Chapter 5

SYSTEM FOR REGULATION

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5.1 BASIC FRAMEWORK FOR AIR POLLUTION CONTROL

The legislative foundations of air pollution control policy were set in 1967 and 1970. The "Basic Law for Environmental Pollution Control", enacted in 1967, is a seven-page document that spells out general principles regarding the responsibilities of business, and of central and local government bodies in a comprehensive pollution control program aimed at protecting human health and conserving the living environment.

In December 1970, a special session of the Diet devoted almost exclusively to environmental issues revised 8 existing pollution control-related laws and established 6 new laws. The Air Pollution Control Law of 1968 was at that time revised, providing a solid legal basis for future air pollution control.

5.1.1 The unique role of ambient air quality standards

Ambient air quality standards are a policy goal, formulated pursuant to the provision of Paragraph 1, Article 9 of the Basic Law for Environmental Pollution Control, which sets forth the air quality desirable to be maintained for the protection of human health. Generally, the term "environment quality standards" as used in the Basic Law refers to the qualities of air, water and soil and the level of noise that are desirable to be maintained for the protection of human health and the conservation of the living environment.

Prior to the enactment of the Basic Law in 1967, emission control for individual sources was designed and applied on a case-by-case basis. Under these circumstances, the growing industrial activity in any particular area resulted in environmental degradation, even if each source of pollution complied with the emission standards. To remedy the shortcomings of the individual approach, the concept of establishing certain standards for environmental quality was incorporated into the Basic Law.

The ambient air quality standards formulated under this comprehensive approach were the policy goals for the protection of human health and the conservation of the living environment. To attain and maintain these goals of air quality, various effective administrative measures were undertaken, such as improving fuel quality, land use planning, facility layout planning as well as individual emission controls. In fact, the ministries and agencies concerned are requested by the law to make every possible effort to ensure the maintenance of the standards by implementing environmental pollution control measures in a comprehensive, effective and appropriate manner. For instance, in the field of air pollution control, closely related policies concerning energy, industry and transportation are generally developed while integrating environmental aspects into their own fields.

Environmental quality standards are based on the scientific studies of the effects of pollutants on human health and living environment under various exposure conditions. As such, the standards may be revised as new scientific knowledge can be obtained with respect to the effect and measurement method of existing and newly identified pollutants.

In Japan, as quality standards play a very important role in pollution control policy, the procedure for setting such standards deserves attention. The general procedure is as follows:

Prior to establishing ambient air quality standards, the Director General of the Environment Agency (the State Minister for the Environment) consults the Central Council for Control of Environmental Pollution on matters relating to the environmental conditions desirable to be maintained and on measurement methods for related pollutants.

In response to the inquiry, the Central Council appoints a Committee of Experts consisting of specialists in evaluating health effects and in measuring methods for related pollutants. The committee, in turn, gathers scientific data and information available relating to the pollutants in question, and after having evaluated and discussed the data and information, it draws up a set of criteria and proposes guidelines for presentation to the Central Council.

The Central Council reviews the criteria and guidelines presented by the committee with the aim of determining measures for attainment, and recommends to the Director General of the Environment Agency a set of environmental conditions that can serve as the basis for environmental quality standards. Based on the recommendations, the Director General announces standard values for environmental quality, methods of measurement, areas to which they apply and the period for achieving such environmental quality. Thus, environmental quality standards are established.

The ambient air quality standards so far established are summarized in Table 5.1. They have been established principally for the protection of human health.

Table 5.1

Ambient air quality standards

Substance	Sulfur dioxide	Carbon monoxide	Suspended particulate matter	Nitrogen dioxide	Photochemical oxidant
Environmental Conditions	0.04 ppm	10 ppm	0.10 mg/m^3	0.04 ppm	0.06 ppm
	0.1 ppm	20 ppm	0.20 mg/m^3	0.06 ppm	
	Daily average of hourly values shall not exceed 0.04ppm, and hourly values shall not exceed 0.1ppm.	Daily average of hourly values shall not exceed 10ppm, and average of hourly values for eight consecutive hours shall not exceed 20ppm.	Daily average of hourly values shall not exceed 0.10mg/m^3, and hourly values shall not exceed 0.20mg/m^3.	Daily average of hourly values shall be within the range of 0.04 ppm and 0.06 ppm or below.	Hourly values shall not exceed 0.06 ppm.

5.1.2 Emission controls for stationary sources

With the aim of meeting the air quality standards, emission control over stationary sources is enforced under the Air Pollution Control Law. Emission standards and fuel standards are enforced for "soot and smoke" emitting facilities, and the standards for structure, operation and management are applied for "particulates" emitting facilities.

The Air Pollution Control Law also provides for special measures in the case of accidental discharging of any of 28 specified substances, such as ammonia.

"Soot and smoke" are defined by the law as follows:

(1) sulfur oxides generated as a result of combustion of fuel;

(2) "soot and dust" arising from fuel combustion or electricity-use as a source of heat; and

(3) the toxic substances released or generated as a result of combustion, synthesis, decomposition or other treatment, that is, cadmium, and its compounds, chlorine and hydrogen chloride, fluorine, hydrogen fluoride and silicon fluoride, lead and its compounds, and nitrogen oxides.

Facilities which generate soot and smoke of a certain size or larger and which are installed at factories or office buildings are defined as soot- and smoke-emitting facilities and, as such, they are subject to emission standards.

Different regulatory measures are prescribed for sulfur oxides, soot and dust, and toxic substances. For the first two, facilities newly installed or added to existing ones in designated areas, where air pollution is already significant, are subject to special emission standards which are more stringent than the ordinary emission standards.

Emission standards prescribed by the government with respect to soot and dust and toxic substances represent the national minimum, and prefectural governments are empowered to establish their own standards by virtue of an ordinance —— a by-law enacted by the local legislative body —— where the situation warrants it. If the Director General of the Environment Agency finds that a certain prefecture needs standards more stringent than the national minimum, he may recommend such standards to the governor.

Prefectures are not allowed to set more stringent sulfur oxide standards than the national standards, because the control of sulfur oxides is closely related to the national energy policy. Instead, the national standards for sulfur oxides reflect local conditions both in K-value control, and total mass control, as described below.

To ensure effective enforcement of emission controls, managers of soot- and smoke-emitting facilities are required to comply with the emission standards and to notify the appropriate regulatory agency of the installation of any new facilities or of any changes in the structure of existing facilities. Violators of these requirements are subject to penalties, and such violators may be ordered to change the proposed plan or to improve the structure or design of modified facilities. In addition, managers of soot- and smoke-emitting facilities are required to monitor and record regularly the quantity of soot and smoke their facilities release into the air. The prefectural governor is empowered to call for reports on the current state of soot- and smoke-generating facilities and may order a competent official or officials of his prefectural government to inspect the premises.

5.1.3 Emission controls for motor vehicle exhaust

The Air Pollution Control Law empowers the Director General of the Environment Agency to establish permissible limits of motor vehicle exhaust emissions. The following exhaust emissions from motor vehicles: CO, HC, NO_x, particulates and lead are designated as those which are liable to affect human health adversely. The Director General of the Environment Agency has established permissible limits for CO, HC, NO_x and diesel smoke. (a permissible limit for lead is not necessary in Japan, because since 1975 only lead-free gasoline has been used for gasoline-powered cars.)

The law also provides that the Minister of Transport should ensure the attainment of the permissible limits by stipulating matters necessary for the enforcement of exhaust emission control in the government order provided for in the Road Transport and Motor Vehicle Law (enacted in 1951). The law demands that any vehicle, which is to be used on roads, must pass an initial or continuation inspection set by the Minister of Transport. Also, virtually all mass produced motor vehicles get type-approval by the Minister of Transport before appearing on the market. The law also obliges all motor vehicles to satisfy the permissible limits of exhaust emissions in their initial or continuation inspections or type-approval tests.

Following on from the early restrictions on motor vehicle exhaust emissions, in 1975 tougher restrictions were put into effect for carbon monoxide, hydrocarbons and nitrogen oxides for gasoline-powered passenger cars. As a result of these restrictions, the levels of carbon monoxide and hydrocarbons in motor vehicle exhaust emission have been reduced by more than 90% from those when there were no restrictions. As for nitrogen oxides, emission levels were also reduced by more than 90% because of the 1976 and 1978 restrictions.

In December 1977, the Central Council for Environmental Pollution Control released a report on Long-Term Policy for the Establishment of Permissible Limits for Motor Vehicle Exhaust Emission. In order to realize the targets as soon as technically feasible, the Environment Agency evaluated and promoted the development of pollution control technology through the Investigation Committee for Motor Vehicle Pollution Control Technology, consisting of university professors.

This led to the phase-I restrictions of nitrogen oxide exhaust from trucks and buses, which were enforced in 1979. The phase-II restrictions were subsequently introduced for light-weight and medium-weight gasoline cars in 1981, for heavy-weight gasoline cars, light trucks and indirect-injection-type diesel vehicles in 1982 and for direct-injection-type diesel vehicles in 1983.

5.1.4 Monitoring of air pollution

(i) Local air pollution monitoring networks. Environmental monitoring in Japan serves as the basis for environmental policy. In fact, environmental monitoring is an essential tool not only in assessing the quality of the environment but also in formulating the environmental policy and evaluating the effects of existing environmental measures. Because of their proven value, a variety of monitoring activities are under way at both national and local levels.

Due to the rapid development in monitoring, data-transmission and data processing techniques, more and more sophisticated environmental policies are being introduced and implemented with considerable success.

The Air Pollution Control Law, contains the following provisions.

[Article 22]

The governor of a prefecture shall continually monitor and survey the level of air pollution.

[Article 20]

The governor of a prefecture shall measure the density of motor vehicle exhaust in the air, on roads or in places surrounding roads where serious air pollution by motor vehicle exhaust occurs or is likely to occur on account of traffic congestion at the traffic intersections, etc.

[Article 24]

The governor of a prefecture shall make public the conditions of air pollution in the areas under his jurisdiction.

Based upon such provisions, local air pollution monitoring networks are being consolidated both by prefectures and by those designated cities that have also been authorized under the Cabinet Order to enforce the law. Table 5.2 shows the number of air monitoring stations operated by local governments.

The purposes of such monitoring stations can be summarized as follows:

1 To ascertain the state of compliance with the ambient air quality standards [SO_2, CO, SPM, NO_2, photochemical oxidants (O_x)].

Table 5.2
Number of air pollution monitoring stations operated by local governments (in 1985)

	General Air Pollution Monitoring	Automotive Emission Monitoring	Total
SO_2	1,647	54	1,701
NO & NO_2	1,321	295	1,616
CO	197	315	512
O_x	1,021	48	1,069
NMHC	306	142	448
SPM	680	65	745
Dustfall	1,478	-	1,478

2 To provide information allowing the necessary steps to be taken in case of emergency.
3 To monitor the effectiveness of regulation.
4 To manage air quality on a regional basis.
5 To watch specific sources of pollution, and to monitor the background conentrations of pollutant, etc.

As is indicated in Fig. 5.1, many major Japanese cities maintain a telemeterized monitoring system. Under the system, fuel consumption, sulfur content in heavy oil, and concentrations of NO_x and SO_x in flue gas as well as ambient data are telemetered from major industrial plants and from air monitoring stations to the monitoring center in the city, for control purposes. In most cases telemeterized data are displayed to the general public.

(ii) National air monitoring network (NAMN). National air pollution monitoring stations and national environmental background air monitoring stations have been established since 1965 with two aims: 1) clarifying the nationwide state of air pollution caused by both currently regulated pollutants as well as other substances and 2) gathering the raw data needed for setting ambient air quality standards and formulating pollution control programs.

National air pollution monitoring stations are installed at 15 sites throughout the country, each being equipped with various instruments for monitoring sulfur dioxide, nitrogen oxides and other air pollutants. The data obtained are analyzed to clarify the cause of air pollution.

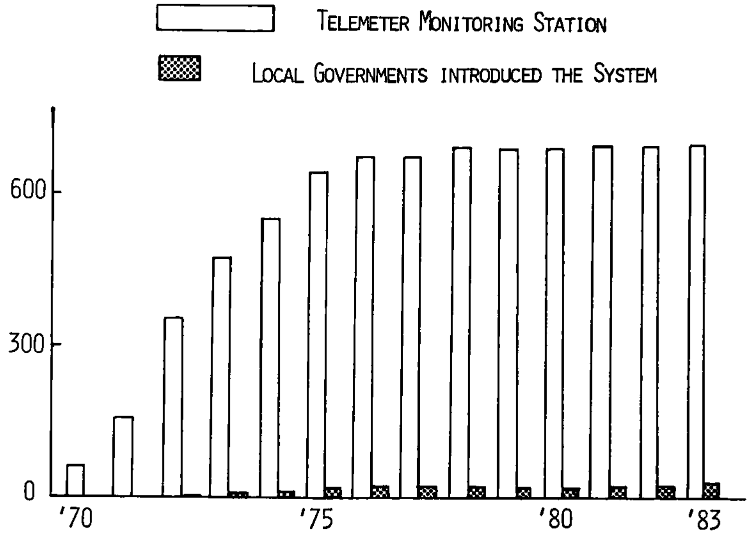

Fig. 5.1. The number of monitoring stations and the number of local goverments having introduced the monitoring system.

National environmental background air monitoring stations are located at eight places for the purpose of understanding ambient air conditions in unpolluted areas on the major plains of Japan. These environmental air monitoring stations are equipped with instruments for measuring hydrogen fluoride and ozone in addition to the normal equipment of national air pollution monitoring stations.

Besides these 23 stations, three national motor vehicle exhaust gas monitoring stations (ambient air) have been in operation in Tokyo since 1968. They monitor CO, SO_2, NO, NO_2, and particulate matter.

5.1.5 The establishment of the Environment Agency

(i) Background. The pollution control administration of Japan was markedly strengthened thanks to the establishment, in July 1970, of the Headquarters for Countermeasures for Environmental Pollution (headed by the Prime Minister) and to the subsequent enactment and consolidation of anti-pollution measures by the 64th (November - December 1970) and the 65th (December 1970 - May 1971) Diet Sessions. However, the wide distribution of pollution control functions among a number of ministries and agencies created serious bottlenecks in the enforcement of comprehensive anti-pollution measures.

In view of the above, Prime Minister Sato decided to establish an Environment Agency not only to control environmental pollution but also to promote administrative measures for the overall conservation of nature including better management of national parks and protection of wild life. As a preliminary step, an inter-agency Preparatory Committee for the Establishment of an Environment Agency, composed of the administrative vice-ministers of all the ministries and agencies concerned, was instituted under the chairmanship of Mr. Yamanaka, Director General of the Prime Minister's Office. The work of this committee rapidly led to the establishment of an independent agency for environmental protection and enhancement. The reasoning underlying this move may be summarized as follows:

a. The responsibilities and concern of the Environment Agency should not be limited merely to pollution control, rather, the Agency's administrative jurisdiction should cover all spheres of environmental protection including nature conservation.

b. Regulatory measures, such as the setting of standards, and the monitoring and surveillance of pollution, which have been spread over a number of ministries and agencies, should be concentrated under a single command, the Environment Agency.

c. In view of the vital importance of scientific research and investigation relating to pollution control, a National Institute for Environmental Studies should be established.

A law for the Establishment of the Environment Agency was approved by the Cabinet on 16 February 1971 and passed the Diet on 24 May. Under the Law, the Environment Agency came into being on 1 July 1971.

(ii) The Environment Agency's responsibilities and the task of the Air Quality Bureau. The Environment Agency is responsible for overall promotion of environmental protection and the following matters are under its jurisdiction.

[General]

These include the planning, drafting and promotion of basic policies relating to protection of the environment; overall coordination of the various branches of the government responsible for environmental protection; coordination of budgetary policies for expenditures related to pollution control; and centralized control of appropriations for research and development. The agency's administrative structure is designed to increase its effectiveness as an overall coordinator.

[Nature Conservation]

The agency has under its jurisdiction enforcement of the Nature Conservation Law, the Natural Parks Law, the Wildlife Protection and Hunting Law and the law relating to the Regulation of Transfer of Special Birds.

[Pollution Control]

Matters coming under the jurisdiction of the agency include establishment of environmental quality standards, enforcement of the Air Pollution Control Law, the Water Pollution Control Law and other laws relating to environmental pollution control.

[Director General of the Environment Agency]

The head of the Environment Agency is called the Director General and is appointed to the Cabinet with the rank of a Minister of State.

When the Director General deems it necessary for the protection of the environment, he has the power to request information or explanations from the heads of other administrative agencies. He (or she) is also empowered to make recommendations to them with respect to important matters. When the situation so warrants, he (or she) can recommend to the Prime Minister that steps be taken.

[Air Quality Bureau]

This bureau is responsible for establishing environmental quality standards and the enforcement of the various pollution control laws relating to pollution caused through air-air pollution, noise, vibration and offensive odour. The Air Pollution Control Division, for which the author worked from July 1981 to October 1984 as the head of the division, is charged with the administrative service relating to the establishment of emission standards, the proper use of fuel to control air pollution as well as the monitoring of air quality. The bureau also covers the control of noise, vibration and offensive odour. It is charged, in addition, with the enforcement of related laws, investigation of environmental pollution in related areas, and drafting of plans. In view of the gravity of pollution caused by automobiles, the bureau has also established an Automotive Pollution Control Division to attack on a broad front environmental pollution caused by automobiles. On 1 October 1978, the Office of Traffic Pollution Control was established to promote and coordinate overall countermeasures for traffic pollution.

5.1.6 R & D in the field of pollution control

R & D in the field of pollution control is very actively pursued at both public and private research institutions. It seems to me that the most important is the Environment Agency's National Institute for Environmental Studies (NIES), which was established in March 1974, in Tsukuba Academic City, which is about 60 km east of Tokyo. The institute was established to play the leading role in environmental research in Japan. It enables inter-disciplinary studies to be undertaken with the participation of outside experts from universities and other research institutes. It also provides large-scale experimental facilities for environmental studies, and conducts field studies.

Since the institute's inception, various efforts have been made to improve its organizational structure and facilities. The administration of research at the institute has recently been improved. Recent research projects in the field of air pollution are shown in Table 5.3.

While extensive research and study in these fields is conducted by various

Table 5.3
Recent study themes conducted by NIES

(a)	Studies on Photochemical Reactions of Hydrocarbon-Nitrogen Oxides-Sulfur Oxides System (1980-1981)
(b)	Experimental Study of the Effect of Combined Air Pollutants (NO_2, O_3 and SO_2) on the Living Body (1982-1986)
(c)	Study of Wide Range Transport, Mixture and Deposition Process on Air Pollutants (1982-1985)
(d)	Study of Air Purification Function by Plant (1982-1985)

research institutes of the government and private industry, the government has also undertaken basic research on the effects and mechanisms of pollution. In addition, it has conducted research on pollution prevention measures such as the establishment of various environmental standards, as well as on the development and assessment of pollution prevention technology. The government has also been encouraging development of large-scale, comprehensive technology such as flue gas desulfurization techniques. These have either high administrative priorities or use innovative techniques that are expected to contribute substantially to pollution abatement. For this purpose the government organizes large-scale project development teams including the private sector or subsidizes private business in their development efforts.

While carrying out such research and study activities, the government is required to establish close links between many research groups since today's research projects include many diverse areas of science and technology, and consequently require the close cooperation of people in various fields. Because of this, the Environment Agency is required by law to coordinate cost estimates of pollution prevention measures to be undertaken by government ministries and agencies. At the same time, it appropriates and administers the total costs of pollution prevention research and studies undertaken by both ministry research institutes as well as all costs of research projects contracted by government ministries and agencies.

Local government research institutes focus their activities on experiments and studies of matters closely related to the local environmental issues. The Environment Agency has taken measures to support their continued activities in this field, by giving financial or technical assistance.

5.2 REGULATION OF SO_x

Japanese experience in sulfur oxides (SO_x) control has been very unique and has proven to be very successful. In fact, the ambient levels of SO_2 throughout Japan have dropped drastically during the past decade or so. Nowadays more than 99% of all air pollution monitoring stations have met the ambient quality standard for SO_2, which is undoubtedly one of the most stringent standards in the world (Table 5.4).

Such achievements in reducing drastically the ambient levels of SO_2 have been made using a number of policy tools based upon the best available technology for the control of SO_x. Among them are K-value regulation, regulation of the sulfur content of fuel oil, and total emission control.

5.2.1 K-value regulation

Initially, the statutory emission control of sulfur oxides was applied to the concentration recorded at stack outlets under the Soot and Smoke Regulation

Table 5.4
State of compliance with sulfur dioxide environmental quality standards

Item		"Effective Stations"	
Year	Total number	Satisfying stations	Rate of achievement (%)
1972	685	227	33.1
1975	1,238	992	80.1
1980	1,571	1,546	98.4
1981	1,586	1,569	98.9
1982	1,605	1,596	99.4
1983	1,613	1,603	99.4
1984	1,623	1,614	99.4

Law of 1962, which is the first air pollution control law ever enacted in Japan. In those days, the regulatory measures were designed to cope with spreading air pollution that was extending to an ever widening area. This was caused by sharp increases in the consumption of energy by the heavy and chemical industries which had kept Japan growing rapidly since the early 1960s. However, the law failed to check the spread of pollution in areas containing industrial complexes, let alone improve the ambient concentrations of sulfur oxides.

The realization of the gravity of the situation led to the institution of ambient air quality standards under the Basic Law for Environment Pollution Control of 1967 as stated before.

Seizing the opportunity when a sweeping amendment was written into the Soot and Smoke Regulation Law in 1968, subsequently known as the Air Pollution Control Law, the system of controlling the K-value was adopted. This method prescribes permissible limits for the quantity of sulfur oxides emitted according to the heights of smoke stacks. The K-value is given under the following formula:

$$q = K \times 10^{-3} \times He^2$$

where

q : hourly volume of sulfur oxides emitted (Nm^3/h)

K : constant given for each area

He: effective height of smoke stack (m)

Here, He is obtained according to the Bosanquet I formula described below:

$$He = Ho + 0.65(Hm + Ht)$$

Ho = real height of smoke stack (m)

$$Hm = \frac{0.795\ (QV)^{1/2}}{1 + 2.58/V}$$

$$Ht = 2.01 \times 10^{-3}\, Q\, (T-288)(2.30 \log J + \frac{1}{J} - 1)$$

$$J = \frac{1}{(QV)^{1/2}}\,(1460 - 296\,\frac{1}{T-288}) + 1$$

The K-value is determined in such a way as to control the maximum ground concentration contributed individually from all the facilities with various stack heights to a certain value, and it is calculated in accordance with the following formula which is based on the diffusion equation by Sutton.

The maximum ground concentration, C_{max}, on the principal axis to the leeward of a source of smoke is obtained according to Sutton's diffusion equation as follows:

$$C_{max} = 0.234\,\frac{Cz}{Cy}\,\frac{Q}{uHe^2}$$

Here, on the assumption that the Sutton's diffusion parameter Cy is equated to Cz (the assumption is reasonable when the stability of the atmosphere is neutral) and the wind velocity u is 6 m/s, C_{max} is given as follows:

$$C_{max} = 0.234\,\frac{Q}{6He^2}$$

where,

C_{max} : maximum ground concentration (3-minute value)(In this case, the reading of concentration is indicated in terms of 10^{-6}, rather than 1 ppm.)

Q : quantity of pollutants emitted in units of m^3/s at 15°C

Generally, the maximum ground concentration is often indicated in terms of hourly values, so that the given 3-minute value is converted into hourly values. According to Rolly's conversion rate for varying averaging time, by multiplying the given three-minute value by 0.15, the hourly value is obtained as follows:

[Hourly value C_{max}] = 0.15 x [3-minute value C_{max}]

Further, Q is translated into standard conditions (0°C, at the standard atmospheric pressure) called q.

$$q = Q \times \frac{273}{273 + 15} \times 3600$$

From the above,

$$q = 0.584\, C_{max} \times 10^6 \times He^2.$$

In terms of ppm, the hourly value is represented by $C_{max} \times 10^6$.

$$q = 0.584\, C_{max}\, He^2$$

where

q : the quantity of pollutants emitted (Nm^3/h)
C_{max} : the maximum ground concentration (ppm)
He : the effective height of smoke stack (m)

The above equation serves as the emission standard and if 0.584 C_{max} is assumed to be K x 10^{-3}, then

$$q = K \times 10^{-3} \times He^2$$

This equation serves as the emission standard provided by the law.

The relationship between the K-value and the maximum ground concentration is represented by K = 584 C_{max}, on the basis of which the K-value is determined. The relationships between the K-value and C_{max} that have been used so far are summarized in Table 5.5 below.

Table 5.5
K-value and maximum ground concentration

K-value	1.17	1.75	2.34	2.92	3.50	4.67	5.26	6.42
C max (ppm)	0.002	0.003	0.004	0.005	0.006	0.008	0.009	0.011
K-value	7.59	8.76	9.34	11.7	14.6	15.8	17.5	18.7
C max (ppm)	0.013	0.015	0.016	0.020	0.025	0.027	0.030	0.032

The K-value is established for each area and has been revised several times. Revisions were made to attain the prescribed ambient air quality standards for sulfur dioxide by the target year, taking into consideration the current state of air pollution in the given area, the overall source inventory for the soot- and smoke-emitting facilities and the projected increase in the consumption of fuels.

Specifically, the K-values were established by the following procedures. In this case, the findings of the latest survey of existing soot- and smoke-emitting facilities (which has been conducted nationally once every two years) served as the basis for computing such K-values.

(a) The total quantity of sulfur oxides emitted (Qo) for each area was estimated for the year when the emission standard (K-value) is to be established by calculating the following:

$$Qo = r \times Qs$$

where

r : the rate of increase in the area-wide fuel consumption for the year over the base year

Q_s : the total quantity of sulfur oxides emitted in the area for the base year

(b) Present state of air pollutants: The measurements of ambient concentration of sulfur oxides during the base year were used. If a given area maintained a large number of monitoring stations, the average concentration monitored at the worst two or three stations was used.

(c) Target value for the ambient concentration: The target value to be attained during a given year represented one of the series of graduated levels of concentration designed to help attain the prescribed ambient air quality standards by the target year.

(d) The permissible total quantity of sulfur oxides for a given area (Q) was calculated according to the following equation:

$$Q = \frac{\text{target value for the ambient concentration}}{\text{present concentration of sulfur oxides}} \times Q_s$$

(e) The required rate of reduction (R) in the quantity of sulfur oxides emitted was computed according to the following equation:

$$R = \frac{Q}{Q_o} \times 100$$

(f) Calculation of the value for the emission standard (K-value):
First, the quantity of sulfur oxides expected to be reduced for each facility when we assume a certain K-value was calculated. Then, the quantities of sulfur oxides reduced in individual facilities were added up and thus the relationships between the rate of reduction in the quantity of sulfur oxides and the assumed K-value were obtained on the basis of which the K-value corresponding to the given R prescribed above was estimated.

Thus, on the basis of the K-value calculated for the given area in accordance with the above-mentioned procedures, the areas are now classified into 16 categories, with K-values ranging from 3.0 to 17.5. For certain areas where sulfur oxide pollution was serious in the past, stricter K-values (1.17, 1.75 or 2.34) are applied for new sources.

For instance, the K-value is 1.17 for metropolitan areas including Tokyo, Yokohama/Kawasaki, Nagoya and Osaka. The K-value is either 1.75 or 2.34 for local industrial cities which suffered in the past from relatively severe air pollution.

Assuming normal plant design and operation of a coal-fired power plant with a unit capacity of 1,000 MW, the maximum flue gas concentrations of SO_x is about 60 ppm in the case of a K-value equal to 1.17. In order to comply with this standard, low-sulfur coal with a sulfur content lower than 0.8% would have to be used and flue gas desulfurization (FGD) equipment with a rate of removal exceeding 90% would have to be installed. Similarly, flue gas concentrations of SO_x if the K-value is 17.5 should be around 1,250 ppm, which can be achieved by using coal with a sulfur content lower than 1.5% without installing FGD equipment.

SO_x emission checks of soot- and dust-emitting facilities are generally run on the basis of reports filed by the management of the factory and competent local government officials who may enter the premises of factories whenever they consider it necessary to verify the conformance to the standards. In certain areas, the managers of factories are required to install continuous emission monitors on their principal pollution sources, which are linked to a local monitoring center through telemeters. In case any factory fails to meet the prescribed emission standards, the local government is empowered to impose penalties on such managers. Normally, however, the local governments cause such factories to restore the compliance of their facilities.

5.2.2 Regulation of the sulfur content of fuel oil

In areas where small- and medium-sized space heaters substantially contribute to air pollution in winter, pollution control based on the K-value prescribed for such areas does not always prove to be effective. Falling into this catagory are the urban areas and, for such areas, fuel standards to control the sulfur content of available fuels are necessary. By nature, they are applicable only during periods when space heating causes heavier air pollution.

In Article 15 of the Air Pollution Control Law, it states:

"If the governor of the prefecture recognizes that serious air pollution of sulfur oxides occurs or is likely to occur in an area where sulfur-oxides-related soot- and smoke-emitting facilities are concentrated whose volume of fuel fluctuates according to season and that any person who emits sulfur oxides in the area uses in the facility any fuel which fails to meet the fuel standard, the governor may recommend such a person to observe the fuel standard within a prescribed period." further,

"If a person who receives a recommendation under the provision of the preceding paragraph does not obey the recommendation, the governor of the prefecture may order him to observe the fuel standard within a prescribed period."

The original fuel standard which was set in 1971 was up-graded in 1976 to a sulfur content ranging from 0.5 to 1.2%. This standard is applied to the factories and business offices located in the 14 areas which are specified under the Cabinet Order; Sapporo, Asahikawa, Sendai, Chiba, Tokyo, Yokohama, Kawasaki, Nagoya, Kyoto, Osaka, Kobe, Amagasaki, Hiroshima and Fukuoka.

5.2.3 Total mass emission control of SO_x

The control system for sulfur oxides has undergone a change from that of concentration control to that of K-value control. Nevertheless, both of these control systems had the following drawbacks:

(a) The system of K-value control, which aims at diffusing the soot and smoke by increasing the height of smoke stacks, may be conducive to improving the highly polluted spots, but it raises the possibility of eventual pollution over much wider areas.

(b) The proven overall behavior of pollutants in an area, where sources of pollutants are highly concentrated, does not conform to the diffusion theory which underlies the system of K-value control.

(c) In cases, where a large number of smoke sources are located over a wide area and where the pollution in individual segments of such an area combines with one another to produce a uniformly high concentration of pollution over the entire area, the answer lies not in increasing the height of smoke stacks but in curtailing the quantity of pollutants.

With a view to remedying such drawbacks, the system of total mass emission control was introduced by a June 1974 amendment to the Air Pollution Control Law and applied to those areas where ambient air quality standards cannot be met with the traditional emission control measures (K-value control in the case of sulfur oxides). This system is designed to ensure the attainment of ambient air quality standards rationally and systematically by curtailing the overall emission of pollutants in a given area to below the calculated permissible total load of pollutants. The method takes into consideration the particular conditions of the area, such as its meteorological and topographical conditions and distribution characteristics of pollutant sources.

Under this system, the government designates, by means of a Cabinet Order, the pollutants (called designated soot and smoke) and the areas (called designated areas) which are subject to control. The governor of the area designated by the Cabinet Order draws up a program for the reduction of total emission of designated soot and smoke, on the basis of which the governor establishes total mass emission control standards applicable to factories and business establishments (specified factories, etc.) which are larger than a certain size. In addition the program includes standards for fuel use (standards for sulfur contents) applicable to factories and business establishments other than the specified factories, etc.

At present, both sulfur oxides and nitrogen oxides are designated as "designated soot and smoke" under the system. Total mass emission control for sulfur oxides is currently applied in 24 areas including almost all major urban and industrial cities of Japan (Fig. 5.2). Together, these 24 areas account for only approximately 3.1% of the nation's land area. However, they account for 31% of the total population of Japan and for approximately 30% of the sulfur oxides emitted.

The term "total mass emission" as used in the context of the total mass emission control does not mean the environmental assimilative capacity; rather, it refers to the permissible total quantity of emission for a given area calculated in such a way as to meet the prescribed ambient air quality standards. For the purpose of the law, the concept of total mass emission is divided into the following four categories:

(1) The total quantity of designated soot and smoke generated as a result of and in the course of all business or other activities of man and emitted into a designated area (actual total emissions).

(2) The total quantity of designated soot and smoke emitted into the air from the soot and smoke emitting sources installed and operating at all specified facilities located within a given designated area (total emissions of all specified facilities).

(3) Such total quantity of designated soot and smoke concerning that referred to in (1) above as calculated by scientific methods in such a way as to satisfy the prescribed ambient air quality standards (targeted total emissions).

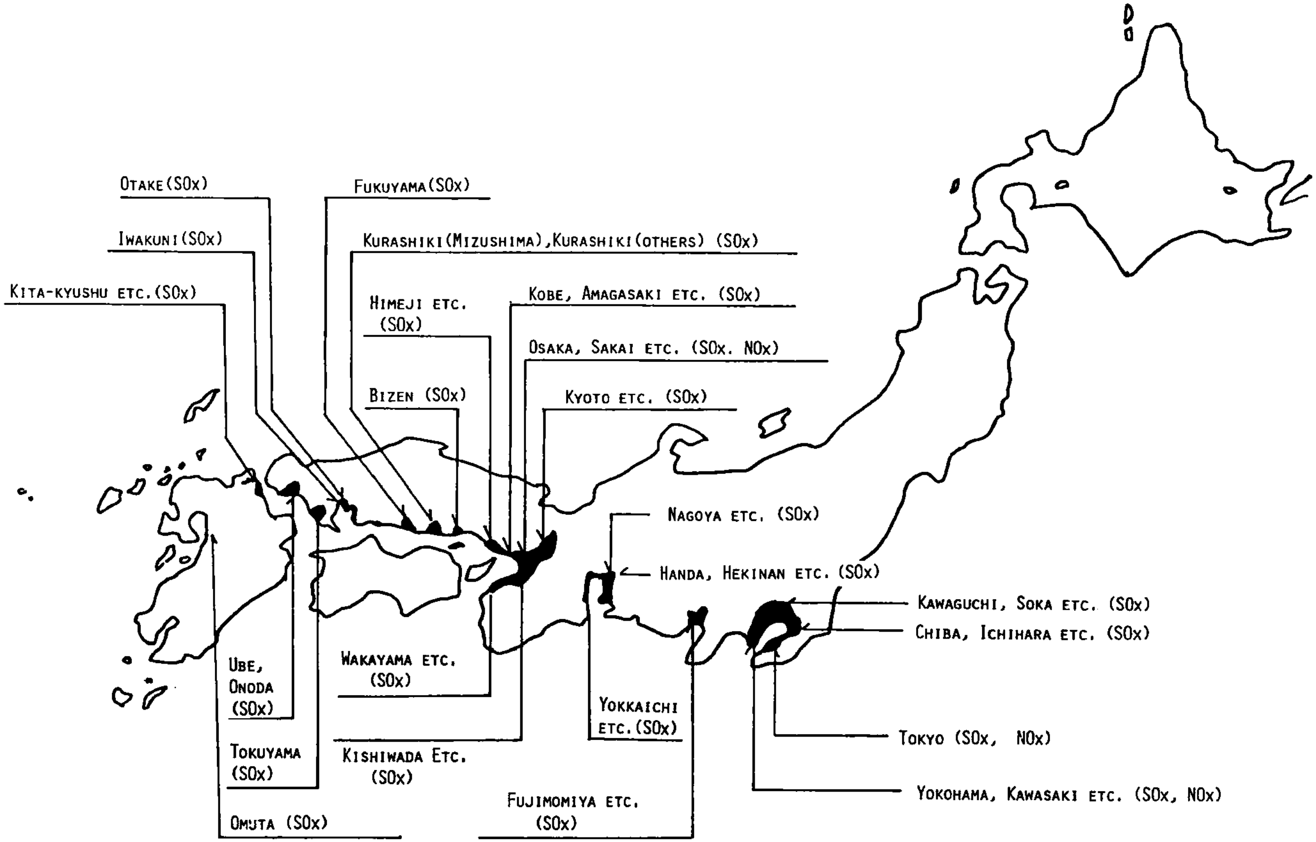

Fig. 5.2. The designated areas for the total mass emission control.

(4) The target quantity to which the total quantity referred to in (2) above is to be reduced (required emission reduction).

The total quantity referred to in (3) above corresponds to the permissible total emission quantity for a given area, and it is calculated on the basis of mathematical diffusion modeling.

An emission reduction plan typically provides for a target quantity (4) by which the total quantity referred to in (1) is to be reduced to that referred to in (3). The plan also specifies an attainment schedule and methods for attaining the target emissions. According to such a plan, the prefecture governor establishes standards for the total mass emission control. There are two methods for determining such standards, but so far only the following formula is used.

$$Q = aW^b$$

where,

Q : permissible emission quantity (Nm^3/h)

W : quantity of fuel used at specified factories

a : constant determined so as to attain the target quantity of reduction

b : constant determined within $0.8 \leqq b < 1$

It is also possible in certain cases, such as when a designated facility is being enlarged or a new designated facility is being constructed, to apply a special total emission standard which is more stringent than the standards applied to existing facilities.

Fuel standards are also set for factories and businesses other than specified facilities which force them to take appropriate control measures. These standards apply throughout the year.

5.3 REGULATION OF NO_x

In 1973 Japan started regulating nitrogen oxides (NO_x). This was about 10 years after the first full-scale SO_x controls and coincided with the first oil crisis. Despite the socio-economic difficulties caused by the oil crisis, Japan started and continued strenuous efforts to abate NO_x pollution arising from both stationary and mobile sources. Thanks to these measures ambient NO_2 levels have gradually and steadily declined throughout the country in recent years. For instance, in Fig. 5.3, where data from 26 monitoring stations reporting continuously since 1965 are shown, a slight upward trend at the beginning has been replaced by generally flat figures in recent years. Similar or more distinct improvement trends can be seen in Table 5.6.

These improvements were produced by advanced combustion technology and by the denitrification of flue gas as well as by fuel conversion. Major aspects

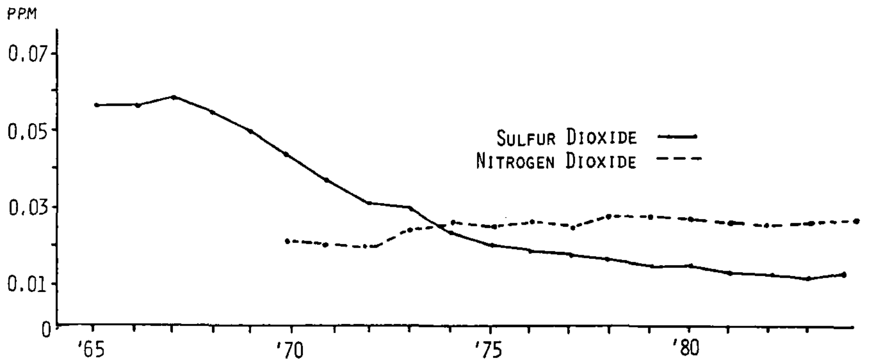

Fig. 5.3. Yearly average concentrations of sulfur dioxide and nitrogen dioxide.

of such technology are listed below.

(1) Low NO_x combustion technique

(i) Improvement of combustion conditions

a) Decreasing air ratio

b) Decreasing air preheating

c) Decreasing heat load of combustion chamber

(ii) Improvement of combustion techniques

a) Using low NO_x burners

b) Two-stage combustion method

c) Flue gas recirculation method

d) Off-stoichiometric (Bias) combustion

Table 5.6

State of compliance with nitrogen dioxide environmental quality standards at general air pollution monitoring stations

Year	1978		1980		1982		1984	
	No. of stations	Ratio (%)	No. of stations	Ratio (%)	No. of stations	Ratio (%)	No. of stations	Ratio (%)
Over 0.06 ppm	75	7.6	44	2.8	25	2.0	43	3.3
Between 0.04 ppm and 0.06 ppm	233	23.8	288	24.4	267	21.4	283	21.7
Under 0.04 ppm	673	68.8	839	71.3	963	76.6	976	75.0
Total	981	100.0	1,169	100.0	1,245	100.0	1,362	100.0

e) Improving combustion chamber design

f) Water or steam injection

g) Using fuel additives

(2) Denitrification of flue gas

As with SO_x control, the regulation of NO_x is based on several policy tools, which include:

(a) setting national uniform emission standards for NO_x and strengthening of the standards in five phases;

(b) total mass emission control;

(c) regulation of motor vehicles.

5.3.1 Emission standards for nitrogen oxides

Nitrogen oxides are pollutants that demand close attention not only because they are harmful to human health but also because of their role in causing photochemical air pollution - so much so that measures designed to control nitrogen oxides have now completely replaced in importance those for sulfur oxides control.

Nitrogen oxides emission standards for facilities which emit smoke and soot were first formulated as regulations for uniform nationwide enforcement in August 1973 on the basis of the Air Pollution Control Law. The first regulations of 1973 were followed by successive measures to toughen the standards in December 1975 (second regulations), in June 1977 (third regulations) and in August 1979 (fourth regulations).

In September 1983, the latest revision (fifth regulations) was made in response to (1) the energy policy which promotes changes from oil to solid fuels such as coal which generate more nitrogen oxides, and (2) technical progress in combustion technology to reduce NO_x emissions. Emission standards for NO_x are very complex; they differ with the type of emitting facility as well as with the volume of flue gas and the date of installation of each facility.

5.3.2 Total mass emission control of NO_x

Nitrogen oxides emission control techniques for stationary sources include stack gas denitrification and low NO_x combustion techniques. The Environment Agency has been continuously following their development since 1975.

Recently, low NO_x combustion technology has been making remarkable progress, effecting considerable reductions of nitrogen oxide emissions by the use of two-stage combustion, low NO_x burners, etc.

Stack gas denitrification techniques have been applied not only to clean gases such as LNG, but also to dirty gases such as heavy oil combustion gas or even to coal combustion gas. The reliability of denitrification has been advanced by techniques such as improved catalyst beds and by solving the problem of acid ammonium sulfate deposition, etc.

Simple non-catalytic denitrification processes have already been put into practical use and have begun to offer an opportunity for process choice depending on the conditions of each facility such as cost efficiency, location, etc.

Total NO_x mass emission control was introduced along with these technological developments after the previous successful application of total SO_x mass emission control. Legally this was made possible by the revision of the enforcement ordinance of the Air Pollution Control Law in June 1981. Three areas of central Tokyo, Kanagawa and Osaka were chosen as "designated areas" for the system.

In these three areas, it was expected that environmental quality standards for NO_2 should be met by 1985 through reductions of 32.0% (Kanagawa), 26.9% (Osaka) and 19.3% (Tokyo) of nitrogen oxides emitted from specified factories by applying the total mass emission control.

The method of total mass emission control of NO_x is, in principle, the same as employed for SO_x. The only differences are as follows:

(1) Because in the case of NO_x, mobile sources such as motor cars are a major source of pollution, mere control of stationary sources does not suffice. Therefore, apart from the total mass emission control, tough measures against mobile sources such as reduction at source and drastic traffic control are necessary.

(2) In the formula to quantify the amount of permissible NO_x discharge from individual stationary sources, not only the formula of $Q = aW^b$ but also $Q = k\,\Sigma(CV)^{\ell}$ is used, here,

Q : Permissible amount of nitrogen oxides emission (unit - cubic meters per hour as converted to the values at a temperature of 0°C and a pressure of 1 atm).

W : Total amount of raw materials and fuels consumed by all soot- and smoke-emitting facilities related to nitrogen oxides in a specified industrial plant, etc., (unit - kiloliters per hour as converted to an amount of heavy oil).

a : Constant prescribed by the prefectural governor so as to achieve the emission reduction target.

b : Constant prescribed by the prefectural governor within the range of not less than 0.80 to less than 1.0 taking into consideration the state of distribution by scale of the specified industrial plants, etc., and the actual conditions of consumption of raw materials fuels within the designated area concerned.

C : Facility coefficient prescribed by the prefectural governor for each type of soot- and smoke-emitting facility related to nitrogen oxides.

V : Amount of gas emission of each soot- and smoke-emitting facility related to nitrogen oxides at a specified industrial plant, etc. (unit - 10 thousand cubic meters per hour as converted to the values at a temperature of 0°C and a pressure of 1 atm).

k : Reduction constant prescribed by the prefectural governor so as to achieve the emission reduction target.

ℓ : A constant prescribed by the prefectural governor within the range of not less than 0.80 to less than 1.0 taking into consideration the state of distribution by scale of the specified industrial plants, etc. and the nitrogen oxides emission characteristics, etc. within the designated area concerned.

5.3.3 Regulation of motor vehicles

Nitrogen oxides emitted from motor vehicles have been regulated since 1973 for gasoline- or LPG-powered motor vehicles and since 1974 for diesel-powered vehicles. A target standard of average emission of NO_x: 0.25 g/km for gasoline- or LPG-powered cars was set in the interim report of October 1972 by the Central Council for Environmental Pollution Control. Regulations approaching this goal were implemented in 1975, 1976 and 1978. The 1978 standard is the most stringent standard in the world.

As a result, the amount of nitrogen oxides emitted from gasoline or LPG-powered passenger cars was reduced by more than 90% from those levels prior to regulation. As the number of motor vehicles conforming to the 1978 regulation increases, the exhaust NO_x emission rate from passenger cars is expected to decrease.

Also, in order to eventually tighten regulations on exhaust gases from trucks and buses, the Central Council for Environmental Pollution Control reported on 26 December 1977, after about two and a half years of studies, on the long-term prospects of reducing the allowable limits of automotive exhaust gases.

Regulations for the first stage targets in accordance with the report became effective in 1979. Also, in order to enforce regulations as soon as possible for the second stage targets indicated in the report, the Investigating Committee for Motor Vehicle Pollution Control Technology was established to assess and review the current development of technology for reducing automotive exhaust gases and to promote technological development.

In response to the first report of the Motor Vehicle Control Technology Committee which was published in April 1979, the second phase regulations on light- and medium-weight gasoline-powered passenger cars were authorized for the 1981 regulations in August 1979. The enforcement began in January 1981 for light-weight gasoline-powered passenger cars and for medium-weight gasoline-powered passenger cars from December 1981.

Again, in response to the second report (published in May 1980), the second-stage regulations on heavy-weight gasoline-powered vehicles, light-weight trucks and indirect injection diesel vehicles were authorized for the 1982 regulations in September 1980. Enforcement started in January 1982 for heavy-weight gasoline-powered vehicles, light-weight trucks and indirect injection diesel passenger cars and in October 1982 for indirect injection diesel vehicles other than passenger cars.

Furthermore, based on the third report (published in May 1981), the second stage regulations for direct-injection diesel vehicles were proposed for 1983. Notification was issued in August 1981, and implementation began in August 1983. After that, the second stage regulations applied to all types of vehicles.

At present, the concentration control applied to diesel passenger cars is the same as that applied to trucks and buses. However, based on the upward trend in the number of diesel-powered passenger cars in recent years, an evaluation study indicated that a change from concentration control to emission load control was needed. Although a target value for emission load was proposed in May 1981 by the committee, the target was meant to be an administrative target to strengthen the regulations. Technical evaluation aimed at achieving the target in a short period is about to proceed.

Because it will take several years for the replacement of aged vehicles by low-pollution vehicles, nitrogen oxides regulations for trucks, buses, etc. will probably not prove effective until around 1985 for the 1979 regulations and around 1990 for the phase-2 regulations.

Other countermeasures as well as vehicle exhaust controls are required for

NO_x air pollution reductions, such as traffic control or improvements of road structures as well as drastic changes in urban transportation modes.

5.4 REGULATIONS OF PARTICULATES, HYDROCARBONS, AND OTHER TOXIC SUBSTANCES

5.4.1 Soot and dust and other particulates

Particulate matter in the ambient air is divided into two classes; dustfall and suspended particulate matter. Suspended particulates fall into two categories: suspended particulate matter less than 10 μm in diameter and other suspended particulates. Environmental quality standards, however, have been set only for suspended particulate matter less than 10 μm diameter.

The sources of such particulate matter are found in various areas, including industrial activities, such as factories or workshops, as well as motor vehicle traffic and naturally, such as soil matter raised by the wind. The Air Pollution Control Law regulates the particulate matter emitted from industrial activities in factories or workshops. This controlled particulate matter is classified into two categories under the law; one is "soot and dust" generated by combustion of fuels or other substances, or by using electricity as a heat source, and the other is "particulates" emitted or dispersed by crushing, grading or other mechanical operations or piling. The Air Pollution Control Law and other regulations also control the particulate matter emitted by motor vehicles such as black diesel smoke.

(i) Regulations against soot and dust. Emission standards for soot and dust are specified for each type and size of dust emitting facility. More stringent specified standards are stipulated for newly installed and expanded facilities in regions where clustered facilities create severe air pollution.

The partial amendments in the regulation for the implementation of the Air Pollution Control Law were promulgated in May 1982. The emission standards for soot and dust were strengthened to cope with changes in energy utilization, to keep pace with major developments in emission control technology and to contribute to the further control of suspended particulate matter.

The gist of the revision is as follows.

(a) The utmost emphasis was laid on revising emission standards for coal-burning boilers. The allowable limits were reduced by nearly halving the pre-revision values for boilers burning heavy oil and other liquid fuels.

(b) Standards for other facilities were also strengthened. The emission standards on other facilities discharging soot and dust were wholly revised. In general most emission limits were reduced to about 50% below the pre-revision levels. The new special emission standards, covering new facilities installed in nine highly polluted areas, including the 23 wards of Tokyo, were set at levels which can only be achieved by adopting sophisticated soot- and dust-control technology, which is now spreading. These standards were also strengthened to about 50% below the pre-revision levels.

(c) A standard oxygen concentration adjustment formula for soot and dust was introduced where its use was deemed appropriate in the light of the mechanisms whereby soot and dust are generated. This measure was taken to prevent polluters from diluting gas emissions to meet the standards and also to ensure fairness in enforcing controls.

(d) New emission standards for soot and dust were set for seven categories of facilities generating smoke and soot, including coke ovens and electrolytic furnaces for aluminum smelting. No emission standards for soot and dust had previously been in force on these facilities.

(e) This revision was put into effect on 1 June 1982. The new standards were immediately applied to new facilities. Previously existing facilities were spared the enforcement of the standards until 30 June 1984.

(ii) Countermeasures against particulates. Standards covering the structure, use, and management of particulate-generating facilities, such as conveyors and crushers were established in 1971.

In view of the increased use of coal and other solid fuels it is anticipated that the standards will be strengthened a little bit further.

(iii) Countermeasures against suspended particulate matter. Since the ambient air-quality standard for suspended particulate matter was established in January 1972, the compliance ratio for the standard remained exceedingly low until 1980. Although the rate has begun to rise in recent years (63% in 1983), it is still far from satisfactory. The establishment of countermeasures was begun in 1981. A 4-year investigation and survey was started to obtain results regarding the controls at the emission source, influence of emissions on the environment and results of improvement of the environment obtained by the implementation of countermeasures.

(iv) Countermeasures against black diesel smoke. Regulations regarding black smoke emitted from diesel-powered vehicles were put into effect in 1972 for new cars, and in 1975 for cars already in use.

Because of the recent upward trend in the number of diesel-powered vehicles, surveys were started in 1980 on actual pollution along roadsides caused by diesel exhaust gases and their effects on human health.

The recent increase in the number of vehicles with studded tires in winter has prompted the Environment Agency to conduct a survey on the environmental impact of dust generated by studded tires.

5.4.2 Countermeasures against photochemical air pollution and regulations of hydrocarbons

Photochemical air pollution is caused by a series of very complicated reactions in which the secondary pollutants of photochemical oxidants, consisting mainly of ozone, are generated from a mixture of air, NO_x, and HC irradiated by sunlight. During every summer since 1970, cases of tangible health damage have been observed. These are characterized by symptoms of irritated eyes, sore throats and sensations of suffocation, most likely caused by photochemical air pollution.

The government established the "Conference for Promotion of Photochemical Smog Control Measures," consisting of representatives of 12 government ministries and agencies in June 1972 in order to advance effective and comprehensive measures against air pollution by photochemical oxidants. In July of that year it reported "Promotion of Photochemical Smog Control Measures" which was a series of interim measures to be executed quickly and basic measures for long-term implementation. The conference decided on "Guidelines for Photochemical Smog Control" to establish more specific measures in April 1975. The Environment Agency has taken action and has conducted a series of surveys and investigations according to these suggestions. It established environmental quality standards for photochemical oxidants in May 1973. Incremental measures have been taken by the agency to tighten the regulation of NO_x emissions from factories, business establishments and automobiles and of HC emitted from automobiles.

The local authorities have adopted emergency guidelines for photochemical oxidant excesses in accordance with Article 23 of the Air Pollution Control Law. They issue photochemical forecasts, warnings or alarms according to observed concentrations of photochemical oxidants and weather conditions.

(i) Present state of photochemical air pollution. Warnings of photochemical oxidant excesses are issued when the hourly values of photochemical oxidants exceed 0.12 ppm and when polluted conditions are expected to continue based on meteorological observations. Warnings were issued on a total of 171 days in 16 prefectures during 1985, which was a significant increase over the period from 1979 to 1982. In those years, less than 100 warnings were issued during each year because of low temperatures in summer and long lasting rainy seasons (Table 5.7).

The breakdown of days with warnings by month for 1985 is one day in April, 19 days in May, 28 days in June, 64 days in July, 45 days in August, 13 days in September and one day in October. The number of warnings were largest in July and August reflecting meterological conditions favoring oxidant formation.

There have been no oxidant alarms issued since 1979. (An alarm is issued when the hourly values of oxidant concentration exceed 0.24 ppm and this condition is likely to continue based on meteorological conditions.)

(ii) Photochemical air pollution forecasts and emergency countermeasures. To obtain the meterological data necessary for the judgement of issuing emergency reports (warnings and alarms), the Environment Agency conducts weather observations every summer in 10 locations of four regions, Tokyo Bay, Ise Bay, Osaka Bay and Seto Inland Sea where the photochemical air pollution is a problem. This meteorological information is shared with local authorities. Meteorological conditions which are likely to threaten photochemical air pollution are forecast and analyzed by the Meteorological Agency at eight air pollution meteorological centers, 11 meteorological centers and 11 meteorological stations. These forecasts are reported to local government. The local governments issue warnings or alarms based on this information together with data from their own monitoring stations in accordance with local guidelines for emergency measures against photochemical oxidants. They may also request voluntary efforts to reduce the emission of air pollutants from stationary sources and voluntary restraint of non-emergency car use. They also provide public information and health care for residents.

(iii) Promotion of research and study on photochemical air pollution. Photochemical air pollution is a very complicated phenomenon with diverse aspects. Surveys of photochemical pollution cover a wide range of fields including: mechanisms of photochemical reactions; meteorological effects such as transport and diffusion; and emission of causal pollutants. Predictive models of photochemical air pollution incorporate these factors as well as the

Table 5.7
Number of days with warnings issued and reported victims (1979-1985)

Year	1979	1980	1981	1982	1983	1984	1985
Number of days with warnings issued (days)	84	86	59	73	131	135	171
Number of reported victims (persons)	4,083	1,420	780	446	1,721	5,822	966

effects of secondary pollutants on human health and of photochemical oxidants on vegetation. Surveys conducted to date have already revealed much about the nature of this difficult problem.

Laboratory research is being conducted in parallel exploring the mechanisms of photochemical reactions - photooxidation reactions in the ambient atmosphere are studied using movable smog chambers. Photochemical reactions of the HC - NO_x - wet air system are studied using large smog chambers located at the National Institute for Environmental Studies. This research is steadily accelerating our theoretical understanding of the details of photochemical reactions. Such efforts are allowing more accurate prediction of smog processes.

On the other hand, observation of the upper atmosphere is being conducted by using pilot balloons and radiosondes. Analytical studies of the relationships between pollutant concentrations and meteorological conditions on the ground surface and of the contributions of meteorological conditions to photochemical air pollution are also in progress, since knowledge of photochemical pollution in the actual environmental atmosphere is very important.

Researchers have developed a physicochemical model which can quantitatively reproduce concentrations of photochemical oxidants occurring in smog events. This model is based upon photochemical reaction models obtained from the above-mentioned studies. Data on pollutants and meteorological states in the upper atmosphere, data on the emission of primary pollutants and data on surface meteorological conditions are provided by daily monitoring. The research, which was started in 1975, has allowed increasingly accurate prediction of photochemical pollution occurring during particular summer days in the Tokyo Bay region. These achievements will support the emergency reporting system allowing improved control of regional photochemical air pollution.

(iv) Control of hydrocarbon emissions.

a. Control of hydrocarbons emitted from stationary sources

The importance of controlling HC, emitted from stationary sources has been pointed out in the "Guidelines for Photochemical Smog Control in the Future" reported both by the Conference for Promotion of Photochemical Smog Control Measures in April 1975 and in the report of the Central Council for Environmental Pollution Control in August 1976.

The Environment Agency established an expert study group for reviewing HC control of stationary sources in November 1979. The agency has conducted surveys on HC emissions and has evaluated emission control techniques since then. It adopted "The Promotion of Countermeasures for HC to Prevent Photochemical Pollution" based on the results of the survey of July 1982 in order to strengthen the control of HC emitted from stationary sources. The report evaluated the present state of HC emitted from stationary sources and emission control techniques and determined the direction of the measures to be taken.

The Environment Agency, in July 1982, requested local government authorities and related organizations to promote measures for emission control, and in March 1983, requested them to collect and organize data on stationary HC sources. It is anticipated that HC emissions from stationary sources would be much more effectively controlled by the use of such data.

b. Control of hydrocarbon emission from motor vehicles

Controls of HC emissions from motor vehicles consist of regulations on: 1) blow-by gas (an unburnt mixture of gas and air, which is emitted from the space between the piston and the cylinder; its major components are HC) from gasoline- and LPG-fuelled motor vehicles in 1970; 2) fuel vapor in 1972; and 3) HC emitted from the exhaust pipe of diesel-powered vehicles in 1974. Regulations for passenger cars, light- and medium-duty gasoline-fuelled vehicles and light cargo vehicles were all tightened in 1975.

As a result, the amounts of HC emitted from regulated passenger cars were reduced by 92% compared to preregulated cars (Fig. 5.4). The amounts of HC emitted from light- and medium-duty gasoline-fuelled vehicles, light cargo vehicles, heavy-duty gasoline-fuelled vehicles and diesel-powered vehicles were reduced by 65%, 52%, 52% and 10%, respectively, compared to those under no regulations.

5.4.3 Emission standards for toxic substances

In addition to NO_x, the Air Pollution Control Law designates the following four groups of substances as toxic substances generated from soot- and smoke-emitting facilities and stipulates control of their emission levels; (1) cadmium and its compounds, (2) chlorine and hydrogen chloride, (3) fluorine, hydrogen fluoride and silicon fluoride, and (4) lead and its compounds.

Standards are set for each of the four groups of toxic substances only, and

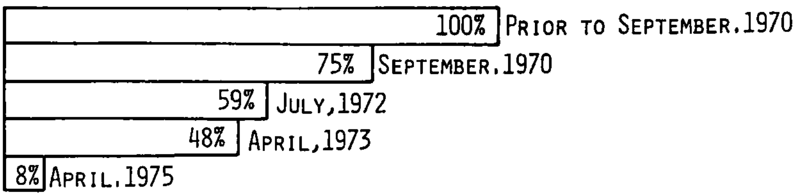

Fig. 5.4. Regulation of hydrocarbons emitted by passenger cars.

are applicable to a very limited number of soot and smoke emitting facilities. For instance, in the case of cadmium and its compounds, the emission standard is 1.0 mg/Nm^3, and as for lead and its compounds, the standard is 10 - 30 mg/Nm^3, depending on the type of furnace.

5.4.4 Regulation of carbon monoxide

Carbon monoxide (CO) emitted from automobiles was first regulated in 1966. Emission levels have been progressively reduced since then. Full-scale controls for three major pollutants (CO, NO_x, HC) were applied to gasoline- or LPG-powered vehicles in 1973, and to diesel-powered vehicles in 1974, both of which strengthened the CO standards. Thanks to the remarkable progress in engine technology including devices such as three-way catalysts, more stringent CO standards were applied to light/medium duty gasoline-powered passenger cars in 1975. This has reduced emission levels by 90% compared to the level of non-regulated vehicles.

This is reflected in the decline of average annual CO values recorded at 15 motor vehicle exhaust monitoring stations which have been taking measurements at roadsides continuously since 1971. Annual average values have fallen each year from a level of 6.0 ppm in 1971 to a level of 2.5 ppm in 1984 (Fig. 5.5). All the 293 roadside stations throughout the country met the ambient quality standard for CO in 1984.

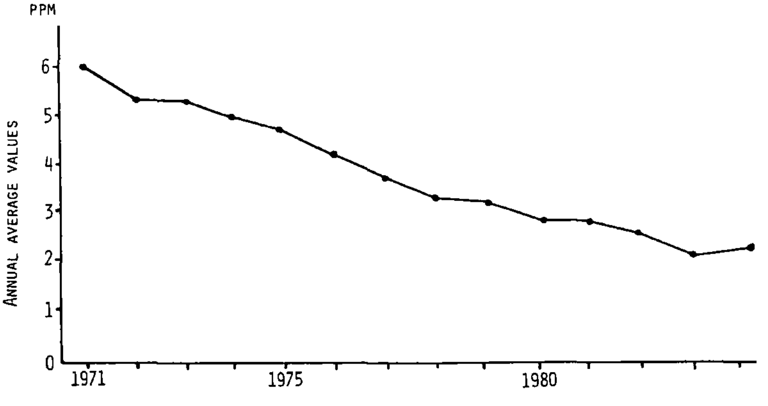

Fig. 5.5. Changes in annual average concentrations of CO.

5.5 UNIQUE EFFORTS BY LOCAL GOVERNMENTS AND INDUSTRY

In Japan, the fight against pollution was initiated and advanced rapidly by certain local governments where pollution problems surfaced in the early days and needed to be solved urgently without waiting for the eventual enactment of nationwide legislation. During this process, local governments devised a variety of effective instruments, some of which were later codified by the central government. Among them are: (1) the setting of stricter emission standards by the local government, and (2) the setting of emission standards by the local government for some pollutants which are not subject to control by national laws.

Japanese industry in general has also responded to the need to improve the environment in very positive ways. They have shown grave concern for environmental protection by concluding agreements with local governments leading to the stricter implementation of various environmental regulations.

Major factories in Japan must now have, by law, their own special departments for pollution control supported by highly educated and skilled personnel. The government conducts an annual national examination to certify competent persons for pollution control work in industry.

In this section such unique systems at both the local government level and in industry will be discussed.

5.5.1 Legislation by local governments

Administratively the Japanese Islands are divided into 47 prefectures and each prefecture is made up of municipalities (cities, towns and villages). In total we have some 3,250 municipalities across the country. "Local governments" are either prefectural or municipal. Each prefecture and each municipality, regardless of its size, must have its own legislative body, all members of which are directly elected by local people. Under the constitution of Japan, any legislative body of the prefecture or municipality can enact an "ordinance (by-law)", but the contents of these must conform with national laws.

Environmental problems, in most cases, are first perceived as local problems with different aspects due to natural conditions such as topography and climate, and social conditions such as population structure and the extent of industrial development. Therefore the local government is almost always the first to face the problem and is charged with the task of solving it, or at least trying to solve it, especially when there are no applicable national laws.

Under such circumstances, the local government has always been in a position to take the initiative in the fight against pollution. To do so legally it has needed ordinances approved by its legislative body. For instance, in Tokyo, as early as 1949, the Industrial Pollution Control Ordinance was enacted and various measures based on the ordinance were taken, although the measures were not strong enough in many respects. This action by the Tokyo Metropolitan Government was followed by similar legislative actions in the Osaka Prefecture in 1950, the Kanagawa Prefecture in 1951 and in many other prefectures and municipalities later on. By now, all prefectures and all major municipalities have enacted very effective pollution control ordinances. To implement measures embodied in the ordinances and measures required by national laws, most local governments have set up special departments for pollution control.

As of 1 October 1985, prefectural governments have a department (division) or a section (office) responsible for pollution control variously named, together with pollution monitoring centers, pollution research institutes and similar organizations. In addition, health centers have also been involved in environmental administration together with the Agriculture and Forestry Offices and prefectural offices. Prefectural offices have a total of 7,054 personnel in charge of pollution control.

As of 1 October 1985, the number of municipal governments which had a department (division, section, office) responsible for pollution control was 155. Municipal governments which provided a group responsible for pollution control numbered 473. Municipal governments which had only full-time officials responsible for pollution control numbered 368, the total of these amounted to 30.5% of all municipal governments. In addition, the number of municipal governments which had either a pollution monitoring center or a pollution research institute was 49. The number of municipal full-time personnel in charge of pollution control was 6,268.

Ordinances enacted by local governments for environmental conservation can be largely classified into the following four categories: 1) ordinances for pollution control; 2) ordinances for environmental conservation; 3) ordinances for nature conservation; and 4) other ordinances concerned with environmental conservation (including ordinances for environmental impact assessment).

Ordinances for pollution control indicate that the basic attitude of the local government toward pollution control is important for systematically promoting practical measures for pollution control in local areas. All prefectures have enacted ordinances for pollution control.

Ordinances for environmental conservation are basic regulations for local governments to achieve integrated environmental conservation. As of 1 October 1985, seven prefectures and one ordinance-designated city have such ordinances.

Ordinances for nature conservation indicate the basic guidelines for local governments to conserve the natural environment, and have been enacted by all 47 prefectures.

Other ordinances for environmental conservation include ordinances for natural parks, controlling quarries and conserving prefectural land. They also include ordinances for maintaining green space in the environment, ordinances for the taking of subterranean water, ordinances for the control of scattered empty cans and ordinances for the prevention of eutrophication of lakes. In addition, ordinances for environmental impact assessment have recently been appearing.

As such, it may be safely said that the state of enactment of ordinances by local governments is extensive and satisfactory, but it seems to me more important to note again that in Japan the ordinance is not just a copy of a national law but it supplements it or even provides stricter control of pollution. In the case of air pollution control, in Article 4 of the Air Pollution Control Law, it states as follows:

> "1. In case any prefecture recognizes that the existing emission standards prescribed under Paragraphs 1 and 3 hereof with respect to soot and dust and toxic substances are inadequate to protect public health or conserve the living environment from the natural and social conditions in a part of its area, it may establish by a prefectural ordinance in accordance with the provisions of the Cabinet Order, a stricter emission standard with respect to such pollutants generated by soot- and smoke-emitting facilities in the part of the area, which supersedes the maximum permissible limits under the provision of Paragraph 1 of the preceding article.
>
> 2. The prefectural ordinance referred to in the preceding paragraph shall clarify the range of such an area.
>
> 3. If any prefecture establishes an emission standard under the provisions of Paragraph 1, it shall notify in advance the Director General of the Environment Agency."

In Article 32 of the same law, it is also stated that

> "The provision of this law shall not prevent the local governments from instituting necessary regulations by ordinances on the emission into the air of substances other than soot and smoke generated by soot- and smoke-emitting facilities, the emission into the air of soot and smoke generated by facilities other than soot- and smoke-emitting facilities, and the discharge or

scattering into the air of particulates generated, discharged or scattered by facilities other than particulates emitting facilities."

Thanks to these articles in the law, in Japan local governments are very well equipped with legislative powers.

5.5.2 Concluding pollution control agreements with industry

Apart from legislative power, local governments came up with one more very unique and effective tool to constrain pollution, viz. through agreements with the private companies concerned. This control system by way of "agreement" was first introduced when the city of Yokohama was about to sell its newly reclaimed offshore land in Isogo to two electric power companies which had intended to build their thermal power plants on the land to meet the ever-increasing demand for power supply in the high economic growth period of the 1950s.

The city of Yokohama, in the negotiation process of selling its reclaimed land as a site for the location of power plants, put forward to the companies a number of conditions for pollution prevention, which were far more stringent than the current regulations under both national laws and local ordinances. Because the site was so close to residential areas, nearby residents had strongly demanded that the city take a hard line on this issue. There was very strong public opinion supporting the city as well as citizens' movements which were rampant in those days. After heated and serious negotiations, the city succeeded in getting the companies to accept the conditions in the form of an agreement in late 1964, which was signed by the mayor and the presidents of the two power companies.

Legally this agreement was neither a law nor an ordinance. It was just a gentlemen's agreement concluded between the mayor and the representatives of private companies. But in effect, it functioned like a legally binding agreement and it forced the companies to take all necessary pollution control measures as promised. For example, the agreed emission control levels for the Isogo Thermal Power Plant of Electric Power Development Co., Ltd., one of the signatories to the agreement, are shown with other relevant information in this matter in Table 5.8.

As the case of Yokohama turned out to be a big success, this "agreement system" spread rapidly to other parts of Japan including almost all types of new industrial development, viz. the location, relocation or expansion of plants.

Factories and other business premises which have concluded agreements of pollution prevention number 25,658 as of 1 October 1984 showing an increase of 1,531 over the previous year.

[For information about the Isogo Plant]

1. Address	:	Shin-Isogo, Isogo-ku, Yokohama City
2. Output	:	Unit No. 1 265,000 kw
		Unit No. 2 265,000 "
3. Month and year of start of commercial operation	:	Unit No. 1 May 1967
		Unit No. 2 September 1969
4. Land area	:	Total area 121,290 m^2 (Including coal stock yard of 20,700 m^2)
5. Power product	:	Gross 3,732 x 10^6KWH (Fiscal year 1982)
		Net 3,366 x 10^6 KWH (")
6. Capacity factor	:	80.4%

7. Fuel

Main fuel

Coal	Consumption quantity: 1,353 x 10^3 t (Fiscal year 1982)
Mining site	Calorific value: 6,200 kcal/kg
Hokkaido	
Kyushu (Miike coal)	Sulfur content: less than 0.6%

Auxiliary Fuel

Heavy and light oil	Consumption quantity: 42 x 10^3 kl/2 unit/year (Fiscal year 1982)
	Calorific value: 9,700 kcal/l
	Sulfur content: less than 1.0%

8. Water

Industrial water	Approx. 3,000t/Day (Average)
Re-use (from Wet FGD)	Approx. 500 " (ditto)

9. Ash disposal

Ash disposal	212×10^3 t/2 unit/year
	(Fiscal year 1982)
Ash quantity for re-use	202×10^3 t/year
	(ditto)
Cement raw material	105×10^3 t/year
Cement mixture material	93×10^3 "
Raw material for fertilizer of potassium silicate	4×10^3 "
Reclamation	10×10^3 "
	(Fiscal year 1982)

10. Gypsum

Product	44×10^3 t/year
Quantity for re-use	44×10^3 "

The number of agreements concluded on pollution prevention has continued to increase probably because 1) agreements on pollution prevention enable the concerned parties to take the proper measures suitable to the geographical conditions and social situations of the local communities and 2) managers of plants are likely to encounter obstacles durng operation unless they obtain the consent of local residents when selecting sites.

The details of agreements on pollution prevention are as follows. The most frequently listed pollution is water pollution. A total of 51.5% of the establishments maintaining agreements include water pollution in their control programs.

Table 5.8

Comparison of strictness by control systems

	Agreed upon levels	National/Local regulation levels
SOx	60 ppm	K = 3.0 ⟶ 200 - 240 ppm TMEC 100 ppm
NOx	159 ppm	480 ppm TMEC 184 ppm
Soot and dust	$0.05\ g/Nm^3$	$0.4\ g/Nm^3$

Note: TMEC stands for Total Mass Emission Control Prescribed by the Kanagawa Prefectural Government

These agreements on pollution prevention have been increasing recently, and are often concluded with local residents participating as one of the parties along with local governments, or alternatively as observers. Such agreements numbered 1,419 as of 1 October 1984, and agreements on pollution prevention made between citizen's groups and industries numbered 3,131.

Agreements on pollution prevention which provide for: 1)restriction of operation; 2)compensation for pollution caused by establishments; 3)liability without negligence; and 4)compensation or spot investigation to ensure the effectiveness of the agreements are increasing in number.

5.5.3 Efforts made by industries

The rapid and remarkable improvement in Japan's environment was brought about by a number of factors, such as increasingly stringent legislation, rigorous implementation by both national and local governments, strong support from the general public and mass media, legal actions in courts of law and structural changes in the industrial structure and energy supply systems. But it is without doubt that Japanese industry as a whole responded very positively to the threatening crisis in the environment in the 1960s and early 1970s, and without such active participation on the part of industry, the environment would now be far less agreeable for the Japanese.

(i) Investment in pollution control facilities. Private business has made enormous investments in the installation of pollution-control equipment and process change. Pollution control investments showed a downtrend after hitting a peak in 1975, but from 1980 they have grown gradually (Fig. 5.6). Installation of primary pollution control equipment began with the introduction of direct heavy-oil-desulfurization equipment followed by indirect heavy-oil-desulfurization equipment. Heavy-oil-desulfurization devices were rapidly installed from the latter half of the 1960s, and now most oil refineries are equipped with them. Installation of stack-gas-desulfurization equipment made rapid headway from the latter half of the 1960s, though the installation rate had somewhat slowed down in the latter half of the 1970s. Such extensive adoption of desulfurization equipment contributed substantially to the decline of sulfur oxide levels in the ambient air (Fig. 5.7).

The installation of stack-gas-denitrification equipment also progressed rapidly from the latter half of the 1970s (Fig. 5.8).

(ii) Technological development for pollution control. Since the 1960s the Japanese private sector has made every effort to apply scientific and technical advances in environmental protection, whether they are of domestic or foreign origin. In fact a number of technical seeds were imported from the United States and Western Europe but, in many cases, it is in Japan where such technology has been developed to levels of highly reliable and efficient

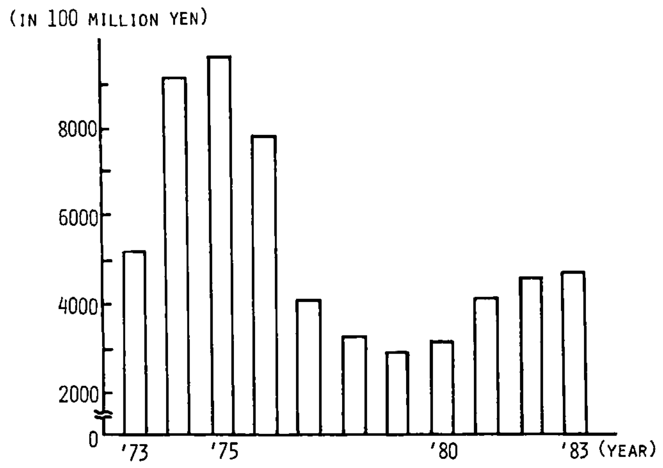

Fig. 5.6. Trends of pollution control investments by major private enterprises.

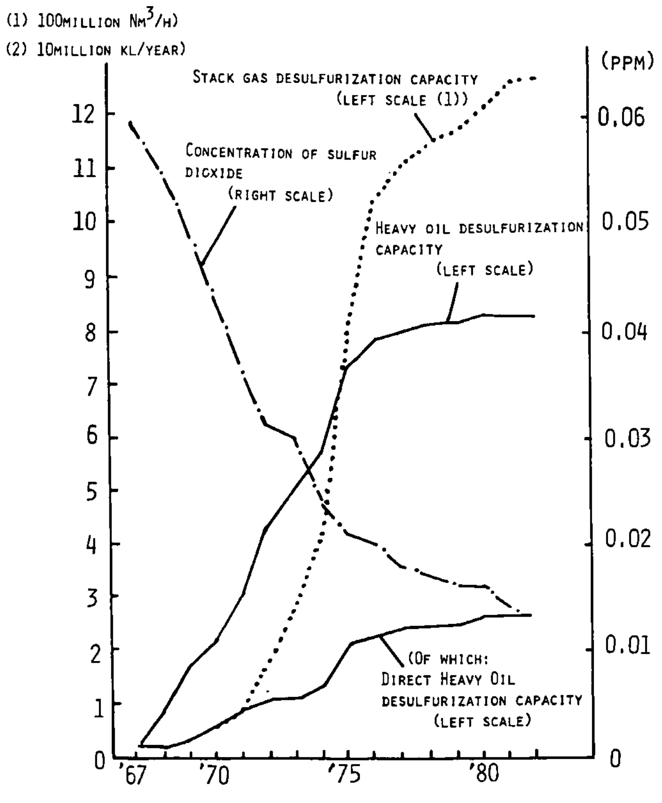

Fig. 5.7. Desulfurization capacity and concentration of sulfur dioxide.

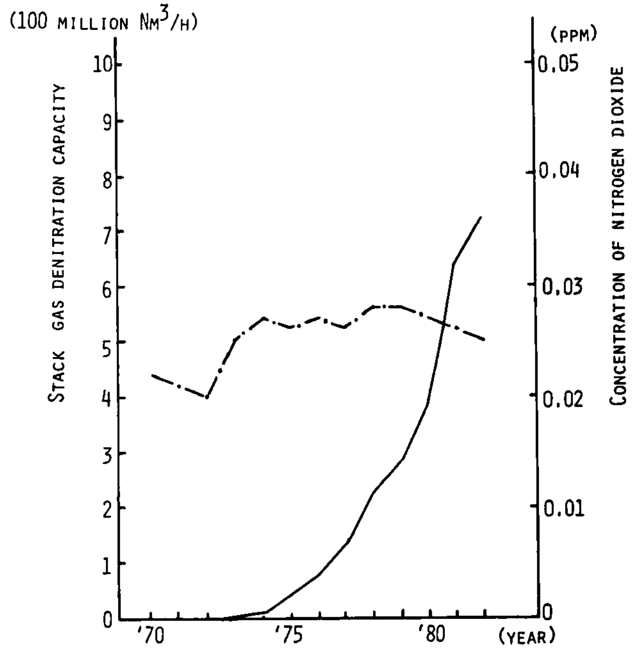

Fig. 5.8. Denitrification capacity and concentration of nitrogen dioxide.

commercial use. Such examples can be seen in a variety of technical fields such as automatic and continuous monitoring devices for air pollutants, telemetering techniques, desulfurization of fuel oil as well as flue gas, three-way catalysts used for motor vehicles, boiler combustion techniques and denitrification of flue gas.

Japanese industry has taken a decisive role in the development and implementation of all these advanced techniques. In this way, further promotion of technological innovation and its commercialization for higher levels of pollution control will continue in Japanese industries.

(iii) Establishment of the pollution control systems in factories. In order to prevent industrial pollution, it is also essential to improve pollution control systems in industrial plants. For this purpose, the Law for the Establishment of Organization for Pollution Control in Specific Factories was enacted in June 1971 to oblige entrepreneurs, from September 1972, to appoint pollution control superintendents to manage operations for pollution control in specific factories. These pollution-control managers must be equipped with specialized knowledge and skills for pollution-control. About 19,000 specific factories have built up their pollution-control systems with such specialists. In 1976, vibration-control managers were newly added.

The statistics of pollution-control superintendents and pollution control managers, from prefectural surveys show that, as of the end of March 1982, pollution-control superintendents numbered about 11,500 and the number of proxies was 11,000. Pollution-control managers, etc. numbered about 21,000, while proxies numbered 19,500.

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