Management of the Industrial Waste When Exploiting Mineral Resources of the Arctic

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Abstract. The question of increasing the efficiency of industrial waste management of the Arctic is of a big importance due to the disturbance of the environment under the influence of intensive exploitation of mineral resources. The analysis of the effectiveness of the solid waste management over the past five years on the Arctic industrial enterprises such as: PJSC Novatek, PJSC ALROSA, Polar Division and Kola MMC of PJSC MMC Norilsk Nickel, Kirovsk branch of Apatit of PJSC PhosAgro, industrial enterprises JSC Karelsky Okatysh, JSC Olcon, JSC Vorkutaugol and JSC Yakovlevsky mine of Division Severstal Resources of PJSC Severstal. Based on data obtained from company reports in open access the dynamics of waste generation and utilization was investigated. It was shown that despite the fact that in recent years the Government of the Russian Federation approved a number of documents related to waste management and aimed at the formation and future development of a new industry for waste management a significant part of enterprises does not pay enough attention and does not take proper measures in the field of industrial waste management.

1. Introduction

Because of the disturbance of the environment under the influence of intensive exploitation of the Arctic mineral resources there is an acute question of increasing the efficiency of industrial waste management. Industrial waste is a renewable resource that usually does not require additional costs for extraction and processing. Improving the rational utilization of industrial waste for commercial products provides significant economic and environmental effects [1]. Reducing industrial waste and its appropriate use is of particular relevance due to the high vulnerability and low ability to recovery of the unique Arctic ecosystems [2].

To increase the efficiency of waste management and utilization the President and the Government of the Russian Federation have adopted a number of decrees and legislative acts including Decree of the President of the Russian Federation No. 204 “On the national goals and strategic tasks of the development of the Russian Federation for the period until 2024”, Federal Laws No. 89 “On the production and consumption waste” and No. 99 “On the licensing certain types of activities”, decrees of the Government of the Russian Federation No. 712 “On the procedure for certification of waste of I-IV hazard classes” and No. 903 “On approval of criteria for defining objects for the federal state environmental supervision ”, orders of the Ministry of natural resources and environment of the Russian Federation No. 349 “On the approval of the Guidelines for the development of draft standards
for waste generation and limits for their disposal”, No. 50 “On the procedure for the development and approval of standards for waste generation and limits for their disposal”, No. 30 “On the approval of the procedure for the submission and control of reporting on the generation, use and disposal of waste (with the exception of statistical reporting)”, No. 792 “On the approval of statistical tools for the statistical monitoring of production and consumption waste for the Federal service for supervision of natural resources”. In accordance with order of the Ministry of natural resources and environment of the Russian Federation No. 536 [3] of December 4, 2014 there are 5 hazard classes of waste by the degree of impact on the environment: 1 class - extremely hazardous, 2 class - highly hazardous, 3 class - moderately hazardous, 4 class - low hazardous, 5 class - practically non-hazardous.

In the sphere of industrial waste management enterprises and organizations must to comply with the regulatory requirements of Russian and international legislation, invest into the development and implementation of new technologies as well as take the necessary measures for the effective utilization of the industrial waste [4-7].

2. Materials and methods
The analysis of the effectiveness of the solid waste management on the Arctic industrial enterprises over the past five years was carried out. For an objective assessment enterprises of large companies providing information in open access were selected: PJSC Novatek, PJSC ALROSA, Polar Division and Kola MMC of PJSC MMC Norilsk Nickel, Kirovsk branch of Apatit of PJSC PhosAgro, industrial enterprises JSC Karelsky Okatysh, JSC Olcon, JSC Vorkutaugol and JSC Yakovlevsky mine of Division Severstal Resources of PJSC Severstal. The volume of waste generated by enterprises over the past five years is presented in table 1.

| Table 1. The volume of waste generated by enterprises, million tons. |
|-----------------|-------|-------|-------|-------|-------|
|                 | 2014  | 2015  | 2016  | 2017  | 2018  |
| PJSC Novatek   | 0.041 | 0.042 | 0.05  | 0.047 | -     |
| PJSC ALROSA    | 90.7  | 82.6  | 65.2  | 67.7  | 66.9  |
| Polar Division of PJSC MMC Norilsk Nickel | 23.1 | 22.3 | 22.6 | 23.3 | 15.71 |
| Polar Division of PJSC MMC Kola MMC | 12.1 | 11.4 | 10.6 | 8.6 | 8.31 |
| Kirovsk branch of Apatit | 70.1 | 77.9 | 84.5 | 79.9 | 88.4 |
| Division Severstal Resources | 184.6 | 178.0 | 185.1 | 189.9 | 193.0 |

Based on data obtained from company reports [8-12] the share of waste utilization in relation to its generation was calculated.

3. Results and discussion
PJSC Novatek explores, mines, processes and sells natural gas and liquid hydrocarbons. Main part of low-hazardous and practically non-hazardous waste (4 and 5 classes) is drill cuttings (about 97%). Less than 3% is moderately hazardous waste (3 class). Extremely and highly hazardous waste (1 and 2 classes) including mercury containing waste are less than 1%. About 33% of the waste is utilized by the company for its own purposes, for example, to use drill cuttings to strengthen roads and reclamation of artificially created cavities. In addition, about 20% of the waste is transferred for use to other organizations. In general, the dynamics of waste generation can be considered negative. According to reports of enterprises this happened due to an increase of production [8]. At the same
time the share of waste use in own production in relation to its generation since 2014 has decreased from 71% to 20%.

PJSC ALROSA explores, mines and processes rough diamonds as well as sells jewelry quality diamonds. The main volume of mining waste (up to 99%) is practically non-hazardous (5 class). It includes overburden from mining, waste from the ore-dressing treatment, glass breakage, rubber and metal waste. Some of these wastes (overburden and ore beneficiation waste) are used to form dams, tailings, for construction work, reclamation of disturbed land, dumping and road maintenance. Less than 1% of wastes are 1, 2 and 3 hazard classes including mercury containing as well as used accumulators. Part of 3 class waste (tire products) is used for the construction and repair of roads, when the wood waste is used for production purposes. Low hazardous waste (4 class) including waste from wastewater treatment facilities are less than 1%. Some of these wastes are disposed at the enterprise itself in special mobile units. The dynamics of waste generation shows a decrease. The company explains this to a decrease of the volume of mining, the use of new technologies for the construction of quarries and block caving of the rock mass using the underground method of ore mining [9]. In average the share of production waste used and neutralized by own resources is about 27%.

Polar Division of PJSC MMC Norilsk Nickel explores, mines and processes sulfide copper-nickel ores and produces cathode copper, cathode and granular nickel, electrolytic cobalt, platinum concentrates and other metal containing products. More than 90% of waste primarily from mining, metallurgical and concentration productions (rock, overburden and slags) are practically non-hazardous (5 class). About 4% of waste belongs to hazard class 4, less than 1% - to 1-3 classes. About 71% of all generated waste is used at the enterprise. Less than 1% of the waste is disposed at the enterprise and transferred to specialized organizations. Mining wastes and chats are used to fill the space of mine workings (granular slag from non-ferrous metal smelting, overburden, rock, mining waste and chats), as a flux for metal smelting, for construction and strengthening of tailings dams and repair of roads. The dynamics of waste generation in recent years is positive. According to the reports on the sustainable development of the enterprise the main reasons are: the separation of the Zapolyarny mine and the Norilsk concentration plant from the branch structure, the disposal of chats due to reconstruction and technical re-equipment of the Talnakh concentration plant and the reduction of production waste generation [10]. In 2016 an increase of waste generation occurred due to the implementation of the project for the reconstruction and technical re-equipment of the Talnakh concentration plant. The share of waste utilization on the enterprise in relation to its generation since 2014 increased from 52.6% to close to 100%. In addition, there was an increase of the waste flow from other organizations up to more than 3 million tons in 2018.

Kola MMC of PJSC MMC Norilsk Nickel mines and processes sulfide copper-nickel ores with the subsequent production of cathode copper, nickel, nickel powder, cobalt concentrate and other metal-containing products. Over 90% of the waste is practically non-hazardous (5 class). They include rocky, overburden rocks, waste from the concentration process and slags from metallurgical industries. About 4% of waste belongs to hazard class 4, less than 1% - to 1-3 class. About 42% of all generated waste is used at the enterprise. Less than 1% of waste is disposed at the enterprise and is transferred to specialized organizations. Mining and concentration waste is used to fill the space of mine workings, as a flux in the smelting of metal and for the construction purposes. The dynamics of waste generation is positive. The company associates this with the cessation of open pit mining at the Yuzhny open pit, reduction of the use of waste for the reclamation of worked open pits, changes in mining technology and a decrease of the production waste generation [10]. The share of waste use in own production since 2014 decreased from 50.5% to 29.6%.

Kirovsk branch of Apatit of PJSC PhosAgro mines and processes apatite-nepheline ores with the production of apatite and nepheline concentrates. The main volume of solid waste (about 63% is overburden, 37% is concentration waste) are practically non-hazardous (5 class). Less than 1% is waste of 1-4 hazard class. About 31% of waste (overburden) is used for the construction purposes and that indicator has not changed significantly over the past five years. Less than 1% is transferred to
third-party organizations for disposal. The amount of waste increases. According to the company reports it is connected with an increase of the concentrate production from 8.4 to 11.1 thousand tonnes. [11]. In 2017 a decrease of the amount of waste according to the reported data was due to a decrease in open-cast mining. Thus the share of waste use remains virtually unchanged despite the measures taken.

In division Severstal Resources of PJSC Severstal that includes JSC Karelsky Okatysh, JSC Olcon, JSC Vorkutaugol and JSC Yakovlevsky mine all industrial enterprises are mining and produce various concentrates. Thus JSC Karelsky Okatysh, JSC Olcon and JSC Yakovlevsky produce iron-containing concentrates and various products including ferrite and strontium powders. JSC Vorkutaugol produces coking coal. The main volume of the waste (more than 95%) is from the mining industry (overburden and concentration waste) which belong to hazard class 5 and are mainly used for the production of broken stone, the laying of mine workings, the production of building materials and the road construction. Low hazardous waste (4 class) is less than 3%, extremely, highly and moderately hazardous waste (1-3 class) - about 1%. In total, according to reports, about 11% of waste is used. Less than 1% of the waste is disposed. The amount of waste increases annually. The company explains this with an increase in ore mining and processing [12, 13]. Division Severstal Resources of PJSC Severstal due to its efficient management have significantly increased waste use from 1.8% in 2014 to 12% in 2018 primarily for improving the infrastructure of the enterprises. In specific years this indicator grows to a greater extent for example in 2015 it reached a value of 25.8%. On average the division Severstal Resources of PJSC Severstal utilizes 11% of waste. This indicates significant unused potential.

4. Conclusion
Despite the fact that in recent years the Government of the Russian Federation approved a number of documents related to waste management and aimed at the formation and future development of a new industry for waste management, including the Order of the Government of the Russian Federation of January 25, 2018 No 84-p “On approval of the Strategy of the Industry Development for the processing, utilization and neutralization of production and consumption waste for the period up to 2030” the amount of mining waste generation for a number of enterprises (PJSC Novatek, Kirovsk branch of Apatit of PJSC PhosAgro, Division Severstal Resources of PJSC Severstal) have increased.
Reduction of waste generation is demonstrated by PJSC ALROSA, Polar Division and Kola MMC of PJSC MMC Norilsk Nickel

The study showed that for the period from 2014 to 2018 the Polar Division of PJSC MMC Norilsk Nickel and the Division Severstal Resources of PJSC Severstal increased the efficiency of industrial waste management, and, as a result, its utilization. At the enterprises of PJSC Novatek and Kola MMC of PJSC MMC Norilsk Nickel the volume of waste utilization has decreased, which indicates that management does not take appropriate measures in this field. PJSC ALROSA and Kirovsk branch of Apatit of PJSC PhosAgro have not show significant changes, which indicates the insufficient attention is paid by enterprises to the effectiveness of waste management.

The results show that it is necessary to improve the system of state regulation regarding ecosystem disturbance and, in particular, increase the level of waste utilization. To increase the efficiency of the solid industrial waste management system when exploiting mineral resources further basic scientific research aimed at scientifically based methods and principles that are the basis for improving the state of Arctic ecosystems is required.

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