CLIMATIC DISTRIBUTION OF POLLUTANTS FROM SELENGA PULP-AND-PAPER MILL

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Received January 16, 1997

Mathematical simulation of atmospheric aerosol distribution is based on a stochastic approach to describing climatic characterization of the regions. This approach is based on multidimensional functions of the probability density of specific meteorological situations. The climatic parameters close the differential equation describing transfer and turbulent diffusion of a pollutant. As an example, the results of numerical experiments estimating the contribution from each industrial source to air pollution in the region of Lake Baykal are given.

Lake Baykal is a unique self-organizing ecological system which does not require interference of external factors. Any ill-considered gross man action could cause gradual violation of the stable operation of that ecological system. If the anthropogenic activity reaches its critical limit, bifurcation period providing the whole continuum of new stable equilibrium states will occur. Therewith, nobody can predict the state which the system will take (see Ref. 1).

That is why, it is very important to analyze carefully the necessity of industrial mills to be in the close vicinity to Lake Baykal, the possibility to reconstruct some operating mills and in some cases to close them. It is quite clear that, for such serious decisions it is necessary to have well established understanding industrial pollution of the atmosphere, rivers, soil and conditions for their dispersal.

In this paper, we make an attempt to simulate distribution of pollutants emitted into the atmosphere from Selenga pulp-and-paper mill (SPPM) which is at 50 km from Lake Baykal. In contrast to common approach to the dispersal of pollutants which allows one to define absolute concentrations of the contaminating species in a certain meteorological situation or under some average meteorological conditions. In this paper we are estimating the areas where the established criteria of maximum permissible concentration are exceeded using random field of velocities (see Refs. 2, 3). In so doing for each point of space involved in calculations the climatic probability density function of meteorological parameters whose integral function is estimated with the account for the wind velocity vector rotation in all directions and possible modules of the vector is constructed in polar system of coordinates. This approach allows a more detailed account for climatic peculiarities of the area under study and estimating dangerous atmospheric pollution.

According to the results presented in Ref. 4, Selenginsk is located in the area with a very high potential atmospheric contamination. Weak wind in combination thermal inversions of a complex structure (near surface inversion with several layers of elevated inversion) providing high level of air contamination at relatively low pollution are observed in that area during more than half a year.

The climate of the area under consideration is continental but the Lake Baykal makes it a little bit more mild. Annual average air temperature is as high as –0.3°C (see Ref. 5). The coldest month is January (monthly mean temperature is –18.5°C), the warmest one is July (+17.2°C). Monthly mean temperature retains positive over period from April to October inclusive.

Annual mean precipitation amount is 441 mm. Its main portion is received during warm time of a year peaking in July and August. Only 18% of the annual portion is received in winter with the minimum in February.

Statistical parameters of the wind field obtained from processing of eight-period long-term observations (1985–1994) of the wind velocity vector from a stationary points of the meteorological observation system are listed in Table I (see Ref. 6).

Here u and v are zonal and meridional components of the wind velocity vector, respectively, σ_u and σ_v are root-mean square deviations of the components from their mean values, r_{uv} is the correlation coefficient of components u and v.

The results obtained show that in summer zonal component caused by the transfer in the west direction, local action of Lake Baykal on land (breeze circulation) and also by west-east direction of Selenga River valley (mountain-valley circulation) has primary control over wind regime in the ground atmospheric layer.

In this connection, east and south-east winds dominate here in winter (December, January). Zonal component of the vector contributes here more significantly to the pollutant transfer toward Lake Baykal in December than in January since thermobaric gradient between the water surface and the land is

0235-6880/97/06 374-04 $02.00

TABLE I. Average statistical parameters of the wind velocity vector.

Month	u, m/s	v, m/s	σ_u, m/s	σ_v, m/s	r_{uv}
January	–0.9	0.36	3.21	1.38	–0.50
February	0.67	0.15	3.18	1.35	–0.30
March	1.93	–0.16	3.09	1.50	–0.14
April	2.81	–0.40	3.16	2.04	0.02
May	2.41	–0.38	3.29	1.92	0.06
June	2.87	–0.06	2.99	1.81	0.18
July	1.99	0.12	3.51	1.75	0.36
August	1.62	0.18	2.94	1.49	0.12
September	1.48	–0.10	3.18	1.72	–0.10
October	1.71	0.04	3.05	1.75	0.30
November	0.38	0.14	3.96	1.98	–0.46
December	–1.36	0.25	3.57	1.91	–0.54

higher in December than in January when the lake is covered with ice. For other months average direction of the vector is reverse (from Lake Baykal). North-west transfer of air masses in combination with an enhanced thermal gradient between the lake still covered with ice and already warming land sharply rise in the period from March to June. This provides favorable conditions for dispersal of the atmospheric pollutants over industrial zone and their emission along the south-east direction.

Analysis of the results of statistical processing of the climatic wind parameters has shown that the most dangerous contaminated zone can form during the month unfavorable for pollutant scattering in the atmosphere (during January and December the pollutants are mainly transported toward the lake, whereas during November maximum contamination is observed in the city itself).

According to the data obtained in 1987, the main contributor to the air pollution in Selenginsk is SPPM which produces 96% of 33000 tons harmful emission (see Ref. 4).

Composition of pollution from SPPM is determined by the sulfate method employed of cellulose production with the use of sodium sulfide resulting in formation of sulfur-containing compounds (see Ref. 7). Products of fuel combustion along with the dust from repair shops and coal store yards are additional sources of pollution.

Sixteen pollutants (see Table II) with known daily mean maximum permissible concentrations (MPC) (see Refs. 7–10) are considered in our simulation. All calculations are oriented to comparison with the daily mean MPC since these MPC have been determined for residential areas which are settled by permanent population of industrial regions.

TABLE II. Average intensity of the pollutants emission and corresponding rates of diurnal mean maximum permissible concentrations.

Component	Quantity, mg/s, winter/summer	MPC, mg/m^3
Alkali aerosol	48	0.01
Benzapiren	0.0035	10^{-6}
Nitrogen dioxide	19267.6/17657.6	0.04
Sulfur dioxide	40361/36801	0.05
Dimethyldisulfide	287	0.08
Dimethylsulfide	337	0.08
Xylene	308	0.2
Methanol	112	0.5
Methylmercaptane	558	$9\cdot10^{-6}$
Nitrogen oxide	3365/2135	0.06
Carbon monoxide	92053	3.0
Sulfuric acid vapor	1.6	0.1
Dust	46934/38485	0.15
Hydrogen sulfide	1184	0.0008
Turpentine	114	0.05
Carbolic acid	32	0.003

As our calculations show, for such pollutants as xylene, methanol, carbolic acid, turpentine the MPC are not exceeded throughout the year. Insufficient exceed of the MPC ranging from 6 to 25 hours per month even under most unfavorable for the admixture dispersal meteorological conditions is observed for benzapiren, nitrogen oxide and sulfur dioxide. Dangerous pollution in terms of carbon monoxide MPC exceeding ranges to about 110 hours (in January and November) over the area of no more than 0.135 km^2.

Since the coal store piles are placed in the area of the mill the dust amount within working zone is relatively high and in the immediate vicinity of the dust sources exceeds the MPC every day during the months under consideration. However, due to a relatively large size of the dust fraction fast sedimentation of the dust particles is evident and the probability of dangerous contamination decreases rapidly with the distance from the sources. Thus, in the vicinity of 6 – 7 km^2 the MPC is exceeded during no longer than 440 hours per month (in January) and only small particles at concentration below the MPC reach the lake. However it should be kept in mind that the particles sedimentation both to the land surface and the lake gradually accumulating in the water and providing conditions for secondary atmospheric contamination.

The largest area where hydrogen sulfide concentration exceeds the MPC with a maximum up to 380 hours over the mill territory (in November) is 25 km^2. In January and December the area of the spot with dangerous contamination reduces to 10 km^2, but its duration increases up to 600 hours per month.

The highest pollution level is caused by methylmercaptane (MM). A 50 – 100-fold MPC may be observed over the mill territory. The 15-fold MPC is possible during 500 hours per month over an area of 300 km^2. No less than 5-fold MPC reaches the Lake Baykal. Calculation of the frequency of MM concentration exceeding MPC in December is presented in Fig. 1. The calculations were made with intervals of 5 km. Isoline *1* outlines the area where the probability of exceeding MPC is no less than 0.1 (3 days per month), isoline *2* outlines the area where the probability is no less than 0.2 (6 days per month) and so on. As indicated in the picture, the zone with increased concentration of MM can approach opposite shore of the Lake Baykal.

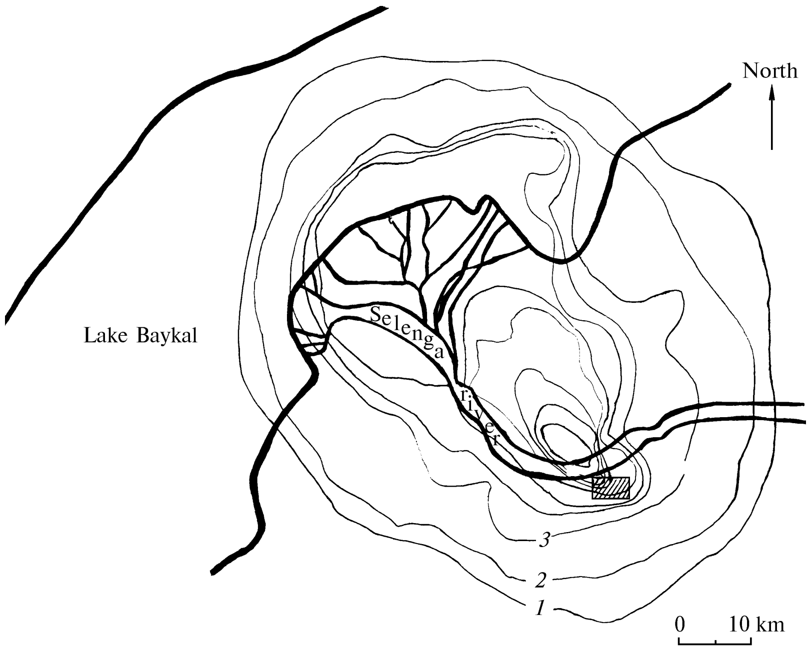

FIG. 1. Climatic distribution of the pollutants from Selenginsk pulp-and-paper mill (SPPM). The frequency of occurrence of the MM concentration exceeding MPC in December, shadowed rectangle designates Selenginsk City.

Calculated values of the probabilities were compared with the data of long-term observations for conditions of atmospheric contamination by various pollutants. Good agreement especially in the case of maximum probabilities was obtained. Maximum deviation of the calculations from experimental data was found for hydrogen sulfide in August. This is derived, probably, from the fact that frequent long fogs are characteristic of this month which are favorable for the admixture to actively react.

The information on zones with dangerous contamination by various pollutants both in the city and outside it can be used in operative practice of experts in different areas of knowledge. For instance, physicians can determine the reasons for specific diseases of the population, dendrologists can find the vegetation oppression conditions.

The models allow us to predict dangerous contamination which may be caused by changing the production of mills, their reconstruction, putting into operation of new capacities and refining installations. The calculational results based on the climatic data have stable behavior.

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