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QUANTIFICATION OF ENVIRONMENTAL IMPACT AND RISK INDUCED BY INDUSTRIAL ACTIVITIES ON GROUND WATER QUALITY: CASE STUDY CORDUN - ROMAN AREA, ROMANIA

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Abstract

The question of whether environmental assessment has achieved its goal of helping to reach better decisions has continually engaged the attention of academics, policy makers and environmental impact assessment practitioners. Answering this question requires several different groups working together and/or in sequence, and examining the effectiveness of environmental impact and risk assessment. *EIA* has tended to focus on the identification of impacts associated with planned activities or projects, whereas *ERA* involves a rigorous analysis of those impacts: the calculation of the probability, and magnitude of effects. The integrated method described herein for environmental impact and risk assessment has the advantages that it is very easy to be used by non environmental experts: it calculates the impacts and risks, correlated with measured concentrations of quality indicators for environmental component, considered representative in assessment process; it is not a subjective method because several mathematical steps are applied. Also, the lack of experience of evaluator doesn't influence the results of assessment process, and it will reflect in a very objective way the real situation. The purpose of this work was to propose a new method for integrated environmental impact and risk assessment and apply it on a case study in order to make the right decision concerning the quality of ground water from evaluated area. Thus, groundwater from ten drillings was sampled and analyzed over the period 1995-2006 (exception years 1997, 1998 and 1999). From each drilling over the period 1995-2006, eight quality indicators considered representative for evaluated situation were analyzed. The results showed that, in period 1995 – 2006, the ground water quality was highly negative influenced by industrial activities developed on studied area. The maximum value for impact and risk induced in ground water is in 1995 year, when the industrial activities from this area were working at maximum capacity. Thus, it is absolutely necessary to apply the measures for remediation to improve the quality of ground water and control the pollution, considering the fact that the ground water quality needs to be at optimum parameters, required by national legislation.

Keywords: ground water, quality indicators, impact and risk assessment, pollution control

1. Impact and risk assessment

Risk assessment has been suggested as a tool to help manage ecological problems. Ecological risk assessment is usually defined as the process that evaluates the likelihood that adverse ecological effects are occurring, or may occur, as a result of exposure to one or more stressors. Risk assessment has been used extensively to link environmental stressors and their ecological consequences. The risks associated with chemical exposure are the typical concern. Quantifying the risk of various chemicals to human health is a logical outgrowth of risk assessment as applied in the insurance industry and other fields. Over the past 20 years, a body of procedures and tools has been used for environmental risk assessment for human health. Risk assessment applied to ecological problems is more recent, but has also focused primarily on chemicals, with animals used as surrogates for *ecological health*. Adapting the risk paradigm from assessing insurance risks to assessing human health risks to assessing ecological

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risks has not been simple (Lackey, 1994). Even so, it is still unclear whether ecological risk assessment will actually improve decision making and ultimately protect ecological resources. In spite of the difficulties of defining problems in complex ecological policy questions, the use of risk assessment to help solve ecological problems is widely supported. Risk assessment could be a valuable tool and should be used extensively in solving ecological problems. Risk assessment has historically been separated from management. Such separation requires that scientists play clearly defined roles as technical experts, not policy advocates; these distinctions are blurred when scientists advocate political positions.

In the last few years, a new, very broad and far from simple art has sprung up within the wide field of risk analysis, *comparative risk analysis*. Applied to environmental risks, it is intended to be an instrument of governmental environmental prioritization, policy making, and policy implementation. Once environmental risks are assessed and ranked, the consideration of additional factors such as the feasibility of risk reduction; the benefits of risk reduction; public risk perception; special risks to subgroups or ecosystems; and political, economic, and social factors, is needed to develop a prioritization of the same risks for attention and, finally, to develop policy options leading to legislation, regulation, or other types of risk abatement possibilities. It is important to note that a ranking according to risk is not synonymous with a ranking according to priority. The entire span of the environmental *comparative risk analysis* (CRA) process consists of the following two major stages, as is the case with other forms of risk analysis:

1. Comparative risk assessment (CRASS), in which the risks associated with specific environmental issues or problems are assessed and compared, usually by being ranked against each other
2. Comparative risk management (CRM), in which there are three stages:
   a. Risk reduction prioritization
   b. Risk reduction policy option development
   c. Implementation of risk reduction policy options, including monitoring of the results.

Carrying out this full process requires several different groups working together and/or in sequence. Thus, *comparative risk studies are very labor intensive*. The question of whether environmental assessment has achieved its goal of helping to reach better decisions has continually engaged the attention of academics, policy makers and environmental impact assessment practitioners (Sandham and Pretorius, 2007). One approach to answering this question is by examining the effectiveness of environmental impact assessment, where effectiveness refers to whether something works as intended and meets the purpose(s) for which it is designed. The newly established Environmental Impact Assessment system (EIA) consisted of the following main steps (Sandham and Pretorius, 2007):

- pre-application consultation;
- plan of study for scoping;
- scoping report (including public involvement);
- plan of study for EIA;
- Environmental Impact Report (EIR) (including public involvement);
- authority review;
- record of decision (including conditions of approval).

One of the purposes of Environmental Impact Assessment (EIA) is in advance to identify and evaluate the important environmental consequences of proposed projects. As a concept of EIA, the impact should be documented and predicted as well in advance as possible (Morris and Therivel, 2004). EIA is also a process that provides information about the proposal to decision makers (Ridgway, 2005). Both of these targets benefit if decent EIA methodology is used to present and organize the high number of variables that an assessment process may produce. It is especially important to understand how distinctly the separate variables have impact on the environment, depending on their nature as either natural or human-induced, extensive or small-scale, cumulative or non-cumulative, local and national planning or generally essential or inessential. The early emphasis on natural environmental consequences of capital projects has since been enlarged to encompass not only the ecological, but also the social, health, and economic effects of projects, policies, programs, plans, technologies or activities. There are many tools and techniques that have been developed for use in impact assessment processes, including scoping, checklists, matrices, qualitative and quantitative models, literature reviews, and decision-support systems (Macoveanu, 2005; Robu, 2005; Sandham and Pretorius, 2007). While impact assessment processes have become more technically complicated, it is recognized that approaches including simpler applications of available tools and techniques are also appropriate (Kuitunen et.al., 2007).

The purpose of this work was to propose a new method for integrated environmental impact and risk assessment and apply it on a case study in order to make the right decision concerning the quality of ground water from evaluated area. Thus, groundwater from ten drillings was sampled and analyzed over the period 1995-2006 (exception years 1997, 1998 and 1999). Eight quality indicators considered representative for evaluated situation were analyzed from each drilling, over the period 1995-2006, and, based on these experimental data, the integrated environmental impact and risk assessment was applied.

2. Site characterization

The iron and steel industry is highly intensive in both materials and energy consumption. Important subject for action in response to environmental concerns are generally considered to relate to controlling of air emissions and managing of solid wastes. Wastewaters discharge from coke oven plants is of significant higher relevance than discharges from the water circuits at blast furnaces, basic-oxygen steel making, and continuous casting plants. Contaminated leakages from the solid wastes disposal sites cause great environmental problems, both, in the near future (short term) and long term. The polluted leakages are formed due to the interactions of solid, liquid and gaseous phases. Over time, both, the wastes and the leakages can considerable change the quality of environmental components, especially soil and groundwater, because the wastes deposits are heterogeneous and dangerous for environment. Different chemical interaction fronts that serve as geochemical barriers accumulate certain types of toxic compounds and move inside the landfills. When the geochemical barriers are damaged, the outflow location suddenly releases the contaminants, accumulated over years.

The evaluated area Cordun-Roman, Romania has an industrial site used for wastes deposit, and represents a potential source of pollution especially for soil, ground and surface water, and it is located in Moldova river bed, on left side with 4-5 m above everglade. This area (4.79 ha) is situated 3 km far of company, where the industrial activities take place, and it is surrounded by residential areas, run off water and pastures. The investigations regarding the quality of soil and vegetation from industrial site, including residential areas, showed that there are 2 kind of pollution: soil acidification from industrial site and heavy metals contamination. It has to be mentioned that the measured concentrations of heavy metals from soil samples didn't reach the maximal allowed concentrations, according to Romanian legislation.

The technical characteristics of industrial site used for wastes deposit are the followings:

- Capacity of deposit is 114168 m^3;
- It can assure minimum 10 years for sludge depositing;
- The area is surrounded by residential area;
- The stockyard has 2 compartments surnamed "cells", used to deposit slag (cell no.1), and sludge, including other different residues (cell no.2).
- The dig made from argyles soil closes the stockyard on 0.6 km length and its high is 4.5 m (0.3 m is underground).

There have been analyzed ten ground water samples from ten drillings, over the period 1995-2006, in order to control the leakages and prevent the ground water pollution (fig.1). The hydro-geologically properties of ground water from evaluated area depend on the layer impermeability, and from hydro geological point of view tow factors are very important: the altimetry position of aquifer and the permeability of soil layers from evaluated site. To control the ground water quality in this area, ten drillings were used (F1 to F10), situated at 4 – 10 m deep (Fig.1):

- Drilling F_1 – 10 m deep, situated off site (upstream) in North–East side;
- Drilling F_2 – 4 m deep, situated on site, in oily scoria cell;
- Drilling F_3 – 5 m deep, situated off site (downstream) in North–West side;
- Drilling F_4 – 8 m deep, situated off site (upstream of cell no. 2), in East side;
- Drilling F_5 – 4 m deep, situated on site of cell no. 2;
- Drilling F_6 – 4 m deep, situated on site, central part of cell no. 2;
- Drilling F_7 – 4 m deep, situated off site, in West side;
- Drilling F_8 – 4 m deep, situated on site, in oily scoria cell;
- Drilling F_9 – 5 m deep, situated on site, cell no. 2;
- Drilling F_{10} – 4 m deep, situated off site, in South-West side.

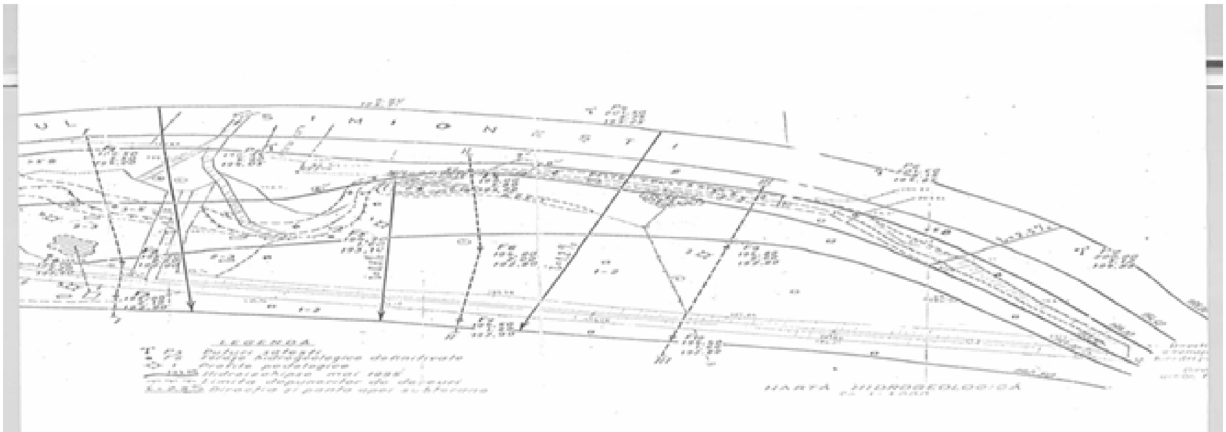

Fig.1. The map of drillings F1 to F10

3. Ground water quality evaluation

3.1. Sampling and analyses

To evaluate the quality of ground water, various samples were taken from ten drillings, on site and off site. Eight quality indicators (CCO-Cr, NO_3^-, NO_2^-, SO_4^-, Fe^{2+}, Pb^{2+}, Cu^{2+}, Ni^{2+}) have been analyzed by standardized methods, according to national legislation, over the period 1995-2006 (exception years 1997, 1998, 1999).

3.2. Results

The results of physical-chemical analysis of ground water samples from evaluated area, over the period 1995 – 2006 (exception years 1997, 1998, 1999) are shown in Table 1.

It can be observed that the evaluated site, especially the ground water is significantly polluted due to the presence of various pollutants such as organic compounds, nitrate, nitrite and heavy metals.

Table 1. Measured concentrations of quality indicators considered in evaluation process

Drilling	*Year* / *MAC**	***Quality indicators*** ***Measured concentrations (mg/dm³)***							
		CCOCr	NO_3^-	NO_2^-	SO_4^{2-}	Fe^{2+}	Pb^{2+}	Cu^{2+}	Ni^{2+}
		5	50	0.5	250	0.20	0.01	0.1	0.02
F1	1995	6.32	40	0.0007	37.8	7.6	-	-	-
	1996	22.12	32	0.0018	63.35	1.2	0.05	0.05	0.009
	2000		27.4	0.008	69.25	0.151	-	-	-
	2001	6.68	20.46	0.010	53.5	0.24	-	-	-
	2002	14.42	20.15	0.017	59.5	0.28	-	-	-
	2003	9.61	23.63	0.040	78.6	2.11	3.0	0.7	0.55
	2004	4.0	62.67	0.045	154	0.63	1.0	0.4	0.01
	2005	9.41	198.07	0.03	79.25	1.51	0.026	0.03	0.00
	2006	54.1	214.5	0.74	176.5	0.14	0.062	0.009	0.02
F2	1995	15.8	20	0.07	78.6	4.8	0.76	0.056	0.01
	1996	42.64	0	0.07	134.5	1.2	0.05	0.185	0.009
	2000	17.75	22.8	0.06	150	3.62	-	-	-
	2001	11.84	19.8	0.036	82.5	1.77	-	-	-
	2002	25.77	15.85	0.024	86	1.46	-	-	-
	2003	29.60	18.81	0.055	102.5	1.51	2.0	0.5	0.32
	2004	11.20	17.17	0.60	120.5	0.545	1.0	0.2	0.01
	2005	13.97	82.07	0.315	79	0.165	0.050	0.01	0.00
	2006	67.79	41.7	0.925	220	0.111	0.092	0.014	0.01
F3	1995	9.48	38	0.0004	55.1	1.6	-	-	-
	1996	20.2	23	0.0018	83	1.2	0.05	0.07	0.08
	2000	3.02	24.25	0.003	91	2.125	-	-	-
	2001	8.47	16.92	0.012	70.25	2.41	-	-	-
	2002	8.49	12.07	0.014	93.75	3.35	-	-	-
	2003	10.35	16.88	0.042	119.5	3.59	2.0	0.5	0.32
	2004	7.94	22.07	0.137	99.25	0.89	1.5	0.2	0.02
	2005	9.01	71.64	0.10	86	0.74	0.083	0.01	0.00
	2006	67.44	116.82	0.22	246	0.09	0.029	0.006	0.008
F4	1995	11.37	11	0.0004	25.1	0.8	-	-	-
	2000	1.58	3.62	0	30.12	0.73	-	-	-
	2001	4.36	2.93	0	40.75	0.15	-	-	-
	2002	6.48	6.12	0.013	58.5	1.18	-	-	-
	2003	3.82	2.54	0.011	43.35	0.40	1.0	0.3	0.15
	2004	7.30	58.7	0.055	53.5	0.23	0.5	0.1	-
	2005	7.87	195	0.012	60.5	0.62	0.11	0.01	0.00
	2006	83.14	104.02	0.156	185.75	0.14	0.0035	0.011	0.008
F5	1995	20.9	0	0.18	93.4	80	0.80	0.04	0.009
	1996	72.7	5	0.0018	1315.24	3.2	0.0575	0.085	0.009
	2000	4.08	6	0	405.5	2.3	-	-	-
	2001	14.37	14.1	0.027	1152	3.38	-	-	-

	2002	13.18	26.32	0.046	1722.5	15.31	-	-	-
	2003	12.77	19.34	0.023	749	13.29	0.5	0.3	0.15
	2004	12.29	27.17	0.042	295.5	4.85	-	-	-
	2005	20.74	54.57	0.072	723.75	5.23	0.17	0.02	0.00
	2006	103.64	30.95	0.176	2230	0.33	0.034	0.015	0.017
F6	1995	15.8	12.4	0.07	87.6	1.24	0.48	0.32	0.009
	2000	5.13	11.55	0.04	117.5	1.52	-	-	-
	2001	9.61	10.25	0.02	277.5	1.17	-	-	-
	2002	11.71	8.55	0.016	430	5.91	-	-	-
	2003	9.47	20.21	0.019	402.5	13.79	2.0	0.3	0.15
	2004	9.17	4.92	0.072	310	6.40	0.8	0.1	-
	2005	26.29	37.26	0.07	787.5	3.67	0.13	0.01	0.00
	2006	65.96	37.2	0.323	1592.5	0.20	0.154	0.012	0.012
	1995	13.9	1	0.07	148.9	11.2	-	-	-
F7	1996	12.6	18	0.07	264.5	2.4	0.065	0.070	0.009
	2000	4.17	8.4	0.039	204.25	1.36	-	-	-
	2001	9.67	9.2	0.012	240.5	1.17	-	-	-
	2002	14.49	9.8	0.010	546.5	2.97	-	-	-
	2003	12.62	15.55	0.013	359.75	9.05	1.0	0.1	0.1
	2004	7.54	30.82	0.514	213	2.01	1.0	0.3	0.02
	2005	15.17	95.09	0.36	480	0.76	0.19	0.01	0.00
	2006	70.57	10.85	0.87	1192.5	0.21	0.059	0.019	0.007
	1995	17.7	39.2	0.037	72.8	1.2	0.36	0.08	0.009
F8	2000	4.03	17.5	0.030	48.75	2.02	-	-	-
	2001	9.35	19.00	0.053	232	3.45	-	-	-
	2002	11.92	14.57	0.032	82.75	5.07	-	-	-
	2003	11.75	18.88	0.018	145.5	6.47	1.0	0.1	0.1
	2004	8.43	59.35	0.549	129.75	1.89	-	0.1	-
	2005	7.47	43.32	0.612	110.5	0.30	0.19	0.02	0.00
	2006	66.63	86.42	0.775	212.5	0.19	0.0085	0.014	0.005
	1995	6.3	17.8	0.037	53.9	2.4	0.28	0.06	0.008
F9	2000	3.31	13.6	0.1	153.75	2.72	-	-	-
	2001	8.04	13.37	0.0075	93.5	1.78	-	-	-
	2002	25.09	13	0.0047	130	1.94	-	-	-
	2003	9.03	18.47	0.024	218.5	2.51	1.0	0.1	0.1
	2004	7.80	18.12	0.108	200	0.71		0.1	0.01
	2005	6.50	66.62	0.075	273	0.36	0.27	0.00	0.00
	2006	64.89	81.12	0.246	517.5	0.22	0.008	0.016	0.006
	1995	11.4	0	0.0018	195	0.42	-	-	-
F10	2000	0.625	5.375	0.073	171.5	0.85	-	-	-
	2001	5.192	5.85	0.001	150	1.45	-	-	-
	2002	6.057	6.1	0.001	406.5	1.10	-	-	-
	2003	7.737	14.94	0.026	328.5	3.75	0.5	0.1	0.1
	2004	4.817	50.47	0.078	142	1.577	0.3	-	-
	2005	15.307	43.07	0.052	499.75	2.665	0.29	0.02	0.00
	2006	67.012	227.7	0.042	1470	0.225	0.137	0.022	0.007

*maximum admissible concentrations concordant to Law no. 458/2002, modified by Law no.311/2004.

Thus, the quality indicators analyzed had values for measured concentrations higher than maximum admissible concentrations:

- Organic compounds analyzed by CCO-Cr indicator had over the period 1995-2006 measured concentrations higher than maximum admissible concentration almost in all drillings. The maximum analyzed value was 103.64 mg/L (in 2006) from samples from drilling F5 and 83.14 mg/L (in 2006) from samples from drilling F4.
- The ground water contamination with nitrate was higher in 2005 in drilling F1 (measured concentration of NO_3^- was 198.07 mg/L and 214.5 mg/L), drilling F3 (measured concentration of NO_3^- was 71.64 mg/L and 116.82 mg/L), drilling F4 (measured concentration of NO_3^- was 195 mg/L in 2005 and 104.02 mg/L in 2006), and drilling F10 (measured concentration of NO_3^- was 227.7 mg/L in 2006).
- The quality of ground water was also highly negative influenced by the presence of nitrites, and

the most influenced areas are from drilling F2 (measured concentrations 0.6 mg/L in 2004 and 0.925 mg/L in 2006) and drilling F8 (measured concentration i0.612 mg/L in 2005 and 0.775 mg/L in 2006).

4. Integrated environmental impact and risk assessment

4.1. Method description

The integrated method to evaluate the environmental impact and risk used herein is a combination between two methods: global pollution index and matrix of significance scale (Gavrilescu 2003, Macoveanu, 2005; Robu, 2005; Robu and Macoveanu, 2005a,b). An algorithm developed as software designed as ***SAB*** was applied to automatically quantify the environmental impacts and risks that arise from an evaluated activity, considering the measured concentration, levels of quality indicators (Robu, 2005; Robu et al., 2005a,b, 2007, 2008).

This new method for environmental impact and risk assessment (***EIRA***) was applied considering only the *ground water* in the assessment process. The evaluation of environmental impacts was done using a matrix in order to calculate the significance of environmental component, potentially affected by the industrial activities. The significance parameter can take values between 0 and 1; value 1 represents the most significant environmental component (in this case the ground water). These values are assigned by the evaluator (Table 2). For the evaluated situation, the rest of environmental components such as surface water, air and soil were not considered in evaluation process (Table 3).

The impact on environmental component (*EI*) directly depends on measured concentration of pollutants, and it is expressed as the ratio between significance units (*IU*) and quality of environmental component (*EQ*), defined as follows (Eq. 1):

$$EI = \frac{IU}{EQ} \tag{1}$$

The parameter *quality of environmental component* (*EQ*) is defined as follows (Eq.2):

$$EQ = \frac{MAC}{MC} \tag{2}$$

where:
MAC – maximum allowed concentration of quality indicators;
MC – measured concentration of quality indicators.

After the calculation of significance units, the next step was to calculate the quality of environmental component defined above. If the quality parameter of environmental component longs for zero, it results that the environmental quality is very poor (this means that the measured concentration of pollutant is very high); if *EQ* value is close to 1, or higher than 1, then the quality of environmental component is very good (Goyal and Deshpande, 2001).

The impact on ***ground water*** (EI_{gw}) is given by Eqs. 3, 4:

$$EI_{gw} = \frac{\sum_{i=1}^{n} EI_{(gw)_i}}{n} \tag{3}$$

$EI_{(gw)i}$ – environmental impact on ground water, considering quality indicator *i*;
i – quality indicators (e.g. COD-Cr, BOD etc.);
n – number of quality indicators considered in evaluation process.

$$EI_{(gw)i} = \frac{IU_{gw}}{EQ_{(gw)i}} \tag{4}$$

$EQ_{(gw)i}$ – quality of *ground water*, considering the quality indicator *i*;
IU_{gw} – significance units obtained by *ground water*.

Table 2. The calculation of *significance units* for environmental components

Environmental component	***Surface water (l)***	***Ground water (m)***	***Soil (n)***	***Air (o)***
Surface water (l)	0.001	(1/m)	(l/n)	(l/o)
Ground water (m)	0.85	(m/m)	(m/l)	(m/o)
Soil (n)	0.001	(n/m)	(n/n)	(n/o)
Air (o)	0.001	(o/m)	(o/n)	(o/o)

l – significance value for surface water, m – significance value for ground water,
n – significance value for soil, o – significance value for air

Table 3. Significance units obtained by solving the matrix from Table 2

Environmental component	***Normalized weights (NW)***	***Significance units (IU = NWx1000)***
Surface water	0.001	1.173
Ground water	0.997	996.48
Soil	0.001	1.173
Air	0.001	1.173

This way the impacts for environmental component ground water considered the most representative for the evaluated situation were calculated. The next step was to quantify the risks that arise, in the view of the results for environmental impacts. The risks are calculated as follows (Eq.5):

$$ER_j = EI_j \cdot P_j \qquad (5)$$

ER_j – environmental risk for environmental component *j*;
EI_j – environmental impact on environmental component *j*;
P_j – probability of impact occurrence on environmental component *j*.

The probability of impact occurrence was calculated using the same matrix as described above (Table 2) to calculate the significance units. The evaluator has to assign values for probability between 0 and 1 (Table 4), concordant to probability description, detailed in Table 5 (Pearce, 1999).

Table 4. Probability units for environmental components

Environmental component	***Probability units (P)***
Surface water	0.001
Ground water	0.65
Soil	0.001
Air	0.001

Considering the fact that the measured concentrations of main pollutants analyzed in samples from ground water are higher than the maximum admissible concentrations (MAC), and the pollution will probably occur in most circumstances, 0.65 probability units were accorded.

4.2. Results

According to integrated method for environmental impact and risk assessment, the first step is to assign the significance of each environmental component for evaluated situation.

This parameter significance have values between 0 and 1, and value 1 value 1 represents the most significant environmental component (in this case the ground water). So that, the value 0.85 was assigned as significance for ground water, and the probability for a negative event (impact) to occur was considered *likely* (0.61-0.9) that will probably occur in most corcumstances (90% of situations).

Quantification of impact and risk induced on ground water quality was automatically done (Table 6). The results of automatically quantification for those ten drillings are presented in Figs. 2 – 11.

It has to be emphasized that if the impact and risk have very high values, then the impact induced by the considered activities in the environment is great and the environmental risks are at an unacceptable level.

High values for environmental impacts and risks underlay the presence of pollutants in environment in very high concentrations, because impact directly depends on the measured concentration of pollutants.

Taking into account the impact classification from method of global pollution index (Rojanschi et.al., 1997; Robu et.al., 2005, 2007, 2008; Robu and Macoveanu, 2005 a, b), a classification of impacts and risks is proposed (Table 7).

Table 5. Description of probability

Probability	***Probability units***	***Description***
Almost certain	0.91-1.0	Is expected to occur in most circumstances (99%)
Likely	0.61-0.9	Will probably occur in most circumstances (90%)
Possible	0.31-0.6	Might occur at some times (50%)
Unlikely	0.05-0.3	Could occur at some times (10%)
Rare	<0.05	May occur only in exceptional circumstances (1%)

Table 6. The quantification of parameter *environmental component quality* Q (ground water) and environmental impact and risk (IM, RM) for each quality indicator analyzed over the period 1995-2006 in ten drillings (example drilling F1)

		1995					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 1995 =**	**8015.00**
COD-Cr, mgO_2/L	5.00	6.32	0.79	1259.55	1253.77		
NO_3^-,mg/L	50.00	40.00	1.25	797.19	793.52	RM_{1995} =	**7978.21**
NO_2^-, mg/L	0.50	0.0007	714.29	1.40	1.39		
SO_4^{-2}, mg/L	250.00	37.80	6.61	150.67	149.98		
Fe, mg/L	0.20	7.60	0.03	37866.35	37692.39		

Pb, mg/L	0.01	0.000	0.00	0.00	0.00		
Cu, mg/L	0.10	0.00	0.00	0.00	0.00		
Ni, mg/L	0.02	0.00	0.00	0.00	0.00		
		1996					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 1996 =**	**2151.30**
COD-Cr, mgO_2/L	5.00	22.12	0.23	4408.44	4388.19		
NO_3^-,mg/L	50.00	32.00	1.56	637.75	634.82	RM_{1996} =	**2141.40**
NO_2^-, mg/L	0.50	0.0018	277.78	3.59	3.57		
SO_4^{-2}, mg/L	250.00	63.35	3.95	252.51	251.35		
Fe, mg/L	0.20	1.20	0.17	5978.90	5951.43		
Pb, mg/L	0.01	0.050	0.20	4982.42	4959.52		
Cu, mg/L	0.10	0.0500	2.00	498.24	495.95		
Ni, mg/L	0.02	0.0090	2.22	448.42	446.36		
		2000					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2000 =**	**397.60**
COD-Cr, mgO_2/L	5.00	0.00	0.00	0.00	0.00		
NO_3^-,mg/L	50.00	27.40	1.82	546.07	543.56	RM_{2000} =	**395.77**
NO_2^-, mg/L	0.50	0.0080	62.50	15.94	15.87		
SO_4^{-2}, mg/L	250.00	69.25	3.61	276.03	274.76		
Fe, mg/L	0.20	0.15	1.32	752.34	748.89		
Pb, mg/L	0.01	0.000	0.00	0.00	0.00		
Cu, mg/L	0.10	0.0000	0.00	0.00	0.00		
Ni, mg/L	0.02	0.0000	0.00	0.00	0.00		
		2001					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2001 =**	**633.60**
COD-Cr, mgO_2/L	5.00	6.68	0.75	1331.30	1325.19		
NO_3^-,mg/L	50.00	20.46	2.44	407.76	405.89	RM_{2001} =	**630.69**
NO_2^-, mg/L	0.50	0.0100	50.00	19.93	19.84		
SO_4^{-2}, mg/L	250.00	53.50	4.67	213.25	212.27		
Fe, mg/L	0.20	0.24	0.83	1195.78	1190.29		
Pb, mg/L	0.01	0.000	0.00	0.00	0.00		
Cu, mg/L	0.10	0.0000	0.00	0.00	0.00		
Ni, mg/L	0.02	0.0000	0.00	0.00	0.00		
		2002					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2002 =**	**988.30**
COD-Cr, mgO_2/L	5.00	14.42	0.35	2873.86	2860.65		
NO_3^-,mg/L	50.00	20.15	2.48	401.58	399.74	RM_{2002} =	**983.77**
NO_2^-, mg/L	0.50	0.0170	29.41	33.88	33.72		
SO_4^{-2}, mg/L	250.00	59.50	4.20	237.16	236.07		
Fe, mg/L	0.20	0.28	0.71	1395.08	1388.67		
Pb, mg/L	0.01	0.000	0.00	0.00	0.00		
Cu, mg/L	0.10	0.0000	0.00	0.00	0.00		
Ni, mg/L	0.02	0.0000	0.00	0.00	0.00		
		2003					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2003 =**	**43327.00**
COD-Cr, mgO_2/L	5.00	9.61	0.52	1915.24	1906.44		

NO_3^-,mg/L	50.00	23.63	2.12	470.94	468.77	RM_{2003} =	**43127.90**
NO_2^-, mg/L	0.50	0.0400	12.50	79.72	79.35		
SO_4^{-2}, mg/L	250.00	78.60	3.18	313.29	311.85		
Fe, mg/L	0.20	2.11	0.09	10512.90	10464.60		
Pb, mg/L	0.01	3.000	0.00	298944.90	297571.49		
Cu, mg/L	0.10	0.7000	0.14	6975.38	6943.33		
Ni, mg/L	0.02	0.5500	0.04	27403.28	27277.39		
		2004					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2004 =**	**13752.60**
COD-Cr, mgO_2/L	5.00	4.00	1.25	797.19	793.52		
NO_3^-,mg/L	50.00	62.67	0.80	1248.99	1243.25	RM_{2004} =	**13689.45**
NO_2^-, mg/L	0.50	0.0450	11.11	89.68	89.27		
SO_4^{-2}, mg/L	250.00	154.00	1.62	613.83	611.01		
Fe, mg/L	0.20	0.63	0.32	3138.92	3124.50		
Pb, mg/L	0.01	1.000	0.01	99648.30	99190.50		
Cu, mg/L	0.10	0.4000	0.25	3985.93	3967.62		
Ni, mg/L	0.02	0.0100	2.00	498.24	495.95		
		2005					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2005 =**	**2373.10**
COD-Cr, mgO_2/L	5.00	9.41	0.53	1875.38	1866.77		
NO_3^-,mg/L	50.00	198.07	0.25	3947.47	3929.33	RM_{2005} =	**2362.21**
NO_2^-, mg/L	0.50	0.0300	16.67	59.79	59.51		
SO_4^{-2}, mg/L	250.00	79.25	3.15	315.89	314.43		
Fe, mg/L	0.20	1.51	0.13	7523.45	7488.88		
Pb, mg/L	0.01	0.026	0.38	2590.86	2578.95		
Cu, mg/L	0.10	0.0300	3.33	298.94	297.57		
Ni, mg/L	0.02	0.0000	0.00	0.00	0.00		
		2006					
Indicator	**MAC***	**Cm****	**Q**	**IM**	**RM**	**IM 2006 =**	**3149.60**
COD-Cr, mgO_2/L	5.00	54.10	0.09	10781.95	10732.41		
NO_3^-,mg/L	50.00	214.50	0.23	4274.91	4255.27	RM_{2006} =	**3135.16**
NO_2^-, mg/L	0.50	0.7400	0.68	1474.79	1468.02		
SO_4^{-2}, mg/L	250.00	176.50	1.42	703.52	700.28		
Fe, mg/L	0.20	0.14	1.43	697.54	694.33		
Pb, mg/L	0.01	0.062	0.16	6178.19	6149.81		
Cu, mg/L	0.10	0.0090	11.11	89.68	89.27		
Ni, mg/L	0.02	0.0200	1.00	996.48	991.90		

*maximum admissible concentrations concordant to national legislation, ** measured concentration

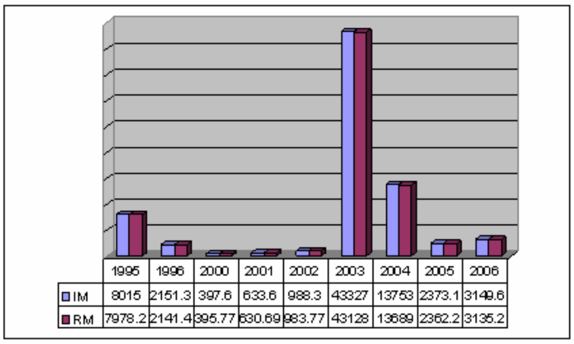

Fig.2. Impact and risk induced on ground water quality, period 1995-2006, drilling F1

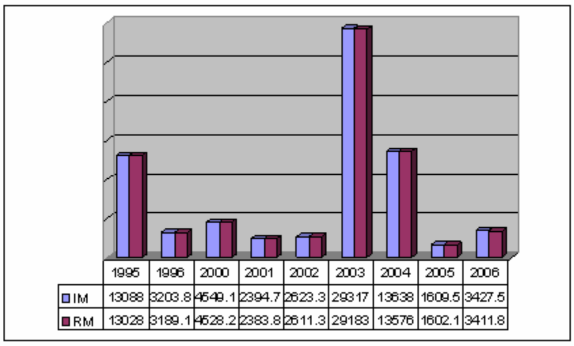

Fig. 3. Impact and risk induced on ground water quality, period 1995-2006, drilling F2

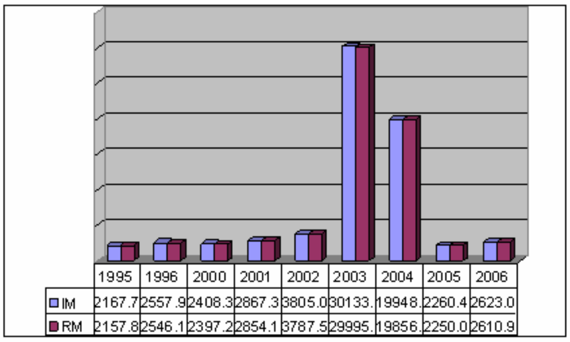

Fig. 4. Impact and risk induced on ground water quality, period 1995-2006, drilling F3

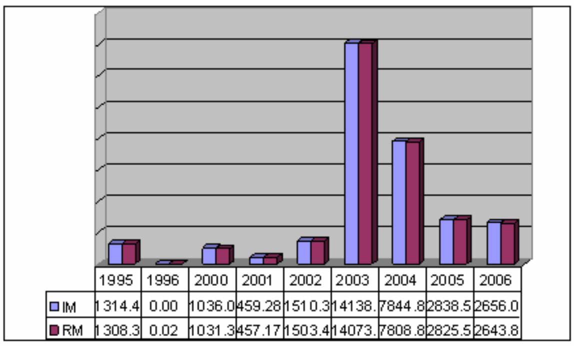

Fig. 5. Impact and risk induced on ground water quality, period 1995-2006, drilling F4

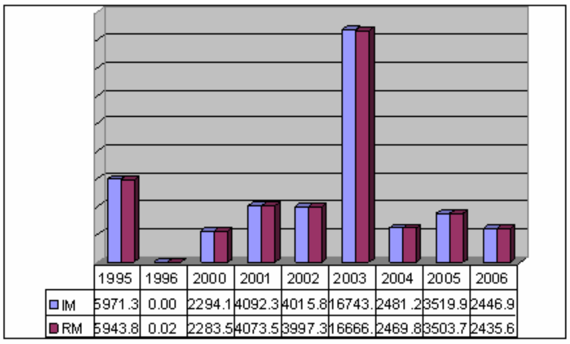

Fig. 6. Impact and risk induced on ground water quality, period 1995-2006, drilling F5

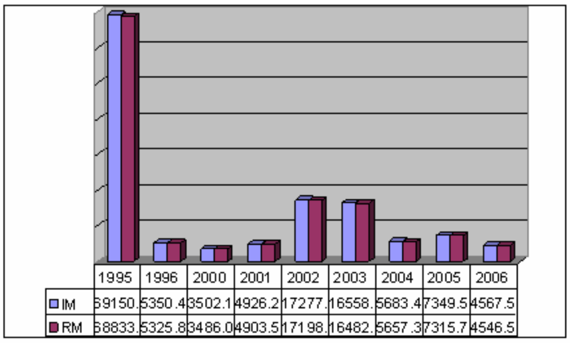

Fig. 7. Impact and risk induced on ground water quality, period 1995-2006, drilling F6

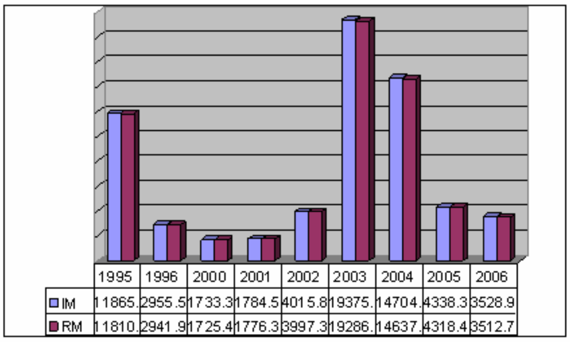

Fig. 8. Impact and risk induced on ground water quality, period 1995-2006, drilling F7

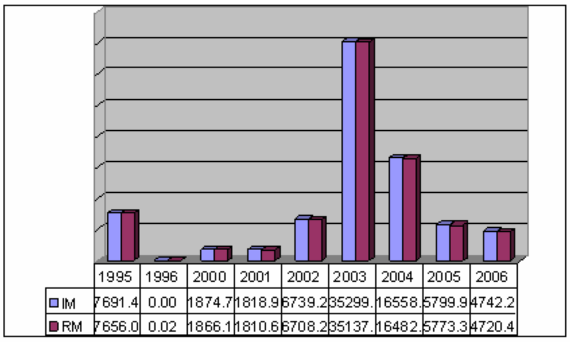

Fig. 9. Impact and risk induced on ground water quality, period 1995-2006, drilling F8

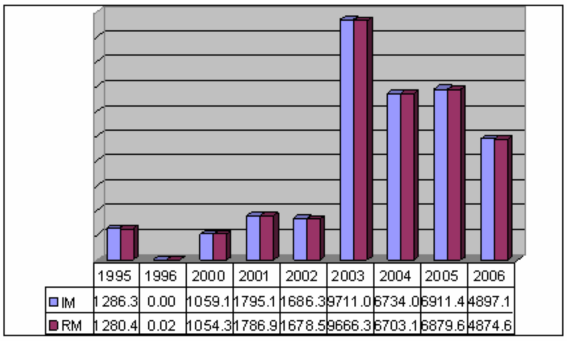

Fig. 10. Impact and risk induced on ground water quality, period 1995-2006, drilling F9

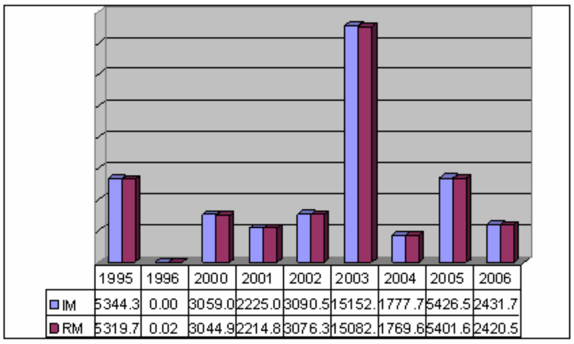

Fig. 11. Impact and risk induced on ground water quality, period 1995-2006, drilling F10

In Fig. 12 the comparison of environmental impact induced on ground water quality, years 2006, 2003 and 1995 is shown.

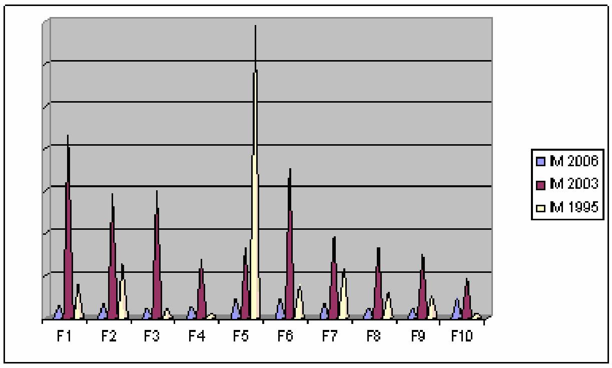

Fig.12. Comparison of environmental impact induced on ground water quality: years 2006, 2003 and1995

It can be observed that the most negative impact induced in ground water was in 1995 and 2003, years when the industrial activities took place on site at maximum capacity of installations, thus, pollution control and monitoring actions should be applied on this site in order to prevent the aquifer and surface water pollution.

Table 7. Classification of environmental impact and risk

Impact Scale	***Impact description***	***Risk Scale***	***Risk description***
<100	Natural environment, not affected by industrial/human activities	<100	Negligible/insignificant risks
100-350	Environment modified by industrial activities within admissible limits	100-200	Minor risks, monitoring actions are required
350-500	Environment modified by industrial activities causing discomfort conditions	200-350	Moderate risk at an acceptable level, monitoring and prevention actions are required
500-700	Environment modified by industrial activities causing distress to life forms	350-700	Moderate risks at an unacceptable level, control and prevention measures are needed
700-1000	Environment modified by industrial activities, dangerous for life forms	700-1000	Major risks, remediation, control and prevention measures are needed
>1000	Degraded environment, not proper for life forms	>1000	Catastrophic risks, all activities should be stopped

6. Conclusions

The purpose of this work was to propose a new method for integrated environmental impact and risk assessment and apply it on a case study in order to make the right decision concerning the quality of ground water from evaluated area. Thus, groundwater from ten drillings was sampled and analyzed over the period 1995-2006 (exception years 1997, 1998 and 1999). From each drilling, over the period 1995-2006 eight quality indicators considered representative for evaluated situation were analyzed, and, based on these experimental data, the integrated environmental impact and risk assessment was applied.

Regarding the experimental results, it can be concluded that the evaluated site, especially the ground water is significantly polluted due to the presence of various pollutants such as organic compounds, nitrate, nitrite and heavy metals. Thus, the quality indicators analyzed had values for measured concentrations higher than maximum admissible concentrations:

- Organic compounds analyzed by CCO-Cr indicator had over the period 1995-2006 measured concentrations higher than maximum admissible concentration almost in all drillings. The maximum analyzed value was 103.64 mg/L (in 2006) from samples from drilling F5 and 83.14 mg/L (in 2006) from samples from drilling F4.

- The ground water contamination with nitrate was higher in 2005 in drilling F1 (measured concentration of NO_3^- was 198.07 mg/L and 214.5 mg/L), drilling F3 (measured concentration of NO_3^- was 71.64 mg/L and 116.82 mg/L), drilling F4 (measured concentration of NO_3^- was 195 mg/L in 2005 and 104.02 mg/L in 2006), and drilling F10 (measured concentration of NO_3^- was 227.7 mg/L in 2006).

The quality of ground water was highly negative influenced by the presence of nitrites, and the most influenced areas are from drilling F2 (measured concentrations 0.6 mg/L in 2004 and 0.925 mg/L in 2006) and drilling F8 (measured concentration i0.612 mg/L in 2005 and 0.775 mg/L in 2006).

The new integrated method applied herein for environmental impact and risk assessment has the advantages that it is very easy to be used by non environmental experts: it calculates the impacts and risks, correlated with measured concentrations of quality indicators for environmental component, considered representative in assessment process; it is not a subjective method because several mathematical steps are applied. Also, the lack of experience of evaluator doesn't influence the results of assessment process, and it will reflect in a very objective way the real situation. The results showed that in period 1995 – 2006 the ground water quality was highly negative influenced by industrial activities developed on studied area. The maximum value for impact and risk induced in ground water from evaluated site is in 1995 year, when the industrial activities from this area were working at maximum capacity. Thus, it is absolutely necessary to apply the measures for remediation, to improve the quality of ground water and control the pollution, considering the fact that the ground water quality needs to be at optimum parameters, required by national legislation.

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