SOIL IMPACT ASSESSMENT OF SOME ECONOMIC ACTIVITIES ON A ROMANIAN INDUSTRIAL SITE

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Abstract

One of the most important and actual problems of modern society is related to the environment pollution and sustainable development. For an acceptable sustainable industrial development is necessary the evaluation of environmental impact generated by each industrial company and, after that, improvements of technologies, raw materials (i.e. use of environment-friendly materials when is possible), application of the best available techniques (BAT), implementation of European Environmental Management System (EMAS) etc. Moreover, following the monitoring, sample collecting and complex physico-chemical analysis of an important environment component - *soil*, into and around an industrial site from a Northern-Eastern Romanian town, it can be evaluated the level of soil pollution generated by all activities and also their impact on soil functions. The environmental impact assessment (EIA) into the studied industrial site is assessed only for soil component using the alternative method of global pollution index (I^*_{PG}). The experimental results correspond to the situation of 'environment modified by industrial/economic activities generating discomfort effects and risks for health of life forms coexisting onto soil site'. In this context, the industrial site must be monitoring in order to prevent supplementary environmental pollution, and control risk pollution.

Key words: soil, industrial site, environmental impact assessment, global pollution index (I^*_{PG}).

There is a growing public concern about the environment and population expansion in recent decades (Xu J. et al., 2006). Moreover, it is envisaged that global economic activity will have increased to the point that man's relationship with the natural environment will be radically altered. The long-term continuity of both economic activity and the global economic system may be threatened as a result. At the same time there is major scientific uncertainty concerning the conditions under which the continuity can be assured in both areas (Cashmore, M., 2004; Milner, S.J. et al., 2005).

Major changes in land use may be anticipated in Europe in the decades to come as a result of technological, socio-economical and political developments as well as global environmental change (Bouma, J. et al., 1998; Alshuwaikhat H.M., 2005). A more productive approach of various land-use options, and estimation of soil/subsoil pollution level can be helpful to guide planners and politicians in deciding future lands use options.

Urban soils are known to have peculiar characteristics such as unpredictable layering, poor structure, and high concentrations of trace elements (Manta, D.S. et al., 2002). They are the 'recipient' of a large amounts of contaminants (i.e. heavy metals, dangerous organic compounds, etc.) from a variety of sources including industrial wastes, vehicle emissions, coal burning waste, and other industrial or economical activities. Urban soils had a lot of important functions, but soils can also be multifunctional by performing many services at the same time (e.g., growing crops and food/biomass production while storing/filtering/ buffering pollutants or transforming of minerals, organic matter, water and energy, and diverse chemical substances; habitat and gene pool; physical and cultural environment for mankind; source of raw materials etc.) (Zaharia, C. et al., 2007). Different activities place different pressures on the soil and cause different impacts. The heterogeneity of soils, the wide range of functions and services they perform and the variety and combination of pressures placed upon them all require much attention (Tzilivakis, J. et al., 2005; Sposito, G., 1989). Generally, soils are poorly understood when compared with other environmental media. They vary enormously in their chemical and physical constitution and, as a consequence, their ability to perform functions (Surpateanu, M., Zaharia C., 2000; Tzilivakis, J. et al., 2005).

The diagnosis of the environmental impact of an industrial productive activity constitutes the first step in the overall assessment of the sustainability of the productive process (Zaharia, C., 2010). Environmental impact assessment (EIA) is considered to be a potential multidisciplinary, objective decision-making tool that helps the company management staff, planners and politiciens to choose the routes of selection, functioning and development of process technology, industrial sites as well as project sites. The EIA method relies on indicators serving as criteria to evaluate whether the objectives have been attained. These indicators take account of local impacts such as noise, odour, aesthetic effects, stress on vegetable and animal life forms, regional impacts such as eutrophication, low agricultural production, or global impacts like greenhouse effects, climate changes (Payraudeau, S., van der Werf, H.M.G., 2005; Cloquell-Ballester, A.V. et al., 2006; Chaker ,A. et al., 2006; McCaig, K., 2005; Goyal, S.K., Deshpande, V.A., 2001).

The analysis of the interactions between economic activities into the studied industrial site is indispensable at this scale of analysis. Indicators based on the environmental effects of industrial activities will take precedence over those based on practices themselves. Some scenarios must be predicted describing how the properties of soil might change, the causes of those changes and what the consequences may be in terms of soil functional ability and other potential environmental impacts. Each scenario must have three core components: (1) activities, including both anthropogenic activities and environmental parameters or processes that influence soil (e.g., cropping or climate, industrial activities), (2) soil properties, that characterise the soil for scenario and describe how it might change (e.g. organic matter, pH and bulk density), and (3) soil functions, that are performed by soils and/or impacts that arise (Tzilivakis, J. et al., 2005). The assessment method also includes an analysis of the uncertainty associated with the results.

This paper will present the required characteristics for developing a well-known Romanian EIA methodology (i.e. global pollution index) that involves the collection of baseline data on soil, noise, technological, biological, and socioeconomic components of the environment on and around the investigated industrial site, identification of potential impacts, prediction of significant impacts, and evaluation of impacts on a commensurate evaluation scale ultimately leading to delineation of an integrated management plan and also of a development unit project (Rojanschi, V., 1991; Rojanschi, V., 2004; Macoveanu, M., 2005).

MATERIAL AND METHOD

Location of the investigated industrial site

The investigated industrial site is situated into an important Northern-Eastern town of Romania (i.e. NE town with around 100000 inhabitants and 65 economic units and institutes) placed near an industrial railway route and international terrestrial traffic route. The total surface of the industrial site emplacement is of 3.50 ha.

There are various 'functioning' or 'no functioning' small and medium scale industries into this industrial site (i.e. the most important are chemical textile production – S_1, bricks production - S_2, sugar manufacturing - S_3, etc.), totalling more than 5 industrial units. Noise levels, in general, are low and well within the standards, except along the major road due to traffic.

The average annual temperature is around 8°-9.5°C with maximum and minimum values recorded into the summer or winter months. Total annual rainfall in the region is about 600-700 mm. One major river flows through the region (i.e. Siret River).

Water quality indicators of surface and ground water sources are close to the admissible levels. However, a stress is felt on the availability and quality of water, particularly during the summer season.

Data collection and analyses

The soil analysis was performed using international standardized analysis methods and specific reagents according with the national environmental legislation (Surpateanu, M., 2004; Surpateanu, M., Zaharia, C., 2002; Zaharia, C., 2008).

Sampling and analyses of the potential pollution generated by the 'functioning' or 'no functioning' industrial activities into the investigated site were made in accordance with the indications of local environmental agency (i.e. conformation plan imposing analyses of some quality indicators for soil, twice times per year, and their maximum admissible limits – M.A.C.) and performed with an authorized environmental analysis laboratory.

The principal physicochemical laboratory analysis was made for specific soil indicators (e.g., actual pH, total oil compounds, total organic carbon (TOC), total extractible compounds into petroleum ether and/or total oil compounds, heavy metals).

EIA alternative methodology of the global pollution index (I^*_{PG})

The potential soil pollution sources on the studied site were identified to be mainly from three different production sectors coexisting in the past and with 'limited functioning' in the present time as: chemical-textile processing, bricks production and sugar manufacturing.

These principal pollution sources are: *1- stationary/organized sources*: trash dispersion of central production and/or heating, and sewerage connections or pluvial water; *2- diffuse sources*: uncontrolled emissions from production sector without local exhausting system (i.e. leaks) and different area of some deposits.

The values of the analysed quality indicators were used to calculate an index to express the quality of *soil component*, EQ_i (Eq.1) (Grec A. et al., 2009; Zaharia C., 2010):

$$EQ_i = C_{i,measured}/MAC_i \qquad (1)$$

where:

- $C_{i,measured}$ - experimental value of analysed compound/substance concentration;
- MAC_i - maximum admissible concentration of analysed compound/substance according with the national environmental legislation or local environmental authority regulation (conformation plan) (Zaharia C., 2008; Zaharia C., 2009a).

The synergetic action of potential contaminants into *soil* is expressing by the average arithmetic value for all index to express the quality of soil (i.e. EQ_{soil}).

For quantification of global pollution of environment (i.e. soil component) into the investigated industrial site, the global pollution index (I^*_{PG}) is used by the alternative methodology (concentric circles graphical methodology) (Popa C. et al., 2005).

The calculation of global pollution index is done as in Eq. (2) (Rojanschi V. et al., 2004; Robu B. et al., 2005; Zaharia C. et al., 2007; Zaharia C., 2009b).

$$I_{GP} = \frac{S_i}{S_r} = \frac{100}{\overline{b^2}} \qquad (2)$$

where:

S_i – geometrical surface corresponding to the non-affected natural state (ideal state of soil component, a circle with the ray of *10*);

S_r – geometrical surface corresponding to the real state of environment (real state of soil component, a circle with the ray equal with the value of $(\overline{b^2})^{1/2}$), and $\overline{b^2}$ is the evaluation score for soil component (b_{soil}) corresponding to the arithmetic mean of the values attributed to each analyzed soil quality indicator in accordance with the evaluation scale (*Fig. 1* and *table 1*) (Zaharia, C., Murarasu, I., 2009; Zaharia, C. et al., 2007; Zaharia, C., Surpateanu, M., 2007; Zaharia, C., Surpateanu, M., 2006a,b; Popa, C. et al., 2005).

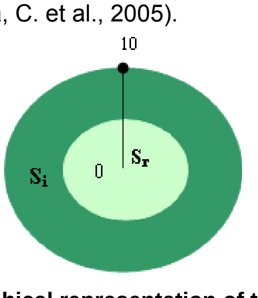

Figure 1 **Graphical representation of the alternative methodology *of* I^*_{PG} corresponding to ideal state (S_i) (circle with the ray of *10*) and real situation (S_r) (circle with the ray equal with the value of $(\overline{b^2})^{1/2}$)**

For soil component the calculation of geometrical surface is performed using the index value to express the soil quality (EQ_{soil}) that corresponds to a specific evaluation score (ES_{soil}) (compliance degree) (*table 1*) (Grec, A. et al., 2009; Zaharia, C., 2010). The correlation into the alternative methodology of global pollution index is presented into table 2 (Rojanschi, V., 1991; Rojanschi, V. et al., 2004; Popa, C. et al., 2005).

Table 1

Correlation scale for the pollution level of soil component (soil quality scale)

Eval. score (ES_i)	Values of EQ_i	Effects on the environmental component and human health
10	0	The environmental component is not affected by the industrial activity. Environment state: natural
9	(0.0-0.2]	The environmental component is affected by the industrial activity. The effect can not be quantified
8	(0.2-0.7]	The environmental component is affected, but under the maximum admissible limits – level 1 Alert level: potential effects
7	(0.7-1.0]	The environmental component is affected, but into maximum admissible limits – level 2 Intervention level: potential effects
6	(1.0-2.0]	The environmental component is affected, over the maximum admissible limits – level 1. The effects are pronounced
5	(2.0-4.0]	The environmental component is affected, over the maximum admissible limits – level 2. The effects are harmful
4	(4.0-8.0]	The environmental component is affected, over the maximum admissible limits – level 3 The harmful effects are pronounced
3	(8.0-12.0]	Degraded environmental component – level 1. The effects are lethal to the average exposure
2	2.0-20.0]	Degraded environmental component – level 2. The effects are lethal at short times of exposure
1	20.0	The environmental component is improper for life

Table 2

Correlation into the global pollution index methodology

Values of I^*_{PG}	Real situation of environment
$I^*_{PG}=1$	Natural environment, not affected by industrial/human activities
$1< I^*_{PG} <2$	Environment modified by industrial/economic activities within admissible limits
$2< I^*_{PG} <3$	Environment modified by industrial/economic activities generating discomfort effects
$3< I^*_{PG} <4$	Environment modified by industrial/economic activities generating distress to life forms
$4< I^*_{PG} <6$	Environment modified by industrial/economic activities, dangerous for life forms
$I^*_{PG} \geq 6$	Degraded environment, not proper for life forms

RESULTS AND DISCUSSIONS

The results of the analyzed physicochemical indicators for the quality of *soil component* on the investigated industrial site are presented in *table 3* (i.e. different soil samples, S_1, S_2, S_3, prelevated at depth of 5 - 10 cm onto the investigated site, average value of specific analyzed quality indicators) and *table 4* (i.e. soil samples, S_1, S_2, S_3, prelevated at depth of 20 - 40 cm onto the investigated site).

Table 3

The values of quality indicators for soil, depth of 5 - 10 cm (*soil component*)

Quality indicator	Measure unit	$C_{measured}$ value	C.M.A. value [a, b]	EQ_i (soil)	ES_i (soil)
S_1 – soil affected by a bricks production sector					
Active pH	-	7.70	neutral	-	-
Total oil compounds	mg/kg dry soil	240	100 [a]	2.4	5
TOC	%	1.15	6 [b]	0.191	9
Lead	mg/kg dry soil	20.91	20 [a]	1.045	6
Nickel	mg/kg dry soil	31.97	20 [a]	1.599	6
Chrome	mg/kg dry soil	34.07	30 [a]	1.135	6
Cadmium	mg/kg dry soil	0	1 [a]	0	10
				EQ_{soil} = 1.062 **ES_{soil} = 7.00**	
S_2 – soil affected by a sugar manufacturing sector					
Active pH	-	7.45	neutral	-	-
Total oil compounds	mg/kg dry soil	500	100 [a]	5.0	4
TOC	%	2.25	6 [b]	0.375	8
Lead	mg/kg dry soil	15.97	20 [a]	0.798	7
Nickel	mg/kg dry soil	38.64	20 [a]	1.932	6
Chrome	mg/kg dry soil	34.77	30 [a]	1.159	6
Cadmium	mg/kg dry soil	0	1 [a]	0	10
				EQ_{soil} = 1.544 **ES_{soil} = 6.83**	
S_3 – soil affected by a chemical production sector					
Active pH	-	6.60	neutral	-	-
Total oil compounds	mg/kg dry soil	300	100 [a]	3.0	5
TOC	%	1.25	6 [b]	0.208	8
Lead	mg/kg dry soil	19.74	20 [a]	0.987	7
Nickel	mg/kg dry soil	47.11	20 [a]	2.355	5
Chrome	mg/kg dry soil	25.51	30 [a]	0.850	7
Cadmium	mg/kg dry soil	0	1 [a]	0	10
[a] M.A.C. according to Ministry Order no. 756/1997, normal levels (Zaharia C., 2008) and regulation from the local environmental conformation plan; [b] Parrakova TOC value for high polluted soil (Surpateanu M., Zaharia C., 2002)				**EQ_{soil} = 1.233** **ES_{soil} = 7.00**	

Considering the calculated index to express the soil quality (EQ_{soil}) into S_1, S_2 and S_3 industrial site sectors, it can be considered that this environmental component (soil) is affected, over the maximum admissible limits (level 1), and the effects are pronounced onto life form and human health.

Table 4

The values of quality indicators for soil, depth of 20 - 40 cm (*soil component*)

Quality indicator	Measure unit	$C_{i,measured}$ value	C.M.A. value [a, b]	EQ_i (soil)	ES_i
S_1 – soil affected by a bricks production sector					
Active pH	-	7.65	neutral	-	-
Total oil compounds	mg/kg dry soil	320	100 [a]	3.20	5
TOC	%	1.32	6 [b]	0.22	8
Lead	mg/kg dry soil	24.48	20 [a]	1.224	6
Nickel	mg/kg dry soil	30.88	20 [a]	1.544	6
Chrome	mg/kg dry soil	35.75	30 [a]	1.191	6
Cadmium	mg/kg dry soil	0	1 [a]	0	10
				EQ_{soil} = 1.23 **ES_{soil} = 6.83**	
S_2 – soil affected by a sugar manufacturing sector					
Active pH	-	7.30	neutral	-	-
Total oil compounds	mg/kg dry soil	600	100 [a]	6.0	4
TOC	%	1.91	6 [b]	0.318	8
Lead	mg/kg dry soil	12.55	20 [a]	0.627	8
Nickel	mg/kg dry soil	36.68	20 [a]	1.834	6
Chrome	mg/kg dry soil	34.53	30 [a]	1.151	6
Cadmium	mg/kg dry soil	0	1 [a]	0	10
				EQ_{soil} = 1.655 **ES_{soil} = 7.00**	
S_3 – soil affected by a chemical production sector					
Active pH	-	6.60	neutral	-	-
Total oil compounds	mg/kg dry soil	360	100 [a]	3.60	5
TOC	%	1.25	6 [b]	0.208	8
Lead	mg/kg dry soil	3.85	20 [a]	0.193	9
Nickel	mg/kg dry soil	87.31	20 [a]	4.365	4
Chrome	mg/kg dry soil	26.36	30 [a]	0.879	7
Cadmium	mg/kg dry soil	0	1 [a]	0	10
[a] M.A.C. according to Ministry Order no. 756/1997, normal levels (Zaharia C., 2008) and regulation from the local environmental conformation plan; [b] Parrakova TOC value for high polluted soil (Surpateanu M., Zaharia C., 2002)				**EQ_{soil} = 1.541** **ES_{soil} = 7.16**	

The evaluation score for soil quality (ES_{soil}) is *7.00* for S_1 site sector, *6.83* for S_2 site sector and respectively *7.00* for S_3 site sector (depth of 5 - 10 cm) and respectively, *6.83*, *7.00*, and *7.16* at soil depth of 20 - 40 cm into the same industrial sectors. It can be observed that an important pollutant into these soils that must be periodically monitoring is pH, TOC, total oil compounds and also the heavy metals.

Appling the alternative method of global pollution index, it is calculated the arithmetic mean of evaluation degrees $(\overline{b^2})^{1/2}$. The value of this parameter is *6.944* ($\overline{b^2}$ = 48.2163), and I^*_{GP} is *2.074*, corresponding to the situation of 'environment modified by industrial/economic activities generating discomfort effects and risks for health of life forms coexisting onto soil site'.

CONCLUSIONS

A Romanian industrial site is assessed in term of environmental impact using the alternative methodology of global pollution index (I^*_{PG}) in condition of 'restrictive functioning' of all productive activities because of some development project implementation or economic crisis and deficit.

The evaluation scores for the quality of *soil* in the three main site sectors (S_1- bricks production sector, S_2 - sugar manufacturing sector, and S_3 - chemical textile production sector) were calculated considering some specific physicochemical indicators of soil quality.

The maximum evaluation score (ES_i) indicating non-industrially polluted soil or natural state into the investigated area is considered to be *10*, and the real evaluation score of soil component was found lower (i.e. values of *7.00*, and *6.83 respectively*).

The calculated value of global pollution index in condition of restrictive or 'no functioning' of some industrial units (i.e. $I^*_{PG}=2.074$, corresponding to an 'environment modified by industrial/economic activities generating discomfort effects and risks for health of life forms coexisting onto soil site') represents a reference value of global pollution index.

This fact requires periodical monitoring actions, pollution control and a developing soil remediation project.

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