Chapter 7
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Efficient Use of Mineral Raw Resources and Mining and Industrial Waste in the Regional Aspect

M J Syvyj [a*], Y A Ivanov [b], P M Demyanchuk [a], N B Panteleeva [c] and B B Havryshok [a]

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ABSTRACT

The present study Highlights about efficient use of mineral raw resources and mining and industrial waste in the regional aspect. Rational (effective) use of nature in the mineral and raw material base of the regions of Ukraine involves a number of measures that contribute to its optimization. At the same time, the solution to the specified problem includes the complex development of mineral deposits, complex use of mineral raw materials and mining waste, optimization of the structure of mining production and consumption of mineral raw materials. The modern interpretation of the rational use of subsoil resources extends to all stages of their development, including the issue of mining waste. At the moment, a huge amount of waste from the mining industry has accumulated on the territory of Ukraine, which creates not only economic and ecological but also significant social and demographic problems. The environmental situation has become particularly acute due to the accumulation of toxic waste, among which the most dangerous are heavy metals, petroleum products, and acid resins. The formation of sustainable development of Ukraine requires not only the development of newly discovered reserves of natural raw materials but also the use of man-made raw materials accumulated in more than 1,600 man-made deposits and objects. Optimizing the development of the country's mineral and raw material base requires an urgent solution at the state level to the problems that inhibit its growth and ecological improvement on the basis of rational use.

[a] *Ternopil Volodymyr Hnatiuk National Pedagogical University, 2 Kryvonosa Str., Ternopil, 46027, Ukraine.*
[b] *Ivan Franko National University of Lviv, 1 Universytetska Str., Lviv, 79000, Ukraine.*
[c] *Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine.*
**Corresponding author: E-mail: syvyjm@ukr.net;*

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1. INTRODUCTION

In the contemporary understanding of this problem, the sensible use of mineral resources encompasses all phases of their development, including the problem of waste disposal. The disposal of the massive volume of mining waste that has been collected in Ukraine's administrative areas has become a serious socio-demographic concern in addition to an economic and ecological one. Environmental problems have become particularly acute due to the accumulation of toxic waste, among which the most dangerous are heavy metals, petroleum products and acid tars [1]. Hundreds of billions of tons of various types of mineral raw materials: combustible minerals, ores, construction materials, etc., are mined from the subsoil every year. Along the way, in the process of mining, host rocks are also removed and remain at the mining site. Human activity has acquired global dimensions and is commensurate with the geological processes involved in the formation of the planet’s landscapes. Desertification refers to land degradation resulting from climactic variations and human activities. It is not a natural process, but the result of mankind’s actions today. What fosters the land degradation process, and the desertification process is the overexploitation of natural resources in vulnerable areas. It is a major threat to humanity and the environment [2]. Long-term exploitation of mineral resources has led to the reduction of their reserves and the depletion of rich or unique deposits. At the same time, the non-restoration and limited reserves are characteristic of the mineral resources, so it is important to find approaches to the effective use of their reserves in order to prevent depletion and excessive losses during extraction. The growing technogenic load and disturbance of the natural environment during the exploration and exploitation of mineral deposits make the issue of overall protection of the geological environment and landscapes an urgent one [3].

The geoecological approach of the mineral resources study arose mainly on the grounds of a need to study the processes accompanying the exploration, extraction and primary processing of minerals [4]. It is caused by the need to monitor, analyze and forecast, aimed at minimizing the negative impact of mining production on the environment, and the development of rational schemes for the environmentally safe activities of mining enterprises in the context of optimizing nature management [3]. The result of the geoecological study of mining areas is the development of measures to improve the quality and conservation of the natural environment and reclamation of mining landscapes [3]. The research is focused on the following issues: protection and rational use of subsoil, surface and groundwater, air environment, reclamation of lands disturbed by mining, disposal of mining waste, ecological and landscape problems of disturbed territories. Due to the global nature of the issue, the purpose of this article is to analyze only the first problem – the rational (efficient) use of mineral resources and mining waste [3].

The issue of conservation and rational use of subsoil resources has been of particular interest to researchers since the late 1960s and early 1970s, but the majority of publications fall into the 1980s. First and foremost, these are the works of Pedan and Mishchenko [5], and Bent [6]. Among the publications of the last decades, the works of Rudko and Shkitsa [7], Andrievsky [8], Galetsky et al [9], Komov [10], Panov [11], Rudenko et al [12], Mishchenko [13], Syvyi et al [14-16], Udalov and Kononenko [17], Kilinska and Kostashchuk [18], Rudko et al [19], Hrinov and Khorolskyi [20,21] should be mentioned.

2. MATERIALS AND METHODS

The mentioned works discuss methodological approaches to the rational use of mineral resources. In particular, they develop a conceptual framework, classifications of ways to comprehensively use mineral resources, the main directions of use, classifications of mining and industrial waste and problems of their disposal, the role of comprehensive use of mineral resources in improving the territorial organization of social production, the effectiveness of comprehensive development of mineral resources, and so on [3]. The theoretical and methodological justification of these directions, the development of technological schemes for extracting valuable components at different stages of the mining production process, and finally, the globalization of the problem - i.e., the processing not only of the methodology of rational use of mineral resources but also of the rational use and protection of subsoil resources in general - are some of the topics discussed in these and many other works that remain relevant today [3].

3. RESULTS AND DISCUSSION

Rational use and protection of the subsoil is an integral part of rational nature management within the mining areas. Rational nature management should be understood not merely as the optimization of the processes of intensive use of natural resources and their protection, but also as a system of measures covering the issues of environmental protection and control, reproduction and preservation of these resources, effective use of capital investments in mining enterprises, the distribution of the productive forces of the region [14,3].

From the general issue of rational nature management in the region, one can single out the rational use of mineral resources. Equally important components of the latter are the comprehensive development of mineral deposits, comprehensive use of mineral raw materials and mining waste, optimization of the structure of mining production and mineral raw materials consumption (Fig. 1) [3].

The maximum satisfaction of society's needs in certain types of raw materials at specified costs and under the condition of compliance with environmental standards can be considered as a criterion for the effective and optimal use of mineral resources [3]. At the same time, factors of an economic, ecological and social nature should be taken into account; in particular, meeting needs for a certain resource, a level of current costs in the production and consumption of the product, economic effect and trends in the development and use of subsoil resources, the implementation of measures to preserve resources for future generations; minimization of harmful effects of mining on the environment, etc. [3].

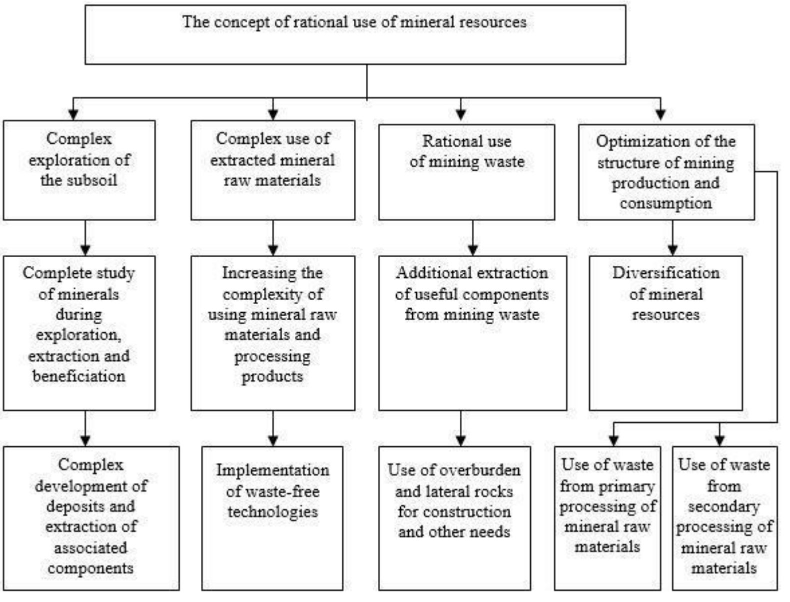

Fig. 1. Structure of measures to solve the problem of rational use of mineral resources in the region

Irrational extraction and use of mineral raw materials lead to an increase in costs at all stages of mining production. Losses of minerals during their extraction and primary processing in some cases amount to 40-50%. The growth of mineral losses causes a deterioration in the quality or a decrease in the volume of concentrates produced by mining enterprises due to a decrease in the volume of useful components, and a reduction in reserves due to their faster depletion [3]. Mineral raw materials depletion of reserves is one of the main problems of environmental protection. High-waste technologies, non-comprehensive use of mineral raw materials and, as a result, environmental pollution, and violation of its dynamic balance are other parts of this problem [3].

The list of tasks for rational use of mineral resources at various stages of their development and environmental protection issues, which need solving, has a following look (Table 1). Rational use of mineral resources covers all stages in their development (search and exploration of deposits, extraction, transportation, primary and secondary processing), including waste disposal. Waste disposal is

limited to those groups and types of waste processing, which are direct replacements of certain mineral resources [3].
The optimal use of mineral resources includes, on the one hand, the most detailed study of deposits at the stage of exploration, pre-exploration and exploitation, the choice of rational schemes for the most complete extraction of useful components during mining enrichment and processing; and, on the other hand, a requirement for a comprehensive use of mineral raw materials (Table 1) [3]. The methods and means of extracting minerals, which are used in modern technologies, do not solve the issue of their complete extraction from the subsoil. The resulting losses sometimes exceed the volume of actual production. Particularly significant losses are recorded in the underground method of development; a quarry method, as a rule, can reduce the loss of raw materials by 3-8% [3].

The problem of comprehensive use of mineral resources is considered in two aspects: a comprehensive development of deposits and a comprehensive use of raw materials.

Comprehensive development of deposits involves the use of rational, effective methods of extraction of the main and associated useful components in host and overburden rocks. Selective extraction of all industrially valuable components, their storage, and shipment to the consumer, or their accounting, in case of temporary non-use, must be ensured. Most mineral deposits are multiply [3]. Sometimes the content of accompanying components can have a completely independent value, and their economic value may even exceed the cost of the main raw material. Multiple components are an important and permanent feature of mineral resources [3]. Genetic associations of minerals (paragenesis) are well known in petrology, and the need for a comprehensive approach to solving the issues of using mineral raw materials is based on the following: the main component is associates with a number of other components. Paragenesis is especially typical for ores of non-ferrous metals. During the comprehensive processing of ore raw materials, in addition to 8-12 proling chemical elements, an additional 62-66 elements can be obtained [19,3].

The economic effectiveness of the comprehensive use of mineral resources is revealed in various approaches. First of all, the accompanying extraction of valuable components significantly expands the mineral base. This is most important for non-ferrous metallurgy, where the majority of rare elements are contained in ores of basic metals. Sometimes there are much fewer of them in special deposits of rare metals [3]. At the same time, in the process of mineral raw materials use, conditions are created for increasing the volume of production with significantly lower capital costs. Many di use elements do not have their own minerals at all. Selenium, tellurium, indium, thallium and rhenium are extracted only from non-ferrous metal production waste, which is the only possibility of their production through complex processing of polycomponent ores [3]. Most of the accompanying components are considered valuable, and even incomplete extraction of them from mineral raw materials makes it possible to expand the raw material base of the industry, reduce production waste, increase its economic efficiency and improve the environmental situation [3].

Table 1. Tasks of rational use of mineral resources and environmental protection

Stages of development of mineral resources	**Main tasks**		
	Study and complete extraction of mineral resources	**Complex use of mineral resources**	**Environment protection**
Search and exploration of mineral deposits	Rational and effective works on subsoil exploration; complete study of the geological structure; reliability of determination of reserves and quality of minerals; a rational approach to establishing the conditions of mineral raw materials	Research of associated components of raw materials and useful components in overburden, lateral and underlying rocks	Implementation of works without unjustified loss of minerals; prevention of pollution of water horizons; preservation of exploratory mines and wells and their liquidation, if they are not suitable for use and have environmental damage
Extraction of minerals	Selection of rational schemes for exploitation of deposits; reduction of losses in the subsoil; ensuring the maximum completeness of working out the reserves of the deposit	Organization of complex development of the deposit; preservation and accounting of associated components through their selective extraction and storage; utilization of overburden and host rocks	Preventing the negative impact of mining and other types of work on the preservation of mineral reserves; protection of deposits from flooding, pollution and construction; treatment of mine wastewater; air protection in quarries; prevention of oil leak-age; rehabilitation of disturbed lands; protection of nature conservation objects
Transportation and processing of mineral resources	Complete extraction of useful (including associated) components from mineral raw materials; reduction of losses during transportation and processing	Economically expedient extraction of associated components from mineral raw materials; use of waste from primary and secondary mineral processing	Use of rational waste storage and preservation schemes with minimal loss of land; use of modern technologies to prevent pollution of the air environment, underground and surface waters, soils, etc.

In addition to the extraction of industrially valuable components from raw materials, its comprehensive use requires the disposal of host and overburden rocks and residual products of enrichment and processing of raw materials. Up to 0.5-0.6 billion tons of rocks and mineral raw materials processing waste are stored annually in surface dumps [3]. The total amount of accumulated mining waste exceeds billions of tons. Up to 1 billion m^3 of mineralized water is pumped out of mines every year [22]. Today, the bulk of such waste cannot be considered as mineral resources, as it cannot be used in industry. On the other hand, their use requires transportation, which is associated with additional costs and makes raw materials uncompetitive [3]. The hundreds of millions of tons of waste accumulated in Ukraine can significantly improve the mineral base of enterprises that extract building stones, raw materials for building ceramics, building sands, and ceramic clays, carbonate raw materials, etc., or drastically reduce the need to open new quarries of building materials [3].

The waste of primary processing (enrichment) of raw materials is various sand and sand-clay sludge. The volumes of this waste in the regions of Ukraine are measured in hundreds of millions of tons. For example, in Kryvbas area, reserves of sludge from the enrichment of iron ores exceed 1 billion tons [3]. Waste from secondary processing of raw materials is accumulated in significant quantities at enterprises of ferrous metallurgy enterprises (blast furnace slag, ferroalloy slags, iron-containing waste), thermal power industry (ash and slag from burning coal), chemical, petrochemical, and coke-chemical industries (phosphogypsum, pyrite cinders, liquid organic and inorganic waste), etc. Often, the content of mining waste in such elements as copper, cobalt, molybdenum, zinc, and others makes them suitable for use in agriculture as agronomic ores [3].

The density of accumulated waste in Ukraine is 6.5 times higher than in the USA and 3.2 times higher than in the countries of the European Union. Every year, more mining waste accumulates in Ukraine than in 12 EU countries. Donetsk, Dnipropetrovsk, Luhansk, Lviv, and Zaporizhzhia regions should be singled out (Table 2). In the densely populated areas of Donbas, Kryvbas, Pre-Dnieper and Pre-Carpathian regions, the level of technogenic load ranges from 2-3 to 10-30 million t/km^2 [3].

Table 3 shows the volumes of technogenic waste accumulated within the main mining basins of Ukraine, which account for 79.2% of the total amount of waste [14].

Ukrainian enterprises generate up to 100 million tons of toxic waste every year, of which more than 3 million tons belong to I-III hazard classes. The total amount of toxic waste accumulation is 4.4 billion tons. In Ukraine, there is no plant for the processing of toxic industrial waste or landfills for their disposal. The conditions of waste storage and disposal do not meet sanitary and hygienic requirements and are one of the factors of intense pollution of atmospheric air, surface, groundwater and soil [3]. It is also worth mentioning the illegal shipment of 25,000 tons of acid tars into the Lviv region; the problem of their disposal has not been resolved by today. In the developed countries of the world, considerable attention is paid to the issue of effective use of mining waste, and the level of their utilization is 65-80% [9]. In Ukraine, this indicator is estimated to be only 10-12%, therefore we have accumulated unused reserves of secondary mineral raw materials [3].

Table 2. Volumes of mining waste in the administrative regions of Ukraine (on the materials of the Ministry of Ecology and Natural Resources of Ukraine) [22]

Administrative units	Dump area, ha	Annual waste volume, million m^3	Volumes of annual waste use million m^3	Volumes of accumulated waste million m3
AR of Crimea	17.0	0.10	0.05	1.52
Vinnytsia region	985.0	6.21	1.94	26.33
Volyn region	251.0	1.93	0.23	35.14
Dnipropetrovsk region	18,331.0	245.08	50.86	2,013.40
Donetsk region	12,284.7	127.60	22.82	2,771.14
Zhytomyr region	2,187.7	15.82	6.70	71.20
Transcarpathian region	27,5	0,48	0,23	3,89
Zaporizhzhia region	1,175.3	2.18	0.51	63.30
Ivano-Frankivsk region	384.2	5.94	2.37	86.81
Kyiv region	146.0	1.30	0.16	32.51
Kirovohrad region	953.6	10.71	1.72	128.00
Luhansk region	4,819.2	32.21	4.56	596.27
Lviv region	4,591.5	48.95	3.52	1,054.20
Mykolaiv region	39.3	0.58	-	3.12
Odesa region	160.6	0.26	0.60	5.34
Poltava region	4,440.6	40.59	3.86	591.80
Rivne region	276.9	2.41	0.69	24.65
Sumy region	63.5	0.84	0.46	6.98
Ternopil region	74.8	1.34	0.36	10.45
Kharkiv region	512.4	2.64	0.38	11.09
Kherson region	90.0	1.55	0.52	0.76
Khmelnytskyi region	201.8	5.43	1.93	95.46
Cherkasy region	796.5	1.28	0.59	8.67
Chernihiv region	224.0	0.12	0.19	1.46
Chernivtsi region	94.6	0.12	0.09	0.43
Total	53,128.4	554.67	105.33	7,643.92

For the sustainable development of Ukraine, it is necessary not only to develop new reserves of natural raw materials but also to develop technogenic mineral resources accumulated in more than 1,600 technogenic deposits and objects. Technogenic deposits contain non-ferrous, rare, noble, ferrous metals, rare earth elements, non-ore, construction and energy raw materials, limestone and gypsum meliorants, etc. These components can be removed using the latest technologies. Every year, a technogenic mass accumulates on the earth's surface: 350 million tons of iron, 7.4 million tons of phosphorus, 5.7 million tons of copper, 2.8 million tons of lead, 2.5 million tons of barium, 230 thousand tons of uranium, 190 thousand tons of arsenic, 7.9 thousand tons of mercury [23,3].

Table 3. Volumes of accumulation of industrial waste in the main mining basins of Ukraine [14]

Mining basin	Area of disturbed geosystems, km^2	Volumes of accumulated waste, billion tons	Inflows of mine and quarry waters, billion m^3/year
Donetsk coal (Donbas)	15,000	9.4	788.4
Lviv-Volyn coal	150	0.5	6.2
Dnipro brown coal	38	0.2	-
Kryvyi Rih iron ore (Kryvbas)	170	7.5	-
Pre-Carpathian sulphurous	160	2.6	45.6
Pre-Carpathian saline	24	0.4	2.0
Total	15,542	20.6	-

The simplest technological option remains the organization of waste disposal for the production of building materials. A list of construction materials, magnesium and sulfur-containing fertilizers, limestone and gypsum meliorants can be compiled from mineral raw materials waste in Ukraine [3]. It is also possible to additionally obtain coal fuel, ferrous, non-ferrous, rare metals, and fluxes from industrial waste, which is important in conditions of acute shortage of raw materials. The development of technogenic deposits in Ukraine makes it possible to expand the mineral base of the mining industry by 15-20%. Up to 30% of overburden and host rocks removed from the subsoil, as well as waste from their enrichment, can be used for the production of building materials [14,3].

The problem of effective use of hydro-mineral raw materials is important. It is possible to extract industrial quantities of lithium, boron, germanium, etc. from underground mine waters. For example, the underground waters of Donbas contain from 0.152 to 0.355 mg/dm^3 of bromine, which exceeds the minimum industrial values of bromine by 20-60 times, germanium by 5-8 times, and lithium by 2 times. It is necessary to continue studying the distribution of useful elements and components in mine waters and developing technologies for their extraction [24,3]. Radioactive waste burial grounds should also be considered as deposits of technogenic raw materials. With a higher level of technological development, they can serve as a source for the extraction and enrichment of radioactive elements.

The main mass of disposed mining waste is used for backfilling spent quarry areas and mine sites, and reclamation of disturbed lands. In the backfilling process, not only waste rock is used, but also industrial waste, which can be processed into useful products. However, the technical level of extraction and use of these wastes is insufficient to establish their rational use [3].

In the main mining regions of Ukraine, there are dozens of technogenic mineral deposits that are preliminarily prepared for processing, which will significantly reduce the cost of their development. According to some estimates, with modern technologies, about 40% of industrial waste can be used to obtain useful raw materials: commercial coal, ore concentrates, cement, building materials, coagulants, chemical meliorants, etc [3]. The Geological Service of Ukraine registered 1,500 industrial waste accumulation sites. Among them, only 13 sites have the status of technogenic deposits (one is being developed), the rest are tentatively classified as potential deposits or technogenic manifestations [13]. According to the amendments to the legislation in the field of waste management, the number of industrial technogenic deposits may reach two or three hundred [3].

Solving the problem of mining waste as one of the components of the state environmental policy is envisaged by achieving Sustainable Development Goal 12 \Responsible consumption and production". By 2030, it is planned to reduce the share of landfilled waste to 35.0% of the total volume of generated waste (in 2015, it was 50.0%). At the same time, the number of enterprises where hazardous substances management systems have been implemented should be brought up to 100.0% of the total number of enterprises that use them [3]. Achieving the goal in terms of waste is expected through the use of innovative technologies, which is defined by national task 12.4 \Reduce the volume of waste generation and increase the volume of its processing and reuse based on innovative technologies and production". The processing of secondary mineral raw materials from mining waste requires significant investments. Solving the problem of attracting foreign investments for the development of the mining industry complicates the Russian-Ukrainian war and the di cult economic situation in Ukraine [3].

Effective use of technogenic mineral raw materials will ensure [22,3]: 1) reduction of costs for the search of new and exploration of exploited mineral deposits; 2) preservation of non-renewable mineral raw materials, extension of the life of mining enterprises; 3) production of additional volumes of cheap precious metals, non-metallic and construction materials, etc.; 4) filling of mine and quarry mine sites, planning of post-mining landscapes, carrying out reclamation and revitalization; 5) reduction of anthropogenic load on disturbed territories; 6) release and rational use of land occupied by mining waste storage facilities, elimination of sources of pollution of the natural environment; 7) attraction of investments and improvement of equipment and raw material processing technology.

The use of energy- and resource-saving technologies in the mining sector will improve the environmental situation in Ukraine. The latest technologies are proven to be effective within a short period of time and ensure the maximum output of the final product per unit of raw mineral. The cost of commercial products from mining waste is 5-15 times lower than from ores extracted by traditional methods from natural mineral deposits [25,3]. Solving the problems of rational use of mineral raw materials is also related to the development and implementation of waste-free technologies. Today, the involvement of man-made waste in production processes is restrained by the low economic capacity of the state [3].

The accumulation of significant amounts of mining waste in Ukraine is a consequence of the irrational use of certain useful components. Under the condition of comprehensive use of mineral resources, the amount of waste will be reduced by two times. Such comprehensive use allows for an increase in the amount of obtained industrial raw materials and is of great economic importance. The reform and development of the mining industry should be based on principles that meet modern economic and environmental requirements [3].

In recent years, numerous cases of unauthorized use of subsoil and other violations of the legislation in this area have been recorded in Ukraine. Individual enterprises that extract local types of minerals (building stone, sand, loam, sand-gravel mixture, etc.) operate without special permits. There is an illegal development of coal, oil and amber deposits, as well as geological exploration of the subsoil. Geological control over the study and use of mineral resources should be strengthened [3].

Subsoil protection involves the implementation of a set of measures for the complete removal of mineral resources from the subsoil and the maximum possible, economically feasible reduction of losses during their development. Legislation in the field of subsoil protection provides [26,3]:

1) Provision of comprehensive geological study of the subsoil, prevention of unauthorized use of the subsoil; 2) rational extraction and use of reserves of minerals and components; 3) prevention of the negative impact of works related to the use of subsoil, the preservation of mineral reserves, mine sites and operated or mothballed wells, as well as underground structures; 4) protection of mineral deposits from flooding, waterlogging, res and other factors affecting the quality of minerals and the industrial value of deposits or complicating their development; 5) prevention of unauthorized development of areas of mineral deposits and subsoil pollution during storage of oil, gas and other substances and materials, burial of harmful substances and production waste, discharge of wastewater [3].

In general, the activities of mining enterprises of Ukraine should be aimed both at the maximum extraction of minerals and the preservation in an undisturbed state of reserves that may become minerals in the future, as well as at bringing areas of land disturbed by mining operations into a condition suitable for further use [3].

Quantitative indicators of the wealth of Ukraine's mineral resources, unfortunately, do not fully reflect the real state of the state's mineral base. Reserves of certain types of minerals, in particular oil and gas, are depleted and imported, the probability of discovering new large deposits is low, and the development of small deposits is unprofitable. Currently, Ukraine mainly has hard-to-reach reserves, the development of which is becoming unprofitable, as well as a large mining industry with worn-out equipment, where the majority of the population is employed [3].

Ukraine is at the beginning of the stage of subsoil depletion. A high degree of geological study of the territory, the depletion of quality reserves of the main types of mineral raw materials, and a low probability of discovering new large and even medium deposits in terms of reserves make it impractical to invest significant funds in prospecting and geological exploration. The technological re-equipment of the mining industry becomes a priority due to the high wear and tear of fixed assets [3].

Since the 1990s, the mineral base of Ukraine has experienced degradation in all its constituent parts. In particular, the overall production of minerals has fallen, and the volume of prospecting and mining exploration decreased to critical values. The consequences of this \collapse" are felt even today [3]. At the same time, a slow rate of decline in production of mining industries in the early 2000s made it possible to increase the share of production in the overall structure of the industry by two times compared to 1990 (from 21.2% to 42.6%). During this period, the share of ferrous metallurgy in the overall structure of the industry increased by 2.5 times, fuel industry - by 1.8 times, non-ferrous metallurgy - by 2.3 times. Despite this, production of oil with condensate decreased by 1.4 times, gas - by 1.6 times, coal - by 2.0 times, iron ore - by 2.2 times, and manganese ore - by 3.6 times. The main factor in the growth of the share of mining industries is the transition to world prices for mineral raw materials, the preservation of the markets for iron, manganese and titanium ores, facing stones and certain other types of minerals [23,3].

Subsoil depletion and the formation of an industry structure burdened by heavy industries are accompanied by significant long-term environmental consequences. This is due to saving on environmental costs at the stages of eld development that gives a significant economic profit. At the same time, the costs for the elimination of the consequences of emergency environmental situations, accidents, and disasters often exceed the pro t from mineral raw materials sale [3].

The biased structure of the economy in the direction of heavy industries and the depletion of the mineral base with the accumulation of negative environmental consequences contributed to the development of a deep economic crisis in the Soviet Union in the mid-1980s. Western countries experienced similar crises back in the 1970s, from which they came out by restructuring their economy with the reduction of heavy industry and the development of knowledge-intensive industries [3]. The economic crisis in most states of the post-Soviet space continues to deepen, and it is exacerbated by a long-lasting and powerful environmental crisis. Ukraine is still in a crisis situation today, despite some signs of stabilization of its economy that was actually achieved as a result of the stabilization of mineral raw materials mining [3]. However, wear and tear of equipment at mining enterprises is very high (up to 70-80%). Due to imperfect technologies of extraction and mineral raw materials processing, and unsatisfactory solutions of issues of comprehensive development of deposits, there are up to 70% of explored oil reserves, up to 50% of salts, up to 28% of coal, and up to 25% of metals that remain in the state's subsoil [27,3].

Ukraine may enter a period of technogenic emergency situations, accidents and catastrophes. Sustainable development of the mining industry can only be ensured by innovative activities. Technical re-equipment of mining enterprises should be carried out to reduce losses of minerals during their extraction and processing; as well as to ensure industrial safety [3].

The analysis of the mineral base of Ukraine gives reason to include into promising types such as non-traditional mineral raw materials for the country as native gold, native copper, rare metals, vein quartz, and various types of precious, manufactured and decorative stones. With certain caveats, this list also includes diamonds and the prospects for opening their deposits have increased [3]. It is predicted that these types of mineral raw materials, after detailed exploration and further exploitation, will lead to the improvement of the state's economic condition and the development of gold and copper ore, rare metal and quartz industries. To expand the prospects for the development of the mineral base, it is necessary to expand the development of such minerals as brown coal, shale gas, and development of non-traditional energy sources, in particular gas-methane from coal deposits and gas hydrates [3].

Ukraine actively participates in the integration processes in the European and world communities. Most industries are related to the functioning of the domestic mineral base. The state's level of development affects the organization of exploration and exploitation of subsoil and the development strategy of its mining industry. Developed countries, even having their own mineral base, are focused on investing in the mining and processing of mineral raw materials in other countries and their imports [3]. Developing countries, on the contrary, count on the intensive use of their own mineral deposits for economic development and obtaining profits from the export of raw materials. The current state of the domestic economy is characterized by a significant export orientation of the mineral base and, at the same time, a high level of industry dependence on imported supplies of certain types of minerals, especially oil and gas [3].

The level of mineral reserves in Ukraine depends on many factors. An example is the situation with stocks of flux raw materials for metallurgical enterprises. Ukraine has been provided with dolomite reserves for many years, but providing enterprises with high-quality raw materials is a difficult problem and is possible only by increasing extraction in Southern Donbas, which is currently occupied [3]. An acute situation has developed with flux limestones, the main reserves of which are also concentrated in Donbas. Several large deposits lie at significant depths or occupy arable land, so a proper economic and ecological assessment of their exploitation options is required. Therefore, the prospects for discovering new deposits of high-quality raw materials are limited [3].

The state is interested in protecting the national producer and promoting the development of export-oriented industries. In Ukraine, industries that secure export growth and, accordingly, are sources of foreign hard currency ow into Ukraine, are material- and energy-intensive and are interconnected with the development and prospects of the mineral base [3]. Today, subsidies are widely used to stimulate exports which causes various forms of dumping. In other cases, we have the export of minerals that have not been converted into a product of intermediate or final consumption. This leads to great losses for the economy of the state, since the prices of raw materials and final production di er by tens or even hundreds of times. This indicates a predatory attitude towards the mining industry and causes depletion of the subsoil without obtaining an economic effect [3].

In the development strategy of Ukraine, it is important to outline the directions of movement in the field of geological study and use of subsoil [3]:

1) a need to build up reserves of mineral resources, provided that the balance reserves of minerals will be enough for hundreds of years;
2) a need to increase the volume of mineral extraction with significant reserves and complex geological conditions and adverse environmental consequences of the development of deposits;
3) to attract investments in the study of deposits of fuel and energy raw materials, both traditional (oil and gas, brown and hard coal, peat), and unconventional (shale gas, coal-bed methane, gas hydrates of the Black Sea shelf).

4. CONCLUSIONS

Analysis of modern approaches to solving the problem of effective mineral raw materials use and mining waste allows us to state the following [3].

1. Efficient use and protection of the subsoil is a part of rational nature management in the mineral base of Ukrainian regions and Ukraine as a whole. Rational nature management should be understood not only as the optimization of the processes of intensive use of natural resources and their protection, but also as a system of measures covering the protection and control of the state of the environment, the reproduction and preservation of these resources, the effective use of capital investments in mining enterprises, and the placement of productive forces in the region.
2. The components for the rational use of the subsoil include a comprehensive development of mineral deposits, a comprehensive use of mineral raw materials and mining waste, optimization of the structure of mining production and mineral raw materials consumption. The maximum satisfaction of society’s needs in certain types of raw materials at specified costs and under the condition of compliance with environmental standards can be considered as a criterion for an effective and optimal use of mineral resources.

3. The rational use of mineral resources in the modern interpretation of this issue extends to all stages of their development, including the issue of waste disposal. Solving the waste problem is limited to covering those groups and types of subsoil resource processing waste that are direct substitutes for certain types of mineral resources. They are grouped under the name of mining waste.
4. A huge amount of mining waste has accumulated in administrative regions of Ukraine, and the issue of their disposal has gone beyond just an economic and ecological problem and has acquired a significant socio-demographic significance. Mainly, this applies to densely populated areas of Donbas, Kryvbas, Pre-Dnieper and Pre-Carpathian regions, where waste density varies from 2-3 to 10-30 million t/km^2. There are no such similar loads in any country in the world.
5. Environmental problems have become particularly acute due to the accumulation of toxic waste, among which the most dangerous are heavy metals, petroleum products and acid tars. Ukrainian enterprises generate up to 100 million tons of toxic waste every year, of which more than 3 million tons belong to I-III hazard classes. The total volume of toxic waste accumulation is 4.4 billion tons. In Ukraine, there is no plant for the processing of toxic industrial waste or landfills for their disposal, and the conditions for storing and eliminating waste do not meet sanitary and hygienic requirements.
6. For sustainable economic development of Ukraine, it is necessary not only to develop new reserves of natural mineral resources, but also to utilize technogenic, secondary, and unconventional mineral resources, which are accumulated in over 1,600 technogenic deposits and objects. Technogenic deposits of various minerals represent a powerful reserve mineral resource base for the development of the mining industry. They contain non-ferrous, rare, precious, and black metals, as well as rare-earth elements, non-ore, construction and energy raw materials, mineral fertilizers, limestone and gypsum ameliorants, and so on. The development of technogenic deposits in Ukraine would expand the resource base of mining and metallurgical, coal and mining-chemical industries by 15...20%. Up to 30% of extracted overburden and associated rocks, as well as waste from their beneficiation, can be utilized for the production of various building materials.
7. The comprehensive utilization of mineral resources can only be achieved through the development and implementation of advanced modern technologies in the areas of exploration, extraction, enrichment, and processing of raw materials. In general, solving the problem of rational use of mineral resources, as well as natural resources in general, is related to the development and implementation of waste-free technologies. A geological assessment of waste as technogenic deposits is also necessary (determining the nature of the distribution of useful components in waste masses, studying their technological characteristics, determining the amount of reserves, etc.). Only after carrying out a complex of such assessment works should the issue of ways and methods of waste utilization in specific territories be addressed. Priority should be given to

environmental protection measures accompanying current mining-industrial production.

8. Currently, scientific research aimed at addressing such problems as improving existing and developing fundamentally new methods for extracting useful minerals from subsoil and useful components from complex mineral raw materials and mining waste; developing methodologies and technological schemes for studying the distribution of useful components in ores and enclosing rocks at the geological exploration stage; and developing an ecological and economic assessment of complex deposits, among others, remains relevant.

9. The main factors that have influenced the economic development of Ukraine, based on intensive and prolonged use of mineral resources, include: 1) the gradual depletion of subsoil; 2) the formation of an economy skewed towards heavy industries; and 3) the accumulation of long-term negative ecological consequences. An economy deformed towards heavy industries requires four to five times more material, capital, energy, mineral, and other resources compared to economies with a balanced industrial structure, where a significant share is comprised of light industry, the service sector, and modern knowledge-intensive production. Depletion of subsoil and the formation of an industrial structure overloaded with heavy industries are accompanied by the accumulation of significant long-term ecological consequences.
10. Further development of Ukraine’s mineral and raw material complex requires urgent resolution of state-level problems that significantly hinder the expansion of the mineral and raw material base, its ecological rehabilitation, and its rational use. The current system of subsoil use in Ukraine does not meet the requirements of modern market economics, and there are no unified requirements or rules for subsoil use and determination of payments for their use in economic theory. Although Ukraine’s mineral and raw material base has sufficient reserves of many types of valuable minerals, some of them are in the stage of depletion, which requires reform of the economic and ecological mechanism for using mineral resources. In strategic terms, it is important for Ukraine to determine the direction of movement in the field of geological exploration and subsoil use.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Biography of author(s)

N B Panteleeva
Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine.

Research and Academic Experience: She graduated from the Kryvyi Rih State Pedagogical University with a major in "Geography and Biology" and qualified as a teacher of geography and biology. She completed her master's degree at Kryvyi Rih State Pedagogical University, majoring in "Pedagogy and methods of secondary education. Geography". She studied at the postgraduate school of the Ternopil National Pedagogical University named after Volodymyr Hnatyuk, majoring in "Constructive geography and rational use of natural resources". She has experience in secondary school. She works as an assistant at the department of Geography and its teaching methods at the State Pedagogical University, Kryvyi Rih, Ukraine. The topic of her scientific research is "Territorial organization and ecological and geographical aspects of the functioning of the mineral and raw material complex of the Dnipropetrovsk region." She also actively participates in the work of the scientific laboratory of teaching methods of geo-information technologies.

Research Area: Her areas of research mainly include constructive geography of mineral resources, mineral resources Dnipropetrovsk region, and geoinformation technologies.

Number of Published papers: The results of her research work are covered in 54 publications, 12 of which are in Scopus, 1 in Web of Science, and 7 in specialized publications.

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