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Russian National technological initiative in the sphere of mineral resource usage

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Professional paper

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Abstract
Operating efficiency improvement of the Russian company MMC Norilsk Nickel will be determined by the extended involvement in production of both new geogenic off-balance ores from combine deposits and previously accumulated technogenic mineral raw materials – metallized rock mass dumps and sand tailings. This article proposes a complex program of technological initiative in the sphere of mineral resource usage, and justifies effective measures aimed at developing the city-forming mining and metallurgical industry.

Keywords
Subsurface resources management, mining companies, mineral raw material base, enrichment processes, mining raw materials

1. Introduction

With the passage of time, all mining companies, in one way or another, experience a crisis (**Vorob'ev et al., 2003**). This may be caused by several reasons: ineffective management, exhaustion of the company mineral resource base, price fluctuations (falling) of manufactured products, transition of the global industry to new products – substitutes of mineral raw materials (first of all, metals).

Particularly, in 2013 the global mining industry was under very difficult economic conditions, caused by a significant reduction of minerals prices (products obtained from minerals), which affected gold the most: its price fell by a record value for the last 30 years (**Mirovye gornodobyvayushchie kompanii perezhivayut krizis, 2014**). During this period, the total revenue of the mining industry amounted to $731 billion, whereas the net income decreased by 49%, down to $68 billion.

The Russian sector of mineral resources usage couldn't evade the global crisis. Thus, the capitalization of Russian mining companies decreased by $36.4 billion since the beginning of 2013.

Therefore, during the crisis, it is more necessary than ever to sharply reduce the costs of the mining industry production and substantially increase its productivity. But the optimization of the costs/income ratio is carried out by many mining companies in the simplest, but in the long term ineffective way – by personnel redundancies.

Thus, the world's second largest mining company Anglo American Plc. planned to reduce its personnel by 19 thousand people until the end of 2015 (**Gornodobyvayushchiy sektor Avstralii v krizise, 2013**). One of the immediate plans of this company was to stop mining at a coal mine Aquila in central Queensland. Glencore Xstrata concern (the largest brown coal exporter) also reduced its personnel and planned to significantly reduce production at several of its mining sites in New South Wales. Further cost reduction and dismissal of a substantial part of personnel were also planned at Peabody Energy and Rio Tinto Group companies.

Such measures are taken under the restructuring of companies (**Vorob'ev et al., 2010**), which was caused by the deepening economic crisis, due to which there was a significant drop in metal prices (**Anglo American Plc., vtoraya po velichine gornodobyvayushchaya kompaniya, Minus 19 000 rabotnikov**).

2. Analysis of the Problem and Discussion

A more effective way is to reduce production costs by the use of innovative approaches to the exploration and

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Table 1: Mineral resources base of OJSC MMC Norilsk Nickel (Vesa et al., **2007**)

Metal volume	Ore volume (thousand tons)	Ni (thousand tons)	Cu (thousand tons)	Pd (thousand ounces)	Pt (thousand ounces)	PGM (thousand ounces)
Proven and probable ore reserves	473,149	5,730	8,712	55,018	13,439	71,778
Explored and indicated deposits of mineral resources	1,868,738	10,436	16,331	135,730	38,804	182,588

development of mineral deposits, which, on the other hand, is longer, more labor-consuming, and requires additional investments.

Thus, fundamentally new ideas embodied in technologies, machinery, and equipment, as well as efficient industry organization and management, provide the 70–85% GDP growth in the leading countries (**Vorob'ev et al., 2013a; Pilipenko, 2011**).

According to the available foreign experience, industrial companies can reduce their operating costs by 10–15 % by massively introducing the specially designed innovative methods and technologies (**Vorob'ev et al., 2013b**).

According to the Message of the President of the Russian Federation V. Putin to the Federal Assembly (2014), the National technological initiative must be developed and implemented in Russia to address problems that the Russian Federation will face in the near future, for which it is necessary to combine the efforts of the most dynamically developing companies and advanced educational and leading research centers.

According to the Forbes annual data, MMC Norilsk Nickel in 2014 ranked among the 2000 world's largest companies (along with 30 other Russian companies):

- rank in this rating: 385
- revenue: $12.8 billion
- income: $3.3 billion
- assets: $18.8 billion
- capitalization: $32.9 billion

The revenue of this company in 2008 amounted to $13.98 billion, whereas, according to the results as of 30 June 2010 (only for 6 months), it was $6.837 billion. In 2010, the net income of NMMC exceeded $5 billion.

It is advisable to carry out a further increase in the efficiency of MMC Norilsk Nickel in cooperation with the scientists from People's Friendship University of Russia (in 2014 included in the TOP-500 world best universities, according to the QS World University Rankings rating system, and also one of the top five universities of Russia) (**Vorob'ev, 2015**).

NMMC has developed the Strategy of industrial and technical development of OJSC MMC Norilsk Nickel for the period up to 2025, which provides for the mineral processing and metallurgical industry development, modernization of the main industrial funds, significant reduction of environmental impact, as well as the development of modern infrastructure.

NMMC industrial development strategy is focused on the growth of existing productive assets at the territory of Taimyr and Kola peninsulas, and its implementation will allow (**Strategiya razvitiya proizvodstva OAO "GMK "Norilskiy nikel" na Taymyrskom i Kolskom poluostrovakh do 2015, 2003**):

- to increase the efficiency of mineral processing industry and improve the quality of concentrates, which leads to the reduction of production costs in metallurgic industry;
- to minimize the unit production costs of metal production, compensate for the negative impact of the inflationary rise of costs, maintain the existing position on production costs (among the main nickel producers);
- to ensure stability of nonferrous and precious metals production;
- to reduce the negative impact on the environment and ensure compliance with the environmental legislation on air pollutant emissions and waste dumping into the water.

In accordance with the Strategy, NMMC has planned to ensure product diversification by the obtained nonferrous metals, platinum-group metals (PGMs) and steelmaking raw materials, through the development of new Russian and foreign deposits of the corresponding mineral resources.

By the strategic plans of mining industry development at NMMC, it is planned to increase this mine's production capacity by 67% until 2019 (from 1.2 mln tons to 2 mln tons of ore per year). This is due to the fact that there are unique and rather significant reserves of various minerals at the disposal of OJSC MMC Norilsk Nickel (see **Table 1**).

The basis of NMMC mineral reserves includes ordinary disseminated ores **(see Figure 1)**, with nickel content of 0.5–0.6% (95.9% of total reserves), while the share of rich ores amounts to 4.1% of ore reserves and 12.4% of metal reserves.

Operating efficiency improvement of MMC Norilsk Nickel will be determined by the extended involvement in production of both new geogenic off-balance ores from combine deposits and previously accumulated technogenic mineral raw materials – metallized rock mass dumps and sand tailings (at the combine the wastewater dumping amount to more than 200 mln m^3 annually). Thus, the expected increase in geogenic reserves

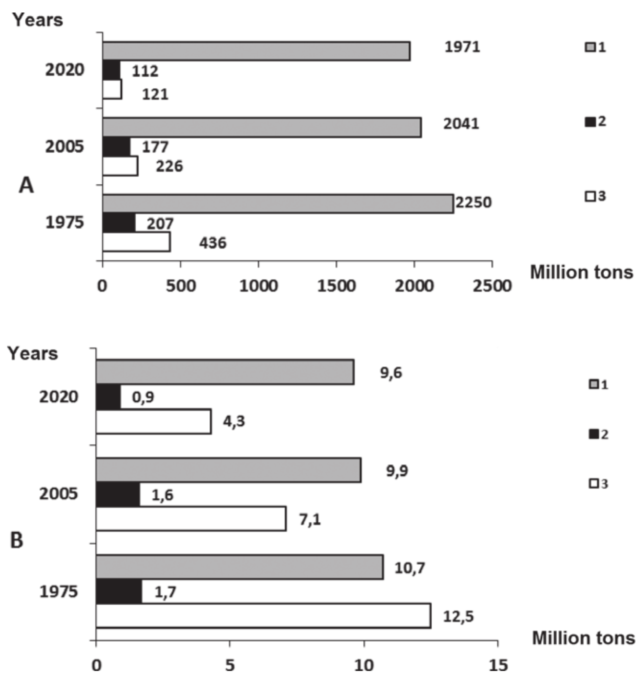

Figure 1: Characteristics of NMMC mineral resources base: A – ore; B – nickel in ore; 1 – years; 2 – million tons; 3 – disseminated ores; 4 – cuprous ores; 5 – rich ores

in the Norilsk industrial district, after additional geological works on the selected prospective areas, will be 9.46 mln tons for copper ores and 4.87 mln tons for nickel ores.

In particular, production capacities of the operating Northern-Deep mine of Kola MMC compensate for the ceased production at the open Central mine. However, the production cost of 1 ton of ore will increase here from $5 to $11, which is the natural difference between open and underground mine development. At the same time, it does not affect the metal production costs, since metal content in the ores of the Northern-Deep mine is about 2 times larger than in the ores mined earlier at the Central mine. Currently, the average nickel content in the ore is 0.7%, copper – 0.3%, and cobalt – 0.022%. Additionally, at this mine the construction of the horizon Eastern section -320 m is continued, which provides for a laying of several new ore passes. This will enable the use of the South-Eastern ore body of the deposit (now the mining is carried out in the South-Western and Central ore bodies) and significantly increase the production capacity reserves. Kola MMC has already ordered a project of -440 m horizon, the purpose of which is to ensure replenishment of retired capacities.

Table 2: Mining assets of MMC Norilsk Nickel

Deposit / Mine	Mine type	Ores[1]
Polar branch		
Oktyabrskoe deposit		Copper-nickel sulphide
Oktyabrskiy	Underground	Rich, cuprous, disseminated
Taimyrskiy	Underground	Rich, disseminated
Komsomolskiy, western field	Underground	Rich, cuprous, disseminated
Talnakh deposit		Copper-nickel
Talnakh mining group		
Komsomolskiy[2]	Underground	Cuprous and disseminated
Mayak	Underground	Disseminated
Skalistyy	Underground	Rich
Norilsk-1 deposit		Copper-nickel sulphide
Medvezhiy ruchey	Open	Disseminated
Zapolyarnyy	Underground	Disseminated
Kola MMC		
Zhdanovskoe deposit		Copper-nickel sulphide
Central	Open	Disseminated
Northern-Deep	Underground	Disseminated
Zapolyarnoe deposit		Copper-nickel sulphide
Northern	Underground	Disseminated
Kotselvaara and Semiletka deposits		Copper-nickel sulphide
Kaula-Kotselvaara	Underground	Disseminated

Notes:
1. Rich ores have a higher content of nonferrous and precious metals. Cuprous ores are characterized by a high content of copper as opposed to nickel. Disseminated ores have a lower content of all metals.
2. Komsomolskiy mine develops Talnakh deposit and the western part of Oktyabrskiy deposit.

Extracting metals from mineral raw materials with their low content by the methods of mine, heap and dump leaching allows to further expand (by 8–15%) the mineral resources base of the combine **(see Table 2)**, and at the same time (by processing the existing technogenic mineral waste accumulations of the mining industry) not only economic and material, but also many environmental and social problems will be solved.

Major study works on mineralogical composition and technological properties of ores at the Taimyr mine at the beginning of the 1970s (during the preliminary and detailed exploration from the day surface) were not fully performed. Because of the seeming simplicity and uniformity of the ore deposits material composition the study of their mineralogy was carried out in an abridged way, without defining a number of technologically important parameters, by the sparse network of exploratory wells, whereas the technological samples selection process was often done in a mixture with ores from other sites and deposits.

Later on, to identify the extent and variability patterns of material composition (especially rich ores), the geological service of the Taimyrskiy mine carried out a considerable amount of study work on the existing documentation and testing the wells and mines, apart from this, they started the technological testing and development of geological and technological ore classification.

The underground geological exploration works were mainly focused on the area of primary mining on the horizon -1050 m. At the same time, there has been a significant lag in the study of the mineral composition of layered ores. In addition, along with the development of mining preparation works, the technological testing production was required of the newly prepared areas (Large horst, horizon -1300 m), as well as the study of the concentration indicators variability within the entire ore deposit.

The main purpose of such works was to carry out geological and technological mapping in the massive sulfide ores in the eastern part of the Kharayelakh deposit processed by the Taimyrskiy mine, and thus to create the necessary information basis for the subsequent allocation of blocks of the underground mine metal leaching.

The most important nickel minerals of the developed ores include the most common and industrial minerals: sulfides (pentlandite (Fe, Ni)S (or $(Ni, Fe)_9S_8$; contains 22–42% Ni), millerite NiS (64.5% Ni), nickeline (kupfernickel, red nickel pyrite) NiAs (up to 44% Ni), nickel pyrrhotite, polidimit, cobalt-nickel pyrite, violarite, bravoite, vaesite NiS_2, chloantit, rammels-bergite $NiAs_2$, gersdorffite (gersfordit, nickel shine NiAsS), ulmanite), water silicates (garnierite, annabergite, chovahsit, revdinscite, shuhardite, nickel nontronites), and nickel chlorites.

Norilsk combine mines and processes the 3 main technological types of sulfide copper-nickel (containing PGMs) ores:

1) solid (rich);
2) disseminated in intrusive rocks;
3) vein-disseminated in host rocks ("cuprous").

Still the base of the industrial production at NMMC are rich ores, among which the chalcopyrites stand out significantly, the so-called highly cuprous and pyrrhotite containing differences: although in the structure of the mineral reserves of Norilsk deposits the major amount (up to 70%) of metal is in the disseminated ores, the share of which steadily increases along with the intensive excavation of rich ores.

Currently, the industrial alliance of ore-dressing factories of the NMMC Polar division began a large-scale reconstruction of the Talnakh ore-dressing factory, which is aimed at increasing the volume of ore-dressing and improving the qualitative and quantitative indicators of copper-nickel ore processing up to global standards with maximum non-ferrous metals extraction (**V proizvodstvennom obedinenii obogatitelnykh fabrik Zapolyarnogo filiala nachalas masshtabnaya rekonstruktsiya Talnakhskoy obogatitelnoy fabriki, 2014**).

The factories' renovation project was developed by CJSC Mekhanobr Engineering (Saint Petersburg) and consists of 3 launch complexes (including the installation of modern technological equipment, the expansion of the main factory housing, construction of new facilities and tailing). After their launch, the factory capacity will increase to 10 mln tons of copper-nickel ore processed per year.

As a part of the 2nd launching complex implementation, it is planned to expand the main Taknakh ore-dressing factory (TOF) building, reconstruct the reagent preparation building, and build a number of new facilities – the building of rich and copper ores overloading, local cleaning facilities, the main step-down substation, and a compressor station.

Along with this, the first phase of the strategically important construction of TOF tailing is performed 5 km away from the factory (on the site of an old quarry and decommissioned TOF sump).

Also, as the tailing dam construction will progress, the installation of communication lines and piping is scheduled, which will pump the pulp from the factory to the facility, whereas the defecated water will go back to TOF technological process from the tailing sump designed for water recycling.

Although this reconstruction project provides for the maximum use of existing (already operating) TOF equipment, the newly installed factory equipment is the most advanced in the world. It includes the flotation complex by the Outotec Company (which includes flotation machines of different sizes and types), as well as the equipment for the separation of condensation and electrification, and also an automated control system. Metso Minerals Company will supply TOF with semi-auto-grinding and regrinding mills Vertimill. There has not been such equipment at NMMC yet, and it fundamentally differs from what is currently operating at the industrial sites of Norilsk and Talnakh ore-dressing factories.

After the 3rd launching complex will be launched, the volume of processed ores will increase up to 16 mln tons per year. TOF will be able to process not only the rich ores of Oktyabrskiy, Taimyrskiy, Komsomolskiy mines and cuprous ores of Oktyabrskiy mine, but also cuprous and disseminated ores of the whole Talnakh deposit.

The existing tailing pond Lebyazhye is located on the lake-alluvial plain between the rivers Schuchya and Kupets (see **Figure 2**) and is intended for receiving and storing the tailings and organizing the water recycling reservoir (**Butyugin and Gulan, 2005**). It consists of a protecting alluvial dam, pond for defecated water, pipeline system for pulp transportation, sluicing the facility and and providing water recycling.

Figure 2: Lebyazhye tailing pond

Figure 3: Tailing pond №1

The height of the protecting dam of this tailing pond is ~16 m, storage area is 4.3 km^2, whereas the volume of landfilled waste is currently more than 80 mln m^3 (while the designed capacity is ~170 mln m^3), water volume in the sump is ~5 mln m^3.

Tailing pond №1 (see **Figure 3**) is located at the base of the Schmidt mountain, it is currently not used for waste disposal, but as a backup water recycling reservoir (**Vorob'ev and Gulan, 2005**). The height of this facility is about 50 m, and the volume of landfilled waste is 160 mln m^3.

Nadezhdinskiy metallurgical plant (NMP) tailing pond is located in the valley of the Burovaya River and serves as a storage of highly toxic waste of the hydrometallurgical industry. This facility includes a riverbed dam 38 m high, with an impervious screen from polyethylene and a cementation pall at the basement. This tailing pond contains for the moment ~21 mln m^3 of tails and 9 mln m^3 of water.

The company also plans to start mining coal, iron ore, molybdenum, chromium, and other metals. Therefore, another aspect of increasing the NMMC production efficiency is the application of methods that purposefully change (without any additional investments in processing) the original quality (by improving physical, mechanical and other characteristics) of the landfilled waste from mines (coal slagheaps).

The Kayerkanskiy deposit of thermal coal (its reserves and resources amount to 687 mln tons by the category A+B+C1+C2), located 18 km to the west of Norilsk city, was explored in 1940. Its operation started in 1943. Originally, Kayerkanskiy coal was mined by underground methods (mines), whereas in 1962 the coal mine exploiting started (see **Figure 4**).

The Kayerkanskiy mine employs 324 people. The mine develops 2 quarries – Kayerkanskiy coal mine №2,

Figure 4: NMMC Kayerkanskiy coal mine

which mines flux sandstone and coal by open cast method and quarry for technological limestone and dolomite processing, and an underground mine Izvestnyakov, which mines cement limestone by the underground method. The mine annually produces and sends 600–720 thousand tons of sandstone, 150–170 thousand tons of coal, and 750 thousand tons of limestone.

Today, due to the transition of the Norilsk combine to gas fuel, coal in Kayerkan is produced only in very small amounts required for certain technological processes.

LLC Northern star, affiliated with NMMC, in 2015 plans to begin mining the coking coal at Syradasayskiy deposit (its resources exceed 5 billion tons of coal) in the area of Dixon port (Taimyr). First, it will produce 8 mln tons of coal annually, but in the long term, the volume will increase up to 15 mln tons (for comparison, the mine of the Russian State trust Arcticcoal in Svalbard provides about 100 000 tons of coal per year).

Besides that, NMMC is interested in the Imangdinskiy coal deposit (where the reserves and resources of coking and thermal coal amount to 416 mln tons by categories A+B+C1+C2) and the Norilsk-1 deposit (159 mln tons), located 80 km to the south-east of Norilsk and in the Norilsk region, respectively.

NMMC also considers promising the Daldykanskiy (738 mln tons by category B+C1+C2, located 20 km to the south-west of Norilsk city) and Listvyano-Valkovskiy (295 mln tons by category C1+C2+P1, located 10 km to the east of Talnakh city) coal deposits.

When developing such a significant amount of coal, numerous mineral wastes of the mining industry inevitably form, usually stored in slagheaps and poorly used.

Product diversification planned by the Strategy (by kinds and types of mineral raw materials) must find its confirmation not only in the development of solid (ores, coal) minerals, but also liquid (oil) and gaseous (traditional combustible gas, gas hydrates) resources.

Also, it should be noted that gas hydrate deposits are quite widespread on sea and ocean shelves (including the Russian Arctic shelf) (**Vorob'ev and Bolatova, 2011; Vorob'ev et al., 2011**). Kara Sea has all the basic conditions (temperature, depth, etc.) for natural formation of extensive aquatic gas hydrate deposits at its bottom part. And taking into consideration the fact that the formation of aquatic gas hydrate deposits is facilitated by low temperatures of the environment, the map of shelf permafrost spread becomes important, which highlights its external border in the Kara Sea (see **Figure 5**).

Apart from this, the basic laws of depth distribution of sub-aquatic permafrost were revealed, which is also important for search and exploration of aquatic gas hydrate deposits.

In addition, in the area of the Kara Sea shelf, it is only NMMC that has the necessary infrastructure, highly qualified personnel, scientific and industrial potential, that allows to quickly develop and implement the technologies of methane production from aquatic gas hydrate deposits.

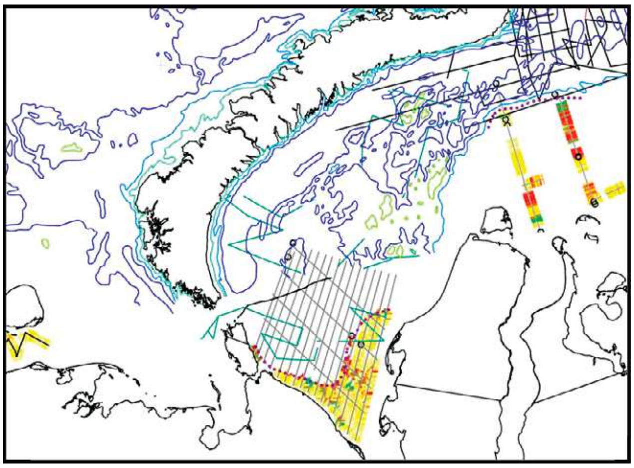

Figure 5: External border of the shelf permafrost spread in the western and central part of the Kara Sea. The color indicates the depths of sub-aquatic permafrost (from the bottom surface) (**Melnikov, 2011**).

Figure 6: Unfit building at Bogdan-Khmelnitzkiy Street

Today, the reconstruction of housing seems quite significant (see **Figure 6**) in the Norilsk municipality. The Norilsk combine (as the city-forming enterprise) in one way or another is involved in metropolitan area maintenance.

In 2005, the program of resettlement from dilapidated and emergency housing in Norilsk needed an annual investment of 250 mln rub., whereas only 19 million was invested.

In addition, the financial state of RJSC Norilsk Nickel is substantially affected by the costs connected with the maintenance of people not involved in major enterprises with the technological process. Thus, the population of the Norilsk industrial region is 262 thousand people. Moreover, there are 36 thousand pensioners, half of which is not working, but is unable to leave Norilsk (due to lack of housing on the "mainland"). And many of them need a new specialty to search for a job on the "mainland" or even in Norilsk itself.

Table 3: Number of employed and labor productivity in 2003

Company	Employees	Revenue / employee 1,000 $US
Norilsk Nickel (Russia)	96,520	53
Falconbridge (Canada)	6400	325 (238)
Inco (Canada)	10,478	236 (205)

In Norilsk, there are several companies that train working specialties (slinger, electrician, etc.), service sector (Housing and utilities facility (HUF)) worker, hairdresser, manicurist, etc.), we should specially highlight the training for a fundamentally new specialty – Management of apartment buildings, but this is evidently not enough.

Correct employment policy will improve the economic effect obtained in the economic system of the Norilsk region due to a fall in unemployment. Recently, there has been a higher economic effect of investment in personnel development than by investment in means of production. Calculations show that $1 invested in personnel development brings $3 to $8 revenue.

The most important indicator of industrial efficiency is labor productivity (see **Table 3**). According to OJSC MMC Norilsk Nickel, in 2009 nickel production amounted to 283 thousand tons, copper – to 402 thousand tons, palladium – to 2 805 thousand ounces (86.955 thousand tons) and platinum – to 661 thousand ounces (20.491 thousand tons).

The enterprises of RJSC Norilsk Nickel employ 150 thousand people, and about 40 thousand people are directly involved in the technological process (as of the first quarter of 2005, OJSC MMC Norilsk Nickel employed 56,384 people). The average number of employees in MMC divisions in 2004 was 59,978, and 70,116 people in 2000.

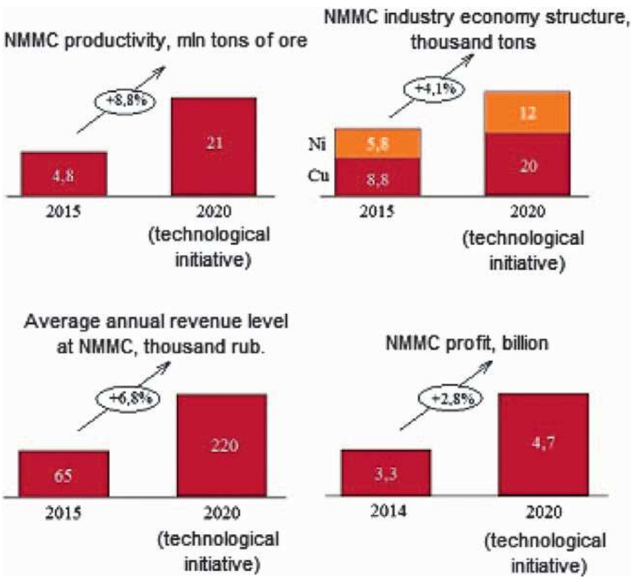

Figure 7: Estimated growth of NMMC economic indicators

Therefore, a scientifically based optimization of NMMC industrial and organizational structure is necessary, as well as organization of integrated security activities of its divisions.

3. Conclusions

Successful implementation of the Complex program of the technological initiative in the sphere of mineral resource usage (see **Figure 7**) will result in the increase of NMMC major economic indicators (along with the growth of labor productivity and workers' income).

4. References

Published papers

Butyugin, V.V. and Gulan, E.A. (2005): Geodinamicheskaya i geoekologicheskaya bezopasnost khvostokhranilishch v Norilskom promyshlennom rayone (*Geo-dynamic and geo-ecological safety of tailing ponds in the Norilsk industrial region*). Gornyy informatsionno-analiticheskiy byulleten (nauchno-tekhnicheskiy zhurnal), 1, 122–126. (*in Russian*)

Melnikov, V.P. (2010): Otchet o nauchno–organizatsionnoy deyatelnosti za 2010 g. po programme fundamentalnykh issledovaniy ONZ RAN No` 17 "Fundamentalnye problemy okeanologii: fizika, geologiya, biologiya, ekologiya"; podprogramma "Kompleksnye issledovaniya Arkticheskogo shelfa" [*Report on the scientific and organizational activities in 2010 of the program of fundamental research DES RAS № 17 "Fundamental problems of oceanology: physics, geology, biology, ecology"; subprogram "Complex research of the Arctic shelf"*]. Tyumen. http://www.ikz.ru/wp-content/uploads/2011/09/otchet2010.pdf. (*in Russian*)

Pilipenko, A.V. (2011): Razvitie vysokikh tekhnologiy: puti stanovleniya uspeshnykh kompaniy [*High technologies development: ways of successful companies formation*]. Sputnik+ Press, Moscow, 207 p. (*in Russian*)

Vesa, R., Riitta, K. and Andreev, O. (2007): GMK "Norilskiy nikel": uspeshnyy primer adaptatsii kompanii k mirovym rynkam [*MMC Norilsk Nickel: a successful example of company adaptation to global markets*]. Sever promyshlennyy, 3. http://helion-ltd.ru/norilsky-nickel-example. (*in Russian*)

Vorob'ev, A.E. (2015): Puti povysheniya effektivnosti finansirovaniya NIR vuzov [*Ways to increase the efficiency of high school research works investments*]. Alma-mater: Vestnik vysshey shkoly, 2, 19–26. (*in Russian*)

Vorob'ev, A.E., Balyhin, G.A., Khloponin, A.G. and Karginov, K.G. (2003): Rynki mineralnogo syrya: protsessy globalizatsii i problemy regionov [*Mineral resources markets: globalization processes and problems of regions*]. People's Friendship University of Russia Publishing, Moscow, 294 p. (*in Russian*)

Vorob'ev, A.E. and Bolatova, A.B. (2011): Akvalnye zalezhi gazogidratov: geologiya i osvoenie [Aquatic gas hydrate deposits: geology and development]. EKSTU, Ust-Kamenogorsk (Kazakhstan), 64 p. (*in Russian*)

Vorob'ev, A.E. and Gulan, E.A. (2005): Tipizatsiya vozdeystviy nakopiteley otkhodov rudoobogashcheniya na komponenty prirodnoy sredy [*Classification of effects of ore-dressing waste accumulators on the constituents of the natural environment*]. Narodnoe khozyaystvo Respubliki Komi: nauch.-tekhn. zhurn. 14, 3.2, 582–585. (*in Russian*)

Vorob'ev, A.E., Kamchybekov, D.K. and Drebenshtedt, K. (2010): Ugolnaya promyshlennost Kyrgyzstana: perspektivy restrukturizatsii i razvitiya [*Kyrgyzstan coal industry: restructuring and development prospects*]. RF President's Office, Moscow, 287 p. (*in Russian*)

Vorob'ev, A.E., Moldabaeva, G.Zh. and Chekushina, E.V. (2011): Nauchnyy analiz mirovykh zapasov akvalnykh zalezhey gazogidratov [*Scientific analysis of world reserves of the aquatic gas hydrate deposits*]. Vestnik KazNTU 6, 88, 65–70. (*in Russian*)

Vorob'ev, A.E., Tulegenova, O.Sh. and Kaukenova, A.S. (2013a): Nauchnaya sostavlyayushchaya industrialno-innovatsionnogo razvitiya gosudarstva [*Scientific component of the industrial-innovative state development*]. AIOG, Atyrau (Kazakhstan), 210 p. (*in Russian*)

Vorob'ev, A.E., Vercheba, A.A. and Kaukenova A.S. (2013b): Metodologiya proektirovaniya innovatsionnykh nauchnykh issledovaniy i formirovaniya tekhnologicheskikh platform [*Design methodology of innovative scientific research and formation of technological platforms*]. MGEI-RSGEU, Moscow, 119 p. (*in Russian*)

Internet sources

Anglo American Plc., vtoraya po velichine gornodobyvayushchaya kompaniya, Minus 19 000 rabotnikov [*Anglo American Plc., the second largest mining company, Minus 19 000 employees*]. Infocrisis.ru special project. (*in Russian*) URL: http://www.infocrisis.ru/sokratili/722.html (accessed 14th June 2016)

Gornodobyvayushchiy sektor Avstralii v krizise [*Mining sector of Australia is in crisis*]. Gold.ru, 28 June 2013. (*in Russian*) URL: http://gold.ru/news/gornodobyvajushhij-sektor-avstralii-v-krizise.html (accessed 14th June 2016)

Kondratyev, V.B. (2012): Globalnaya gornodobyvayushchaya promyshlennost [*Global mining industry*]. 16 October 2012. (*in Russian*) URL: http://forum.polismi.org/index.php?/topic/3454-%D0%B3%D0%BB%D0%BE%D0%B1%D0%B0%D0%BB%D1%8C%D0%BD%D0%B0%D1%8F-%D0%B3%D0%BE%D1%80%D0% BD%D0%BE%D0%B4%D0%BE%D0%B1%D1%8B%D0%B2%D0%B0%D1%8E%D1%89%D0%B0%D1%8F-%D0%BF%D1%80%D0%BE%D0%BC%D1%8B%D1%88%D0%BB%D0% B5%D0%BD%D0%BD%D0%BE%D1%81%D1%82%D1%8C (accessed 14th June 2016)

Mirovye gornodobyvayushchie kompanii perezhivayut krizis [*Global mining companies go through a crisis*]. Vesti Finance, 27 June 2014. (*in Russian*) URL: http://www.vesti-finance.ru/articles/44382 (accessed 14th June 2016)

Strategiya razvitiya proizvodstva OAO "GMK "Norilskiy nikel" na Taymyrskom i Kolskom poluostrovakh do 2015 [*Norilsk Nickel: industry development strategy on the the Taymyr and Kola peninsulas*]. 24 April 2003. (*in Russian*) URL: http://infogeo.ru/metalls/news/?act=show&news=335 (accessed 14th June 2016)

V proizvodstvennom obedinenii obogatitelnykh fabrik Zapolyarnogo filiala nachalas masshtabnaya rekonstruktsiya Talnakhskoy obogatitelnoy fabriki [*Industrial alliance of the JSC GMK Norilsk Nickel Polar Division has started a large-scale reconstruction of the Talnakh ore-dressing factory*]. Mediaservice Sdelka, 4 April 2014. (*in Russian*) URL: http://mssdelka.ru/news/v_proizvodstvennom_obedinenii_obogatitelnykh_fabrik_zapoljarnogo_filiala_nachalas_masshtabnaja_rekonstrukcija_talnakhskoj_obogatitelnoj_fabriki/2014-04-04-3258 (accessed 14th June 2016)

SAŽETAK

Ruska nacionalna tehnologijska inicijativa u području uporabe mineralnih resursa

Poboljšanje operativne učinkovitosti ruske tvrtke MMC Norilsk postići će se većom uključenošću u proizvodnju kako geogenskih, tj. prirodno nastalih, izvanbilančnih rezervi, tako i nakupljenih mineralnih sirovina tehnološkoga podrijetla, uglavnom na različitim odlagalištima. Predložen je složen program tehnološke inicijative u domeni uporabe mineralnih resursa te donošenje prikladnih mjera za razvoj rudnika i metalurgije općenito.

Ključne riječi
upravljanje potpovršinskim resursima, materijalna (mineralna) sirovinska baza, postupak obogaćivanja, rudarsko pridobivanje