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DEVELOPMENT OF THE AGGREGATION MODEL OF ADVERSE ENVIRONMENTAL AND HEALTH EFFECTS FOR EVALUATION OF LARGE AREAS OF ECOLOGICAL HAZARD *

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Abstract. The model of aggregation of 12 parameters describing the environmental and health effects in areas of ecological hazard has been elaborated. The values of particular indices create the characteristic profile useful for selection of dominant environmental problems. The general index of hazard is suitable for establishing priorities among ecological hazard areas.

The problem of evaluation of large areas of ecological hazard is recognized as one of the most difficult tasks, because of the complexity of factors which should be submitted to assessment as well as lack of uniform methodology and lack of principles for interpretation of the collected data. The undertaking of such an evaluation becomes much more complicated if the health effects which result from the existing environmental hazards are to be included (2, 3, 4).

The 27 areas of ecological hazard existing in Poland were initially treated as equal, but in the course of time people started to differentiate them according to pollution and hazards which exist in these areas (9–12). However, the most important factor, health effects have been never taken into account in those assessments. Furthermore, the literature does not include a complex approach which consists of environmental and health effects in larger areas.

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Only for small areas (e.g. 10 km diameter) around the known source of pollution, the environmental health effects have been evaluated, however, the environmental pollution has not been quantitatively assessed (6, 7).

The aim of this study was to select environmental and health factors which will best reflect the situation in the investigated area. In addition, we undertook to evaluate them quantitatively by the use of the scoring system and present them in the form of indices, which will create the characteristic profile.

The main task in the recent study was, however, to elaborate the aggregation model for particular indices of hazardous environmental factors and adverse health effects.

The baseline for this study was the previously published paper (3) on toxicological indices for helath risk assessment in areas of ecological hazard. The ideas presented there have been modified, however, according to the assumption that health effects should play the dominant role in construction of the general index of hazard which will next be used for establishing priorities.

This is why the particular indices have to be selected carefully to make a real characterization of the evaluated area and to serve for creating and aggregation model which should combine all of them while still emphasizing the health effects.

The elaborated method has to be universal enough to make use of the existing data available for each area of ecological hazard.

Taking into consideration all these assumptions and limitations, the following parameters have been selected for the construction of the profile and calculation of the general index of hazard.

They have been divided into four groups:

Group I — concerns those parameters which characterize the pollution of the environment and create the potential hazard for living environmental components:

1. Annual emissions of gaseous (SO_2, NO_x, CO, and others) and dust pollutants into the ambient air;
2. Annual discharge of non treated waste water;
3. The amount of deposited solid wastes.

Group II — comprises indices of degradation of particular environmental components:

4. Areas of damaged forests;
5. Areas of dumping grounds;
6. Areas of acidic soil;
7. Length of contaminated rivers.

Group III — includes indices which characterize the exposure of the population to harmful substances. All three sources: air, water and food contaminations were taken into account:

8. The extent of exposure to air pollutants;
9. The percentage of population using drinking water of good quality;
10. The indirect evaluation of the contamination of food.

Group IV — refers to parameters characterizing the health status of the population. Numerous available health status indices have been used for the construction of the synthetic measure (for example: neonatal mortality, mortality from cardiovascular diseases etc.) which should reflect the intensity of health effects. Also the ratio of observed and expected death was used for the construction of health risk index:

11. Synthetic measure (18);
12. Health risk.

The group I and II indices have been used for the whole areas of ecological hazard whereas indices of the groups III and IV have been calculated separately for urban and rural regions in each EHA (Ecological Hazard Area).

The quantitative evaluation of each parameter was based on the uniform scoring system in which the following scale was applied:

index 1 – was used for admissible values or smallest intensity of the phenomenon,
index 2 – was used for excessive values,
index 3 – was used for inadmissible values or highest intensity of the phenomenon.

This general rule was, however, individually applied for quantification of each parameter selected for evaluation. Toxicological and ecological criteria have been used for quantification of environmental and health quality parameters, but in cases when it was not possible, a logical, mathematical division was used for each of the 3 ranges of values for which the increasing index number was attributed.

It should be emphasized that, wherever possible, the indices describing not only the level of the phenomena but also their extent have been applied.

As far as group I is concerned, available information or guidelines on admissible or excessive emissions of toxic substances to the ambient air, discharge of solid wastes or waste water in particular areas of ecological hazard does not exist. The absolute values, in particular EHA, are very differentiated, so for each sequence of numbers describing for example, the intensity of SO_2 emission per 1 km^2 in 27 EHAs, the geometric mean (Gm) and the standard deviation (GSD) were calculated. For values smaller than $Gm-\frac{1}{2}GSD$ the index value 1 was attributed. Values in the range of $Gm-\frac{1}{2}GSD$ to $Gm+\frac{1}{2}GSD$ received the index value 2. All values above this range were marked as index 3. In this way all values were divided into 3 almost equal ranges and the attributed index values describe the intensity of the phenomenon. Similar mathematical operations were applied for the rest of the parameters in this groups.

For the group II the same mathematical operation was applied for evaluating the intensity of environmental degradation, however, the basic evaluation was supported by ecological criteria.

Group III characterizes the exposure of population to environmental toxins. The availability of data was very differentiated here. The best documented were the concentrations of pollutions in the ambient air. Based on toxicological criteria the additive index of exposure was calculated to describe the exposure to SO_2, NO_x and dust. These air pollutants have been considered as priority environmental toxic substances in Poland (5). The area index calculated in this way was multiplied by the number of inhabitants in each EHA to obtain the extent of exposure. The numbers of the extent of exposure for 27 EHAs were used for calculation of the geometric mean and standard deviation which in turn have been applied for evaluating index values as described above.

For assessing the index values which indicate the exposure due to the contamination of drinking water, information on the water quality was used. The index value 1 was used if over 90% of the population used good quality drinking water. Good drinking water used by 50–90% of the population was marked by index value 2. In cases where less than 50% of the population used good quality tap water the index value was 3.

Exposure from food contamination was evaluated on the base of the assumption that dust-fall is an indirect indicator of the contamination of food, the content of toxic metals and benzoalfapyren (BaP) in soil contributes to food contamination and that the frequency of information in professional journals on contamination of diets and food products reflex the exposure from these sources.

In this way the index value 1 was applied for these EHAs in which the dust-fall was less than allowable value of 200 g/km, and the content of toxic metals and BaP in soil and in diets and food products was below the admissible value.

The twofold excess of allowable value for the dust-fall, existing reports of excess values for the single toxic metals or BaP in soil, food product or diets was marked by index value 2.

The index value 3 was used in case of over twofold excess of hygienic normative for dust-fall, and existing reports of excess values of numerous toxic metals, BaP, or other contaminations in soil, food products or diets.

Finally, group IV contains parameters indicating health effects. Among numerous available indicators of health status only these were selected, which could be bound with environmental contamination. First used health effects index was constructed as a combination of several health indices to create one synthetic measure (1). The numerical value of the considered index was divided into 3 ranges according to the above described rules based on geometric mean and standard deviation.

The next selected health parameter was based on the over-mortality in EHAs as compared with "clean" areas in Poland. The ratio of observed to expected death in all EHA was divided into 3 ranges according to the above mentioned rules and each range was marked as index 1, 2 or 3.

The 12 particular indices calculated according to the above described methods have served for two purposes:

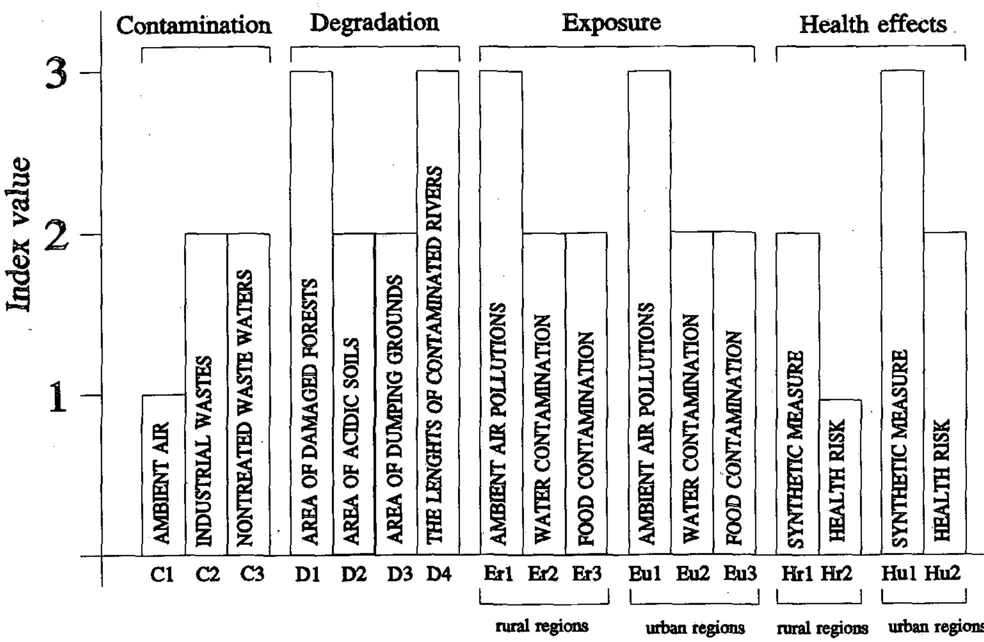
1. Creation of a characteristic for each EHA profile of valorization of environmental and health status parameters (Fig. 1).

2. Aggregation of single index values for calculating the general index of hazard which could be used for indicating priorities among EHAs (Fig. 1).

Profile characterizing the investigated EHA is very useful for indicating the dominant problems and concentration of efforts on the right direction for the improvement of the situation. All data indicated in the profile are fully comparable, which very much facilitates the undertaking of decision in environmental management. The graphic presentation of the profile very clearly illustrates the existence of excessive contaminations, degradation, exposure or adverse health effects as compared with the 3 levels scale of the index. Additionally, if necessary, the absolute values of particular parameters could be shown.

According to the preliminary assumptions, a model for aggregation of the individual numerical index values was constructed in such a way that health status indices have the dominant role in the creation of the general index of hazard. They have been recognized as the most essential parameters which characterize the EHA.

The health status parameters will not rise the value of the general index in case of their lowest intensity. On the contrary, in the case of high health status index the value of the general index will be substantially increased.



Formula for calculation of the general index of hazard

(C1+C2+C3+D1+D2+D3+D4+Er1+Er2+Er3)*Hr1*Hr2 = Jr index of hazard in rural regions

(C1+C2+C3+D1+D2+D3+D4+Eu1+Eu2+Eu3)*Hu1*Hu2 = Ju index of hazard in urban regions

Jr+Ju = Jg	general index of hazard

Fig. 1. The profile of valorization of environmental and health status parameters in areas of ecological hazards.

The general index of hazard is a good measure for establishing priorities among EHAs. It also classifies and segregates these areas according to the most essential causes and effects of environmental contamination. Three categories could be named here:

– state of hazard
– state of ecological degradation
– state of ecological disaster,

according to the criteria which could be elaborated and applied on the base of theoretical and practical grounds.

Both the profile of environmental and health effects parameters and the general index of hazard for EHA are the new tools which could rationalize the process of environmental quality management in Poland.

The system of uniform ecological evaluation of large areas elaborated and presented above also possesses more universal significance. For the first time it allows for the uniform approach to valorization and quantitative assessment of large areas from the point of view of environmental hazards. This has fundamental significance in solving environmental protection problems.

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