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CHARACTERISTIC OF AREA VALORIZATION METHOD IN THE AIR PROTECTION

Characteristic of area valorization method in the air protection was presented. The application of taxonomic methods (as opposed to traditional methods) permits evaluating in a short time a number of heterogeneous elements of environment in the numerical form. The values of area valorization index reflect the density rate of the area tested with elements sensistive to air pollutants. The product of area valorization index and air pollutant concentrations more adequately renders the environmental risk than the spatial dispersion of concentrations of pollutants applied so far. Environmental risk level established in such a way may be utilized in the optimization calculus of expenditures on air protection.

The application of the method presented has been illustrated by Cracow province valorization in a grid of 10×10 km.

During research on the optimization of expenditures on air protection, conducted in the Institute of Environmental Engineering [8], the evaluation of area investigated – meant as the natural environment [4] – was considered to be of crucial importance.

For the purposes of environment protection there were determined some legally valid standards [7], specifying the permissible concentrations of pollutants. These standards denote only two ranges of pollutant concentrations according to which the country area can be classified either as regions under protection or regions under special protection. Such a classification is sufficient for the complex evaluation of environment.

Mathematical models, which describe natural environment as a weight function of the area investigated, are being used more frequently to evaluate the potential damage caused by air pollution [6].

The product of the concentration of pollutants value and the area valorization index is assumed as the criterion for evaluation of the environmental risk level [1]:

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$$\sum_i \sum_j C_{ij} V_j \rightarrow \min \tag{1}$$

where:

C – concentration of pollutants,

V – area valorization index,

i – number of pollutants emission sources,

j – number of spatial elements of area investigated.

The optimization calculus is defined by the minimum sum of the product of pollutant concentrations and the value of area valorization index. Due to the method described, the problem of area valorization can be solved. Results of the valorization are described in the form of a weight function characteristic of an area investigated and expressed as numerical values. The method allows a wide-range investigation of the area elements, particular attention being paid to the human being.

Literature data provide numerous examples of direct and/or indirect methods of area valorization. Traditional methods (physiographic-ecological) [11] based on carthographic and descriptive techniques are widely used. Although these methods lead to detailed conclusions, they are still labour- and time-consuming and rather useless for the optimization purposes because they do not give a synthetic numerical presentation of results.

Newer valorization methods provide results in numerical form [2], [13]. They are determined by a team of experts by means of the so-called Delphic method. Each element of an area is evaluated with reference to a certain point range. One of such methods, widespread in the world, is the US method of the influence of investment on environment evaluation, known as the "Environmental Impact Assessment" [2]. The above-mentioned method allows us to make only a relative evaluation of harmful impact of particular investment objects on environment. Other numerical (economical) methods [5], [12] enable us to evaluate a few measurable area elements (in terms of costs); strickly speaking, they serve as an estimation of losses caused by air pollution.

The valorization methods, mentioned so far, are very subjective, and because of poor accuracy of results they are not very useful in the optimization of expenditures on air protection.

Therefore, taxonomic methods have been applied [9] to our purposes. They permit an explicit and objective, in due measure, evaluation of environment and simultaneously are not time-consuming. They have been used for a long time in biological, geographic, economic or social sciences and enable the detection of regularities in statistical samples whose units are defined by the set of relatively numerous variables.

Hellwig's method of taxonomic development measure [3] has been applied. It allows the linear ordering of the area elements depending on their distance from a certain, artificial point, named taxonomic area pattern. The value of measure has been identified with the values of area valorization index expressing a weight function of an area investigated. The method discussed permits evaluation of a number of various area elements which very often cannot be compared directly. It also enables us to get information from a variety of current statistical records which makes the valorization process much shorter and efficient. At the same time, the method described, which has a very simple algorithm as its basis, allows application of diverse detailed variational options.

The method applied is presented in the form of a block diagram (fig. 1).

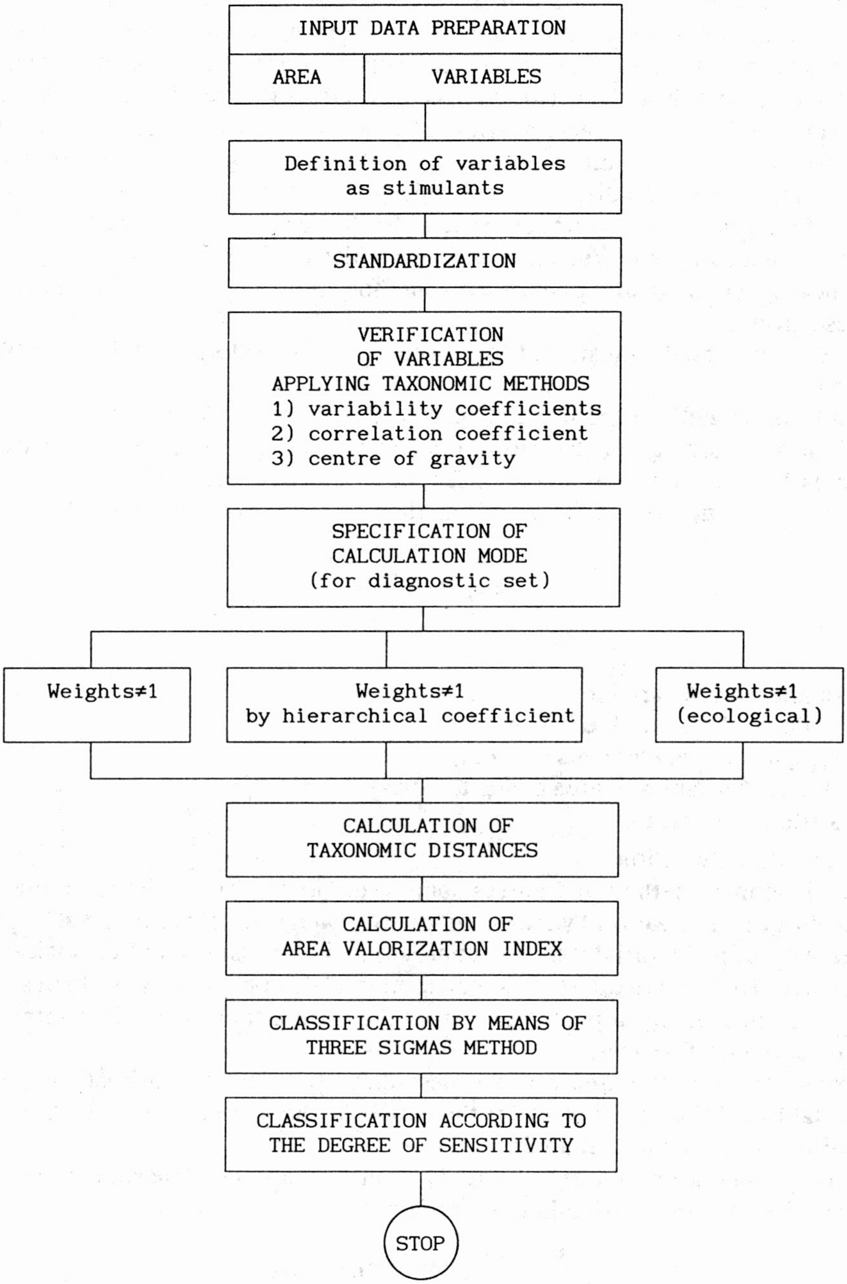

Fig. 1. Schematic diagram of the area valorization method

The application of the taxonomic method determines the way of data collecting and processing. The area investigated is being divided into smaller spatial elements (e.g. provinces into communes; towns into districts and housing estates) and then described by possibly maximum number of natural and anthropogenetic variables (area characteristics). The spatial elements should be characterized by a substantial sensitivity to pollution.

The set of 29 initial area characteristics is subject to a verification in order to eliminate those which are not significant and highly correlated as well as to establish the set of diagnostic characteristics. The diagnostic variables reflect the most essential features of the initial set. Other taxonomic methods are used for verification of characteristics. These are as follows: a sphere method collecting variables which define the spatial areas investigated in more homogeneous groups and a gravity method allowing the choice of representatives from these groups.

For example, the diagnostic set for Cracow province valorization includes the following variables:

1. Anthropogenetic: a) population density, b) acreage of urban areas.

2. Natural: a) forest area, b) area of open waters, c) agricultural productivity, d) area of particularly protected areas, e) coefficient of area size compensation.

Before application of the taxonomic method, the variables are standardized:

$$z_{jk} = \frac{x_{jk} - \overline{x}_k}{\sigma_k} \tag{2}$$

where:

z_{jk} – standardized variable,
x_{jk} – value of k-th variable in j-th area,
$j = 1, ..., w$ (spatial elements of area),
$k = 1, ..., n$ (variables = area characteristics),
$\overline{x}_k$– arithmetical mean,
σ_k – standard deviation.

The taxonomic method guarantees some wide possibilities of determining different detailed aims of valorization by means of granting weights, i.e. preferences, to particular variables or groups of variables. Two approaches, i.e. statistical and ecological, may be distinguished. The statistiscal weights render internal diversification of statistical data preceding the standardization process, whereas the ecological weights determine the subjective research preferences.

Having delimited the area which is described by the set of diagnostic variables and having established the preferences for the variables, the procedure of calculation of area valorization index is being initiated.

First of all the taxonomic area model P_0 (vector composed of maximum values of area characteristics – the set of stimulants) is obtained:

$$P_0 = (z_{01}, z_{02}, ..., z_{0s}, ..., z_{0m}) \tag{3}$$

where:

$$z_{0s} = \max_j z_{jk} \quad \text{if } k \in I,$$

I – set of stimulants,

z_{jk} – standard value of k-th variable in j-th area,

$m \leq n$.

Then a taxonomic distance d_{j0} between respective spatial elements and point P_0 is obtained:

$$d_{j0} = \left(\sum_{k=1}^{m} (z_{jk} - z_{0s})^2 \right)^{1/2} \tag{4}$$

for $j = 1, ..., w$.

Finally, the area valorization index V_j is expressed by the following formula:

$$V_j = 1 - \frac{d_{j0}}{d_0}, \quad V_j \in (0, 1) \tag{5}$$

where:

$$d_0 = \bar{d}_0 + 2\sigma_0,$$

$$\bar{d}_0 = \frac{1}{w} \sum_{j=1}^{w} d_{j0},$$

$$\sigma_0 = \left(\frac{1}{w} \sum_{j=1}^{w} (d_{j0} - \bar{d}_0)^2 \right)^{1/2}.$$

The values of area valorization index range from 0 to 1. Its interpretation is as follows: the closer the value of V_j to 1, the richer the density rate of the area investigated in elements that are sensitive to pollution and therefore need protection.

The following seven sensitivity grades have been distinguished:

$(\bar{V}_j + 3\sigma;\ 1]$ I grade, extremely sensitive areas,

$(\bar{V}_j + 2\sigma;\ \bar{V}_j + 3\sigma]$ II grade, very sensitive areas,

$(\bar{V}_j + \sigma;\ \bar{V}_j + 2\sigma]$ III grade, sensitive areas,

$(\bar{V}_j;\ \bar{V}_j + \sigma]$ IV grade, fairly sensitive areas,

$(\bar{V}_j - \sigma;\ \bar{V}_j]$ V grade, little sensitive areas,

$(\bar{V}_j - 2\sigma;\ \bar{V}_j - \sigma]$ VI grade, very little sensitive areas,

$(\bar{V}_j - 3\sigma;\ \bar{V}_j - 2\sigma]$ VII grade, insensitive areas,

where:

$\bar{V}_j$ – mean arithmetic value of area valorization index,

σ – standard deviation of area valorization index.

The area characterized by the valorization index is then compared (by means of product formation) with the dispersion of mean concentrations of chosen air pollutants [10]. The spatial dispersion of pollutant concentrations has provided so far an exclusive information on environmental hazard. The value of the product of the concentrations of pollu-

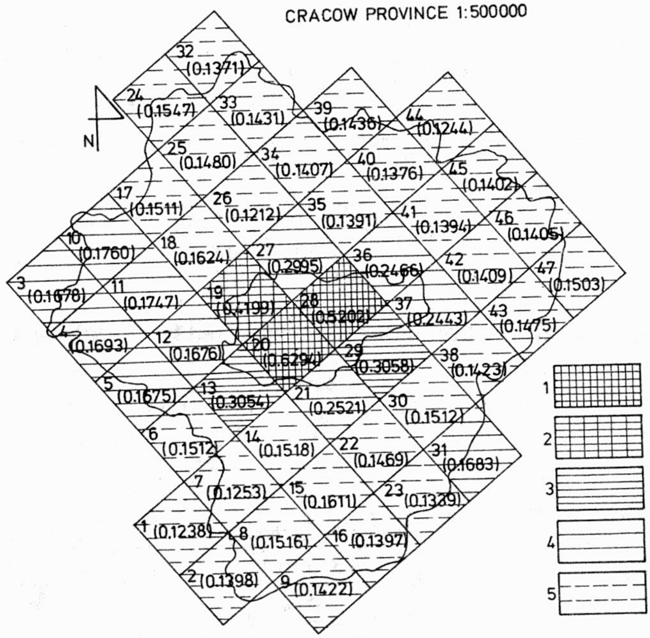

Fig. 2. Spatial dispersion of values of area valorization index for 7 diagnostic variables in a computational grid

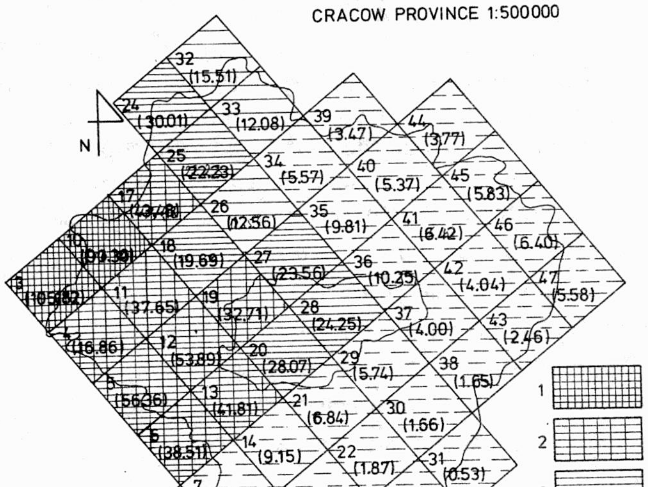

Fig. 3. Spatial dispersion of mean concentrations of pollutants (SO_2 $\mu g/m^3$ year)

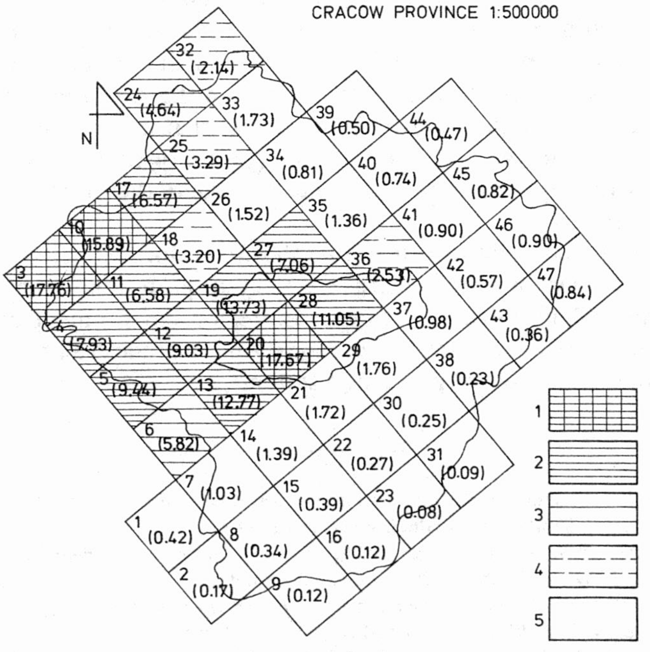

Fig. 4. Spatial dispersion of environmental hazard

tants and the area valorization index – giving an evidence for the level of environmental hazard – more adequately renders the threat of air pollution [1].

Level of environmental hazard defined in such a way may find its application in optimization calculus of expenditures on environment protection. At first, some production procedures are adopted in order to limit the emission of pollutants from those plants which guarantee the greatest drop in the environmental hazard on the extremely sensitive areas.

Such an initial calculus of optimization procedure, by means of the method of area valorization, was carried out within the frames of the State Fundamental Research Programme in 1990 at the Technical University of Warsaw [8].

The following double division of the area investigated has been applied: primary, in accordance with administrative division (e.g. into communes), and secondary, in a grid of 10×10 km. The latter was used to evaluate the environmental hazard in Cracow province.

Thereafter the values of area valorization index calculated for diagnostic set of 7 variables were presented as weighted means in the grig (fig. 2). The maximum values of the index are characteristic of the city of Cracow and the minimum values – of the southern and eastern parts of province.

Figure 3 presents spatial dispersion of mean concentrations of SO_2, emitted from 31 chosen power plants , which are situated mostly in Cracow and Katowice provinces. They are characterized by considerable emission of SO_2 and were used in preliminary calculations of costs of introduction of one of four technologies which allow to reduce emissions

[8]. The maximum values of SO_2 concentrations are found in the north-western part of the province, and the maximum values – in the southern and eastern parts of it.

Figure 4 presents the spatial dispersion of environmental hazard of Cracow province. The greatest hazard was characteristic of two areas. In the first area (the north-western part of province) environmental hazard is the same as that in areas of maximum concentrations of pollutants, whereas in the second one (centre of Cracow) it corresponds with that in the areas extremely sensitive to air pollution (where the value of area valorization index is the greatest).

The above-mentioned example proves that the area valorization index strongly affects spatial dispersion of environmental hazard caused by air pollution. It may be applied both in economic models of optimization of expenditures on environment protection and in spatial planning or assessment of investment location. The index can be an useful tool for designer-analyst of environmental protection systems.

REFERENCES

[1] DOBIJA J., *Metoda waloryzacji środowiska w strategii ochrony atmosfery* (typescript), Politechnika Warszawska, Wydział Inżynierii Sanitarnej i Wodnej, Warszawa 1990.

[2] *EIA Methods – Networks/Systems Diagrams; Scaling-Weighting Checklists. Training Course on Environmental Impact Assessment (EIA)*, 4–17 July, 1982, Aberdeen, Scotland, UK.

[3]HELLWIG Z., *Zastosowanie metody taksonomicznej i typologicznego podziału krajów ze względu na poziom ich rozwoju i strukturę wykwalifikowanych kadr*, Przegląd Statystyczny nr 4, 1968.

[4] HOPFER A., CYMERMAN R., NOWAK A., *Ocena i waloryzacja gruntów wiejskich*, PWRiL, Warszawa 1982.

[5] JANIKOWSKI R., STARZEWSKA A., *Straty gospodarcze i społeczne wynikające z zanieczyszczenia środowiska*, Instytut Kształtowania Środowiska, Warszawa 1983.

[6] JUDA J., *Zasady stosowania analizy systemowej w kształtowaniu środowiska. Człowiek i Środowisko*, Ossolineum, 1978.

[7] NOWICKI M., *Inżynierskie metody badania i obliczania stanu zanieczyszczenia powietrza atmosferycznego*, Zeszyty Problemowe PZIiTS NOT nr X/84–85, Warszawa 1984/1985.

[8] *Opracowanie metodyki optymalizacji nakładów na ograniczenie emisji SO_2 w skali kraju i regionu (na przykładzie województwa krakowskiego)* (typescript), pod red. J. Judy, Zadanie 04.10.10.02.05.03 w CPBP Nr 4.10, Politechnika Warszawska, Warszawa 1990.

[9] PLUTA W., *Wielowymiarowa analiza porównawcza w badaniach ekonomicznych, PWE, Warszawa 1977.*

[10] *Program ochrony powietrza atmosferycznego dla m. Krakowa do 2010 roku* (typescript), pod kierunkiem J. Judy, Politechnika Warszawska, Instytut Inżynierii Środowiska, Warszawa 1986.

[11] STALA Z., *Dokumentacja ekofizjograficzna na potrzeby projektowania osiedli mieszkaniowych*, Instytut Kształtowania Środowiska, Warszawa 1983.

[12] *Straty spowodowane degradacją powietrza atmosferycznego*, Prace Naukowe AE i PAN, Instytut Podstaw Inżynierii Środowiska w Zabrzu, problem węzłowy 10.2 pod red. F. Piontka, Katowice 1985.

[13] *Waloryzacja rolniczej przestrzeni produkcyjnej Polski według gmin*, pod kierunkiem T. Witka, JUNG, Puławy 1981.

CHARAKTERYSTYKA METODY WALORYZACJI TERENU W STRATEGII OCHRONY ATMOSFERY

Przedstawiono charakterystykę metody waloryzacji terenu w strategii ochrony atmosfery. Wykorzystane metody taksonomiczne – w przeciwieństwie do tradycyjnych – umożliwiają szybkie opisanie za pomocą wartości liczbowych wielu niejednorodnych elementów środowiska. Uzyskany wskaźnik waloryzacji charakteryzuje stopień nasycenia badanego obszaru elementami szczególnie wrażliwymi na zanieczyszczenia powietrza. Iloczyn

wskaźnika waloryzacji i wartości stężeń zanieczyszczeń dokładniej określa poziom zagrożenia badanego terenu niż dotychczas stosowany rozkład przestrzenny stężeń zanieczyszczeń powietrza. Tak obliczany poziom zagrożenia środowiska służy do optymalizacji nakładów na ochronę powietrza.

Metodę zilustrowano przykładem waloryzacji obszaru województwa krakowskiego w siatce kwadratowej 10×10 km.

ХАРАКТЕРИСТИКА МЕТОДА ВАЛОРИЗАЦИИ МЕСТНОСТИ В СТРАТЕГИИ АТМОСФЕРЫ

Представлена характеристика метода валоризации местности в стратегии охраны атмосферы. Использованные таксономические методы — наоборот как традиционные — дают возможность быстрого описания при помощи численных значений многих однородных элементов среды. Полученный показатель валоризации характеризует степень насыщения исследуемого района элементами особенно чувствительными к загрязнениям воздуха. Произведение показателя валоризации и значений концентраций загрязнений точнее определяет уровень опасности для исследуемой местности, чем применяемое до сих пор пространственное распределение концентраций загрязнений воздуха. Вычисленный таким образом уровень опасности для среды служит оптимизации издержек на охрану воздуха.

Метод проиллюстрирован примером валоризации территории краковского воеводства в квадратной сетке 10x10 км.