

## ECOLOGICAL AND ECONOMIC ASSESSMENT OF INDUSTRIAL POLLUTION IN THE CONTEXT OF ORE MINING AND DRESSING ENTERPRISES INVESTMENT POLICY FORMATION

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**Abstract.** The issues of successful investment activity and efficient allocation of capital investments at modern industrial enterprises taking into account their limited financial possibilities in conditions of uncertainty and economic instability are considered. The influence of investment policy on preservation of an environment as one of the ways for global world problem of a significant state of ecology deterioration decision is presented.

**Keywords:** investment activity, innovation, atmospheric emissions, ecological and economic model, social responsibility.

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### Introduction

The process of industrial enterprises production rate increasing is urgent in modern economic conditions and is always accompanied by a negative impact on the environment: significant emissions of harmful substances into the atmosphere, water bodies pollution, soil, man-made disasters, etc. These factors have a significant impact on the economic component of business activity and cause additional monetary costs to compensate for the damage caused to the environment, and in some cases, the destruction of sustainable development of the economies of the states. Particular attention is paid to the unsatisfactory ecological condition of the Kryvyi Rih region - the mining and metallurgical center of Ukraine. Ensuring sustainable economic development and environmental safety of industrial enterprises is possible only at the expense of production intensification, which cannot be carried out without attracting the necessary amount of investment resources in country economy. Therefore, the assessment of investment projects aimed at regional ecological state improving in the context of investment activity of enterprises is extremely important for society and sustainable development of the countries of the world.

The problems of ecological and economic development, environment state analysis, studying factors of influence on the ecological situation which were carried out by foreign and Ukrainian scientists such as V. Danylov-Danylyan, L. Melnyk, L. Hens, E. Girussov, I. Sotnik, V. Tarasova, A. Borlakov and others. In addition, various methods of ecological and economic mathematical modeling are used for modifying and adapting research works to regional specificity that in practice allows applying certain decisions in enterprise investment policy.

Therefore, at present, there is an objective necessity to deepen and supplement the methodological approaches to the environmental and economic assessment of industrial pollution in the environment and to determine the importance of its impact on the investment provision of modern ore-dressing enterprises.

The objective of the study is to model the relation between environmental and economic factors of ore-dressing enterprises with the subsequent economic ground for implementation of investment projects aimed at developing strategies for obtaining environmental competitive advantages through the production of iron-containing products aimed at preserving the environment.

### **Analysis of investment activity and its relation with ecology**

Most industrial enterprises of Ukraine in their production activity are aimed at obtaining profits due to successful management of investment resources, which in our opinion needs a corresponding scientific and economic substantiation. E. A. Stefanovich defined 'Investment activity' as a complex of measures of the state, individuals and legal entities, aimed at efficient allocation of resources in order to obtain the expected effect. The effect may be not only profit, but also, for example, infrastructure development, improvement of living conditions, etc. (*Stefanovych, 2010*).

In other words, speaking about modern approach of scientific thought to the notion of investment activity, it can be argued that investors are more oriented towards the rules of socially responsible behavior, and attract funds not only for expanding production but also for improving the improvement and trust of citizens in a particular enterprise. In the context of environmental social responsibility L. Potrashkova in her work highlights the following main issues: production of safe for consumers and the environment products; using materials manufactured in conditions that meet social and environmental requirements (*Potrashkova, 2017*). At the same time, O. Rudneva distinguishes the principles on which the sustainable development of enterprises should be based:

- environmental sustainability (significant limitation of non-renewable resources use, restrictions on the use of renewable resources, limitation of emissions to the environment, taking into account the factor of environmental renewal);
- economic stability (orientation of the economy for the future, preservation of tangible and intangible assets, stabilization of money circulation, prevention or restriction of 'new' debts, efficient use of resources, guarantee of 'transparency' of expenses);
- social stability (ensuring the possibility of realizing human rights, high life quality, guaranteeing security and justice, equality of opportunity, guaranteeing social protection, investing in the education of future generations, etc.) (*Rudneva, 2012*).

K. Goryacheva in her work suggests to pay attention to the following environmental indicators of sustainable development of industrial enterprises: the volume of toxic waste and

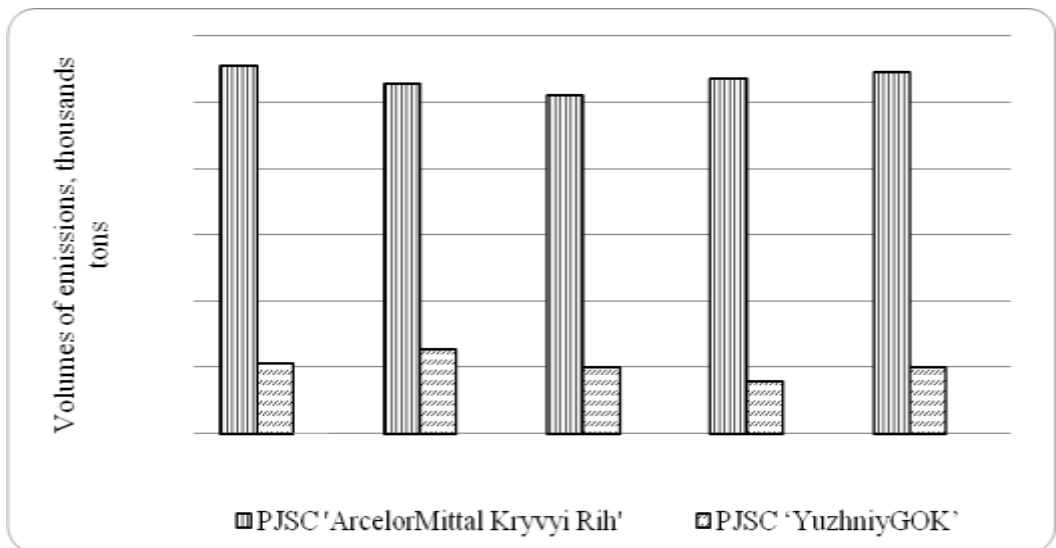
emissions into the air; quantity of resource-saving, energy-saving and low-energy technologies; the number of taken environmental protection measures (*Goryacheva, 2014*).

Summarizing the above socio-economic norms and principles of behavior and applying it to the specifics of the mining and metallurgical complex of the Kryvyi Rih region, the investment policy of enterprises should be aimed at gradual reduction of emissions of harmful substances, especially in the atmosphere, as a possibility of sustainable development.

A lot of works have been devoted to long-term environmental research, in particular, authors (*Lindenmayer et al., 2012*) have pointed out that long-term environmental research is crucial for providing key ideas in the field of ecology, environmental change, rational use of natural resources and biodiversity conservation. They also describe the five components that, in their opinion, are the basis of such studies, in particular:

1. Quantitative environmental responses to the causes of ecosystems changes.
2. Understanding the complex processes occurring in ecosystems over long periods.
3. Providing basic environmental data that can be used to develop theoretical models of environmental and parameterization and simulation testing.
4. To be the basis for joint research promoting interdisciplinary research.
5. Data provision and understanding of the scale for making managerial decisions.

Today, such measures for improving the state of the environment are quite formal and, as a rule, ineffective. In the total volume Krivbass industrial enterprises emit into the atmosphere about 327 thousand tons of solid and gaseous substances, therefore they cause considerable damage to the environment. The main enterprises that have a negative impact on airspace are PJSC 'ArcelorMittal Kryviy Rih' and PJSC 'YuzhniyGOK' (Figure 1).



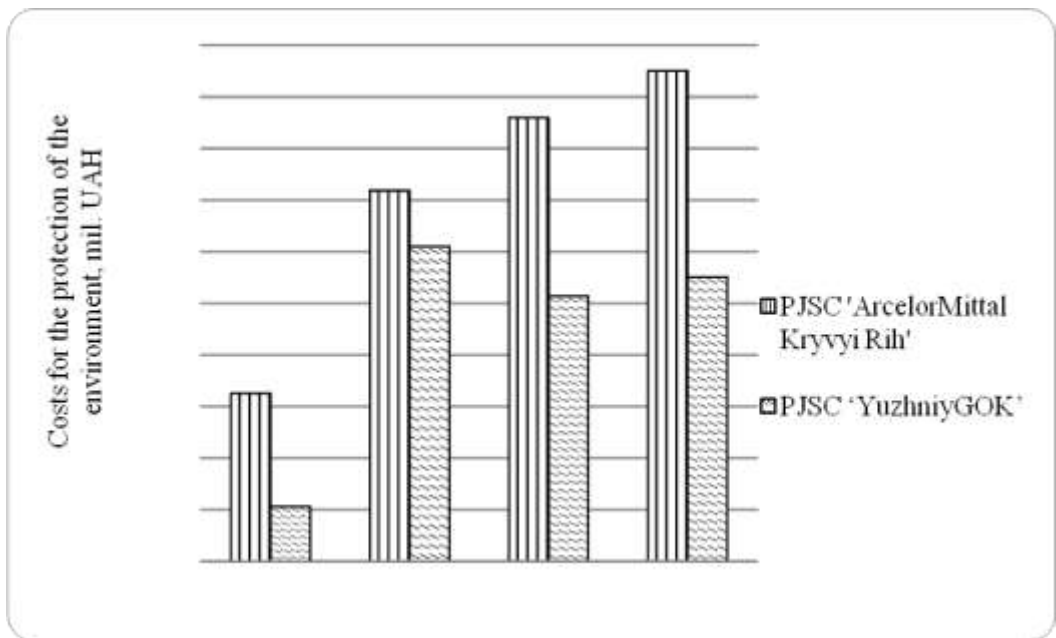
**Fig. 1. Actual emissions of pollutants into the air of Kryvyi Rih region**

It is clear from the histogram that emissions of harmful substances on both plants increased in 2016, and there is a steady tendency of environmental pollution over the last five years. Therefore, these problems are exacerbated and require the promptest solution,

especially in the context of improving the environmental situation, and hence the people health in Kryvy Rih region.

In developed countries, ‘circular economy’ practice is increasingly being used to promote the circulation of materials and products instead of linear ones, as a means of reducing environmental impacts and maximizing resource efficiency. For example, in the policy of China the circular economy began to be used by law from 2009 (Moreau *et al.*, 2017). In other words, the reverse cycle of use, in the case of PJSC ‘YuzhniyGOK’ the residual return of natural or blast furnace gas for the manufacture of agglomerates will reduce not only its costs, but also the impact of harmful substances on atmospheric air.

Consider the dynamics of environmental costs of Kryvy Rih region enterprises (Figure 2).



**Fig. 2. Costs for environmental protection PJSC ‘ArcelorMittal Kryviy Rih’ and PJSC ‘YuzhniyGOK’**

Based on the analysis of histogram indicators, investment volumes in 2016 increased and, respectively, make up 950.1 million UAH for PJSC ‘ArcelorMittal Kryviy Rih’, PJSC ‘YuzhniyGOK’ – 550.7 million UAH. The given graphic interpretation of environmental problems suggests a mismatch in the growth of investment costs and environmental pollution. For example, the sharp increase in expenses of PJSC ‘ArcelorMittal Kryviy Rih’ on environmental protection in 2014 reduced atmospheric emissions by only 9.061 thousand tons.

The peculiarity of such tendency is that the basis of investment processes in mining and metallurgical enterprises is the application of not always economically sound policies for the maintenance of worn-out fixed assets and carrying out constant repairs without the introduction of innovative technologies (Sobakinskykh, 2017).

For example, PJSC ‘YuzhniyGOK’ data on investment activity indicates the prevalence of programs supporting the technical and technological base and capital repairs of fixed assets on the creation of innovative investment projects.

In 2016, the Complex completed investments in priority projects and increased by 508.77 million UAH. Investment in support activities program, which includes the renovation of technological equipment: restoration sections of ore-enrichment, expansion tail economy at the amount of 827.53 million USD. At the same time, less investment in capital repairs was made compared to 2015 at UAH 33.91 million, amounting to UAH 183.71 million.

At the same time, outdated technology hasn’t any positive effect from attracting investment in further production and economic activity, since wearing coefficient though is within the norm, and tends to increase. Calculation of depreciation coefficients of fixed assets is the first component of integrated assessment of investment attractiveness of enterprises and organizations method that was approved by the Order of the Agency for Enterprises and Organizations Prevention of Bankruptcy 23, February 1998 № 22 (*Rudnyeva, 2012*). In particular, at the end of 2016, the depreciation rate at the plant is 28%, the suitability factor of fixed assets - 72%, respectively.

This means that the assets are suitable for effective use, if they are updated on time. The refinement factor in 2015 increased by 19% compared to the previous one, but in the next 2016 it decreased by 6%, which leads to a decrease in the intensity of the introduction of new fixed assets in operation. In addition, one of the main problems of investment activity in Ukraine is the lack of support from the state for an acceptable investment climate, since most enterprises are financed at their own expense, including PJSC ‘YuzhniyGOK’, which in 2016 used as investment capital of 94.8% of its own resources.

It is also necessary to take into account the fact that today Ukrainian economy is in a state of uncertainty, which complicates the process of formation of investment strategy and increases the likelihood of rising prices for iron ore raw materials, energy resources, increasing environmental tax, and so on. Therefore, M. Krochak in his work identifies four states of uncertainty: fairly predictable future; alternative options for the future; range of possible options for the future; complete uncertainty (*Korchak, 2017*). Based on the research of the scientist we will determine that the state of uncertainty of the economy in which PJSC ‘YuzhniyGOK’ is located has alternative options for the future.

This state of uncertainty is the most widespread since industrial enterprises often face changes in state regulation and legislation. Alternative alternatives for the future involve the identification of several separate development scenarios or investment policies; the scenario method involves the presence of several stages, each of which performs a certain sequence of actions.

Solving the problem of choosing the direction of investment policy, as already noted, is increasingly based on economic and mathematical modeling. Thus, N. Kameneva in her work proposes a scenario approach for the implementation of a discrete model for optimizing the environmental investment strategy, in which scenarios of the choice of strategy are: I. Selective-Innovative strategy, II. Investment strategy, III. Budget strategy, IV. Selective strategy. Scenario III and IV reflect the situations in which environmental activity is necessarily the costliest and, most of all, planned unprofitable.

In these cases, the optimal level should be understood as an acceptable level of environmental and economic security, exceeding which is not economically feasible, because it reduces the potential economic growth and, accordingly, undermines the financial basis for the development of environmental activities in the future. Scenario II is used in cases where

adverse environmental risks occur in territories with high potential of economic returns from environmental protection and restoration activities. Scenario I is a scenario of a practically ideal from the ecological point of view option, which, however, may have some disadvantageous environmental and economic aspects.

This scenario can be implemented either in territories with a relatively low level of economic use and with high assimilation potential, or in highly developed countries with vast material resources to maintain a high level of socio-ecological balance. The development of the model proposed by N. Kameneva includes assessing the level of environmental safety by the following partial estimates:

- estimation of damage has been already inflicted and damage is being inflicted on environment by human activity;
- assessment of currently occurring environmental risks;
- estimation of assimilation potential;
- assessment of the protective and restorative effect of environmental activity (Kameneva, 2016).

Gurman V. suggests using the socio-ecological and economic model of the region, the concept of which treats the region as an open system, divided into three interacting subsystems: economic, natural and social. The economic subsystem includes traditional manufacturing and non-productive sectors and non-traditional activities aimed at restoring or improving the state of the natural and social subsystems. The dynamics of the natural and social subsystems is described as the same type. Innovations are taken into account due to the modification of the established regional model by supplementing it with a special block describing innovation processes. Since in reality, innovation is associated with some object, to which certain innovative processes are applied, the concept of 'innovation' is treated formally as any purposeful change in the parameters of the model that describes this object (Gurman, 2011).

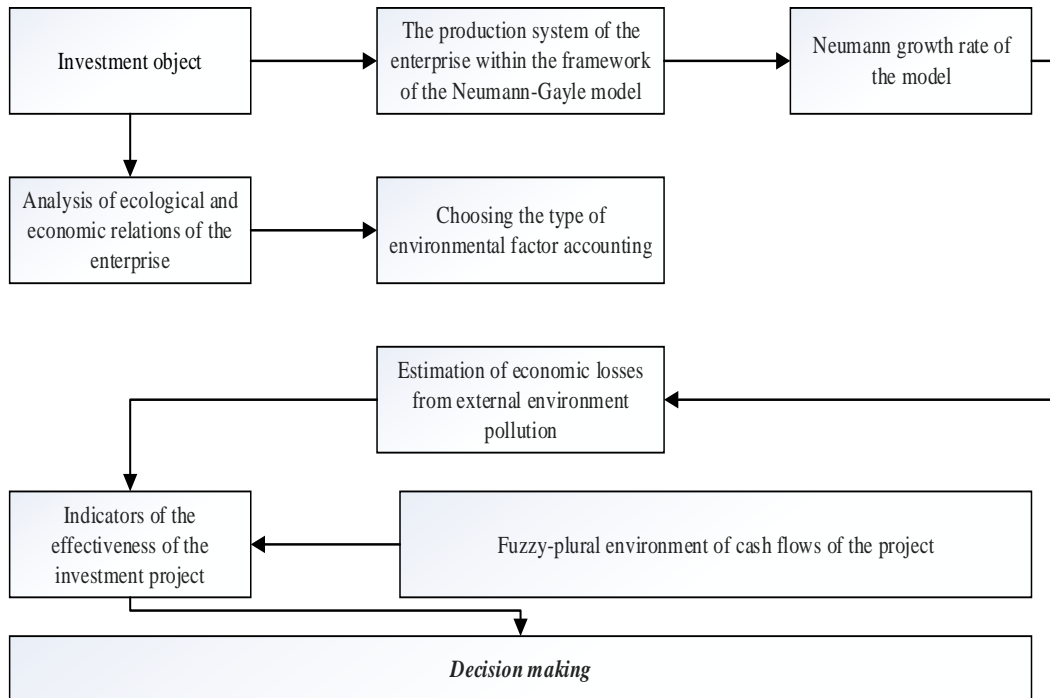
Thus, analyzing the factors of investment policy aimed at improving the ecological state of the city and region, is first and foremost identified with the concept of 'innovation'.

As an alternative to the assessment of environmental investment, we propose the application of the Neumann-Gayl ecological and economic model, the advantage of which, unlike the above-mentioned model, is the possibility of evaluating a specific investment project aimed at improving the environmental situation in the region, using well-known and easy-to-calculate indicators of the effectiveness of the investment project.

It is worth noting that taking into account the environmental factor in the Neumann-Gayle model can be either active or passive.

In particular, the passive nature of taking into account environmental factor does not imply the introduction of pollution vector limitation. Instead, active involves managing pollution in the technological process by introducing a vector of pollution:  $\bar{z} \leq \bar{z}^*$ ,  $\bar{u} \leq \bar{u}_{lim}$ , where  $\bar{z}^*$  - vector of environmental norms,  $\bar{u}_{lim}$  - a vector of intensity limits. The use of such restriction can be applied only in the case of 'non-dirty' production, with very environmentally friendly production. To determine the degree of environmental production it is necessary to analyze certain environmental and economic relations of the enterprise.

The algorithm for making a reasonable solution based on the modeling of the environmental and economic assessment of investment projects is presented in Figure 3.



**Fig. 3. Methodology of ecological and economic assessment of investment project**

As output characteristics for the analysis of ecological and economic relations of production can be applied:

- The main indicators of production and economic activity of the enterprise: capital stock, labor productivity;
- Coefficients of environmental production: the hazard class of the production of DCP, calculated by the formula:

$$CP = \sum_{j=1}^n \sum_{i=1}^s \frac{p_{ij}}{\rho_{ij}} a_i, \tag{1}$$

where  $a_i$  - the coefficient of bringing various contaminants to the aggregated species, characterizes the danger of pollutants;

$p_{ij}$  - the volume of pollution of the  $i$ -th species;

$\rho_{ij}$  - concentration of the substance in the atmosphere.

If the value of  $DCP > 10^6$ , the enterprise is the most polluting. When  $DCP = 10^4, 10^6$  - the second category of danger,  $DCP = 10^3, 10^4$  - third, with  $DCP < 10^3$  - to the lowest fourth category;

- indicators of environmental activity focused on the characterization of environmental management at the enterprise level and reflect the effectiveness of various environmental measures. Indicators of this group include:



- 1) The cost of production funds aimed at the protection of the environment;
- 2) Coefficient of efficiency of current expenditures for environmental protection measures:

$$K_{es} = \frac{EPC}{\sum z_t}, \tag{2}$$

where EPC - the cost of environmental protection measures.

Thus, according to the indicated indicators, it is possible to determine the degree of environmental friendliness of production, and to choose an active or passive type of account of the environmental factor in the Neumann-Gayle model.

The economic growth rate of the Neumann-Gayle model  $\bar{\beta}$  is the following ratio, which means the growth rate of cash losses from pollution:

$$\bar{\beta} = \min_{p \geq 0} \max_{(x,y,z) \in Z} \frac{p(y)p(z)}{p(x)}, \tag{3}$$

- where  $p(y)$  – raw material costs, natural units;
- $p(z)$  – price of atmospheric air pollution, mg/ton;
- $p(x)$  – unit price of raw materials, UAH/ton.

The economic (monetary) loss of the enterprise refers to the cost value of the costs associated with the negative impact on the environment of technological emissions. Assessing the damage, it should be taken into account that information on emissions of pollutants into the air is not always adequate. The main reason for this is the technical complexity of direct production monitoring.

The model for determining the economic costs of atmospheric air pollution at time t is as follows:

$$OF_t^a = \begin{cases} \varphi \mu \sum_{i=1}^s P_{it}^{a'} a_i p_{it}, p_{it} \leq AEL_i \\ \varphi \mu \sum_{i=1}^s P_{it}^{a''} a_i AEL_i + \varphi \mu \sum_{i=1}^s P_{it}^{a''} a_i (p_{it} - AEL_i), p_{it} > AEL_i \end{cases}, \tag{4}$$

- where  $AEL_i$  – maximum permissible emission of substance;
- $P_{it}^{a'}$  – cost estimation of losses from the unit of emissions into the atmosphere of the i-th harmful substance, which does not exceed the limit value of AEL;
- $P_{it}^{a''}$  – cost estimation of losses from the unit of emissions into the atmosphere of the i-th harmful substance that exceeds the limit value of AEL;
- $p_{it}$  – volume of pollution of the i-th species;
- $\mu$  – coefficient taking into account the nature of the dispersion of harmful substances in the atmosphere;
- $\varphi$  – coefficient taking into account regional features of the territory that is subject to pollution;
- $a_i$  – the coefficient of bringing various contaminants to the aggregated species, which characterizes the relative danger of pollutants.



We pass to the calculation of indicators efficiency of the investment project in which the costs for ecology and economic expenses will be accumulated in a single cash flow.

Net Present Value (NPV). NPV is the difference between the discounted cash flows of investments and the costs incurred during the project implementation. For projects with a constant uniform negative impact on the environment NPV is calculated by the model:

$$NPV = \sum_{t=1}^n \frac{I\tilde{F}_t - O\tilde{F}_t - OF_t}{(1+r(t))^t} - IC_{t0}, \quad (5)$$

where  $I\tilde{F}_t$  – cash flow, presented in a fuzzy form;

$O\tilde{F}_t$  – outflow of funds in a fuzzy form;

$OF_t$  – permanent environmental costs in money terms arising as a result of the project's impact on the environment;

$IC_{t0}$  – volume of initial investments;

$r(t)$  – discount rate.

Within this indicator, a project can be considered profitable if  $NPV > 0$  and loss-making if  $NPV < 0$ , but if  $NPV = 0$ , then the project can be considered neither profitable nor loss-making, additional information is needed.

Projected value  $OF_t$  can be calculated based on the formula:

$$OF_{t+1}^e = \bar{\beta} OF_t, \quad (6)$$

where  $\bar{\beta}$  - economic growth rate of the model.

Modified Internal Revenue Rate (MIRR). Modified Revenue Rate or adjusted reinvestment rate where internal rate of return allows partially eliminate the disadvantages of the Internal Rate of Return (IRR) method associated with multiple outflows of cash and additional reinvestment. MIRR provides for the calculation of the discount factor taking into account the total estimated value of outflows and the terminal value of inflows:

$$MIRR = \sqrt[n]{\frac{\sum_{t=0}^n I\tilde{F}_t (1+r(t))^{n-t}}{\sum_{t=0}^n \frac{OF_t - OF_t}{(1+r(t))^t}}} - 1, \quad (7)$$

Profitability Index (PI). The index shows the relative profitability of the investment project per unit of initial investments:

$$PI = \frac{\sum_{t=1}^n \frac{I\tilde{F}_t - O\tilde{F}_t - OF_t}{(1+r(t))^{-t}}}{IC_{t0}}. \quad (8)$$

According to this criterion, a project can be considered profitable if  $PI > 1$ , unprofitable if  $PI < 1$ , but if  $PI = 1$ , then the project is neither profitable nor unprofitable.

Discounted payback period (DPP) is the period of time required to return the initial investment. This indicator allows us to assess the riskiness of the project as a long pay-back period is a signal of risk:

$$\left\{ \begin{array}{l} DPP = \min n, \\ \sum_{t=1}^n \frac{i\tilde{F}_t - o\tilde{F}_t - oF_t}{(1+r(t))^t} = IC_{t0} \end{array} \right. \quad (9)$$

Using DPP a project can be considered acceptable if the pay-back period does not exceed the established deadline (*Borlakova, 2014*).

Proceed directly to the implementation of the model in the conditions of sinter production. The object of investment receipts at PJSC 'YuzhniyGOK' is the project of replacement of gas treatment systems on four sintering machines K-1-75 with a total investment of 837895.16 UAH. Project terms are 4 years (48 months). Technical planning: construction of a modern dust and complex on 4 sintering machines, both the sintering zone and the cooling zone; The project consists of 4 main launching complexes; each of the launch complexes consists of 2 sections (1 degree of purification - cyclones HARRICLON and the second one is desulfurization bag filter). The project implementation will reduce dusting up to 90% as well as sulfur emissions up to 46%.

The choice of the type of environmental factor accounting is performed by calculating the following indicators. Indicators of production activity: capital-labor ratio = 802.5 UAH per person; labor productivity = 2152.6 UAH per person.

The coefficient of ecological production: - hazard class of production according to the formula (1) = 244128.7 UAH.

Indicators of environmental activity: - cost of production funds aimed at environmental protection = 550 million UAH; - coefficient of efficiency of current costs for environmental protection measures (see formula 2) = 48.3%.

Based on the data we have:

- the hazard class of the production DCP >  $10^6$ , indicating the first, the most dangerous and contaminating level;
- PJSC 'YuzhniyGOK' on the coefficient of efficiency of current expenditures for environmental measures is at a very low level.

According to the results obtained, we can draw conclusion that within the framework of Neumann-Gayle model, the environmental factor should be passive while calculating without the need to introduce pollution vector limitation. We consider the definition of the growth rate of the enterprise within the framework of Neumann-Gayle model. The enterprise provides one way of producing iron ore sinter. According to the collected information on air pollution, it is known about 3 types of harmful substances from the agglomerate production.

We introduce the following input and output matrices:

$$A = \begin{pmatrix} 229748.3 \\ 67702 \\ 3736 \\ 111969.8 \\ 60267.6 \\ 48006.8 \end{pmatrix}; B = \begin{pmatrix} 518.35 \\ 492.16 \\ 417.02 \\ 139.95 \\ 15304.63 \\ 61969 \end{pmatrix}$$

where  $A_1$  – expenditures of sintering ore, ths. UAH;

$A_2$  – costs of limestone, ths. UAH;

$A_3$  – costs of gratings, ths. UAH;

$A_4$  – consumption of solid fuel, ths. UAH;

- $A_5$  – costs of gaseous fuel, ths. UAH;
- $A_6$  – electricity costs, ths. UAH;
- $B_1$  – volumes of sintering ore, ths. UAH;
- $B_2$  – volumes of limestone, ths. ton;
- $B_3$  – volumes of gratings, ton;
- $B_4$  – volumes of solid fuel, ths. ton;
- $B_5$  – volumes of gaseous fuel, ton.;
- $B_6$  – electricity volumes, ths. kW per hour.

We find the intensity vector for the production of iron-ore agglomerate using the following limitation:

$$\begin{cases} \bar{p}B\bar{u} \rightarrow \max \\ A\bar{u} \leq S \end{cases}, \tag{10}$$

- where S - stocks of products for industrial and technical purposes, thousand UAH;
- $\bar{u}$  - intensity vector of agglomerate production;
- $\bar{p}$  - unit price of the resource for the agglomerate production, UAH / unit.

Having solved the optimization problem, we have full use of the reserves 604210 ths. UAH and the intensity vector  $\bar{u} = (2.629)$ .

Consequently, we have matrices of growth rates:

$$\bar{x} = A\bar{u} = (604210 \quad 178046.8 \quad 9825.19 \quad 294466.9 \quad 158496.5 \quad 126252)$$

$$\bar{y} = B\bar{u} = (1363.19 \quad 1294.32 \quad 1096.71 \quad 368.05 \quad 40249.33 \quad 162970.9)$$

$$\bar{z} = Py = (5.52 \quad 0.894 \quad 0.056)$$

We calculate the economic growth rate of a model by the formula (3):

$$\bar{\beta} = \frac{162970,9 + 5,52}{604210} = 1,489.$$

The next step is to make monetary evaluation of losses from air pollution. In the composition of the main air pollutants, the process of making iron ore agglomerate at PJSC ‘YuzhniyGOK’ include dust, carbon oxide and sulfur oxide, the concentrations of which are presented in Table 1.

Table 1

**Composition of air pollutants from agglomeration of iron ores at PJSC ‘YuzhniyGOK’ as of 2016**

Contaminator	Concentration of substance ( $\rho$ ), mg/m <sup>3</sup>	Background concentration ( $C_{fi}$ ), mg/m <sup>3</sup>	Ecological and economic risk factor of substance (a)	Maximum allowable concentration ( $C_{MAI}$ ), mg/m <sup>3</sup>
Dust	0.8	0.07	100	0.15
Carbon monoxide	2	1.8	1	3
Sulfur oxide	0.012	0.01	16.5	0.05

To find the monetary costs of pollution, we calculate the maximum permissible emission by the following formula:

$$AEL = \frac{(c_{MAi} - c_{fi})H^2}{A \cdot F \cdot m \cdot n \cdot \eta} \sqrt[3]{V_1 \Delta T} \tag{11}$$

It is known that the value of the coefficient taking into account the peculiarities of the polluted atmosphere  $\varphi = 1.25$ ;  $H = 8.8$  m - height of the emission source;  $\Delta T = 23,3$  °C - difference between emission temperature and average annual temperature of the external environment;  $A = 200$  - coefficient of stratification;  $F = 1$  - dimensionless coefficient taking into account the precipitation rate of harmful substances in the air;  $\eta = 1$  - dimensionless coefficient taking into account the influence of terrain;  $V_1 = 0,068$  m<sup>3</sup>/c - gas mixture flow rate;  $n = 2,146$  - gas flow rate standard. The results of calculations are shown in Table 2.

Table 2

**Data for calculating the costs of atmospheric air pollution by PJSC ‘YuzhniyGOK’ activities as of 2016**

Contaminator	Actual emission (p), g/sec	Maximum allowable emission (AEL), g/sec	$P^{a'}$ (at $p \leq AEL$ ), UAH, per ton	$P^{a''}$ (at $p \geq AEL$ ), UAH, per ton
Dust	0.32	0.013	3611.61	81393.4
Carbon monoxide	0.165	0.193	83.07	101.86
Sulfur oxide	0.056	0.006	538.13	641.2

As you can see, dust and sulfur oxide emissions exceed the maximum allowable level. At the same time, according to the indicator (a) they have the most dangerous properties (hazard ratios of 100 and 16.5 respectively).

Substituting the obtained values into the formula (4), we get monetary damage ( $OF_t^s$ ) in the amount of 8298120 UAH per month.

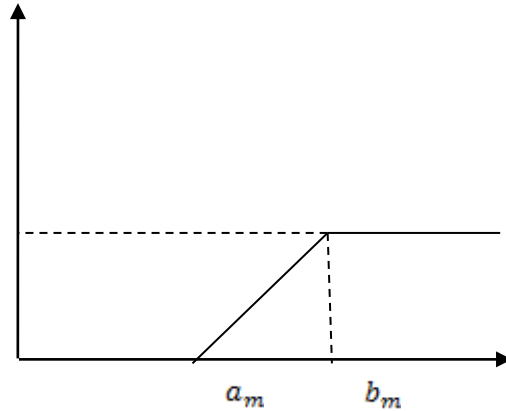
Proceed to the effectiveness evaluation of the proposed investment project by creating the generation of optimistic and pessimistic cash flow scenarios.

The manager, adopting the appropriate managerial decision, determines the optimistic and pessimistic scenarios of the cash flow and outflow limits given the uncertain economic situation. Then, for the proposed project from a financial point of view:

- optimistic cash flow scenario  $\bar{IF}^{opt} = 12000$  thousands UAH;
- pessimistic cash flow scenario  $\bar{IF}^{pes} = 10000$  thousands UAH;
- optimistic cash outflow scenario  $\bar{OF}^{opt} = 7000$  thousands UAH;
- pessimistic outflow scenario  $\bar{OF}^{pes} = 9000$  thousands UAH.

Further, the assumed values of cash flows are broken down for the period of project development, according to the planned interest rates by the manager. To generate casual cash flows within specified intervals ( $a_m; b_m$ ), Microsoft Excel RANDOM is used.

At the next stage of modeling we use the graph of the fuzzy value function of cash flows to their universal set w shown in Figure 4.



**Fig. 4. Graph of fuzzy value function of cash flows**

As the manager works under the conditions of uncertainty, the theory of fuzzy sets is used to identify unsuitable cash flow values in order to predict the possible income of the investment project that are not in the plane of the membership function  $\mu$  in the range from 0 to 1 and, along the x axis, on the range of cash flows boundaries ( $a_m$  and  $b_m$ ) of their multiplication  $w$ . The manager independently selects the membership function based on its properties, such as symmetry, monotony, continuity, and also taking into account the existing uncertainty regarding the distribution of project cash flows. The very function of membership is as follows (12):

$$\mu(w) = \begin{cases} 0, 0 \leq w < a_m \\ \frac{w-a_m}{b_m-a_m}, a_m \leq w \leq b_m, \\ 1, b_m < w \end{cases} \quad (12)$$

where  $a_m$  and  $b_m$  - the upper and lower limits of cash flows;  
 $w$  - universal set of cash flows.

To allocate a clear number of cash flows from the fuzzy set, we perform defuzzification by integrating the center of gravity method using the following formula:

$$y = \frac{\int_a^b w\mu(w) dw}{\int_a^b \mu(w) dw} \quad (13)$$

Thus, the project with initial investments in the amount of 837895.1 UAH and the term of 48 months (4 years) contains the following environmental costs:

- $OF_1^e = 8298,12$  thousand UAH,  $t = 1 \dots 12$ ;
- $OF_2^e = OF_1^e * \bar{\beta} = 12363,9$  thousand UAH;
- $OF_3^e = 12363,9 * 1,489 = 18421,7$  thousand UAH;
- $OF_3^e = 18421,7 * 1,489 = 27447,7$  thousand UAH.

Substituting them into the appropriate formulae for estimating the project effectiveness (5, 7, 8, 9), we obtain the following results: NPV = 136187 UAH, MIRR = 43%, PI = 3.11, DPP = 2 years.

Considering that the installation of the newest gas scrubbers using sintering machines will reduce approximately by 10% of dust emissions and 5.1% of sulfur oxide emissions each year, we will get a potential reduction in cash costs from emissions of these harmful substances by 12% in 2019 and by another 14% in 2020.

Thus, the total possible reduction of dust emissions will reach 40% (by 37531.8 thousand tons) and 5.1% sulfur oxide (by 14618.6 thousand tons) as a result of the project realization that will save costs on environmental protection of PJSC 'YuzhniyGOK' in the amount of 346268.2 thousand UAH. This, of course, will also affect the net present cost indicator that will be 349175.3 thousand UAH.

To estimate the dividends received from the realization of the investment project, we use the indicator of economic value added - EVA, according to the formula:

$$EVA = NOPAT - WACC * IC, \quad (14)$$

where NOPAT is net operating income after tax;  
WACC - weighted average capital cost;  
IC - invested capital.

$$EVA = 1408122 \text{ thousand UAH} - 16.8 \times 837895.16 \text{ thousand UAH} = 1267355.7 \text{ thousand UAH}$$

Thus, the amount of net profit exceeds the cost involved in obtaining capital for 1267355.7 thousand UAH. Thus, it can be argued that due to the realization of the proposed project, PJSC 'YuzhniyGOK' will create an additional cost and the proposed investment project is economically feasible.

As one of the important tasks in the investment activity of the plant was to optimize the structure of capital, such as the enterprises of the leading countries (60% equity capital and 40% borrowed), we calculate EVA indicator from the point of view of reorganization of sources of financial resources formation.

$$EVA = 1408122 \text{ thousand UAH} - 15.3 \times 837895.16 \text{ thousand UAH} = 1279508.4 \text{ ths. UAH}$$

Growth of the prevailing net profit is 12152.7 ths. UAH.

### Conclusions and suggestions

Using the proposed Neumann-Gayle ecological and economic model in a scientific work will allow us to determine how the realization of the environmental investment project will affect the possible reduction of emissions of harmful substances into the atmosphere, and hence, the reduction of monetary costs for compensation of damage in the nearest future. The proposed model allows to systematize the effectiveness indicators of the investment project taking into account the assessment of the environmental performance of the enterprise activity that creates the grounding for effective management decisions in the context of conducting well-balanced financial policy under the conditions of economic instability and uncertainty. At the same time, the indicators used in the model reflect the close relationship between

emission volumes at PJSC 'YuzhniyGOK' into the atmosphere and the results of the investment project such as, for example, net present value. The information obtained after the calculations concerning the ecological and economic efficiency of the enterprise investment project will contribute to reducing the negative environmental consequences both at the level of economic entities and in Kryvyi Rih region as a whole.

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