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The Air

You are lucky, a breeze is blowing today. It is still possible to breathe.
Chemical industry worker interviewed by a *Pravda*
journalist visiting the Bashkir city of Sterlitamak

On July 21, 1989, severe smog in Siberia's third largest city of Omsk forced the local government to declare a state of emergency. A heat wave had exacerbated air pollution problems created by oil refineries, tire factories, chemical plants, and other industrial enterprises crammed into the city of 1.1 million residents. To combat the smog, the city government ordered factories to reduce output and limited the use of private automobiles to daytime hours.¹ In August 1989, "Vremya," the evening news television program, carried the following report from the city of Sterlitamak in the Bashkir republic of Russia:

Immense chimneys belching out clouds of smoke into the sky and a blue-grey pall of poisonous smog creeping over the horizon—thus the second [largest] city of Bashkiriya . . . where 270,000 people live, awakens. The Ministry of the Chemical Industry and the Ministry of the Petrochemical Industry have so crammed Sterlitamak with enterprises that they annually discharge 200,000 tons of harmful waste. The citizens have to pay the highest price possible for this large-scale chemical industry: their health. . . . Discharge of the most harmful wastes occurs, as a rule, at night. Drivers of trolley buses who work early in the morning are the first to breathe the fumes. It is they who issued an ultimatum to the executive committee of the city soviet: If the ecological situation in the city did not improve by the beginning of August, then trolley bus traffic would be stopped. This is the main form of public transport in Sterlitamak.²

One year later, Boris Yeltsin visited the city as part of a major tour of Siberia; he met a populace angry over a recent accident at the Kaustik

chemical plant that resulted in the release of poisonous gases. Summing up his travels, Yeltsin concluded: "I have been travelling through Tatarsiya and Bashkiriya for a week now, but until [here], I had not received such a grim impression, especially after visiting Kaustik. My impression was depressing, simply sickening."³

According to the Soviet environmental protection agency, air pollution ranked highest on the list of environmental problems that faced the Soviet Union. On the eve of the collapse of the USSR, the country produced roughly the same volume of air pollution as the United States, despite its lower economic output. Meanwhile, the high concentration of industry focused the environmental and public health impact of air pollution in urban regions, resulting in citizens living in many industrial areas suffering some of the worst air pollution in the world. Minimal pollution controls on industry and automobiles have prevented citizens of the former Soviet Union from enjoying the improvement in air quality that U.S. residents have enjoyed with the imposition of tighter emission controls since the 1960s. On a visit to California, one Kazakh environmentalist summed up the situation in her hometown: "Los Angeles's pollution is *nothing* in comparison to Alma-Ata's."⁴

THE VOLUME OF ATMOSPHERIC EMISSIONS

In 1980, the Soviet meteorological service, Goskomgidromet, began collecting data on the output of atmospheric emissions classified into two broad categories: stationary sources (i.e., industrial enterprises, power plants, and heating plants) and transport. Determination of the former was made possible by a nationwide inventory of air pollution sources in urban and industrial regions conducted that year. The figures for exhaust fumes from vehicles were estimated using data on the consumption of motor fuel and on traffic loads in urban regions.⁵

According to this methodology, 58.5 million tons of toxic substances were discharged into the atmosphere from over 3,000 sources in 1989.⁶ The single greatest polluters that year were the USSR Ministry of Ferrous and Nonferrous Metallurgy⁷ and the USSR Ministry of Power Engineering and Electrification; their plants produced one-half of all air pollution from stationary sources. Other major polluters at the all-Union (Soviet-wide) level were the oil and chemical industries, accounting for 9 and 7 percent of emissions, respectively (see Table 2.1). By republic, Russia accounted for more than 60 percent of emissions from stationary sources (see Figure 2.1).

Automobiles contributed another 35.5 million tons of air pollution, bringing the total for 1989 to 94 million tons. However, this figure should

TABLE 2.1 Crude weights of atmospheric emissions by selected all-Union industries, 1989

	<i>Metric Tons (in thousands)</i>	<i>Percent of Total</i>	<i>Percent Change from 1986</i>
Total stationary sources	58,508	100	- 12.0
Power engineering and electrification	14,517	24.8	- 16.5
Ferrous and nonferrous metallurgy	15,348	26.2	- 12.9
Oil industry	5,209	8.9	+9.0
Chemical and petrochemical industry	4,183	7.1	- 19.2
Gas industry	2,628	4.5	+12.4
Construction materials industry	2,091	3.6	- 48.7
Forestry industry	1,286	2.2	- 15.5
Fertilizer industry	556	1.0	- 26.1
Other sectors	12,690	21.7	- 1.2

Source: USSR Goskompriroda, *Sostoyanie prirodnoi sredy i prirodookhrannaya deyatel'nost' v SSSR v 1989 godu* (Moscow: Institut Molodezhi, 1990), p. 13.

not be considered the sum of pollution for several reasons. First, as mentioned before, the data for transportation are for urban areas only. Second, this figure excludes other sources of pollution such as diesel locomotives, boats, and airplanes. Third, the counting of stationary sources does not include other sources, such as waste landfills and evaporation ponds. Finally, the data do not account for malfunctioning or leaking equipment, accidents, and unregistered pollution sources; these are crucial factors, given the fact that enterprises traditionally have reported their emissions to the government but because officials lacked the resources to audit the data, underreporting was probable.

A breakdown of atmospheric emissions from transport and stationary sources for major cities (including the capitals of the fifteen former Union republics) in 1987 is presented in Table 2.2. The table should not, however, be interpreted as a complete list of the cities with the greatest emissions; it also indicates the relatively small share of transport-based pollution in the Soviet Union compared with other cities around the world.

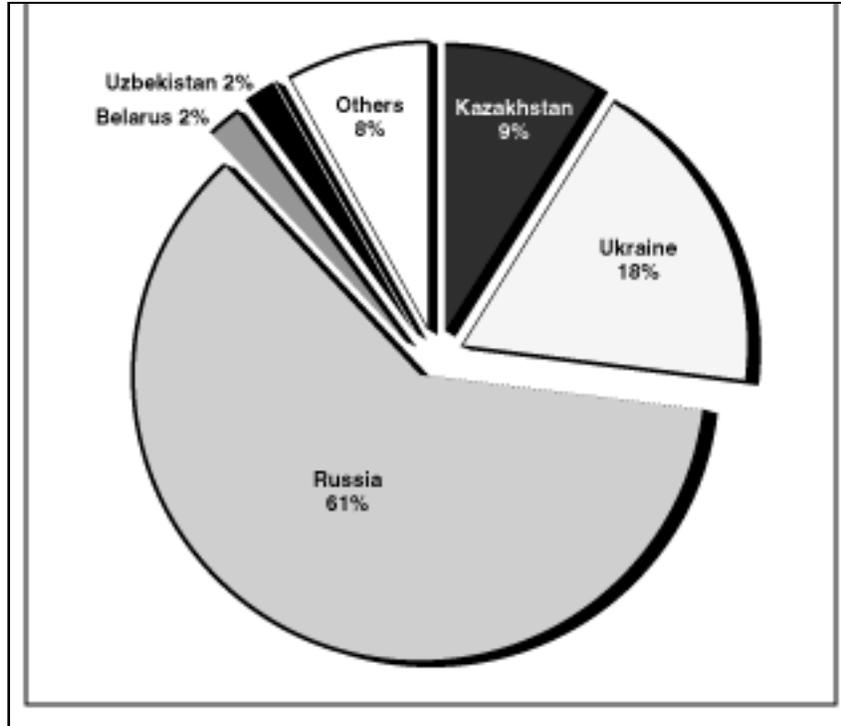


FIGURE 2.1 Atmospheric emissions from stationary sources by republic, 1989.

One characteristic of many former Soviet cities is the high concentration of pollution from industrial sources. The city with the record emissions was Norilsk, a Stalin-era industrial boomtown located 200 miles above the Arctic Circle in central Siberia. In 1991, the volume of pollutants pumped by local metal smelters into the air over the city amounted to 2.5 million tons—roughly half the volume of air pollution of Mexico City although Norilsk has only 1 percent the number of inhabitants and a similar fraction of automobiles.⁸ Industries based on the mining of oil shale and phosphorites clustered in the Narva region of northeast Estonia accounted for over one-half of stationary source emissions in the republic and produced more sulfur dioxide than all of Sweden in the late 1980s.⁹ According to the Soviet statistical agency, the area around the southern Ural Mountains, which includes cities such as Yekaterinburg, Ufa, Chelyabinsk, Sterlitamak, and Magnitogorsk, is the industrial region in the former Soviet Union with the highest emissions per unit of area.¹⁰

Regionwide, stationary sources accounted for 62 percent of all air pollution in 1989, but the balance between air pollution from stationary sources and transport varied greatly by city. In many cases, a city's pollution problem derives from a single plant or industry. In Norilsk, for example, the principal source of pollution is the city's copper, cobalt, and nickel smelters run by the Norilsk Mining and Metallurgical Combine. In total, stationary sources account for over 99 percent of the city's air pollution. In many cities, such as Ashkhabad, Kishinev, and Vilnius, motor vehicles are the dominant air pollution source. Generally, the larger, wealthier cities (state capitals, for example) suffer more from automobiles. In the late 1980s, Moscow counted 800,000 trucks and automobiles and suffered concomitant air pollution problems; in 1987, motor vehicles generated 73 percent of the total air pollution.¹¹



Pollution from a smelter of the Norilsk Mining-Metallurgical Combine drifts over the Arctic city. Taken together, Norilsk's factories represent the single largest stationary source of air pollution in Russia and the largest point source of sulfur dioxide emissions in the world. Photo: DJ Peterson.

TABLE 2.2 Atmospheric pollution emissions for selected cities in 1987

City	Total (1000s of metric tons)	Source of Emissions (percent)	
		Transport	Stationary
Alma-Ata (Kazakhstan)	213	77	23
Angarsk (Russia)	482	3	97
Arkhangelsk (Russia)	116	28	72
Ashkhabad (Turkmenistan)	46	87	13
Baku (Azerbaijan)	788	38	62
Bishkek (Kyrgyzstan)	163	46	54
Chelyabinsk (Russia)	534	16	84
Dnepropetrovsk (Ukraine)	444	28	72
Donetsk (Ukraine)	328	41	59
Dushanbe (Tajikistan)	114	67	33
Irkutsk (Russia)	152	41	59
Kiev (Ukraine)	327	71	29
Kishinev (Moldova)	133	68	32
Krasnoyarsk (Russia)	400	27	73
Krivoi Rog (Ukraine)	1,369	6	94
Magnitogorsk (Russia)	900	3	97
Minsk (Belarus)	235	53	47
Moscow (Russia)	1,211	70	30
Nizhnii Tagil (Russia)	712	4	96
Norilsk (Russia)	2,426	1	99
Novokuznetsk (Russia)	949	6	94
Riga (Latvia)	138	71	29
St. Petersburg (Russia)	626	59	41
Sterlitamak (Russia)	201	9	91
Tallinn (Estonia)	108	62	38
Tashkent (Uzbekistan)	362	86	14
Tbilisi (Georgia)	312	87	13
Temirtau (Kazakhstan)	1,018	2	98
Ufa (Russia)	475	27	73
Vilnius (Lithuania)	97	62	38
Volgograd (Russia)	396	29	71
Yerevan (Armenia)	248	71	29
Munich ^a	213	27	73
Mexico City	5,027	80	20
São Paulo	2,110	86	14
Athens ^b	394	59	41
London ^c	1,200	86	14
Los Angeles ^d	3,391	87	13

^a1974/1975^b1976^c1978^d1982

Sources: USSR Goskomstat, *Okhrana okruzhayushchei sredy i ratsional'noe ispol'zovanie prirodnnykh resursov v SSSR* (Moscow: Finansy i statistika, 1989), pp. 22–27; Asif Faiz, *Automotive Air Pollution: An Overview* (Washington, DC: World Bank, 1990), cited in World Resources Institute, *World Resources 1992–93* (New York: Oxford University Press, 1992), p. 196.

In comparison, the United States produced about 127 million tons of air pollutants in 1988, making the volume of the two countries' emissions approximately equal. As can be seen in Table 2.3, stationary sources generated the same volume of air pollution in the Soviet Union as in the United States, despite the fact that the Soviet economy before the breakup of the USSR was generally estimated to measure one-fourth to one-half that of the United States. Soviet performance compared with that of the United States was even worse in the transportation sector. Motor vehicles serve as an example. In the United States, automobiles emitted 70 million tons of pollution in 1988.¹² Although U.S. motor vehicles overall produced about 85 percent more toxic fumes by volume than those in the Soviet Union, their numbers were far greater: In the United States, there were approximately twelve times as many privately owned automobiles as in the Soviet Union.¹³ In terms of usage, U.S. trucks hauled more than twice as much freight as their Soviet counterparts, and U.S. buses 17 percent more passengers.¹⁴

CIA estimates of Soviet gross national product can be used as a crude yardstick to determine that the Soviet economy produced roughly \$26,000 of output for every ton of air pollutants in 1988. The corresponding figure for the United States was about 50 percent higher—\$38,000. In addition to stricter emissions controls in the United States, another factor contributing to the discrepancy is the greater presence of heavy industry in the economy of the former Soviet Union and of service industries in the U.S. economy. In 1987, for example, the Soviet Union produced 80 percent more steel, 85 percent more fertilizer, and twice as much cement and generated about the same quantity of primary energy as did the United States.¹⁵

TABLE 2.3 Air pollutant emissions from stationary sources, 1987 (in millions of metric tons)

<i>Substance</i>	<i>USA^a</i>	<i>USSR</i>
Particulates	4.3	13.7
Sulfur oxides	19.8	16.8
Nitrogen oxides	11.4	4.5
Carbon monoxide	12.3	14.0
Volatile organic compounds	9.4	8.4
Lead (thousands of tons)	2.5	6.3 ^b
Total	57.2	57.4

^a1988^b1989

Sources: USSR Goskompriroda, *Sostoyanie prirodnoi sredy i prirodookhrannaya deyatel'nost' v SSSR v 1989 godu* (Moscow: Institut Molodezhi, 1990), p. 12; US Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: Government Printing Office, 1991), p. 209.

Because of the size of the Soviet economy, its emphasis on heavy industry, and its relative inefficiency, the region plays a major role in global environmental issues. In 1989, the Soviet Union was responsible for the emission of over 1 billion tons of carbon into the atmosphere—18 percent of the world's carbon emissions resulting from energy production that year. The USSR was second only to the United States, which produced 22 percent.¹⁶ In terms of total global greenhouse gas emissions (including chlorofluorocarbons and methane), the USSR accounted for about 13.5 percent of global output in 1989—the second largest share—although unaccounted leaks from natural gas pipelines could make the share larger. According to the World Resources Institute, the USSR ranked number 14 in per capita emissions behind other industrialized nations such as the United States (6), Canada (9), and Czechoslovakia (13).¹⁷ In 1986, the Soviet Union accounted for 9.5 percent of global chlorofluorocarbon production, slightly less than the share produced by Japan.¹⁸

AMBIENT AIR QUALITY IN THE SOVIET UNION

The Soviet meteorological service began monitoring air quality in the mid-1960s and by 1988 had checked the air for 80 substances in 534 cities. Under the Soviet regime, cities with a population of over 100,000 were assigned at least one monitoring station, with Moscow having the largest number (twenty-three). According to a standard methodology, each station sampled the air for at least eight substances over a twenty-minute

period, and most conducted these tests three to four times a day. The observations were averaged over various time intervals and compared with established norms.¹⁹ Standards for individual pollutants in the atmosphere were expressed in terms of maximum permissible concentrations (*predel'no dopustimaya kontsentratsiya* in Russian, or PDK) tolerated for human health. These standards were established by the USSR Ministry of Health and were derived from the minimum concentration of a substance that demonstrated an observable physiological effect. This principle was in line with methodologies for determining air pollution standards in the United States and other Western countries, and it produced standards that according to one observer were "very strict."²⁰

The basic conclusion from local reporting is that no major city in the former Soviet Union escaped air pollution problems. In 1989, all major cities failed to comply with standards for suspended particulate matter, nitrogen dioxide, ammonia, and phenol. The most problematic pollutants nationwide were carbon disulfide, formaldehyde, and benzopyrene (a carcinogenic substance found in coal tar); concentrations of these compounds exceeded norms everywhere by a factor of 2 to 4.²¹ Given the uneven nature of Soviet development, air quality and the specific types of pollutants vary greatly by location, and some unfortunate cities have fared worse than average. For example, in 1989 the mean daily concentration of particulates in the Russian oil- and gas-producing city of Nizhnevartovsk was six times PDK. Mean daily formaldehyde concentrations in the Russian city of Lipetsk averaged almost ten times PDK. And in the Siberian city of Bratsk, home to one of the world's largest aluminum smelters, mean daily concentrations of benzopyrene measured 17 times PDK.²² See Table 2.4 for an official list of those cities with the worst problems with specific pollutants.

TABLE 2.4 Major air pollutants and cities with the highest mean annual concentrations, 1989

<i>Pollutant</i>	<i>City (Republic)</i>	<i>Factor by Which Standard Exceeded</i>
Dust	Kutaisi (Georgia)	8.5
	Nizhnevartovsk (Russia)	6.0
	Ararat (Armenia)	5.4
Soot	Aleksandrovsk-Sakhalinskii (Russia)	5.2
Sulfur dioxide	Karabash (Russia)	5.4
Carbon monoxide	Yerevan (Armenia)	2.0
	Zestafoni (Georgia)	1.6
	Tbilisi (Georgia)	1.4
Nitrogen dioxide	Yerevan (Armenia)	3.8
	Zyryanovsk (Kazakhstan)	3.6
Ozone	Bekabad (Uzbekistan)	2.8
	Yerevan (Armenia)	2.5
	Alma-Ata (Kazakhstan)	2.4
Phenol	Dzerzhinsk (Ukraine)	5.3
	Norilsk (Russia)	3.5
Chlorine	Yavan (Tajikistan)	1.6
	Sumgait (Azerbaijan)	1.4
Formaldehyde	Lipetsk (Russia)	9.8
	Groznyi (Russia)	7.8
	Severodonetsk (Ukraine)	7.1
	Odessa (Ukraine)	7.1
Ammonia	Dneprodzerzhinsk (Ukraine)	5.1
	Andizhan (Uzbekistan)	4.5
	Rustavi (Georgia)	3.7
Benzopyrene	Zima (Russia)	22.2
	Ussuriisk (Russia)	18.9
	Bratsk (Russia)	17.0

Source: USSR Goskomprroda, *Sostoyanie prirodnoi sredy i prirodookhrannaya deyatel'nost' v SSSR v 1989 godu* (Moscow: Institut Molodezhi, 1990), pp. 45–46.

In 1989 and 1990, about 130 Soviet cities being monitored for air pollution were included on the “black list”—that is, there were periods when the concentration of a single pollutant exceeded PDK by at least 10 times²³—an increase from the 103 cities reported in 1988.²⁴ Nationwide, 3,300 such violations were reported in 1990. Often pollution levels reached 50 or more times above health norms.²⁵ Air pollution affected

every corner of the USSR; according to a 1989 statement by the Uzbek environment agency, "There is not one industrial center nor large settlement in the republic in which the air quality complies with health norms."²⁶

The "black list" has often been cited by commentators and politicians to demonstrate the seriousness of the air pollution problem.²⁷ Counting the number of cities that exceed pollution norms, however, does not adequately convey the impact of air pollution on the environment and public health. On the one hand, readings by a monitoring station measure pollution at one locus and therefore may be affected by relative proximity to a polluter; pollution may disperse before reaching populated areas; and high readings may be registered as the result of unusually large or transient discharges or because of prevailing weather conditions. On the other hand, measurements based on peak emissions do not reflect ambient concentration over extended periods of time, the toxicity of a single pollutant, or the effect of a "bouquet" of combined pollutants.

To have a better measure, scientists at USSR Goskompriroda, in conjunction with specialists from Goskomgidromet and the USSR Ministry of Health, developed the Index of Atmospheric Pollution (*Indeks zagryazneniya atmosfera*, or IZA). According to this subjective measure, the concentration of the five most problematic pollutants in a city was tabulated by taking their concentrations, weighted according to their relative levels of toxicity, and aggregated to yield an index of air pollution. Using this system, scientists arrived at a list of 73 cities—which in 1989 included about 32 million inhabitants, or over 10 percent of the Soviet population²⁸—deemed "especially dangerous for living."²⁹ Table 2.5 identifies the 30 cities that scored the worst over the period 1985–1989 and lists the problem pollutants and their sources.

Drawing comparisons with the West is difficult given incompatible methodologies for measuring air quality. However, Soviet air pollution standards compare roughly to those in the West, and it is not surprising that over 100 Soviet cities failed to meet air quality standards at least once yearly in the late 1980s and early 1990s. By way of comparison, 52 metropolitan areas in the United States exceeded the norm for low-level ozone concentrations for at least one day in 1989; the Los Angeles area exceeded that standard for 122 days.³⁰ Milan exceeded World Health Organization norms for sulfur dioxide for an average of 66 days per year in the early 1980s, and Beijing exceeded norms for suspended particulate matter for an average of 272 days annually.³¹ What is unusual is the number of Soviet cities that experienced periodic episodes above norms

TABLE 2.5 Thirty-five cities with the worst air quality and its derivation, 1985–1989

<i>City (Republic)</i>	<i>Problem^a</i>	<i>Source</i>
Alma-Ata (Kazakhstan)	BP, F, dust	power plants, automobiles
Almalyk (Uzbekistan)	BP, ammonia, dust	fertilizers, nonferrous metallurgy
Bishkek (Kyrgyzstan)	BP, F, dust, NO ₂	power plants, automobiles
Bratsk (Russia)	BP, methylmercaptan, carbon bisulfide	nonferrous metallurgy, paper, power plants
Chardzhou (Turkmenistan)	BP, hydrogen fluoride, dust	fertilizers, automobiles, power plants
Chelyabinsk (Russia)	BP, F, sulfur dioxide	iron and steel, power plants
Dneprodzerzhinsk (Ukraine)	BP, F, ammonia, dust, NO ₂	fertilizers, steel, construction materials
Donetsk (Ukraine)	BP, NO ₂ , dust, phenol	iron and steel, coal
Dushanbe (Tajikistan)	BP, F, nitric oxide	construction materials, power plants, railways
Dzhambul (Kazakhstan)	BP, dust, hydrogen fluoride, ammonia	fertilizers, power plants
Fergana (Uzbekistan)	BP, F, NO ₂ , dust	petrochemicals, fertilizers, power plants
Groznyi (Russia)	F, BP, NO ₂ , phenol	petrochemicals
Kemerovo (Russia)	BP, F, ammonia, NO ₂	fertilizers, chemicals, iron and steel
Kommunarsk (Ukraine)	BP, NO ₂ , dust	iron and steel
Komsomolsk-on-Amur (Russia)	BP, lead, F, dust	electronics, iron and steel, power plants, petrochemicals
Krasnoyarsk (Russia)	BP, dust, NO ₂ , F, carbon disulfide	chemicals, nonferrous metallurgy, construction materials, automobiles
Magnitogorsk (Russia)	BP, carbon disulfide, NO ₂	iron and steel
Mariupol (Ukraine)	BP, F, hydrogen fluoride, ammonia	iron and steel
Nizhni Tagil (Russia)	BP, F, phenol, dust	iron and steel
Novokuznetsk (Russia)	BP, F, dust, hydrogen fluoride	iron and steel, nonferrous metallurgy, coal, power plants
Odessa (Ukraine)	BP, F, hydrogen fluoride, phenol	metal casting, fertilizers, automobiles
Osh (Kyrgyzstan)	BP, dust, NO ₂	power plants, construction materials, industrial boilers
Perm (Russia)	BP, F, hydrogen fluoride	petrochemicals
Rustavi (Georgia)	BP, dust, ammonia, phenol	construction materials, iron and steel, fertilizers
Samara (Russia)	F, hydrogen fluoride, BP	petrochemicals, electronics
Ust-Kamenogorsk (Kazakhstan)	lead, BP, F, sulfur dioxide	nonferrous metallurgy, power plants
Yerevan (Armenia)	BP, chloroprene, NO ₂ , ozone	chemicals, power plants, automobiles
Zaporozhye (Ukraine)	BP, NO ₂ , phenol, F	iron and steel, nonferrous metallurgy
Zestafoni (Georgia)	manganese dioxide, BP	iron and steel
Zyryanovsk (Kazakhstan)	BP, dust, NO ₂	nonferrous metallurgy

^aBP = benzopyrene; F = formaldehyde; NO₂ = nitrogen dioxide.

Source: USSR Goskompriroda, *Sostoyanie prirodnoi sredy i prirodokhrannaya deyatel'nost' v SSSR v 1989 godu* (Moscow: Institut Molodezhi, 1990), pp. 47–48.

by a factor of 10 or more and, as indicated in Table 2.4, the number that chronically exceeded norms by a factor of 2 to 3 times or more.

In contrast, most infractions of air quality standards in the Los Angeles area, the region with the worst overall pollution in the United States, are relatively minor; in the late 1980s, episodic pollution levels rarely reached twice the federal norm. Comparisons with other regions of the world may be more appropriate. In the early 1980s, mean annual sulfur dioxide levels in Milan, the worst performer monitored by the United Nations, exceeded UN guidelines 3 times; Seoul and Rio de Janeiro were not far behind. Shen-yang, New Delhi, Beijing, and Calcutta exceeded UN guidelines for particulates 3 to 4 times, Kuwait 6 times.³²

THE FALLOUT FROM AIR POLLUTION

According to the Soviet environmental agency, “extensive studies” based on public health data established “a clear relationship between the level of air pollution and population morbidity.”³³ Numerous reports in the specialist and popular media have linked air pollution with the public’s health—as does this report from Moscow’s evening newspaper *Vechernyaya Moskva*:

Increased air pollution manifests itself in an increase of lung illnesses. Thus, the incidence of bronchial asthma, acute bronchitis, conjunctivitis, pharyngitis, tonsillitis, and chronic otitis is 40–60 percent higher in raions (districts) with increased air pollution. Children living in houses along the Garden Ring Road . . . experience six times the incidence of ear, throat, and nose infections and three times the incidence of bronchitis as children living, for example, around Filevskii Park.³⁴

Three large chemical plants are crowded in the southern Kazakhstan city of Dzhambul; one of the plants, Khimprom, spewed out over 10,000 tons of toxic gases alone in 1989.³⁵ In response to rising concern about air pollution in Dzhambul, *Leninskaya smena* (Leninist Youth), a regional paper, carried the following report from Kazakh health authorities:

Spontaneous abortions in the polluted zone . . . surrounding the plants . . . occur 12.5 times as frequently as the average, the rate of premature births is 5.4 times as high as the average, and the rate of infertility is 3.8 times as high. People in the zone are 13.5 times as likely to seek medical treatment for acute respiratory diseases, and 13.5 times as likely to seek treatment for chronic pharyngitis and laryngitis. The inhabitants of these neighborhoods are 7 times as likely to suffer from bronchial pneumonia. . . . We shall see if this distressing news provides the momentum for immediate measures for the ecological recovery of the city.³⁶

Nine-tenths of the residents of Nikel, along the remote Russian-Norwegian border, suffer from serious respiratory ailments, among other maladies, according to the estimates of local doctors.³⁷ Moscow Radio likened living in the city to sitting on death row.³⁸ Such allegations of a linkage between air quality and public health problems are, however, difficult to substantiate given the poor state of local medical data and confounding factors, such as the high rate of cigarette smoking. On the other hand, the linkages between certain air pollution problems and environmental quality are less problematic to establish.

Three massive smelters producing refined nickel, copper, and cobalt on Russia's Kola Peninsula—at Nikel, Zapolyarnyi, and Monchegorsk—discharged a collective estimated 1 million tons of pollutants, 700,000 tons of it sulfur dioxide—twice as much sulfur as emitted in all of Finland.³⁹ The fallout of sulfur and heavy metals has eradicated flora and fauna for hundreds of miles. Nikel and Zapolyarnyi are located close to the Finnish-Russian border; thus a large share of their air pollution crosses the border and damages the forests across northern Scandinavia. In Lapland, the pollution has reduced the forest to a lunar landscape, in the appraisal of one Finnish diplomat.⁴⁰ The situation on the Kola Peninsula is not unique: Industrial pollution from Norilsk, the south Urals, the Kuznetsk Basin, Krasnoyarsk, and the Angara Basin has damaged adjacent forest and tundra lands. Across the former USSR, air pollution has seriously affected 10,000 square kilometers of forest.⁴¹

According to researchers at the USSR Academy of Sciences Economics Institute, the cost, in pre-price reform values, of correcting the environmental damage caused by the emission of one ton of pollutants ranged from 150 to 180 rubles.⁴² With atmospheric emissions averaging about 100 million tons in the late 1980s, that would yield a total bill of 15–18 billion rubles. Other sources pegged the cost to remedy air pollution damage at 13–16 billion rubles a year.⁴³

To minimize damage to the landscape and public health in the immediate vicinity of industrial sites, engineers built tall stacks to send fumes high into the atmosphere where they could be dispersed more widely. This may lessen environmental damage locally, but the potential for damage far from the source of the pollution increases. When they linger in the atmosphere, sulfur and nitrogen, for example, are converted into acids that then precipitate back to earth in the form of rain and snow. The potential impact of long-range atmospheric pollution is important to conditions in the former Soviet Union, because the region's environment is particularly susceptible to degradation due to the lower productivity of its ecosystems, particularly in the tundra and taiga of the north. As a result of climatic conditions and geography, almost all of the forestry

stock is classified as low- and medium-yield and, therefore, more sensitive to pollution.

In 1980, Goskomgidromet began operating a nationwide network of almost 1,000 stations to measure the level of pollutants in the snow cover. Another 300 stations monitored pollution in precipitation. Using the data collected from this network, Soviet scientists estimated in the late 1980s that 13.8 million tons of sulfur were deposited on the continental Soviet Union every year. About 1.1 million tons of sulfur annually fell on the Black, Caspian, and Aral seas, and 300,000 tons fell on the Arctic Ocean.⁴⁴ The Soviet Union's geographical location and the prevailing weather patterns put the region in the position of a net importer of air pollution; over one-fifth of the supply of atmospheric sulfur in the Soviet Union (about 4 million tons annually) came from transboundary sources, largely from neighboring states in Eastern Europe.⁴⁵ In the region immediately adjacent to the western boundaries of Belarus and Ukraine, incoming sulfur reached 30–40 percent of deposits.⁴⁶ In contrast, transboundary exports of atmospheric sulfur from the Soviet Union amounted to about 1.6 million tons per year.⁴⁷

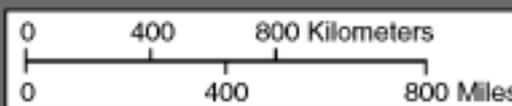
Although the volume of pollution in the atmosphere over the Soviet Union was high in the late 1980s, the acidity of the precipitation has exceeded established environmental norms on only a relatively small part of Soviet territory. Elevated levels of acidity in the soil (a pH less than 5.0) have been registered in relatively confined regions along the western borders of Ukraine and Belarus and downwind from large cities and industrial centers; these include the northwest region of Russia (St. Petersburg and northward through Karelia), western and central Ukraine, Tula and Kalinin oblasts, the Vorkuta Basin, and the eastern Urals, including Yekaterinburg and Tyumen. Moderately acidic conditions (pH of 5.0–5.5) have been registered on the Kola Peninsula and along the coasts of the Kara and Laptev seas. (See Map 2.1.)

TRENDS IN EMISSIONS AND AIR QUALITY

In 1988, the USSR State Committee for the Protection of Nature announced that in the cities monitored using the IZA system, overall air quality had been improving steadily. Whereas the average city registered pollution in excess of four the times the maximum permissible concentration in 1974, the average in 1988 was down to half that.⁴⁸ During the second half of the 1980s, ambient concentrations of particulates decreased by 12 percent, and sulfur compounds were reduced by up to 25 percent. Even greater decreases were registered for less common but potentially more harmful compounds like ammonia (13 percent), hydrogen

Legend

 Areas affected by acidic snow



Source: USSR Goskompiroda, *Sostoyanie prirodnoi sredy v SSSR v 1988g.* (Moscow: VINITI, 1989), p. 23.

Map 2.1. Regions with Acidic Snow Cover (pH less than 5.5), 1988

sulfide (48 percent), hydrogen fluoride (14 percent), and phenol (14 percent). Concentrations of lead and formaldehyde, however, remained unchanged.⁴⁹

This improvement was possible because the total volume of pollutants being released into the atmosphere from monitored sources in the Soviet Union decreased by about 18 percent during the 1980s, despite an increase in economic output. Between 1980 and 1990, the volume of pollutants emitted from stationary sources in the Soviet Union declined by over 23 percent (see Table 2.6). A modest 8 percent decrease in emissions from motor vehicles during the same period yielded a decrease in total emissions of 18 percent (see Figure 2.2). In comparison, total emissions in the United States decreased by about 17 percent between 1980 and 1988.⁵⁰ Despite the reported decrease in overall emissions from the transport sector, ambient concentrations of carbon monoxide and lead remained constant, and nitrogen dioxide and nitric oxide levels increased by 12 and 8 percent, respectively, during the second half of the 1980s.⁵¹

Interestingly, the decrease in automobile emissions occurred despite a rapid expansion of the transport sector. In the early 1970s, the Soviet Union reported to the World Health Organization that motor vehicle fumes (from trucks, buses, and automobiles) accounted for 13.1 percent of all toxic pollutants produced.⁵² Thereafter, this sector expanded dramatically: Between 1970 and 1988, the trucking industry increased by about 225 percent, and use of buses similarly.⁵³ Meanwhile, a 16-fold increase in sales of automobiles for private use⁵⁴ brought the number of privately held automobiles to 16 million vehicles by 1990.⁵⁵ Thus, the

TABLE 2.6 Atmospheric emissions, 1980–1990 (million tons)

	Total	Source of Emissions		Percent of Total	
		Stationary	Transport	Stationary	Transport
1980	110.8	72.8	38.0	66	34
1985	105.0	68.3	36.7	65	35
1986	103.6	66.5	37.1	64	36
1987	100.5	64.3	36.2	64	36
1988	97.5	61.7	35.8	63	37
1989	94.0	58.5	35.5	62	38
1990	90.7	55.7	35.0 ^a	61	39

^aEstimate.

Sources: USSR Goskomstat, *Okhrana okruzhayushchei sredy i ratsional'noe ispol'zovanie prirodnnykh resursov v SSSR* (Moscow: Finansy i statistika, 1989), p. 7; USSR Goskomprroda, *Sostoyanie prirodnoi sredy i prirodookhrannaya deyatel'nost' v SSSR v 1989 godu* (Moscow: Institut Molodezhi, 1990), p. 20; *Ekonomika i zhizn'*, No. 35, 1991, p. 6.

share of air pollution emitted nationwide by the transport sector increased to 34 percent in 1980 and 39 percent in 1990.

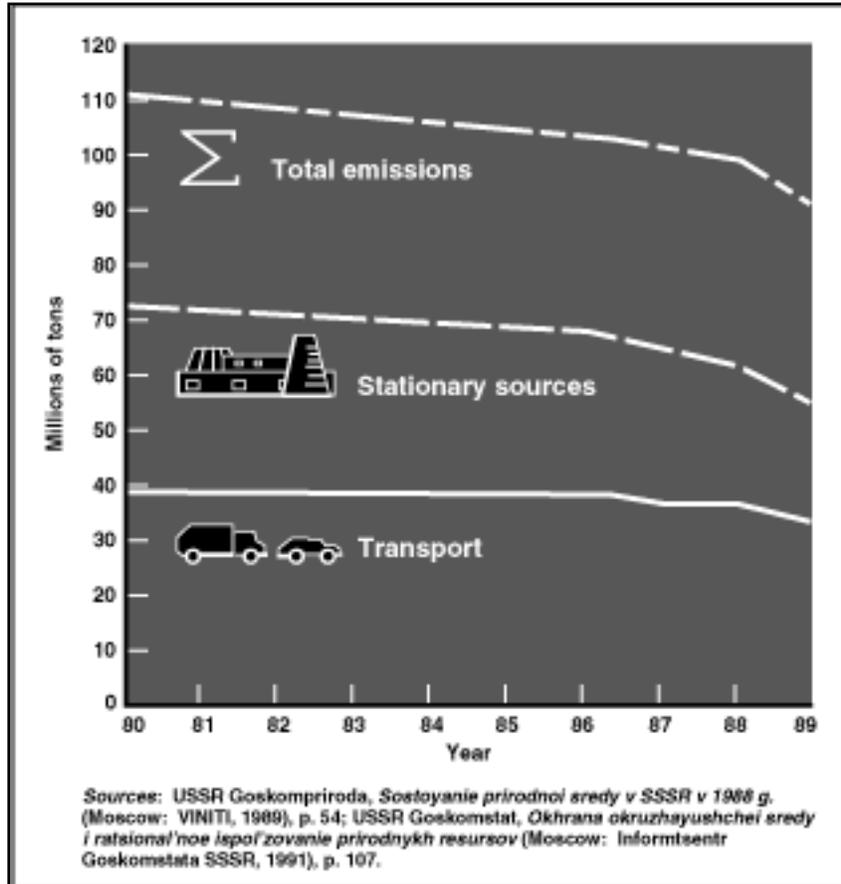


FIGURE 2.2 Air pollution emissions, 1980–1989.

AIR POLLUTION CONTROL EFFORTS

The decrease in emissions in the Soviet Union was the result of an effort initiated by the government in the 1970s to improve urban air quality. In conjunction with the USSR Ministry of Health, the USSR State Committee for Hydrometeorology developed standards of maximum permissible emissions (*predel'no dopustimyi vybros* in Russian, PDV) and temporarily permissible emissions limits for over 200 hazardous pollu-

tants. A Soviet law, which took effect in 1981, required all new enterprises or enterprises that renovated or modernized their production processes to ensure that emissions complied with the established norms. Existing facilities were not subject to the same requirement, but were expected to control their emissions at least to some extent.

To attain these goals, the government allocated 2.15 billion rubles for capital investment in measures to reduce air pollution from stationary sources between 1981 and 1989. This effort, however, was hampered by a lack of adequate and readily available technology and by reluctance on the part of the ministries to sacrifice output in favor of pollution control. As a result, a significant portion of the government's money went unspent every year, and government targets for pollution reduction regularly were unmet. Between 1985 and 1989, outlays for capital investments increased 78 percent, yet the portion of funds unspent every year during this period increased from about 10 percent to almost 25 percent.⁵⁶ As a result, the installation of pollution control equipment did not keep pace with the construction of new industry, not to mention the demands of retrofitting established enterprises. Between 1985 and 1988, the share of pollution sources outfitted with pollution control equipment fell from 47 percent to 40 percent.⁵⁷

In February 1990, during a major speech on environmental policy to the Ukrainian Supreme Soviet, V. A. Masol, the chairman of the Ukrainian Council of Ministers, noted the small fraction of the republic's enterprises fitted with air pollution control equipment, pointing out that even in cases where it was installed, such equipment did not always work as designed:

The primary reason for [high levels of air pollution] is that the technological processes are imperfect and the outfitting of industrial enterprises with treatment equipment is unsatisfactory. Thus, in power engineering and the chemical and coal industries, only 30–40 percent of pollution sources have treatment installations, and in petrochemicals, 20 percent. No less damage is done by the low efficiency of the treatment equipment [installed]. The Ukrainian State Committee for the Protection of Nature checked the status of gas and dust scrubbers at the Voroshilovgrad and Krivoi Rog [power plants]. Practically all of them were in disrepair or worked at very low efficiency. Unfortunately, such examples are not isolated. They attest to the low level of production expertise and discipline. Of course, fines are being levied on the individuals guilty of these gross violations. But, in the end, they can in no way compensate for the damage done to the environment and people's health.⁵⁸

The performance of pollution control equipment installed on factories has been very poor, especially when compared with Western control

technologies. In 1989, overall efficiency of Soviet-built technology was rated at 78 percent. The process efficiency equipment to scrub down flue gases in specific was pegged at just 31 percent; for heat and power plants, the single greatest polluting sector, the rate was a mere 1.2 percent in 1989.⁵⁹

Two factors account for the poor performance of Soviet air pollution controls. First was the low quality of Soviet technology installed. According to *Business in the USSR*, the best available Soviet air pollution control technologies for the chemical industry were at least twenty years behind world standards.⁶⁰ Scrubbers at the Nikel plant could remove only 10 percent of sulfur emissions; Western technology on the same plant would be able to trap an estimated 85 percent or more of the pollution.⁶¹ A large share of equipment was either outdated or worn out. Control technologies on plants in Narva, Estonia, for instance, were built in the 1950s.⁶² According to USSR Goskompriroda, the low quality of Soviet scrubbers and filters resulted in an extra 9 million tons of pollutants (about 15 percent of total annual emissions from stationary sources) being emitted every year.⁶³

Second, the poor manner in which pollution controls were operated contributed to pollution problems. In 1987, the Soviet government conducted a survey of the effectiveness of 61,300 air pollution control installations at enterprises across the country. The results were remarkable: One-fifth of the equipment tested operated at less than its designed capacity.⁶⁴ The chief reasons for such poor performance were many: Plant managers refused to halt production in order to perform necessary maintenance and repairs; spare parts were in short supply; personnel were poorly trained in proper operation of the equipment; and technologies were installed for tasks they were not designed to handle. In some cases, filters were simply turned off—usually at night when local residents could not see the effect.⁶⁵ A scientist at the Kazakh Academy of Sciences reported his observation of air pollution controls at the fertilizer plants in Dzhambul:

[Smokestack] filters never work 100 percent of the time. They are often disabled and they are often simply disconnected, since they consume a lot of electricity. Energy is constantly in short supply, and the deficit is ever increasing. In spite of the growing attention to ecological questions, filters continue to be disconnected at night and at the end of the month and the quarter, when the equipment runs at maximum capacity in order to fulfill the plan. On average, filters were not used 15–20 percent of the time.⁶⁶

According to USSR Goskompriroda, the failure of Soviet air pollution devices to perform at their designed capacities resulted in 7 million more

tons of pollutants (11 percent of emissions) unnecessarily being sent into the atmosphere in 1987.⁶⁷ Given all of these problems, only 40 percent of Soviet enterprises were in compliance with emissions norms as of the beginning of 1991.⁶⁸

In addition to its effort to combat pollution from stationary sources, the Soviet government mandated that automobile factories take measures to reduce vehicle emissions. These efforts were stymied, however, as auto plant managers, focused on fulfilling their output quotas, were able to avoid many of the government's edicts. Through the early 1990s, cars continued to be produced without catalytic converters and basics like electronic ignition and exhaust-gas recirculation. Once on the road, many cars did not meet the government's modest emissions standards; in 1989, almost 10 percent of all cars tested for compliance failed.⁶⁹ Under a strict monitoring program called "Clean Air" implemented in Moscow in the mid-1980s, 50 percent of automobiles were found to have above-norm emissions in 1987; by the following year, the rate had been reduced to 20 percent.⁷⁰

Given problems with Soviet air pollution control efforts, the decrease in emissions achieved during the 1980s was not attributable solely to the modest accomplishments of Soviet pollution control technology. As discussed in Chapter 7, another factor was officials' increasing tendency to shut down "objects having especially great environmental impact."⁷¹ A large proportion of the reduction also can be attributed to a dramatic shift in the country's energy balance away from a heavy reliance on oil and coal in favor of increased consumption of natural gas. The impact of the shift in the region's fuel balance was most significant in terms of sulfur emissions because only a few electric power stations (the principal source of sulfur emissions) were outfitted with sulfur-scrubbing technology as of the early 1990s.⁷²

Between 1980 and 1989, for example, the consumption of natural gas by the Soviet economy increased by 91 percent; the use of coal and oil fell slightly.⁷³ Accordingly, the sharp drop in emissions from the electric power industry noted in Table 2.1 was effected largely through the wide-scale conversion of power plants from burning high-sulfur bunker oil to natural gas.⁷⁴ In 1985, one-third of electricity was generated using natural gas, compared with 20 percent the decade before.⁷⁵ Moreover, the rapid expansion of centralized urban steam-supply systems (fired largely by natural gas) replaced reliance on in-house boilers, many of which were fueled with oil and coal.⁷⁶ By 1985, natural gas accounted for four-fifths of the fuel burned for heat and power in Moscow, contributing to a 60 percent reduction of particulate emissions and a 39 percent cut in sulfur dioxide emissions from 1975 levels,⁷⁷ which helped to bring the cap-

ital into compliance with air quality standards for these compounds.⁷⁸ The Soviet government's gasification program also extended to motor vehicles under a pilot program begun in 1983. By 1989, over 100,000 general-purpose trucks on the roads were natural-gas powered—about 1.4 percent of the fleet.⁷⁹

Unlike the situation in the United States and other advanced industrialized nations, energy demand and, concomitantly, carbon emissions grew steadily in the USSR throughout the 1970s and 1980s as domestic price controls eliminated the economic imperative for firms to increase efficiency after the energy price shocks of the 1970s. Without the dramatic shift in favor of natural gas, which has a significantly lower carbon content, the USSR's contribution of greenhouse gases could have been far worse.

EMISSIONS TRENDS IN THE FUTURE

During 1990 and 1991, emissions from stationary sources dropped by over 10 percent from 1989 levels—a significant increase over the rate of improvement registered in the mid-1980s. This turn for the better was not attributed to wild success in the government's antipollution program but to the rapid deterioration in the state of the economy (in 1991 alone GNP was estimated to have fallen 17 percent) and in the oil refining, iron and steel, and cement industries in particular.⁸⁰ That emissions did not drop even more in accordance with the overall economy may have been because enterprise managers, under such severe economic pressures, were more likely than before to ignore environmental concerns.

Finally, the breakdown of the Soviet economy has produced good news in terms of global climate change. According to Christopher Flavin of the WorldWatch Institute, carbon emissions from the Soviet Union decreased by 4 percent in 1990 and were estimated to decrease another 5 percent in 1991, largely because of the decline in economic output. By 1995, the drop in carbon emissions may reach 30 percent, thereby contributing to a 5 percent decline in global carbon output.⁸¹

Notes

1. Radio Moscow, July 23, 1989; TASS, August 2, 1989.
2. Central Television, "Vremya," August 10, 1989.
3. *Pravda*, August 14, 1990, p. 2.
4. Hamida Yernazarov, staff assistant, Kazakh Ecological Fund, personal communication, Los Angeles, April 1992.
5. G. L. Gromyko, ed., *Sotsial'no-ekonomicheskaya statistika* (Moscow: Izdatel'stvo Moskovskogo Universiteta, 1989), pp. 106–108.

6. USSR Goskompriroda, *Sostoyanie prirodnoi sredy i prirodookhrannaya deyatel'nost' v SSSR v 1989 godu* (Moscow: Institut Molodezhi, 1990), p. 13.

7. This "superministry" was created in 1989 as a result of an amalgamation of the former ministries of ferrous metallurgy and nonferrous metallurgy; in 1988 they were responsible for 17 percent and 10 percent, respectively, of total stationary emissions. USSR Goskompriroda, *Sostoyanie prirodnoi sredy v SSSR v 1988 g.* (Moscow: VINITI, 1989), p. 55.

8. Asif Faiz, *Automotive Air Pollution: An Overview* (Washington, DC: World Bank, 1990), cited in World Resources Institute, *World Resources 1992-1993* (New York: Oxford University Press, 1992), p. 196.

9. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 234; Friends of the Earth, cited in *Svenska Dagbladet*, July 29, 1989, p. 3, translated in FBIS-SOV-89-161, p. 52.

10. USSR Goskomstat, cited in S. B. Lavrov, "Regional and Environmental Problems of the USSR: A Synopsis of Views from the Soviet Parliament," *Soviet Geography*, September 1990, p. 498.

11. *Vechernyaya Moskva*, December 23, 1989, p. 2. The figure of 800,000 motor vehicles was cited by A. I. Kudin, chair of Moskompriroda, the city's environmental protection agency. Another source estimates the number of vehicles at almost 1 million, a figure that includes 680,000 Moscow-registered automobiles and 300,000 from out of town. Fatei Shipunov, "Smog nad Moskvoi," *Moskva*, No. 4, 1989, p. 164.

12. U.S. Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: Government Printing Office, 1991), p. 209. This comparison is based on data for emissions of five principal air pollutants: carbon monoxide, sulfur dioxide, nitrogen oxides, volatile organic compounds, and particulates. In 1988, these substances accounted for about 98 percent of all emissions in the Soviet Union. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 55.

13. USSR Goskomstat, *Sotsial'noe razvitiye i uroven' zhizni naseleniya SSSR* (Moscow: Finansy i statistika, 1989), p. 122; U.S. Bureau of the Census, *Statistical Abstract of the United States: 1990* (Washington, DC: Government Printing Office, 1990), p. 603. Given America's greater reliance on the automobile, the difference in gasoline consumption and miles-per-vehicle driven in the United States and the former USSR is even greater, but a lack of Soviet data on vehicle travel prevents an exact comparison.

14. U.S. Bureau of the Census, *Statistical Abstract, 1990*, p. 589; USSR Goskomstat, *Narodnoe khozyaistvo SSSR v 1988 g.* (Moscow: Finansy i statistika, 1989), pp. 572, 579. Comparisons are made in terms of ton-kilometers for trucks and passenger-kilometers for bus transport.

15. Central Intelligence Agency, *Handbook of Economic Statistics, 1989* (Washington, DC: Government Printing Office, 1989), pp. 24, 63-68. The figures are for Soviet GNP and U.S. GDP and are calculated using purchasing-power equivalents.

16. William Chandler, ed., *Carbon Emissions Control Strategies: Executive Summary* (Washington, DC: Conservation Foundation, 1990), pp. 3-4. This figure is based on 1986 worldwide carbon emissions of 5.6 billion tons produced from

the burning of fossil fuels, which accounts for about three-quarters of all carbon emissions caused by human activity.

17. Estimates are by the International Panel on Climate Change and World Resources Institute, cited in *World Resources, 1992–1993*, pp. 208, 210.

18. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 33. For comparison, production in the United States and the European Community amounted to 30 and 45 percent of global output, respectively.

19. *Trud*, July 5, 1989, p. 1; USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, pp. 5–6.

20. Charles E. Ziegler, *Environmental Policy in the USSR* (Amherst: University of Massachusetts Press, 1987), p. 105.

21. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 40.

22. *Ibid.*, pp. 45–46.

23. *Ekonomika i zhizn'*, No. 5, 1991, p. 11.

24. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 14.

25. *Ekonomika i zhizn'*, No. 5, 1991, p. 11. In 1988, 16 Soviet cities reported peak levels of various pollutants at more than 50 times the permitted maximum. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 14.

26. *Pravda vostoka*, November 21, 1989, p. 3.

27. See, for example, the speech made by Mikhail Gorbachev to the First Congress of People's Deputies, *Pervyi s"ezd narodnykh deputatov SSSR: Stenograficheskiy otchet*, Vol. 1 (Moscow: Izdatel'stvo Verkhovnogo Soveta SSSR, 1989), pp. 444–445.

28. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, pp. 48–50.

29. *Ekonomika i zhizn'*, No. 4, 1989, p. 18.

30. U.S. Bureau of the Census, *Statistical Abstract, 1991*, p. 210.

31. Hilary F. French, *Clearing the Air: A Global Agenda*, WorldWatch Institute, Paper No. 94, Washington DC, January 1990, pp. 10–11.

32. United Nations Environment Programme, *Environmental Data Report* (Oxford: Blackwell, 1989), pp. 14–15.

33. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 129. Since the late 1980s, Soviet media accounts have been replete with reports of elevated illness rates in localities with severe pollution problems, although such stories usually fail to establish a causal linkage.

34. *Vechernyaya Moskva*, February 17, 1990.

35. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, pp. 196.

36. *Leninskaya smena*, April 13, 1991, p. 1, as translated in JPRS–TEN–91–014, pp. 86–87.

37. *Guardian*, January 11, 1991; Radio Moscow, September 13, 1991.

38. Radio Moscow, September 13, 1991.

39. *Aftenposten*, April 27, 1991, p. 12, translated in JPRS–TEN–91–012, pp. 77–78.

40. *Wall Street Journal* (European ed.), October 24, 1989.

41. *Ekonomika i zhizn'*, No. 41, 1990, insert page 1.

42. *Argumenty i fakty*, No. 15, 1990, p. 1.

43. See comments by Nikolai Vorontsov in USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 8; and V. A. Shirokov, "Pochemy 'ne rabotaet' zakon ob atmosfernogo vozdukha?" *Energiya: Ekonomika, tekhnika, ekologiya*, No. 11, 1988, p. 29.
44. V. N. Vasilenko et al., "Zagryaznenie territorii SSSR vypedaniyami sery i azota," *Meteorologiya i gidrologiya*, No. 8, 1988, Allerton Press translation, pp. 49–56.
45. *Ibid.* p. 32. Anthropogenic emissions from the USSR were pegged at 11.8 million tons per year. Another 2.1 million tons of sulfur come from the upper troposphere or natural sources, bringing the total atmospheric supply to 17.9 million tons annually.
46. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 25.
47. Vasilenko et al., "Zagryaznenie," pp. 49–56. The breakdown for transboundary emissions is as follows: Precipitation over the Arctic Ocean, 300,000 tons; transport across the western boundary, 600,000 tons; transport across the southern and eastern boundaries, 200,000 tons. Releases into the upper troposphere total 500,000 tons. As previously mentioned, another 1.1 million tons of sulfur fell on the Black, Caspian, and Aral seas annually; the two former instances may be considered in part transboundary emissions.
48. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 12.
49. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 42.
50. U.S. Bureau of the Census, *Statistical Abstract, 1991*, p. 209.
51. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 42.
52. Cited in Victor L. Mote, "Air Pollution in the USSR," in Ivan Volgyes, ed., *Environmental Deterioration in the Soviet Union and Eastern Europe* (New York: Praeger, 1974), p. 38.
53. During the period 1970–1988, turnover in general-use trucking increased from 64.2 billion to 143.4 billion ton-kilometers, and bus use increased from 202 billion to 480 million passenger-kilometers. USSR Goskomstat, *Narodnoe khozyaistvo SSSR v 1988 g.*, pp. 557, 568.
54. *Ibid.*, p. 117.
55. *Za rulem*, No. 1, 1991, p. 7.
56. USSR Goskompriroda, *Sostoyanie . . . v 1988 g.*, p. 138; *Vestnik statistiki*, No. 11, 1988, p. 56; USSR Goskomstat, *Press-vypusk*, No. 226, June 7, 1990.
57. USSR Goskomstat, *Narodnoe khozyaistvo SSSR v 1988 g.*, pp. 249; USSR Goskomstat, *Okhrana okruzhayushchei sredy i ratsional'noe ispol'zovanie prirodnykh resursov v SSSR* (Moscow: Finansy i statistika, 1989), pp. 86–87.
58. *Pravda Ukrainy*, February 17, 1990.
59. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 13. The gas-scrubbing efficiencies of control technologies in the natural gas and coal industries were 4.8 and 0.6 percent, respectively.
60. "Questions for Puzzle Enthusiasts" (no author), *Business in the USSR*, October 1990, p. 39.
61. *Guardian*, January 11, 1991.
62. K. K. Rebane, "Severo-vostok Estonii: Bolevaya tochka sostoyaniya okruzhayushchei sredy," *Izvestiya Akademii Nauk SSSR*, No. 11, 1988, p. 87.

63. *Vestnik statistiki*, No. 11, 1988, p. 57.
64. USSR Goskomstat, *Sbornik statisticheskikh materialov, 1988* (Moscow: Finansyi statistika, 1989), pp. 278–280.
65. V. G. Glushkova, “Vazhnye napravleniya ekologicheskoi situatsii v Moskve,” in E. M. Pospenov et al., eds., *Problemy uluchsheniya ekologicheskoi situatsii i ratsional’nogo prirodopol’zovaniya v Moskovskom regione* (Moscow: Moskovskii filial Geograficheskogo obshchestva SSSR, 1989), p. 71.
66. Leonid Liubomirskii, “Another Look at the Reliability of Official Soviet Pollution Control Statistics,” *Environmental Policy Review*, Vol. 5, No. 1, January 1991, p. 34.
67. USSR Goskomstat, *Sbornik statisticheskikh materialov*, pp. 278–280; USSR Goskomstat, *Okhrana okruzhayushchei sredy*, p. 89.
68. *Vestnik statistiki*, No. 11, 1991, p. 65.
69. *Za rulem*, No. 1, 1991, p. 7. Of those cars that failed their emissions test, about one-half reportedly had their registration revoked.
70. Glushkova, “Vazhnye,” p. 72.
71. *Vestnik statistiki*, No. 11, 1991, p. 63.
72. R. Caron Cooper, “Former Soviet Republics and Transboundary Pollution: SO₂,” paper presented at Trilateral Graduate Student Conference on the Post-Soviet Era, RAND, Los Angeles, May 1992, p. 17.
73. “Soviet Energy Situation Update for 1989,” *PlanEcon Report*, Nos. 9–10, 1990, p. 7.
74. The reduced reliance on oil has been especially significant because the oil supplied to electric plants has a sulfur content of 2.5 percent or higher in contrast to the 0.5 percent content of oil consumed in Japan and the United States. I. A. Glebov et al., “Ekologiya: Nasha obshchaya trevoga i zabota,” *Elektricheskie stantsii*, No. 9, 1989, p. 3; Yu. K. Semenov, “O sostoyanii elektroenergetiki, i problemakh energoobespecheniya na perspektivy i sotsial’noi zashchishchennosti trydyashchikhnya otrasli,” *Elektricheskie stantsii*, No. 3, 1991, p. 7.
75. A. A. Troitskii, ed., *Energetika SSSR v 1986–1990 godakh* (Moscow: Energoatomizdat, 1987), p. 13. By comparison, the U.S. share of electricity generated using natural gas declined over the 1980s, to about 10 percent. U.S. Bureau of the Census, *Statistical Abstract, 1990*, p. 573. For more on the shift in the energy balance of Soviet power stations, see Matthew Sagers, “News Notes,” *Soviet Geography*, No. 3, 1990, pp. 227–231.
76. A. A. Bekker, “Sostoyanie i tendentsii ismeneniya zagryazneniya atmosfernoggo vozdukha v Moskve,” in Pospenov et al., eds., *Problemy uluchsheniya ekologicheskoi situatsii*, p. 55. Between 1980 and 1985 alone, generation of heat in centralized systems increased by over 18 percent. Troitskii, *Energetika*, p. 12.
77. Bekker, “Sostoyanie i tendentsii,” p. 56.
78. USSR Goskompriroda, *Sostoyanie . . . v 1989 godu*, p. 88.
79. USSR Goskomstat, *Okhrana okruzhayushchei sredy*, p. 90. Original plans called for a total of 500,000 gas-powered vehicles by 1990. For an early review of the USSR’s gas-powered motor vehicle program, see *Ekonomicheskaya gazeta*, No. 41, 1987, p. 17.

80. *Ekonomika i zhizn'*, No. 6, 1991, p. 13. See also *Vestnik statistiki*, No. 11, 1991, p. 63.

81. *New York Times*, December 8, 1991, p. 17. Christopher Flavin, vice-president, WorldWatch Institute, personal communication, Los Angeles, January 1992.