 6, 12.5 and 25 m. Curves 1, 2 and 3 correspond to path irregularities of 6, 12.5 and 25 m in length. The magnitude of the dynamic deflections of an articulated wagon is 6% greater than that of a four-axle freight wagon.

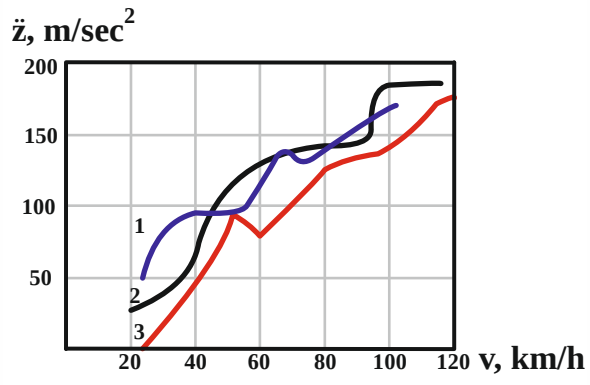

Figure 2 – Graphs of the dependence of the acceleration of the rear of the car on the speed in case isolated bumps. The curves correspond to: 1- the length of the roughness is 6 m; 2 - the length of the roughness is 12.5 m; 3- the length of the roughness is 25 m

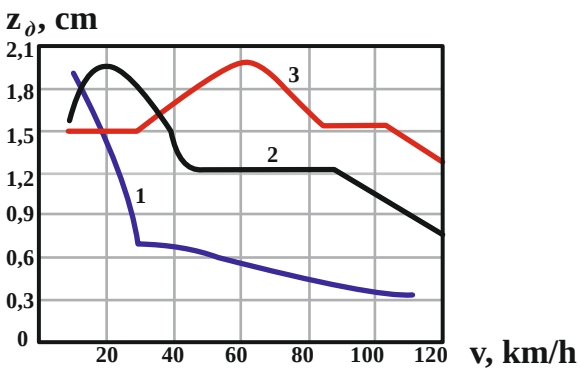

Figure 3 – Dynamic deflections of the rear spring sets depending on the speed of movement in the case of an isolated unevenness. The curves correspond to: 1- the length of the roughness is 6 m; 2 - the length of the roughness is 12.5 m; 3- the length of the roughness is 25 m

Figures 4-5 show graphs of the dependence of accelerations on speed with periodic irregularities of the path, respectively, for the front and rear parts of the car. Curves 1 and 2 correspond to irregularities of the path 12.5 and 25 m long. The values of the vertical accelerations of the front and rear of the articulated car are 30% greater than that of a typical car.

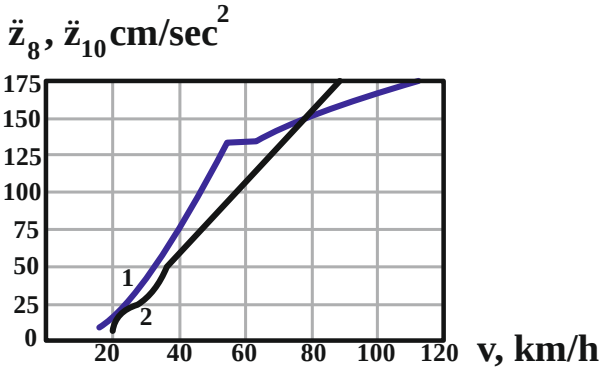

Figure 4 – Graph of the acceleration of the front parts of the car on the speed with periodic irregularities of the path. 1 - the length of the roughness is 12.5 m; 2- the length of the roughness is 25 m

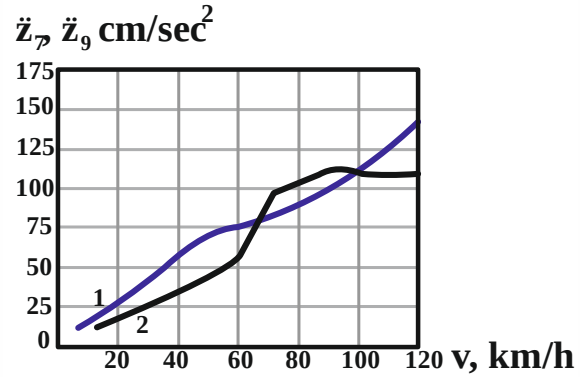

Figure 5 – Graph of the acceleration of the rear of the car from the speed. 1 - the length of the bumps is 12.5 m; 2- length of the roughness 25 m

In the case of isolated irregularities (lengths of 6, 12.5 and 25 m), the articulated car has a decrease in the value of vertical dynamic deflections with an increase in speed from 80 to 120 km / h. In the case of an isolated roughness of 6 m or less in length on an articulated car, the value of the vertical dynamic deflections significantly decreases beyond the critical speed.

In an articulated car, the vertical dynamic deflection reaches a maximum value of 2.0 cm in spring sets in the case of three irregularities, respectively, with a length of 6, 12.5 and 25 mm.

Conclusions. Based on the analysis of the results obtained, it was revealed that articulated wagons: exclude the possibility of relative vertical movements of adjacent wagons, ceteris paribus dynamic parameters; lead to a noticeable deterioration in driving properties, accompanied by an increase in the magnitude of the vertical acceleration of the body. The values of accelerations and dynamic deflections of an articulated wagon are 6% more than that of a four-axle freight wagon. It should be noted that the results obtained by the authors of [1-3] are in good agreement with the results of this work.

The vertical acceleration of the front and rear of an articulated car is 30% greater than that of a typical car. Outside the critical speed of an articulated car, the value of vertical dynamic deflections significantly decreases in the case of an isolated roughness of 6 m or less in length.

The analysis of the obtained results shows that the use of the articulation device of the SAC-1 RUS model worsens the dynamic characteristics of the articulated car, therefore, requires additional design solutions. Hence, as a consequence, it is necessary to conduct experimental studies in order to clarify the influence of dynamic loads on the track in accordance with the Technical Regulations for Traffic Safety in Railway Transport.

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ЖҮК ВАГОНЫНЫҢ ДИНАМИКАЛЫҚ КӨРСЕТКІШТЕРІНЕ МҮШЕЛЕУ ҚҰРЫЛҒЫСЫНЫҢ ӘСЕРІН МОДЕЛДЕУ

Аннотация. Мақалада моделі SAC-1 RUS мүшелеу құрылғысы бар жүк вагонының динамикалық көрсеткіштері зерттелген. Динамикалық көрсеткіштердің бағалау критерийі ретінде вагон шанашағының үдеу және «рессор-арба» жүйесінің динамикалық иілу сипаты алынған, олар қозғалыстың бірқалыптылығын және вагонның рельстен шығып кетпеу жағдайын сипаттайды.

Мүшеленген вагонның әртүрлі тегіссіздік бойымен қозғалғанда оның ұзындығы бойынша түрлі нүктелерде пайда болатын үдеу жағдайы бірдей болмайды. «Рессор - арба» жүйесінің дифференциалдық теңдеулер жүйесін құрастыруда математикалық аппарат ретінде екінші ретті Лагранж теңдеуі қолданылды. Вагон қозғалысының дифференциалдық теңдеулер жүйесінің шешімінен арба табанының үстіндегі және мүшелеу құрылғыларының үдеу сипаты, яғни далалық сынақ жүргізу кезінде үдеу датчиктері орнатылатын нүктелерде анықталды.

SAC-1 RUS маркалы мүшелеу қондырғысымен қосылған жүк вагондарының секциялары олардың көлденең және вертикаль жазықтықта өзара айналуына мүмкіндік береді. Құрылғы бір жалпы арбада тіреуіші бар екі тізбектей орналасқан вагон секцияларын қосуға арналған.

Вагон секцияларының үш координаталық оське қатысты бұрылуы құрылымда болатын сфералық шарнирге байланысты. Тегіссіздіктің екі түрі қарастырылды, атап айтқанда түрлі ұзындықтағы периодты және оқшауланған жол тегіссіздігі. Вагон құрылымының және жұту аппаратының қаттылығы мүшелеу құрылғысының қаттылығы арқылы ескеріледі, яғни орташа қаттылық алынады.

Доңғалақ жұптары өзінің Оу осіне қатысты айналады және арбалардың бүйірлік арқалығына қатысты ілгерлемелі орын ауыстырмайды. Екі бөліктен тұратын шанашақтың вертикаль орын ауыстыру жағдайы – z_1 және z_2, ал шоқырақтау бұрыштары – θ_1 және θ_2. Жалпыланған координаттар ретінде z_2, θ_1 және θ_2алынды.

Вагонның жүргізгіш қасиеттерін бағалау критерийлері ретінде шанашақтың үдеуі мен рессордың динамикалық иілуі алынды. Біріншісі вагон қозғалысының бірқалыптығын сипаттайды, ал екіншісі дөңгелек тұрақтылығын, яғни дөңгелектің рельстен шығуын сипаттайды. Вагон ұзындығы бойымен түрлі нүктелердегі үдеу шамасы бірдей емес екендігі белгілі, өйткені шанашақтың вертикаль шоқырақтау тербелісі вертикаль секіру үдеуінің сан мәніне әсер етеді. Сондықтан қозғалыс дифференциалдық теңдеуін шешкен кезде дененің үдеу үдерісі екі нүктеде анықталды: арба табандарының үстінде және жүк вагондарының мүшелеу құрылғысының табанында немесе жұп доңғалақтарының үстінде, яғни вагондарды далалық сынақтан өткізу барысындағы үдеу датчиктері орнатылған жерлерде.

Алынған нәтижелерді талдау негізінде мүшеленген вагондардың: брдей динамикалық параметрлі көршілес вагондардың салыстырмалы вертикаль орын ауыстырмайтындығы анықталды; шанақтың вертикаль үдеуінің сан мәнінің өсуі жүру сипатын айтарлықтай нашарлатады. Мүшеленген вагонның үдеуі мен динамикалық иілуінің сан мәні төрт осьті жүк вагонына қарағанда 6% артық. Мүшеленген вагонның алдыңғы және артқы бөліктерінің вертикаль үдеуінің сан мәні типтік вагонға қарағанда 30% үлкен. Ұзындығы 6 м немесе одан да аз оқшауланған тегіссіздікте критикалық жылдамдықтың шегінен асқанда, мүшеленген вагонның вертикаль динамикалық иілу үдерісі айтарлытай азаяды.

Түйін сөздер: мүшеленген вагон, шанақтың үдеуі, динамикалық иілу, қозғалыстың бірқалыптылығы, мүшелеу құрылғысы, жолдың тегіссіздігі.

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МОДЕЛИРОВАНИЕ ВЛИЯНИЯ УСТРОЙСТВА СОЧЛЕНЕНИЯ НА ДИНАМИЧЕСКИЕ ПОКАЗАТЕЛИ ГРУЗОВЫХ ВАГОНОВ

Аннотация. В статье исследуются динамические показатели грузового вагона с устройством сочленения – модели SAC-1 RUS. В качестве критерия оценки динамических показателей выбраны ускорения кузова вагона и динамические прогибы системы «рессора – тележка», которые характеризуют плавность хода и устойчивость вагона от схода с рельсов при различных неровностях пути.

При движении сочлененного вагона по различным неровностям пути ускорение, возникающее в различных точках по длине вагона, не одинаково. При составлении системы дифференциальных уравнений движения системы «рессора – тележка» в качестве математического аппарата использовано уравнение Лагранжа 2-го рода. Из решения системы дифференциальных уравнений движения вагона определялись ускорения над пятниками тележки и устройством сочленения, т.е. в точках где, как правило, устанавливаются датчики ускорения при натурных испытаниях.

Секции вагона, соединенные устройством для сочленения грузовых вагонов марки SAC-1 RUS, допускают их взаимный поворот в горизонтальной и вертикальной плоскости. Устройство предназначено для соединения двух последовательно расположенных секций вагона с опиранием на одну общую тележку.

Поворот секций вагона относительно трех осей координат происходит за счет наличия в конструкции сферического шарнира. Рассматривались два типа неровности, а именно периодическая и изолированная неровность пути при различных длинах. Жесткость конструкции вагона и поглощающего аппарата учитываются через жесткость устройства сочленения, т.е. берется осредненная жесткость.

Колесные пары вращаются относительно собственных осей Оу и отсутствует поступательное перемещение относительно боковых балок тележек. Вертикальные перемещения кузова, состоящего из двух частей, соответственно, z_1 и z_2, а углы галопирования - θ_1 и θ_2. В качестве обобщенных координат приняты: z_2, θ_1 и θ_2.

В качестве критериев оценки ходовых свойств вагонов выбраны ускорения кузова и динамические прогибы рессор. Первые характеризуют плавность хода вагона, а вторые – устойчивость колеса, т.е. сход с рельсов колеса. Известно, что величина ускорения в различных точках по длине вагона неодинакова, поскольку на значение вертикального ускорения подпрыгивания вносит вклад вертикальные колебания галопирования кузова. Поэтому при решении дифференциальных уравнений движения ускорения кузова определялись в двух точках: над пятниками тележек и пятником устройства для сочленения грузовых вагонов или над колесными парами, то есть в местах, где устанавливаются датчики ускорения при натурных испытаниях вагонов.

На основе анализа полученных результатов выявлено, что сочлененные вагон: исключают возможность относительных перемещений по вертикали соседних вагонов, при прочих равных динамических параметрах; приводят к заметному ухудшению ходовых свойств, сопровождающихся ростом величины вертикальных ускорений кузова. Величины ускорений и динамических прогибов сочлененного вагона больше на 6%, чем четырехосного грузового вагона. Вертикальные ускорения передней и задней части сочлененного вагона больше на 30%, чем у типового вагона. За пределами критической скорости у сочлененного вагона величина вертикальных динамических прогибов существенно уменьшается в случае изолированной неровности длиной 6м и менее.

Ключевые слова: сочлененный вагон, ускорение кузова, динамический прогиб, плавность хода, устройство сочленения, неровность пути.

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СТАНДАРТНЫЕ ПОКАЗАТЕЛИ МОДИФИЦИРОВАННЫХ БИТУМОВ

Аннотация. В статье определены и проанализированы основные стандартные показатели (пенетрация при 25 °С, растяжимость при 25 °С, температура размягчения, температура хрупкости) битумов марок БНД 100-130, БНД 130-200 и 21 модифицированного битума. Чистые битумы марок БНД 100-130 и БНД 130-200 произведены в Павлодарском нефтехимическом заводе и удовлетворяют требованиям стандарта СТ РК 1373-2013.

В качестве модификаторов были приняты полимеры Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS 198, SBS (L30-01A), KUMHO, резиновая крошка и полифосфорная кислота. Модификация битумов была осуществлена в лаборатории Казахстанского дорожного научно-исследовательского института (КаздорНИИ). Полученные модифицированные битумы удовлетворяют требованиям стандарта СТ РК 2534-2014.

Стандартные показатели чистых и модифицированных битумов были определены в лаборатории КаздорНИИ по стандартам: пенетрация при 25 °С - СТ РК 1226-2003; растяжимость при 25 °С - СТ РК 1374-2005; температура размягчения - СТ РК 1227-2003; температура хрупкости - СТ РК 1229-2003.

Установлено, что при добавке к битумам все примененные полимеры и полифосфорная кислота понижают пенетрацию, тем самым изменяют марку битумов. После модификации 43% полимербитумов переходят на следующую марку, 43% изменяют марку на 2 единицы и 14 % имеют марку более вязкую на 3 единицы.

Все рассмотренные полимеры и полифосфорная кислота повышают температуру размягчения, тем самым улучшают высокотемпературную устойчивость битумов. Определено, что при модификации битумов марок БНД 100-130 и БНД 130-200 повышение температуры хрупкости составляет 32-45 % и 28-93 % соответственно.

Большинство (71 %) полимеров и полифосфорная кислота повышают температуру хрупкости (понижают низкотемпературную устойчивость). В четырех случаях из двадцати одного (19 %) модификация практически не изменяет температуру хрупкости. Только в двух случаях (10 %) модификации битума марки БНД 130-200 получен положительный эффект – понижение температуры хрупкости.

Только в трех случаях (14 %) модификации отмечено повышение растяжимости битумов. В четырех случаях (19 %) исходная растяжимость остается неизменной. В остальных случаях (67 %) растяжимость битумов уменьшается от 26 % до 86 %.

Ключевые слова: битумы, полимеры, резиновая крошка, полифосфорная кислота, пенетрация, растяжимость, температура размягчения, температура хрупкости.

1. Введение. В условиях резкоконтинентального климата как в Казахстане для повышения эксплуатационной надежности асфальтобетонных покрытий автомобильных дорог необходимо улучшить высоко- и низкотемпературные характеристики дорожных битумов [1-5]. В настоящее время в мире в дорожном строительстве принято, что одним из общепринятых способов повышения эксплуатационных характеристик дорожных битумов является модификация их разными полимерами, иногда включая полифосфорную кислоту [1-3, 6-15].

В Казахстанском дорожном научно-исследовательском институте (КаздорНИИ) в течение последних 15 лет систематически исследуется вопрос о повышении эксплуатационных характерис-

тик битумов, асфальтобетонов и других дорожных материалов. В частности, были испытаны около 50 битумов разных заводов, модифицированных разными полимерами и полифосфорной кислотой.

В настоящей работе представлены и анализируются основные стандартные показатели (пенетрация при 25 °С, растяжимость при 25 °С, температура размягчения, температура хрупкости) битумов марок БНД 100-130 и БНД 130-200, произведенных Павлодарским нефтехимическим заводом (ПНХЗ), и еще 21 модифицированного битума, полученного путем добавки в указанные исходные чистые битумы 7 полимеров, резиновой крошки и полифосфорной кислоты.

2. Материалы и методы

2. 1. Битумы. В настоящей работе для изучения стандартных показателей были приняты 2 чистых и 21 модифицированный битум. Чистые битумы марок БНД 100-130 и БНД 130-200 были произведены в Павлодарском нефтехимическом заводе из нефти Западной Сибири (Россия) методом прямого окисления и удовлетворяют требованиям стандарта СТ РК 1373-2013 «Битумы и битумные вяжущие.

Битумы нефтяные дорожные вязкие. Технические условия».

2.2. Модификаторы. В качестве модификаторов были приняты полимеры Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS 198, SBS (L30-01A), KUMHO, резиновая крошка и полифосфорная кислота. Модификация битумов указанными добавками была осуществлена в лаборатории КаздорНИИ. Полученные модифицированные битумы удовлетворяют требованиям стандарта СТ РК 2534-2014 «Битум и битумные вяжущие. Битумы нефтяные модифицированные, дорожные. Технические условия». Более подробную информацию о приготовлении модифицированных битумов можно получить в работах [7,9]. Данные об испытанных битумах и их сокращенные обозначения приведены в таблице 1.

Таблица 1 – Данные об испытаниях чистых и модифицированных битумах

№	Марка битума	Название модификатора	Количество модификатора,%	Сокращенное обозначение
1	БНД 100/130	–	–	PNHZ_100-130
2	БНД 100/130	Elvaloy 4170	1,4	PNHZ_100-130+Elvaloy1
3	БНД 100/130	Elvaloy AM	2,0	PNHZ_100-130+Elvaloy2
4	БНД 100/130	Kraton	4,0	PNHZ_100-130+Kraton
5	БНД 100/130	Calprene 501	4,0	PNHZ_100-130+Calprene
6	БНД 100/130	Butonal NS 198	3,0	PNHZ_100-130+Butonal
7	БНД 100/130	SBS (L 30-01 A)	3,0	PNHZ_100-130+SBS
8	БНД 100/130	KUMHO KTP	3,0	PNHZ_100-130+KUMHO3
9	БНД 100/130	KUMHO KTP	6,0	PNHZ_100-130+KUMHO6
10	БНД 100/130	Резиновая крошка	10	PNHZ_100-130+РК10
11	БНД 100/130	Резиновая крошка	15	PNHZ_100-130+РК15
12	БНД 130/200	–	–	PNHZ_130-200
13	БНД 130/200	Kraton	6,0	PNHZ_130-200+Kraton
14	БНД 130/200	Elvaloy 4170	1,8	PNHZ_130-200+Elvaloy 1
15	БНД 130/200	Calprene 501	6,0	PNHZ_130-200+Calprene
16	БНД 130/200	Butonal NS 198	3,5	PNHZ_130-200+Butonal
17	БНД 130/200	SBS (L 30-01 A)	5,0	PNHZ_130-200+SBS
18	БНД 130/200	Elvaloy AM	2,2	БНД 130/200+Elvaloy 2
19	БНД 130/200	PPA	1,0	PNHZ_130-200+PPA
20	БНД 130/200	Kraton PPA	5,5 0,02	PNHZ_130-200+Kraton+ PPA
21	БНД 130/200	Elvaloy 4170 PPA	1,6 0,02	PNHZ_130-200+Elvaloy 1+ PPA
22	БНД 130/200	Calprene 501 PPA	5,5 0,02	PNHZ_130-200+Calprene+ PPA
23	БНД 130/200	Butonal NS 198 PPA	3,0 0,02	PNHZ_130-200+Butonal+ PPA

2.3. Стандартные показатели. Основные стандартные показатели битумов были определены в лаборатории КаздорНИИ. Стандартные показатели и стандарты, по которым они определены, приведены в таблице 2.

Таблица 2 – Основные показатели и стандарты

Показатель	Стандарт
Пенетрация, 25 °С, 100 г, 5 с (0,1 мм)	СТ РК 1226-2003 Битумы нефтяные и вяжущие материалы на основе битума. Метод определения глубины проникания иглы
Растяжимость, 25 °С (см)	СТ РК 1374-2005 Битумы и битумные вяжущие. Метод определения растяжимости
Температура размягчения, °С	СТ РК 1227-2003 Битумы и битумные вяжущие. Определение точки размягчения методом кольца и шара
Температура хрупкости, °С	СТ РК 1229-2003 Битумы нефтяные и битумные вяжущие. Метод определения температуры хрупкости по Фраасу

3. Результаты и обсуждение

3.1. Пенетрация. На рисунке 1 представлены значения пенетрации испытанных чистых и модифицированных битумов при температуре 25 °С. Видно, что модификация полимерами существенно понижает пенетрацию битумов. Так как по этому показателю определяется марка битумов, можно сказать, что модификация полимерами изменяет марку битумов. Так, после модификации ни один битум не имеет начальную марку: 9 из них переходят на следующую марку, еще 9 становятся более вязкими на две марки, а 3 из них показывают пенетрацию ниже на 3 марки.

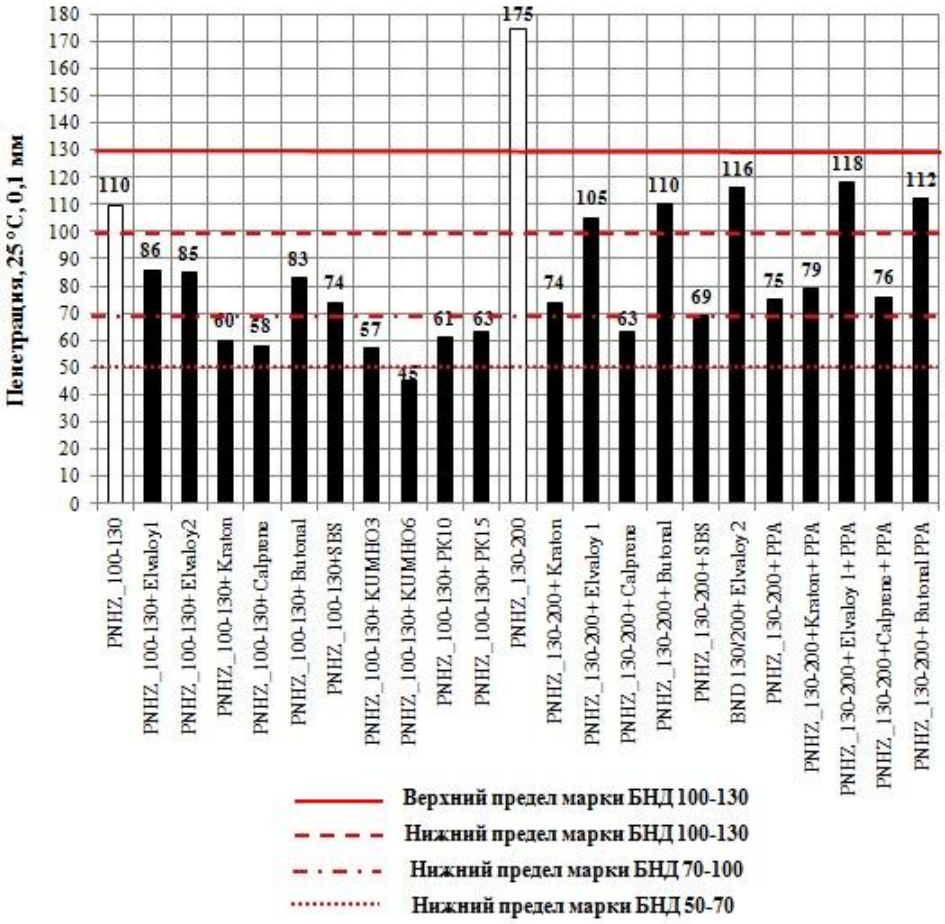

Рисунок 1 – Пенетрация битумов при температуре 25 °С

3.2. Температура размягчения. Как следовало ожидать, модификация полимерами повышает температуру размягчения битумов (рисунок 2). Большинство полимеров повышает температуру размягчения в среднем на 18-20 °С, а некоторые из них (Kraton, Calprene 501, SBS, KUMHO, Calprene 501+PPA) – почти два раза. Оказалось, что добавка в полимербитумы полифосфорной кислоты, как правило, несколько снижает их температуру размягчения. Так как температура размягчения косвенно характеризует устойчивость битумов при высоких температурах, полученные результаты показывают возможность существенного повышения высокотемпературных характеристик дорожных битумов путем модификации их различными полимерами. Это дает основание считать, что асфальтобетоны, приготовленные с использованием полимербитумов, могут быть рекомендованы для применения в жарких климатических условиях.

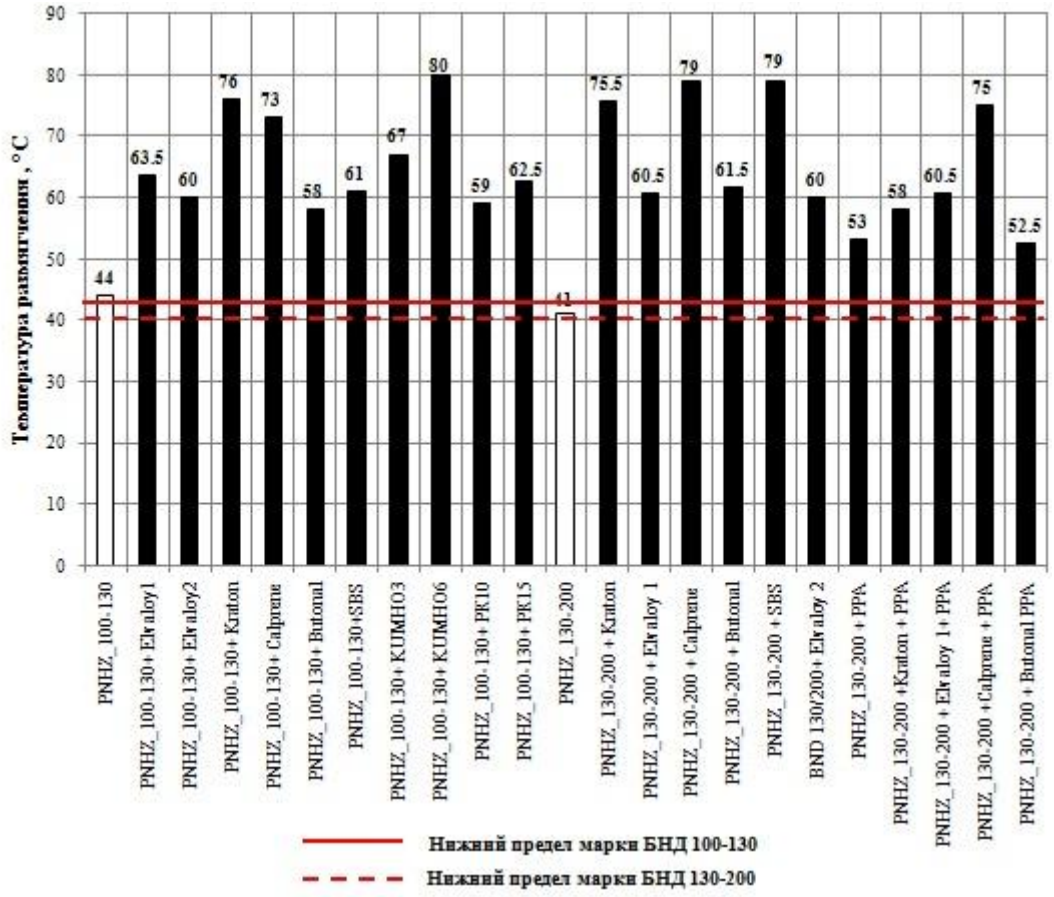

Рисунок 2 – Температура размягчения битумов

3.3. Температура хрупкости. В настоящее время по температуре хрупкости оценивают устойчивость битумов при низких температурах. Естественно считать битум с более низкой температурой хрупкости более приемлемым (предпочтительным) в регионах с холодным климатом. Результаты испытаний показали (рисунок 3), что большинство полимеров и полифосфорная кислота повышают температуру хрупкости (ухудшают низкотемпературную устойчивость) битумов. Добавка полимеров Elvaloy 4170, Kraton в битум марки БНД 100-130 и добавка полимеров Kraton, Calprene 501 в битум марки БНД 130-200 практически не изменили температуру хрупкости. Понижение температуры хрупкости было достигнуто только в двух случаях – при добавке полимеров Elvaloy 4170 (на 3,9 °С) и Butonal NS 198 (на 1,9 °С) в битум марки БНД 130-200. Эти результаты показывают, что для понижения температуры хрупкости битумов при их модификации полимерами необходимо учитывать как вязкость (марку) битума и вид полимера.

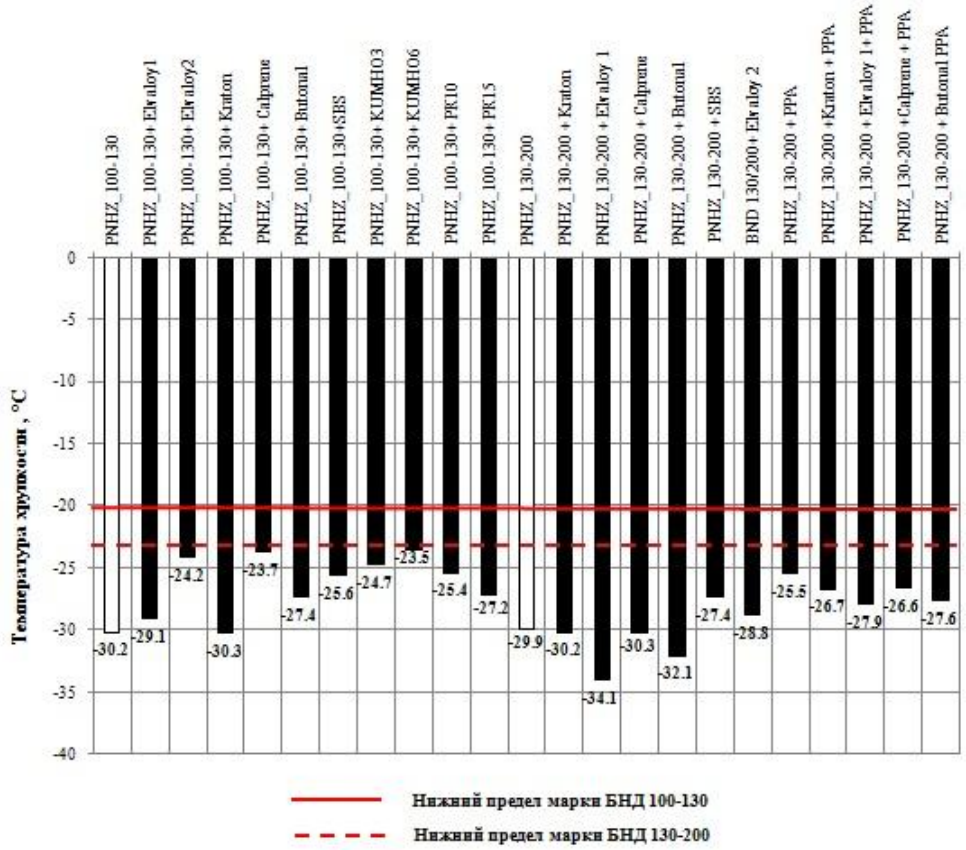

Рисунок 3 – Температура хрупкости битумов

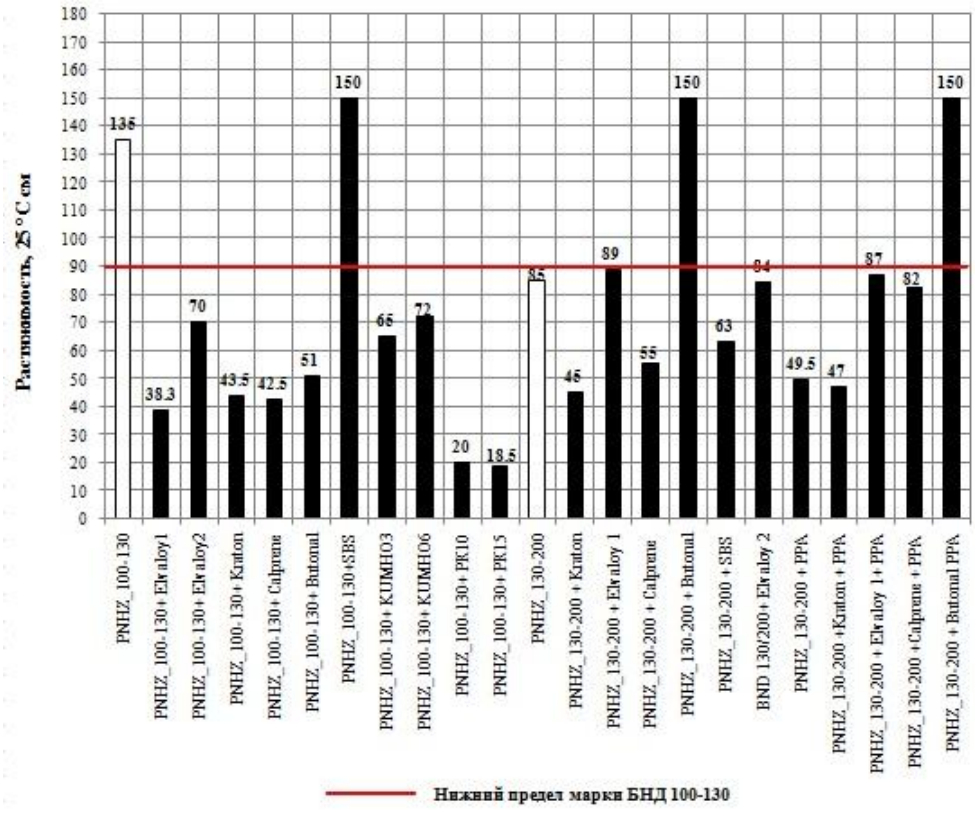

Рисунок 4 – Растяжимость битумов при температуре 25 °С

3.4. Растяжимость. Из рисунка 4 видно, что большинство полимеров и полифосфорная кислота уменьшают растяжимость битумов. Так, при модификации битума марки БНД 100-130 только полимер SBS повысил растяжимость на 11 %. Остальные 9 полимеров уменьшили растяжимость на 47-86 %. В случае модификации битума марки БНД 130-200 установлено, что: имеются полимеры (Elvaloy 4170, Elvaloy AM, Elvaloy + PPA, Calprene 501+ PPA), при добавке которых растяжимость битума остается практически неизменной; полимеры Kraton, Calprene 501, SBS, Kraton+PPA и полифосфорная кислота уменьшают растяжимость на 47 %, 35 %, 26 %, 44 % и 42 % соответственно; только добавка в битум полимера Butonal и полимера Butonal совместно с полифосфорной кислотой повышает растяжимость на 76 %.

Заключение. Анализ результатов определения основных стандартных показателей битумов марок БНД 100-130 и БНД 130-200, модифицированных полимерами и полифосфорной кислотой, выполненный в настоящей работе, показал следующее.

1. При добавке к битумам все примененные полимеры и полифосфорная кислота понижают пенетрацию, тем самым изменяют марку битумов. Установлено, что после модификации 43 % полимербитумов переходят на следующую марку, 43 % изменяют марку на 2 единицы и 14 % имеют марку более вязкую на 3 единицы.

2. Все рассмотренные полимеры и полифосфорная кислота повышают температуру размягчения, тем самым улучшают высокотемпературную устойчивость битумов. Определено, что при модификации битумов марок БНД 100-130 и БНД 130-200 повышение температуры хрупкости составляет 32-45 % и 28-93 % соответственно.

3. Большинство (71 %) полимеров и полифосфорная кислота повышают температуру хрупкости (понижают низкотемпературную устойчивость). В четырех случаях из двадцати одного (19 %) модификация практически не изменяет температуру хрупкости. Только в двух случаях (10 %) модификации битума марки БНД 130-200 получен положительный эффект – понижение температуры хрупкости.

4. Только в трех случаях (14 %) модификации отмечено повышение растяжимости битумов. В четырех случаях (19 %) исходная растяжимость остается неизменной. В остальных случаях (67 %) растяжимость битумов уменьшается от 26 % до 86 %.

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МОДИФИКАЦИЯЛАНҒАН БИТУМДАРДЫҢ СТАНДАРТТЫҚ КӨРСЕТКІШТЕРІ

Аннотация. Жұмыста МЖБ 100-130 және МЖБ 130-200 маркалы таза битумдардың және 21 модификацияланған битумның негізгі стандарттық көрсеткіштері (25°С-тағы пенетрациясы, 25°С-тағы созылғыштығы, жұмсару температурасы, морттық температурасы) анықталып, талданды. МЖБ 100-130 және МЖБ 130-200 таза битумдары Павлодар мұнай-химия зауытында Батыс Сібірдің (Ресей) мұнайынан тіке тотықтыру әдісімен өндірілді және Қазақстанның ҚР СТ 1373-2013 «Битумдар және битумдық тұтқырғыштар. Мұнай жол тұтқыр битумдары. Техникалық шарттар» стандартының талаптарын қанағаттандырады.

Модификаторлар ретінде Elvoloy 4170, Elvoloy AM, Kraton, Calprene 501, Butonal NS 198, SBS (430-01A), KUMHO полимерлері, резеңке ұнтағы және полифосфор қышқылы қабылданды. Битумдарды модификациялау Қазақстан жол ғылыми-зерттеу институтының (ҚазжолҒЗИ) зертханасында жүргізілді. Алынған модификацияланған битумдар Қазақстанның ҚР СТ «Битумдар және битумдық тұтқырғыштар. Модификацияланған мұнай жол битумдары. Техникалық шарттар» стандартының талаптарын қанағаттандырады.

Таза және модификацияланған битумдардың стандарттық көрсеткіштері ҚазжолҒЗИ зертханасында Қазақстанның келесі стандарттары бойынша анықталды: 25 °С-тағы пенетрациясы – ҚР СТ 1226-2003 «Мұнай битумдары және битум негізіндегі тұтқырғыш материалдар. Иненің ену тереңдігін анықтау әдісі»; 25 °С-тағы созылғыштық – ҚР СТ 1374-2005 «Битумдар және битумдық тұтқырғыштар. Созылғыштықты анықтау әдісі»; жұмсару температурасы – ҚР СТ 1227-2003 «Битумдар және битумдық тұтқырғыштар. Сақина және шар әдісімен жұмсару нүктесін анықтау»; морттық температура - ҚР СТ 1229-2003 «Мұнай битумдар және битумдық тұтқырғыштар. Фраас негізінде морттық температураны анықтау әдісі».

Битумға қосқанда барлық полимер мен полифосфор қышқылы пенетрацияны азайтады, яғни битум маркаларын өзгертеді. Модификациядан кейін полимербитумдардың 43 %-ы келесі маркаға өтеді, тағы 43 %-ының маркасы екі сатыға, 14%-ының маркасы үш сатыға төмендейді.

Қарастырылған барлық полимер мен полифосфор қышқылы битумдардың жұмсару температурасын жоғарылатады, яғни жоғары температуралық ортықтылығын жақсартады. МЖБ 100-130 және МЖБ 130-200 маркалы битумдарын модификациялағанда жұмсару температурасының 32-45 %-ға және 28-93 %-ға тиісінше жоғарылайтыны анықталды.

Полимерлердің көбісі (71%) және полифосфор қышқылы битумдардың мортты температурасын жоғарылатады (төменгі температуралық орнықтылығын төмендетеді). Жиырма бір жағдайдың төртеуінде (19 %) модификация морттық температураны өзгертпейді. МЖБ 130-200 маркалы битумды модификациялаудың екі жағдайында (10 %) ғана оң нәтиже алынды – мортты температура төмендеді.

Модификациялаудың тек үш жағдайында (14 %) ғана битум созылғыштығының артатыны анықталды. Төрт жағдайда (19 %) бастапқы созылғыштық өзгермейді. Қалған жағдайларда (67 %) битумдардың созылғыштығы 26 %-дан 86 %-ға дейін төмендейді.

Түйін сөздер: битумдар, полимерлер, резеңке ұнтағы, полифосфор қышқылы, пенетрация, созылғыштық, жұмсару температурасы, мортты температура.

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STANDARD INDICATORS OF MODIFIED BITUMENS

Abstract. The main standard indicators (penetration at 25 °C, ductility at 25 °C, softening point, Fraas point) have been determined and analyzed in this work for bitumens of the grades BND 100-130, BND 130-200 and 21 modified bitumens. The neat bitumens of the grades BND 100-130 and BND 130-200 have been produced at Pavlodar petrochemical plant from the oil of Western Siberia (Russia) by method of direct oxidation and they satisfy the requirements of the standard of Kazakhstan ST RK 1373-2013 “Bitumens and bituminous binders. Oil road viscous bitumens. Technical specifications”.

The polymers Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS 198, SBS (L30-01A), KUMHO, crumb rubber and polyphosphoric acid have been accepted as modifiers. The modification of the bitumens has been performed in the laboratory of Kazakhstan Highway Research Institute (KazdorNII). The manufactured modified bitumens satisfy the requirements of the standard of Kazakhstan ST RK 2534-2014 “Bitumens and bituminous binders. Oil modified road bitumens. Technical specifications”.

The standard indicators of the neat and modified bitumens have been determined in the laboratory of KazdorNII according to the following standards of Kazakhstan; penetration at 25 °C - ST RK 1226-2003 “Oil bitumens and binder materials based on bitumen. Method for determination of needle penetration depth”; ductility at 25 °C - ST RK 1374-2005 “Bitumens and bituminous binders. Method for determination of ductility”; softening point - ST RK 1227-2003 ‘Bitumens and bituminous binders. Determination of softening point by ring and ball method”; Fraas point - ST RK 1229-2003 ‘Oil bitumens and bituminous binders. Method for determination of Fraas point”.

It is found out that all the applied polymers and polyphosphoric acid when adding them to the bitumens decrease the penetration thereby changing the grade of the bitumens. After modification 43 % of the polymer bitumens convert to the next grade, 43 % change their grade for 2 units and 14 % have the grade more viscous for 3 units.

All the considered polymers and polyphosphoric acid increase the softening point thereby improving the high temperature resistance of the bitumens. It is determined that at modification of the bitumens of the grades BND 100-130 and BND 130-200 the increase of the Fraas point is 32-45 % and 28-93 % respectively.

Most (71 %) of the polymers and polyphosphoric acid increase the Fraas point (decrease the low temperature resistance). In four cases out of twenty-one (19 %) the modification does not practically vary the Fraas point. The positive effect has been obtained only in two cases (10 %) for the modification of the bitumen of the grade BND 130-200 - the decrease of the Fraas point.

The increase of the ductility for the bitumens has been recorded only in three cases (14 %) for their modification. In four cases (19 %) the initial ductility remains constant. In other cases (67 %) the ductility of the bitumens is decreased from 26 % to 86 %.

Key words: bitumens, polymers, crumb rubber, polyphosphoric acid, penetration, ductility, softening point, Fraas point.

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PROSPECTS FOR RATIONAL USE OF MINERAL RESOURCES OF THE DZHAKSY-KLYCH DEPOSIT, THE ARAL REGION

Abstract. Rational use of mineral resources is becoming an important task for the development and economic growth of Kazakhstan. The purpose of the research was to study the state of salt-containing raw materials to determine the prospects for rational use of mineral resources of the Dzhaksy-Klych Deposit, one of the salty halite lakes of the Aral region. Exploration studies have shown that the Deposit is layered, where the halite layer is underlain by a sulfate layer: astrakhanite, mirabilite, tenardite, located on a layer of silt, the bed of salt deposits is dark brown clays, less often - clay Sands. Mineralogically, the halite formation is represented by, %: halite – 90-96, epsomite -1,2-2,6, mirabilite -0,2-1,9, gypsum-0,2-1,4. The production of table salt results in waste containing 65.5% chlorides, 24.5% sulfates, 6.5% sodium carbonates, and 3.5% sodium silicates, which can be used for pharmaceutical and medical purposes. Bottom silty mud by its origin and chemical composition belongs to the mainland silt-sulfide type and can be used for Spa and balneological treatment. The reserves of sulphate salts in the field are significant, with the average thickness of the sulphate reservoir in the southern basin being 0.87 m, and in the Northern basin 0.91 m. Intergranular and surface brine containing sodium and magnesium chloride-sulfate salts is of particular interest. Analysis of the state of mineral resources of the Dzhaksy-Klych Deposit revealed prerequisites for expanding the range of opportunities for using salt-containing raw materials. A promising direction for the development of the mineral resource base is the production of soda based on sodium chloride, as well as the production of a commercial product based on sodium sulfate and magnesium chloride. Microbiological examination showed the presence of non-pathogenic forms of halophilic bacteria in the salt-containing raw materials, which indicates safety for use in pharmaceutical and medical practice. In the Aral sea region, there is every reason for the development of the cosmetology industry, where a wide range of cosmetology and pharmaceutical products can be produced based on a combination of salt-containing and local vegetable raw materials.

Key words: Dzhaksy-Klych Deposit, salt-containing raw materials, halite salt, sulfate salt, brine, natural resources.

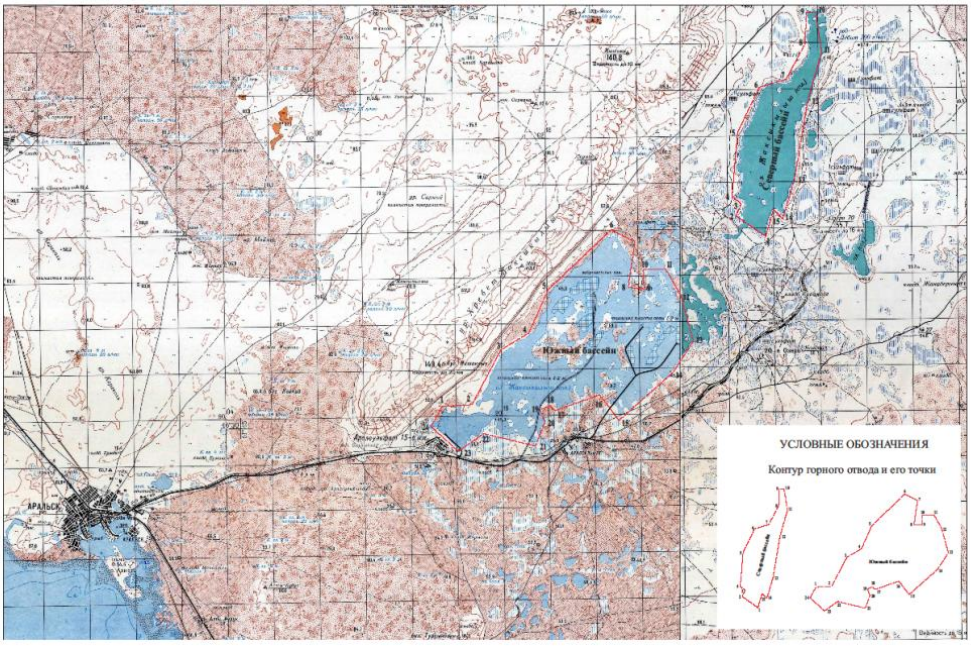
Introduction. One of the main riches of the Republic of Kazakhstan is the mineral resource base. Assessment of natural resources, their reserves, extraction and rational use is becoming an important task for the development and economic growth of our state. It should be noted that the rational use of natural resources, including the mineral resource base, implies the most complete extraction of all valuable components with the least change in the resource potential and the state of the environment (Luneva E. V., 2017). Kazakhstan has a developed mineral resource base, while the Republic ranks sixth in the world in terms of mineral reserves. According to international experts, the value of the proven balance reserves of the main types of minerals is 10 trillion us dollars. According to E. G. Karibayev (2014) the Republic of Kazakhstan has significant forecast resources of oil – 17 billion tons, iron – 148 billion tons, manganese – 4.7 billion tons and chromite ores – about 3 billion tons, copper – 182 million tons, lead – 108 million

tons, zinc 220 million tons, bauxite – 1.2 billion tons, tungsten – 4.8 million tons, molybdenum – 6.2 million tons, gold – 15 thousand tons, nickel – 4.8 million tons, titanium – 291 million tons, tin – 1.7 million tons, uranium – 600 thousand tons and coal 90 billion tons. Attracting investment in the development of the mineral resource base of Kazakhstan contributed to the republic's entry into the top ten countries both in terms of mineral reserves and the development of new deposits.

In the future, the forecast reserves of minerals, which can include deposits of various salts, are of great importance. The Aral sea and the system of lakes located around it represent a mineral resource base of various salt-containing raw materials, ranging from various types of salts to types of brine, silt and, importantly, waste after processing of the initial salts. Of particular interest is the Dzhaksy-Klych salt lake, which has become a salt deposit as a result of drying up. Despite the long history of studying lake systems and the Aral sea itself, a number of established parameters of the chemical, mineralogical and microbiological composition of the Dzhaksy-Klych Deposit require additional research. This need is dictated by the search for rational use of the entire potential of the mineral resource base.

In this regard, the purpose of the research was to study the state of salt-containing raw materials to determine the prospects for rational use of mineral resources of the Dzhaksy-Klych Deposit.

Objects and methods of research. The object of the study was the Dzhaksy-Klych Deposit, located in the North-Eastern Aral sea region, northeast of the Sary-Chaganak Bay of the Aral sea, 15-20 km from the railway station and occupies the Dzhaksy-Klych hollow (figure). In addition, the research uses salt-containing raw materials of the deposit: halite, sulfate, magnesium, mixed salts, brine, silt**.**



Map location of the deposits Dzhaksy -Klych

The area of the Northern basin with islands is 19,21km^2, without islands – 18,97 km^2. The area of the Southern basin is more than 35 km^2 (without islands). The area of the deposit belongs to the zone of deserts and semi-deserts, where the average annual precipitation is 126-182 mm, falling in dry years to 64-70 mm.

Exploration work was carried out by “Onyx-R” LLP on the order of “Araltuz” JSC. In 2017-2019, an exploration network of 300x400m (Northern basin) and 400x400m (Southern basin) was used for field exploration, with maximum overlap with the workings of the predecessors. The field was studied to a depth of by drilling wells. The drilling depth is determined by the peculiarities of the geological structure and was 0.3-6.1 m. Exploration drilling volumes totaled 392 wells (847.5 m), including 252 wells (494.5 m) in the Southern basin and 140 wells (352.5 m) in the Northern basin. The core yield from exploration wells was 100%.

Drilling was carried out by UKB-12/25 "Pombur" and "Strong Hydro 21PU" drilling rigs using the core method with graphite crowns without flushing. The drilling diameter of ordinary wells is 93mm. The representativeness of the main core testing for exploration wells with a drilling diameter of 93mm is controlled by sampling core samples from control wells with a larger diameter of 151mm.

The volumetric weight was determined from the surface by excavating the salt pillars by clogging a pipe with a diameter of 219mm with an internal diameter of 201mm, a length of 400mm and a massive square head. A total of 126 volume mass determinations were made during the exploration period, including 72 determinations in the Southern basin and 54 in the Northern basin.

Methods of differential thermal analysis and differential scanning calorimetry were used to study the chemical, mineral, and mineralogical compositions of salt-containing raw materials. The analyses were carried out at the A. Mickiewicz state University of Poznan (Poland).

Microbiological examination was carried out according to the methods accepted in Microbiology with isolation of microorganisms on the nutrient media with a content of 1.0% NaCL: heterotrophs –on MPA, enterobacteria –on Endo-Ploskirev medium, micromycetes-on Chapek medium.

Statistical processing. Experiments were carried out five times in repetition, calculate the standard deviation at 0.95> P> 0.80. Statistical processing was performed using the statistical software package Microsoft Excel on a PC «Pentium-IV». By the number of measurements and in general diagnostic group determined the arithmetic mean (Schabenberger O. and Pierce F.J., 2002). In some cases, statistical processing of results to represent averaged data does not show the entire range of primary data obtained, so the data series is shown in the "from" and "to" variants.

Research results. The Dzhaksy-Klych Deposit is confined to modern lake deposits. All salt lakes of the Deposit are divided into three main types according to their regime, composition of salt deposits and genesis features: mirabilite, tenardite and halite. The Southern and Northern basins of the Dzhaksy-Klych Deposit are considered to be halite lakes. The salt deposit has a plast-like shape and is surrounded by a silt "pillow"on all sides. The top layer is always represented by halite. The halite layer is mainly underlain by a sulfate layer: astrakhanite, mirabilite, tenardite, and less often others, which is underlain by a layer of silt below. The bed of salt deposits is dark brown clay, less often- clay sands. Measurements and calculations showed that the volume weight of halite is 1.28±0.10 t/m^3. Averaged data on the component composition of the Northern/Southern basins are as follows, %: NaCI - 92.23/92.27; Ca -0.46/0.74; Mg - 0.64/0.40; SO_4 -2.4/2.4. mineralogical characteristics of the halite formation are presented, %: halite – 90-96, epsomite -1.2-2.6, mirabilite -0.2-1.9, gypsum-0.2-1.4.

Using differential thermal analysis and differential scanning calorimetry, it was found that the initial salt-containing raw materials of the Dzhaksy-Klych Deposit contain NaCl , Na_2CO_3, $CaSO_4{\times}2H_20$, Na_2SO_4, Na_2SiO_4. Some samples contain minerals of a more complex structure such as astrakhanite ($Na_2Mg(SO_4)_2 \times 4H_2O$). Some salt samples are a mixture of halite (NaCl), astrahanite, magnesium sulfate hexahydride ($MgSO_4 \times 6H_2O$), gypsum ($CaSO_4{\times}2H_2O$), and sodium sulfate (Na_2SO_4), presumably in the form of mirabilite ($Na_2SO_4 \times 4H_2O$).

Microbiological examination showed the presence of mobile halophilic heterotrophic rod-shaped and coccoid bacteria in samples of halite salts taken from depths of 0-10 cm. The largest number of bacteria (103 CFU/g) was found in samples taken along the coastline, and a pattern was observed for reducing the number of bacteria to $10\text{-}10^2$ CFU/g as the distance from the coast to 10-12 m.

Of interest are the waste products of table salt production from this deposit, which contain 65.5% chlorides (NaCl), 24.5% sulfates ($CaSO_4{\times}2H_20$ and Na_2SO_4), 6.5% sodium carbonates (Na_2CO_3), and 3.5% sodium silicates (Na_2SiO_4).

In addition, the deposit has a large reserve of bottom silty mud, which by origin and chemical composition belongs to the continental silt-sulfide type, which includes sand, clay, iron sulfurous compounds, colloidal substances of mineral and organic origin. The amount of water varies between 37.5±3.5%. The ionic composition of the mud liquid phase solution is: sodium – from 1.99 to 18.12%; sulfate - ion from 25.7 to 44.23%.; calcium - from 1.11 to 2.16%.; magnesium – from 3.89 to 4.24%.; potassium – from 0.78 to 1.11%.; carbonate-ion– from 0.22 to 0.57%.; chlorine– from 1.89 to 3.11%. In addition, it contains a large number of trace elements.

The average thickness of the sulphate reservoir in the Southern basin is 0.87±0.05 m, and in the Northern basin 0.91±0.06 m. The mineralogical composition is represented by,%: halite (from 0.7 to 70),

astrakhanite (from 10 to 50), epsomite (from 1 to 30), kizerite(from 0.9 to 30), mirabilite (from 0.2 to 30), tenardite (from 0.3 to 65) and gypsum (from 0.2 to 10). The ionic composition is represented by chlorides, sulfates, bicarbonates, potassium, sodium, magnesium and calcium with a predominance in the Southern/In the Northern basin, sulfate ions 36.58/37.21 %; chloride ions -20.95/19.09%; sodium - 19.38/18.49%. In the mineral composition of a sulfate formation consisting of $Ca(HCO_3)_2$, KCl, NaCl, $MgCl_2$, $CaSO_4$, $MgSO_4$, K_2SO_4, Na_2SO_4 dominate, respectively, Southern/Northern basins - NaCl (34.19/30.89 %), $MgSO_4$ (25.28/25.49%); Na_2SO_4 (19.35/18.8%). Of particular interest is brine, a concentrated salt solution that permeates salt deposits. Brine density: 1.15-1.40 g/cm^3 at temperatures from +7^{0}C to -16^{0}C. Hydrogen indicator (pH) – of 6.79 and 7.33. The salinity of the brine – 299,29-428,18 g/dm^3. To study the amount of brine evaporation, two evaporators for brine and fresh water were installed in each of the pools (Northern and Southern). Measurements and calculations showed that in the Northern basin , the volume of brine evaporation per day is 3.343 l/m^2, in the Southern basin - 4.020 l/m^2, while the annual volume of brine evaporation in the basins is, mln.m^3: Northern basin – 20.26; Southern basin - 53.41 (table).

Chemical composition of intercrystal brine of the Dzhaksy-Klych Deposit

№	Components	Content					
		Southern basin			Northern basin		
		from	to	average	from	to	average
Ions, mg/dm^3							
1	Na^+	57000	81250	54446	49500	79700	61176
2	K^+	668	8830	6695	2680	13060	49500
3	Ca^{2+}	<2	<2	<2	<2	<2	<2
4	Mg^{2+}	23104	52288	42020	11552	51072	37088
5	CO_2^{2-}	<8	<8	<8	<8	<8	<8
6	HCO_3^-	439	1025	787	275	1495	859,8
7	Cl^-	163102	207423	184598	161329	187922	172897
8	SO_4^{2-}	3787	80097	37613	13994	67914	45208

The mineral composition of both types of brine differs only in the magnesium component and is represented by the following characteristics of intercrystal/surface brine in the Southern basin, %: KCl - 1.28/0.8; NaCl - 13.92/18.61; $MgCl_2$ - 12.3/7.48; $MgSO_4$ - 5.26/2.99. In the Northern basin,%: KCl - 1.49/0.99; NaCl - 15.51/18.97; $MgCl_2$ - 10.85/6.97; $MgSO_4$ - 4.65/3.0. The absence of $Ca(HCO_3)_2$, K_2SO_4, Na_2SO_4, and $CaSO_4$ in all samples. In the brine selected from the halite formation from a depth of 0.3 m, bacterial microflora was observed, represented by small halophilic coccoid and rod-shaped mobile bacteria.

Halite reserves were calculated for the Northern basin in categories B+C_1 – 17520. 87 thousand tons (NaCl-92.19%), for the Southern basin these indicators are higher – 30239. 75 thousand tons (NaCl-92.26%). In the Northern basin, the bottom layer halite reserves are classified as off – balance sheet in categories C_1-3 687.17 thousand tons (NaCl-83.44%). Established reserves for brine: for the Northern basin in categories C_1 – 11,822,0 thousand m3 with a NaCl content of 15.51% and for the southern basin in categories C_1 - 21,899,1 thousand m^3 with a NaCl content of 13.92%. Stocks taken as off-balance - it supplies the mixed sulfate salts - the Northern pool C_1 – 17 520.87 thousand tons, for the Southern pool C_1 – 39567.88 thousand tons. Revealed that the reserves of halite resume number: for the Northern basin – 343.4±30.3 thousand tons per year, for the Southern basin - 393.59±35.3 thousand tons per year.

Discussion. Currently, only halite salt is widely used, while “Araltuz” JSC produces a wide range of products of more than 39 names that meet regulatory requirements (SanPiN 2.3.2.560-96 (4.01.047-97), ST RK GOST R 51574-2003, Iskakov T. U. et al., 2020). However, rational use of the mineral resource base of the Dzhaksy-Klych Deposit implies expanding the range of possibilities for using salt-containing raw materials in addition to obtaining an assortment of sodium chloride products. A promising direction

for the development of the mineral resource base is the production of soda based on sodium and magnesium sulfates, chloride and mixed salts (Yuan F., et al., 2020). Unfortunately, such a resource as salt-containing raw materials: salt, silt, brine is not used by any of the Kazakh companies that produce cosmetology products. Despite the well-known antiseptic and bleaching properties of salt, saturation of the skin with minerals, macro and microelements, acceleration of regeneration of damaged integuments and stimulation of the autonomic nervous system, this component is undeservedly overlooked (Panova O., 2012). The use of salts and mud from the Dead sea, lakes in France and Gabon for cosmetic purposes is known (Portugal-Cohen, M. et al., 2009, Eba, F et al., 2010), studies have been conducted related to the use of Dead sea mineral water to protect the skin from air-polluting ingredients (Portugal-Cohen, M., et al.,2017). Laboratory experiments have shown that the salts, brine, and clay of lake Dzhaksy-Klych have a detrimental effect on hydrobiont organisms, including pathogenic microflora (Issayeva et al., 2018). According to the results of microbiological studies conducted on various salt-containing sources, the microflora is characterized by a wide variety of halophilic forms of viruses(Emerson J. B. et al., 2013), bacteria (Jioang H. et al., 2007; Lee and Lee, 2014, Kemp B. L. et al., 2018), micromycetes and protozoa (Haner G. and Rogerson A., 2005).

Despite the revealed heterotrophic microflora in salt-containing raw materials, according to numerous studies (Litshfield, 2011; Canfora L. et al, 2017). Research is continuing on the effect of salt-containing raw materials on various parameters of age-related skin. The interfacial distribution of boric acid between aqueous solutions and modified cellulose was studied (Sarsenov et al., 2018). For rational use of the entire potential of the mineral resource base, it is necessary to take into account the plant resources of the region. Currently, 342 species of vascular plants belonging to 43 families and 170 genera have been registered in the Aralkum desert in Kazakhstan. The leading families are: Chenopodiaceae (83 species), Asteraceae (45), Brassicaceae (32), Fabaceae (22), Roaceae (19), Boraginaceae (13), Suregaseae (5), Ariaceae (5). Among the life forms, annuals (41.5%), herbaceous perennials (31.9%) and shrubs (16.7%) predominate. Studies by L. A. Dimeeva and I. Pankratova (2011) showed that the flora of the Aral sea coast includes 414 species belonging to 43 families and 192 genera. We have compiled a summary of the flora of medicinal plants of the Aral sea region, represented by 56 plant species of which 25% belong to the families Asteraceae, Poaceae 32%, Amaranthaceae 22%, Tamaricaceae 21%. The complete composition of phenolic compounds of a number of medicinal plants, including a list of about 200 compounds, was studied. More than 10 prototypes of cosmetic products have been developed, including bath salts, scrubs, masks, soaps, etc., and their effect on the condition of different skin types has been studied. The preliminary results show the prospects of using domestic salt-containing and plant raw materials and the need for further research in the rational use of the entire potential of the mineral resource base of the Dzhaksy-Klych Deposit and the surrounding area. The combination of plant and salt resources will allow you to develop a wide range of cosmetic products for baths, lotions and rinses. The obtained information provides a basis for predicting the prospects for the use of salt-containing and plant resources in Spa and balneological treatment and the creation of cosmetology production for the innovative and industrial development of the Aral sea region.

Conclusion. As a result of geological exploration studies, it was revealed that the halite layer in the Northern and southern basins of the field is underlain by a sulfate layer: astrakhanite, mirabilite, tenardite, and less often others, which is underlain by a layer of silt below. The bed of salt deposits is dark brown clay, less often- clay sands. Mineralogical characteristics of the halite formation are represented by halite, epsomite, mirabilite, and gypsum. Waste from the production of table salt contains 65.5% chlorides, 24.5% sulfates, 6.5% sodium carbonates, 3.5% sodium silicates, which can be used for pharmaceutical and medical purposes. The Deposit has a large reserve of bottom silty mud, which by origin and chemical composition belongs to the mainland silt-sulfide type and is applicable for Spa and balneological use. The Dzhaksy-Klych Deposit has significant reserves of sulfate salts, intercrystal and surface brine. The analysis of the state of the mineral resource base of the Dzhaksy-Klych Deposit showed a wide range of possibilities for using salt-containing raw materials. A promising direction for the development of the mineral resource base is the production of soda based on sodium chloride, as well as the production of a commercial product based on sodium sulfate and magnesium chloride. Microbiological examination showed the presence of non-pathogenic forms of halophilic bacteria in the salt-containing raw materials, which indicates safety for use in pharmaceutical and medical practice.

In the Aral sea region, there are all prerequisites for the development of the cosmetology industry, where a wide range of cosmetology products can be produced on the basis of salt-containing and local plant raw materials, which will not only make rational use of the mineral resource base of the Dzhaksy-Klych Deposit, but will also help reduce social tension in the region by creating additional jobs.

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АРАЛ ӨҢІРІНДЕГІ ЖАҚСЫ ҚЫЛЫШ КЕН ОРНЫНЫҢ МИНЕРАЛДЫ ШИКІЗАТ РЕСУРСТАРЫН ҰТЫМДЫ ПАЙДАЛАНУ ПЕРСПЕКТИВАЛАРЫ

Аннотация. Минералды шикізат ресурстарын ұтымды пайдалану Қазақстанның дамуы мен экономикалық өсуі үшін маңызды міндетке айналуда. Зерттеудің мақсаты – Арал өңіріндегі тұзды галит көлі – Жақсы қылыш кен орнының минералды шикізат ресурстарын ұтымды пайдалану перспективаларын анықтау үшін құрамында тұзы бар шикізаттың жай-күйін зерттеу. Геологиялық барлау зерттеулері кен орнының қабатты болып келетінін көрсетті, онда галит қабаты сульфат қабатының: астраханит, мирабилит, тұнба қабатында орналасқан тенардит, қара қоңыр саз, сирек сазды құм тұзды шөгінділердің астында жатады. Минералогиялық тұрғыдан галит қабаты, %: галит 90-96, эпсомит 1,2-2,6, мирабилит 0,2-1,9, гипс 0,2-1,4. Ас тұзын өндіру нәтижесінде құрамында 65,5% хлорид, 24,5% сульфат, 6,5% натрий карбонаттары, 3,5% натрий силикаттары бар қалдықтар пайда болады, оларды фармацевтикалық және медициналық мақсаттарда пайдалануға болады. Төменгі сазды балшық шығу тегі мен химиялық құрамы бойынша материктік тұнба – сульфид түріне жатады және оны курорттық-бальнеологиялық емдеу үшін қолданады. Кен орнындағы сульфат тұзының қоры едәуір кездеседі, бұл ретте Оңтүстік бассейні бойынша сульфат қабатының орташа қуаты 0,87 м, ал Солтүстік бассейн бойынша 0,91 м құрайды. Натрий мен магнийдің хлоридті-сульфатты тұзы бар кристаларалық және беттік рапс ерекше қызығушылық тудырады. Жақсы қылыш кен орнының минералды шикізат ресурстарының жай-күйін талдау құрамында тұзы бар шикізатты пайдалану мүмкіндігінің ауқымын кеңейту үшін алғышарттарды анықтады. Минералды шикізат базасын дамытудың перспективалы бағыты – натрий хлориді негізінде сода өндіру, сондай-ақ натрий сульфаты мен магний хлориді негізінде тауарлық өнім алу. Микробиологиялық тексеру құрамында тұзы бар шикізатта галофильді бактериялардың патогенді емес түрлерінің кездесетінін айқындады әрі бұл фармацевтикалық және медициналық практикада қолданудың қауіпсіздігін білдіреді. Арал өңірінде косметологиялық саланы дамыту үшін барлық негіз бар, онда құрамында тұзды және жергілікті өсімдік шикізатының үйлесімі негізінде косметологиялық және фармацевтикалық өнімдердің ассортиментін өндіруге болады.

Түйін сөздер: Жақсы қылыш кен орны, құрамында тұзы бар шикізат, галит тұзы, сульфат тұзы, рапа, минералды шикізат ресурстары.

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ПЕРСПЕКТИВЫ РАЦИОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ МИНЕРАЛЬНО-СЫРЬЕВЫХ РЕСУРСОВ МЕСТОРОЖДЕНИЯ ДЖАКСЫ-КЛЫЧ, АРАЛЬСКИЙ РЕГИОН

Рациональное использование минерально-сырьевых ресурсов становится важной задачей для развития и экономического роста Казахстана. Целью исследования было изучение состояния солесодержащего сырья для определения перспектив рационального использования минерально-сырьевых ресурсов месторождения Джаксы-Клыч, одного из соленых галитовых озер Аральского региона. Геологоразведочные исследования показали, что месторождение сложено послойно, где пласт галита подстилается сульфатным пластом: астраханитом, мирабилитом, тенардитом, расположенном на слое ила, ложем соляных отложений являются тёмно-коричневые глины, реже – глинистые пески. Минералогически галитовый пласт представлен, %: галитом – 90-96, эпсомитом – 1,2-2,6, мирабилитом – 0,2-1,9, гипсом-0,2-1,4. В результате производства поваренной соли образуются отходы, содержащие 65,5% хлоридов, 24,5% сульфатов, 6,5% карбонатов натрия, 3,5% силикатов натрия, которые возможно использовать в фармацевтических и медицинских целях. Донная илистая грязь по происхождению и химическому составу относится к материковому илово-сульфидному типу и может быть использована для курортно-бальнеологического лечения. Запасы сульфатных солей на месторождении значительны, при этом средняя мощность сульфатного пласта по Южному бассейну составляет 0,87м, а по Северному бассейну – 0,91м. Особый интерес представляет межкристальная и поверхностная рапа, содержащая хлоридно-сульфатные соли натрия и магния. Анализ состояния минерально-сырьевых ресурсов месторождения Джаксы-Клыч выявил предпосылки для расширения диапазона возможностей использования солесодержащего сырья. Перспективным направлением развития минерально-сырьевой базы является производство соды на основе хлорида натрия, а также получение товарного продукта на основе сульфата натрия и хлорида магния. Микробиологическое обследование показало наличие в солесодержащем сырье непатогенных форм галофильных бактерий, что указывает на безопасность для применения в фармацевтической и медицинской практике. В Приаральском регионе имеются все основания для развития косметологической отрасли, где на основе сочетания солесодержащего и местного растительного сырья можно производить широкий ассортимент косметологической и фармацевтической продукции.

Ключевые слова: месторождение Джаксы-Клыч, солесодержащее сырье, галитная соль, сульфатная соль, рапа, минерально-сырьевые ресурсы.

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ELECTROPHYSICAL CHARACTERISTICS OF THE COAL ASH OF THE MAYKUBEN BASIN

Abstract. In this work, the temperature dependences of the electrophysical characteristics (electrical capacitance, electrical resistance, dielectric permittivity) were investigated in the range of 293-483 K for coal ash of the Maikuben basin (Kazakhstan) in its initial form, after electromagnetic (EM) and electrical discharge (ED) treatments. The temperature ranges in which the material exhibits both semiconductor properties and metallic conductivity are established. The band gap width (ΔE) was calculated for the studied samples. The measurement results showed that in comparison with the initial ash and ash after the EM treatment, the ash after the ED treatment has the highest values of electrical capacitance and dielectric permittivity and the lowest electrical resistance. Analysis of the research results showed that coal ash after ED treatment seems promising as a prepared raw material for its further thermochemical processing with the extraction of such valuable components as rare metals, silica, alumina, as well as a capacitive material (capacitor) and semiconductor.

Key words: coal ash, electrical resistance, electric capacity, dielectric permittivity, electric discharge treatment, semiconductor conductivity, metallic conductivity, band gap.

Introduction. When coal is burned, mineral components are converted into ash and slag, which are stored as waste products of energy production in ash and slag dumps. Despite the fact that ash dumps are classified as waste of the fifth hazard class (practically safe), they negatively affect the environment.

In Kazakhstan, the concept of transition to a "green" economy was approved. In accordance with it, all sectoral and regional development programs should be analyzed for compliance with the principles of a "green" economy. Strengthening control over compliance with environmental standards by industrial enterprises and the introduction of stringent requirements for including ash and slag waste disposal (ASW) projects into TPP projects determines the relevance of ash processing facilities.

Coal-fired power plants are suitable for cost-effective use in various industries by extracting many valuable components from ASW: aluminosilicate and magnetic microspheres [1], silica [2], alumina [3-5], rare metals [6-11] and using the remaining mass of ash as a raw material for the production of building materials [1,12,13].

Traditionally, fossil coals are attributed to semiconductors, since their electrical conductivity at constant current and room temperature is in the range of 10^{-8}–10^{-6} $\Omega^{-1}\cdot m^{-1}$. In a sufficiently large temperature range up to 200° C, the electrical conductivity increases with increasing temperature, which is characteristic of semiconductors [14-16]. Therefore, the study of these properties of the mineral part of coal, taking into account the widespread use of ash and slag waste, is of definite scientific and practical interest.

The purpose of this work is to study the electrophysical characteristics of ash from coal combustion of the Maikuben basin (the Shoptykol deposit, Kazakhstan).

Earlier, we conducted similar studies to determine the electrical characteristics of the initial and activated shale of Kendyrlyk field [17].

Research methodology. Ash and slag wastes from coal combustion of the Maikuben basin (hereinafter Maikuben coal) were used as feedstock, which were kept in a muffle furnace at 815 °C for 1.5 hours to remove underburning (carbon part of ASW).

The objects of research are samples of ash of Maikuben coal (after removal of underburning) in its initial form, after processing on an electromagnetic apparatus (hereinafter EM treatment) for fine grinding of ash, and after electric discharge treatment (hereinafter ED treatment) for weakening and/or breaking chemical bonds in an aqueous solution of ash.

EM processing of ash samples was carried out on an electromagnetic apparatus EMA-1, consisting of an inductor, a working chamber and a tripod. Electric parameters of EMA-1: rated current - 8 Amps; nominal electromagnetic field strength in the center of the inductor (at 220 V) – 40-45 kA/m; active power – 0.15-0.2 kW; The power and capacity of capacitors to compensate for cosφ is 400 microfarads.

Before EM treatment, the ash was mixed with magnetic granules (2-3 mm in diameter) (mass-to-mass ratio of magnetic granules – 1:10; magnetic granules occupied 70-80% by volume of the working chamber) and then poured into the working chamber installed inside the inductor (in the middle). During processing (3 times for 8 minutes), the ash was thoroughly mixed and crushed due to the strong rotating and colliding actions of the magnetic granules, which is caused by the induction of the vortex electric field due to the alternating electromagnetic field. Visually, it was found that the size of the ash particles after electromagnetic treatment decreased markedly compared with the particles of the original ash.

The ED treatment of coal ash was carried out on a laboratory electrical discharge installation consisting of a power regulator, a capacitor unit, a step-up transformer (from 220 V to 30 kV), a reactor (200 ml capacity) with two electrodes. Ash (40 g) and water (80 ml) were thoroughly mixed and the resulting solution was poured into the reactor. The installation was turned on via a special remote control and the solution was treated with an electric discharge for 3 minutes and then dried to a dry state.

The elemental composition of the ash of Maikuben coal was studied by energy dispersive X-ray spectroscopy on a scanning electron scanning microscope *SEM* (*Quanta 3D 200i*) with an attachment for energy dispersive analysis (*EDAX*). The samples were fixed on a copper holder with conductive adhesive paper. Previously, a thin conducting layer of carbon was deposited on the surface of the samples in a special vacuum unit for the best passage of charges. The energy of the exciting electron beam in the analysis was 15 keV, the working distance was 15 mm.

Measurements of the Maikuben coal ash electrophysical properties were carried out according to the procedures [18,19]. The study of electrophysical characteristics (permittivity ε and electrical resistance R) was performed by measuring the electrical capacity of samples *C* on a LCR-800 serial instrument (Taiwan) at a working frequency of 1 kHz continuously in dry air in a thermostatic mode with a holding time at each fixed temperature.

Previously, plane-parallel samples were made in the form of disks with a diameter of 10 mm and a thickness of 5-6 mm with a binding additive (~ 1.5 %). Pressing was performed under a pressure of 20 kg/cm^2. The resulting disks were fired in a silica oven at 400 °C for 6 hours. Then they were thoroughly double-sided grinding.

The dielectric permittivity ε was determined from the electrical capacity of the sample at known values of the sample thickness and the surface area of the electrodes. To obtain the relationship between the electrical induction *D* and the electric field strength *E*, the Sawyer-Tower circuit was used. Visual observation of *D* (*E* hysteresis loop) was performed on a C1-83 oscilloscope with a voltage divider consisting of a resistance of 6 mΩ and 700 kΩ and a reference capacitor of 0.15 μF. The frequency of the generator is 300 Hz. In all temperature studies, the samples were placed in a furnace, the temperature was measured with a chromel-alumel thermocouple connected to a B2-34 voltmeter with an error of ±0.1 mV. The rate of temperature change is ~5 K/min. The magnitude of the dielectric permittivity at each temperature was determined by the formula $\varepsilon = \frac{C}{C_0}$, where $C_0 = \frac{\varepsilon_0 \cdot S}{d}$ – the capacitance of the capacitor without the test substance (air).

The calculation of the width of the forbidden zone (ΔE) of the test substance was determined by the formula: $\Delta E = (2kT_1T_2)/(0{,}43(T_2 - T_1)) \cdot (lgR_1 - lgR_2)$ (where k – Boltzmann constant, equal to $8.6173303 \cdot 10^{-5}$ eV·K^{-1}; R_1 – resistance at T_1; R_2 – resistance at T_2).

Results and discussion. The results of elemental energy dispersive analysis of coal ash, shown in Table 1, show that the main macroelements of ash are acidic and amphoteric oxides of silicon, aluminum and iron, the total concentration of which is 85.06 %, which is comparable with similar data obtained in [20] for the ashes of the Maikuben coal (84.31%).

Table 1 – The chemical composition of the mineral part of the Maikuben coal

Content, %								
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	SO_3	P_2O_5	$K_2O + Na_2O$
50.16	26.63	8.27	5.84	2.79	1.05	0.93	0.87	1.16

The results of measurements of the Maikuben coal ash electrophysical characteristics in its initial state, after the EM and ED treatments in the range of 293-483 K, are given in tables 2-4 and figures 1-3.

Table 2 – Dependence of electrical resistance (R), electrical capacitance (C) and dielectric permittivity (ε) on temperature (coal ash in its initial form)

T, K	*C*, nF	*R*, Ω	ε	lgε	lg*R*
293	0.02053	7208000	163	2.21	6.86
303	0.04537	5566000	359	2.56	6.75
313	0.18698	2827000	1480	3.17	6.45
323	0.64511	1509000	5107	3.71	6.18
333	1.5823	946300	12527	4.10	5.98
343	3.7755	567400	29890	4.48	5.75
353	8.5853	346200	67968	4.83	5.54
363	18.691	210100	147973	5.17	5.32
373	37.243	132200	294845	5.47	5.12
383	72.458	84260	573636	5.76	4.93
393	121.55	59750	962287	5.98	4.78
403	152.67	51220	1208658	6.08	4.71
413	124.82	61420	988175	5.99	4.79
423	9.708	362600	76856	4.89	5.56
433	1.4072	1127000	11141	4.05	6.05
443	0.35224	2415000	2789	3.45	6.38
453	0.07079	5306000	560	2.75	6.72
463	0.02075	8575000	164	2.22	6.93
473	0.01138	7107000	90	1.95	6.85
483	0.0096	6003000	76	1.88	6.78

Table 3 – Dependence of electrical resistance (R), electrical capacitance (C) and dielectric permittivity (ε) on temperature (coal ash after EM treatment)

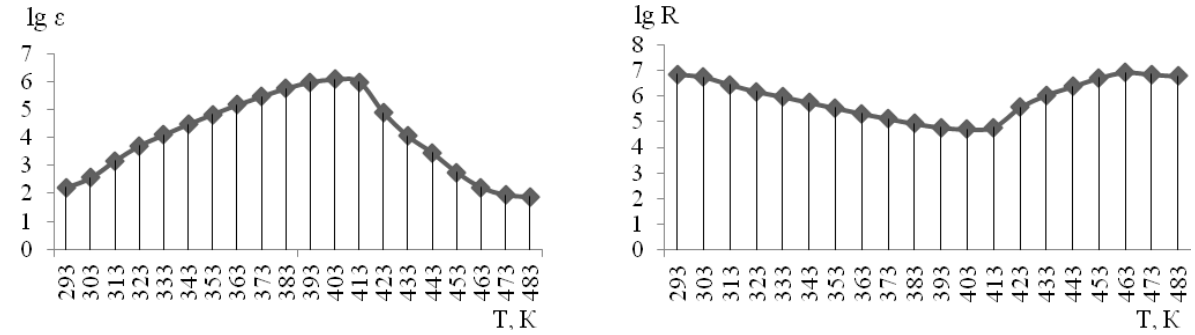
T, K	*C*, nF	*R*, Ω	ε	lgε	lg*R*
293	0.11632	3981000	1088	3.04	6.60
303	0.34158	2130000	3196	3.50	6.33
313	1.4915	984100	13955	4.14	5.99
323	6.1317	447800	57370	4.76	5.65

Continuation of table 3

T, K	*C*, nF	*R*, Ω	ε	lgε	lg*R*
333	15.199	256000	142205	5.15	5.41
343	30.494	165300	285309	5.46	5.22
353	56.837	108900	531779	5.73	5.04
363	104.7	72710	979596	5.99	4.86
373	101.25	76420	947317	5.98	4.88
383	45.854	125500	429020	5.63	5.10
393	12.499	301400	116943	5.07	5.48
403	0.96776	1499000	9055	3.96	6.18
413	0.02377	9965000	222	2.35	7.00
423	0.00699	8370000	65	1.82	6.92
433	0.0061	4731000	57	1.76	6.67
443	0.00568	2586000	53	1.73	6.41
453	0.00549	1891000	51	1.71	6.28
463	0.00569	828900	53	1.73	5.92
473	0.00527	1498000	49	1.69	6.18
483	0.00565	3416000	53	1.72	6.53

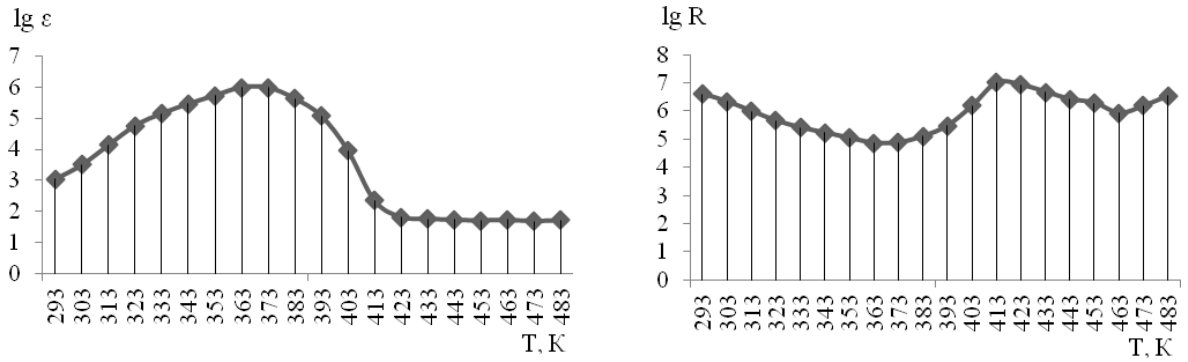
Table 4 – Dependence of electrical resistance (R), electrical capacitance (C) and dielectric permittivity (ε) on temperature (coal ash after ED treatment)

T, K	*C*, nF	*R*, Ω	ε	lgε	lg*R*
293	89.205	28610	770420	5.89	4.46
303	102.89	26190	888611	5.95	4.42
313	140.56	21370	1213948	6.08	4.33
323	185.14	17820	1598964	6.20	4.25
333	260.53	13610	2250070	6.35	4.13
343	362.6	10160	3131599	6.50	4.01
353	497.02	7641	4292519	6.63	3.88
363	710.51	5586	6136327	6.79	3.75
373	948.76	4405	8193976	6.91	3.64
383	1278.1	3418	11038325	7.04	3.53
393	1602.9	2815	13843463	7.14	3.45
403	1815.5	2590	15679585	7.20	3.41
413	1162.9	4156	10043398	7.00	3.62
423	536.08	10650	4629861	6.67	4.03
433	208.62	33220	1801749	6.26	4.52
443	82.004	87670	708228	5.85	4.94
453	23.295	192800	201188	5.30	5.29
463	2.232	808900	19277	4.29	5.91
473	0.17871	3219000	1543	3.19	6.51
483	0.0604	5514000	522	2.72	6.74



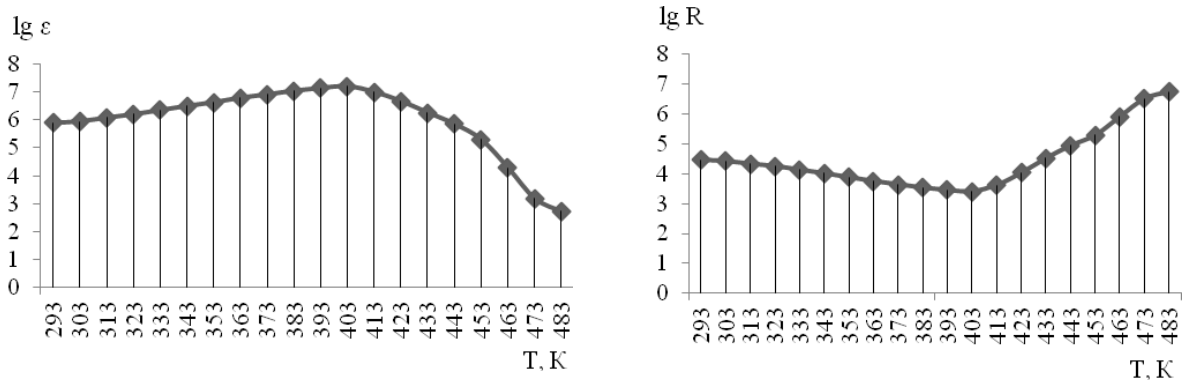
a b

Figure 1 – Temperature dependence of the dielectric permittivity (a) and electrical resistance (b) of coal ash in its initial form



a b

Figure 2 – Temperature dependence of the dielectric permittivity (a) and electrical resistance (b) of coal ash after EM treatment



a b

Figure 3 – Temperature dependence of the dielectric permittivity (a) and electrical resistance (b) of coal ash after ED treatment

The results of the obtained data showed that the samples of the initial ash and ash after the EM treatment in the temperature ranges 293-403 K and 293-363 K, respectively, exhibit semiconductor properties, in the intervals 403-463 K and 363-413 K, they exhibit metallic conductivity, in the intervals 463-483 K and 413-463 K – semiconductor properties. In addition, the ash after the EM treatment in the range of 463-483 K exhibits metallic conductivity again. In contrast to these samples, the ash after the ED-treatment has only one temperature interval of 293-403 K, where it exhibits semiconductor conductivity, and the metallic conductivity exhibits in the interval of 403-483 K. Thus, the ED-treatment

of ash leads to the expansion of the temperature range when heated, in which the metallic conductivity is manifested.

A comparative analysis of the electrophysical parameters shows that if the initial ash and ash after the EM treatment are approximately comparable, then after the ED-treatment these parameters differ significantly, mainly in the range of 293-453 K. Thus, the electrical intensity of the ash after the ED-treatment varies 89-1800 *nF*, which is substantially more than in the initial ash (0-153 *nF*) and the ash after the EM treatment (0×105 *nF*). The dielectric permittivity of the ash after the ED treatment ($\sim 10^7$) is an order of magnitude greater, unlike the samples of the initial ash and ash after the EM treatment ($\sim 10^6$). The ash after the ED treatment is also characterized by lower values of electrical resistance compared to other test specimens.

It should be noted that the highest values of C and ε and the lowest electrical resistance for all samples are observed at the points of transition from semiconductor to metallic conductivity (up to 403 K). At the same time, the highest values of R are reached at the points of transition from metallic to semiconductor conductivity (with the exception of ash after ED-treatment, where this transition point is the final temperature of metallic conductivity of 483 K)

The calculation of the width of band gap (ΔE) of the investigated substances was carried out on the basis of the following parameters (based on tables 2-4) given in table 5.

The results of the calculation of ΔE are:

– for the initial ash 1-я зона $\Delta E \approx 0.63$ эВ;

– for the ahs after EM treatment: 1st zone $\Delta E \approx 0.83$ eV, 2nd zone $\Delta E \approx 1.81$ eV;

– for the ahs after ED treatment: $\Delta E \approx 0.56$ eV.

The calculation of ΔE for the initial ash in a very narrow interval of 463-483 K has no practical meaning.

Table 5 – Initial data for calculating the width of the band gap (ΔE)

Ash	1st interval of semiconductor conductivity				2nd interval of semiconductor conductivity			
	T_1, K	T_2, K	$lg\ R_1$, Ω	$lg\ R_2$, Ω	T_1, K	T_2, K	$lg\ R_1$, Ω	$lg\ R_2$, Ω
Initial	293	403	6.86	4.71	–	–	–	–
After EM treatment	293	363	6,60	4.86	413	463	7.00	5.92
After ED treatment	293	403	4.46	3.41	–	–	–	–

As can be seen from the calculated data, the value of ΔE for ash after the EM treatment increases when going from the 1st to the 2nd forbidden zone. The obtained values of the band gap (ΔE = 0.56-1.81 eV) show that virtually all the ash samples studied are narrow-gap semiconductors.

Findings. The results of the study showed that the high-voltage electric discharge treatment of the ashes of the Maikuben coal leads to a significant change in its electrophysical characteristics. This can be practically used in the process of preparing coal ash for the purpose of its further thermochemical processing with more complete leaching of valuable components (rare metals, silica, alumina) and/or the possibility of carrying out the process at lower values of technological parameters (temperature, concentration of reagents, exposure time of solutions etc.), compared with the original ash. Moreover, as shown by the analysis, coal ash after ED-treatment seems promising as a capacitive material (capacitor) and semiconductor.

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МАЙКҮБЕН БАССЕЙНІ КӨМІР КҮЛІНІҢ ЭЛЕКТРФИЗИКАЛЫҚ СИПАТТАМАЛАРЫ

Аннотация. Жұмыста Майкүбен бассейнінің (Қазақстан) көмір күліне қатысты 293-483К интервалында электрмагниттік және электроразрядтық өңдеуден кейінгі бастапқы түрдегі электрофизикалық сипаттамалардың (электр өткізгіштігі, электр кедергісі, диэлектрлік өткізгіштігі) температуралық тәуелділігі зерттелді. Көмір күлін электромагнитті өңдеу индуктордан, жұмыс камерасы мен штативтен тұратын ЭМА-1 электромагнитті аппаратында 8 минуттан 3 рет жүргізілді. ЭМА-1 аппаратының электрлік параметрлері: номиналды ток - 8 Ампер; индуктор ортасындағы электромагниттік өрістің номиналды кернеулігі (220 В кезінде) - 40-45 кА/М; белсенді қуаты - 0,15-0,2 кВт; cosφ компенсациясына арналған конденсаторлар қуаты мен сыйымдылығы - 400 мкФ. Электромагнитті өңдеуден бұрын күл диаметрі 2-3 мм магнитті түйіршіктермен араластырылады (ұнтақталатын материал массасының магнитті түйіршіктер массасына қатынасы 1:10) және одан кейін индуктор ортасында орнатылған жұмыс камерасына төгіледі. Көмір күлін электр зарядты өңдеу қуат реттегіштен, конденсатор блогынан, жоғарылататын трансформатордан (220 В-тан 30 кВ-қа дейін), көлемі 200 мл екі электродты реактордан тұратын электр зарядтау қондырғысында жүргізілді. Күлді (40 г) және суды (80 мл) мұқият араластырып, алынған ерітіндіні реакторға құйды. Арнайы пульт арқылы қондырғыны қосып, ерітіндіні 3 минут электр разрядымен өңдеп, одан әрі құрғақ күйге дейін кептіреді. Электрофизикалық сипаттамаларды өлшеу 1кГц жұмыс жиілігі кезінде термостатты режимде құрғақ ауада үздіксіз термостатты режимде әр тіркелген температурада ұстау уақытымен үлгілердің электр қабылдағыштығын өлшеу арқылы LCR-800 (Taiwan) сериялық аспабында жүргізілді. Диэлектрлік өткізгіштігі үлгінің қалыңдығы мен электродтар беті ауданының белгілі мәнінде үлгінің электр сыйымдылығынан анықталды. D электр индукциясы мен E электр өрісінің кернеулігі арасындағы тәуелділікті алу үшін Сойер-Тауэр схемасы қолданылды. Визуалды бақылау 6 мОм және 700 кОм кедергіден тұратын кернеу бөлгіші және 0,15 мкФ эталондық конденсаторы бар С1-83 осциллографында D (E гистерезис ілмегі) жүргізілді. Генератордың жиілігі 300 Гц. Барлық температуралық зерттеулерде үлгілер пешке орналастырылған, температура ±0,1 мВ қателігімен В2-34 вольтметріне қосылған хром-алюмельді термобарамен өлшенген. Температураның өзгеру жылдамдығы 5 К/мин. Тыйым салынған аймақ енін есептеу (ΔЕ) температура мен электр кедергінің бастапқы және соңғы мәніне сүйене отырып жүргізілді. Алынған мәліметтер нәтижелері бастапқы күл мен күлдің үлгілері электромагниттік өңдеуден кейін 293-403К және 293-363 К температуралық аралықтарда жартылай өткізгіштік қасиеттер, өткізгіштіктің металл сипаты сәйкесінше 403-463 К және 363-413 К аралығында, ал 463-483 К және 413-463 К аралығында қайта жартылай өткізгіштік қасиеттер байқалатынын көрсетті. Бұдан басқа, 463-483 К аралығында электромагниттік өңдеуден кейінгі күл қайтадан металл өткізгіштігін көрсетеді. Электр зарядты өңдеуден кейінгі күлдің осы үлгілерінен айырмашылығы тек бір 293-403 К температуралық интервал болады, онда жартылай өткізгіштіктік қасиет көрсетіледі, ал металл секілді өткізгіштікті 403-483 к интервалында көрсетеді. Бұл нәтижелерді талдау күлді электр разрядтау арқылы өңдеу металл өткізгіштік пайда болатын қыздыру барысында температуралық диапазонды кеңейтеді. Электрофизикалық параметрлердің салыстырмалы талдауы, егер электрмагниттік өңдеуден кейінгі күл мен бастапқы күлде шамамен бірдей болса, онда электроразрядты өңдеуден кейін бұл параметрлер негізінен 293-453 К интервалында айтарлықтай ерекшеленеді. Сонымен, электр разрядтық өңдеуден кейінгі күлдің электрсыйымдылығы 89-1800 nF аралығында өзгереді, бұл бастапқы күлге (0-153 nF) және электромагниттік өңдеуден кейінгі күлге (0-105 nF) қарағанда айтарлықтай көп. Электроразрядты өңдеуден кейін күлдің диэлектрлік өткізгіштігі (~ 10^7) электромагниттік өңдеуден кейін бастапқы күл мен күл үлгілеріне қарағанда (~10^6) бірнеше есе көп. Электр зарядты өңдеуден кейінгі күл басқа зерттелетін үлгілермен салыстырғанда электр кедергісінің аз мәнімен ерекшеленеді. Электр өткізгіштіктің және диэлектрлік өткізгіштіктің үлкен мәні және барлық үлгілеріне қатысты аз электр кедергі жартылай өткізгіштен металдық өткізгіштікке өту нүктелерінде (403 К-ге дейін) байқалады. Сонымен қатар, электр кедергісінің ең үлкен мәні металдық өткізгіштіктен жартылай өткізгіштікке өту нүктелерінде жетеді (өту нүктесі металдық өткізгіштіктің соңғы температурасы 483 К болып саналатын электр разрядтау өнімінен кейінгі күлді қоспағанда). Тыйым салынған аймақ енін есептеу нәтижесі (Δ*E*) бастапқы күл үшін Δ*E* ≈0,63 эВ (1-ші аймақ), электромагнитті өңдеуден кейінгі күлге қатысты Δ*E* ≈ 0,83 эВ (1-ші аймақ) және ΔЕ ≈ 1,81 эВ (2-ші аймақ), электроразрядты өңдеуден кейінгі күлге қатысты ΔЕ ≈ 0,56 эВ. Тыйым салынған аймақ енінің алынған мәні (ΔЕ = 0,56-1,81 эВ) күлдің барлық зерттелетін үлгілері тар аймақты жартылай өткізгіш болып саналатынын көрсетеді. Осылайша,

жүргізілген зерттеу нәтижелері Майкүбен көмір күлінің жоғары кернеуде электр разрядты өңдеу оның электрфизикалық сипаттамаларының айтарлықтай өзгеруіне әкелетінін көрсетті. Мұны көмір күлін дайындау үдерісінде оны одан әрі қарай термохимиялық өңдеу мақсатында, құнды компоненттерді (сирек металл, кремнезем, глинозем) неғұрлым толық ерітіндіге өткізумен және/немесе бастапқы күлмен салыстырғанда технологиялық параметрлердің неғұрлым төмен мәндері (температура, реагенттер концентрациясы, ерітінділерді ұстау уақыты және т.б.) кезінде үдерісті жүргізуге пайдалануға болады. Сонымен қатар, жүргізілген талдау жұмыстары көрсеткендей, электр зарядты өңдеуден кейін көмір күлі сыйымдылық материал (конденсатор) және жартылай өткізгіш ретінде қолдану тиімді болып саналады.

Түйін сөздер: көмір күлі, электр кедергісі, электр сыйымдылығы, диэлектрлі өткізгіштік, электр разрядты өңдеу, жартылай өткізгіштік, металды өткізгіштік, шектеулі аймақ ені.

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ЭЛЕКТРОФИЗИЧЕСКИЕ ХАРАКТЕРИСТИКИ ЗОЛЫ УГЛЯ МАЙКУБЕНСКОГО БАССЕЙНА

В работе исследованы температурные зависимости электрофизических характеристик (электроемкость, электросопротивление, диэлектрическая проницаемость) в интервале 293–483 К для золы угля Майкубенского бассейна (Казахстан) в исходном виде после электромагнитного и электроразрядного воздействий. Электромагнитную обработку золы угля проводили 3 раза по 8 минут на электромагнитном аппарате ЭМА-1, состоящем из индуктора, рабочей камеры и штатива. Электрические параметры ЭМА-1: номинальный ток – 8 Ампер; номинальныя напряженность электромагнитного поля в центре индуктора (при 220 В) – 40-45 кА/м; мощность активная – 0,15-0,2 кВт; мощность и емкость конденсаторов для компенсации cosφ – 400 мкФ. Перед электромагнитной обработкой золу перемешивали с магнитными гранулами диаметром 2-3 мм (соотношение массы измельчаемого материала к массе магнитных гранул – 1:10) и затем высыпали в рабочую камеру, установленную посередине внутри индуктора. Электроразрядную обработку золы угля проводили на электроразрядной установке, состоящей из регулятора мощности, блока конденсаторов, трансформатора, повышающего (от 220 В до 30 кВ) реактора объемом 200 мл с двумя электродами. Предварительно золу (40 г) и воду (80 мл) тщательно смешивали и полученный раствор сливали в реактор. Через специальный пульт включали установку и обрабатывали раствор электрическим разрядом 3 минуты и далее сушили до сухого состояния. Измерения электрофизических характеристик проводили путем измерения электроемкости образцов на серийном приборе LCR-800 (Taiwan) при рабочей частоте 1кГц непрерывно в сухом воздухе в термостатном режиме со временем выдержки при каждой фиксированной температуре. Диэлектрическую проницаемость определяли из электроемкости образца при известных значениях толщины образца и площади поверхности электродов. Для получения зависимости между электрической индукцией D и напряженностью электрического поля *E* использована схема Сойера-Тауэра. Визуальное наблюдение D (E петли гистерезиса) проводилось на осциллографе С1-83 с делителем напряжения, состоящим из сопротивления 6 мОм и 700 кОм, и эталонным конденсатором 0,15 мкФ. Частота генератора 300 Гц. Во всех температурных исследованиях образцы помещались в печь, температура измерялась хромель-алюмелевой термопарой, подключенной к вольтметру В2-34 с погрешностью ±0,1 мВ. Скорость изменения температуры ~5 К/мин. Расчет ширины запрещенной зоны (Δ*E*) проводили, исходя из начальных и конечных значений температуры и электросопротивления. Результаты полученных данных показали, что образцы исходной золы и золы после электромагнитной обработки проявляют полупроводниковые свойства соответственно в температурных интервалах 293-403К и 293-363 К, металлический характер проводимости соответственно в интервалах 403-463 К и 363-413 К, а в интервалах 463-483 К и 413-463 К – снова полупроводниковые свойства. Кроме того, зола после электромагнитной обработки в интервале 463-483 К проявляет опять металлическую проводимость в отличие от данных образцов золы после электроразрядной обработки, имеет только один температурный интервал 293-403 К, где проявляет полупроводниковую проводимость, а металлическую проводимость проявляет в интервале 403-483 К. Анализ этих результатов показал, что электроразрядная обработка золы приводит к расширению температурного диапазона при нагревании, в котором проявляется металлическая проводимость. Сравнительный анализ электрофизических параметров показывает, что если у исходной золы и золы после электромагнитной обработки примерно соспоставимы, то после электроразрядной обработки данные параметры существенно отличаются, в основном в интервале

293-453 К. Так, электроемкость золы после электроразрядной обработки изменяется в пределах 89-1800 nF, что существенно больше, чем в исходной золе (0-153 nF) и золе после электромагнитной обработки (0-105 nF). Диэлектрическая проницаемость золы после электроразрядной обработки (~ 10^7) на порядок больше, в отличие от образцов исходной золы и золы после электромагнитной обработки (~10^6). Зола после электроразрядной обработки также отличается меньшими значениями электросопротивления по сравнению с другими исследуемыми образцами. Наибольшие значения электроемкости и диэлектрической проницаемости и наименьшее электросопротивление для всех образцов наблюдаются в точках перехода из полупроводниковой в металлическую проводимость (до 403 К). Вместе с тем, наибольшие значения электрического сопротивления достигаются в точках перехода из металлической в полупроводниковую проводимость (за исключением золы после электроразрядной обработки, где данной точкой перехода является конечная температура металлической проводимости 483 К). Результаты расчета ширины запрещенной зоны (ΔE) составили для исходной золы ΔE ≈0,63 эВ (1-я зона), для золы после электромагнитной обработки ΔE ≈ 0,83 эВ (1-я зона) и ΔE ≈ 1,81 эВ (2-я зона), для золы после электроразрядной обработки: ΔE ≈ 0,56 эВ. Полученные значения ширины запрещенной зоны (ΔE = 0,56-1,81 эВ) показывают, что фактически все исследуемые образцы золы являются узкозонными полупроводниками. Таким образом, результаты проведенного исследования показали, что электроразрядная обработка высоким напряжением золы Майкубенского угля приводит к существенному изменению ее электрофизических характеристик. Это можно практически использовать в процессе подготовки угольной золы с целью ее дальнейшей термохимической переработки с более полным выщелачиванием ценных компонентов (редких металлов, кремнезема, глинозема) и/или возможностью проведения процесса при более низких значениях технологических параметров (температура, концентрация реагентов, время выдержки растворов и т.д.), по сравнению с исходной золой. Более того, как показал проведенный анализ, зола угля после электроразрядной обработки представляется перспективной в качестве емкостного материала (конденсатор) и полупроводника.

Ключевые слова: зола угля, электросопротивление, электроемкость, диэлектрическая проницаемость, электроразрядная обработка, полупроводниковая проводимость, металлическая проводимость, ширина запрещенной зоны.

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FTIR- SPECTROSCOPIC CHARACTERISTICS OF THE DZHAKSY-KLYCH DEPOSIT SALTS

Abstract. Kazakhstan is a country with an arid climate, where a number of salt lakes are located, where industrial production of edible salt is carried out. Due to the increase in the volume of salt production for export needs and the possibility of expanding the scope of its use for medical and cosmetic purposes, new layers and deposits of salt are being developed. The purpose of this study was to refine the characteristics of Dzhaksy-Klych Deposit salts using FTIR spectroscopy. The objects of the study were samples of salt-containing raw materials selected from different sites of Dzhaksy-Klych Deposit. Based on the conducted research, it can be predicted that when the Aral sea turns into a chloride salt lake, the main sediment will be sodium chloride, with additional formation of salt deposits from sodium sulfate, calcium or magnesium. The results obtained provide useful information about the mineralogical composition of the Aral sea region salts, which complements the knowledge about the composition of minerals. The results of FTIR analyses show that the samples of salts of lake Dzhaksy - Klych are represented by the following compositions: halite, astrakhanite, hexahydrate, gypsum, mirabilite, and the absence of toxic substances in the studied salt samples confirms their suitability for use in food, pharmaceutical and cosmetic purposes.

Key words: salt, Dzhaksy-Klych deposit, FTIR spectroscopy, chemical composition, compounds.

Introduction. According to Zholtayev G. Zh. et al. (2018) opinion, each field must be subjected to a comprehensive study to determine its position in the regional and local structures, study the material composition. Salt is one of the natural components that can accumulate in solid form near natural and artificial reservoirs. There are known studies related to the negative environmental impact on the environment, and in particular on the biodiversity of soil and water(Emerson J. B. et al., 2013). A direct correlation was established between the level of soil salinity and the quantitative and qualitative characteristics of water microflora (Canfora L. et al., 2017). The influence of various factors on the indicators of biological activity of saline soils was studied (Yazdanpanah, N. et al., 2016). On the other hand, salt is an important source of valuable components for the full functioning of human and animal life (Thompson L. J., 2018).

Weather and climatic conditions of Kazakhstan contribute to the formation of salt deposits almost throughout the state, so the volume of table salt in the regions of the Republic is distributed as follows, thousand tons, according to region: Kzyl-Orda -27383.0; Aktyubinsk-8267.0; Atyrau-1069000.0; Kustanay - 2012.0; Kokchetau -42509. 0; Pavlodar – 163447.0; Semipalatinsk -29728.0; Taldy - Kurgan - 627.0; South-Kazakhstan-3887.0; Dzhambul – 10040.0.

At the same time, due to a number of reasons, the Kzyl-Orda region, in particular the region of the Aral sea region, was undeservedly excluded from the list of regressive regions. Indeed, it is necessary to recognize that environmental problems occur in the Aral sea region (Kurbaniyazov et al., 2009). At present, the level of the Aral sea has decreased in comparison with the level of 1957. (then the absolute mark was 54 m) by more than 14 m. Its area has decreased from 66.5 thousand km^2 to about 36 thousand km^2, and its water volume has decreased from 1000 km^3 to 320 km^3. The salinity of the water during this

time increased from 8 to 14 g/l to a value of 25-50 g/L. The area of the exposed bottom is approximately 3 million ha (Zavyalov et al., 2012). In the Aral sea region, dust and salt storms have become common. Every year, according to the space monitoring laboratory, about 72 million tons of salt is carried away by the wind outside the Aral sea region. The content of sulfates exceeds 31% (of the total amount of salts), and sodium chloride is only 54%. The ionic composition of the salts is as follows: sodium – from 2.83 to 13.73%; sulfate - ion - 7.5 – 30.14; calcium - up to 1.08; magnesium – 3.03; potassium – 0.93; carbonate - ion– 0.18; chlorine– 2.09; water– up to 55.23%.

Sea salt is extremely important for human nutrition, both for daily internal consumption and for external influences in the composition of therapeutic baths and cosmetic products. Salt minerals are actively involved in all the metabolic processes of our body (Lee & Lee, 2014). Therefore, salt is used for the prevention and treatment of many diseases (Kohlmeier M., 2015).

According to Internet resources, only in one quarter of the year, the volume of iodized salt production in Kazakhstan reaches 68.7 thousand tons. Every year, only the Kyzylorda region produces 66.9 thousand tons. The production of iodized salt is being increased by producers of the Zhambyl region: in the three months of 2019, 1.4 thousand tons were produced, despite the fact that in the same period of 2018, there was no salt production in the region at all. In the Turkestan region, salt production amounted to 0.4 thousand tons. Kazakhstan practically does not need to import salt: in January–February 2019, deliveries from abroad amounted to only 6.4% of resources (3 thousand tons). Kazakhstan's salt exports to foreign markets amounted to 35.9 thousand tons, an increase of 33.4% over the year. Salt is used mainly for food purposes, but such aspects of its use as use for medicinal or cosmetic purposes are not fully in demand. Despite the fact that the chemical compositions of the salts of most salt deposits in Kazakhstan are sufficiently studied, new areas and layers are being developed, the composition of which requires additional research and clarification. In this regard, the purpose of this study was to refine the characteristics of the Dzhaksy-Klych lake salts using Fourier-infrared spectroscopy.

Objects and methods of research. The objects of the study were samples of gold-containing raw materials selected from different points of Lake Dzhaksy-Klych.

Lake Dzhaksy-Klych –the biggest salt lake of the Caspian lowlands located in the Aral sea region. The lake is of marine origin and consists of two parts with an area of 18 and 58 km. The thickness of the salt deposit is about 2 m. Sampling was carried out in accordance with GOST 33770-2016. Samples were taken from the Dzhaksy-Klych Deposit by “Onyx-R” LLP and the authors of the article (table).

Description of Lake Dzhaksy-Klych samples

Sample	Sampling site (well No.)	Sampling depth, m	Coordinates (WGS 84)		pH	t, °C
			n.l.	e.l.		
1 (S1)	3s	0.0-0.5	46^0 56'3,38"	62^0 2'32.34"	7,3	25
2 (S2)	7s	0.6-1.1	46^0 55'53,09"	62^0 3'29.09"	7,2	25
3 (S3)	4s	0.6-1.1	46^0 56'0,81"	62^0 2'46.49"	7,3	26
4 (S4)	6s	1.2-1.3	46^0 55'55,66"	62^0 3'14.93"	7,1	27
8 (S5)	14s	1.5-2.0	46^0 56'7,71"	62^0 3'16.93"	7,2	27

Five different salts from Dżaksy-Klych Lake (sample 1, 2, 3, 4 and 8 denoted later as S1, S2, S3, S4, S5) were chosen for the further study (figure 1).

Figure 1 – Dried and milled salt samples

In the study of salt-containing raw materials, a mass spectrometer with inductively coupled plasma was used, the elements were determined in accordance with ST RK ISO 17294-2-2006. Chemical analysis was carried out according to GOST 13685-84. Research conditions: temperature-25^{0}C; humidity -83.0%; pressure-714 mm Hg.

FTIR spectroscopy: A Fourier transform infrared spectrometer (Cary 630, Agilent) was used to obtain the IR spectra. Spectra were collected in 4 cm^{-1} resolutions and coadded 100 scans. A 45-degree reflection-absorption optical accessory was used to perform the measurements. In this optical system, a gold-coated plate was used as a reflection reference. To remove the spectral interference from water absorption bands, samples S1, S2, S3, S4 and S5 were dried (100^{o}C, 24 or 72h) before measuring the reflection-absorption IR spectra. Dried salts were placed on top of the gold-coated plate to obtain the reflection spectra. FTIR spectra were displayed in an ordinary absorption unit.

Statistical processing of the results was performed by calculating the arithmetic mean and the standard deviation. All determinations were carried out in 3-and 5-fold repetitions. The data was processed using an IBM Pentium personal computer based on Excel application software packages.

Results and discussion. FTIR studies of the salts help in the identification of minerals present in the salts. The coupled vibrations are appreciable due to availability of various constituents. In figure 2, FTIR spectra of all salts are shown.

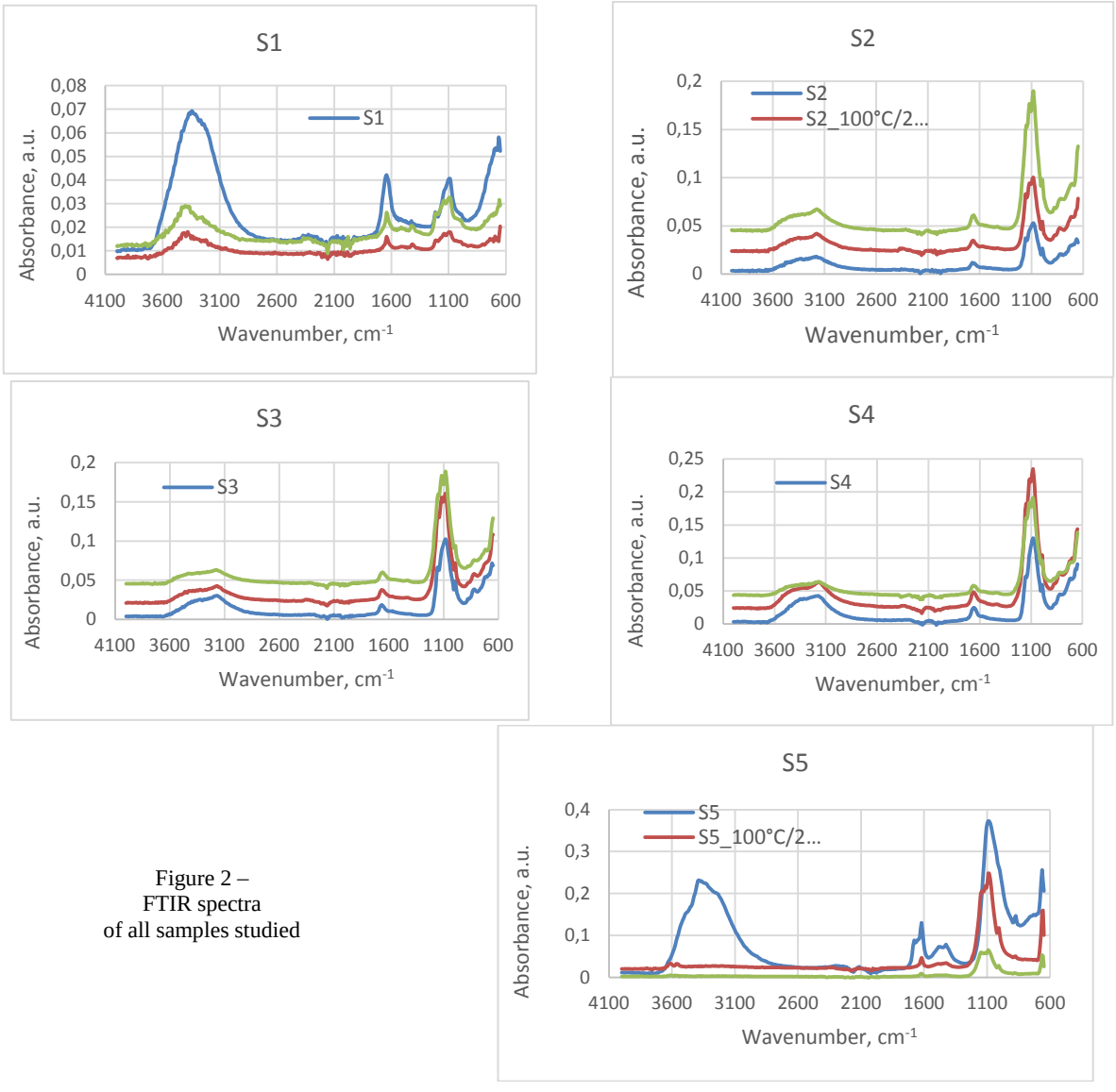

Figure 2 –
FTIR spectra
of all samples studied

In all samples, there are 3410 and 1635 cm^{-1} peaks. This peaks come from water in structure of sample. In other regions the following minerals were considered (Miller F.A., Wilkins Ch.H., 1952):

1. Sodium carbonate Na_2CO_3 700, 705, 855, 878, 1440, 1755, 2500, 2620 cm^{-1} peaks;
2. Calcium sulfate $CaSO_4$. $2H_20$ 667, 1010 , 1130, 1630, 1670, 2200, 3410 cm^{-1} peaks;
3. Sodium sulfate Na_2SO4 645, 1110 cm^{-1} peaks;
4. Sodium silicate 775, 832, 980, 1125, 1165, 1695, 2330, 3280 cm^{-1} peaks.

The sharp peak at ~1100 cm^{-1} was mainly assigned to such associated complexes of alkali and alkaline earth metals and SO_4^{2-}.The reference data is presented in figure 3.

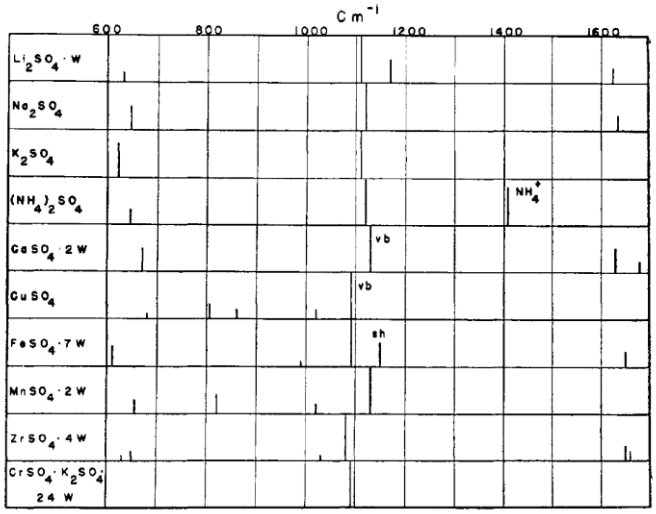

Figure 3 – Comparison of FTIR data for different sulfates (Miller F.A., Wilkins Ch.H., 1952)

Just as with sulfates, most other polyatomic ions exhibit characteristic frequencies. These are summarized in figure 4. However, it seems that mainly bands from sulfates are present.

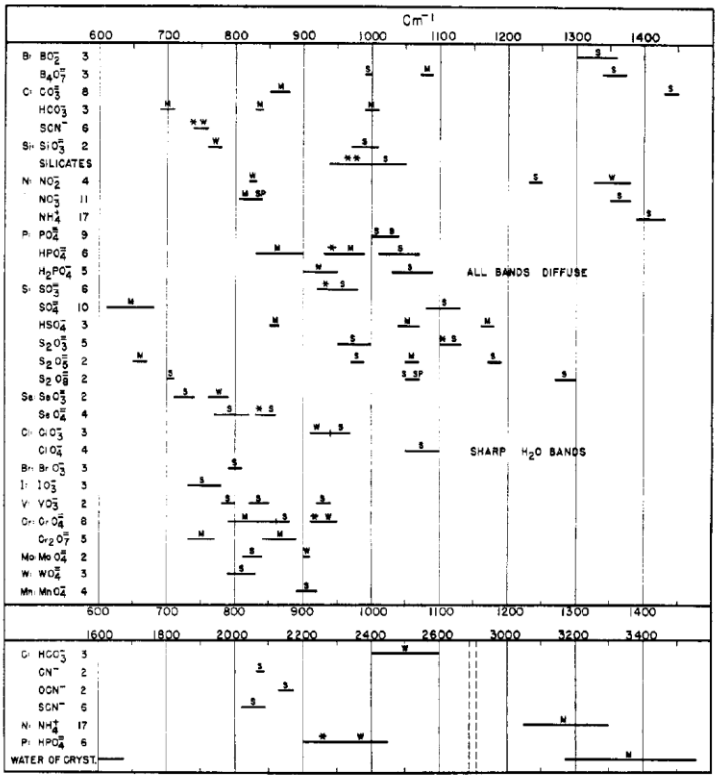

Figure 4 – Characteristic frequencies of polyatomic inorganic ions (Miller F.A., Wilkins Ch.H., 1952)

We can assume that with the transformation of the Aral Sea into a chloride salt lake, only NaCl will be deposited. Thus NaCl will be the main precipitate, whereas other salts will be minor. One can expect sodium (e.g. Na_2SO_4), calcium (e.g. $CaSO_4$) or magnesium salts ($MgSO_4$), and others.

The performed analyses provided useful information about the mineralogical composition of the salts. This is a fundamental step in gaining knowledge about the constituent of minerals.

Conclusions. The results of these studies give grounds for predicting that only NaCl will be deposited when the Aral sea turns into a chloride salt lake. Thus, NaCl will be the main precipitate, while other salts will be secondary. In addition, you can expect the formation of salt layers from sodium (for example, Na_2SO_4), calcium (for example, $CaSO_4$), magnesium ($MgSO_4$) and others. The analyses provided useful information about the mineralogical composition of the salts. This is a fundamental step in gaining knowledge about the composition of minerals. As a result of the conducted FTIR analyses, it was found that the samples of lake Dzhaksy -Klych salts are represented by the following compositions: halite, astrakhanite, hexahydrate, gypsum, mirabilite. The absence of toxic substances in the salt samples confirms their suitability for use in food, pharmaceutical and cosmetic purposes.

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ЖАҚСЫ-КЛЫШ КЕН ОРНЫ ТҰЗЫНЫҢ ИҚ-ФУРЬЕ СПЕКТРОСКОПИЯЛЫҚ СИПАТТАМАСЫ

Аннотация. Қазақстан аридтік климатты мемлекет болып келеді, ас тұзын өнеркәсіпте өндіретін бірқатар тұзды көлі бар. Экспорттық қажеттіліктерге тұз өндірісінің ұлғаюы және оны емдік, косметологиялық мақсаттарға қолдану аясын кеңейту мүмкіндігіне байланысты жаңа қабаттар мен тұз шоғыры игерілуде. Қазақстанның ауа-райы мен климаттық жағдайы елде тұзды шөгінділердің пайда болуына ықпал етеді, сондықтан республика аймақтарындағы ас тұзы (мың тонна) келесідей бөлінеді: Қызылорда 27383,0; Ақтөбе 8267.0; Атырау 1069000.0; Қостанай 2012.0; Көкшетау 42509. 0; Павлодар 163447,0; Семей 29728,0; Талдықорған 627,0; Оңтүстік Қазақстан 3887,0; Жамбыл 10 040,0. Бірқатар себеп бойынша Қызылорда аймағы, атап айтқанда, Арал теңізі регрессивті аймақ тізімінен шығарылды. Шын мәнінде экологиялық проблемалар Арал маңында туындайтынын мойындау керек. Бұл зерттеудің мақсаты ИҚ-Фурье спектроскопия әдісімен Жақсы-Клыш кен орында тұз сипаттамаларын нақтылауды қамтиды. Зерттеу нысаны ретінде Жақсы-Клыш кен орындағы түрлі нүктеден таңдалған күкіртті шикізаттың 5 үлгісі алынды. Барлық сынамада галиттің бар екендігі анықталды. Астраханит тек 2,3 және 4 сынамада анықталады. 3 және 4 сынамада гексагидрат және гипс белгіленген. 4-сынамадан мирабилит табылды. Ауыр металдар мен улы заттар табылған жоқ, бұл осы қабат тұзын кеңінен қолдануға ұсынуға мүмкіндік береді. Зерттеу нәтижелері Арал теңізі хлоридті тұзды көлге айналған кезде тек NaCl шөгетінін көрсетті. Сонымен, NaCl негізгі шөгінді, ал қалған тұздар екінші реттік болады. Сонымен қатар, натрийден (мысалы, Na2SO4), кальцийден (мысалы, CaSO4), магнийден (MgSO4) және басқалардан тұз қабаты пайда болады деп болжанады. Талдау жұмыстары тұздың минералогиялық құрамы туралы пайдалы ақпарат берді. Бұл – минералды негіз алудың іргелі қадамы. FTIR көлін талдау нәтижесінде Жақсы-Кылыч ұсынған тұз сынамалары келесі композиция арқылы ұсынылатындығы анықталды: галит, астраханит, гексахидрат, гипс, мирабилит. Тұз сынамасында улы заттардың болмауы олардың тағамдық, фармацевтикалық және косметикалық мақсаттарда қолдануға жарамдылығын көрсетеді.

Түйін сөздер: тұз, Жақсы-Кылыч кен орны, ИҚ-Фурье спектроскопиясы, химиялық құрамы, қосылыстар.

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ИК-ФУРЬЕ СПЕКТРОСКОПИЧЕСКАЯ ХАРАКТЕРИСТИКА СОЛЕЙ МЕСТОРОЖДЕНИЯ ДЖАКСЫ-КЛЫЧ

Аннотация. Казахстан является государством с аридным климатом, где расположен ряд соленых озер, где производится промышленная добыча пищевой соли. В связи с увеличением объемов добычи соли на экспортные нужды и возможностью расширения сферы ее применения в лечебных и косметологических целях осваиваются новые пласты и залежи соли. Погодно-климатические условия Казахстана способствуют формированию солевых отложений практически на всей территории страны, поэтому объем поваренной соли в регионах республики распределяется следующим образом, тыс. тонн по регионам: Кзыл-Ординская - 27383,0; Актюбинск-8267.0; Атырау-1069000.0; Костанай - 2012,0; Кокшетау - 42509. 0; Павлодар - 163447,0; Семей -29728,0; Талдыкорган -627,0; Южно-Казахстанская-3887,0; Жамбыл - 10040,0. При этом по ряду причин Кзыл-Ординский регион, в частности район Приаралья был незаслуженно исключен из списка регрессивных регионов. Необходимо признать, что экологические проблемы возникают в районе Аральского моря. Целью данного исследования было уточнение характеристик солей озера Джаксы-Клыч методами ИК-Фурье спектроскопии. Объектами исследования послужили 5 образцов солесодержащего сырья, отобранных из разных точек озера Джаксы-Клыч. Было установлено, что во всех пробах присутствует галит. Астраханит выявлен только в пробах 2,3 и 4. В пробах 3 и 4 отмечены гексагидрат и гипс. В пробе 4 обнаружен мирабилит. Тяжелые металлы и токсичные вещества обнаружены не были, что позволяет рекомендовать соли данных пластов для широкого применения. Результаты этих исследований дают основание прогнозировать, что только NaCl будет откладываться, когда Аральское море превратится в хлоридное соленое озеро. Таким образом, NaCl будет основным осадком, а другие соли - вторичными. Кроме того, можно ожидать образования слоев соли из натрия (например, Na2SO4), кальция (например, CaSO4), магния (MgSO4) и других. Анализ предоставил полезную информацию о минералогическом составе солей. Это фундаментальный шаг в получении знаний о составе минералов. В результате проведенных FTIR-анализов установлено, что образцы солей озера Джаксы-Клыч представлены следующими составами: галит, астраханит, гексагидрат, гипс, мирабилит. Отсутствие токсичных веществ в образцах солей подтверждает их пригодность для использования в пищевых, фармацевтических и косметических целях.

Ключевые слова: соль, месторождение Джаксы-Клыч, ИК-Фурье спектроскопия, химический состав, соединения.

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