## 5.23 STUDY AND PREDICTION OF ATMOSPHERE POLLUTION IN CITIES OF ARMENIA

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### INTRODUCTION

Atmosphere pollution is a sensitive especially for Yerevan. Its hollowed relief structure, large repeatability of terrestrial and raised inversions, often calms, arrangement of large industrial enterprises in a direction of prevailing winds, promote accumulation of harmful admixture industry and transport, and rise of their concentration in air basin of Yerevan.
Based on parameters of emissions (height of pipes, volume, weight, temperature and velocity of admixture emissions), there is a dangerous wind velocity for each enterprise, at which maximal concentration of harmful admixture in the terrestrial layer of atmosphere, i.e. at the level of human activities occurs. It is not always possible to take out large sources of air pollution far beyond cities, however, a number of measures are currently initiated to improve the state of the air basin of Yerevan.
Often it becomes necessary to reduce the emissions into the atmosphere time to time during the periods of time, when meteorological conditions are unfavourable and the high level of air pollution threatens residential areas. The prediction of the level of air basin pollution, based on the data of meteorological conditions, makes it possible to take actions to prevent negative consequences in time, as well as reduce their impact. In case of prediction of dangerous concentration, which exceeds sanitary norms, the emissions into the atmosphere should be standardized.

According to the guidance of atmosphere pollution control, it is necessary to have the forecast of meteorological conditions determining high level of air pollution to regulate the emissions in dangerous meteorological conditions.

**Mathematical model of atmosphere pollution in Yerevan caused by industrial emissions**
For the solution of the task, the equation for distribution of admixture is as follows:

$$\frac{\partial\varphi}{\partial t}+u\frac{\partial\varphi}{\partial x}+V\frac{\partial\varphi}{\partial z}+w\frac{\partial\varphi}{\partial z}+p\varphi-\frac{\partial}{\partial x}k_x\frac{\partial\varphi}{\partial x}-\frac{\partial}{\partial y}k_y\frac{\partial\varphi}{\partial y}-\frac{\partial}{\partial z}k_z\frac{\partial\varphi}{\partial\varphi}=F(x,y,z,t) \quad (1)$$

**Where:** $\varphi$ - concentration of admixture in the air; $t$ - time; $x,y,z$ - decartian coordinates; the axes Ox and Oy are located in a horizontal plane, the axis Oz is directed vertically upwards; $u,v,w$ - wind velocity according to these axes; $k_x,k_y,k_z$ - coefficient of horizontal and vertical components exchange., $p$ - parameter describing changes of admixture concentration during transformations, connected with the life time of substation.

$F(x,y,z,t)$ - function describing actions of pollution sources, i.e. their location in the considered area, capacity and conditions of activization. It is possible to present the function of $F(x,y,z,t)$, for example, as follows:

$$F(x,y,z,t) = Q\,\gamma(t)f_{xoyo}(x,y)\delta(z-h)$$

**Where**: Q - intensity of sources,

$$\gamma(t) = \begin{cases} 1.0 \le T \le T_0 \\ 0,\ t > t_0 \end{cases}$$

$$f_{x_0 y_0}(x,y) = \begin{cases} 1,\ x_0 - \Delta x \le x_0 \le x_0 + \Delta x, Y_0 - \Delta y \le y_0 \le y_0 + \Delta y \\ 0, \text{ outside of area} \end{cases}$$

$t_0$ - time of source actions, $\Delta x$ and $\Delta y$ characterize horizontal extent of admixture source in vicinities of point ($x_0, y_0, h$), $\delta$ - is the function of Dirak. In case of a dot source $\Delta x = \Delta y = 0$.

The area $\Omega$ Is set in the following kind:

$$\Omega = \{(x,y,z): 0 \le x \le L_x, 0 \le y \le L_y, z_0(x,y) \le z \le z_0(x,y) + H\},$$

Where $z = z_0(x,y)$ (spreading surface) and $z = z_0(x,y) + H$ - equation of the bottom and top borders of the area $\Omega$, and $L_x, L_y$ - its horizontal scales.
The border conditions on a vertical enter is recorded in the following way:

$$k_z \partial\varphi/\partial z - \beta\varphi = 0, \quad \text{at } z = z_0(x,y), \qquad (2)$$

$$\varphi = 0, \quad \text{at } z = z_0(x,y) + H.$$

$\beta$ characterizes interaction of admixture with a spreading surface.

Considering the horizontal sizes of area $\Omega$ as rather large, on the other $L_{x,} L_y$ borders of the $\Omega$ area are accepted as zero boundary conditions:

$$\varphi\Big|_{L_x, L_y} = 0 \qquad (3)$$

primary condition is presented as:

$$\varphi\Big|_{t=0} = \varphi(x,y,z) \qquad (4)$$

The primary condition (4) together with the border conditions (2) and (3) allows to set forth the only solution (1), if the function $F(x,y,z,t)$ is known.
The task (1) - (4) is solved numerically. For making an algorithm the curved area of integration is brought to rectangular means of replacement of variables. As a differenced scheme the obvious scheme of Djufor-Frankel was taken [1].
This scheme was used for dispersion of harmful admixture, thrown by industrial enterprises and energy power stations in Yerevan. Let's describe some details of application of the given scheme. The considered area is a horizontal section on axis Oy -17,5 kms, and on axis Ox - 16 kms. It is broken on a square net with a step 500 m, on axis Ox -32, on axis Oy - 35 of calculated units. By each unit of a net the relief height is determined which is the entrance parameter of the model. These data are taken from the relief card in scale 1:10000. The following entrance data are the fields of wind velocity, of which the accuracy of spreading and distribution of polluters depends. The estimations were carried out on the climatic data of wind on the ground, and by height at the second level, which was accepted by Dicon’s law at

the following three levels; the velocity is taken from the data of Yerevan radiosonde with 10-year's period in average. Other parameters and coefficients of considered scheme are described in [1]. The step for time was accepted as $\Delta t$ = 2 minutes, based on conditions of stability of the scheme of estimation.

For substantiation of the priority list for enterprises of Yerevan, acting as main sources for air basin pollution in the city, the data on weight of emissions of polluting substances in an atmosphere in 1990 were used. As a result the data on 172 enterprises polluting air pool of Yerevan were analyzed and systematized. They were grouped into 7 basic groups, which are shown in the picture. Here the isoclines of concentration are presented in an hour of evolution normalized on the maximum (mg/m3), with an interval of 0,5. As it can be seen from the picture the most polluted areas are the southern industrial areas of the city, where the relative rate of concentration is 15-25 units.

This method is used for town-planning areas and standardization of emissions.

**Meteorological method of atmosphere pollution.**

The scheme for prediction of air pollution in Yerevan is developed by the method of identification of images offered by the Main Geophysical Observation. Some additions and modification have been made in it. The scheme is developed for separate months and four directions of wind [2].

The method of prediction defines the level of affinity of a concrete situation typical to situations of air pollution. For characterizing the air pollution of the city as a whole parameter p = m1/n1 is used as a general index. Here n1 - total number of observations for concentration of admixture in the city within one day on all stationary points, m1 – the number of observations during the same day with the increased concentration of q, which exceeds mid seasonal meaning of qcp more than in 1,5 times (q = 1,5 qcp). Here parameter p was counted by all admixture of 6 years observations of pollution.

The scheme for prediction is developed on the basis of data of different months in 1980-1985 by results of study of links between parameters of pollution and meteorological conditions of Yerevan.

The meaning of parameter p was disposed in decreasing order and then broken into three groups: 1-st ($p \geq 0{,}40$), 2-nd group 0,20 $\leq$ P < 0,40, 3-rd group p $\leq$ 0,19; by four directions: N(315°-44°), S (135°-224°), E (45°-134°), W (225°-314°).

For each group the average meaning of predictors and their mean quadratic deviation $\sigma$ was calculated:

$$\sigma = \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \Big/ n}$$

**Where** $x_i$ - is characteristic meaning of predictor, $n$ - number of cases in the given group.

As predictors the following parameters have been used by us: $p'$ - initial size of parameter p, $v_{850}$ - velocity of wind at height of 850 mb from surface, $T_0$ -air temperature at ground surface, $U_{0-1.5}$ - average air humidity in a layer up to 850 mb from the surface, $\gamma$ - gradient of air temperature $(-\partial T/\partial z)$ calculated in a layer up to 850 mb from surface. All these are the data of a radiosonde of Yerevan, averaged by four observations at a day. The direction of wind is taken in the period of 1430 at a level of 850 mb from the surface.

The affinity between a situation of a concrete day and characteristic situation of the group is defined by the so-called, “distance” between them. “Distance” between the given situation i- (i = 1,2,3) groups.

$$\rho_i^2 = \frac{(p' - \overline{p}')^2}{\sigma_{p_i}^{\ 2}} + \frac{(v_{850} - \overline{v}_{850})^2}{\sigma_{v_{850i}}^{\ 2}} + \frac{(T_0 - \overline{T}_0)^2)}{\sigma^2_{T_{0i}}} + \frac{(U_{0-1.5} - \overline{U}_{0-1.5})^2}{\sigma^2_{U_{0-1.5i}}} + \frac{(\gamma - \overline{\gamma}_0)^2}{\sigma_{\gamma i}}.$$

Here $\overline{p}', \overline{v}_{850}, \overline{T}_0, \overline{U}_{0-1.5}$, $\overline{\gamma}$ - average meaning of predictors i of group, $\sigma_{p_i}{}', \sigma_{v_{850}}, \sigma_{T_{0,i}}, U_{0-1.5}, \sigma_{\gamma_i}$ - their mean quadratic deviations.

On the basis of the given parameters a special table is developed, where the average meanings of predictors are given $\overline{x}$ and their mean quadratic deviation in three groups of air pollution by directions of wind. With the help of the developed table is predicted $p$. The group is predicted, for which $\rho_i^2$ is the least size.

Let's note, that real justification for prediction of high air pollution is important (p $\geq 0{,}40$) even from the viewpoint of atmosphere protection. The given technique was introduced into daily practice of Armstatehydromet.

It was approved in Meteo France, for Bordeaux city. In France the pollution level is divided into 10 groups, which were presented in the three groups identified by us: 1-4 - I groups, 5-7 - II and 8-10 - III. As predictors the daily data of the following sizes in a terrestrial layer, at height 500 m and 1500 m (pressure, temperature, humidity, size of velocity and direction of wind) are taken. By altering the method for these 15 elements a computer program was developed and the approbation was carried out in Toulouse. For each day in 1998, the forecasts and results were compared with fact data. The total justification was 77 %, and the justification for the forecast of dangerous pollution - 83 %.

**REFERENCES**

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