Industrial production: use of green technologies to conserve the environment and resources

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Abstract. In the study, the authors provide an overview of the latest technologies used in industry. Such technologies in the modern world have become in demand for many reasons, which have an economic, social and, above all, environmental character. The "green" agenda affects many countries of the world because of the ecological state of the environment, as well as many economic issues can be solved within the framework of this agenda, such as the reduction of resource costs. Limited resources on the Earth represent the most basic problem for the world economy and for each individual country. Therefore, the relevance of applying the latest technologies is a subject of interest for industrialists, science, business and government. The study of the applied technologies makes it possible to determine the prospects for solving economic and environmental problems of the society

1 Introduction

Providing the needs of the population with various material goods is a necessary process accompanied by the need to increase the extraction of mineral raw materials. The expansion of mining enterprises requires the development of the resource base, which becomes possible with the development of new technologies.

In modern conditions, the economic use of the environment both locally and globally has a significant impact on its condition, which determines to a greater extent the well-being and welfare depends not only on the population of a particular territory, but also on the population of each country, region, etc.

Control and rationing of nature use is established and regulated by normative legislative acts in the interests of each national economy (examples: On Environmental Protection from 10.01.2002 7- FZ; Land Code of the Russian Federation from 25.10.2001 136-FZ; Water Code of the Russian Federation 74 FZ from 03.06.2006, etc.). Among industrialists there is a demand for modern technologies to improve the efficiency of production processes and reduce costs in the interests of increasing production efficiency and profit.

In this study, the authors have analysed the available new and latest technologies in mining industry of extraction and processing hard rock resources, where innovative solutions form the so-called "green agenda".

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2 Materials and Methods

The modern mining industry is knowledge-intensive, requiring the latest and advanced technologies, where such methods as detailed sludge analysis, modern IT-developments, software, which allow to perform necessary operations, works in production, have already been proposed, but at the same time they need further improvement, automation "and even begin to "think" themselves due to machine and deep learning, thereby eliminating the possibility of error due to the human factor" [1].

In our country, over hundreds of years a large-scale volume of mining and processing wastes (dumps, which according to experts' estimates amount to about 50 billion tonnes [5], has been accumulated over hundreds of years of industrial production development, growing at a significant rate. In modern conditions of development and application as well as application of innovative technologies, such dumps serve as sources of extraction that could not be extracted by traditional methods and technologies.

Throughout the entire territory of Russia (the North-Western and South-Eastern parts, the Urals, the South-Eastern and Eastern Asian part of Russia, Central Siberia), anthropogenic dumps have formed a class of mining deposits with a peculiar and diverse mineral composition, which constitute potential sources of metal resources, especially non-ferrous, rare and noble metals. In Russia, non-ferrous metal deposits are characterised by their scattered nature (lack of large-scale deposits, unlike iron ore deposits, such as the Kursk Magnetic Anomaly) and the processing of accumulated mining dumps opens up a wide range of opportunities for the preservation of subsurface resources, environmental protection, economy and efficiency of industrial production and other socio-economic opportunities.

According to experts' estimates, the content of metals in mining dumps often exceeds their content in the extracted rocks and supplied for enrichment to metallurgical plants. This is especially true for dumps formed 70-80 years ago, i.e. in the last century, when comprehensive analyses of mineral studies in our country have not yet been given due attention [5]. Experts also highlight the problem of insignificance of the volume of processing of dumps, technogenic deposits due to the fact that their wide involvement in processing requires new production with the use of other technological principles and solutions.

Similar and other industrial production problems are also being solved in foreign countries using 4th industrial revolution technologies such as Newmont, LKAB 5.0, Dundee Precious Metals and others [2, 8, 12].

For analysis and synthesis, the authors have analyzed the latest methods and developments in the field of mining production attributed to "green" technologies, an overview which is presented in Table 1.

Table 1. Green technologies in the sphere of industrial production

Technology	Characterisation	Opportunities
Russian experience of the industrial revolution (Smart Mining):		
BIM technologies (information modelling)	Computer modelling of ore treatment processes (digital technologist; digital twin; machine vision system).	reduction of time, labour and investment costs; - minimising the influence of the human factor; - prompt decision-making.
Energy saving technology for enrichment plants	- software in the area related to ore processing (destruction of ores and improvement of subsequent beneficiation processes).	- reduction of energy costs; - increase in ore treatment productivity; - minimization of operating costs of the ore treatment process;

		- increase in energy efficiency of ore destruction processes.
Eco-technology of mineral extraction	- convergent system of technological solution, the latest "cellular" technology of mineral development; - 3D modelling of underground field development.	- does not require extensive blasting; - extraction of ore by drilling several vertical "tubes".
Unified geotechnical model	- creation of a comprehensive model of the environment; - normalizing all calculations; - understands new drilling data, description.	- reducing the time for decision-making; - allows best practice to be systematized; - ensuring stability of mining structures.
Smart Mining	Industry 4.0 technologies: - Big data; - artificial intelligence; - simulation models; - digital twins.	- expansion of the resource base; - introduction of the latest technologies for processing lithogenic resources; - increasing productivity while reducing operating costs.
New coal processing technologies	Increase of coke concentrate yield by re-enrichment of fine and coarse machine-grade product (screw separators; hydrogenizes).	- ensuring the efficiency, safety and environmental friendliness of mining operations.
Cellular underground mining technology (without blasting)	- sustainable honeycomb mining structures underground; - nature-like (convergent) and functional structure of subsoil development; - ore extraction by drilling vertical "tubes".	- reduction (several times) of waste rock volumes; - reduction of production accidents and personnel injuries; - maximising practicality, zero waste and safety; - preservation of the subsoil structure.
Technology of extraction of gold and other useful components from mining dumps	- module in a plastic casing with a core of activated carbon - sorbent.	- increasing the efficiency of metal ore mining; - processing of technogenic dumps; - elimination of harmful impact of dumps on the environment; - elimination of corrosion elements getting into the soil (in case of using iron pipes).
International experience of the industrial revolution (Smart Mining)		
Newmont	- refusal of diesel machinery (on electricity); - mining operations (transport, drilling, precise positioning of drilling rigs) without people.	- reduction of greenhouse gas emissions; - increased productivity with reduced operating costs.
LKAB 5.0	- a new global standard for sustainable underground mining at great depths.	- emission-free $CO_2$$ - environmental preservation.
I^2Mine	- mining minerals at greater depths; - IntelliMine concept of invisible, safe and harmless mines with zero impact.	- significant reduction of transport costs, above-ground drilling rigs; - reduced environmental impact.
Dundee Precious Metals	- exploration of the existing deposit;	- reducing the impact of technogenic dumps on the environment;

	- processing of process "tailings" and technogenic-mineral formations (TMF)	- reducing the ecological load on the environment.

In Table 1, the types of new technologies of the "green" agenda of industrial production have significant advantages in use both in Russia and in foreign countries. Science responds to the requests of industrialists with the results of research and development: an example is the scientific and practical conference "Mine of the Future" held in November 2021 [11]. [11], where the solutions to the set tasks allow to bring the production process to a new level.

BIM design (information modelling) is a new tool for construction of facilities as part of enrichment processing plants, aimed at reducing time and labour costs of construction works. These technologies have formed an additional direction - a set of solutions for promising issues of the project functioning at the stage of its design (digital technologist, digital twin, augmented reality technologies). Specialists note that it is the aggregate of BIM-technologies that "allow to bring a project of any complexity from the design of the object to its commissioning" [11].

In Russia, non-ferrous metal deposits are characterised by a complex composition, where, accordingly, traditional extraction methods have become ineffective for their development. However, no universal cost-effective processing technology has been proposed yet, so each specific deposit requires the development of a unique technological scheme, which BIM-technologies allow for.

Among BIM technologies, the most common are:

- AVR recycling technology (extraction of the desired substance from both solutions and slurries);
- SART recycling technology (solid precipitation, thickening and filtration, neutralisation of substance solutions).

Energy saving as the most important factor in the profitability of mining and processing enterprises, for which energy intensity is a factor-requirement of their functioning. Reduction of energy consumption according to experts [11] is possible due to:

- "modernisation of existing technological schemes with the use of modern digital tools";
- reasonable choice of ore preparation equipment;
- optimisation of the choice of equipment operating modes and configuration of technological schemes with the use of digital tools.

A modern natural trend in the last decade has been the demand for digital technologies in mining mechanics and mining production. One of the leading trends in the development of this sphere are the tools of Industry 4.0: big data, artificial intelligence, simulation models, digital twins, etc.

Today the solution of these problems is offered on the basis of specialised programs of geological, geofiltration, numerical modelling of stress-strain state, etc. Problem solving for each mine requires an individual approach and separate geomechanics service.

According to experts, an important problem of mining operations is "the lack of technological environment for calculations and design" [10], which should constitute a unified information system. The previous regulatory framework is becoming obsolete due to the emergence of the latest technologies, geomechanical safety requirements, digitalisation, etc., developing at a significant pace.

Experts have identified a base of earthquakes caused by human activity, where about 25% are caused by the development of solid lithogenic resources, 33% are caused by hydraulic fracturing, oil and gas production [10]. Experts note "a general increase in geodynamic and seismic activity on Earth in the 90s and zero years" due to significant changes in hydrogeological regimes, disturbance of regional geodynamic equilibrium, and the appearance of new faults [10].

Mining safety issues require qualitatively new approaches to geomechanical problems.

Environmental problems always accompany the mining process: formation of zones of technogenic destruction of the lithosphere, disturbance of adjacent areas of the Earth's crust, etc. In addition, the process of beneficiation of mined minerals is accompanied by the formation of a mass of waste materials such as waste rocks after the extraction of the useful component.

To solve the problem of underground voids, specialists have proposed "creation of stable honeycomb mining structures underground", which are innovative in nature, significantly reducing the volume of waste rock stored on the surface of the ground, reducing accidents and injuries at mining enterprises [6]. This new system of drilling underground vertical "tubes" represents a very stable mining structure (similar to load-bearing structures in construction). Practice confirms that this system allows to significantly (2-3 times) reduce mining losses, and in the exhausted underground chambers "it is convenient to store mining wastes", including other wastes of life activity [6].

The method of underground rock structures has significant advantages:

"- reduction of acting stresses in rock massifs;

- minimisation of the probability of rock impacts, processes of unpredictable deformation and shear of rocks;

- significant reduction of accidents in mines and at mines" [6].

The methods of technogenic waste processing proposed by researchers are interesting in practical activities. For example, Perm geologists have developed a new sorption module for the extraction of gold from technogenic dumps. The most remarkable thing is that this method is environmentally safe and can be used to extract other useful components from mining dumps.

The Perm researchers assembled the module in a plastic case with a core filled with activated carbon as a sorbent. The module is immersed in gold-containing water and as the technogenic water flows through it, metal particles accumulate in the sorption core. The cartridge is then removed from the module body and sent for recycling to extract the accumulated metals. Such a module can be used to extract other metal components such as dissolved non-ferrous and rare earth metals. For each type of metal to be recovered, it is only necessary to select the appropriate sorbent for each type of metal to be recovered.

3 Results and Discussion

As a result of the study, we can conclude that the available types of technologies in the field of industrial production allow to solve the problems of modern society in a comprehensive way. Figure 1 shows the classification of main groups related problems, the solution of which is largely determined by the intensification of the use of "green" technologies.

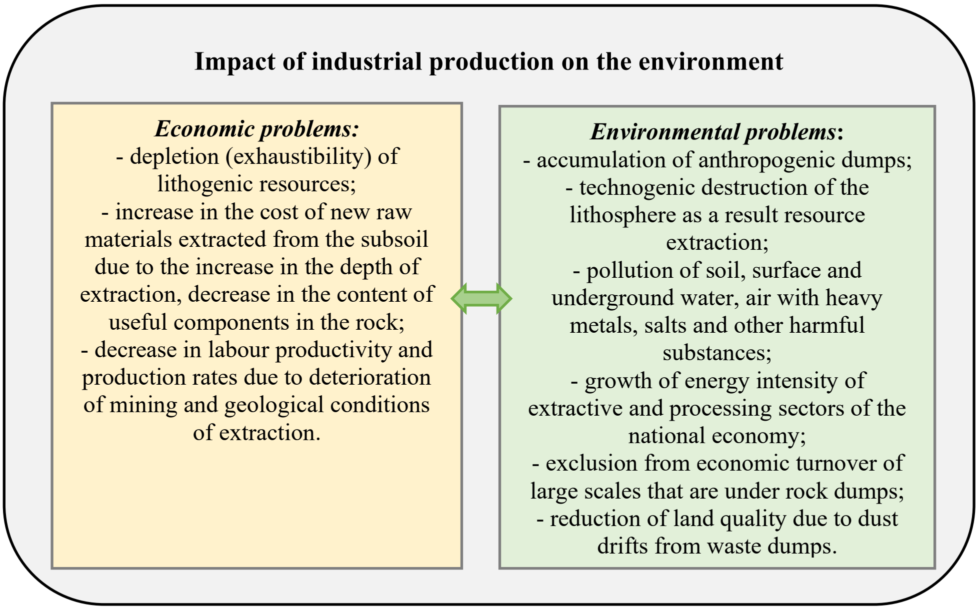

Fig. 1. Impact of industrial production on the environment.

4 Conclusion

In conclusion of the study it should be noted that today modern industrial production, the process of mining and processing of minerals require special attention from the authorities, subsoil users, scientific community, where each party ultimately understands - the achievement of public welfare and well-being acquires a strategic goal of the national economy, the achievement which depends on each participant of production relations.

The necessary requirements for more successful implementation of "green" technologies in practice can be identified:

- Significant increase in the volume of technological reorganization in industry;
- creation and improvement of the regulatory and legal framework;
- development of methodological and technological issues of technogenic deposits for transition to waste-free technologies.

All this, of course, will take time, including effective and efficient co-operation between science, production, business and government because it is not enough just to invent and patent, you also need to implement it.

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