Assessment of socio-eco-economic effectiveness of circular business models in mineral production

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Abstract

Introduction. According to Russian state reports on the environment, mining sector in Russia accounts for a significant amount of environmental impact.

Research aim is to substantiate a methodological approach to assessing the effectiveness of using environmentally friendly circular business models in mining enterprises.

Research methodology includes the study, critical assessment and systematization of the methods of environmental circular activity results determination in mineral production.

Research results. The effectiveness of circular business models is considered as a condition for their application. It consists of ecological, socio-ecological and eco-economic effectiveness, so it can be termed in an integrated manner as the socio-eco-economic effectiveness. Ecological and socio-ecological types of effectiveness are determined by the prevention, minimization or elimination of environmental and social harm. Considering that environmental and social losses, for well-known reasons, can never get a fair integrated assessment, in practice it is necessary to apply the indicators of ecological and socio-ecological damage, which do not fully reflect the amount of harm caused. The eco-economic effectiveness of circular business models is associated with the prevention, minimization or elimination of national economy's (economy of the country) existing or possible losses (damage) and/or additional costs caused by human impact to the environment in the process of subsurface use. In this case, we are talking about reducing the amount of eco-economic damage.

Research results application. The research makes it possible to study and systematize currently proposed methods for assessing the extent of environmentally related damage caused by mining. The methods considered are intended to be applied in assessing the ecological, socio-ecological and eco-economic effectiveness of environmentally friendly circular business models in this field.

Key words: mining; circular business models; environmentally related damage; socio-eco-economic effectiveness.

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Introduction. According to Russian state reports on the environment (*Minprirody* (Ministry of Natural Resources and Environment of the Russian Federation). State reports “On the state and protection of the environment in the Russian Federation”. Available from: http://www.mnr.gov.ru/docs/gosudarstvennye_doklady [Accessed 09 March 2020]), in Russia it is the mining sector that accounts for a significant amount of environmental impact. The comparative analysis of negative environmental impact indicators made by main industries of the Russian Federation, categorized in accordance with OKVED (Russian National Classifier of Types of Economic Activity), in 2010–2018 reveals a great impact into air contamination made by mineral production by means of discharging pollutants into the outer air from the stationary sources.

Nevertheless, a yet more harmful environmental impact by this type of economic activity is made by generating industrial and consumer waste (table 1). On average, it accounts for 91.4% of total waste.

The statistics of the extent of the damage made by the subsoil use on various elements of the environment and different research results [1–3] convince of the need in improving the level of environmental friendliness of mining processes, particularly by applying environmentally friendly circular business models. The latter are aimed at implementing the concept of circular economy (an economic system of closed loops) focused at forming the economy of closed delivery chains, similar to natural [4–9].

Table 1. Comparative characteristic of the negative impact on the environment caused by the main types of economic activity in Russia in 2010–2018

Таблица 1. Сравнительная характеристика негативного воздействия на окружающую среду основных видов экономической деятельности, осуществляемых в России в период 2010–2018 гг.

Indicators of the negative impact on the elements of the environment	Mean in 2010–2018 by the main types of economic activity					
	Mineral production	Farming, forestry, hunt, fishing and fisheries	Processing	Electricity supply, gasification, steam distribution, air conditioning	Other types of economic activity	Total amount
<i>Effect on the outer air</i>						
Total amount of pollutants discharge into the outer air from the stationary sources, in total, t	5176.8	189.5	5868.6	3751.4	3128.0	18110.8
<i>Water management</i>						
Water withdrawal from natural water bodies, mln m ³	3165.9	16982.2	4986.3	41888.4	6369.2	71333.0
Dirty discharge into the surface water bodies, mln m ³	854.6	807.5	2676.1	6843.6	3726.9	14886.6
Water leakage when transporting, mln m ³	16.2	4327.2	93.2	2448.5	532.4	7198.1
Fresh water, mln m ³	1977.9	8863.5	5094.1	37056.8	4084.3	55666.2
<i>Waste production</i>						
Industrial and consumer waste, mln t	4811.6	37.8	299.9	35.8	76.6	5261.7
<i>Efficient energy use</i>						
Total energy consumption, mln TOE	90.6	18.0	405.1	68.2	561.2	1148.2

Source: compiled by the authors in accordance with the data from State reports “On the state and protection of the environment in the Russian Federation”

Research aim is to substantiate a methodological approach to assessing the effectiveness of using environmentally friendly circular business models in mining enterprises.

Research methodology includes the study, critical assessment and systematization of the methods of environmental circular activity results determination in mineral production.

Research results. The effectiveness of circular business models, which takes into account the possible outcome for the nature, society and economy, is considered as

a condition for their application. Other conditions are commercial effectiveness, technological feasibility, and institutional (economic, legal, administrative) security. They are all interrelated (fig. 1). Without the indicated conditions, the idea of their realization in mining enterprises doesn't make sense.

The effectiveness of circular business models is a composite of ecological, socio-ecological and eco-economic effectiveness (table 2). This approach well meets the concept of calculating losses caused by the human environmental impact "per recipient". Natural environment (nature, ecosystems), society (human being) and national economy (country's or region's economy) are considered as scaled-up recipients in this case.

In this regard it is possible to apply a complex term of *socio-eco-economic effectiveness*.

Fig. 1. Conditions of applying circular business models in the field of mining

Рис. 1. Условия применения циркулярных бизнес-моделей в сфере добычи полезных ископаемых

Ecological and socio-ecological types of effectiveness are determined by prevention, minimization or elimination of environmental and social harm. This condition formulation is based on the authors' opinion that when describing the negative impact on the nature and society comprehensively it is correct to apply the concept of harm, not damage. Damage should be considered as that very part of environmental and social harm which is subject to evaluation carried out in the conditions of a particular direction and character of the evaluation work. Considering that environmental and social losses, for well-known reasons, can never get a fair integrated assessment, in practice it is necessary to apply the indicators of ecological and socio-ecological damage, which do not fully reflect the amount of harm caused.

In O. Ia. Glibko's opinion, "*ecological damage* is a very important component of environmental harm, which evaluates direct and indirect losses of natural resources and is subject to quantitative assessment" [10]. Research author considers it correct to distinguish between the concepts of "economic damage" and "ecological damage", seeing a fundamental difference in their relation to material losses in ecosystems; monetary evaluation of material losses in ecosystems are analyzed from the economy's point of view and environment-forming role – from the ecology's point of view. Due to the natural features' peculiarities, standard economic approaches to property valuation cannot be applied when evaluating the amount of harm caused to them (ecological damage). Ecological damage assessment is associated with pollution and depletion of natural ecosystems and destruction of ecological relations. The assessment has to be carried out "naturally" and expressed by the magnitude of ecological goods complex losses considering the following:

- any business operations or other activity connected with environmental impact is potentially harmful;
- losses in the natural environment may be connected not only with the direct reduction of particular ecological goods but also their growth;

- when assessing human impact, not only particular natural elements have to be considered, but the ecosystem in general, i.e. inter-organizational relations and their alternation;
- it is correct to assess the human impact taking into account some individual factor features of the ecosystem expressed in impact factor complexity;
- direct losses, as a rule, can be estimated with adequate accuracy, while the estimate of indirect losses is of a high-level character;
- when valuating the damage, time factor should be accounted through the estimation of exposure time and the period of restoration.

Table 2. The components of circular business models effectiveness**Таблица 2. Составляющие результативности применения циркулярных бизнес-моделей**

Recipients (negative impact objects)	Type of the ecologically related harm	Type of effectiveness
Environment (nature, ecosystems)	Ecological harm (harm caused to the environment)	Ecological effectiveness
Society (human being)	Ecologically related harm to the society	Socio-ecological effectiveness
National economy (country's or region's economy)	Ecologically related harm to economy	Eco-economic effectiveness

In the conditions of subsoil use when assessing harm to natural environment (which consists not only of the outer air, bodies of water, land resources, flora and fauna, but also mineral wealth), apart from the methods developed by biologists and ecologists, the methods for lithosphere impact evaluation (geological environment) should be taken into account which are developed by geologists and geoecologists. Iu. O. Slavikovskaia, L. V. Rudakova and R. B. Rudakov [11] distinguish between the biospheric and lithospheric types of damage. E. I. Panfilov in his article [12], dedicated to the analysis of technogenic impact on subsoil resources, proposes the notion of “geological damage” meaning damage done to the geological medium from human activity in the course of its investigation, field development (exploitation) and completion of development (mining), i.e. abandonment (temporary shutdown) of mine facilities.

The development of the feedstock base is connected not only with current, but also with the accumulated ecological damage; in accordance with *Rosproridnadzor (Federal Service for Supervision of Natural Resources Use) order of 25 April 2012 “On the establishment of Methodological recommendations on doing an inventory of facilities with accumulated ecological damage”* is characterize as “harm caused to the environment or its components as a result of business operations or other activities including violation of environmental law including material losses (expenditure) on mitigation and prevention of detrimental consequences from the environmental harm”. The sites with the accumulated environmental damage are “polluted territories including vacant territories which appeared as a result of former business activity, as well as waste disposal sites and other facilities (buildings, structures, and polluted land lots) which are polluted and accumulate pollution around, and where business activity was carried out in the past leaving waste which has negatively affected the natural environment”.

Accumulated environmental damage facilities inventory carried out in accordance with the instructions from the Government of the Russian Federation of 3 October 2012 no. DM-P9-5838 has made it possible, among other things, to distinguish between the following types of facilities with the accumulated environmental damage in our country: the results of former business activity in the field of mining and ore-dressing; oily

pollution; accumulated environmental damage facilities of the processing industry [13]. An overwhelming majority of the territories has been contaminated as a result of the former business activity in the field of mining and ore-dressing; land lots hosting dumps and tailing pits are usually either unowned or were/are owned by bankrupt companies being state-owned or municipally owned. According to the data from Russian Minprirody preliminary estimate, the most problematic constituent entities of the Russian Federation are Zabaykalsky Krai, Kemerovo region, Sverdlovsk region, and the Sakha (Yakutia) Republic.

Since 2014 the Federal target program "Elimination of the accumulated environmental damage" for 2014–2025 has started its operation; the aim the program is to restore the disturbed ecosystems earlier exposed to the negative man-made and technogenic impact as a result of former business activity. In order to achieve the goal, a solution to the problem has been specified on ecological restoration of the territories which have been exposed to negative impact from the facilities of the accumulated environmental damage as a result of former business activity in the field of mining and ore-dressing.

The accumulated environmental damage is conditioned by the accumulation of hazardous concentrations of pollutants in soil and water, while at the same time it is oriented towards reduction as soon as the natural environment possesses the assimilation potential associated with the process of adsorption (artificial substance decaying and their negative impact elimination) [14].

Socio-ecological damage is a component of the harm caused to the population as a result of human impact on the environment. Similar to the ecological damage, taking into account the peculiarities of population as a research object, when assessing the harm caused to the population (socio-ecological damage), some special methods of assessing the damage to life and health of population have to be applied. The assessment of socio-ecological damage has to be carried out "naturally" by medical scientists and expressed by the magnitudes of morbidity and mortality level rise and life quality and expectancy fall.

Both ecological and socio-ecological damages are associated with a number of technogenic risks of subsoil resources development, namely risks of strong technogenic impacts associated with the negative environmental impact in the conditions of normal (accident-free) business activity together with the risks of catastrophic technogenic impacts caused by technogenic catastrophes, accidents and incidents [15]. System analysis of methodological approaches to the assessment of the consequences of mining enterprises environmental impact is presented by the scientists of the Institute of Economics UB RAS [11, 16].

Eco-economic effectiveness of circular business models is associated with the prevention, minimization or elimination of national economy's (economy of the country) existing or possible losses (damage) and/or additional costs caused by human impact to the environment in the process of subsurface use. In this case, we are talking about reducing the magnitude of eco-economic damage.

Traditional procedure for determining eco-economic damage consists in composite monetary estimate of all "natural" (ecological and socio-ecological) damages connected with human impact on the environment. In this case, losses (damages) and costs caused by the adverse change in the environment itself are taken into account, but it is correct to consider losses (damages) and costs from the changed properties of the recipients' environment. The recipients are the following: agricultural land and animals, forest reserves, fishery resources, property assets of industry and transport, facilities of housing, utility, and personal service infrastructures, and leisure and medical resort facilities as core assets for business activity which take up the human impact on the environment as well as the population as a base for reproduction and economic (labor force) resource.

Interim standard procedure of 1986 has been the first in this country to comprehensively describe the essence of eco-economic damage through the category of “economic damage caused to the national economy by the environmental contamination”. According to the Procedure’s logic, it turns out that eco-economic damage consists of the sum of two types of expenses: *precautionary (prevention) costs* incurred to avoid the impact of the changed environment on the recipients (expenditures for sewage dilution, water treatment, air conditioning, building noise control installations, and waste collection and burial); *liquidation costs* are expenditures aimed at compensating for the changed environment impact on the recipients (for example, expenditures for medical treatment, compensation for the loss of goods caused by the decline in productivity of the fixed assets of land, forest, water, etc. resources).

Fig. 2. Methodological approach to the estimation of circular business models effectiveness in the field of mineral production

Рис. 2. Методологический подход к оценке результативности применения циркулярных бизнес-моделей в сфере добычи полезных ископаемых

E. V. Riumina considers the essence of two approaches to the determination of eco-economic damage that can possibly be applied calling it “economic damage from ecological disturbances” [17]: depending on the state of the environment and on the amount and character of harmful emissions.

According to E. V. Riumina, the first approach is actively realized in western countries through comparative and market methods [18]. Comparative methods (analogue approach) are presented by the method of control areas based on the hypothesis about the fact that the indicators of recipients’ condition directly determining the magnitude of eco-economic damage in the investigated and control (matching in various social, economic, and ecological parameters with the region under investigation) regions depend only on pollution concentration. The following scheme of forming the eco-economic damage is used when applying this method: firstly, the environment is exposed to human impact and its parameters are changed, secondly, the changed environment influences the recipients which results in economic losses. Market methods

are based on the subjective factors of cost and realized by means of sociological research; they are presented by the following: willingness-to-pay method, willingness-to-get-compensation method, hedonic method (a method for determining the price of ecological goods in the minds of population), and transportation costs method. The methods of analytical dependences (dose response technique) which is frequently presented in textbooks and scientific publications is not taken into account by E. V. Riumina in the damage assessment procedures classification as soon as it is considered as a method for processing statistical data which can be obtained through any damage assessment method.

The second approach to eco-economic damage determination, connected with the calculation of the amount and character of harmful emissions into the environment, provides for the use of the system of standards fixing the dependence between the negative effects and the main damage-forming factors. M. N. Ignatieva, A. A. Litvinova and V. A. Ignatiev [19] distinguish between the following: the impact factors depending on the parameters of the sources, their density, as well as on climate, topography and other parameters of the territory; factors of perception characterized by the structure and the number of recipients; the factors of condition determining losses per one unit of the percipient. This approach is actively applied in this country. In accordance with this approach, *Interim standard procedure of 1986* was created, which contains the procedures of calculating the damage caused by air, water basin, and acoustic medium contamination, and *The Procedure of averted ecological damage determination by Goskomekologii of Russia, 1999*, which includes the procedures of calculating the damage done to the atmosphere, water resources, soil and land resources, and biological resources.

When assessing eco-economic damage, scientists [17, 19, 20] propose that there should be a distinction between the methods for assessing the damages caused by regular ecological disturbances (for example, caused by environmental contamination by permanent sources of pollution) and damages caused by emergencies (random hazardous processes of natural or technogenic character). In the latter case, environmental impact has to be considered as a possible process.

From the authors' point of view, it's reasonable to systematize the types of eco-economic damage, which is an economic category above all, based on traditional methodology of assessing the value of economic assets and providing for the distinction between income, cost, and comparison approaches. It is suggested that income approach includes the method of indirect estimates presented in *Interim standard procedure of 1986*, which contains the procedures of calculating the damage caused by air, water basin, and acoustic medium contamination, and *The Procedure of averted ecological damage determination by Goskomekologii of Russia, 1999*, willingness-to-pay method, willingness-to-get-compensation method, and transportation costs method. Method of control areas and method of control areas may be applied as comparative approaches. The authors agree with A. V. Vusov [21] in his opinion that it is possible to use the methods of income approach in order to determine half-received and lost profit.

Research results application. The research has made it possible to substantiate the methodological approach to the evaluation of the effectiveness of circular business models in mining (fig. 2), study and systematize currently proposed methods for assessing the extent of environmentally related damage caused by mining. The methods considered are intended to be applied in assessing the ecological, socio-ecological and eco-economic effectiveness of environmentally friendly circular business models in this field.

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Оценка социально-эколого-экономической результативности применения циркулярных бизнес-моделей в сфере добычи полезных ископаемых

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Реферат

Введение. В соответствии с государственными докладами о состоянии и об охране окружающей среды Российской Федерации на такой вид экономической деятельности, как добыча полезных ископаемых, в России приходится значительный объем воздействия на окружающую среду.

Цель работы заключается в обосновании методологического подхода к оценке результативности применения экологически безопасных циркулярных бизнес-моделей на предприятиях горнодобывающего производства.

Методика проведения исследований. Исследования проводятся путем изучения, критической оценки и систематизации методик определения результатов от экологически ориентированной циркулярной деятельности в сфере добычи полезных ископаемых.

Результаты исследований. Результативность циркулярных бизнес-моделей рассматривается как одно из условий их применения. Она складывается из экологической, социально-экологической и эколого-экономической результативности, поэтому ее можно обозначить комплексным термином – социально-эколого-экономическая результативность. Экологическая и социально-экологическая результативность определяются недопущением, минимизацией или ликвидацией наносимого вреда окружающей природной среде и обществу. При учете того, что потери в природе и обществе по известным причинам никогда не могут получить объективной комплексной оценки, на практике приходится применять показатели экологического и социально-экологического ущерба, в полной мере не отражающие величину наносимого вреда. Эколого-экономическая результативность применения циркулярных бизнес-моделей связана с недопущением, минимизацией или ликвидацией имеющих место либо возможных потерь (убытков) и/или дополнительных затрат от антропогенного воздействия на окружающую среду для народного хозяйства (экономики страны) в процессе недропользования. В данном случае речь идет о снижении величины эколого-экономического ущерба.

Область применения результатов. Проводимое исследование позволяет изучить и систематизировать предлагаемые в настоящее время методики по определению величины экологически обусловленного ущерба, наносимого добычей полезных ископаемых. Рассмотренные методики предполагается применить при оценке экологической, социально-экологической и эколого-экономической результативности экологически безопасных циркулярных бизнес-моделей в данной сфере деятельности.

Ключевые слова: добыча полезных ископаемых; циркулярные бизнес-модели; экологически обусловленный ущерб; социально-эколого-экономическая результативность.

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