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EXPERIMENTAL RESULTS CONCERNING THE RISK OF POLLUTION IN AIR USING DATA WAREHOUSES

Abstract. *In this paper, the authors present the experimental results obtained, based on a systemic approach, to quantify the polluting phenomena in the air and various measures of risk to quantify it. The systemic approach takes into account all the factors involved in this phenomenon (polluting or economic agent responsible to control and adjust the polluting phenomena). The authors propose different measures of risk to analyze this phenomenon and also a degree of risk associated to each polluting enterprise, which allows applying measures of punishment or stimulation to each economic polluting agent. The factors of decision involved in this process can better establish their decisions, taking into account also the historical information for a period of 1 /3 years, using for this propose, the information available in data warehouses. The results of this analysis allow the economic agent and also the control unit to adjust their economic policies concerning the environmental pollution.*
Keywords*: Data warehouse, multidimensional model, cybernetic multilevel system, measure of risk.*

JEL Classification D23.

1.INTRODUCTION

A person's relative risk due to air pollution is a serious public health problem because an enormous number of people are exposed over an entire lifetime. Until May 2004, the American Heart Association had not issued any expert reviewed statement about the short-term and long-term effects of chronic exposure to different pollutants. This was due to flaws in research design and methodology of many pollution studies. During the last decade, however, epidemiological studies conducted worldwide have shown a consistent, increased risk of cardiovascular events, in relation to short- and long-term exposure to present-day concentrations of pollution, especially particulate matter. Air pollution is composed of many environmental factors, they include carbon monoxide, nitrates, sulfur dioxide, ozone, lead, secondhand tobacco smoke and particulate matter. Particulate matter, also known as particle pollution, is composed of solid and liquid particles within the air. It can be generated from vehicle emissions, tire fragmentation and road dust, power generation and industrial combustion, smelting and other metal processing, construction and demolition activities, residential wood burning, windblown soil, pollens, molds, forest fires, volcanic emissions and sea spray. These particles vary considerably in size, composition and origin. The concentrations of both particulate matter and sulfur dioxide often change in parallel. The oxidation of sulfur dioxide in the atmosphere is linked with the formation of various particulate compounds, including acid sulfates.

The Environmental Protection Agency (EPA) has declared that "tens of thousands of people die each year from breathing tiny particles in the environment."

The process of environmental pollution represents a actual problem, which must be carefully monitored, in view of the permanently developing industrial production, and its negative consequences for the environment.

Monitoring the pollution in water, air or earth implies several actions, namely:

- gathering data and information about the polluting agents, and the factors that produce them;
- organizing the data in order to access them rapidly or in real time, using data warehouses;
- establishing the degree of risk of each polluting factor for the environment, and the moments of time and location where they arise ;
- taking the adequate decisions by the Environment Ministry or its departments in order to diminish the risk of pollution produced by different economic units.

In this paper, the experimental results refer to the pollution of the air in the Arges region.

The data furnished by the Environment Ministry highlight that the pollution of the air occurring in Arges region is given 90% by the enterprise Arpechim and Dacia and in Dambovita region 85% by Carpatcement Holding SA and the Special Steeling enterprise Targoviste . For this reason, only the polluting phenomena given by this enterprise are considered, and the analysis is based on the theoretical results published by the authors in 2009 /7/.

2. CONTROL AND ADJUSTMENT THE POLLUTING PHENOMENA IN AIR USING A MULTILEVEL CYBERNETIC SYSTEM.

Taking in view the globalization process of economies and the global warming process, it is necessary to use a systemic approach to monitor pollution phenomena at the level of each state, continent or the whole planet. This type of approach is necessary because the polluting process of a region or country produce consequences in chain, which are felt on a large area, with bad consequences for the environment. To control the polluting process, a hierarchical system with three level is used, depending on the domain of influence where the factor of decision who monitors this process acts.

Establishing the environment policies can be viewed as a game between the polluting unit and the decision unit which regulates the polluting process of environment.

Taking in view the short- and long-term consequences, and also the environmental policies that must be taken concerning this area, *we can claim that to controlling the risk of environmental pollution can be considered a cybernetic multilevel system (fig 1).*

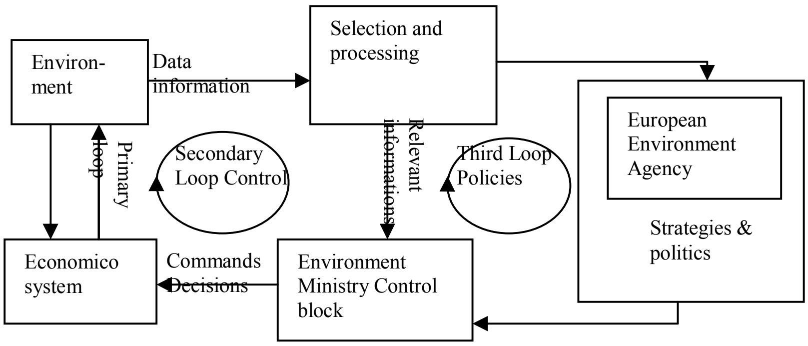

Figure 1. Multilevel cybernetic system for polluting

In figure 1, we observe that on the lower level are placed the economic polluting unit, its environment and the local environmental agency, which through its decisions acts like a feedback over the functionality and profit of the economic unit.

On the second level is placed the Environment Ministry, who has as attributions to establish standards, taxes and stipends, to supervise and control the polluting process at the level of each region, taking into account also the type of polluting economic units lied in each region and the level of noxa produced by them.

On the higher level acts the European Environment Agency, which exercises its environmental pollution control policies, based on prognoses of the evolution and trends at a European and global level. The strategies established by the European Environment Agency for each country take into account its specificity namely: its type of the industrialization, the shape of relief, the degree of risk prognosis and the area where it acts, the duration amplitude and impact of the polluting factors

Taking into account this hierarchical decomposition and also the interaction between the three levels, we can sustain that the control system of the pollution environment must be a cybernetic multilevel system adaptable through structure and inputs.

Adaptability through inputs implies taking measures in order to change the standards regarding the polluting factors, such as: the admissibility level, the interval to override it, the level of punishment fixed for different polluting factors, and the subsides assigned to them, in order to respect the standards of pollution imposed.

Adaptability through structure implies major changes in the system that supervises the risk of pollution, determined by: the economic context at European and global levels, the environmental parameters which must be adapted as a function of on the strategies concerning the global warming process and the polluting phenomena

Setting up new organizations to supervise the pollution phenomena at European, state or regional levels, and also changing or creating new policies, with the target of diminishing the polluting process of the environment, represents vectors of adaptability through structure.

The Environment Ministry of our country, taking into account the directions and standards imposed by the European Agency for the Environment, draws up its own environmental policies in accordance with the characteristics of each region and with its own economic needs of development. It is the responsibility of the Environment Ministry to adjust permanently its standards, taxes penalties and subsidies in accordance with the results obtained from experiments and with the changes in strategies and standards imposed by the EU. Working out the decisions for the substantiation of the pollution policies, we must observe on the one hand the macroeconomic indicators that must be reached, and on the other hand the social needs but also the insurance of the functional limits for every economic unit as it can stay profitable, thus exist. As it was shown in the paper, the authors propose that the Environment Ministry endorse a flexible strategy regarding the penalties applied to a polluting unit, depending on the pollution level of the area where it exists, and the pollution history of the unit in repeatedly exceeding the admissible or alert levels imposed by standards. Successfully achieving these objectives implies the application of proper methods for gathering, processing and storing data regarding pollution, and taking timely decisions for its prevention and adjustment. In this way, the authors propose in the paper to assign to every polluting unit a degree of risk . If we have a data warehouse and performing instruments like OLAP to access and display these data and to compare them, one can elaborate a flexible and effective decisional strategy for the substantiation of environment pollution politics.

To evaluate correctly and in a timely fashion the pollution of the environment and the efficiency of the decision applied to counteract this phenomenon, implies to use adequate models and measures of risks in order to identify and quantify the factors (polluting agents, economic polluting units) responsible and involved in this process.

It is known that for the risk's measures different approaches were given in the literature, some of them, so called "standard risk measures", which are very useful in practical cases. The risk of an alternative decision was usually associated with the variance of random variables that characterize the process in question. In different economic fields, other measures of risk where used that were better suited to the desired objective functions. For instance, in the banking field, the Value-at-Risk, Shortfall risk which measures the risk associated to the probability of falling under the established target. A general class of risk measures is the k upper moment ($k = 1, 2, \ldots$)

$$LPM_k(z,X) = E\left[\max(z-X,0)^k\right]$$

or normalized form

$$R(X) = LPM_k(z,X)^{1/k}$$

3. MULTIDIMENSIONAL MODELING, A PROPER TOOL TO QUANTIFY THE DEGREE OF RISK OF ENVIRONMENTAL POLLUTION.

The multidimensional modeling is a technique that allows the conceptualization and representation of the quantitative aspects of an activity, in connection with the context where it take place. The context in this case are the main parameters which characterize the activity, namely who initialized it, who executed it, who was the beneficiary, what resources were used, in what place and time it was realized. In this way the context is able to furnish important data about the gathering process of the polluting tests for each polluting factor or polluting economic unit, and through processing and interpretation of data done by the qualified control organisms, to take the correct decision to supervise the polluting process. The multidimensional modeling works with three concepts: dimensions, measures and facts. If dimensional measures usually define the static aspects of the factors implied in the polluting process (polluting agents, polluting unit), the facts reflect the dynamic aspects of this phenomena.

Introducing the new concept of *the degree of risk assigned to each polluting enterprise*, one also takes into account its pollution history, and consequently we can claim that this concept has a dynamic character and not a static one. The dimensions define the qualitative aspects of an activity and they can be detailed on many levels organized hierarchically considering different degree of resolution. This type of data organization allows fast access of information, a clustering of them useful in the process of viewing information for the decision factors lying on different hierarchical levels.

The dimensions considered in our case are:

- ***T*** time, with its members year, season, month, day.
- ***L*** location, with its members: developments regions, administrative regions, economic units.
- ***P*** polluting factors, with its members: type (air, water earth), code name, unit measure, alarm threshold, alert threshold.
- ***E*** the experimental data gathered, with its members: type of test, category of polluting factor, location, time and frequency.

The measures define the quantitative aspects of an activity and they are used in analyses for future decisions. They can be expressed directly through the gathered values or through calculated values.

The measures considered in our case are:

- the measured values;
- the number of tests;
- the maximum value allowed;
- the number of values that surpass the maximum or admissible level;
- the computed value of risk (polluting factor or polluting enterprise).

The facts represent collections of measures for an activity and together with the dimensions that identify the context where they are proceed. The facts contain numeric values which allow a future analysis of the studied phenomena. Because a fact can be associated with many dimensions it needs unique identification, to specify the value for each dimension. The facts are defined for different combinations of the members of a dimension which reflect different resolution degrees of the studied phenomena. The facts are stored in the fact table and the linkage with the information lying in the dimension table is realized through pointers.

The dimension of the model is given by the number of its elements $\{ d_1 d_2 \ldots d_n \} \in D$ and the possible combinations build with the parts of D, card $P(D) = 2^n$, where :

$$P(D)= \{\phi, \{d_1\}, \ldots \{d_n\} \ldots \{d_1 d_2\}. \ldots \{ d_1 d_2 \ldots d_k \} \ldots \{ d_1 d_2 \ldots d_n \}\}$$

The multidimensional modeling is based on the existence of a data warehouse.

A *data warehouse* is a collection of data organized by domain and subjects, which contains detailed, aggregate and historical data, correlated in time, nonvolatile and whose propose is to deliver precisely and timely information to the factors of decision that act at various hierarchical levels of an economic system.

Using intelligent search engines and modern tools for analyzing data, like the OLAP system, allows the efficient use of the information in a data warehouse, in the decision process.

OLAP is a efficient tool, able to furnish the multidimensional visualization of data, rapid access to them, aggregations of them depending of the objectives desired, multiple sharing of data, and the ability to obtain prognoses about them. In our case we have a quadruple dimensional model represented in figure 2.

The number of visualizations that can be realized with the OLAP tool is in our case 2^4 or even more if we take into account the members of each dimension. If D represents the number of elements in the model and its parts, by selecting different parts we can obtain different types of visualization, useful to the decision makers responsible for the economic unit.

We can in this way obtain a view at a certain moment in time, for a certain polluting factor who acts in a specific region, and establish the risk of pollution produced by it. If one takes into account a detailed level of resolution, we can determine the polluting enterprises responsible for this process and, even more, we can identify the tests on which these results are based.

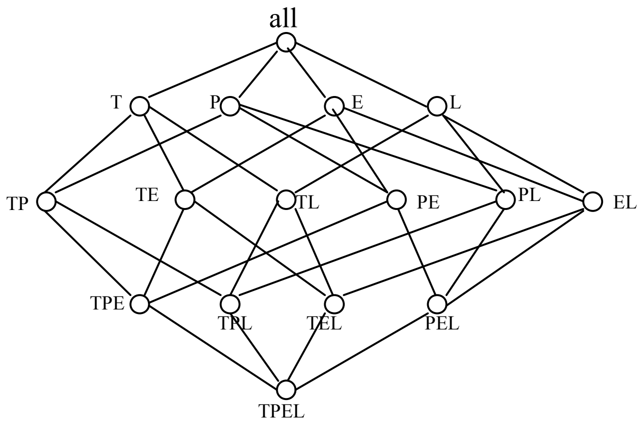

Figure 2. The representation of the parts for the four dimensional model

The model allows visualization in a certain interval of time, required by the responsible decision factors, of all information about the polluting unit in order to establish the degree of risk assigned to it. Thus, the decision makers of different departments can make a correct analysis of the polluting phenomena for each polluting unit. In the next paragraph we detail this measure of risk, and present the diagrams built on the experimental data.

4. MEASURES OF RISK USED TO QUANTIFY THE POLLUTION OF AIR BASED ON EXPERIMENTAL RESULTS

To quantify the pollution process in the air, caused by various polluting factors such as: nitrogen oxide, monoxide carbon, sulfur dioxide, powders, metals produced by different polluting economic units, the authors propose to use some measures of risk. It is necessary to take into account many measures of risk in the analyses done by the control authority for environment, in order to have a comprehensive analysis based on the polluting history of enterprises or on some unforeseeable natural phenomena (explosions, volcanic clouds, big storms). This analysis is the substantiation for putting in practice the adequate decisions by the environmental regional agencies and by the Environment Ministry, in order to control, adjust and prevent the polluting process.

In our case we treated only the pollution of the air but these measures can be successfully extended for polluting factors in earth or water. To explain the formula

used for each polluting factor or for the degree of risk assigned to the polluting unit, we introduce the following notations:
S – total number of region in the country; $s \in S$ – index of region;
J^s - number of economic units lied in region s;
P – number of polluting products; $p \in P$ – the index for the type of polluting product;
N – total number of tests gathered in the time interval $[t, t+1]$;
q_p^{admis} - admissible level for the polluting factor p;
q_p^{alert} - alert level of pollution for the polluting factor p;
$A_1 = \{i \in N / q_{pi} > q_p^{admis}\}$ the set of samples for polluting product p which overpass the admissible level q_p^{admis};
n^{ad} = card A_1, ;
$A_2 = \{j \in (N - A_1) / q_{pj} > q_p^{alert}\}$ the set of samples for polluting product p which are overtake only the alert level q_p^{alert};
n^{al} = card A_2 ;
$f_p^{ad} = n^{ad} / N$ - frequency of violation the admissible level of polluting factor p;
$f_p^{al} = n^{al} / N$ - frequency of violation the alert level of polluting factor p;
$\alpha_{1,j}$ - the weight assigned to violation of the admissible level for unit j in calculus of the risk ;
$\alpha_{2,j}$ - the weight assigned to violation of the alert level for unit j in calculus of the risk ;
r_p^s - the risk calculated for the polluting factor p for the whole region s;
r_j^s - the risk computed for the economic unit j lied in region s taking into account all its polluting products;
r_p -risk computed for polluting factor p at the level of the whole country.
where:

$$r_p^s = \sum_{j \in J^s} r_{pj}^s, \qquad r_j^s = \gamma_j \sum_{p \in P} \rho_p r_{pj}^s, \qquad r_p = \sum_{s \in S} \sum_{j \in J^s} r_{pj}^s$$

$$r_{pj}^s = \alpha_{1j} f_p^{ad} \sum_{k \in A_1} \left(q_{pk} - q_p^{admis}\right) / q_p^{admis} + \alpha_{2j} f_p^{al} \sum_{k \in A_2} \left(q_{pk} - q_p^{alert}\right) / q_p^{alert}$$

We consider four categories of measures of risk, the first three concerning the polluting factors implied (in our case nitrogen dioxide, carbon dioxide, carbon monoxide, sulfur dioxide powders, metals), while the last refers to the polluting unit.

The degree of risk assigned to each polluting unit allows taking into account also its polluting history, and in this way the decisional authorities that supervise this process can stimulate or penalize the activity of the polluting economic units. The measures of risk proposed by the authors have as main components the upper level of first or second degree depending on the attitude of the decision makers versus risk – more permissive or restrictive. In case of natural disasters, the second upper degree was considered because such effects cumulate with those produced by the economic units that acts in the area. ***The first category of measures of risk*** concerning the pollution in air, take into account only the admissibility level with the two alternatives versus risk. The expressions of these measures are given by the following formulas:

$$r_{pj}^{s} = \sum_{k \in A_1} \left(q_{pk} - q_{p}^{admis}\right) / \left(n^{qd} q_{p}^{admis}\right) \quad r_{p}^{s} = \sum_{j \in J^{s}} r_{pj}^{s}, \qquad r_{p} = \sum_{s \in S} \sum_{j \in J^{s}} r_{pj}^{s}$$

$$r_{pj}^{s} = \sum_{k \in A_1} \left(q_{pk} - q_{p}^{admis}\right)^{2} / \left(n^{qd} q_{p}^{admis}\right)$$

In spite of the classical formula for the second upper degree, the authors introduce in the denominator the value of admissible level, to quantify the value of this surpass versus this threshold, and to point out in this way, the amplitude of pollution produced by the polluting factor and which allows us to compare the risk degree between different polluting factors. In case the polluting factor has a persistent cumulative character in the previous formula of risk, the n^{ad} is discarded from the denominator.

The second category of measures of risk proposed by the authors also takes into account the alert level. In this way, the competent authorities who supervise the process of environmental pollution can better evaluate the risk produced by each polluting factor, in the area where it acts, because the polluting units are tempted to surpass the alert level often since no penalties are applied. The cumulative effect of frequently surpassing the alert level for a certain polluting factor by the enterprises lying in a region can lead finally to surpassing the admissible level. The authors introduce also different weights for the two levels considered, with the porpose of penalizing the economic units that often surpass the alert level, in which case the weight has a greater value. The expressions proposed, depending of the decision makers' attitude towards risk, are:

$$r_{pj}^{s} = \alpha_{1j} \sum_{k \in A_1} \left(q_{pk} - q_{p}^{admis}\right) / \left(n^{qd} q_{p}^{admis}\right) + \alpha_{2j} \sum_{k \in A_2} \left(q_{pk} - q_{p}^{alert}\right) / \left(n^{alert} q_{p}^{alert}\right)$$

or

$$r_{pj}^{s} = \alpha_{1j} \sum_{k \in A_1} \left(q_{pk} - q_p^{admis}\right)^2 / \left(n^{qd} q_p^{admis}\right) + \alpha_{2j} \sum_{k \in A_2} \left(q_{pk} - q_p^{alert}\right)^2 / \left(n^{alert} q_p^{alert}\right)$$

The third category of measure of risk proposed in this paper, take into consideration the relative frequency (number of overpasses the threshold divided by total number of experiments). Those in this case, as opposed to the measures of risk from the second category, realize a fine quantification of the polluting effect produced by each polluting factor because one takes into account the reported number of over passing in the number of tests gathered. Also in this case, depending on the attitude of decision makers towards risk, the two upper moments modified are taken into account:

$$r_{pj}^{s} = \alpha_{1j} f_p^{ad} \sum_{k \in A_1} \left(q_{pk} - q_p^{admis}\right) / q_p^{admis} + \alpha_{2j} f_p^{al} \sum_{k \in A_2} \left(q_{pk} - q_p^{alert}\right) / q_p^{alert}$$

$$r_{pj}^{s} = \alpha_{1j} f_p^{ad} \sum_{k \in A_1} \left(q_{pk} - q_p^{admis}\right)^2 / q_p^{admis} + \alpha_{2j} f_p^{al} \sum_{k \in A_2} \left(q_{pk} - q_p^{alert}\right)^2 / q_p^{alert}$$

In order for the Ministry Environment and the local environment agencies to apply more correctly penalizations or subsides to the economic units responsible for pollution, the authors propose four categories of measures of risk concerning the enterprise and its polluting history.

Based on the degree of risk computed for each polluting factor *p*, produced by the economic unit *j,* lied in region s , we propose the following measure of risk assigned to enterprise *j*:

$$r_j^s = \gamma_j \sum_{p \in P} \rho_p r_{pj}^s$$

where:

γ_j - penalty or stimulation factor that takes into account the pollution history of the economic unit, for a period of 1-3 using the data warehouse information's.

ρ_p - the weight assigned to polluting factor *p* which considers its negative impact on the environment, its duration (for example the dioxide carbon can affect the ozone layer for a long period of time);

r^s_{pj} the risk assigned to the polluting factor *p*, emanated by the enterprise *j* in region*s*.

5. EXPERIMENTAL RESULTS OF THE CASE STUDY

Experimental results of the case study take into account the analyze of data concerning the pollution of air in region Arges and Dambovita for a period of 6 month, namely autumn 2009 and winter 2010. Considered six polluting factors (nitrogen dioxide, carbon dioxide, carbon monoxide, sulfur dioxide, powders, metals) of air at the level of three regions.

The main air polluting units in Arges county are in the ratio of 85% the companies Arpechim and Dacia and in Dambovita county the Steel Factory Targoviste and

Carpatcement Holding SA. The polluting substances considered are sulfur dioxide SO_2 nitrogen oxide and dioxide (NO, NO_2), carbon monoxide CO and metal powders with diameter 10 µm because they are responsible for 90% from air pollution. Gathered data represent mean values measured daily at the measurement stations during a month for the five polluting substances. Data are based on monthly reports given by the Regional Environmental Agencies and interview with decision factors from the agencies. Compared to data gathered in 2008 for region Arges presented by the authors in paper /3/ on can observe a diminution of the pollution level for nitrogen oxide and dioxide and carbon monoxide. This is due to the fact that admissible levels imposed by the Environment Ministry based on European Directives are in each year smaller and penalties bigger. Exceeding those levels many times with a significant value, may lead finally for the polluting company to loose his production license.
The following remarks are referred first to the period of winter 2010, for the four enterprises lied in the region Arges and Dambovita. Considering first, the formula for the measures of risk from the first category, we observe that a stronger attitude of decision maker towards risk (formula which contain the second upper degree) lead to higher values of risk for each polluting factor.
In these experiments one considered also the polluting factor sulfur dioxide SO_2, because it has an important negative influence on environment pollution.
As one can observe in figures 1(a, b) powders (metallic residues and the ones produces by road vehicles) are causing the highest levels of air pollution.

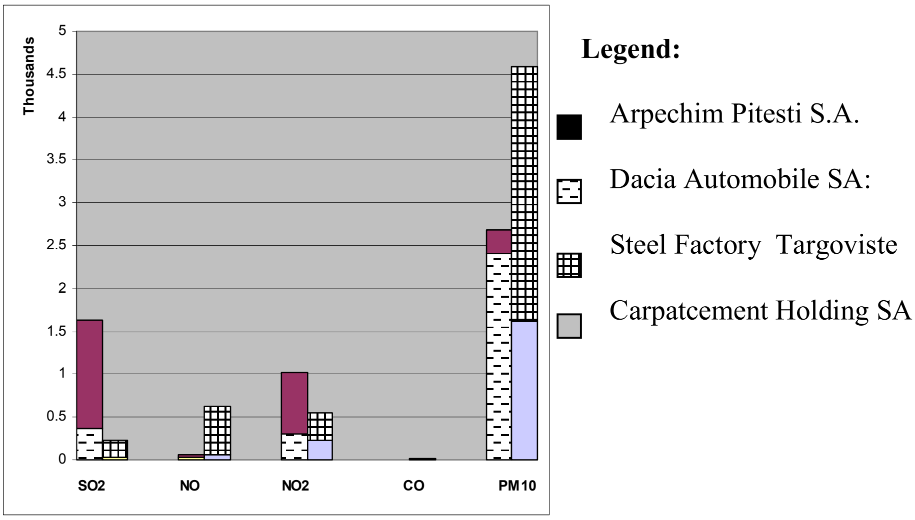

Figure 1 a.
Evaluation with measure of risk I category (first degree) for violation the admissible level.

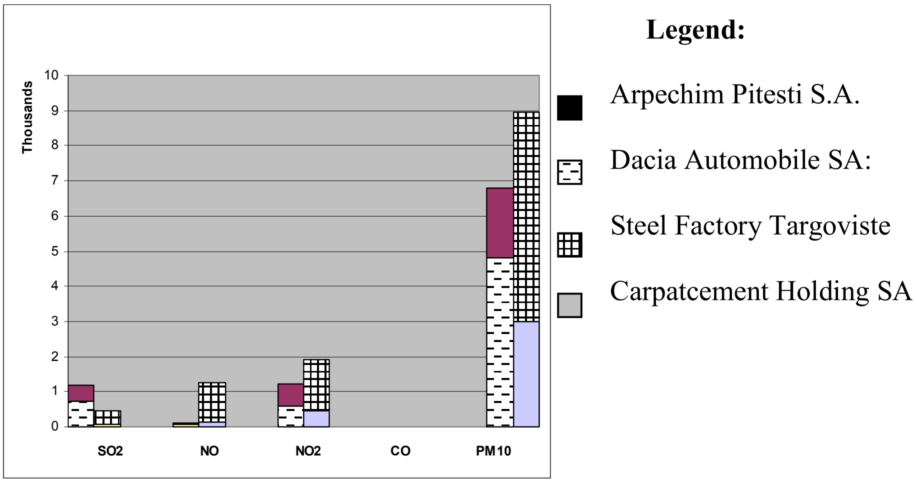

Figure 1 b.
Evaluation with measure of risk I category (second degree) for violation the admissible level.

The pollution of air in region Arges compared to those in Dambovita is higher for SO_2, NO_2, and PM 10. We must underline that the pollution of air with NO_2 is particularly dangerous because it affects the ozone layer of the atmosphere, and for this reason the responsible control units of environment pollution must take the corresponding actions.

The second category of measure of risk takes into account also the alert level for the polluting factors that leads evident to higher values for the risk. This measurement is more effective because permits to apply more correctly penalizations for the companies who frequently exceed the alert level- see figures 2(a, b) and cumulating this effects, lead to higher pollution in the atmosphere.

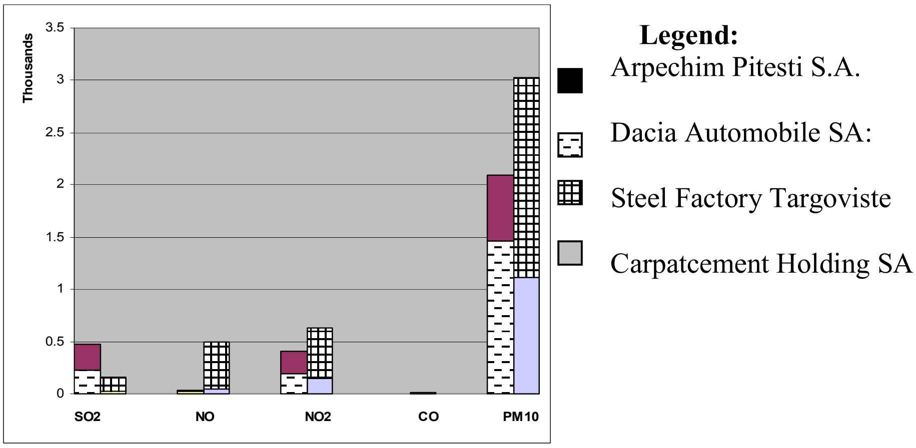

Figure 2 a.
Evaluation with measure of risk II category (first degree) for violation the admissible and alert levels.

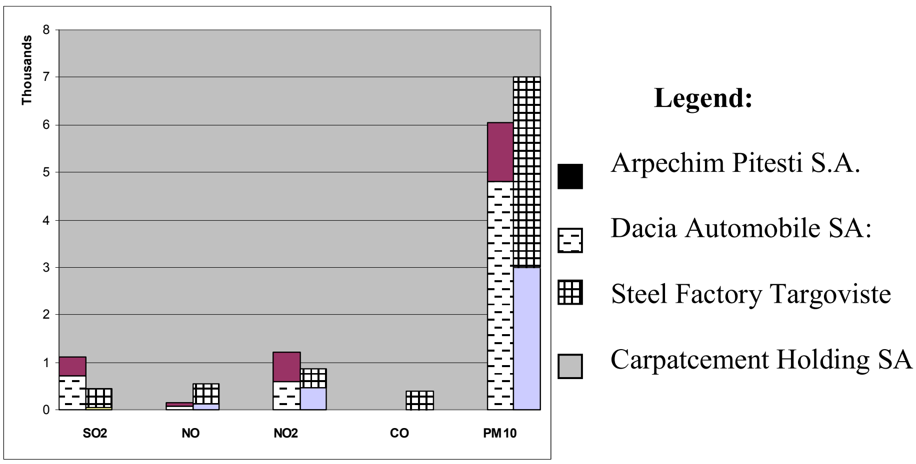

Figure 2 b.
Evaluation with measure of risk II category (second degree) for violation the admissible and alert levels.

The third category of measures of risk exemplified on the data gathered in the two region Arges and Dambovita, can be seen on figures 3(a, b). One can observe that risk value are smaller then in the measure of risk of types one and two, because we take into account also the relative frequency of over passing the two thresholds

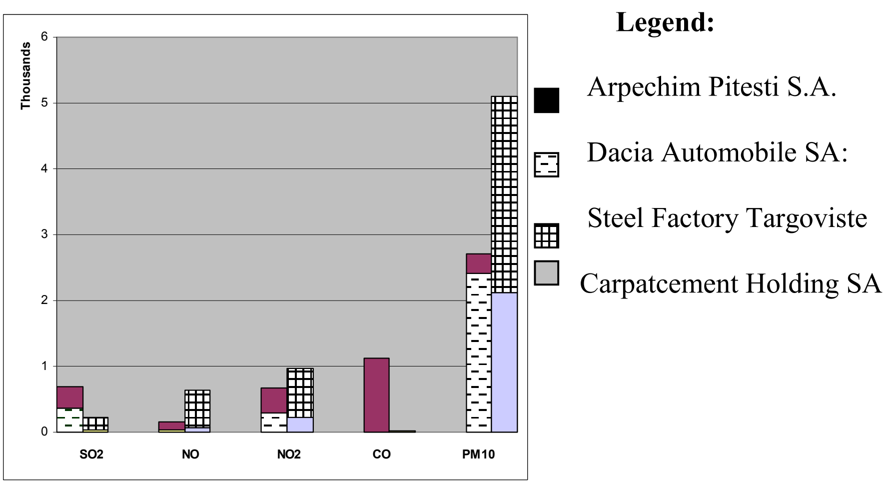

Figure 3 a.

Evaluation with measure of risk III category (first degree) for violation the admissible and alert levels at economic units with taking in account the relative frequency

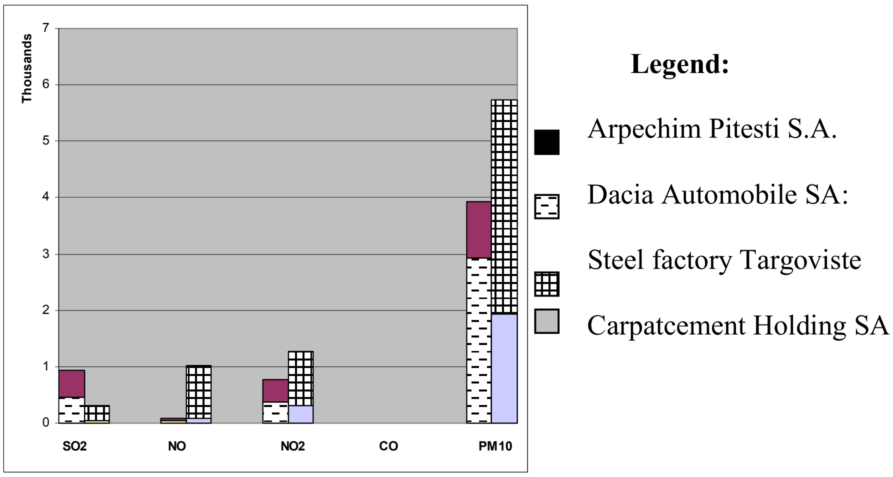

Figure 3 b.

Evaluation with measure of risk III category (second degree) for violation the admissible and alert levels at economic units with taking in account the relative frequency.

From calculus made using data gathered in the period autumn 2009, for the same regions and polluting companies one observe a rising of the pollution risk for the majority of polluting factors, because the production of these companies were bigger in this period compared to the winter period. There is to notice, that the EU directives stipulate that in the near future will not be allowed to exceed the admissible threshold for the polluting factors with high noxious effects or with long time lasting effects.

Analyzing the *degree of risk assigned to each polluting company*, one can observe that the biggest value are for Carpatcement Holding SA and Steel Factory Targoviste.

In our calculus, the values for weight ρ_j were 1.2 for SO2, 1.5 for NO2 and NO, 1 for CO and PM10 but γ_j were 1.2 for Arpechim, 1.5 for Carpatcement SA, 1.1 for Steel Factory Targoviste and 1 for Dacia SA.

The degree of risk that takes into account the second upper degree is also in this case obviously bigger as the one of first order for all the types of risks. In this case, the same as for the polluting factors, the enterprise risk that takes into account the measures of risk from the second category is bigger but his sensitivity is smaller compared to the risk for polluting factors.

The degree of enterprise risk calculated using the third category of measures, has smaller values because one takes into account the total number of over passing in the number of test gathered.

These results may be extended at the level of all regions in the country and further one can made comparative studies based on them, that will be used in the future for better decisions politics applied by the environment agencies and polluting enterprises.

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