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Air pollution in Moscow

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Abstract

Fuel use, pollutant emissions and air quality in Moscow are examined. The concentration of NO_2 is the major aspect of air pollution where problems are encountered in compliance with air quality standards. During recent years a considerable reduction of TSP and SO_2 levels has been achieved through the increased use of natural gas. Introduction of more stringent emission controls on vehicles is required in order to prevent a rise in CO pollution.

1. Introduction

Many major cities experience poor air quality. Since the problem was recognised in the 1950s, good progress has been made in controlling air pollution in the industrialised countries of Western Europe, North America and in Japan. Air pollution and its control has received considerably less attention in Eastern Europe and in the former USSR (Shahgedanova & Burt[1]) even though cities in those regions are at present especially prone to deterioration of air quality (Shahgedanova & Burt [2]). This paper attempts to analyse air pollution problems and measures for its control in Moscow, the capital of the Russian Federation. Although the largest city in Eastern Europe, Moscow does not have the worst pollution (Shahgedanova & Burt[2]); however, it provides an example which combines all aspects of air quality deterioration typical of an East European city.

2. General Information and Climate

Moscow is located in the central part of the East European plain (latitude 55°45'N, longitude 37°34'E), in the broad valley of the Moskva River. Moscow had a population of 9.39 million in 1990 with a population density of 10.000 people km^2. The entire city covers a territory of 994 km^2; most of the area, about 780 km^2, is built up; about 180 km^2 are occupied by parks and woods. Power generation and space heating are centralised. Moscow has a developed system of motorways and roads which follow an "orbital-radial" pattern.

Throughout the year Moscow is dominated by the south-westerly and westerly winds; north-easterlies are most infrequent. Daily mean temperatures are below freezing from the beginning of October to the beginning of April, this determines the high demand for heating and thus the increase of atmospheric emissions during this time. On average, 8 -10 days in each winter month have a mean daily temperature below -15°C. Though such cold spells do not persist for a long time, they have particularly negative effect on air quality: low temperatures and calms promote development of ground based inversions despite the heat island effect; this results in accumulation of pollutants near the surface. Subsequent destruction of the cold anticyclone due to the advection of warmer air is often accompanied by the formation of a lifted inversion which reduces the capacity of the atmosphere to disperse pollution from elevated stacks.

Wind speeds are considerably reduced in the city centre; calms are observed on 44% of all days. Calms are most common in summer, especially in the early morning; the chance of dangerous combination of calm and inversion reaches 20% in August. Moscow has a pronounced urban heat island effect: air temperature in the city centre is 1-3°C higher than in the suburbs; in summer, in the absence of a strong zonal flow its intensity reaches 7-10°C inducing a closed heat-island circulation within which pollution levels build up steadily.

3. Air Pollution Control and Air Quality Monitoring

Air pollution control is the responsibility of the Moscow division of the State Committee for the Environment and of the Moscow City Council. The legal basis for control of emissions is the Law on Air Quality of 1980 (Shahgedanova & Burt[1]) which established "maximum permissible emission levels". These are determined by calculating the total contribution of pollution sources to a regional concentration standard, and then defining a norm for the individual source in such a way that the sum of total emissions will not exceed the mandated concentration standard. The Law obliges all enterprises officially identified as sources of pollution to supply data on emissions, fuel statistics, technological processes and pollution control equipment. Local authorities supply data on transport from which vehicle emissions are estimated on the basis of car fleet composition and types and volumes of fuel consumed. Enforcement of this Law has always been difficult and on many occasions compliance with the emission and air quality standards has never been achieved (Shahgedanova & Burt[1]).

Continuos monitoring of air quality in Moscow was started in 1975, approximately two decades later than in Western Europe and North America. At present, the monitoring network consists of 19 sites (fig. 1). Air is sampled on filters or sorbents with subsequent analysis for four major pollutants: CO, NO_2, TSP and SO_2. Measurements of TSP and SO_2 have received much criticism (Rovinsky[3]) : TSP is measured gravimetrically, sensitivity of the method being extremely low - 100 μgm^{-3}; the method of SO_2 analysis introduced in 1986 is applicable only to the concentrations exceeding 50 μgm^{-3}. Observations are normally carried out between two and four times a day. No comparisons have been made between these methods and more conventional 24-hour or continuos monitoring methods employed by the Global Environmental Monitoring System.

4. Fuel Use and Trends in Emissions and Ambient Concentrations

The first emissions inventory was compiled in 1975, the results being annually updated since. At present, there are some 1600 stastionary sources of pollution in Moscow (Rovinsky[3]). Two major sources are power plants and industry; commercial, administrative and domestic premises are not sources of pollution themselves as centralised heating plants are used throughout the city. Emissions from power plants and district heating plants are estimated by applying emission factors to figures for fuel consumption. Emissions from industrial sources are evaluated through direct measurement of emissions conducted by the enterprises themselves and reported to the Committee for the Environment, and through estimations performed by inspectors on the basis of fuel statistics, information on technological processes and pollution control equipment. The results obtained by these two methods are compared, and the larger figure is taken. Emissions of fugitive dust and suspended matter from diesel vehicles are not included into the survey which may result in underestimation of TSP emissions. The poor condition of vehicles and modifications to private vehicles by owners in order to reduce fuel costs reduces the reliability of emission calculations based on fuel consumption. Emissions for mobile sources other than cars are not known; only nitrogen oxides and CO are assessed.

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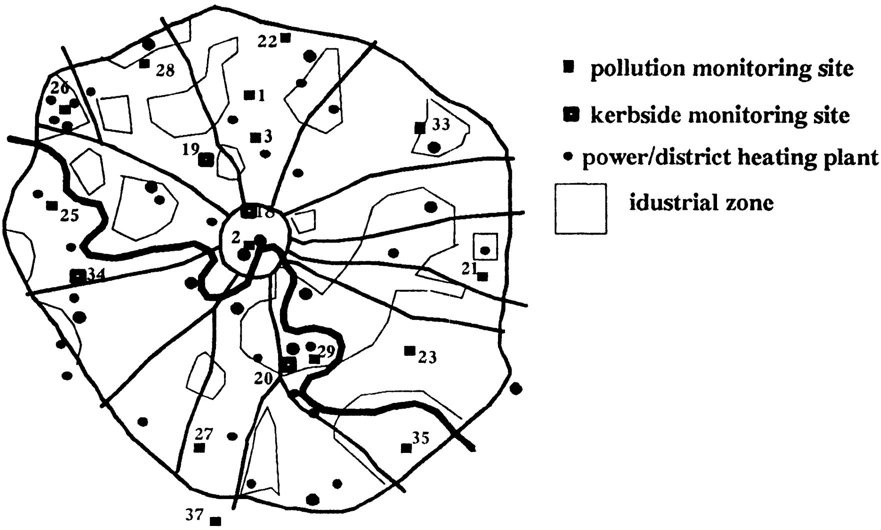

Figure 1: Sketch map of Moscow.

Table 1. Ambient Concentrations of NO_2 and CO in 1990-1991 as measured at 1.00 p.m.

Site	NO_2, 1990			NO_2, 1991			CO, 1990			CO, 1991		
	mean	σ	98%	mean	σ	98%	mean	σ	98%	mean	σ	98%
1	49	41	140	64	39	150	1830	940	5000	2320	1480	6000
2	105	57	260	100	71	280	2690	1210	6000	2920	1350	7000
3	73	43	180	63	36	160	1880	1060	5000	2270	990	5000
18	48	28	130	104	110	460	2760	1790	7000	3090	1600	8000
19	88	54	220	87	61	240	2420	1453	7000	2770	1420	7000
20	77	74	230	82	51	200	3000	2050	9000	3040	1720	8000
21	96	38	180	101	52	230	2090	1050	5000	2230	1050	5000
22	100	58	250	91	52	250	2170	1050	5000	2530	1070	6000
23	53	35	120	67	66	290	2090	1018	5000	2330	1160	6000
25	114	63	270	108	61	270	2190	1260	6000	2660	1250	6000
26	78	52	200	67	45	190	1900	1000	5000	2210	1080	6000
27	51	41	160	73	62	240	2220	1160	6000	2560	1150	6000
28	83	46	200	82	51	240	2090	1090	6000	2290	1250	6000
29	146	78	390	64	46	210	2420	1210	6000	2880	2430	1400
33	110	60	280	107	53	240	2080	990	5000	2440	1170	6000
34	64	33	140	76	45	210	2290	1180	7000	2480	1240	5000
35	70	52	200	108	103	330	1970	1370	6000	2180	1160	5000
37	68	49	200	66	42	190	1870	1013	5000	2110	1260	5000

Total emissions of the four major pollutants and the emissions by source category (power generation, industry and transport) are presented in fig. 2. Considering TSP and SO_2 first, power generation and space heating are the major contributors. A marked decrease of TSP and SO_2 emissions and ambient concentrations has been observed since 1980. This can be attributed to the considerable decline in coal and oil use for power generation. Thus, between 1987 and 1990 the combustion of coal by the power plants was reduced by 70%, and of oil by 30% (Rovinsky[3]). In 1990, natural gas was the only type of fuel consumed by the district heating plants; it also comprised 76% of fuel burned by the thermal power plants. Oil was the main type of fuel for just two of twelve power plants; due to the high sulphur content of the oil (2.5-3%), these were the major sources of sulphur dioxide pollution in the city (45% of the 1990 total). Coal (sulphur content 2%) accounted for 29% of the fuel balance of just one power station (though the largest one), which made it the major source of suspended particulates (7% of the city total). Neither Russian environmental legislation, nor the Moscow City Council places a limit on the sulphur content of fuel. Another reason for reduction of ambient TSP and SO_2 levels may be a considerable decrease in a number of small heating boilers located mainly in the city centre. These burn coal and gas and have the low stacks of just 10-15 m height. Low chimney stacks make these sources considerable contributors to the pollution build up though their emissions are significantly less than those from district heating plants and power plants. No acceptable minimum chimney height is specified in Moscow in contrast to London (Ball & Armorgie[4]); however, the policy is to construct higher stacks. Thus chimney stacks of district heating plants of modern design are 60-100 m high (the older ones are of 25-45 m); those of the power plants are of 180-250 m (the older ones are 60-120 m high). Changes in fuel use have not affected NO_x emissions which have been growing since 1985; an increase of ambient NO_2 concentrations was registered in all sectors of the city too (fig. 3). Unlike many western cities, where NO_x is contributed largely by vehicles, energy generation was the major source of nitrogen oxides in Moscow accounting for 70% of the total in 1990.

In contrast to the large administrative centres of the West, Moscow still accommodates a considerable number of the heavy industrial enterprises, though a large number was removed from the city in the 1960s. Industry accounted for 46% of TSP emissions in 1990; high emissions of NO_x and CO came from the steel works and machinery manufacturing plants. Relocation of industry has been

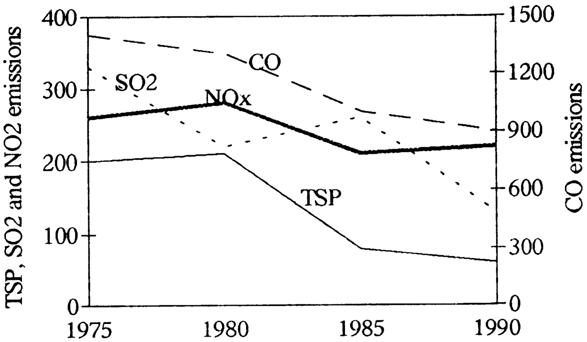

Figure 2: Total emissions between 1975 and 1990 (thousand tonnes a^{-1}).

slow, though a planned decrease in production has been achieved in the last ten years. The contribution of transport to NO_x emissions is not particularly high (17%); in contrast 80% of CO is contributed by motor vehicles. A steady reduction in CO emissions has been observed since 1975 (fig. 2), despite an increase in car numbers (435.000 in 1985 - 665.000 in 1989; Finansy i Statistica[5]). This can be attributed to the introduction of newer engine designs, growth of diesel fuel consumption and changes in driving patterns (in 1985, the City Council banned lorry traffic from the city centre except for deliveries). Until 1990, CO concentrations were declining (fig. 3) and in 1990-1991 they were 2-3 times lower in Moscow than in London, which is comparable in size and population (GEMS[6]). However, the booming growth of car ownership after 1990 led to an increase in concentrations in 1991 (fig. 2, table 1). As the Law on Air Quality is mainly aimed at power generating and industrial sources, and the City Council has failed to provide adequate measures for the control of transport emissions, Moscow may soon face a serious problem in regard to the CO pollution.

5. Spatial and Seasonal Variations of Emissions and Ambient Concentrations

The highest emission densities coincide with the location of power plants and with the three industrial zones: north-western (includes aircraft engine manufacturing, cast-iron works and a cluster of heating plants), south-eastern (includes a number of power plants, two motor vehicle manufacturing plants, an oil refinery), and eastern (includes a steel works). The highest emission densities (fig. 4) are associated with the south-eastern zone. The north-western has a particularly strong effect on air quality in the entire city due to the prevailing winds. With the expansion of the urban area, industrial locations on the outskirts of the city have become densely populated residential areas. It is now common to find households in the close proximity to industrial sources even though legislation requires that a cordon sanitaire should be designated for each source of pollution.

High NO_2 concentrations appear to be the major air quality problem in Moscow: in 1990, all 19 sites failed to comply with the Russian standards (40 μgm^{-3} for a daily mean, 150 μgm^{-3} for a maximum concentration), even those

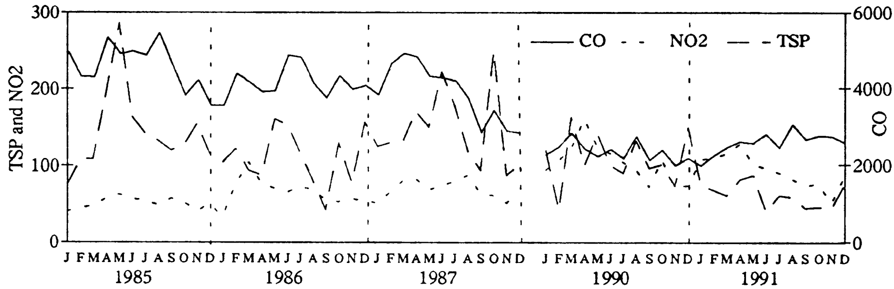

Figure 3: Monthly mean concentraticns of CO, TSP and NO2 (μgm^{-3}) at site 02.

located well away from sources (sites 1 and 37); many failed to comply with EC standards for the extreme concentrations (a 98 percentile of 200 μgm^{-3}). Maximum levels of NO_2 were registered in the central, north-western and eastern sectors of the city this being consistent with the emission densities and the prevailing winds. In contrast to the majority of observations elsewhere, concentrations measured at kerbside sites were not the highest in Moscow. Considering seasonal variations of NO_2, the largest monthly means are seen in spring (fig. 3) when emissions from space heating sources are still high; at the same time, the mixing depth increases, promoting more pronounced fumigation; and with increasing insolation, photochemical oxidation becomes more intense enhancing formation of NO_2. The worst pollution events are more typical of

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winter; they are mainly caused by warm advection near the surface which intensifies NO oxidation and destroys the stable layer which had been preventing fumigation of elevated down to the ground. CO concentrations are distributed rather uniformly with the maxima at roadside sites, in the city centre and in industrial locations. Pollution episodes are most frequent in winter, when inversions develop near the ground under conditions of high pressure and flux divergence which reduce the dispersion capacity of the atmosphere. Mean concentrations are highest in spring and summer (fig. 3): traffic volume in winter is about 30% lower than in summer. TSP concentrations are highest in industrial locations and on the lee side of the city; the highest levels occur in April following an increase of the fugitive dust emissions after snow melts; in 1990, April monthly means were as high as 250 μgm^{-3} (Russian daily mean limit is 150 μgm^{-3}; the EEC -130 μgm^{-3}) Conditions governing the extreme TSP pollution events are similar to those for CO.

Conclusions

In the past 20 years Moscow has benefitted from changes in fuel use patterns which have resulted in an overall diminution in SO_2 and TSP concentrations. These trends are likely to continue as natural gas is the cheapest and most widely available fuel (Shahgedanova & Burt [2]). Reduction of NO_2 pollution, which is not is affected by the choice of fuel, presents a more complicated task. The main threat would appear to lie in the possible future growth of CO emissions.

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