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MODERN ENVIRONMENTAL AND ECONOMIC APPROACH OF MINING INDUSTRY

In the article, the need of transition to the rational subsoil use (the alternative mining approach) is proved, which unlike general one supposes the increasing of extraction rate of valuable components in the deposit and multiple use of raw materials, the maximizing recycling, the decreasing of land occupation, the increasing of the development period of deposit at some income decrease up to the moderate level, which is enough to provide the attraction for investors.

The multicriteriality is considered as the crucial principle of rational subsoil use at taking management decisions, i.e. the considering of ecological, economic and social targets, aimed at receiving moderate profit at proper social and environmental standards. The graphic representation of models of the general

mining approach and the alternative one allows to emphasize the specified advantages of transition to rational subsoil resources development and reflect them in design equation.

In the paper, three performance strategies providing the implementation of the alternative approach are offered: full-field development, application ecologically and economically effective systems and the development processes, consideration of reclamation and minimization of long term environmental effects of mining.

Keywords: alternative mining approach, moderate profit, sustainable development, performance strategy

Recently the stimulation of oil extraction processes have been characterized by growth of negative impacts on the environment and landscape modification. The reason is that the considerable part of the world market of mineral raw materials is supplied by the countries of underdeveloped legislative base and low requirements for quality control and safety. As historical development of production proceeded from readily available deposits with the high maintenance of commercial components to mine development with lower contents and difficult conditions of production. Today, growth of expenses expected to be in the future, despite the parallel development of technologies. As the result, rational approach to design of mining processes of ecological and economic aspects and the existing technical potential of mine development with less waste is an issue of prime importance. The presented strategy is based on the rational use of deposit potential, application of environmentally friendly technologies and demanded actions for contaminated soil remediation integrated into a planning process and conducting production. This strategy leads to economic effects and promotes decrease of environmental pressure on the environment being the significant contribution to a sustainable development of mining processes.

Essentially the sustainable development is understood as the balanced development of economic, ecological and social spheres influencing at each other (fig. 1).

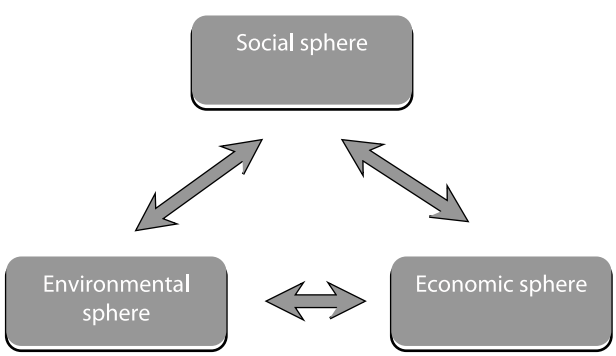
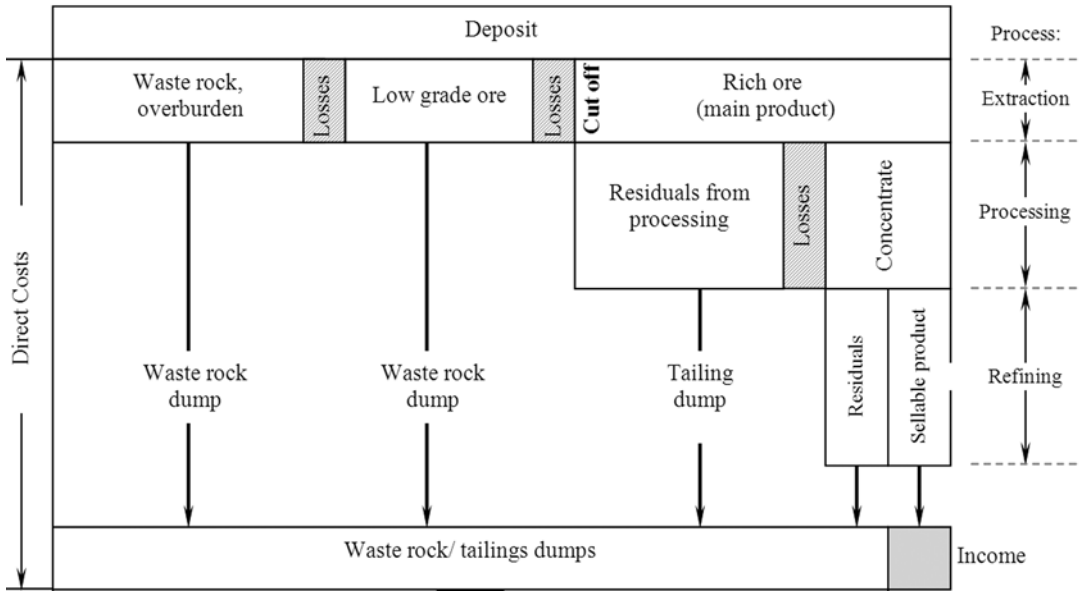


Рис. 1. *Principle of a sustainable development*

Advantage belongs to social issues of society development. The principal idea of sustainable development is that any consumption of material and energy resources has to be caused by consciousness of social responsibility for future generations. For the first time, this idea was opened by the head of the mining inspectorate of the kingdom of Saxony Ghanaian Charles von Karlovitts (Hans Carl von Carlowitz). In his work «Sylvicultura Oeconomica» issued in 1713, he proves the need of landing a new tree instead of each cut down.

The main objective of mining into a market economy is a preference of fast and maximum profit from the invested capital for steady investment. In case projects of the mining industry in the future have to correspond to the principle of a sustainable development; therefore, the imaginary conflict between profitability and profit, on one hand, and additional expenses for the ecological and social interests induced by the project, on the other hand are objectified. The important principle of an objectification of the approach is the general consideration of being in complex interaction economic, environmental and relevant, social factors, and also comparison by comparative criterion of possible scenarios. Meanwhile, the maximum profit is not always in the attention center. Under certain circumstances, it makes sense to aim at moderate profit to conform to higher environmental and social standards and at the same time to develop steadily. Rational approach to deposit potential at the design of the mining enterprises allows reducing considerably impact of mining operations on the environment, but the profitability of the enterprise will be characterized by the moderate income.

For example, the project of optimization of the cutting process leads to reduction of energy consumption, wear and dust development during the cutting process and also decrease in power consumption, materials (the dust release of the working body caused by additional expenses), and also considerably decreases a dust release that leads to the reduction of expenses for fight actions against dust.



Indirect costs:
- Land occupation costs
- Environmental protection costs/Health care
- Reclamation costs
- Long term costs (decrease of land value, climate change)
- Monitoring costs

Fig. 2. *General mining approach*

As a whole expenses and emissions and morbidity rate of staff of the mining enterprise will decrease.

The main characteristics of general mining approaches are concentration of production on one main product and getting maximum P_{DG} profit from its realization. In this case, they seek to minimize direct costs i.e. the direct expenses connected with the release of a product (costs of extraction, processing, refining) that allows providing the maximum P_G profit. Additional expenses, as a rule, are hardly considered.

$$\text{(Maximum) Profit}_{PG} = \text{Income}_{OG} - \text{Direct Costs}_{CDG}. \quad (1)$$

Not optimized processes with relatively high losses of valuable components lead to the high volume of waste material being in storage. That conducts to the growth of the indirect costs (C_I) of the mining industry (fig. 2).

Generally C_I indirect costs can be summarized by following Formula:

$$C_I = C_L + C_{IN} + C_H + C_{LTI} + C_R + P_C. \quad (2)$$

Where C_L — costs connected to land occupation (rent, compensations of loss of the income and (or) decrease in fertility, etc.); C_{IN} — costs connected to environment (prevention, burial, monitoring of negative changes (pollution) of environment, in particular, lands, water and air); C_H — costs for health care (similar to environmental costs in relation to a human body); C_{LTI} — costs for long-term investment (Early end of deposit reserve); C_R — costs for contaminated soil remediation; P_C — profit from additional costs (for example, from realization of deposit remediation).

Indirect costs depend on the level of impact on territories, on time of influence, changes and extent of extraction, use of a deposit.

The general mining approaches correlate to high need for the areas and a considerable level of pollution. In usual programs of the mining industry, the need for the area and the potential of contamination are rather high. Negligence to the potential of deposit leads not only to income loss, but also to additional expenses. Therefore, the development of the alternative concept of the mining industry is necessary (fig. 3).

Moderate profit according to the alternative mining approach is defined as follows:

$$P_A = I_A - C_{DA} - C_{IA}, \quad (3)$$

where P_A — profit; I_A — income; C_{DA} — optimizes direct costs; C_{IA} — optimized indirect costs.

Lower indirect costs can be decreased according to the most rational approach to the passing and minor products of mining, higher extraction of use-

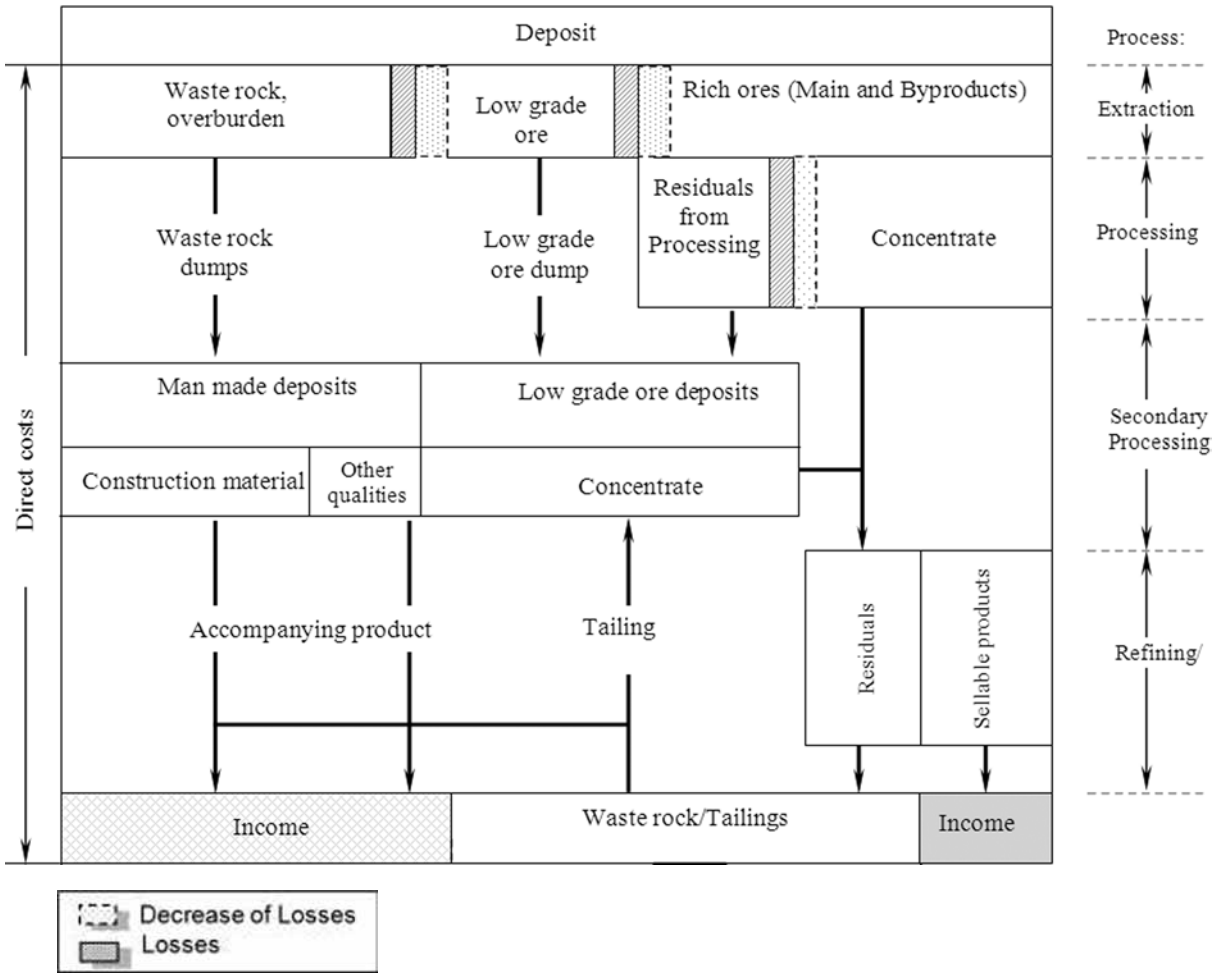


Fig. 3. *Alternative mining approach*

ful component, and also inclusion of poor ores and enrichment waste in a production chain. As a rule, it leads to increase directs costs and cost supplement of mine-mill processes. However the aim at moderate income allows optimizing direct and indirect costs. In this regard, complex and objective studying of influence of ecological level on the economy of the project takes the central place. Moderate is a profit, when the level is attractive for investors with high environmental and social standards i.e. level of profitability of the invested capital has to be taking into account risk at least in a limit of bank percent.

An example of the mining enterprises working according to the concept of the moderate income is the enterprises with not joint-stock form of ownership (for example public funds or family property). The dependences of C costs, I income and P profit on K_{EX} extraction coefficient of commercial elements from M ore mass illustrated in fig. 4 and 5 at the general and alternative approach.

— Income is raised in direct ratio to coefficient of extraction. It is result production volume multiplied by the price of product unit PRP:

$$P = M \cdot K_{EX} \cdot P_{RP}; \quad (4)$$

— direct costs of C_D are raised according to increase of coefficient of extraction. The higher is K_{EX}, the quicker growth of costs.

$$C_D = f(K_{EX}) \rightarrow \max; \quad (5)$$

— indrect costs of C_I are decrease with increase of coefficient of extraction. The higher is K_{EX}, the quicker decrease of C_I costs.

$$C_I = f(K_{EX}) \rightarrow \min; \quad (6)$$

— the subtraction of costs from income is profit. At the corresponding ratio between the C_D and C_I reveals a maximum:

$$P = I - (C_D - C_I). \quad (7)$$

According to the comparison of the general mining approach (index «*G*») illustrated in fig. 4, with the alternative approach (index «*A*») illustrated in fig. 5, the conclusions as follows:

— coefficient of extraction and profit at the general approach usually less compared to at offered alternative approach

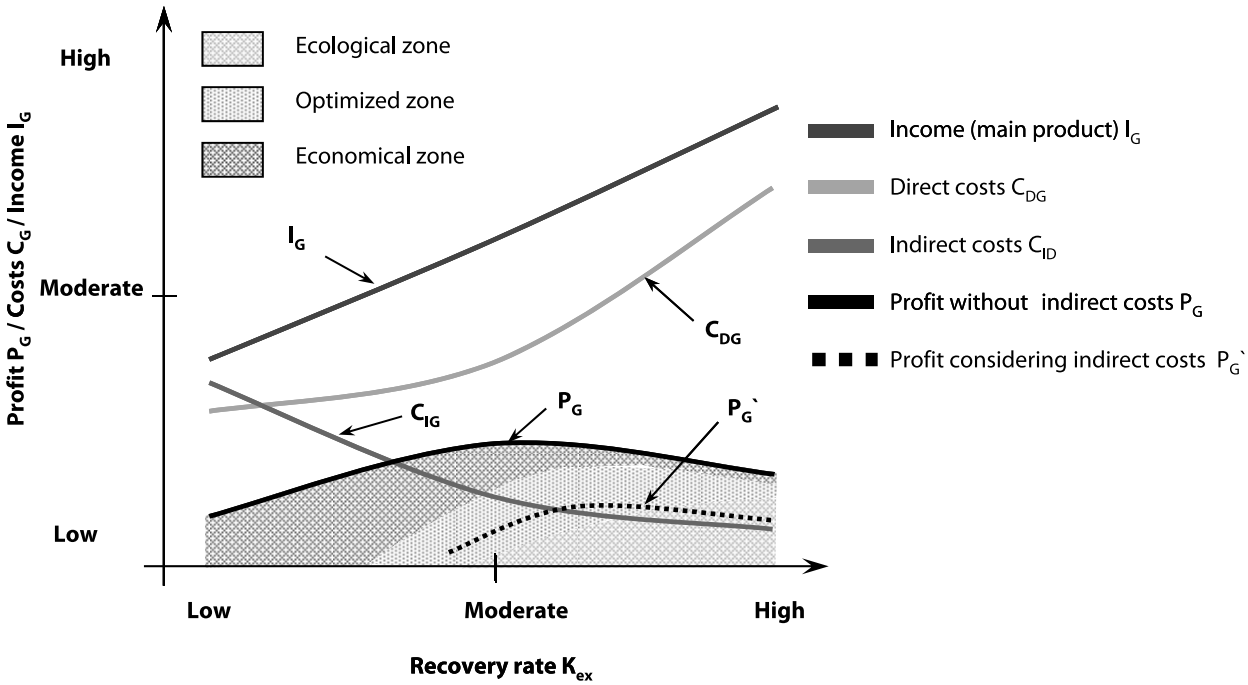


Fig. 4. *Economic parameters of general mining approach, depending on extraction level*

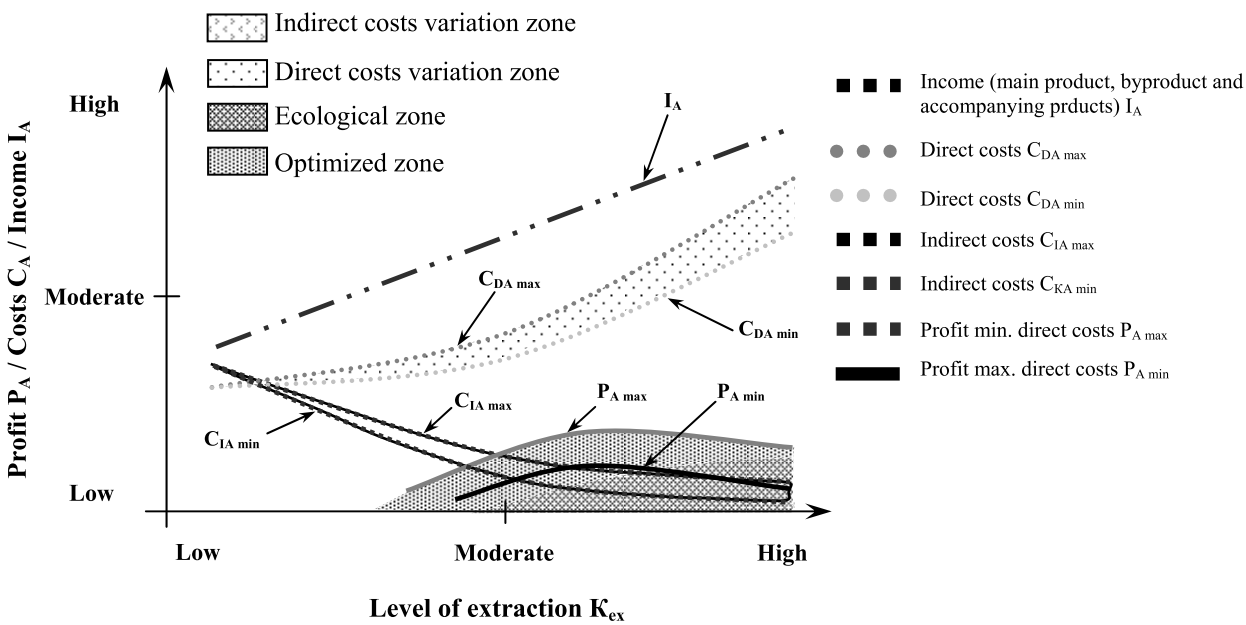


Fig. 5. *Economic parameters of the alternative mining approach depending on extraction level*

$$I_G < I_A, K_{EXG} < K_{EXA}; \quad (8)$$

— application of innovative technologies in the alternative approach may decrease or increase direct or indirect costs in relation to these indicators at the general concept (variation zones of costs in figure 5). General increase of C_{DA} decrease C_{IA}:

$$C_{DG}, C_{IG} < \text{or} > C_{DA}, C_{IA}; \quad (9)$$

— other things being equal, the profit $P_A < P_G$, as P_A considers C_I indirect costs of the mining enterprise. Moreover, effects of increase of extraction are considered as well, and also influence changes of C_{DA} and C_{IA} therefore, P_A changes in the certain range concerning P_G. Meanwhile, at the minimum values of costs of $C_{DA\min}$ and $C_{IA\min}$ the profit is maximum $P_{A\max}$, and at the maximum indicators of costs of $C_{DA\max}$ and $C_{IA\max}$ the profit is minimum $C_{A\min}$. In fig. 6 the summary image of the stated is presented. It is meant that increase of the coefficient of extraction of K_{EX} на ΔK_{EX} decrease profit of P on ΔP if consider all costs as C_D and C_I.

The profit of the alternative approach P_A is considered as the moderate income. Wherein the mining enterprise with the alternative concept assumes

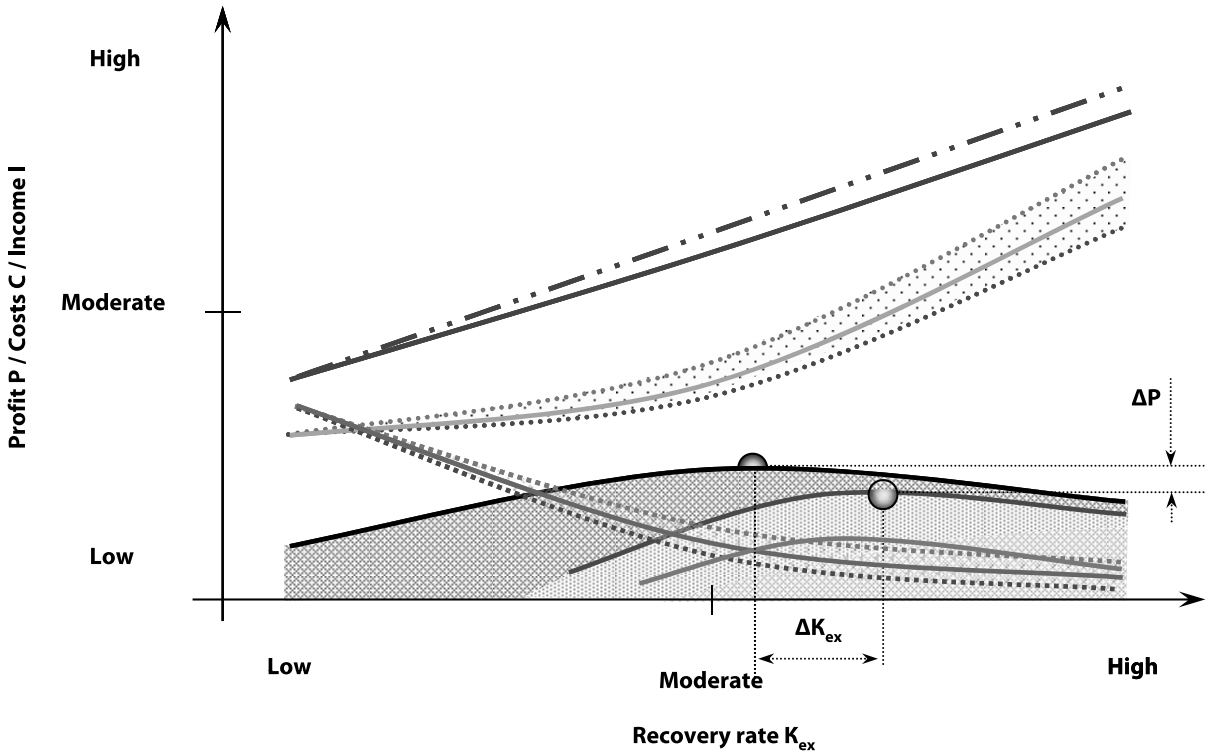


Fig. 6. *Comparison of the general mining concept with the alternative one*

not aiming at the obtaining the maximum profit but working in such mode when the profit allows providing normal economic activity of the enterprise taking into account all expenses.

Realization of this approach is possible only at other considerably different consciousness, assuming understanding of economic responsibility. If the state promotes the principle over the profit, pursuing the aim at receiving high tax payments, realization of this approach is impossible because of in such system at low profitability of the enterprise its competitive capacity decreases. People usually are not ready to pay more for more eco-friendly product or process.

This approach also creates barriers to the interests of stockholders interested in getting high dividends without environmental friendliness of a product, otherwise — the selling of stock may lead to full closing of the enterprise. As a result, it is required set of incentives from the state promote outputting of high ecological products. The interrelation between environmental and economic aspects of the mining enterprise is illustrated in fig. 4–6 by corresponding zones.

Ecological zone:

— the curve of indirect costs in this place on graphics testifies the high environmental friendliness of the mining enterprise;

— the curve of profit in a zone of environmental friendliness testifies that the enterprise is unprofitable and demands to subsidize owing to the high environmental friendliness.

Economical zone:

— at the developed general approach a mining enterprise aim at the curve of profit to be on an edge of this area for the purpose of obtaining the maximum profit;

— the C_{IG} indirect costs in the field are maximum in comparison with other options, but, as a rule, they are not considered by the enterprises. The accounting of indirect costs leads to the P_G profit curve to be appear in an environmental friendliness zone;

— this area is characterized by the decrease P_G after point of maximum and further increase of extraction of K_{EX} as higher extraction is characterized by considerable technical and technological costs of C_{DG}.

Optimized zone:

— P_A profit curve of environmental and economic enterprise is usually in this zone. In this case, the enterprise has the moderate profit using the maximum potential of deposit and minimum impact environment (from the point of view of profitability, i.e. the working without subsidizing);

— the curve of indirect costs testifies to the compliance of the mining enterprise to all requirements of environmental friendliness;

— the curve of $P_{A\max}$ profit is possible at application of the technical and technological decisions

allowing at $C_{DA\min}$ minimum direct costs to raise the level of extraction, to consider indirect costs and to work thus with the maximum moderate profit.

Realization of the considered approach is based on the method of an environmental and economic estimation of mining concentrating enterprises meeting the requirements of balance of environment and modified for the purpose of application in mining. The mining and concentrating enterprises may do considerable contaminate the environment and landscape. So, for example, negative impacts on the environment are made by noise, dust, concussions and allocations of gases along with high consumption of materials and energy to which production also impacts on the environment, carrying out a complex assessment of flows in the system of mining and concentrating enterprise and load of the environment, falling on the mass of the made product is necessary. Along with aspects of environmental friendliness it is necessary to take into account the technical feasibility and profitability of the process since not each option of technological processes of extraction and processing being characterized high environmental friendliness is practically applied. It takes place in those cases when costs considerably exceed indicators of other options, and their covering subsidizing is not possible.

At the heart of this approach lie three actions helping reach both economic and environmental improvements of work of the mining enterprises, reducing the negative impacts of mining:

1) full-field development;

2) application economic and ecologically effective systems and development processes;

3) consideration of reclamation and minimization of long term environmental effects of mining.

The environmental and economic assessment is a system of elements being in complex interrelation with aspects of social character as a whole and perception by the public of mining — in particular. The last strengthens influence of economic and environmental factors in the system of environment balance as high economic efficiency and the demands made to standards of environment, allow having created workplaces, to increase social and economic welfare of the population without drawing a significant damage.

The choice of equipment and technologies in the mining industry is majority based on criteria of profitability and application of thus checked technical solutions. In the countries with the developed legislative and legal basis environment, protection demands an assessment of the negative impact on the environment made by the mining industry, for the purpose of its compensation. The complex assessment and studying of alternative methods of extraction and their impact on the environment for choice of environmentally friendly mining technology are not so safe because of lack of methodical bases. Therefore, methodical bases of estimation and choice of system of development taking into account environmental and economic aspects are necessary.

Implementation of the decision. Today's planning methods of field development are not good. Considerable ore resources are not used because of losses during extraction, processing and transportation. The existing approach to the potential developed fields leads to the need of early development of new deposits that in turn demands earlier investments.

In this regard, the costs caused by the traditional mining technologies as well as negative impacts on the environment, caused by their application are estimated critically that requires of development of alternative approaches that reduce the negative impacts of mining. This circumstance can lead to negative economic and environmental consequences after development of deposits, which elimination demands additional costs.

In isolated cases exists both reasoning, and practical examples of more rational development of deposits. Complex use of the industrial potential of mining seldom observed in practice private aspects are in most cases considered. As a rule, in the conditions of market economy is realized only part of the actions, being characterized by a high degree of profitability in the short-term period. This approach contradicts both to economic requirements and requirements of a sustainable development while rational approach to the potential of fields is characterized by long-term positive results from held activities and put investments, thus increases both the general time of equipment operation, and efficiency of depleted resources. The part of byproducts and accompanying products for the main productions subject to utilization and demanding capital investments, as, for example, elimination of ecologically objectionable material of the mining and processing enterprises demanding to carry out extensive actions for safety and control is coincidently reduced. At the same time, implementation of measures for complex development of deposits can be characterized by positive economic effect and at the same

time lower negative consequences of impacts on the environment. Therefore at an initial stage of the design of the mining enterprise is necessary preliminary research for the purpose of effective and steady formation of flows of raw materials at all levels of productions.

What dose comprehensive approach of field development includes. Extraction of byproducts and accompanying products: Extraction of byproducts and accompanying products: rational approach to the potential of the field demands in the presence of accompanying components of inclusion them in the production process on condition of economic profitability. This is corresponding to the concept of a sustainable development of the mining enterprise taking into account decrease in impact on the environment and the creation of additional workplaces. Profitability of implementation of byproducts and accompanying products makes expediency and the advantages of their extraction to option when they are the main object of extraction. In case of the unprofitability of implementation of byproducts and accompanying products for mining enterprise, it needs to develop such strategy of their stock, which allows with minimum expenses to include these technogenic fields into a mining and processing cycle. Accompanying components at field development may be the materials extracted and processed together with the main product, as, for example, the associated ores. Byproducts are presented by the materials of a field developed separately from the main product, for example, by overburden rock at developing of ore or coal fields used as raw materials for building industry [2].

Application of poor ores and low-grade ores: it is possible to include raw material resources of next years the low maintenance of commercial element, subjected to extracting at field development owing to the development of working space of open-cast mine. The product is stored in stockpiles of poor ores and low-grade ores which at that time do not represent economic interest. However the price escalation and development of technologies allow including them in a technological chain as an additional source, as well as the main component, and an accompanying one.

Making technogenic fields: as a result of processing, the considerable volumes of byproducts are annually allocated, that caused by the distinction of mineral elements depending on mining field. At hydraulic laying of these units in stockpiles by management of parameters of shore deposition owing to fractionation of particles creation of technogenic fields with the set distribution of a useful component. An example of it is coal slimes and slimes of refining phosphoric ores.

Application of wastes for improvement of quality of lands at a contaminated soil remediation: The decrease in volumes of waste kept in the stockpile and received at various stages of conducting technological process is one of rational ways of increasing both ecological and economic indicators of the enterprise, along with an introduction of low-waste technologies at mining. This can be achieved by selling these products. Thermal power plant ashes are a popular example, the ashes received at coal firing, cannot be stocked at large volumes properly especially when its ash-content is high. At the same time, thermal power plant ashes have a number of characteristics depending on which it is possible to sell them in a field such as road and landscape construction, production of cement, agriculture, land reclamation and et cetera. Another example is slimes of processing of phosphate ores, containing, besides phosphorus, a number of commercial components, for example, potassium, magnesium, calcium, iron capable do favorably affect on the biological productivity of soils. As a result, one of the best ways of its utilization is applying as mineral fertilizers.

To effective waste management of byproducts of mining and processing cycle besides the decrease in load of the environment (such as, dusting of dumps and storages, alienation of landtake and etc.) is the decrease in a requirement for other natural raw material resources, replaced by these technogenic raw materials, and also the cumulative economic effect connected to it.

Application of economic and ecological effective systems and development processes. Along with the development of commercial components from byproducts and accompanying raw materials at the same time is necessary to consider innovative technologies and technical solutions of mining providing environmental friendliness of production considering economic aspects: application of alternative sources of fuel for the mining equipment, environmental and economic approach to production materials. For example, application of biodiesel fuel for mining cars instead of mineral machines.

Reduction of dust development and process optimization during the cutting process. Dust development is the result of the cutting process it influences negatively and dangerous for health, environment

and etc. The analysis of the cutting process shows that dust formation depends on set parameters of cutting and can be reduced. Required efforts and energy consumption can be reduced at the cutting process. That has an economic positive effect along with improvement of health and the environment.

Management of processes of extraction and processing. Traditional ore processing, for example, copper or gold, is based on the crushing, the grinding and pyrometallurgical or hydrometallurgical milling methods. Therefore, the main purpose is to load the crushing machine with the average maintenance of commercial component. The mechanical characteristics of rock are not considered enough, particularly their fortress, granulometric structure, and also texture and structure. With loading the ores characterized by certain mechanical properties and mineralogical structure, reduce energy consumption and losses of processing by application of suitable technology of parallel or consecutive processing are possible. The result is achieved as well as economic and environmental effects.

The third crucial issue of environmental and economic aspects applied of producing method, covering questions of remediation and consequences of field development is the integrated accounting of requirements of contaminated soil remediation [3].

Planning method of contaminated soil remediation. When planning approach of field development it is necessary to develop the basis for reducing the environmental impacts and increasing the recovery rate in the post mining landscape. As a rule, the geological field substrata possessing certain qualities according to the purpose of the applications, i.e. low acidity and high fertility are used for the design of further landscape. Costs for separate extraction and warehousing of a substratum are considered in the planning process of production. It provides the reliability of reclamation at any moment.

Further application of territories mining industry. Planning of application of the territories of mining enterprises after its closing is another issue that should be considered. Early stage of planning of further application of territories mining industry helps to reduce costs and volumes of technical actions for their design and allow derive a profit from the realization of these areas.

Model of evaluation for long term mining expenditures. Another evaluation issue is to define the costs for long term mining impacts created during mining operation and sufficient financial fund for fighting against negative influences. The typical example is the formation of acidic waters at progressing aeration of sulfuric connections or carrying out of earlier created acid potential. In the ore deposits, formation of acid waters leads to dissolution of heavy metals depending on their concentration and the result are various negative consequences. The certain approach of overburden rocks helps resist the formation of acid waters during basic technology processes that will reduce long-term costs of next years. Otherwise, the question of financing and organization of solution of long-term tasks remains unresolved.

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