RISK ASSESSMENT OF DUST CONTAMINATION OF AIR

Vladimirov Lyubomir

University of Russe – Razgrad, Bulgaria

Vladimirov Lyubomir, lvvladimirov@uni-ruse.bg

Abstract: Dust contamination is a risk factor for the population of the town of Ruse. It is very strongly expressed during the heating period. The paper presents the results from long-lasting investigations of dust content in the free air by residential districts, at different weather conditions and other factors. Results are compared with sociologic research among the townspeople. An attempt is made to assess the influence of Thermo-electric Power Plant and other industrial sources. Criticality is assessed according to the differential risk for dangerous action. It is compared with data about sick rate among population.
Keywords: dust, contamination, research, criticality

Introduction

Dust contamination of free air is a problem, which is unsolved and not studied enough. That fact is confirmed by a number of researches [2,3]. It can be classified as a phenomena, which causes critical situations and events, in differential and integral aspect, especially during the cold season, when cyclic trends of continuous and significant contamination are established [5].

At present criticality of dust contamination is assessed only by comparison of currently measured concentrations and allowable limits. Methods of measuring, used in Bulgaria, are based on discrete measurements over the course of time. Arithmetic mean values are determined and then they are compared to the standard values. Based on that comparison conclusions are made about degree of contamination. The time interval between measurements is adopted to be 4 hour. This is mainly because of organizational considerations.

Actually the process of dust contamination is very dynamic with significant fluctuations. Discrete measurements are not able to follow such dynamics and therefore assessment of contamination is not objective. This is confirmed by our research [3], as well as by the research of other authors [2] about the conditions in the town of Rousse.

To classify them as critical, situations of contamination of the components of environment are subject to several conditions, which determine their dangerous action [3,4,5]. The first condition is the spatial combination of object of exposure and risk factors. Therefore the object toward which criticality is assessed shall be defined precisely. The second condition is the above mentioned, namely the level of imissions of dangerous factors shall exceed the allowable limit. The third condition is combination over the course of time. This condition is expressed with the period of action of contaminating factors, during which the level of imissions exceeds the allowable limits. The fourth condition is that the period of action shall be larger than the allowable time of stay and work under the measured imission. This condition refers to factors, which exposition is standardized. The fifth condition is the coincidence of the time of action with the time of exceeding of allowable values.

The criticality of dangerous events resulting from contamination of environment according to the risk models, backed up with arguments by us [5,6], should be determined by the type of damage, its localization, heaviness and restorability. It is appropriate to compare them with the reactions of the objects of exposure.

The purpose of this study is to establish criticality of dust contamination of free air in the town of Rousse during the cold season.

The basic tasks that are solved are:

1. To provide grounds for a method of research and assessment of dust contamination, following its dynamics over the course of time;
2. To determine indicators of critical situations caused by dust contamination;
3. To establish critical events caused by contamination among population;
4. To establish dependence between criteria about criticality of contamination and criteria about criticality of health status of the population.

Material and Methods

Research was made in four districts in the town of Rousse. We used data from the automatic measuring stations and the fixed analytical sampling points of the Regional Inspectorate of Environment and Waters, of the Hygienic and Epidemiological Inspectorate and own measurements. When solving the first task we applied experimentally the probabilistic-statistical method of analysis and assessment. It is based on the theory of accidental processes [1]. Dust contamination is examined as a continuous accidental process with normal distribution, which is verified in [3]. Its basic statistical characteristics are function and density of distribution. We draw up the probabilistic characteristics of dust imissions for the time period t -mathematical expectation $m_x(t)$, equal to the average value *E[X]*; dispersion $\sigma_x^2(t)$; correlation function $R(\tau)$; spectral density $S(\omega)$ [1]. A check is made about stationariness and ergodicity of the process of dust contamination. Stationariness is examined in its wide sense, characterized with the equations: $m_x(t) = m_x = const.,$ $\sigma_x^2(t) = \sigma_x^2 = const., R_x(t_1,t_2) = R_x(t_2 - t_1) = R_x(t).$ Ergodicity is based on the coincidence of statistical characteristics, calculated by the multitude of realizations and the characteristics, calculated for continuous enough and averaged over the course of time realization of imissions. Thus determination of probabilistic characteristics is made according to the dependencies:

$$m[x] = lim_{T\to\infty}\frac{1}{T}\int_0^T x(t)dt;\ \sigma_x^2[t] = lim_{T\to\infty}\frac{1}{T}\int_0^T [\overset{o}{x}(t)]^2 dt;$$

$R_x(t) = lim_{T\to\infty}\frac{1}{T}\int_0^T \overset{o}{x}(t)\overset{o}{x}(t+\tau)dt,$ where $\overset{o}{x}(t) = x(t) - m(x)$ is the centered realization of accidental processes.

Correlation function and spectral density are applied to find the internal structure of the processes of dust imission in free air. They are connected with the transformations $R_x(\tau) = \int_0^\infty S_x(\omega)\cos\omega\tau d\omega;\ S_x(\omega) = \int_0^\infty R_x(\omega)\cos\omega\tau d\omega$, where ω is

frequency. Through the correlation function $R_x(\tau)$ are established the process relations and the character of the process of contamination as a function of time, and through the spectral density $S_x(\omega)$ - its frequency composition.The standardized correlation functions $\rho(\tau)$ and the standardized spectral densities $\sigma(\omega)$ [5] for the whole period of monitoring and their characteristics are determined, namely: - time τ_o of fall of correlation; - the average half-period τ_ρ ; - damping frequency of the correlation function; - shear frequency ω_c ; - frequency ω_o of the maximum value of spectral density; - spectrum width $\Delta\omega$. Modeling of the process of dust contamination is done by means of a typical correlation function [1]

$R(\tau) = \sigma_x^2 e^{-\mu|\tau|}(\cos\beta\tau + \frac{\mu}{\beta}\sin\beta|\tau|)$, where μ, β are the function factors. *The number of exceedings* n_x *for a unit of time is:*

$$n_x = \frac{\sqrt{\mu^2 + \beta^2}}{2\pi} e^{-\frac{(x_O - m_x)^2}{2\sigma_x^2}},$$

and their average duration τ_x is

$$\tau_x = \frac{\pi}{\sqrt{\mu^2 + \beta^2}} e^{\frac{(x_O - m_x)^2}{2\sigma_x^2}} \left[1 - \Phi\left(\frac{x_o - m_x}{\sigma_x}\right)\right],$$

where Φ(x) is the Laplas function [1];

x_o- allowable limit of dust contamination.

Results & Discussion

To determine risk of occurrence of dangerous actions, according to the integrated model, adopted by us [4,5], we assume that:

- Dust distribution is only in free air, which supposes respiratory effect on people. Distribution of dust in other media is not followed;
- Duration of action is determined by the period of work of the central hot-water heating from the moment of turning on to the moment of turning off;
- Area of distribution covers four districts K1, K2, K3, K4;
- Probability of exceeding is the relative frequency of occurrence of dust volumetric concentration higher than the allowable value;
- Time of exceeding is equal to the total duration of all exceedings during the period of research.

The duration of action of imissions are related with the operation of the central hot-water heating, respectively its power source – Thermo-electric Power Plant "Iztok", because our research [4,5] established correlation between its technical and operational indicators and the volumetric concentration of dust in the air of the town.

The duration of heating operation of Thermo-electric Power Plant "Iztok" in the period 2003-2007 was studied. It was found out that it obeys the normal law of distribution

with the following values of basic characteristics: average value *E[X]*=116,5 days; dispersion σ =12,4 days; coefficient of variation V=10,14 days, probability of occurrence of the duration of imissions in the interval *E[X]* $\pm \sigma$ -*Рим*=0,3451.

Results from the research of dust concentrations as an accidental process in four districts in the town of Rousse are given as:

- Mathematical expectation m_x in mg/m^3 is close to, but lower than the maximum single concentration. The dispersion is large, which means that the allowable concentration is exceeded;
- The number of exceedings a day n_x for district K1 varies from 1,5 to 3,7. Analogous range is measured for distirct K4. For the two other districts the number of exceedings is higher and in wider interval - from 2,4 to 12,6. Average duration of exceedings in district K1 is from 1,03 to 1,79 h, in district K2- from 1,46 to 2,12h, in district K3 – from 1,32 to 2,45h, in district K4 from 1,14 to 1,67h. These characteristics allow to determine approximately the total interval during which the allowable value of dust contamination is exceeded;
- Our thesis that dust contamination in the town of Rousse is very dynamic process is confirmed. This is proven by the characteristics of the correlation function and the spectral density. To make an objective assessment it is appropriate to apply the proposed method. When comparing only the average value from the measurements of dust contamination with the allowable value, the duration and the number of exceedings may not be established. The reason is that the interval between measurements is not correctly chosen;
- It is established that there is big correlation between the discrete values of contamination, which is for a period of 1,03-2,93h for different districts. Maximum frequency varies in very wide limits – from 0,23 to 2,24h^{-1}.

Except the typical characteristics for accidental processes, the probability of occurrence of one exceeding is established too. For its determination was made a check of the hypothesis of the law of distribution. Because the number of exceedings is a discrete accidental value, the check was made according to Poason's law and the binominal distribution. The hypothesis for the Poason's law was not rejected. Based on the values of its characteristics, the probability for occurrence of one exceeding a day was calculated. It varies in very wide limits by districts and by years - from 0,0914 to 0,4573.

For the purpose of passing from natural to accidental values and therefore to determine the risk of dangerous action of dust contamination, a check was made of the law of distribution of the duration of exceedings. The check established that this duration obeys the normal law of distribution, which characteristics for different districts vary in the following ranges: average value *E[X]*=0,87-2,38h*;* dispersion σ =0,66-1,02 h*;* quadratic mean deviation σ^2 =0,31-1,04h*;* coefficient of variation *V*=30,67-88,13%.

We calculated the probabilities for duration of exceedings within the range *E[X]* $\pm\sigma$ for every district. We obtained the following values: for district K1-0,8255, for district K2-0,6827; for district K3-0,6617 and for district K4-0,7629.

By taking into account the obtained values of the probabilistic components, we calculated the differential risk of dangerous action of dust contamination. We should mention the limiting conditions, namely: For a cold season with the above specified characteristics of the normal law of distribution of its duration, For occurrence of one exceeding of allowable limit a day (distribution of the number of exceedings according to

Poason's law), Duration of the exceeding in the range from $E[X]-\sigma$ to $E[X]+\sigma$, again under normal law of distribution.

Under these conditions of the task, the following values of differential risk of dangerous action by districts were obtained: K1-0,0286; K2-0,0345; K3-0,0357; K4-0,0263. The analysis shows that risk is highest in district K3 and K2, which are located closest to the basic producer of heat for the central heating of the town of Rousse – Termo-electric Power Plant "Iztok". Lowest is the risk in the districts, which are far from the thermo-electric power station, where local heating is used, mainly with solid fuel. The differential risk of occurrence of dangerous effects caused by dust contamination require establishing the type and the localization of damage, heaviness, restorability of the objects of risk research.

To establish the type of damages among the population of the studied districts we studied the pulmonary diseases from data received from the District Pulmonary Dispensary and the district polyclinics. We focused on diseases, connected with allergic reactions. For the period of the research were found 536 cases of such diseases with hospitalization. The check of the hypothesis for the law of distribution shows that the day number of diseases during the cold season obeys the Poason's law. This is due to the discrete character of the studied accidental value. The following results were obtained about the characteristics of the law for the four districts: Average value $E[X]$=0,89-1,39*;* dispersion σ =0,94-1,39*;*coefficient of variation V=84,81-105,99%; day probability of occurrence of one pulmonary diseases from 0,3559 to 0,3678.

The check of the hypothesis for the law of distribution of the duration of hospitalization, as a criterion of the heaviness of damage, shows that the hypothesis for normal distribution is not rejected. The values of its characteristics for the four districts in the period 2003-2007 vary as follows average value $E[X]$=12,7-16,34 days*;*dispersion σ *=2,12-4,57;* quadratic mean deviation σ^2 =4,49-20,88 days*;*Coefficient of variation V=16,18-27,96 %. The probability of occurrence of a disease with duration from $E[X]-\sigma$ to $E[X]+\sigma$ varies from 0,6327 to 0,6895.

The differential risk of occurrence of dangerous effects from the studied type – pulmonary diseases due to allergic reactions by districts is as follows: district K1-0,2342; district K2-0,2729; district K3-0,3139; district K4-0,2349. These results comply with the obtained values for the characteristics of dust contamination by districts, described above. In addition 883 cases of respiratory reactions with symptoms of allergies were registered. For these cases it is not possible to assess heaviness because there is no accurate information about the duration of treatment as it takes place at home. Thus the same values as for hospitalization were adopted. Distribution of respiratory reactions is again according to Poason's law with the following characteristic values: average value $E[X]$=1,37-1,94*;* dispersion σ =1,15-1,39*;* coefficient of variation V=71,79-86,71%; the day probability of occurrence of one respiratory reaction with allergic symptoms of pulmonary disease is from 0,2788 to 0,3518. The differential risk of occurrence of dangerous effects of respiratory reactions with symptoms of allergies is: district K1-0,2151; district K2-0,2040; district K3-0,1894; district K4-0,2261.

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