DEVELOPING A NEW METHODOLOGY FOR CALCULATING RELIABILITY MARKS FOR ENVIRONMENTAL FACTORS (WATER)

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Abstract: This paper proposes developing a new methodology for calculating the reliability marks given to environmental factors (used in the procedure of environmental impact assessment through global index) which takes into account issues such as toxicity of pollutants, the probability that they reach dangerous concentrations in environmental compartments, etc. The paper should be regarded as a proposal and it should be noted that the calculation refers only to reliability marks for water.

Keywords: impact assessment, reliability marks, indicating parameters, weighting factors.

Introduction

One of the most important environmental protection activities is to evaluate the impact of human activities on the environment. This activity is particularly important in Romania, currently regulated by Government Decision 1213 of 06.09.2006 (with amendments and subsequent additions, replaces GD 918 from 2002 which in turn replaced the Order 125 of 1996) and establishes the overall procedure for environmental impact assessment.

Although environmental impact assessment is a legally regulated activity for 15 years, a common feature of normative acts mentioned above is the lack of establishing a (some) ways to perform this assessment.

In the absence of such published methods, in Romania, are used a range of methods taken from Western Europe and the U.S. (impact matrix, impact networks, thematic maps, checklists, etc.). This methods can sometimes be difficult to understand (especially if we consider public participation in the evaluation of environmental impact) or can be used wrongly.

But there is a method, often used nationally to assess the impact, which is more accessible and understandable to the general public, namely the method for assessing the overall pollution (impact) index.

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Presentation of overall pollution index method

Thus this method considers that the aim of assessing the impact of human activities on the environment and the evolution of the phenomenon of pollution requires a comprehensive assessment of environmental pollution at a time.

Such an assessment would allow a mapping on a regional - macro-regional level in terms of environmental quality status.

In general, it is considered possible to appreciate the environmental quality of an area and at a time by:

Air quality;
Water quality;
Soil quality;
State of flora and fauna of the area;
The health of the population in the area;
Landscape.

Each of these factors is characterized by representative quality indicators for assessing pollution and for which there are established acceptable limits (MAC). Depending on the enrollment in the normal range reliability marks (RM) are given.

Ideal state is represented by a regular geometric figure that circumscribed circle radius passing through the polygon vertices are divided into ten units of reliability, counting from the center of the circle.

By joining points from location expressing the true state values, an irregular geometric figure is obtained with a smaller area, which is submitted to the regular geometric figure representing the ideal status.

The global pollution (impact) index of an ecosystem (IPG) results from the ratio of the surface representing the ideal state (Si) and the surface representing the real condition (Sr):

$$IPG = Si / Sr$$

When there are no changes in environmental quality, so when there is no pollution, this index is equal to 1.

Conventionally a scale from 1 to 6, for overall pollution index, was established as follows:

IPG = 1 - natural environment unaffected by human activities;

1 <IPG <2 - environment affected by human activities within reasonable limits;

2 <IPG <3 - environment affected by human activities causing discomfort for life forms;

3 <IPG <4 - environment affected by human activities causing disorders for life forms;

4 <IPG <6 - environment severely affected by human activities, dangerous for life forms;

IPG> 6 - degraded environment, inappropriate for life forms [1].

The method can be used in any of the phases of a project, environmental quality assessment before starting a anthropogenic project, environmental quality assessment during the implementation of an anthropogenic project, environmental quality evaluation after a anthropogenic project is put into practice, environmental quality assessing after the decommissioning of an anthropogenic project, environmental quality assessment after the rehabilitation of the area of interest and to evaluate the environment at a time and identify and quantify of pollution sources (in an area of interest) and evaluating environmental quality in crisis situations (earthquakes, landslides, hurricanes, tornadoes, cyclones, drought, etc.). [2]

The necessity for weighting the reliability marks

One of the disadvantages of the method is that the establishment of the reliability marks for environmental factors, as a method of calculating, is considered the arithmetic mean of the reliability marks awarded for each quality parameter describing the environmental factor in question. In other words it is considered that each parameter involved in determining the final reliability mark in terms of importance is equally.

Looking at this procedure, especially in terms of the relationship between quality parameters of the environmental factors (water) and human health is easy to understand why it is considered a disadvantage of the method. It is clear that in terms of action of pollutants on human health, of flora and fauna, of their toxicity, the possibility that a pollutant is present in an environmental compartment at a concentration considered to be dangerous to the health, of flow regime and the possibilities for self-cleaning, are different and for these grounds requires a weighting of reliability marks, in view of those above.

Below is presented a way of achieving this weighting factor for water (surface water), mentioning that for establishing the weighting factors an urban area typology was especially considered.

Identifying the weighting factors for surface water quality parameter

Weighting factors assigned values (taking into account the criteria outlined above) are presented in Tables 1, 2 and 3.

Radioactivity on the existing rules establish the following benchmarks: for drinking water maximum annual effective dose 0,1 mSv/year, 0,1 Bq/dm^3 alpha activity, beta activity Bq/dm^3 1,0, and for beta activity of natural waters three benchmark 2,0 Bq/dm^3 - threshold of attention, 5,0 Bq/dm^3 - warning threshold, 20,0 Bq/dm^3 - alarm threshold. Whatever type of water (fresh, flowing, natural lake or reservoir) the weighting factor assigned is 10.

Table 1. Indicators for the eutrophication process

Crt. no.	Parameter	Measuring unit (MU)	Category of natural lake or reservoir (MAC in conformity with Order 1146/2002)				
			Ultraoligotrophic	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic
1	Nutrients	P total /N mineral total mg/dm^3/mg/dm^3	0,005/0,200	0,005-0,01/0,2-0,4	0,01-0,03/0,4-0,65	0,03-0,1/0,65-1,5	>0,1/1,5
2	Biomass of phytoplankton	mg/dm^3	0 - 1	1 - 3	3 - 5	5 - 10	over 10
3	Chlorophyll „a”	mg/dm^3 (annual average/maximum annual average)	<1/<2,5	<2,5/<8	2,5-8/8-25	8-25/25-75	27-75/>75
4	Dissolved oxygen saturation	%	over 70	over 70	10 - 70	under 10	under 10

It is believed that all indicating parameters of the degree of eutrophication have the same weighting factors and then the final reliability mark is calculate by the arithmetic average of the reliability marks awarded for each parameter, namely:

$$NB_f = \frac{\sum NB_i}{i}; i = \overline{1,4};$$

Where: NB_f - the final reliability mark, NB_i - the reliability mark given for each parameter.

Table 2. Sediments (fraction <63 μm)

Crt. no..	Parameter	MU	MAC cf. Ord. 1146/2002	Weighting factors (regardless of the flow regime or type of lake)
1	Arsenic	mg/kg	17	7
2	Cadmium	mg/kg	3,5	8
3	Chromium	mg/kg	90	6
4	Copper	mg/kg	200	5
5	Lead	mg/kg	90	6
6	Mercury	mg/kg	0,5	10
7	Zinc	mg/kg	300	3
8	Benz(a)pyren	mg/kg	750	2
9	Lindane	mg/kg	1,4	8
10	PCB - s	mg/kg	280	4

PCB – Polychlorinated biphenyls

Reliability mark calculation:

$$NB_F = \frac{\sum (NB_i \cdot f_i)}{\sum f_i}$$

Where: NB_f - final reliability mark, NB_i - reliability mark given for each parameter, f_i - the weighting factor of each parameter.

For physical-chemical indicators (Table 3) calculating the final reliability mark involves two stages:

I. Calculate the reliability mark for each group of indicators of water quality parameters as:

$$NB_G = \frac{\sum (NB_i \cdot f_i)}{\sum f_i}$$

Where: NB_G - reliability mark determined for each group of indicators, NB_i - reliability mark given for each parameter, f_i - the weighting factor of each parameter.

II. The final reliability mark for the environmental factor of water is carried by the formula:

$$NB_F = \frac{\sum (NB_G \cdot f_G)}{\sum f_G}$$

Where: NB_F - the final reliability mark for environmental factor of water, NB_G - reliability mark determined for each group of parameters separately, f_G - weighting factor of each group.

For determining the weighting factors were taken into account the effects of each pollutant (or group of pollutants) on aquatic ecosystems (flora and fauna regardless of their place in the food chain), the possibilities of water use (especially for drinking water, for food and other sensitive uses that require strict quality conditions) and the toxicological data (direct and indirect influence on human health).

When for determining water quality analysis are performed on the parameters contained in one group then the final reliability mark for water will be equal to the mark of reliability obtained for group in question.

If only one parameter is determined from a group, then its assigned weighting factor is equal to the weighting factor of the respective group.

Weighting factors have values between 1 and 10 (1 a very low importance and 10 the utmost importance).

Table 3. Physico-chemical indicators for surface water quality

Crt. no.	Group	Parameter	MU	MAC							Weighting factor (turbulent flow regime)	Weighting factor (laminar flow regime and lakes)	Group weighting factor
				Category of quality cf. Ord. 1146/2002					Used waters cf. GD 352/2005				
				I	II	III	IV	V	NTPA 001	NTPA 002			
1	Physical indicators	Temperature	ºC	nn	nn	nn	nn	nn	35	40	3	5	4
2		pH	pH units	6,5-8,5					6,5-8,5 (9)	6,5-8,5	6	6	
3		Suspensions	mg/dm^3	nn	nn	nn	nn	nn	35 (60)	350	3	3	
4	Oxygen regime	DO	mgO_2/dm^3	7	6	5	4	<4	nn	nn	8	9	8
5		BCO5	mgO_2/dm^3	3	5	10	25	>25	25	300	6	8	
6		CCO - Mn	mgO_2/dm^3	5	10	20	50	>50	nn	nn	6	8	
7		CCO - Cr	mgO_2/dm^3	10	25	50	125	>125	125	500	6	8	
8	Nutrients	NH_4^-	mg/dm^3	<0,2	0,2	0,3	0,6	>1,5	2 (3)	30	6	8	6
9		NO_2^-	mg/dm^3	0,01	0,06	0,12	0,3	>0,3	1 (2)	nn	9	9	
10		NO_3^-	mg/dm^3	1	3	6	15	>15	25 (37)	nn	4	6	
11		N total	mg/dm^3	1,5	4	8	20	>20	10 (15)	nn	4	6	
12		PO_4^{-3}	mg/dm^3	0,05	0,1	0,2	0,5	>0,5	nn	nn	7	8	
13		P total	mg/dm^3	0,1	0,2	0,4	1	>1	1 (2)	5	6	8	
14		Chlorophill „a”	mg/dm^3	0,025	0,05	0,1	0,25	>0,25	nn	nn	7	8	
15	General ions, salinity	Residue filtred at 105ºC	mg/dm^3	bkg	500	1000	1300	>1300	2000	nn	6	6	5
16		Na^+	mg/dm^3	bkg	50	100	200	>300	nn	nn	4	5	
17		Ca^{+2}	mg/dm^3	75	150	200	300	>300	300	nn	3	4	
18		Mg^{+2}	mg/dm^3	bkg	25	50	100	>100	100	nn	3	4	
19		Fe total	mg/dm^3	bkg	0,1	0,3	1	>1	5	nn	5	7	
20		Mn total	mg/dm^3	bkg	0,05	0,1	0,3	>0,3	1	2	6	7	
21		Cl^- (chlorides)	mg/dm^3	bkg	100	250	300	>300	500	nn	5	6	
22		SO_4^{-2}	mg/dm^3	80	150	250	300	>300	600	600	4	5	
23	Metals Dissolved fraction	Zn^{+2}	$\mu g/dm^3$	bkg	5	10	25	>25	nn	nn	4	5	7
24		Cu^{+2}	$\mu g/dm^3$	bkg	2	4	8	>8	nn	nn	6	6	
25		Cr total	$\mu g/dm^3$	bkg	2	4	10	>10	nn	nn	6	6	
26		Pb^{+2}	$\mu g/dm^3$	bkg	1	2	5	>5	nn	nn	5	6	
27		Cd^{+2}	$\mu g/dm^3$	bkg	0,1	0,2	0,5	>0,5	nn	nn	8	9	
28		Hg^{+2}	$\mu g/dm^3$	bkg	0,1	0,15	0,3	>0,3	nn	nn	9	9	
29		Ni^{+2}	$\mu g/dm^3$	bkg	1	2	5	>5	nn	nn	4	5	
30		As	$\mu g/dm^3$	bkg	1	2	5	>5	nn	nn	5	6	

Continuation

31	Metals	Total concentration	Zn^{+2}	µg/dm^3	bkg	100	200	500	>500	500	1000	4	6	8
32			Cu^{+2}	µg/dm^3	bkg	20	40	100	>100	100	200	5	6	
33			Cr total	µg/dm^3	bkg	50	100	250	>250	1000	1500	5	6	
34			Pb^{+2}	µg/dm^3	bkg	5	10	25	>25	200	500	6	7	
35			Cd^{+2}	µg/dm^3	bkg	1	2	5	>5	200	300	7	8	
36			Hg^{+2}	µg/dm^3	bkg	0,1	0,2	0,5	>0,5	50	nn	8	9	
37			Ni^{+2}	µg/dm^3	bkg	50	100	250	>250	500	1000	5	6	
38			As	µg/dm^3	bkg	5	10	25	>25	100	nn	6	7	
39	Organic substances		Phenols	µg/dm^3	fond	1	20	50	250	300	30000	7	8	10
40			Detergents	µg/dm^3	fond	500	750	1000	>1000	500	25000	5	7	
41			AOX	µg/dm^3	10	50	100	250	>250	nn	nn	6	8	
42			Petroleum Hydrocarbons	µg/dm^3	bkg	100	200	500	>500	5000	nn	6	8	
43			Lindane	µg/dm^3	0,05	0,1	0,2	0,5	>0,5	nn	nn	9	9	
44			DDT	µg/dm^3	0,001	0,01	0,02	0,05	>0,05	nn	nn	10	10	
45			Atrazine	µg/dm^3	0,02	0,1	0,2	0,05	>0,05	nn	nn	9	9	
46			Triclormethane	µg/dm^3	0,02	0,6	1,2	1,8	>1,8	nn	nn	9	9	
47			Tetraclormethane	µg/dm^3	0,02	1	2	5	>5	nn	nn	8	9	
48			Trichlorethane	µg/dm^3	0,02	1	2	5	>5	nn	nn	8	9	
49			Tetrachlorethane	µg/dm^3	0,02	1	2	5	>5	nn	nn	8	9	
50	Biological and microbiological indicators		Saprodic index MZB		<1,8	1,81-2,3	2,31-2,7	2,71-3,2	>3,2	nn	nn	5	6	8
51			Total coliforms	colonies/100ml	500	10000	nn	nn	nn	nn	nn	6	6	
52			Fecal coliforms	colonies/100ml	100	2000	nn	nn	nn	nn	nn	8	10	
53	Other indicators		CN	µg/dm^3	nn	nn	nn	nn	nn	100	1000	8	10	7
54			S^{-2}, HS^{-}	µg/dm^3	nn	nn	nn	nn	nn	500	1000	6	8	
55			SO_3^{-2}	µg/dm^3	nn	nn	nn	nn	nn	1100	2000	7	8	
56			Cl_2 (residual)	µg/dm^3	nn	nn	nn	nn	nn	200	500	4	6	
57			Cr^{+6}	µg/dm^3	nn	nn	nn	nn	nn	100	200	6	7	
58			Co^{+2}	µg/dm^3	nn	nn	nn	nn	nn	1000	nn	5	6	
59			Se^{+2}	µg/dm^3	nn	nn	nn	nn	nn	100	nn	6	7	
60			Mo^{+2}	µg/dm^3	nn	nn	nn	nn	nn	100	nn	6	7	
61			Ag^{+2}	µg/dm^3	nn	nn	nn	nn	nn	100	nn	5	6	
62			Al^{+3}	µg/dm^3	nn	nn	nn	nn	nn	5000	nn	5	7	

() – valid values for Danube river, nn – not - normed, DO – dissolved oxygen, AOX – organochlorine substances, bkg – background.

Example to highlight the importance of study

To show how the reliability mark is influenced for the environmental factor water when the weighting factors are applied to calculation was considered following example (data from Table 4 represents a real case):

Table 4. Water quality analysis

Crt. no.	Parameter	MU	Average determined values	RM
1	pH	unit pH	6,71	10
2	Diss. O_2	mg/dm^3	8,61	8
3	NH_4^+	mg/dm^3	0,34	9
4	NO_2^-	mg/dm^3	0,04	7
5	HS^-	mg/dm^3	0,02	9
6	Fe	mg/dm^3	0,11	9
7	CCO-Mn	mg/dm^3	38,14	4
8	Cl^-	mg/dm^3	14,29	9
9	Ca	mg/dm^3	25,83	9
10	Mg	mg/dm^3	6,03	9

If we calculate the reliability mark for this case based on the arithmetic average a 8,3 value is achieved.

If we apply the methodology of calculation of the reliability mark presented, by using weighting factors, for turbulent flow regime is obtained a value of 8,17 and for laminar flow regime and lakes a value of 8,03 is obtained.

Conclusions

The decrease of the reliability mark for groups in which several parameters were analyzed leads to a sensitive decrease in the final reliability mark. So we can say that to characterize water quality based on the importance of the analyzed parameters requires more complex analysis, to determine the concentration of as many elements and substances present in water.

Although the decrease of the reliability mark is of only 0,13 respectively 0,27 if we would analyze more parameters the decrease could be a much more significant, and if we apply similar methodologies for the other environmental factors (soil, air, flora and fauna, landscape), and taking into account the method of calculation of the global pollution index (ratio of surface area of the ideal state and surface area of actual state - which in this case would decrease), its value could be changed significantly (for instance from a value between 1 and 2 - environment affected by human activities within reasonable limits to a value between 2 and 3 - environment affected by human activities causing discomfort for life forms).

This method can also be seen as one of finesse, being able to identify in detail those very values of global pollution index located at the boundary between two categories of environment (as they were defined conventionally)

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