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ADVANCED ENVIRONMENTAL IMPACT ASSESSMENT: QUANTITATIVE METHOD FOR RED MUD DISPOSAL FACILITIES

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Abstract

The environmental impact assessment has gained a very important role in decision making processes regarding different projects, investments, actions and proposals. The environmental impact assessment is a systematic process which deals with the consequences of the future developments in advance. The methodology of the assessment includes several techniques. The quantitative methods focus on the evaluation of the impacts by assigning importance values to the environmental parameters and quality scores. A quantitative method devised previously was further developed and a protocol for the determination of the complex environment state index was devised. This method is adapted for a disposal facility and conclusions are made on the environmental impacts of the company.
The environmental impact assessment method devised was used for a disposal facility exhibiting high environmental risks. The objective of the paper is to test this method on a red mud disposal facility in Hungary in light of the legal stipulations and limit values to support the more efficient operation of the environmental management system of the company with identification of the significant environmental issues.

Key words: complex environmental index, environmental impact assessment, red mud

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1. Introduction

There is a continuously increasing interest for the environmental impact assessment (EIA), especially in light of our commitment to the sustainable development. Parallel to this increasing interest, the countries all over the world introduced continuously tightening environmental legislations. The development and practical implementation of the EU directive 85/337 accelerated the spreading of the environmental impact assessment in the European Union (CD, 1985). The environmental impact assessment is a process which includes several key steps: project screening, scoping, consideration of the alternatives, project actions, description of the baseline conditions, impact identification, prediction of impacts, evaluation of the significance, public consultation, negotiations with authorities, review, recommendations on mitigation measures, decision-making and monitoring.

The environmental impact identification techniques are as follows: checklists, matrices, quantitative methods, networks and overlay maps (Glasson, 1995; Mocanu et al., 2012; Rédey et al., 2002). The quantitative methods establish the relative importance/significance of environmental impacts by weighting, standardizing the impacts to define a complex index. One of the methods is the environmental evaluation system which calculates the cumulative environmental impact units for a

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given project alternative on the basis of the importance of the environmental parameters (parameter importance weighting) and environmental quality indices (Petts and Eduljee, 1994).

The quantitative method devised by Robu (2005) defines the importance units for the selected environmental components to be considered, with values ranging between 0 and 1, according to the number of environmental parameters in the category of the selected environmental components (Robu, 2005; Robu et al., 2007). An environmental element matrix is defined from which the importance index values are calculated. The environmental quality parameter is defined as a function of the measured/calculated value and limit/target value for the environmental parameter defined by legal stipulations (Robu et al., 2005). The environmental impacts can be calculated according to the environmental parameters within a given class of the environmental component (Carlig et al., 2008). The average environmental impact for an environmental component can be calculated and on the basis of the environmental component impact values and the total environmental impact can be determined.

The goal of the paper is to adopt the newly developed EIA quantitative method for the Hungarian red mud spill in 2014, in order to define the impacts on the most injured environment elements: soil and surface water. The outcome of the environmental impact assessment supports the determination of the significance of the impacts of the catastrophe, and the elaboration of the recommendations on the mitigation measures, decision-making and soil / water monitoring schedule in the region of the catastrophe.

2. Experimental

2.1. Environmental impact assessment method

The procedure of the environmental impact assessments starts with the determination of the environmental components/elements considered within the scope of the assessment. It is important to define the environmental components/elements for the study, e.g.: air, water, groundwater, soil, flora, fauna, ecosystem, artificial environment, land, human beings etc. For the environmental components/ elements selected, it is necessary to determine the environmental parameters to be evaluated in the environmental assessment procedure and the number of environmental parameters should be defined for each environmental component/element category (Glasson, 1995).

The number of the environmental parameters depends on the nature and complexity of the environmental component/element. For each environmental parameter a relationship should be defined with the objective to define a correlation between the environmental quality and the measured/calculated environmental figures in consideration of the limit/threshold values for the environmental parameters (Rédey et al., 2002; Robu 2003). Environmental quality classes have to be defined in the function of the measured/calculated environmental parameters and limit/threshold values. Environmental quality classes from 1 to 10 are defined, where environmental quality class 1 represents the heavily polluted case and environmental quality class 10 represents the high quality environment case.

Environmental quality categories should be assigned to each environmental quality class with the definition of the actual state of the environmental component/element (Cserey, 1994). The ranking of the environmental quality classes and categories should be based on professional judgment. If the stipulations of the environmental regulations cannot be transferred into the environmental quality classes then ranking systems should be set up. It is not necessary to define a linear scale system for the classification. Following the determination of the quality classes for each parameter of the environmental component/element the environmental element quality scores (S_e) should be determined as given below (Eq. 1):

$$S_e = \sum_{i=1}^{n} \frac{J_i}{n} \tag{1}$$

where: S_e – environmental component/ element quality score for environmental element, e; J_i – quality class for environmental parameter, i; n - number of environmental parameters considered in case of the environmental component/element.

On the basis of the environmental component/ element quality scores determined for the different environmental components/elements the complex environmental index (S) can be determined as follows (Eq. 2):

$$S = 100 / \left[\sum_{i=1}^{a} \left(\frac{S_e}{a} \right) \right]^2 \tag{2}$$

where: S – complex environmental index; S_e – environmental component/element quality score; a – number of environmental component/ elements considered in the study.

On the basis of the value of the complex environmental index, S, information can be obtained on the status of the environment as given in Table 1.

2.1. The red mud disaster

The containment wall of the red mud waste reservoir (cassette No. 10.) burst on October 4, 2010 during daytime in Hungary. The catastrophe occurred near to Ajka in the Central Transdanubian Region, about 50 km from the Lake Balaton and at a distance of 130 km from Budapest. About 1 million m^3 of red mud sludge spilled killing people and covered a territory of about 1,017 hectares. The caustic sludge flooded three villages (Kolontár, Devecser and

Somlóvásárhely) and had a significant impact on seven villages as well. Since 300 houses were flooded by the red mud sludge therefore people were evacuated from the villages of Kolontár and Devecser where houses were completely or partially destroyed or wiped out by the alkaline red mud slurry. Ten people died in the red mud sludge disaster.

One of the most serious nature related risks of the red mud sludge catastrophe was that the red mud could get into the River Danube that would have caused unpredictable impacts. The polluted surface waters (Stream Torna, River Marcal, River Rába) effected by the red mud catastrophe are part of the catchments area of the River Danube.

The daily average results measured on the day of the catastrophe were used for the environmental impact assessment. Data were available on the soil and surface water contaminations. Regarding the soil samples were taken from the top 10 cm soil layer, and water samples were taken and analyzed from the Stream Torna. The sampling location is indicated in Fig. 1. The distribution of the surface water contamination of Stream Torna can be seen in Fig. 2.

The objective of the study was to determine of the pollution of the environment on the basic of a quantitative assessment technique. The data presented in the paper are based on measurements carried out on October 4, 2010.

3. Results and discussion

In this study the surface water and the soil were considered as environmental components/ elements (a=2), since these two environmental components/elements were the most heavily polluted environmental components/elements from all environmental component category. Regarding the water the environmental parameters controlled and monitored, the quality classes and categories are given in Table 2 for seven environmental measured: metals (Cr, Zn, Pb, Cu), dissolved oxygen (DO), conductivity and pH. Those parameters were chosen for monitoring since they limits are strictly regulated by the Governmental Decree 10/2010 (GD, 2010). The limit values are given in the row of quality class 6 of Table 2 with shaded/black indication.

The water analyses showed the following values for investigated parameters: Cr 10 μg/L, Zn 12 μg/L, Pb 64 μg/L, Cu 154 μg/L, DO 10190 μg/L, Conductivity 995 μS/cm and pH 8.41. The actual measured figures of the environmental parameters were allocated according to their quality class and are indicated by grey background in Table 2. The deviations of the environmental parameters from the limit values in case of environmental component/element surface water are given in Fig. 3, (Eq. 3):

$$S_{Surf,w} = \sum_{i=1}^{7} \frac{J_i}{n} \quad (3)$$

where: S_w – environmental component/ element quality score for water; J_i – quality class for environmental parameter, i; n – number of the environmental parameters, total number is 7.

$$S_w = \sum_{1}^{7} \frac{8+10+1+1+10+6+7}{7} = 6.14 \quad (4)$$

The environmental element score for water is 6.14 (Eq. 4). The same methodology is used for the environmental component/element soil. Seven metals were measured in soil samples: As, Ni, Cu, Ba, Pb, Cr Co and those limits values are restricted by Governmental Joint Degree 6/2009 (GJD, 2009). Regarding the soil the environmental parameters controlled and measured, the quality classes and categories are given in Table 3 for seven environmental parameters measured. The limit values are given in the row of quality class 6 of Table 3 with shaded/black indication.

The soil analyses showed the following values for investigated parameters: As 40.34 mg/kg, Ni 205.07 mg/kg, Cu 46.66 mg/kg, Ba 48.65 mg/kg, Pb 94.56 mg/kg, Cr 268.14 mg/kg and Co 43.81 mg/kg. The actual measured figures of the environmental parameters were allocated according to their quality class and are indicated by grey background in Table 3. The deviations of the environmental parameters from the limit values in case of environmental component/element soil are given in Fig. 4, (Eq. 5).

$$S_{Soil} = \sum_{i=1}^{7} \frac{J_i}{n} \quad (5)$$

where: S_{soil} – environmental component/ element quality score for soil; J_i – quality class for environmental parameter, i; n – number of the environmental parameters for soil.

The environmental element score for soil is 5.43 (Eq. 6).

$$S_{soil} = \sum_{1}^{7} \frac{3+3+8+9+7+3+5}{7} \cong 5.43 \quad (6)$$

The complex environmental index, S, can be calculated on the basis of environmental element quality scores (Se) for soil and water according to the method developed by Robu (Eq.7):

$$S = 100 / \left[\sum_{i=1}^{n} \left(\frac{S_e}{a} \right) \right]^2 \quad (7)$$

where: a – number of the environmental elements considered.

The complex environment influencing index of the red mud disaster is 2.98. On the basic of the assessment it can be concluded that the catastrophe had influenced the environment in extremely high extent (Table 1.), and due to this immediate and efficient environmental mitigations measures were necessary to be implemented.

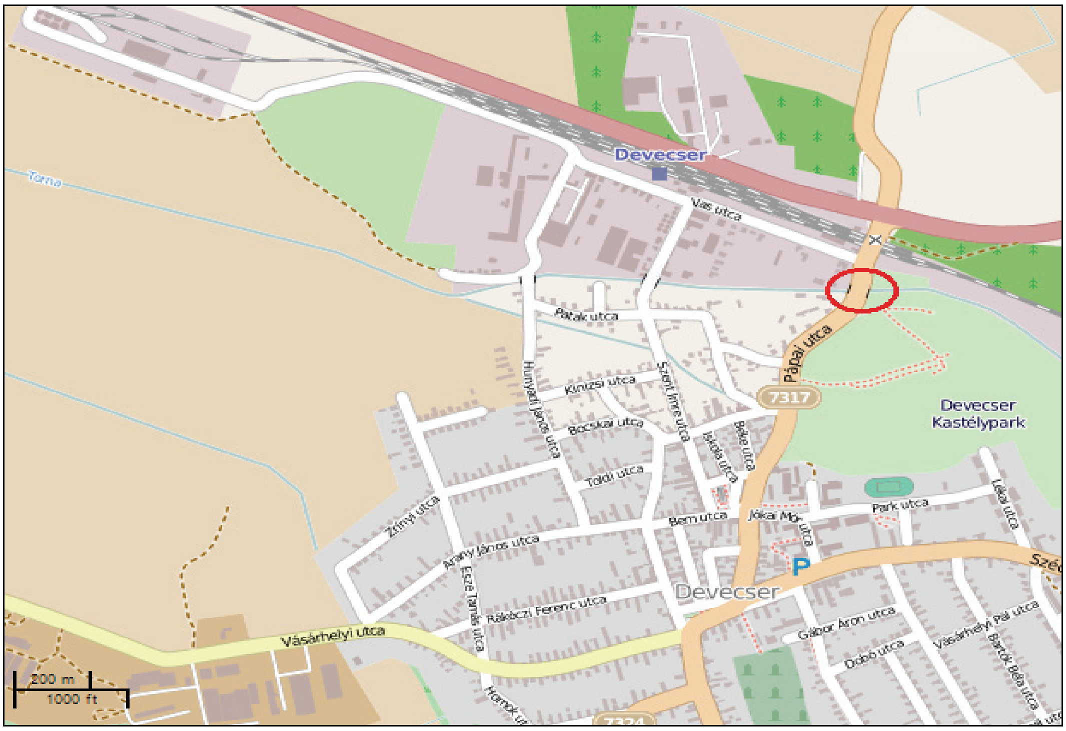

Fig. 1. The sampling location

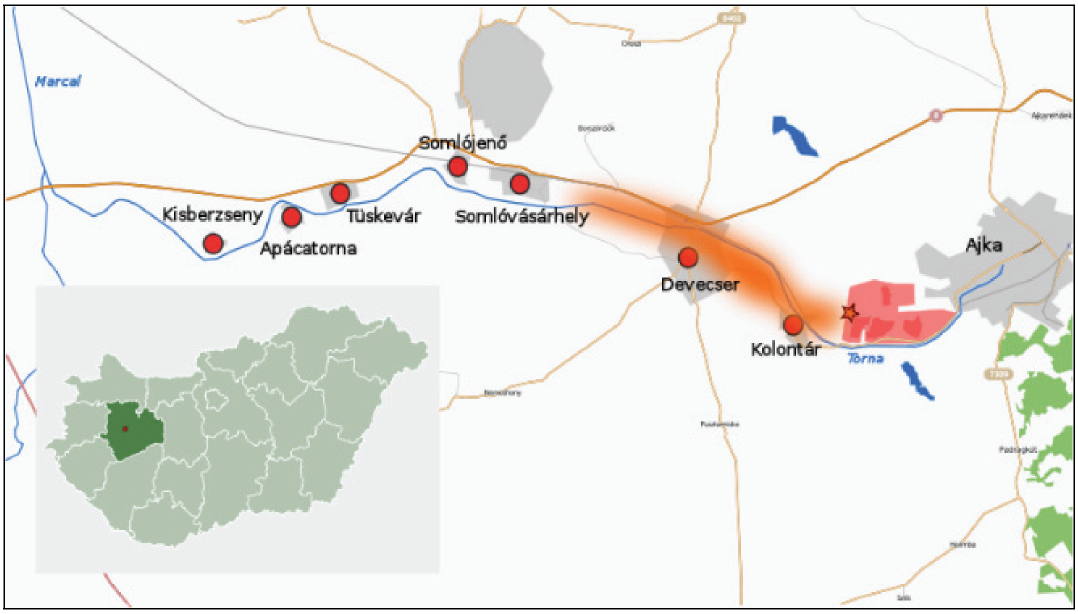

Fig. 2. Affected area by the red mud disaster

Table 1. The relation between the complex environmental index and status of the environment

S	***Complex environmental index***
S = 1	The human activity is not influencing the environment
1 < S < 2	Environment exposed to human activities under the allowed limits
2 < S < 3	The human activity is influencing the environment, could cause environmental disturbances
3 < S < 4	The human activity is influencing the environment, could cause environmental damages
4 < S < 5	The human activity is seriously damaging the environment
5 < S < 6	The environment is degraded, not suitable for preserving the flora and fauna

Table 2. Quality classes and categories for water based on Governmental Decree 10/2010 (GD, 2010)

Quality class, J_{water}	***Quality category***	***Cr [µg/L]***	***Zn [µg/L]***	***Pb [µg/L]***	***Cu [µg/L]***	***DO [µg/L]***	***conductivity [µS/cm]***	***pH [ε]***
		On the basis of the limit values						
1	Significantly higher than limit value	200	750	50	100	1000	10000	-6;+7
2		150	600	30	80	2000	5000	-4;+6
3	Higher than limit value	100	450	20	60	3000	3500	-3;+5
4		70	300	15	40	4000	2750	-2;+4
5	Close to limit value	40	150	10	20	5000	1500	-1;+3
6		20	75	7.2	10	7000	900	-0.5;+2
7		15	60	5	15	8000	750	-0.5;+1.5
8	Satisfactory	10	40	2	5	8750	500	-0.5;+1
9		5	20	1	1	9500	250	-0.5;+0.5
10	Good	1	1	0.1	0.1	10000	100	0

Table 3. Quality classes and categories for the soil according to Governmental Joint Decree 6/2009 (GJD, 2009)

Quality class J_{soil}	***Quality category***	***As [mg/kg]***	***Ni [mg/kg]***	***Cu [mg/kg]***	***Ba [mg/kg]***	***Pb [mg/kg]***	***Cr [mg/kg]***	***Co [mg/kg]***
1	Significantly higher than limit value	60	325	200	1000	500	400	80
2		45	250	175	750	350	300	70
3	Higher than limit value	38	175	150	500	250	225	60
4		30	120	125	400	180	150	50
5	Close to limit value	22	75	100	300	120	100	40
6		15	40	75	250	100	75	30
7		12	30	60	175	80	50	20
8	Satisfactory	8	20	40	100	60	30	10
9		4	10	20	40	30	15	5
10	Good	1	5	10	10	15	5	1

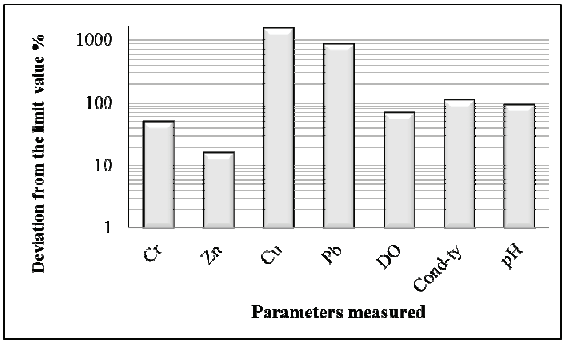

Fig. 3. Deviations from the limit values in case of the water

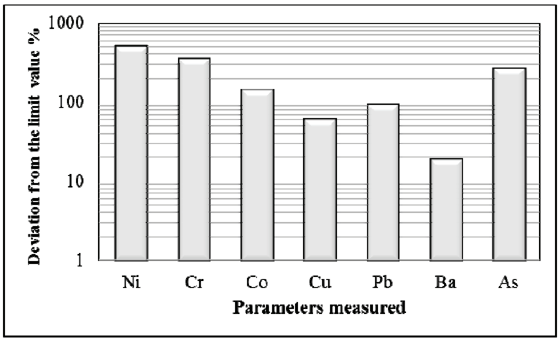

Fig. 4. Deviations from the limit values in case of the soil

4. Conclusions

The environmental assessment procedure carried out after the red mud disaster emphasized the seriousness of the environmental damages and revealed how the red mud sludge contamination affected the quality of the surface water and the soil on a large area.

It can be concluded that the environment was significantly deteriorated, however, the surface water and soil contamination has not resulted in an irreversible impacts in the environmental components/elements.

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References

Carlig E.D., Robu B., Macoveanu M., (2008), Quantification of environmental impact and risk induced by industrial activities on ground water quality: case study Cordum – Roman area, Romania, *Environmental Engineering and Management Journal*, **7**, 791-803.

CD, (1985), Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on environment, *Official Journal*, **L175**, 40–48.

Cserey B., (1994), *Environmental Impact Assessment of Developments* (in Hungarian), Budapest, Hungary.

GD, (2010), Governmental Decree No 10/2010. (VIII. 18.) of Ministry of Rural Development (VM) laying down rules for establishment and use of water pollution limits of surface water, Budapest, Hungary.

GJD, (2009), Governmental Joint Decree No 6/2009. (IV. 14.) of Ministry of Rural Development (KvVM–EüM–

FVM) laying down limits necessary for the protectionof geological medium and groundwater against pollution and on measurements of pollutants
Glasson J., (1995), *Introduction to Environmental Impact Assessment*, UCL Press, London.
Mitran G., Ilie S., Tabacu I., Nicolae V., (2012), Modeling the impact of road traffic on air pollution in urban environment case study: a new overpass in the city of Craiova, *Environmental Engineering and Management Journal*, **11**, 407-412.
Mocanu A.M., Luca C., Odochian L., Zaharia C., Iordache C., (2012), Assessment of the environmental impact of some new aryloxyalkyl carboxylic acid derivatives applied as plant protection compounds, *Environmental Engineering and Management Journal*, **11**, 413-420.
Petts J., Eduljee G., (1994), *Environmental Impact Assessment for Waste Treatment and Disposal Facilities*, John Wiley and Sons, Chichester.
Rédey Á., Módi M., Tamaska L., (2002), *Environmental Impact Assessment*, (in Hungarian), Pannon University, Veszprem, Hungary.
Robu B., (2005), *Environmental Impact and Risk Assessment for Industrial Activities*, EcoZone Press, Iasi, Romania.
Robu B., Zaharia, C., Macoveanu M., (2005), Environmental impact assessment for steel processing, *Environmental Engineering and Management Journal*, **4**, 51-65.
Robu B., Caliman A.F., Betianu C., Gavrilescu M., (2007), Methods and procedures for environmental risk assessment, *Environmental Engineering and Management Journal*, **6**, 573-592.