ГИАБ. Горный информационно-аналитический бюллетень /
MIAB. Mining Informational and Analytical Bulletin, 2022;(10-2):62–70
ОРИГИНАЛЬНАЯ СТАТЬЯ / ORIGINAL PAPER

УДК 622 DOI: 10.25018/0236_1493_2022_102_0_62

ТЕХНОЛОГИЧЕСКАЯ УСТОЙЧИВОСТЬ КАК ОСНОВА УСТОЙЧИВОГО ПРОМЫШЛЕННОГО РАЗВИТИЯ РЕГИОНОВ АРКТИКИ

В. С. Жаров
Институт экономических проблем им. Г. П. Лузина Федерального исследовательского центра «Кольский научный центр РАН», Апатиты, Россия

Аннотация: рассмотрены различные виды устойчивости и соответствующие им определения. Целью статьи является рассмотрение новых понятий «технологическая устойчивость» и «устойчивое технологическое развитие», возможности достижения производственными системами такого состояния развития и оценка влияния технологической устойчивости производства в условиях перехода мировой экономики на концепцию развития «Индустрия 4.0» на экономическую, экологическую и социальную устойчивость развития экономических систем разного уровня, в том числе арктических регионов России. Исследование базируется на введенном в научный оборот понятии жизненного цикла технологического развития производственных систем (производственных фирм и отраслей производства), состоящем из шести стадий, где каждая стадия показывает изменение значений во времени (увеличение либо уменьшение) показателей материалоотдачи, фондоотдачи и самое важное — коэффициента уровня технологичности производства как отношения материалоотдачи к фондоотдаче. Устойчивое технологическое развитие производственных систем обеспечивается лишь на одной стадий из шести возможных, когда одновременно увеличиваются значения материалоотдачи, фондоотдачи и коэффициента уровня технологичности производства. В результате за счет существенного повышения уровня материалоотдачи, а значит снижения уровня материалоемкости, при внедрении технологических инноваций снижается расход сырья , материалов и энергии на единицу выпускаемой продукции и тем самым снижается воздействие производства на природную среду, в том числе и за счет уменьшения объема отходов производства, то есть обеспечивается экологическая устойчивость. Рассмотренные теоретико-методологические положения были использованы для оценки устойчивости промышленного технологического развития четырех регионов — субъектов Федерации, полностью входящих в Арктическую зону РФ, за период 2005–2016 гг.

Ключевые слова: технологтческая устойчивость, устойчивое промышленное развитие, регионы Арктики, жизненный цикл технологического развития.

Для цитирования: *Жаров В. С.* Технологическая устойчивость как основа устойчивого промышленного развития регионов Арктики // Горный информационно-аналитический бюллетень. — 2022. — № 10-2. — С. 62–70. DOI: 10.25018/0236_1493_2022_102_0_62.

Technological sustainability as a basis for sustainable industrial development of the Arctic regions

V. S. Zharov
Luzin Institute of Economic Problems of the Federal Research Center "Kola Scientific Center of the Russian Academy of Sciences", Apatity, Russia

Abstract: Various types of stability and their corresponding definitions are considered in the literature. The purpose of the article is to consider the new concepts of "technological sustainability" and "sustainable technological development", the possibility of achieving such a state of development by production systems and to assess the impact of technological sustainability of production in the context of the transition of the world economy to the concept of development "Industry 4.0" on the economic, environmental and social sustainability of the development of economic systems of various levels, including the Arctic regions of Russia. The research is based on the concept of the life cycle of technological development of production systems (manufacturing firms and industries) introduced into scientific circulation, consisting of six stages, where each stage shows a change in values over time (increase or decrease) in material productivity, capital productivity and, most importantly, the coefficient of the level of manufacturability of production as the ratio of material productivity to capital productivity. The sustainable technological development of production systems is ensured only at one stage out of six possible, when the values of material productivity, capital productivity and the coefficient of the level of manufacturability of production simultaneously increase. As a result, due to a significant increase in the level of material output, which means a decrease in the level of material consumption, the introduction of technological innovations reduces the consumption of raw materials, materials and energy per unit of output and thereby reduces the impact of production on the natural environment, including by reducing the volume of production waste, that is, environmental sustainability is ensured. The theoretical and methodological provisions considered were used to assess the sustainability of the industrial technological development of four regions — subjects of the Federation, which are completely included in the Arctic zone of the Russian Federation, for the period 2005—2016.

Key words: technological sustainability, sustainable industrial development, Arctic regions, the life cycle of technological development.

For citation: Zharov V. S. Technological sustainability as a basis for sustainable industrial development of the Arctic regions. *MIAB. Mining Inf. Anal. Bull.* 2022;(10-2):62—70. [In Russ]. DOI: 10.25018/0236_1493_2022_102_0_62.

1. Introduction

Modern scientific ideas about the sustainability of economic systems since 1987, that is, after the report to the UN General Assembly of the World Commission on Environment and Development under the leadership of Norwegian Prime Minister G. H. Brundlandt [1], have undergone significant changes and are now shifting their view from environmental protection to the triad of sustainability assessment: environmental, economic and social [2—4]. Currently, most scientists recognize that innovation is needed for the sustainable development of such systems, the development of an intelligent person, and the state [5,6,7].

Accordingly, when implementing the "Industry 4.0" development concept in the world economy, attention is being increased to assessing the impact of technological aspects of the IV Industrial Revolution from various positions — environmental, economic and social [8,9], that is, the task is to assess the sustainability of economic systems using technological innovations, digitalization of the economy and the introduction of artificial intelligence elements into production management systems [10—12].

At the same time, the results of scientific research on the assessment of the impact on the stability of the life cycle of systems are actively published in modern foreign literature [13], however, these results are still diverse and fragmentary. The most developed studies are on the environmental assessment of the life cycle [14, 15] and, to a certain extent, the assessment of the cost of life products (goods) [16]. There are very few results of research on the life cycle of processes, primarily technological ones [17,18]. In this regard, the research of S-curves has been significantly developed [19,20], in the study of which, in relation to changes in production technologies at the level of an individual firm, Prof. K. Christensen made a significant contribution [21]. However, research in this direction is primarily related to changes in the effectiveness (productivity) of technologies over time and does not determine the relationship of changes in production costs with changes in the stages of production technology.

In the last decade, foreign literature has also been actively discussing, but mainly at the theoretical level, issues related to the development of various business models, including those related to the use of technological innovations [22], however, the assessment of the sustainability of enterprises is not considered. Also recently, the mutual influence of technological, managerial and marketing innovations has been discussed [23] from the point of view of assessing the possible increase in the efficiency of firms in various sectors of the economy. However, as a rule, conclusions are based on the results of processing a variety of data using correlation analysis methods and are not related to the stability of firms. At the same time, specific indicators of innovation performance have not yet been determined, the values of which clearly show a connection with the sustainability of firms [24].

The purpose of the article is to consider the new concepts of "technological sustainability" and "sustainable technological development", the possibility of achieving such a state of development by production systems (enterprises and industries) and to assess the impact of technological sustainability of production in the context of the transition of the world economy to the concept of development "Industry 4.0" on the economic, environmental and social sustainability of the development of economic systems of different levels.

2. Materials and methods

When considering the economic development of the country and regions, the determining factor is the achievement of a state of economic stability, but at the same time, in order to ensure the maximum possible rates of economic growth, it is necessary to achieve maximum efficiency in the use of basic production resources — material, labor and physical capital (fixed assets). In economic theory, at the macroeconomic level, this is well demonstrated by the curve of production capabilities, which is the boundary of achieving such a state. However, it is possible only with the use of the most efficient production technologies. Accordingly, the question arises — how is the use of production technologies directly related to the efficiency of the use of production resources at the micro level, that is, at the enterprises level?

From the point of view of the theory of the development of complex systems and the consideration of their life cycle, stability is ensured only at certain stages of the life cycle curve and, above all, at the stage of quantitative accumulation of elements in the system, that is, at the stage of growth, until the moment when negative external and internal conditions of the development of the system lead it to a state of instability and then to the point of bifurcation characterizing revolutionary changes in the system.

Any technology used in the production of goods can also be considered as a system from the point of view of its development, that is, its introduction into production, improvement, obsolescence and subsequent replacement with a new technology. However, it is not clear how these stages are directly related to the efficiency of the use of production resources and how to determine this efficiency when using production resources together?

We have developed the foundations of a new type of economic analysis of the activity of production systems — the analysis of their technological renewal, where it is shown that there is a proportional analytical dependence between the capital intensity of production and its material intensity [25]. Such dependence as a measure of proportionality is quantitatively expressed by the coefficient of the production manufacturability level (Cpml), since the increase in its value is directly determined by the degree of renewal of the main production assets of the enterprise, and above all their active part, that is, machinery, equipment and vehicles. Quantitatively Cpml is calculated by the ratio of the value of the capital intensiveness of production to the material intensity of products or by the ratio of the value of material efficiency to the efficiency of capital. As a result of a joint study of changes in the values of material intensity and capital productivity (as the inverse of the value of capital intensity) and the corresponding change in the values of Cpml the example of the activities of many industrial enterprises over a long fifteen-year period of time, we have developed a matrix of possible directions of their development, and based on it — a graphical model of the life cycle of technological development of production systems (enterprises and industries) in the form of a curve, which in appearance corresponds to the schedule of development of any system [26]. The resulting curve shows the change in the level of material output values as the inverse of the material intensity, depending on the degree of renewal of fixed assets and the corresponding changes in the values of the level of capital output and the coefficient of the level of manufacturability of production. Thus, this curve directly shows the influence of the level of novelty of the technology used simultaneously on the economic efficiency of using all three main types of production resources, since it is known that the increase in the level of capital return is an intensive factor in increasing the level of labor productivity.

3. Results and discussion

The curve of the life cycle of technological development of production shows that, firstly, the technology used makes it possible to increase the value of material output, that is, to reduce the material intensity of production, only to a certain level, even with its improvement, and this level can be calculated for each specific enterprise based on the analysis of its reporting data. Secondly, one full cycle of technology development includes six stages, in which at three stages the values of material return, capital return and the coefficient of the level of manufacturability of production increase, and at the other three decrease, and only at one stage the values of all three indicators increase simultaneously. Thus, only at this single stage of technology development, the maximum possible efficiency of the use of material, labor resources and physical capital is achieved, and therefore the maximum possible increase in profit from each unit of manufactured and sold products. Accordingly, the technological development of production systems at this stage, which corresponds to the concept of “technological stability”, ensures their economic stability, but not only it.

The fact is that, firstly, with the improvement of technology, a decrease in the material intensity of production due to an increase in material output leads to a decrease in the volume of production waste, and the introduction of a new technology will allow the use of previously accumulated production waste, that is, the environmental sustainability of production is ensured. Secondly, due to the maximization of the level of capital return due to the intensive renewal of fixed assets, the level of labor productivity will significantly increase, and hence the level of average wages at enterprises and in production sectors. If at the same time, at enterprises due to the active use of technological innovations, the growth rate of the average salary will exceed the average industry rate or the average for the country as a whole, then it becomes possible to use part of the salary fund to form a guaranteed income fund to pay the personnel of enterprises released as a result of productivity growth or for other social activities. Accordingly, social sustainability will be ensured at the enterprises.

Thus, when production systems achieve technological sustainability, economic, environmental and social sustainability will be ensured at the same time, which will correspond to the concept of "sustainable technological development". It is very important to keep in mind that with this type of development of production systems, the main economic interests of enterprises, regions-subjects of the Federation and the state are combined, since a decrease in the level of material intensity of production simultaneously leads to an increase in the profit of enterprises per unit of sales volume, as well as to an increase in the share of value added in this volume, which means that the growth of the gross regional product (GRP) of the regions-subjects of the Federation and the growth of the gross domestic product (GDP) of the country is ensured. At the same time, the regions and the country receive additional amounts of tax deductions, therefore they should be interested in accelerating the technological renewal of production systems, therefore they should create the necessary preferences for enterprises and manufacturing industries, primarily in the formation of an effective system for stimulating innovation.

The above theoretical provisions were used to assess the sustainability of the technological industrial development of the four Arctic regions — the subjects of the Federation, which are completely included in the Arctic zone of the Russian Federation, for the period 2005—2006 (table 1).

The calculated data given in the table show that in all regions the production of electricity, gas and water has been developing more technologically steadily, but the maximum efficiency of using resources (development stage 1—1): material, labor and physical capital (fixed assets) was achieved in each region only in certain years.

Mining has been developing relatively technologically steadily (with a lower level of resource efficiency) in all regions.

Accordingly, of the three types of industrial activity, the most problematic situation with the sustainability of technological development has developed in the processing industry, especially in the Nenets National District and in the Murmansk Region, where in the analyzed period of time the values of the coefficient of the level of manufacturability of production had a tendency to decrease.

Conclusions

For the sustainable development of economic systems, innovations are necessary, primarily technological ones, but their specific impact on the achievement of economic, environmental

Table 1

Parameters for assessing the sustainability of technological development of the Arctic regions by types of industrial activity[a]

Regions	Indica-tors	2005	2010	2011	2012	2013	2014	2015	2016
Nenets Autonomous Okrug									
Mining	MI	0,207	0,253	0,286	0,330	0,282	0,272	0,268	0,183
	EC	0,986	0,590	0,595	0,509	0,493	0,455	0,418	0,346
	Cpml	4,90	6,69	5,87	5,95	7,19	8,07	8,91	15,79
	No		4 – 2	3	4 – 2	2	2	2	2
Processing	MI	0,611	0,746	0,610	0,592	0,524	0,905	0,947	0,966
	EC	2,654	4,212	3,050	3,455	1,889	10,670	19771	40,073
	Cpml	0,61	0,32	0,54	0,49	1,01	0,10	0,05	0,03
	No		3	2	1 – 2	2	3	3	3
Electricity, gas and water production	MI	0,195	0,224	Н.д	0,471	0,413	0,343	0,357	0,412
	EC	1,269	0,837	Н.д	0,750	0,825	0,888	0,801	0,911
	Cpml	4,02	5,33	Н.д	2,83	2,93	3,28	3,50	2,66
	No		4 – 2		4 – 1	1 – 1	1 – 1	4 – 2	3
Murmansk region									
Mining	MI	0,469	0,431	0,407	0,421	0,405	0,524	0,460	0,438
	EC	1,312	1,246	0,599	0,527	0,583	0,428	0,489	0,527
	Cpml	1,62	1,86	4,10	4,50	4,24	4,46	4.44	4,33
	No		2	2	4 – 2	1 – 2	4 – 2	1 – 2	1 – 2
Processing	MI	0,256	0,539	0,546	0,614	0,625	0,650	0,683	0,720
	EC	1,895	2,971	2,590	2,707	2,273	2,667	3,027	2,833
	Cpml	2,06	0,62	0,71	0,60	0,70	0,58	0,48	0,49
	No		3	4 – 2	3	4 – 2	3	3	4 – 2
Electricity, gas and water production	MI	0,629	0,656	0,680	0,678	0,673	0,655	0,607	0,588
	EC	0,584	0,617	0,482	0,491	0,456	0,327	0,377	0,426
	Cpml	2,72	2,47	3,05	3,01	3,26	3,85	4,37	3,99
	No		3	4 – 2	1 – 2	2	2	1 – 1	1 – 2
Yamalo-Nenets Autonomous Okrug									
Mining	MI	0,257	0,329	0,308	0,305	0,318	0,295	0,264	0,284
	EC	0,421	0,255	36,683	0,301	0,325	0,318	0,330	0,249
	Cpml	9,26	11,92	0,09	10,89	9,69	10,69	11,48	14,14
	No		4 – 2	1 – 2	2	3	2	1 – 1	4 – 2
Processing	MI	0,674	0,857	0,891	0,876	0,848	0,856	0,877	0,890
	EC	3,882	2,515	1,388	2,584	3,189	0,905	6,248	0,371
	Cpml	0,38	0,46	0,81	0,44	0,38	1,29	0,18	3,03
	No		4 – 2	4 – 2	1 – 2	1 – 2	4 – 2	3	4 – 2
Electricity, gas and water production	MI	0,504	0,428	0,347	0,419	0,350	0,320	0,366	0,363
	EC	0,397	0,292	0,282	0,296	0,351	0,247	0,222	0,119
	Cpml	4,99	7,99	9,34	8,05	8,14	12,68	12,34	23,15
	No		2	2	3	1 – 1	2	4 – 1	2

End of Table 1

Regions	Indica-tors	2005	2010	2011	2012	2013	2014	2015	2016
Chukotka Autonomous Okrug									
Mining	MI	0,650	0,581	0,517	0,494	0,576	0,620	0,612	0,603
	EC	2,127	2,217	2,207	1,680	1,096	1,675	2,023	1,620
	Cpml	0,72	0,78	0,88	1,20	1,58	0,96	0,81	1,02
	No		1—1	2	2	4—2	3	1—2	3
Processing	MI	0,824	0,414	0,639	0,849	0,867	0,826	0,649	0,562
	EC	40,143	0,541	0,670	0,541	0,585	0,959	0,799	0,606
	Cpml	0,03	4,46	2,33	2,18	1,97	1,26	1,93	2,94
	No		2	3	4—1	3	1—2	2	2
Electricity, gas and water production	MI	0,355	0,209	0,150	0,296	0,385	0,262	0,299	0,252
	EC	0,495	0,527	0,384	0,526	0,497	0,402	0,411	0,401
	Cpml	5,68	9,06	17,33	6,42	5,22	9,49	8,14	9,90
	No		1—1	2	3	4—2	2	3	2

[a] Calculated on the basis of data from the annual statistical collections "Regions of Russia. Socio-economic indicators". MI — the material intensity of products, EC — the efficiency of capital, Cpml — the coefficient of the production manufacturability level, No — the number of the stage of development.

and social sustainability by production systems at the same time is not considered in the scientific literature.

To do this, it is proposed to use the concept of the life cycle of technological development of manufacturing enterprises and industries and a curve graphically reflecting such a cycle, including six stages. At the same time, the concept of "technological stability" corresponds to the development of the production system only at one stage, when the values of the efficiency of the use of three main types of production resources — material, labor and physical capital simultaneously increase (fixed assets). As a result, the simultaneous achievement of economic, environmental and social sustainability by the production system is ensured, which is proposed to be designated by the concept of "sustainable technological development".

Since this state of development ensures the coordination of the economic interests of manufacturing enterprises with the interests of the regions-subjects of the Federation and the country as a whole, its achievement through active technological renewal of production should be supported by the state through the formation of an effective system of stimulating innovation.

The theoretical and methodological provisions considered in the article were used to assess the sustainability of the technological industrial development of four regions — subjects of the Federation, which are completely included in the Arctic zone of the Russian Federation, for the period 2005—2016.

REFERENCES

1. World Commission on Environment and Development (WCED). (1987). Our Common Future (NY: Oxford University Press).

2. Zhukovskiy, Y., Tsvetkov, P., Buldysko, A., et al. (2021). Scenario modeling of sustainable development of energy supply in the Arctic. Resources, 10(12), 124. DOI: 10.3390/resources10120124.

3. Strange, T., Bayley, A. (2008). Sustainable development: Linking economy, society, environment (Paris: OECD Insights), 142. DOI: 10.1787/9789264055742-en.

4. Dmitrieva, D., Romasheva, N. (2020). Sustainable Development of Oil and Gas Potential of the Arctic and Its Shelf Zone: The Role of Innovations. Journal of Marine Science and Engineering, 8, 1–18. DOI: 10.3390/jmse8121003.

5. Lee, S. M., Trimi, S. (2016). Innovation for creating a smart future. Journal of Innovation & Knowledge, 3(1), 18. DOI: 10.1016/j.jik.2016.11.001.

6. Zhang, Y. (2019). The Influence of Management Innovation and Technological Innovation on Organization Performance. A Mediating Role of Sustainability. Sustainability, 11(2) 495. DOI:10.3390/su11020495.

7. Samylovskaya, E., Makhovikov, A., Lutonin, A. (2022). Digital Technologies in Arctic Oil and Gas Resources Extraction: Global Trends and Russian Experience. Resources, 11(3), 29, 21100808642. DOI: 10.3390/resources11030029.

8. Tcvetkov, P., Cherepovitsyn, A., & Fedoseev, S. (2019). The Changing Role of CO2 in the Transition to a Circular Economy: Review of Carbon Sequestration Projects. Sustainability, 11(20), 5834. DOI: 10.3390/su11205834.

9. Dvoynikov, M., Buslaev, G., Kunshin, A., Sidorov, D., Kraslawski, A., & Budovskaya, M. (2021). New Concepts of Hydrogen Production and Storage in Arctic Region. Resources, 10(1), 3. DOI: 10.3390/resources10010003.

10. Vasilyeva, N. V., Boikov, A. V., Erokhina, O. O., & Trifonov, A. Y. (2021). Automated digitization of radial charts. *Journal of Mining Institute*, 247, 82–87. DOI: 10.31897/PMI.2021.1.

11. Litvinova T. E., Suchkov D. V. Comprehensive approach to the utilisation of technogenic waste from the mineral resource complex. *MIAB. Mining Inf. Anal. Bull.* 2022;(6–1):331–348. [In Russ]. DOI: 10.25018/0236_1493_2022_61_0_331.

12. Linkov, I. (2018). Governance Strategies for a Sustainable Digital World. Sustainability, 10(2), 440. DOI:10.3390/su10020440.

13. Finkbeiner, M. (2010). Towards Life Cycle Sustainability Assessment. Sustainability, 2 (10), 3309- 3322. DOI:10.3390/su2103309.

14. O'Brian, M. (1996). Social and Environmental Life Cycle Assessment (SELCA). The International Journal of Life Cycle Assessment, 1(4), 231–237.DOI:10.1007/BF02978703.

15. Khan, F. I. (2002). Effective environmental management through life cycle assessment. J. Loss Prev. Process Ind, 15,455–466.

16. Kloepffer, W. (2008). Life Cycle Sustainability Assessment of Products. The International Journal of Life Cycle Assessment, 13(2), 89–95.DOI:10.1065/lca2008.02.376.

17. Khan, F. I. (2002). GreenPro-I: A risk-based life cycle assessment and decision-making methodology for process plant design. Environmental Modelling and Software, 17(8), 669–691. DOI:10.1016/S1364–8152(02)00028–2.

18. Khan, F. I. (2004). Life cycle index (LInX): a new indexing procedure for process, and product design and decision-making. Journal of Cleaner Production, 12(1), 59–76. DOI:10.1016/S0959–6526(02)00194–4.

19. Becker, R. H., Speltz, L. M. (1983). Putting the S-Curve Concept to Work Research Management, 16 (5), 31–33.

20. Christensen, C. M. (1992). The Innovator's Challenge-. Understanding the Influence of Market Environment on Processes of Technology Development in the Rigid Disk Drive Industry D. B. A. dissertation. Graduate School of Business Administration (Cambridge, MA: Harvard University).

21. Christensen, C. M. (2009). Exploring the Limits of the Technology S-Curve. Part I: Component Technologies. Production and Operations Management, 1(4), 334–357. DOI:10.1111/j.1937–5956.1992.tb00001.x.

22. Teece, D. (2010). Business Models, Business Strategy and Innovation. Long Range Planning, 43, 172–194. DOI:10.1016/J.LRP.2009.07.003.

23. Zhang, Y. (2019). The Influence of Management Innovation and Technological Innovation on Organization Performance. A Mediating Role of Sustainability. Sustainability 11(2), 495. DOI: 10.3390/su11020495.

24. Dziallas, M., Blind, K. (2018). Innovation indicators throughout the innovation process: An extensive literature analisis. Technovation, (80–81), 3–29. DOI:10.1016/j.technovation.2018.05.005.

25. Zharov, V. S. (2018). Using innovative investment leverage to evaluate areas of technological development of industrial production.St. Petersburg State Polytechnical University Journal. Economics, 11(1), 177–187.DOI: 10.18721/JE.11116.

26. Zharov, V. S. (2018) The interrelation of technological and economic development of production systems. St. Petersburg State Polytechnical University Journal. Economics, 11(3) 32–44. DOI: 10.18721/JE.11303 ГИАБ

ИНФОРМАЦИЯ ОБ АВТОРАХ

Жаров Владимир Сергеевич — д-р экон. наук, профессор, главный научный сотрудник,
e-mail: zharov_vs@mail.ru,
ORCID ID: 0000-0002-1877-9214,
Институт экономических проблем им. Г. П. Лузина Федерального исследовательского центра «Кольский научный центр РАН», 184209, Апатиты, Россия.
Для контактов: *Жаров В. С.*, e-mail: zharov_vs@mail.ru.

INFORMATION ABOUT THE AUTHORS

Zharov V. S., Dr. Sci. (Economics), Professor, Chief Researcher,
e-mail: zharov_vs@mail.ru,
ORCID ID: 0000-0002-1877-9214,
G. P. Luzin Institute of Economic Problems of the Federal Research Center “Kola Scientific Center of the Russian Academy of Sciences”, 184209, Apatity, Russia.
Corresponding author: *Zharov V. S.*, e-mail: zharov_vs@mail.ru.

Получена редакцией 20.03.2022; получена после рецензии 15.07.2022; принята к печати 10.09.2022.
Received by the editors 20.03.2022; received after the review 15.07.2022; accepted for printing 10.09.2022.