POLLUTION OF THE ATMOSPHERE OF NIZHNEVARTOVSK PART III. RELATIVE CONTRIBUTION OF ENVIRONMENTAL FACTORS

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Received February 5, 1993

Main sources of impurity emissions have been identified on the basis of experimental investigations of air composition in the warm and cold seasons. A pattern of formation of a pollution field in Nizhnevartovsk has been outlined and confirmed by appropriate estimates by the budget method.

In our previous papers[1,2] we reported the results of investigation of aerosol and gaseous air composition as well as its vertical profile and temporal dynamics in the atmosphere of Nizhnevartovsk. An analysis of these data allowed us to identify the main sources of air pollution of this town. Among these are motor transport, products of combustion of accompanying gases in plumes of oilfields, evaporation of petroleum products spilled on the ground, and emissions from technological and public boiler houses. However, we failed to identify the contribution of individual sources in such an unclosed system as the atmosphere. This makes the design and performance of corresponding measures for salvaging our environment difficult. Therefore, the object of this paper is the estimate of relative contribution of each of the above–enumerated factors, because they have approximately the same composition of emissions.

AN AMOUNT OF MOTOR–TRANSPORT EXHAUST

At present the motor–transport exhaust is the main source of pollution in many large cities of the world. Nizhnevartovsk is not large. Nevertheless, it is strongly acted upon by this source. There are 22,000 personal and 26,000 public automobiles in the comparatively small territory of the town. The total effect of motor transport can be assessed with the use of general diagram shown in Fig. 1. It displays the zones of maximum concentration of each of the surface air pollutants measured in the course of both experiments.

It can be seen from Fig. 1 that zones of maximum concentration of individual pollutants, as a rule, are superposed inside of the town. They seem to be attached to the main transport arterial roads of this town. At the same time zones displaced on the periphery of the town are indicative of the pollution influx from the outside. Because the information available from the literature[3,4] gave no idea of all the impurities of interest to us, we performed special experiment on determination of the amount and composition of exhaust of diesel and carburetor automobiles.[2] Our estimates are based on the results reported in Ref. 2. Let us rely on the information that in Nizhnevartovsk about 200,000 t of diesel fuel and 100,000 t of benzine is burnt by the motor transport a year.

The data on the amount of substances exhausted in air are presented in Table I for the above–indicated amount of fuel. It can be seen from Table I that the total amount of motor–transport exhaust is equal to 34920 t a year considering only the measurable pollutants for this consumption of fuel. According to Ref. 5, hydrocarbons measured in Ref. 2 make up 47% of total exhaust and inorganic gases – 29%. Consequently, the obtained amount of exhaust must be multiplied by a factor of 1.316.

TABLE I. The amount of motor transport exhaust in Nizhnevartovsk.

Component	Exhaust		Total
	Carburetor	Diesel	
Ammonia	2.3	–	2.3
Acetylene	1244.0	2710.0	3954.0
Acetone	54.0	268.6	322.6
Benzine	361.8	3621.4	3983.2
Benzene	113.3	1097.4	1210.7
Xylene	184.3	847.4	1031.6
Toluene	205.1	2563.4	2768.5
Nitrogen oxide	434.7	1705.4	2140.1
Nitrogen dioxide	28.5	516.0	544.5
Carbon oxide	1982.0	2964.0	4946.0
Sulphur dioxide	76.5	242.4	318.9
Hydrogen sulphide	4.2	<	4.2
Σ CH of petroleum	1575.7	8833.4	10409.1
Ethyl ether	333.5	273.2	606.7
Soot	80.8	2481.4	2562.2
Lead	41.0	1.2	42.2
Cl^- aerosol	15.5	57.6	73.1
Totals			34919.9

Under assumption that this amount of substance spreads only within the zone of Nizhnevartovsk whose area is 26×35 km^2 at altitudes up to 100 m [recall that another source is at an altitude of 200 m (see Ref. 2)], we obtain average–annual concentration of pollutants of 0.384 g/m^3 only due to motor transport. This value is somewhat hypothetical since repeated air exchange and its purification due to precipitation will take place in the town in the course of a year. The emissions of the other sources are subject to the same effect, and since the emissions of these sources have the approximate composition of motor–transport exhaust, this approach is assumed to be correct.

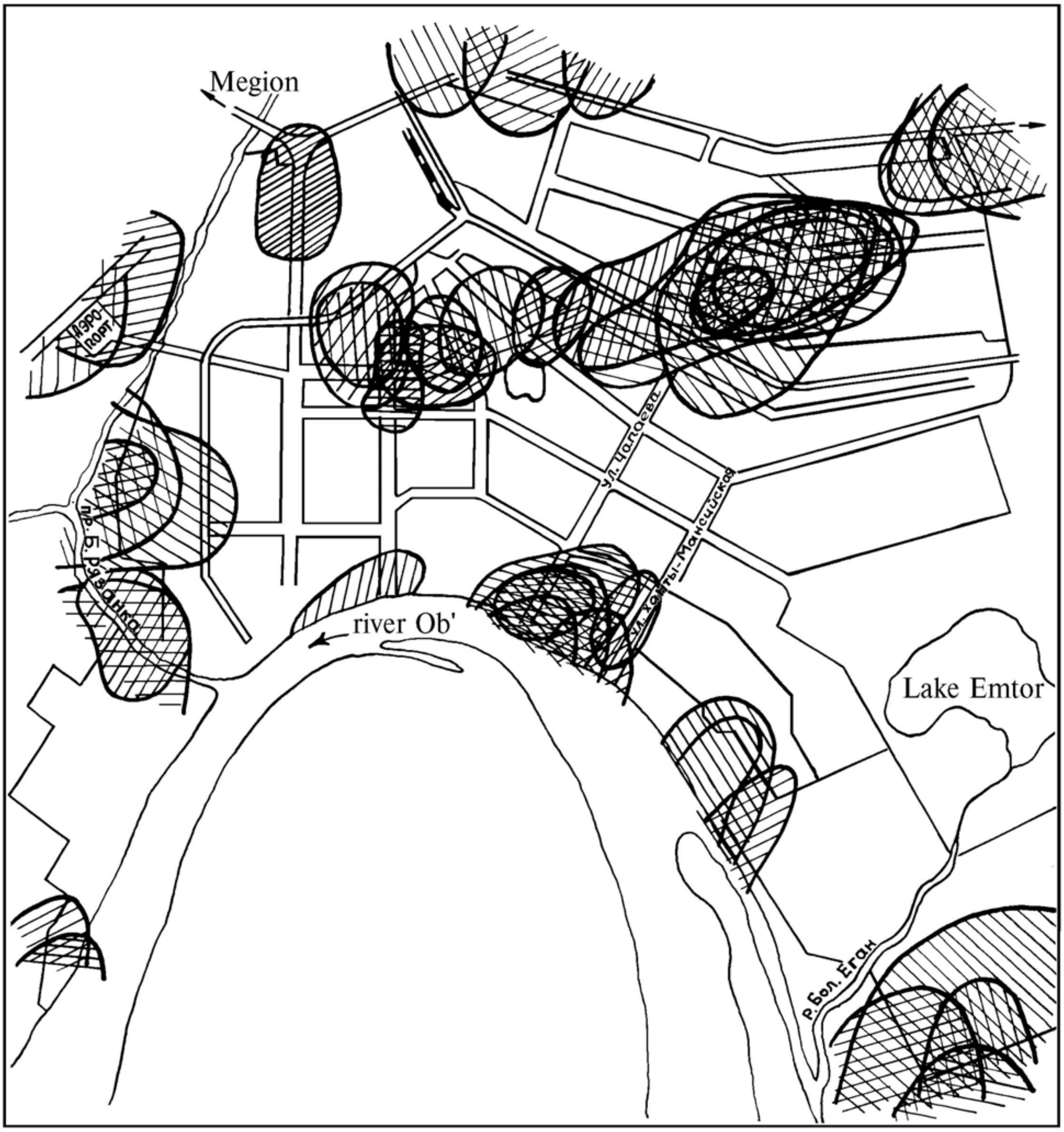

FIG. 1. General diagram displaying the zones of maximum concentration of different pollutants in the territory of Nizhnevartovsk.

BACKGROUND AIR POLLUTION DUE TO PLUMES OF OILFIELDS

Emissions from plumes of oilfields into the surface air layer take place outside the town. However, spreading of impurities of these plumes results in higher level of background air pollution in the region thereby having an indirect effect on the atmosphere of Nizhnevartovsk.

The composition of emissions from plumes of oilfields was reported in Ref. 2. It was found that emissions differ not only in composition but also in strength. Therefore, it is expedient to estimate both minimum and maximum amount of emitted substances. Conducting a flight around the town and oilfields by the square routes, we counted the number of burning plumes located inside the territory being monitored. Their total number was 47. Since it is very expensive to measure the emission from each plume, and the plumes differ in their strengths disregarding accidents or projected emissions, we assume that the strengths of the remainder of the sources are intermediate between minimum and maximum values given in Table II. The total volume of their spreading is $2.605\cdot10^{12}$ m^3 under the assumption that the impurities spread at altitudes up to 1,000 m in winter and 1,800 m in summer. The values of minimum and maximum concentration of pollutants in this volume then will be 0.396 and 1.203 g/m^3, respectively.

TABLE II. The amount of average–annual emissions from the plumes of oilfields (t/year).

Component	Emission from the first plume		Total emission	
	Min	Max	Min	Max
Ammonia	121	3249	5667	152703
Benzine	1334	33304	629698	1565288
Benzene	728	2166	34216	101802
Xylene	6551	–	307897	–
NO	801	542	37647	25474
NO_2	121	–	5687	–
CO	2365	8935	111155	419945
SO_2	970	1625	45590	76375
ΣCH of petroleum	8856	16246	416232	763562
Aerosol	55	596	2585	28012
Total	21902	66663	1029394	3133161

RELATIVE CONTRIBUTION OF EMISSIONS FROM BOILER HOUSES

This source of pollution contributes only in the cold season. The composition of emissions is analogous to that of the two above–considered sources. Direct measurement of the amount of substances emitted by all boiler houses is impossible. For this reason we employed the indirect technique.

According to the data of the Nizhnevartovsk Municipal Committee on Protection of the Environment, about 1,000,000 t of petroleum is burnt by public and technological boiler houses a year. The data reported in Ref. 6 indicate that the amount of pollutants emitted into the atmosphere in the process of exploitation of the boiler houses burning liquid fuel is approximately equal to the amount of pollutants exhausted by the motor transport. In this case we imply the amount of substances per unit mass of burnt fuel.

This amount of pollutants will be considered to spread within the zone of Nizhnevartovsk at altitudes up to 300 m [the lower maximum of concentration can be seen in the vertical profiles at the altitude $H = 200$ m (see Ref. 2)]. Under this assumption the average–annual concentration of pollutants will be 0.109 g/m^3. Taking into account the fact that this source contributes only half–year, the estimated concentration should be doubled. The resultant value will be 0.218 g/m^3.

EVAPORATION OF PETROLEUM PRODUCTS SPILLED ON THE GROUND

A comparison between the data obtained in the warm and cold seasons[2] showed that this source of pollutants contributes only in the warm season when the underlying surface is free of snow.

The procedure of direct calculation of the amount of evaporated petroleum products based on numerous field experiments was proposed in Ref. 7. However, it is applicable only under exactly controllable conditions which is impossible for the entire region. Therefore, we employed the budget estimate.

According to the data of the Municipal Committee on Protection of the Environment, from 200,000 to 400,000 t of petroleum products a year are spilled in the region of Nizhnevartovsk and adjacent oilfields as a result of technological accidents. A portion of these products enters the soil, a portion is washed out in water basins, and a portion of them evaporates.

To estimate the amount of evaporating petroleum products, we make use of the information about the composition of petroleum of the Megion and Samotlor oilfields. The information was borrowed from the Databank of the Institute of Petroleum Chemistry of the Siberian Branch of the Russian Academy of Sciences kindly put at our disposal by Yu.P. Turov. It is summarized in Table III.

Based on the data given in Table III we obtain a total index of evaporability of 0.371 for Samotlor oilfield and of 0.354 – for Megion oilfield. Since we know only the total amount of emission, we will use the average evaporability which is equal to 0.3625. Then from 72,500 to 145,000 t of total amount of spilled petroleum can be evaporated in air.

TABLE III. The composition of petroleum of Megion and Samotlor oilfields.

Fraction	Composition, %		Evaporability
	Samotlor	Megion	
Benzine	25.4	22.5	< 99
Kerosene	10.9	11.4	˜ 50
Kerosene–gasoline	31.3	35.9	≤ 20
The rest	32.4	30.2	–

Let us assume that evaporated petroleum spreads uniformly within the zones of Samotlor and Megion at altitudes up to 100 m. Then the average vapor concentration of petroleum in air may vary from 0.227 to 0.445 g/m^3. In this case we will take the maximum value since we ignore evaporation from petroleum storage tanks making additional contribution to the concentration of vapor of petroleum products.

NET BUDGET OF EMISSIONS FROM DIFFERENT SOURCES

For comparison of the strengths of pollution sources in the region of Nizhnevartovsk, all the above–given estimates are summarized in Table IV.

It follows from Table IV that the largest contribution to the total air pollution in Nizhnevartovsk both in the cold and warm seasons comes from motor transport which makes up from 37.5 to 45.1% of total amount of emissions.

Taking into account all the factors, the average–annual contribution of motor transport makes up 32.3%. However, as can be seen from Table IV, the contribution of motor transport is not predominant (as it was previously assumed by the local authorities) and its effect is comparable with the effect of the other sources.

TABLE IV. The average–annual concentration of pollutants from different sources in Nizhnevartovsk.

Source	Warm season		Cold season		Annual	
	g/m^3	%	g/m^3	%	g/m^3	%
Motor transport	0.505	37.5	0.505	45.1	0.505	25.3
Plumes	0.396	29.4	0.396	35.4	0.396	25.3
Boiler houses	–	–	0.218	19.5	0.218	13.9
Evaporation	0.445	33.1	–	–	0.445	28.5
Total	1.346	100	1.119	100	1.564	100

The average–annual contribution of spilled petroleum products is on the second place and makes up 28.5% of the total concentration while in the warm season 33.1%.

The average–annual background air pollution due to plumes makes up 25.3%. In the warm season it is equal to 29.4% while in the cold season up to 35.4%.

The last place is occupied by the emissions from the boiler houses: they contribute 19.5% in fall–winter season and their average–annual contribution is 13.9%.

The total concentration of air pollution decreases from 1.346 to 1.119 g/m^3 in going from warm to cold season. This is due to ceasing of evaporation of spilled petroleum products as a factor contributing to air pollution in the cold season which is not compensated by the emissions from the boiler houses. This conclusion is supported by the data of direct measurements reported in Refs. 1 and 2.

CONCLUSION

Experimental investigation of air pollution over Nizhnevartovsk and analysis of its sources allow us to outline the following pattern of formation of the impurity field.

In the warm season three sources contribute to the total air pollution. They are spreading of the plumes of oilfields, evaporation of petroleum products, and motor transport exhaust. The first two sources contribute to the background air pollution while motor transport exhaust is sharply pronounced against this background air pollution.

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