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ИННОВАЦИОННАЯ АКТИВНОСТЬ СЕВЕРНЫХ ГОРНОПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЙ КАК ВАЖНЕЙШИЙ ФАКТОР СНИЖЕНИЯ ВОЗДЕЙСТВИЯ НА ОКРУЖАЮЩУЮ ПРИРОДНУЮ СРЕДУ

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Аннотация: российские горнопромышленные предприятия, функционирующие на Севере и в Арктике, негативно влияют на окружающую природную среду. Следовательно, для осуществления «зеленой» революции необходима разработка и реализация технологических инноваций. Целью работы является количественный анализ уровня инновационной активности горнопромышленных предприятий северных регионов. Показано, что инновационная активность большинства северных горных предприятий низкая. Внедрение инновационных технологий освоения и переработки минерально-сырьевых ресурсов позволяют снизить материалоемкость производства и уменьшить объемы отходов. На основе использования нового методологического подхода выполнена количественная оценка уровня инновационной активности трех российских корпораций (АО «Олкон», АО «Карельский окатыш», ПАО «ГМК «Норильский никель») и шведской компании «Boliden Group». При отсутствии в России эффективной системы стимулирования инновационной активности предприятий, в том числе горнопромышленных, для активизации их инновационной деятельности предлагается порядок разработки каждым предприятием собственной стратегии инновационного развития. Формирование таких стратегий покажет, с одной стороны, возможности предприятий по достижению высоких значений целевых показателей инновационной активности, а, с другой стороны, определит целесообразность и возможность государственной финансовой поддержки.

Ключевые слова: Север и Арктика, горнопромышленные предприятия, инновационная активность, стратегия инновационного развития, стимулирование.

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Innovation activity of northern mining enterprises as the most important factor of reducing the impact on the environment

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Abstract: Russian mining enterprises operating in the regions of the North and the Arctic have a negative impact on the environment. Therefore, for the implementation of the "green" revolution it is necessary to develop and implement technological innovations. The aim of the work is a qualitative analysis of the innovation activity level of the mining enterprises of the northern regions. It is shown that the innovation activity of the majority of northern mining enterprises is low. Implementation of the innovation technologies for the exploitation and processing of mineral resources allow to decrease the material intensity of production and reduce the waste volume. Based on the use of a new methodological approach a quantitative assessment of the innovation activity level of three Russian corporations (JSC Olcon, JSC Karelsky Okatysh, PJSC MMC Norilsk Nickel) and the Swedish company Boliden Group was carried out. With the absence in Russia of an effective system for stimulating the innovation activity of enterprises including mining a procedure for each enterprise to develop its own strategy of innovation development in order to activate their innovation activity is proposed. The formation of such strategies will show on the one hand to identify the possibilities of enterprises to achieve high values of target indicators but on the other hand will determine the expediency and possibility of state financial support.

Key words: the North and the Arctic, mining enterprises, innovative activity, innovative development strategy, stimulation.

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1. Introduction

Mining enterprises are the basis of the economy of the most regions of the North and Arctic that are subjects of the Federation, therefore their development determines the further growth of the gross regional product (GRP) [1]. At the same time, mining enterprises have a negative impact on the environment [2]. Herewith rich ore deposits decrease forcing to exploit poor ore deposits. At the same time the amount of hazardous production waste containing a number of toxic elements will increase. Accordingly, to prevent such tendency it is necessary to develop and implement innovation technologies that allow to ensure the "green revolution" [3 – 5].

In this regard, it is necessary to conduct a quantitative analysis of the innovation activity level of the mining enterprises from the point of view of the technological innovations to decrease the level of their impact on the environment which is the purpose of the work.

2. Materials and methods

The concept of innovation activity in the scientific literature does not have an unambiguous definition [6], since for this it is necessary, first of all, to formulate self-consistent indicators (one or more interconnected), the change in the values of which will show how innovatively or non-innovatively a particular enterprise has developed. If innovatively then what is the degree of innovation activity that characterizes the rate of change in the values of indicators used for such an assessment.

In [7] it is shown that in the economic literature two approaches to determining the innovation activity of enterprises are considered. In the first approach, an enterprise that implements any innovations in the appropriate period of time is considered to be innovatively active. In accordance with the second approach, innovatively active enterprises will include any enterprise that has R&D costs. It is used more often, but in [7] this approach

is rightly criticized, since the volume of R&D costs does not correlate with sales revenue. At the same time, the authors of the work propose their own approach based on an expert assessment of the significance of three blocks of indicators, however, firstly, such an assessment is always subjective. Secondly, each block includes many different indicators, and some of them are absent in the public reporting of enterprises. As a result, a comparative assessment of the innovation activity of different enterprises becomes impossible.

It is proposed a new approach to measuring the innovation activity of industrial enterprises and industrial sectors of the economy of the regions — subjects of the Russian Federation and the country as whole. Its basis is the proposed by authors a new type of the economic analysis of the activities of enterprises and industries — an economic analysis of the technological renewal of production. In accordance with this method technological development of enterprise or industry depending on the economic efficiency of using the main types of production resources (material, including energy, labor and physical capital in the form of fixed assets) is determined by its life cycle which includes six stages [8].At the same time, an indicator of the transition of an enterprise to the corresponding stage is a change of the value in one direction or another of one of three interrelated indicators: coefficient of the production manufacturability level (CPML), material efficiency (ME) and efficiency of capital (EC). First of these indicators is defining one since the growth rates of its values show in authors' opinion the degree of innovation activity of enterprises and industries and the absolute value of CPML in the corresponding period of time indicates the level of their innovation technological development. 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 and its essence lies in the fact that the technological renewal of the active part of fixed assets (machinery, equipment and vehicles), that is according to the classification of G. Chesbro [9] open innovations in the form of materialized ("bodily") knowledge, has a direct impact on reducing the material intensity of manufactured products, that is, on increasing the level of material efficiency. This theoretical assumption which results from the theory of endogenous economic growth is confirmed by numerous calculations of the proportional relationship between the values of material intensity and capital intensiveness carried out according to the data of the activities of many industrial enterprises primarily located in the regions of the North and the Arctic over a long (more than 15 years) period of time [10].

Of the six stages of the life cycle of technological development of enterprises and industries mentioned above only one stage shows the possibility of a simultaneous increase of the values of all three indicators. Accordingly, in order to maximize the efficiency of use of basic economic resources each enterprise should strive to achieve production activities precisely at this stage but then the question arises — how can it make such a transition and whether it possible based on its current or prospective financial capabilities?

3. Results and discussions

Decree of the President of the Russian Federation of May 7, 2018 No. 204 set the task to increase the number of organizations implementing technological innovations to 50% of their total amount by 2024. To determine the innovation activity of the northern industrial enterprises

in terms of introducing technological innovations 19 mining companies that provide information in the public access on websites and in the annual reports as well as in scientific publications for the period 2013 — 2020 were chosen.

Companies that have implemented technological innovations:

Kirovsk branch of JSC "Apatit" PJSC "PhosAgro".

In 2017 the enterprise developed and implemented a technology for cyclical-flow transportation of overburden with the participation of Thyssen Krupp Industrial Solutions (Germany), which made it possible to increase ore production by 10%.

In 2018 the enterprise developed and implemented a fine screening technology using high-frequency Landsky screens, manufactured by Beijing Screen Technology Co., Ltd. (China), which allowed to increase the efficiency of ore separation by size classes and process lean and off-balance ores (with a P2O5 content from 4 to 6%).

In 2019 the enterprise together with PLC Epiroc RUS developed and implemented a technology for remote control of drilling equipment for underground ore mining which made it possible to increase the drilling efficiency by 20%.

JSC Kola MMC is a subsidiary of PJSC MMC Norilsk Nickel

In 2017 the enterprise together with PLC Gipronickel developed and implemented a technology for briquetting copper-nickel concentrate which allowed to reduce sulfur dioxide emissions by 35 — 40 thousand tons per year.

In 2018, the enterprise developed and implemented a technology for controlling finished products in the briquetting section using artificial intelligence and machine vision which made it possible to improve quality control of finished products.

In 2019 the enterprise together with LLC Gipronickel developed a technology for producing electrolytic nickel from solutions of chlorine dissolution of nickel powder of tube furnaces which makes it possible to increase the production of electrolytic nickel from 120 thousand to 145 thousand tons per year and to increase the level of nickel extraction into concentrate by 1%.

JSC North-Western Phosphorous Company is a subsidiary of PJSC Acron.

In 2020 the company introduced a water accumulation technology allowing to reduce the load on the pumping equipment of the mine and the industrial site of the mining and processing plant.

JSC Olkon part of the Severstal Resources division of PJSC Severstal.

In 2015 the enterprise together with PLC SPB-Giproshakht introduced the technology of cyclical-flow delivery of ore using a steeply inclined conveyor which made it possible to reduce transportation costs by 2 times [11].

In 2019, the enterprise together with scientists from the MI FRC KSC RAS introduced the technology of magnetic-gravity separation which allowed to increase the iron content in the concentrate to 68.46%.

In 2020, the enterprise together with the FRC KSC RAS introduced a screw separation technology which made it possible to obtain hematite concentrate at a level of 62%.

PLC Mayskoye Gold Mining Company is a subsidiary of JSC Polymetal.

In 2018 the enterprise together with the company "SGS" (Russia) implemented a technology for processing oxidized ore in a combined way allowing to increase the share of gold in concentrate by 24%.

Polar Division of PJSC MMC Norilsk Nickel.

In 2017 the enterprise together with JSC Mekhanobr Engineering at the Talnakh enrichment plant introduced a technology for enrichment of a charge of rich and

cuprous ores which made it possible to process low-nickel pyrrhotite [12].

Thus for only 13 out of 19 (30%) considered enterprises have implemented technological innovations. Including JSC Karelsky Okatysh and JSC Vorkutaugol (as part of the Severstal Resources division of PJSC Severstal), JSC Kovdorskiy GOK, MCC PJSC Eurochem, PLC Lovozersky GOK, Rusal Kandalaksha — a branch of JSC Rusal Ural UC Rusal.

Thus, one can state that the innovation activity of the majority of Russian mining enterprises in the North and the Arctic is relatively low but this is a very generalized conclusion characterizing only the introduction of new production technologies which is usually rarely carried out at Russian enterprises unlike, for example, the Scandinavian countries located mainly in the North. Many Russian mining enterprises are engaged in improving existing production technologies, however, in accordance with the approach mentioned above they are not considered to be innovatively active [13—15].

In authors' opinion a more accurate classification of mining enterprises as innovatively active can be obtained using the calculation of the absolute values of the coefficient of the production manufacturability level and the rate of their change. To substantiate this conclusion, the technical and economic indicators of activities of two mining and processing enterprises that have approximately the same production technology and are part of the same holding of PJSC Severstal: JSC Olkon and JSC Karelsky Okatysh for ten years (2011—2020) (tables 1 and 2) were considered. Sales revenue of products at each enterprise during this period increased equally by 71 percent [16].

The mentioned above calculated data show that, first, for the analyzed period

Table 1

Technical and economic indicators of activities of JSC Olcon[1]

Indicators	2011	2012	2013	2018	2019	2020	growth rate for the period (%)
ME	4,27	2,89	2,88	2,71	3,54	3,69	86,5
EC	3,36	2,24	1,92	2,64	2,87	2,87	85,4
CPML	1,27	1,29	1,50	1,02	1,23	1,29	101,6

Table 2

Technical and economic indicators of activities of JSC Karelsky Okatysh[1]

Indicators	2011	2012	2013	2018	2019	2020	growth rate for the period (%)
ME	4,27	2,89	2,88	2,71	3,54	3,69	86,5
EC	3,36	2,24	1,92	2,64	2,87	2,87	85,4
CPML	1,27	1,29	1,50	1,02	1,23	1,29	101,6

[1]Calculated by the authors based on the data of annual reports on the activities of enterprises [16], where ME — material efficiency of manufactured products;

EC — efficiency of capital of production by the residual value of fixed assets at the end of the year;

CPML — coefficient of the production manufacturability level.

Indicators corresponding to the best stage of the technological development life cycle are marked in bold.

of time, the rates of change in the values of the coefficient of the production manufacturability level at the two enterprises are almost the same. At the same time JSC Karelsky Okatysh was actively engaged in improving production technology, which allowed it in 2020 to only slightly reduce material efficiency and efficiency of capital compared to 2010. Accordingly, this enterprise can also be considered innovatively active.

Second, due to the introduction of new production technologies in 2018 – 2020, JSC Olcon managed to significantly increase the level of material efficiency and, accordingly, reduce the specific consumption of materials and energy per ruble of manufactured products, although the level of 2011 was not reached. However, without the activation of such type of innovation activity the decrease of the values of material efficiency would be more significant.

Third, JSC Olcon over the past two years has developed as efficiently as possible in terms of increasing resource efficiency, that is, at the best stage of the life cycle of technological development of enterprises. At the same time, JSC Karelsky Okatysh reached the best stage of technological development only in 2019. This shows that in the future this enterprise will not be able to reach the maximum possible resource efficiency of production only by improving the production technology.

Compared to mining and processing enterprises, mining and metallurgical enterprises have a more significant environmental pollution. In this regard, it is of interest to compare the level of their innovation activity, and it is especially important to compare the results of innovation activity and the corresponding change of the volume of pollutant emissions of Russian and foreign enterprises.

To perform a comparative analysis, two non-ferrous metallurgy enterprises – PJSC MMC Norilsk Nickel (Russia) and Boliden Croup (Sweden) (tables 3 and 4) for the period of their activity of 2011 – 2020 were selected. Each of them produces copper and nickel among the group of metals. In addition, they are relatively comparable in scale of production (in 2011, the volumes of sales revenue of these companies in US dollars were the same, however, in 2020, the Russian enterprise increased its sales volume three times, and the Swedish – only one and a half times, mainly due to for lower rates of growth in prices for zinc and lead compared to prices for cobalt and palladium).

The main conclusion from the data obtained is that the innovation activity of the Russian company was mainly aimed at improving the existing production technology, when in the Swedish one – at the introduction of new technological processes, since over ten years the value of the coefficient of the production manufacturability level for PJSC MMC Norilsk Nickel has increased only by 20%, and the Boliden Group by 70%. At the same time, the Swedish company showed a steady growth trend of the CPML values, and the sharp increase of the values of this indicator at the Russian company in 2012 – 2017 is mainly due to the change in the organizational structure of PJSC MMC Norilsk Nickel and the corresponding changes in the data on the volume of material costs. The obtained conclusion is confirmed by the fact that R&D expenditures of the Boliden Group in relation to sales revenue are more than 1.3% and have doubled in absolute expression over ten years. At the same time, such costs for the Russian company are ten times less and, according to scattered data from annual reports, amount to about 0.02% of sales revenue.

Table 3

Results of production and innovation activities of PJSC MMC Norilsk Nickel[1] [17,18]

Indicators	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ME	5,16	8,23	7,60	9,71	10,28	9,53	6,95	7,09	7,09	4,96
EC	3,03	2,48	2,12	2,57	1,31	1,23	1,26	1,63	2,46	2,34
CPML	1,70	3,32	3,59	3,77	7,86	7,74	5,52	4,35	2,88	2,12
Air emission of SO_2, thousand tons	2016	2044	2033	1948	2009	1878	1785	1870	1898	1911
Air emission of solids, thousand tons	21,0	19,0	20,0	21,5	19,6	13,6	13,0	13,1	11,2	10,2
Wastewater discharge, million m^3	139	147	146	146	141	144	148	164	142	202,5

Table 4

Results of production and innovation activities of Boliden Group[1] [19]

Indicators	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ME	1,59	1,59	1,57	1,64	1,66	2,00	2,04	1,99	2,06	1,97
EC	1,76	1,59	1,26	1,29	1,42	1,16	1,36	1,35	1,14	1,29
CPML	0,90	1,00	1,25	1,27	1,17	1,72	1,50	1,47	1,81	1,53
Air emission of CO_2, thousand tons	924	1008	1000	1001	889	1052	1024	971	917	897
Air emission of SO_2, tons	7410	8240	6410	7320	7210	7060	7360	7720	6240	6310
Air emission of metals, tons	23	92	75	126	88	100	109	92	69	60
Metal discharge into water, tons	14	21	23	21	18	13	9	8	51	37
Share of R&D expenditures in revenue, %	0,89	1,07	1,18	1,07	1,23	1,31	1,33	1,34	1,48	1,33

[1]*Data on* environmental pollution are given from the annual reports of companies, and the other values of indicators are calculated by the authors based on the data of these reports.

As a result of such innovation activities in 2020 compared to 2011 the material efficiency of the Russian company decreased by 4.5% and in the Swedish company is increased by 23.9% that is the consumption of natural capital (raw materials, materials and fuel) decreased significantly per unit of production value.

It should be noted that each company carries out significant targeted activities to reduce environmental pollution by production waste but even so for example a Russian company has even increased wastewater discharge over ten years while a Swedish company has more than doubled its metal emissions into the atmosphere and water.

The problem of utilization of sulfurous gases deserves special attention. The Boliden Group has practically solved it since less

than ten thousand tons of SO_2 are emitted into the atmosphere and there is a tendency for a further decrease. At PJSC MMC Norilsk Nickel the problem of utilizing sulfur dioxide is much more complicated since the volume of SO_2 emissions is about two million tons that is more than 200 times higher than the emissions of the Swedish company. It should be noted that the Russian company uses more high-sulfur ore but its processing technology has been used for several decades without significant changes. The current situation will change significantly for the better only after the full implementation of the "sulfur project" in the coming years.

The low level of innovation activity of Russian mining industrial enterprises is largely determined by the fact that in Russia unlike for example the subarctic countries the system of stimulating the introduction of innovations is poorly functioning [20, 21]. The state policy in the field of innovation activities is reduced only to the formation of various Strategies and Development Programs but their implementation turns out to be ineffective including due to the lack of federal bodies (organizations) existing in all Scandinavian countries which main tasks are to coordinate innovation policy in the country, information and advisory support of innovation activities and selection of highly effective projects and financing of investments in such innovation projects (directly or through various funds).

The proposed industrial policy for increasing resource efficiency by transferring enterprises to the best available technologies (BAT) [22] will not solve the problem of a significant reduction in the material intensity of production and reduction of the impact of enterprises on the environment since in general such technologies will allow only to improve the technological processes existing in production.

Each enterprise including mining one with an increase of the level and degree of its innovation activity especially when transition to new innovation production technologies may experience a great risk of failure to reach the required technological, technical and economic results including from ineffective implementation of relevant investment projects. In this regard any enterprise in order to determine the need for and the possibility of enhancing innovation activities in order to increase resource efficiency should, in authors' opinion, develop its own strategy for innovation development based on the possibility of using not only its own financial resources but also attracting borrowed capital from various external sources however subject to compliance the required level of financial stability.

The primary basis of such a strategy should be a preliminary determination of the prospective values of the mentioned above target indicators that is CPML, ME, EC and the amount of investments from various sources required to reach them. Then through iterative calculations the real possibility of reaching the target values is checked and if necessary they are adjusted downward..

4. Conclusions

1. The performed analysis based on a new methodological approach of the level of innovation activity of Russian northern mining enterprises showed a low level of implementation of innovation technologies for the exploitation and processing of mineral resource, which could reduce the material intensity of production and reduce the negative impact on the environment.

2. A comparative analysis of the level of innovation activity of four enterprises (JSC Olcon, JSC Karelsky Okatysh, PJSC MMC Norilsk Nickel,

Boliden Group (Sweden)) for the period 2011 – 2020 was carried out. The analysis showed that an increase of the production manufacturability level is typical only for enterprises of the Boliden Group where a significant increase of material efficiency and accordingly a decrease of the level of natural capital use and hence the impact on the environment is ensured.

3. With the absence in Russia of an effective system for stimulating the innovation activity of enterprises, including mining, in order to activate innovation activities, the procedure for developing each enterprise's own strategy for innovation development is considered where the coefficient of the production manufacturability level and the interrelated with it indicators of the level of material efficiency and efficiency of capital are proposed as target indicators. Formation of such strategies will show on the one hand the ability of enterprises to achieve high values of target indicators and on the other hand will determine the expediency and possibility of state financial support.

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ИНФОРМАЦИЯ ОБ АВТОРАХ

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