

## Quantitative assessment of investments: regional eco-efficiency

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Received February 18.2015: accepted January 20.2016

*Abstract.* The article is dedicated to development of the methodological approach to determine the most effective ways and areas of investments use aimed at reducing the negative impacts of pollution. This takes into account the reality that the level of pollution is different for different areas (regions), and the degree of negative impact is due to two main factors – volume of gas emissions and the number of residents living in these territories. Taking into account the lack of quantitative laws regarding the impact of pollution on human lives the expediency to limit some qualitative considerations that significantly contribute to the solution of the problem are developed in the article. The paper develops analytic approach, which is based on establishing the parameters that characterize the essence of the developed phenomenon. The state of air pollution in particular is seen as the main factor that significantly affects the residents' life quality. At one and the same degree of negative pollution, its effect will depend on the number of residents living in the area. As our research continues with the assessment of air pollution reduction state, where two indicators were developed – harmful gas components in the air and population density in the area. Based on the hypothesis of parabolic type, the corresponding functional relation between the parameters proves, that the product of assumed parameters determines the priority of pollution reduction in some areas. The conducted proposed approach to interpretation of dust pollution on the example of regions of Poland is developed.

*Key words:* eco-investments, population's density, industrial gas pollutants.

### INTRODUCTION

The sustainable economic growth and development is seen more and more in recent decades from the

environmental point of view. It is impossible to achieve better life quality and sustainable growth without paying more attention to ecological component of human life. According to the report of the European Agency for the Environment and Air Quality 2013, "there are more basic problems to human health caused by poor air quality. We are still far from our goal-to reach the level of air quality policy, which have generated significant negative impacts on human health and the environment" Janek Potochnyk, European commissioner for the environment [3].

Polish membership of the European Union entails a wide array of environmental-protection requirements. Some have been satisfied by Poland to a greater extent than required, for instance, as regards greenhouse gases emissions, the reduction of which in 2008-2012 in relation to the base year, i.e. 1988, should be 6 %. In 2011 Poland achieved a reduction of 29 % in the emission of greenhouse gases, expressed as a carbon dioxide equivalent, in relation to the base year. In particular, the emission of carbon dioxide dropped by 30 %, methane by 34 %, and nitrous oxide by 33 %. The reduction in greenhouse gases emissions achieved by Poland has therefore considerably exceeded the level required under the Kyoto Protocol [4, 5, 10, 20].

### THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The analysis of recent researches shows big interest in the field of investments and regional economic

development. Many authors, such as Paranchuk S., Korbutyak A., Ramadani V., Gergudi S., Kuzmin O. consider investments from the innovation-oriented point of view [8, 9, 15, 16, 17]. Other scientists develop factor approach towards the analysis of regional economic development, main publications here are developed by Alekseev I., Svyatokho N., Yachmeneva V. and others [17, 18, 19].

Thus, the importance of environmental security is stressed by The United Nations Resolution "The Future we want" [1], not mentioning, that it's stated in the Millennium Development Goals Framework, as goal number 7 "Ensure Environmental Sustainability" [2]. Among all 34 OECD countries, it was observed, that pollution decreases in last decade [11, 12, 15, 16].

However there is a small number of publications, that would link regional production potential and environmental factors, such as gas pollution.

### OBJECTIVES

The main study task is the idea, that by means of having information on the contamination of certain areas is important to prioritize its reduction by implementing certain measures of ecological investment projects and programs. In turn, the definition of priorities involves the selection of the primary factors that characterize the contamination as well as to quantify the parameters of negative impacts on people. Further, called by identifying the relation between parameters, we aim to develop the problem by aiming to achieve the evaluation criteria for determining priorities, which would be scientifically proved, would have practical application, which is simple, logical and would not cause controversy.

### THE MAIN RESULTS OF THE RESEARCH

The option of gas emissions that affects people is being considered as an important factor in favor concentration of harmful elements and the air. Equivalent to a certain extent characteristic of concentration is considered to be corresponding:

$$d = \frac{z}{S}, \quad (1)$$

where:  $Z$  – emissions into environment,  $S$  – emissions area.

With the increase of the negative component in the air, which is consumed in the process of human life, we should expect more significant damage to the human body at the same conditions. While analyzing the impact of pollution on humans there, the problem of identifying the quantitative relations between reasons and consequences arises. In general the definition of the relevant laws requires a special complex and long-term

research with specialists in various industries. At the same time to solve a number of practical problems is sufficient to approximate approaches that allow to take real effective solutions, in particular, on the basis of logical reasoning.

From the standpoint of selecting analytical interrelationships between factors we offer to focus on the Powers features the following:

$$E = cd^2, \quad (2)$$

where:  $e$  – negative impact from the consequences of environmental pollution per capita,  $c$  – constant coefficient.

This dependence is characterized by the fact that, firstly, in the absence of pollution there will be no negative consequences, that is consistent with logical reasoning. Secondly, there is non-linearity effect of pollution. This means that one and the same absolute reduction of pollution for its various levels leads to unequal results of its influence. For higher limits overall pollution effect of the measures to reduce it to grow. General idea for the pollution reduction priority in areas with high gas emissions concentrations should be considered quite reasonable and this approach is often used in the practice of management.

Lets assume, that on the certain territory  $N$  people are living, then the dependence (2) can be modified as follows:

$$E = Ncd^2, \quad (3)$$

By using the derivative apparatus for elementary functions, that determine the quantitative relation between changes in pollution and its effect

$$DE = 2cdudZ, \quad (4)$$

where:  $u$  – population density in the area of contamination.

As can be seen from the dependence (4), the assumptions taken overall effect of the pollution is caused by changes in the product of two factors – pollution concentrations and density of the population living in the territory.

The priority towards pollution reduction require first of all areas with high degree of contamination and higher population density. The fundamental difference is the product of these two parameters.

Reducing pollution in general can be achieved in different ways – change in the sectoral structure of the economy, introduction of innovative technologies, the use of industrial waste, construction of treatment facilities, carrying out afforestation and so on. Typically, the implementation of such measures requires some investment costs. In terms of quantitative assessment of the effect of eco-investments requires identifying appropriate dependencies linking the size of investment with the value of the results obtained.

One way of such a dependence can be inear type functions such as:

$$DE = bK, \quad (5)$$

where:  $K$  – the volume of eco-investment,  $b$  – constant coefficient.

For typical projects the pollution reduction capital intensity is known and can be used for the purposes of economic analysis of investment options. In some cases, may also be involved and analyzed a combination of standard and custom project developments.

A typical example to be considered a renewal of vehicles resulting in reduced fuel consumption by one mile and accordingly reduces the amount of gas emissions.

Our studies revealed the quantitative regularities for the process of system update consistency of equipment in industrial plants, which can similarly be used to analyze the dynamics of pollution.

In particular, it should be considered a reasonable to use the following quantitative patterns:

$$\Delta Z = \frac{Z_0 - Z_n}{F_n} K, \quad (6)$$

where:  $Z_0$  – pollution emissions in the operation of machines in the base period,

$Z_n$  – amounts of pollution emissions during the operation of the new equipment that replaces existing equipment,  $K$  – cost imposed by the new equipment

The analysis of the dependence shows that investments' eco-efficiency is determined primarily by the size of the ratio of pollution to the cost of fixed assets in the base period of operation.

Also significant value has the innovative new technology that characterizes the “jump” to reduce pollution when replacing existing technology innovation. I should add that this factor is determined by the parameters of existing and new technology.

In accordance with presented dependence more investments correspond to a current number of vehicles, which in turn intensifies the reduction of pollution.

However, it should be noted, that this directly proportional dependence occurs in the form of approximately stable volumes of production. If the dynamics of these volumes occurs, the indicated dependence shall be slightly adjusted.

Of course, the environmental effectiveness of a new technology depends on its technological purpose, the rate of technological progress, industry conditions and so on.

The variety of vehicles and assets raises the problem of determining the best areas of the eco-investments, and those investments that tangentially affect the state of pollution. Lets analyze a number of parameters of air pollution on the example of Poland – Voivodships [4,12].

Overall, during the study period, pollution by dust has decreased by large size – about 2 times. At the same

time gas pollution emissions decreased by 19 %. Significantly (by 45 %) were reduced the emissions of sulphur dioxide [4,12].

On the same level remained emissions of carbon dioxide and nitrogen oxides.

Taking into consideration the current trends, we can conclude that dust contamination is possible to reduce more rapidly, including through the use of appropriate technology filtering gas mixtures.

Using the raw data, we develop such quantities as population density, the ratio of its size to the size of the residence surface area and the average concentration of pollution – emissions related to the size of the territory they pollute.

Taking into consideration obtained data under the proposed approach we shall multiply the results and thus, that will determine the Voivodship rating factor on the priority pollution reduction. For some types of equipment, there are three levels of performance: low, medium and high. Obviously, there is a difference in the cost of the equipment, which makes specific factory rational choice alternative treatment. In some cases, the improved treating achieved by means of multiple staging of this process. For example, two stages option purification takes place the following quantitative relation:

$$U = U_1 + (1 - U_1) U_2, \quad (7)$$

where:  $U$  – share of “hard” phase mixture shown cleaning system in relation to the amount of “hard” phase input,  $U_1$  – share of “hard” phase, which remains after the first stage of filtration,  $U_2$  – fraction of the solid phase, which remains after the second stage of filtration.

If we consider the value of entered indicators as filtration efficiency, the overall efficiency in some way connected with the relevant local efficiency. If for example we assume that  $U_1 = U_2 = 0,8$ , then the resulting efficiency is equal to  $U = 0,96$ . That is already a two stage filtration, that provides a significant effective performance compared with similar local efficiency.

The economic problem here is that by means of increasing stages of filtering significantly increases the cost of the equipment, while increasing efficiency to a lesser extent.

This is an important law, since there is a need to correlate the cost of the equipment with its performance.

Lets take a regional interpretation of equation (4) as an example the emission of dust pollution on the territory of Poland Voivodships. Relevant primary statistics are given below in Table 1 [5, 10, 19, 20].

The statistical data are further used to determine for each of the Voivodship concentration of gas

emissions and population density in the area. The result of these indicators can serve as a measure of efficiency (rate) of pollution reduction. It shall be noted, that a priori the volume of pollution emission and population in the territory the correlation is not expected. At the same time, the analysis shows a statistical relation, that illustrates a dependency of the correlation. In quantitative form, it has the following linear interpretation:

$$Z = -0,262 + 1,429N. \quad (8)$$

The graphic interpretation of given correlation can be observed in Fig. 1.

The coefficient of correlation is equal to  $r = 0,77$ . Thus, distress communication is significant.

By dividing the left and right side of the equation on the size of the surface  $S$ , we obtain the dependence of the concentration of impurities on the density of the population living in the territory:

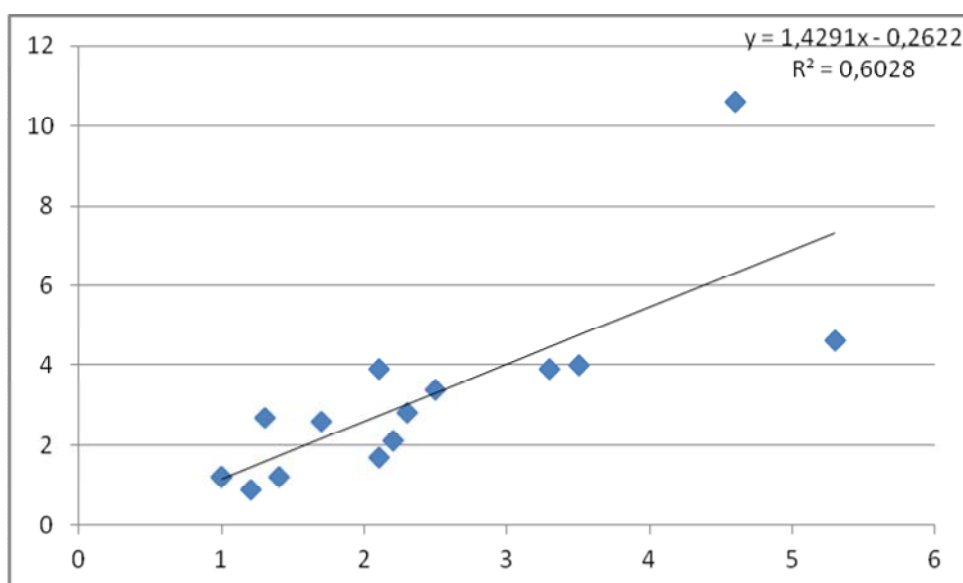
$$\frac{Z}{S} = \frac{0,262}{S} + \frac{1,429N}{S}. \quad (9)$$

General conclusion is that in real business practices the pollution is closely linked to population density in the area. The reason for this phenomenon may be the concentration of production and consequently attract a large number of employees. Concentration in turn leads to an intensification of contamination. Selected primary statistics allow to access the problem of prioritization, that reduces pollution by individual region.

The results of the corresponding calculations are presented in Table 2 [4].

**Table 1.** The statistical data main parameters at Polish Voivodeships in 2012 [4]

Nr	Voivodeships	Population, mln., ppl.	Area, in thousand, km <sup>2</sup>	Particulate dust pollutants emission, in th. ton.
1	Lower Silesian	2,9	19,9	4,0
2	Kuyavian-Pomeranian	2,1	18,0	3,9
3	Lublin	2,2	25,1	2,1
4	Lubusz	1,0	14,0	1,2
5	Łódź	2,5	18,2	3,4
6	Lesser Poland	3,3	15,2	3,9
7	Masovian	5,3	35,5	4,6
8	Opole	1,0	9,4	1,2
9	Subcarpathian	2,1	17,8	1,7
10	Podlaskie	1,2	20,2	0,9
11	Pomeranian	2,3	18,3	2,8
12	Silesian	4,6	12,3	10,6
13	Świętokrzyskie	1,3	11,7	2,7
14	Warmian-Masurian	1,4	24,2	1,2
15	Greater Poland	3,5	29,8	4,0
16	West Pomeranian	1,7	22,9	2,6



**Fig. 1.** The correlation between dust pollutants and population

**Table 2.** The definition of Voivodeship's rating for reducing dust pollution

Nr	Voivodships	Population density, mln., ppl./ th. km <sup>2</sup> , v	Pollution concentration, th. ton/ th.km <sup>2</sup> , v	100dv, indicator	Ranking of pollution influence
1	Lower Silesian	0,15	0,20	3,0	3
2	Kuyavian-Pomeranian	0,12	0,22	2,6	5
3	Lublin	0,09	0,08	0,7	13
4	Lubusz	0,07	0,09	0,6	14
5	Łódź	0,14	0,19	2,7	4
6	Lesser Poland	0,22	0,26	5,7	2
7	Masovian	0,15	0,13	2,0	7
8	Opole	0,11	0,13	1,4	10
9	Subcarpathian	0,12	0,10	1,2	11
10	Podlaskie	0,06	0,04	0,2	16
11	Pomeranian	0,13	0,15	1,9	8
12	Silesian	0,37	0,86	11,8	1
13	Świętokrzyskie	0,11	0,23	2,5	6
14	Warmian-Masurian	0,06	0,05	0,3	15
15	Greater Poland	0,12	0,13	1,6	9
16	West Pomeranian	0,07	0,11	0,8	12

If we compare the ratings we shall observe, that the top three priority on reducing pollution include the following Provinces: Silesian, Lesser Poland, Lower Silesian. The results are conditioned by the fact that in these Voivodships is the largest concentration of pollution and population density living in these areas.

The reason for it should be considered as the presence of large scale industrial production, which requires the involvement of a significant number of employees and activities which are based on industry specifics, that are related to pollution.

Priority means that first of all shall be implemented the environmental initiatives in these areas. But the choices of eco-investments significantly affects the readiness of technical and technological solutions. Also important factors include absolute and specific costs, including such factors as capital intensity reduction of pollution [7].

As was previously analyzed from the two areas of air quality improvement for dust pollution better results are achieved, which decreased more rapidly.

A priori, this can be explained by the fact that there are appropriate technical solutions that do not require for their implementation major capital expenditures. At the same time, the chemical nature of pollution may require more complex development projects and significant capital investment. Do not forget about the diversification aspects of environmental activities. In the majority of cases, the environmental measures of Voivodships are carried out independently at their own expense and opportunities. A compromise between the interests of the community as a whole and the community in some areas can be achieved through the introduction of appropriate criteria and constraints. Some approaches in this direction, were considered in [5, 8].

## CONCLUSIONS

The performed work have shown, that the choice of parameters, that quantify environmental assessment should take into consideration the pollution's negative impact at first on the life quality of one man, and then summarize the number of residents living in a particular area.

Taking into consideration air pollution, the output parameters for the performed research should be considered a harmful gas in the air, the component that is correlated with the amount of gas emissions per unit of area. For residents of the entire territory the overall pollution impact is considered additive, which will be proportional to the population.

The statistical analysis of Polish Voivodeship illustrates, that these indicators and their product significantly differ for different areas – different regions of one country, on given example of Poland. Because of this, the latter figure may be used to identify priority areas for the implementation of measures in order to reduce air pollution. In order to select appropriate investment projects, we require further assessment of the eco-costs effectiveness, which is largely dependent on the innovation degree of new technology. The strategy to reduce pollution at the country level should consist in the eco-activities for individual Voivodeships considering the level of local pollution, their industrial specifics as well as general and local resource capacity allocation, formation and implementation of eco-investment projects.

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