Use of Mineral Waste of Industrial Enterprises in the Arctic Zone of the Russian Federation

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Abstract. The work considers the problems of the mining industry in the sphere of mining and processing waste formation and use by industrial enterprises in the Arctic Zone of the Russian Federation. The methodological basis of the work are the annual reports of enterprises, official documents and scientific publications. In result it was determined that the dynamics and efficiency of waste use by companies differ both in quantitative indicators and in the constancy of growth dynamics and the current situation is characterized by low market motivation and lack of incentives. Proposals to increase the involvement of industrial waste in economic circulation and processing was developed. It was established that it is necessary to involve industrial waste in use because of its potentially valuable consumer properties, to develop and implement low-waste technologies in cooperation with scientific organizations, and to increase the transfer of waste to other organizations as resources for the production of products.

1. Introduction

One of the problems of the mining industry in the Arctic Zone of the Russian Federation (Arctic) is the formation of a significant volume of mining and processing waste whose main part is associated with the extraction of minerals negatively affecting the environment and human health. Of the entire mass of waste only a certain part is processed and the rest is stored in dumps and tailings. [1, 2, 3]. At the same time, many waste storage facilities do not meet modern environmental requirements.

Mining companies perform only certain management functions (organization of placement, storage, etc.) in accordance with field development projects [4, 5, 6]. Currently there is a discussion of the issue related to the adjustment of the Law "On Subsoil" in terms of the use of waste from mining industries as a type of subsoil use, limiting the possibilities of companies to dispose of waste [6, 7].

One of the most important tasks of mineral waste management is their use when exploiting and processing mineral resources by industrial enterprises. A number of government documents are devoted to solving this problem, such as Decree of the President of the Russian Federation «On national goals and strategic objectives of development of the Russian Federation for the period up to 2024», Fundamentals of state policy in the sphere of environmental development of the Russian Federation for the period up to 2030, Strategy of environmental safety of the Russian Federation for the Period up to 2025 in which among the main tasks in the sphere of ecology are indicated as: ensuring effective waste management; creation of conditions and modern infrastructure for the recycling of waste prohibited for disposal; efficient use of natural resources; increasing the level of utilization of production and
consumption waste; use of environmental regulation systems by all objects that have a significant negative impact on the environment; ensuring the introduction of environmentally efficient innovation technologies; scientific and informational-analytical support of environmental protection and ecological safety [8, 9, 10]. The use of mineral waste from industrial enterprises in the Arctic is also of particular importance. Decree of the President of the Russian Federation «On the foundations of the state policy of the Russian Federation in the Arctic for the period up to 2035» is devoted to this issue [11].

2. Materials and methods
The aim of the work is to study the level of formation and the efficiency of mineral waste use from Arctic industrial enterprises in recent years and to develop proposals for the activation of scientifically based technologies for their use. The study was conducted on the example of large industrial companies that directly operate in the Arctic and provided data (reports) in the public access. The following companies were selected: PJSC NOVATEK, division Severstal Resources of PJSC Severstal, PJSC “MMC“ Norilsk Nickel “, in addition, the reported waste volume data from Kirovsk branch of JSC Apatit of PJSC PhosAgro and PJSC ALROSA were used.

PJSC NOVATEK is engaged in the production of natural gas, gas condensate and oil. Some of the main gas producing companies are LLC NOVATEK-YURKHAROVNEFTEGAZ and JSC ARCTICGAZ. Table 1 presents data on the use of mineral waste by PJSC NOVATEK.

Table 1. PJSC NOVATEK [12].

| Year | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|------|------|------|------|------|------|------|------|------|------|
| Waste generated, million tons | 0.02 | 0.03 | 0.02 | 0.04 | 0.04 | 0.05 | 0.05 | 0.07 | 0.08 |
| Waste used, % | - | - | - | 71 | 27 | 13 | 20 | 18 | 12 |
| Waste stored at own facilities, % | - | - | - | 21 | 67 | 60 | 40 | 18 | 19 |
| Waste transferred to specialized enterprises, % | - | - | - | 7 | 5 | 20 | 38 | 60 | 51 |
| Waste neutralized, % | - | - | - | 1 | 1 | 7 | 2 | 4 | 18 |

The growth of waste is mainly due to an increase of production wells drilling and the formation of cuttings, an increase of drilling waste at Yamal LNG as well as the construction and commissioning of new facilities.

Most of the waste (over 95%) is drill cuttings which are classified as non-hazardous or low-hazard waste. At the Yurkharovskoye oil and gas condensate field operates a drill cuttings treatment and disposal workshop that uses technology that allows water and drilling fluid to be separated for reuse and the cuttings are buried at a specialized landfill. Drilling cuttings and waste drilling mud are sent to landfills or to sludge pits. Part of the drill cuttings is processed into building material gravilat and burolite blend and used to strengthen the slopes of roads, bushes and for the reclamation of artificial cavities. Part of the waste including water separated from oil during its preparation and condensate containing oil products are used for needs of the company and pumped into the reservoir pressure maintenance system.

It can be noted a significant decrease of the waste use by the company in its own production, storage at facilities of the company remained at the same level, transfer to third-party organizations and neutralization increased many times over.

Division Severstal Resources of PJSC Severstal includes JSC Olcon, JSC Karelsky Okatysh, JSC Vorkutaugol, JSC Yakovlevsky GOK which produce iron ore pellets, iron ore concentrate, coal
concentrate, coal, strontium ferrite powders, crushed stone. Table 2 presents data on the use of mineral waste by division Severstal Resources of PJSC Severstal.

Table 2. Division Severstal Resources of PJSC Severstal [13].

|                | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Waste generated, million tons | 184   | 213   | 220   | 185   | 178   | 185   | 190   | 193   | 203   |
| Waste utilized, million tons | -     | 29    | 25    | 3     | 46    | 17    | 12    | 23    | 14    |
| Waste neutralized, tons | -     | 64    | 0.4   | 0.5   | 0.5   | 0.76  | 0     | 1     | 186   |
| Waste stored at own facilities, million tons | -     | 184   | 194   | 181   | 113   | 187   | 178   | 170   | 189   |

JSC Yakovlevsky GOK. The amount of waste generated increased due to production growth, mining operations, an increase in overburden formation at JSC Karelsky Okatysh, JSC Olcon and JSC Vorkutaugol, the expansion and acquisition of a new resource enterprise JSC Yakovlevsky GOK.

Overburden and tailings are classified as non-hazardous waste and make up 99% of the mass of all waste. They are partially used at enterprises of the company for the production of crushed stone, the organization of on-site driveways, road filling, embankment of dams, the laying of artificially created quarry cavities, the construction of internal infrastructure facilities (sites, warehouses, transfer points) and the strengthening of the tailing dump beaches.

JSC Karelsky Okatysh implemented a project to build a pyrolysis waste processing unit to reduce the volume of the company's waste and a waste dewatering complex to reduce the tailings storage area. A crushed stone mini-plant was launched and the old one was reactivated to use waste rock as raw material to fill up open pit roads. At JSC Vorkutaugol as a result of the launch of the coal flotation waste filtration system the remaining waste takes up less storage space and is easier to transport in solid form. Mineral sludge is partially processed at the Pechorskaya central processing plant. In general, in the division it can be noted an increase in waste neutralization and storage and a decrease in utilization.

PJSC “MMC” Norilsk Nickel ” produces technical sulfur, technical selenium, cathode copper, precious metal concentrates, nickel matte, primary nickel, nickel carbonyl shot, nickel carbonyl powder, nickel concentrate, cobalt concentrate, electrolyte cobalt, technical sulfuric acid, sodium sulfate, sodium chloride, nickel matte, copper matte. Table 3 presents data on the use of mineral waste by PJSC “MMC“ Norilsk Nickel ”.

Table 3. PJSC “MMC“ Norilsk Nickel ” [14].

|                | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Waste generated, million tons | 40.9  | 43.5  | 40.5  | 35.2  | 33.6  | 33.2  | 31.9  | 30.7  | 23.5  |
| Waste utilized, million tons | -     | 20.89 | 19.35 | 18.24 | 18.81 | 20.15 | 20.76 | 21.63 | 22.76 |

Reduction of waste generation was due to the decrease of production waste from Polar Division and JSC Kola MMC, the cessation of open pit mining at the Yuzhny open pit of JSC Kola MMC and the separation of the Medvezhy Ruchey company from the structure of the Zapolyarny mine branch.
More than 90% of production waste generated at the company's enterprises is non-hazardous waste, including rock and overburden, tailings, metallurgical slags, etc. Overburden is used after crushing into crushed stone for backfilling quarries, rocks are used to fill the mined-out space of mines, the tailings of concentration plants are used for the construction of tailings dams and in the preparation of filling blends. Metallurgical slags are used for the construction and strengthening of tailings dams, as a filling material for the elimination of tailings, as a flux for smelting of metal in smelting furnaces, for laying the mined-out space of mines, sprinkling of roads, embankments of railway tracks.

The company implements projects for the construction of new and reconstruction of existing tailing dumps, expanding the directions and volumes of use of the main types of large-tonnage industrial waste: overburden and rock, tailings and dump metallurgical slags. As part of improving the activities for the arrangement of waste disposal facilities a project to reconstruct the Nadezhda Metallurgical Plant tailing dump with an increase in useful capacity was carried out. As part of the reconstruction and technical re-equipment of Talnakh Concentrator the construction of a new tailing dump was carried out. In general, the volume of waste utilization in the company increased.

Kirovsk branch of JSC Apatit of PJSC PhosAgro produces apatite and nepheline concentrates. Table 4 presents data on the generation of mineral waste by kirovsk branch of JSC Apatit of PJSC PhosAgro.

| Waste generated, million tons | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|------------------------------|------|------|------|------|------|------|------|------|------|
|                              | 109  | 109. | 93.9 | 70.1 | 77.9 | 84.5 | 79.9 | 88.4 | 101  |

Main part of the waste (up to 70%) is potentially non-hazardous rock and overburden. A number of Kirovsk branch of JSC Apatit of PJSC PhosAgro waste (car tires, waste sleepers, timber, etc.) are utilized of and neutralized at a thermal destruction unit and a thermal waste neutralization complex with high-temperature afterburning of exhaust gases.

The decrease in waste volumes at the Kirovsk branch of JSC Apatit of PJSC PhosAgro is mainly due to the increase of underground ore mining and a decrease of rocks and overburden formation.

PJSC ALROSA specialized at diamond mining and processing. It is located in the Republic of Sakha (Yakutia) being the leader of the extraction of diamonds, gold, antimony in the Russian Federation. Also in the Arkhangelsk region JSC Severalmaz is developing the Lomonosov diamond mine. Table 5 presents data on the generation of mineral waste by PJSC ALROSA.

| Waste generated, million tons | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|------------------------------|------|------|------|------|------|------|------|------|------|
|                              | 84.5 | 90.6 | 82.8 | 90.7 | 82.6 | 65.2 | 67.7 | 66.9 | 81.8 |

The decrease of the waste volume was due to a decrease of mining operations, the use of technologies for the construction of open-pit mines with ultra-high side ledges, block collapse of the rock mass in the underground method of ore mining and a decrease of the volume of overburden waste rock.

99.98% of the company's production waste is practically non-hazardous for the environment. Overburden and tailings, partially used in own production for the construction and repair of roads, sites and dams, for laying the mined-out area of open pits, preparing soil for technical reclamation of used blocks, etc. Part of the waste is stored on the territory of production sites in specially designated places, another part is transferred to specialized enterprises.
3. Results and discussion

Studies showed that taking into account the specifics of the natural conditions of the Arctic ecosystems for the period from 2011 to 2019 the enterprises of PJSC NOVATEK and division Severstal Resources of PJSC Severstal increased the volume of waste generation and neutralization, reducing the volume of use and utilization. PJSC NOVATEK also reduced waste storage at own facilities, increasing the share of transfer to other organizations. Division Severstal Resources of PJSC Severstal increased the share of waste storage. PJSC “MMC” Norilsk Nickel”, Kirovsk branch of JSC Apatit of PJSC PhosAgro and PJSC ALROSA show a reduction in waste generation. PJSC “MMC” Norilsk Nickel ”also shows an increase in waste utilization. The main reasons for the growth in waste generation are the increase in production volumes and the commissioning of new facilities. However, the dynamics and efficiency of waste management differ in both quantitative indicators and the constancy of growth. Thus, PJSC “MMC“ Norilsk Nickel ”can be noted as the most efficient company in the sphere of mineral waste management and PJSC NOVATEK and Division Severstal Resources of PJSC Severstal as the least efficient.

The current situation is characterized by low market motivation, lack of incentives for companies to use mining waste and a coherent state policy in the sphere of mineral waste use. For industrial companies it is more profitable to pay for the negative impact on the environment than to introduce environmentally friendly technologies and recycle waste. This leads to the fact that companies do not conduct research, do not implement and develop projects to improve the efficiency of waste use. At present mining waste management comes down to compliance with the technological regulations of mining projects and ensuring the main production processes. But the peculiarities of the operation regions of some resource enterprises (the absence of large consumers of the building industry) make it possible to process and transfer waste for use in a very limited amounts. The decline in the quality of the mineral resource base with the continuing trend towards the extensive use of subsoil resources allows to conclude that the mass of waste will grow in the future.

Despite a number of reasons that lead to the accumulation of mineral industrial waste with a high degree of environmental load on the environment including during their storage the solution of the problem of waste reduction is the maximum possible processing of raw materials and identifying the possibilities of involvement of waste into economic circulation. The need to involve waste in industrial use is also due to the potentially valuable consumer properties of the minerals and components contained in that were not extracted during primary mining and processing and their use as sources of secondary raw materials and energy. It can be noted that recently industrial companies performed an insufficient work to increase the waste transfer to other organizations for the production.

4. Conclusion

The resource potential of the generated waste, a decrease in the volume of their storage at the enterprise and a partial economy of the raw materials used are fully realized with the introduction of low-waste technologies, organizational schemes and mechanisms as well as in the process of their transfer to other organizations for neutralization and further processing. To increase the degree of use of mineral waste there is a need of independent projects the development and implementation of which together with scientific organizations requires certain efforts and the interest of companies. It is necessary to improve the state environmental policy in the Arctic in the sphere of waste management, to increase the availability of subsidies or other financial incentives aimed at implementing the developed environmental innovations, environmental control system and the development of the regulatory framework.

5. References

[1] Nevkaya M A, Marinina O A 2016 Substantiation of the project approach to the management of mining waste in the mineral resource sector Online Journal Naukovedenie 3 355-366
[2] Tsukerman V A, Ivanov S V 2020 IOP Conf. Series: Earth and Environmental Science 042066
[3] Tsukerman V A, Goryachevskaya E S, Ivanov S V 2019 *International Science Conference on Business Technologies for Sustainable Urban Development* 02058.

[4] Alexandrova T N, Grekhnev N I, Lipina L N 2015 Some approaches to improving the regulation of the waste management of mining enterprises *Mining informational and analytical bulletin (scientific and technical journal)* 8 328-333

[5] Tsukerman V A, Ivanov S V 2020 Environmental policy of resource corporations at industrial exploitation of mineral deposits in the Arctic zone of the Russian Federation *Mining informational and analytical bulletin (scientific and technical journal)* 10 56–66

[6] Shishkov A Yu 2020 New prospects for the use of mining waste in the Karelo-Kola region *Transactions of the Karelian Research Centre of the Russian Academy of Sciences* 2 90-97

[7] Law of the Russian Federation "On Subsoil" on February 21, 1992 No 2395-1 [Electronic resource] URL: http://www.consultant.ru/document/cons_doc_LAW_343/ (last accessed: 22.07.2021).

[8] Decree of the President of the Russian Federation of May 7, 2018 No 204 "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024" [Electronic resource] URL: http://www.kremlin.ru/acts/bank/43027 (last accessed: 22.07.2021)

[9] Fundamentals of state policy in the sphere of environmental development of the Russian Federation for the period up to 2030: approved by the President of the Russian Federation on April 30, 2012 [Electronic resource] URL: http://kremlin.ru/events/president/news/15177 (last accessed: 22.07.2021)

[10] The strategy of environmental safety of the Russian Federation for the period up to 2025 (approved by the Decree of the President of the Russian Federation of April 19, 2017 No 176) [Electronic resource] URL: http://www.kremlin.ru/acts/bank/41879 (last accessed: 22.07.2021)

[11] Decree of the President of the Russian Federation of March 5, 2020 No. 164 "On the foundations of the state policy of the Russian Federation in the Arctic for the period up to 2035" [Electronic resource] URL: http://static.kremlin.ru/media/events/files/ru/f8ZpjhpAaQ0WB1zjywN04OgKii1mAvAM.pdf (last accessed: 22.07.2021)

[12] Sustainability reports of PJSC NOVATEK [Electronic resource] URL: http://www.novatek.ru/ru/development/ (last accessed: 22.07.2021)

[13] Corporate social responsibility and sustainable development reports of PJSC Severstal [Electronic resource] URL: https://www.severstal.com/ru/sustainable-development/documents/reports (last accessed: 22.07.2021)

[14] Sustainable development reports of PJSC “MMC “Norilsk Nickel” [Electronic resource] URL: https://www.monnickel.ru/sustainability/reporting/ (last accessed: 22.07.2021)

[15] Annual reports of PJSC “PhosAgro” [Electronic resource] URL: https://www.phosagro.ru/investors/reports_and_results/ (last accessed: 22.07.2021)

[16] Social and environmental reports of PJSC ALROSA [Electronic resource] URL: http://www.alrosa.ru/documents/социальные-отчёты/ (last accessed: 22.07.2021)