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Reduction in SO₂ and NO₂ Emissions from Stationary Sources in Japan

Helmut Weidner

1. Introduction

The road from the ecological ignorance of the government and industry in Japan to the active antipollution policy that made Japan a pace-setter, especially in air pollution control policy, was long and, for the population, often painful. There is no other industrial country in which so many diseases and deaths in the 1950s and early 1960s were so obviously attributable to such a variety of sources of environmental pollution. The country's economic growth policy earned a world-wide notoriety through the Minamata and Itai-Itai diseases, both caused by toxic compounds that industrial plants had discharged into water bodies. Starting in the late 1960s, the country's conservative government reacted in a variety of ways and by a multitude of means, achieving results in short and medium-term air pollution control that were outstanding by international standards.

However, neither the Japanese government (or the famous power triangle: politicians of the then ruling party, central bureaucrats, industrial leaders) nor the conventional regulatory instruments that were enacted had the most decisive influence on the improvements. Actually, it was a complex combination of various flexibly managed regulatory policy instruments, the use of "meta-instruments" (e.g. liability laws, negotiation procedures, information systems), political pragmatism, the capability of reaching consensus among strategic groups with respect to environmental targets, tremendous political pressure (and, related to this, increasing "political costs") on the government and industry from the environmental movement as well as innovative behaviour by local administration – to mention only the most important factors.

After World War II, Japan experienced rapid economic development and a sharp increase in energy consumption, especially if the figures were considered per unit of habitable land: only one third of Japan's approximate surface area of 370,000 km² is habitable, about 60% of the population living on 13% of the total land area. Between 1955 and 1974, the Gross National Product (GNP) showed a 5.4-fold increase at an average growth rate of nearly 9% annually. This high rate of economic growth was accomplished through a high concentration of industry

and population, principally in the three big agglomeration areas of Tokyo, Osaka and Nagoya from the 1950s onwards.

The Japanese government's economic policy centered on heavy industry and petrochemicals, the preferred strategy at that time being to promote the establishment of large complexes of (interrelated) oil refineries, petrochemical and power plants (*kombinatos*), and of heavy industry in general.

Rising energy demand, changing industrial structure, the fuels used and the extremely weak national regulations on air pollution control led to a dramatic increase of emissions in "classical" air pollutants, such as SO_2 , NO_2 and particulates. The effects were extremely high air pollution levels of these pollutants in urban agglomerations and industrial growth zones, increasing smog incidents, damage to nature and to human health.¹

The development of air pollution in the city of Yokkaichi provides a good example for the situation at that time. It had become notorious for a dramatic increase in respiratory diseases due to air pollution. These diseases were called "Yokkaichi asthma" (*Yokkaichi Zensoku*). The sharp increase in respiratory ailments provided empirical evidence for hitherto more diffuse fears among the public that these *kombinatos* were a threat to health and the environment. In 1965 the city government established a Medical Relief Programme for Pollution-Related Diseases, including financial support for officially certified air pollution victims. Court action against polluting enterprises and increasing opposition against industrial expansion – both successful – were the result. All of this makes Yokkaichi a cornerstone for the changes in Japan's environmental policy. Private and public development projects were rejected with the slogan "no further Yokkaichis". The successful opposition against the construction of the nation's largest industrial development project in the area of Mishima and Numazu, considered by the government as a basic element of its overall industrial policy, was the first major domestic challenge to its postwar economic policies, and came as a shock to the bureaucracy, big-business leaders and leading members of the Liberal Democratic Party, the then ruling party.

Criteria for Selecting SO_2 and NO_2

SO_2 and NO_2 abatement measures at stationary sources were chosen as the topic for this contribution for the following reasons:

In the 1960s, air pollution by stationary sources became the central target of the national outcry against environmental pollution. It was also (especially SO_2) at the focus of one of the four major environmental pollution trials that were all

1 For a general overview on the development of environmental policy in Japan cf. Huddle, Reich & Stiskin 1975, Gresser, Fujikura & Morishima 1981, Miyamoto 1987, Tsuru & Weidner 1989.

won by the plaintiffs – the pollution victims. On the other hand, rising SO₂ and NO₂ emissions – in view of the little developed pollution abatement technology of the time – were almost inseparably linked to the economic growth strategy pursued, which called for huge amounts of emission-intensive fuels. Strict environmental measures met with fierce opposition from the most powerful economic and political groups in Japan. Despite these fundamentally unfavourable preconditions for substantial change, Japanese industry and power plant operators reduced SO₂ and NO₂ emissions from stationary sources within a relatively short period of time; after the first oil crisis of 1973 these – both nationally and internationally – outstandingly high reduction rates did not drop for quite a long period. Negative impacts of the air pollution abatement measures on economic growth, employment, currency stability, overall technological progress and export rates are either unknown or very slight. These achievements were made about 10 to 15 years earlier than in other advanced industrial countries competing with Japan in the world market. They stimulated abatement measures in other countries by strengthening the arguments of pro-environmental groups.

Table 1: Sulphur and Nitrogen Oxide Emission Volume per Habitable Area in Three Regions 1955 and 1971 (unit: t/km²)

	Sulphur Oxide		Nitrogen Oxide	
	1955	1971	1955	1971
Kanto Littoral Region	18.3	165.2	2.3	68.3
Tokai Region	8.4	71.7	1.0	27.4
Kinki Littoral Region	27.8	188.2	3.0	61.1
Total of the Three Regions	16.2	131.3	1.9	49.8
National Average	6.6	45.6	0.6	17.0

Source: Environment Agency, Quality of the Environment in Japan 1974 (no date, no place), p. 43

Table 2: SO_x Emissions by Sector in 1,000 t/a

Sector	Energy Conversion:			Final Energy Consumption:					Energy Consumption Total	Various Others ¹⁾	Grand Total
	Total	Power Generation	Others	Total	Industry	Transport	Road Traffic	Others			
Year											
1975	829	631	198	1,628	1,225	223	77	180	2,457	114	2,571
1980	460	350	110	984	595	253	117	136	1,444	160	1,604
1985	288	202	87	770	430	232	141	108	1,058	117	1,175
1987	274	197	78	711	350	254	168	108	985	158	1,143

Annual Average Change in %

75-80	-11.1	-11.1	-11.1	-9.6	-13.4	+2.5	+8.7	-5.4	-10.1	+7.0	-9.0
80-85	-8.9	-10.4	-4.7	-4.8	-6.3	-1.7	+3.9	-4.6	-6.0	-6.1	-6.0
85-87	-2.4	-1.2	-5.3	-3.9	-9.8	+4.7	+8.5	-0.2	-3.5	+16.2	-1.3
75-87	-8.8	-9.3	-7.5	-6.7	-9.9	+1.1	+6.7	-4.2	-7.3	+2.8	-6.5

1) Non-metal refining, sulphuric acid manufacturing

Source: Energy Utilization in Asia and the Global Environment, published by The Science and Technology Policy Research Institute of the Science and Technology Agency, Japan, April 1992 (in Japanese)

Table 3: NO_x Emissions by Sector in 1,000 t/a

Sector Year	Energy Conversion:			Final Energy Consumption:				Energy Con- sumption Total
	Total	Power Genera- tion	Others	Total	Industry	Transport	Road Traffic	Others
1975	410	317	93	1,919	546	1,274	887	100
1980	314	239	76	1,817	473	1,244	849	101
1985	260	187	73	1,688	420	1,170	863	99
1987	248	188	60	1,687	386	1,197	885	104

Annual Average Change in %								
75-80	-5.2	-5.5	-4.0	-1.1	-2.8	-0.5	-0.9	+0.2
80-85	-3.8	-4.7	-0.9	-1.5	-2.3	-1.2	+0.3	-0.5
85-87	-2.3	+0.2	-9.1	0.0	-4.2	+1.2	+1.3	+3.0
75-87	-4.1	-4.3	-3.6	-1.1	-2.9	-0.5	0.0	+0.3
								-1.8
								-1.8
								-0.3
								-1.5

Source: Energy Utilization in Asia and the Global Environment, published by The Science and Technology Policy Research Institute of the Science and Technology Agency, Japan, April 1992 (in Japanese)

2. Description of the Improvement

2.1. Emissions

Total national SO_2 emissions decreased from almost 5 million tonnes in 1970 to half this amount (about 2.6 million tonnes) within only 5 years, falling to 1.143 million tonnes in the 1980s.² This brought about the best ratio of SO_2 emissions per capita and those per unit of Gross Domestic Production (GDP) among industrial countries.

Total NO_2 emissions have dropped from 2.329 million tonnes in 1975 to 1.935 million in 1987, and slightly less than 1.3 million tonnes in 1991.³ Deviating from these figures, data published by the OECD show considerably lower emission volumes for NO_2 (1.651 million tonnes for 1970, 1,782 for 1975, 1.176 for 1986, and 1,301 million tonnes for 1989; cf. OECD 1993), although a similar trend of continuous reduction. By international standards this is a high abatement rate, simply because in all other OECD member countries NO_2 emissions have increased in comparison to 1970 levels. The ratio of NO_2 emissions per capita and those per unit of GDP is also by far the best among OECD countries (OECD 1991).⁴ A Japanese source claims that in 1986 Japan's SO_2 emissions were about one-tenth and NO_2 emissions about one-fifth the average level of OECD countries (*Look Japan*, 38, 435, 1992: 13).

With respect to the various industrial sectors, the largest reductions in SO_2 were achieved in electricity generating power plants, non-ferrous metals, iron and steel, the chemical industry, and refineries. Figure 1 gives an overview on the development of SO_2 emissions for various sectors (stationary sources) between 1970 and 1978.

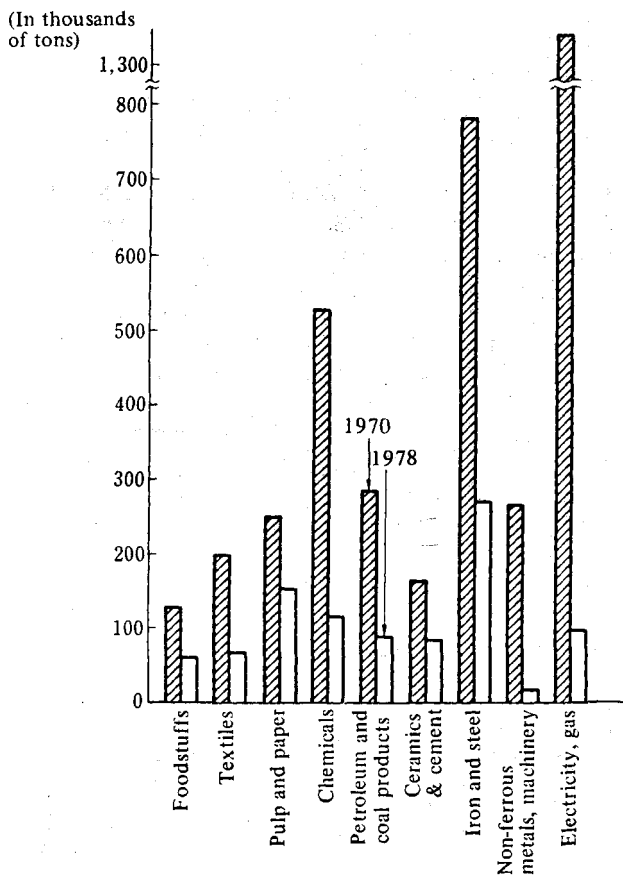
With respect to NO_2 emissions, reductions were achieved not only at stationary sources but also at mobile sources (passenger cars, trucks) between 1970 and 1985, but then started to rise again. This was due mainly to the general increase in the number of motor vehicles, especially diesel-engined cars. The proportion of diesel engines to the total number of vehicles rose from 17.1% in 1977 to 25.2% in 1988 (Environment Agency 1991a).

2 OECD (1993), in contrast, gives the following figures: 4.973 million tonnes in 1970 and 876 million tonnes in 1989.

3 Data submitted by the Environment Agency. Nearly 700,000 tonnes of the total NO_2 emission in 1991 were emitted by factories and power plants, about 600,000 tonnes by motor vehicles.

4 The recently published OECD report "Environmental Performance Review of Japan", which could not be considered systematically in this study, states that over the past two decades Japan's economy expanded by 122% while its SO_2 emissions decreased by 82% and its NO_2 emissions by 21% – "the best performance among OECD countries."

Figure 1 Trends in the Emission of Sulphur Dioxides by Industry (in 1,000 t)



Notes: 1. Figures have been calculated on the basis of Energy Economics Institute, *Energy Matrices* and Oil Federation materials.

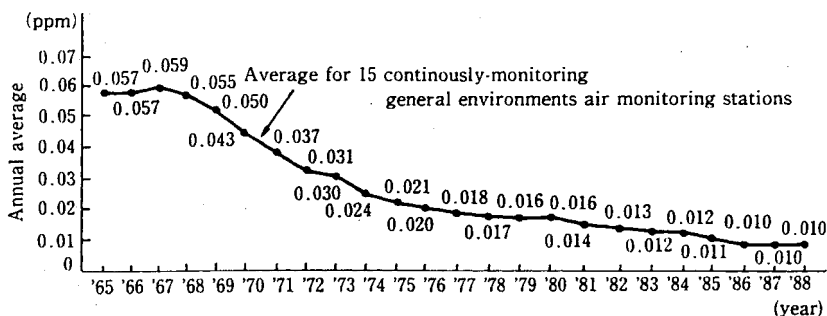
2. Emission amounts are derived from the amounts of coal and oil used, their sulphur contents and the amounts treated by flue-gas desulphurization equipment.

Source: Environment Agency 1980: 48

2.2. Ambient Air Quality

The reduction in the total volume of SO₂ and NO₂ emissions has had an overall positive effect on ambient air quality, particularly in agglomerations and in heavily polluted industrial zones.⁵ For example, SO₂ concentrations had reached a maximum of 0.059 ppm in 1967; since then the average concentration has declined continuously, approaching 0.010 ppm in 1988. At present, almost all SO₂ monitoring stations throughout the country indicate compliance with the Environmental Quality Standard (= EQS: a. The daily average of 1h values shall not exceed 0.04 ppm; b. 1h values shall not exceed 0.1 ppm); in 1988 compliance with the EQS for SO₂ (long-term criteria) reached 99.79 % (short-term criteria: 98.9 %). The development for 1965 to 1988 is shown in figure 2.

Figure 2 Trends in Sulphur Dioxide (SO₂) Concentrations



Source: Environment Agency 1992: 168 (2)

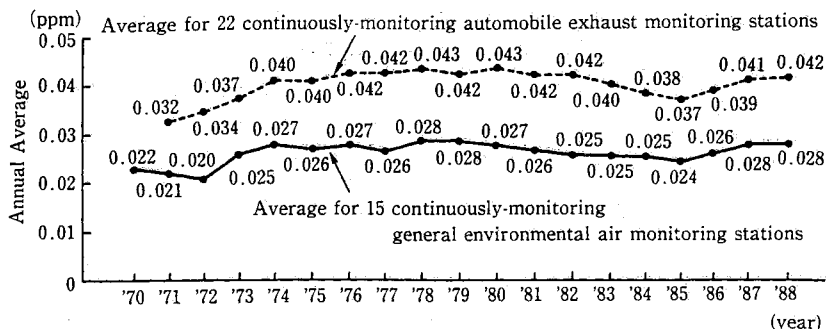
The situation relating to NO₂ concentrations is more complicated and not nearly as favourable as for SO₂. From 1979 on, there were signs of a slight improvement, but in 1986 the concentrations increased again: "Since 1986, nitrogen dioxide concentration levels have worsened. In 1989, concentrations remained at a high level, indicating a need for further countermeasures" (Environment Agency 1991a: 5; see also figure 3).

The bad record for the development of NO₂ concentrations in major urban areas is due almost exclusively to the increase in mobile emitting sources. Although Japan was a pace-setter in introducing "low pollution cars" – in 1978

5 The sources used in this subchapter are Environment Agency 1993, 1992, 1991a, 1991b.

Japanese car makers were able to meet emission standards that were stricter than U.S. standards – the continuous increase in the total number of cars, particularly the increase of diesel-fueled cars, set off the positive effects of the three-way catalytic devices adopted for passenger cars. The total number of automobiles rose from 21.22 million in 1971 to 55.14 million in 1988.

Figure 3 Trends in Nitrogen Dioxide (NO_2) Concentrations



Source: Environment Agency 1990: 168 (1)

2.3. Developments in Major Cities

The general reduction in SO_2 and NO_2 emissions from stationary sources can be impressively illustrated by the examples of some major cities (cf. Tsuru & Weidner 1989, Weidner 1987). In *Yokkaichi* – the former "asthma city" – SO_2 emission levels of more than 100,000 t/a before 1971 had decreased to 17,000 t/a by 1975; NO_2 emissions had also declined but not at such a dramatic rate. In *Kawasaki* SO_2 emissions from large emission sources dropped from 152,000 tonnes in 1965 to 17,900 tonnes in 1975 and 7,000 tonnes in 1981. In *Osaka* total SO_2 emissions decreased from over 220,000 tonnes in 1971 to almost 10,000 tonnes in 1987, the largest decrease being between 1971 and 1975 (about 60,000 tonnes). *Yokohama*, with more than 3 million inhabitants Japan's second largest city, had become one of the most heavily polluted cities in the late 1960s when SO_2 concentrations had reached their peak levels between 1967 and 1968.

The city faced the challenge and developed a unique approach which became known as the "Yokohama method" of air pollution control. In essence, this method consisted in concluding so-called pollution control agreements (kogai

boshi kyotei) between companies and the city administration. The first agreement was signed in December 1964 by the City of Yokohama and the Electric Power Development Company for a coal-fired power plant. It stipulated much stricter emission limits than did national legislation. Similar agreements followed concerning the construction and expansion of other power plants as well as steel, oil, gas and chemical plants. It was primarily due to these agreements that the total SO_2 emission in Yokohama dropped from its peak level of 104,500 tonnes in 1968 to 7,780 tonnes in 1977 and to 5,260 tonnes in 1985. The total amount of NO_2 emissions was reduced from 54,000 tonnes in 1974 to 32,900 tonnes in 1983.

3. Reasons for the Improvement: The Direct Causes

The reduction in SO_2 and NO_2 emissions from stationary sources was primarily achieved by 5 types of measure⁶ that can be characterized as

- (1) End-of-pipe treatment (desulphurization and denitrification of flue gases, direct and indirect desulphurization of heavy oil)
- (2) Specific change of the combustion process (low NO_x burner, etc.)
- (3) General changes in combustion/production processes (energy saving, improving energy efficiency)
- (4) Change in the mixture of input factors (substitution of high pollution fuels for low pollution fuels)
- (5) Modification of industrial structure (shrinking of high-pollution and energy-intensive industrial branches).

3.1. Flue Gas Desulphurization

The first flue gas desulphurisation (FGD) plant opened in 1970. Within the next 5 years almost 1,000 units (with a total processing capacity of 100 million Nm^3/h) were installed at various plants, not only power plants. This rapid development was partly enhanced by the oil crisis in 1973 which led to a sharp increase in prices for low-sulphurous oil and made FGD competitive against the import of these types of oil. By 1991 the number of FGD units had risen to 1843 (with a total processing capacity of 179 million Nm^3/h).

In 1987, emission control regulations for small boilers (capacity of 50 litres of Oil Equivalent Fuel Consumption per hour) were tightened; as a consequence plants with a capacity of less than 30 MW also require a partial FGD and, with respect to NO_2 abatement the installation of low- NO_x burners became necessary.

⁶ For this chapter I have used the following publications: Environment Agency 1993, 1992, OECD 1972, International Energy Agency 1991, Nishimura 1989, Tsuru & Weidner 1989.

As in other areas of environmental technology, Japanese industry imported the basic inventions of FGD technology, in this case primarily from the U.S. and Germany, and developed them to a state of high reliability and efficiency so that they finally became not only important articles of export but also accelerated progress in environmental policy in other countries, especially in Germany.

3.2. *Flue Gas Denitrification*

The removal of NO_x from smoke-stack gases by means of denitrification facilities started in 1972. Japan is undoubtedly the world leader in the development and operation of flue gas denitrification facilities. In 1990, 430 units with a total processing capacity of 159 million Nm^3/h were in operation. The SCR technology achieves reductions of up to 90%, whereas low- NO_x burners and combustion control methods reduce NO_x emissions by 30 to 50%.

3.3. *Heavy Oil Desulphurisation*

In 1967, the *direct* heavy oil desulphurization process was introduced, followed by the *indirect* process. Almost all oil refineries are equipped with these techniques. In 1990, direct desulphurization reached a capacity of 66,000 kl/day (12 plants) and indirect desulphurization a capacity of 135,000 kl/day (28 plants).

3.4. *Low- NO_x Combustion Methods*

Since 1975, low- NO_x combustion technologies have been widely used in all industrial branches as well as in the commercial and the domestic sectors. This technology aims at controlling NO_x concentrations by modifying combustion processes.

3.5. *Fuel Substitution*

The substitution of low sulphur fuels for high sulphur fuels started in the 1960s. The imports of (extremely expensive) low-sulphur crude oil and of liquified natural gas (LNG) were supported by a Low-Sulphur Fuel Supply Programme implemented by the Ministry of International Trade and Industry (MITI) in December 1969. Large emission sources in the vicinity of urban areas switched to these fuels – with the effect that Japan became the world's leading importer of LNG. About three quarters of LNG imports are used for electricity generation. Japan also puts great emphasis on the development of nuclear power. Alternative energy sources (hydropower, geothermal and solar energy, alcohol fuels and other renewable sources) do not yet play a prominent role in air pollution abatement. To stimulate production and the use of alternative energy sources, various incentive programmes have been implemented.

3.6. *Energy Saving/Energy Efficiency*

In the two decades before the so-called oil shock of 1973, Japan's total energy demand grew by 12% per year – somewhat faster than its GNP. During the period of rapid economic growth, 1965-1973, energy consumption increased at an annual rate of 11.2%, GNP by 9.1% (International Energy Agency 1991). After 1973, Japan succeeded in decoupling economic growth from energy consumption, primarily by energy conservation and modernization processes in the industrial sector. The latter ones had a relatively strong effect on energy savings because Japan's industry – in contrast to many other countries – accounts for more than one half of total demand. Efforts in energy conservation and increased efficiency, particularly in the industrial sector, have made Japan's economy one of the most energy-efficient in the world with one of the lowest ratios of total primary energy supply per unit of GDP. Whereas between 1973 and 1988 GDP increased by 81% in real terms, energy demand grew by only about 16%.

3.7. *Changes in Industrial Structure*

A systematic industrial policy was developed and implemented in the 1970s to change industrial structure. The main aim was to shift from heavy (high-pollution and energy-intensive) industries to cleaner ("knowledge-intensive") industries (e.g., manufacturing and assembling industries, electronics, IC production). Although environmental protection matters were partly considered when developing this policy, the main stimulus came from the two oil crises of 1973 and 1979. Implementation of this industrial policy was to a large extent successful, which also contributed to the decrease in SO₂ and NO₂ emissions. However, the transfer of "old-fashioned" industries to other, predominantly Asian countries came close to what environmentalist groups labeled as "pollution export". Now transport poses the biggest problem to environmental policy in its efforts to comply with the ambient air quality standards (AAQS) for NO₂ in metropolitan areas. Figure 4 gives a sketchy overview of the ways and means by which SO₂ emissions were reduced between 1974 and 1986.

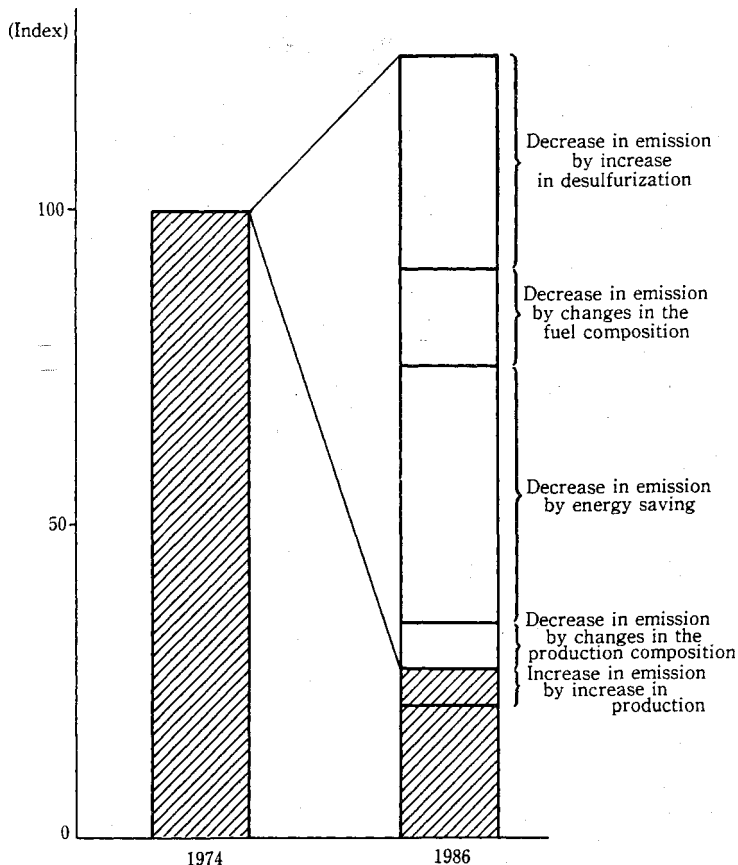
4. **Influencing Factors and Motives**

For about the first two decades after World War II, very little attention had been paid to environmental protection, and a more systematic environmental policy by national government did not start before the mid-1960s.⁷ Previously existing air

⁷ For a detailed description and evaluation of the various policy instruments as well as the organisational arrangements of Japan's environmental policy (and the other issues dealt with in this chapter), see Weidner 1992. For the use of market-based instruments, see Kato 1993.

pollution control regulations – primarily based on the command and control approach (e.g., Soot and Dust Regulation Law, 1962) – proved too weak and too narrow to cope with soaring pollution. Regulation of air pollution was tightened step by step – with one important exception: the AAQS for NO_2 was relaxed in 1978 – , allowing industry a certain lead time for developing the necessary abatement technology. From the very beginning, SO_2 reduction became one of the most important issues in environmental policy.

Figure 4 Analysis of Emission of Sulphur Oxides and Causes of Their Changes



Note: For the index, the emission of 1974 is set at 100.

Source: Environment Agency 1992: 75

The new national environmental policy started with the enactment of the *Basic Law for Pollution Control* in 1967.⁸ It is primarily an "enabling law" (framework law) which had to be made manageable and enforceable by specific regulations, directives and ordinances. Pursuant to the Basic Law, the government enacted the Air Pollution Control Law in 1968 and the Ambient Air Quality Standards (AAQS) for SO₂, NO₂, suspended particulate matters (SPM), CO and photochemical oxidants. The AAQSs for SO₂ and NO₂ were enacted in 1969 and 1973, respectively. The Basic Law and the Air Pollution Control Law were made stricter by amendments in 1970 and 1974. The regulatory system for air pollution control from stationary sources is also based on emission standards specified for each facility, a so-called area-wide total pollutant-load control system (applied in heavily polluted areas), and on fuel standards (sulphur content).

As required by the Basic Law, the AAQS for SO₂ was established in February 1969 (0.03 ppm/year). At that time, SO₂ pollution was considered the most serious air pollution problem and taken as a general indicator for air pollution in Japan. With respect to the attainment period, it was decided to attain the standard within 10 years in those areas where air pollution was already serious, within 5 years in considerably polluted areas, and to maintain the standard in the other areas. To achieve compliance with the standard within these periods, government decided to promote a low-sulphur policy, comprising fuel and flue desulphurisation, increasing volumes of low-sulphur fuel, and to draw up and implement an Environmental Pollution Control Programme in accordance with art. 19 of the Basic Law. It soon became clear that the measures would suffice to meet the standard at almost all monitoring stations by 1974.

However, the number of persons with respiratory diseases increased continuously in heavily polluted areas. Therefore the SO₂ standard was harshly criticised for being too weak. Furthermore, one of the most important court decisions in favour of those concerned by air pollution was made in 1972. It was the so-called Yokkaichi case, one of the so-called Four Major Pollution Trials in the post-war period. The proceedings themselves and, of course, the final decision fueled the general public debate on air pollution problems and aroused heavy criticism against government and industry. In response, the national government expressed its regret about the delay in developing effective anti-pollution measures and recognized an urgent need for more effective action. One of the consequences was the establishment of a stricter AAQS for SO₂ in May 1973, managed by the national Environment Agency (founded in 1971). The new standard was equivalent

⁸ A new (stricter and more comprehensive) Basic Environmental Law was enacted in November 1993. It is expected, among other things, to contribute positively to a rational reorganization of environmental administration, strengthen the Environment Agency and promote global environmental activities.

to 0.017 ppm/year. Much stricter abatement measures consequently became necessary to meet this new standard within the required 5-year-period (i.e., in 1978).

Despite rising levels of NO₂ concentrations in urban agglomeration areas and incidents of photochemical smog leading to health impairment (particularly in Tokyo in summer 1970), there was a rather slow reaction by governmental regulatory machinery. The first AAQS for NO₂ was set in 1973. This standard (0.02 ppm/24 h, to be achieved within 10 years) was an extraordinarily strict standard from an international point of view (the then existing U.S. standard of 0.05 ppm, for example, was heavily criticised by the U.S. industry for being unreasonably strict). It was relaxed after a heated debate in 1978. Especially the iron and steel and automobile industries lobbied intensively to revise the NO₂ standard, trying to lower it at least to the level of the U.S. standard. In July 1978, the Environment Agency issued a notification setting a new NO₂ standard within the range of 0.06 to 0.04 ppm/24 h or less. The target date for achieving the standard was set at 1985. In addition, the principle of non-degradation was to be applied to areas already meeting this AAQS.

SO₂ emissions at stationary sources are regulated primarily by the so-called *K-value system*, where a maximum tolerable emission value is determined per facility, depending on the height of the chimney and the existing air pollution in selected regions with reference to the SO₂ AAQS. At present, there are 16 rankings of K-values which vary according to regions from 3.00 to 17.5 (the smaller the K-value the stricter the emission standard and the control requirements). By now all of Japan is regulated by this system. Since December 1968, the K-values have progressively been tightened no less than 8 times. For a total of 28 heavily polluted or pollution-sensitive areas (e.g., Tokyo, Yokohama, Kawasaki, Nagoya, Yokkaichi) there are special, strict emission standards (K-values ranging from 1.17 to 2.34) to be applied at new facilities.

The regulation of the *sulphur content* of fuels was revised in 1976, one area being added to the previous list of 14 regulated areas. At present, the sulphur content standards range from 0.5 to 1.2%. In June 1992, the Environment Agency decided to lower the sulphur-content limit for light fuel oil (used for diesel-fueled automobiles) from 0.4% to 0.05%.

In 1974, the *System of Area-wide Total Emission Control* for SO₂ was introduced; the same control system was applied for NO₂ in 1981. This system was established for regions where it had become difficult to achieve the AAQS primarily by the standard requirements. These highly polluted areas were specified by the central government. The prefectural governments of these regions were called upon to work out special programmes fixing envisaged reduction in emissions and time limits for achieving these reductions. On the basis of these programmes, the permitted amount of emission is individually determined for each of

the larger stationary emission sources. The companies concerned are free to a certain degree to decide which emission abatement measures they wish to apply to which specific outlet. This enlarges the flexibility of business decisions. 24 districts have now been designated as SO₂ total emission control areas and (only) 3 districts (Tokyo, Yokohama and Osaka City) are subject to total control of NO₂ emission. The 24 SO₂ areas account only for 3.1 of the total land area but for 31% of the total population and about 30% of the total SO₂ emission in Japan. Considerable decreases in SO₂ emissions from plants have been achieved by this system. In the three NO₂ control areas it was planned to meet the AAQS by 1985 through NO₂ reductions of about 32% (Yokohama), 27% (Osaka) and 19% (Tokyo) of total emissions from specified plants. However, the envisaged AAQS could not be attained within this set period because of air pollution produced by automobiles.⁹

Nation-wide NO₂ emission standards for large stationary sources were established in August 1973 and have been gradually strengthened since then. In September 1985 small-sized boilers and in October 1987 gas turbines and diesel engines were added.

The regulatory system described above can be considered as the basic regulatory system aiming directly to reduce air pollution (concentrations and emissions) by NO₂ and SO₂. More general and complex regulations do also exist and also have had a decisive reduction effect on SO₂ and NO₂ emissions from stationary sources.

Regional Environmental Pollution Control Programmes pursuant to art. 19 of the Basic Law provide a wide-ranging approach to coping with pollution. The government is authorised to develop pollution-control plans for designated areas where pollution is high or where there is a danger that high pollution levels will be caused by trends in population and industrial developments. Air pollution control is an integral part of such a comprehensive pollution control programme. Designated areas receive special subsidies, e.g. for meeting the additional administrative costs for managing the programmes, but also loans, favourable interest rates, etc. for the owners of regulated facilities. The first of such programmes was started in 1971; by 1977, pollution control programmes had been implemented for almost all major industrial zones and urban areas. At present, such programmes are established for 39 areas. They account for about 9% of the total area of the country, for about 54% of the population and about 63% of the country's manu-

⁹ In June 1992, the Environment Agency announced new regulations (Automobile Nitrogen Oxide Law) to bring about sharp cuts in vehicle exhaust gases by way of a phased reduction of NO₂ emissions from gasoline-fueled cars (starting 1994) and from diesel-fueled cars (starting 1997). In addition, financial incentives systems will be introduced (e.g. tax relief, low interest loans) for those who switch from old cars to new low-NO₂ ones (Environment Agency 1993).

facturing production. A programme is usually formulated for a 5-year-term but in most cases it is prolonged afterwards. In these regional control areas, the AAQS for SO₂ was met at all monitoring stations in 1988; the upper value of the AAQS for NO₂ of 0.06 ppm was exceeded at 6.7% of all monitoring stations in 1988.

The so-called *Cost Apportionment Scheme for Firms*, enacted in 1970, plays only a minor role in the reduction of air pollutants. This law provides for private firms to meet part of the costs paid by public authorities to safeguard or improve the environment. The firms contribute in accordance with the degree to which they bear responsibility for restorative measures becoming necessary. With respect to air pollution, this system is used for the construction of green belts around industries.

Governmental pollution control management was strengthened by the establishment of the national *Environment Agency* in July 1971. The Agency played its most decisive role in stimulating and enforcing air pollution control measures in the 1970s.

Research and development by public institutions in the field of air pollution control is primarily managed by the Environment Agency's *National Institute for Environmental Studies*, established in 1974 in the Tsukuba "Science City"; there is also a research institute related to MITI doing research on pollution abatement technology as well as on energy-related problems. The Japanese government also established a programme for developing flue gas desulphurization and denitrification techniques. It was especially active in encouraging industry by several means to organize common research pools to speed the process of developing effective abatement techniques.

Remarkable reduction effects have also resulted from several *energy conservation programmes* established and implemented by MITI (see figure 4 above). Not only the promotion of energy conservation but also the restructuring of the energy mix and the shaping of industrial structure were initiated and promoted by MITI. The Energy Council, for example, an advisory body to MITI, suggested in 1971 that Japan's energy-intensive industrial structure should be converted to the minimum-energy-consumption type by promoting knowledge-intensive industries – not mainly for environmental reasons but also for the security of oil supplies. This mirrored the growing of a new political consensus finally reached after the oil crisis in 1973 on a new energy policy for Japan: The focus on cheap oil, as a critical input to Japan's strategic industries, was abandoned. In 1973, MITI then developed a comprehensive energy conservation programme. The low-sulphur fuel supply programme was also implemented as early as 1969 by MITI. In 1979, the Law for the Acceleration of Alternative Energy Sources was enacted. As early as 1974, a governmental programme was started to promote alternative energies – the so-called "Sunshine Programme". In 1978 the so-called "Moonshine Programme" was established to promote energy conservation measures in

selected areas. In 1971 the Law for the Establishment of Pollution-Control Managers in Specified Factories was enacted. It requires large energy consumers to appoint energy managers (certified by government-regulated examination) to rationalize the use of energy in factories. In March 1993, the *Energy Supply and Structure Advancement Law* and the *Energy Conservation and Recycling Law* were enacted to stimulate energy conservation with the help of various measures including economic incentives, obligatory monitoring/reporting for energy-intensive enterprises, as well as penalties: MITI is empowered to publish the names of uncomplying firms.

Finally, it should be mentioned that the government's management of the electricity tariff system contributed decisively, though indirectly, to a reduction in emissions. In 1974, the government introduced a systematic and comprehensive revision of the energy tariff system with the main aim of promoting energy savings. Japan's energy electricity prices became (and are still among) the highest in the world. Electricity rates were reduced in 1988 and 1989 to reflect the decline in fuel costs. As early as 1987, mainly owing to low oil prices, energy consumption rose rapidly and, energy conservation measures coming to an effective halt, the energy and fuel efficiency rate in industry and transport suffered stagnation (Environment Agency 1992: 69ff.). At present, the international discussion of global warming gives great impetus to Japanese government and industry to develop and implement comprehensive energy conservation measures. These are primarily directed to reducing CO₂ emissions, but as a rule this has also positive effects on SO₂ and NO₂ emissions

Because the central Japanese government has strong legislative and financial powers to control the administration of prefectures and municipalities, one might assume that there is little room for discretion on the part of local governments to influence pollution control. Actually, this is not the case. Prefectures and municipalities ("local governments") have played leading roles in the development of environmental policies in Japan. They did so not only by formal means, e.g., by enacting their own legislation, but also – and with great impact on the development of national environmental policy – by guidelines, guidance and various other sophisticated and flexible means to exert political pressure on industry and the national government (cf. Foljanty-Jost 1988). Therefore, as a rule, environmental policies and standards of local governments are stricter and wider in scope than those of the national government.

It was also at the local level that some of the unique systems of environmental management were initiated and developed. Because of their key role in Japan's environmental policy system, three of these instruments – the so-called "anti-pollution agreements", the "pollution-related health damage compensation system" and the "environmental monitoring and reporting system" are worth looking at in detail.

Let us first take a look at the *anti-pollution agreements*. Local governments use their broad leeway to enter direct negotiations with representatives of proposed or existing plants to reach, so to speak, private agreements concerning environmental initiatives, many of which go far beyond what is legally required. Sometimes the standards fixed in such anti-pollution agreements are two, three or more times stricter than national emission standards.

The number of anti-pollution agreements grew rapidly throughout Japan from a handful in the late 1960s, more than 800 in 1970, to about 37,000 at present. In most cases, the parties to these agreements are firms and municipalities responsible for the area in which the plant is sited. Citizen groups are also involved in the negotiations. There are also anti-pollution agreements concluded exclusively between citizen groups and firms, and their number has increased from 37 in 1969 to over 4,000 at present. Citizen groups and local authorities consider the anti-pollution agreements as one of the most appropriate means to supplement national environmental law to meet specific local needs and desires. In this regard, such agreements are the expression of a decentralised on-site environmental policy. The agreements are not legally binding in the strict sense of civil and public law. They are gentlemen's agreements. Nevertheless, firms will relatively seldom fail to honour them.

The successes of Japanese air pollution control policy for stationary sources cannot be fully explained without mentioning the comprehensive modern system of providing *environmental information*. The nature and scope of the Japanese information system, especially that for air quality control, is probably unique in the world. Not only environmental quality but also emissions by large plants are continuously monitored, and the data are automatically transmitted to the responsible authorities. Most of the data are available to the public. The heart of the Japanese system of environmental monitoring and reporting is the information system for air pollution. At present, more than 1,600 monitoring stations for SO₂ and more than 1,300 monitoring stations for NO₂ are in continuous operation. Since about 1970, automatic emission measuring devices using remote data communication (telemeter system) have been installed at major stationary sources of emissions. These monitoring devices primarily measure fuel consumption, the sulphur content of fuels, the concentration of nitrogen oxides and sulphur dioxide in flue gas. The data gathered are published in both written form (in weekly, monthly, or yearly environmental reports) and in electronic form (electronic display panels located in environmental agencies and on public squares report on selected environmental spheres, such as air pollution and noise levels).

As far as one can tell, the Japanese information system has decisively increased the influence of both citizens and responsible authorities, on environmental protection issues without swamping firms with a wave of impossible demands. The only firms disadvantaged by the disclosure of environmental data

are those doing little to protect the environment. Furthermore, transparency on environmental developments is a fundamental prerequisite for the ability of citizens to bring about rational decisions, for example on which products from which firms they want to buy. One can say that a comprehensive information system is a basic condition for the development of flexible, cost-minimizing policy instruments. It also can often replace measures of a formalistic, bureaucratic nature.

The third, and probably most famous system is the *compensation system for health damage* caused by environmental pollution. The basic structure of the system was developed by local governments in the late 1960s to compensate so-called pollution victims. In 1974, a national system pursuant to a corresponding law was established. Japan is still the only country with a special law to regulate a comprehensive compensation system for health impairment caused by environmental pollution. It provides for certain injuries to be compensated on a regulated scale reflecting the severity of the disability. Under this law, compensation payments and other benefits have been received by over 104,000 persons in 1989, over 102,000 of them because of respiratory disorders. For damage due to air pollution, the approach to apportioning costs is highly interesting because it is based in part on the polluter-pays principle. Costs are covered by a compensation fund financed by fees charged to SO₂ emitting firms exceeding a specified size. The rates they pay depend upon the affected area and the number of certified pollution victims. Air polluters in polluted areas must pay considerably higher fees per unit of emission than their counterparts in less polluted areas.

Because of considerable problems that evolved during the period of implementation of this system and in reaction to severe criticism from industrial pressure groups, the compensation system for air pollution was substantially modified in 1988. As a consequence, no new persons will be entitled to compensation. Instead, the polluting industrial plants (and the automobile manufacturers) have voluntarily committed themselves to paying into a fund to promote preventive environmental protection measures. Although the compensation system was not originally established as an economic incentive system to reduce emissions, the financial burden incurred by the SO₂ levy worked in that direction in some heavily polluting industrial branches (cf. Kato 1993: 8).

5. General Evaluation of Achievements

As briefly mentioned in the introduction, the air pollution control measures for SO₂ and NO₂ at stationary sources described have had no or only very slight negative impacts on Japan's economic growth, employment, currency stability and export rates. However, as far as I know, there is no comprehensive and systematic study on their *efficiency*. A recent study by members of the Environment

Agency (Study Group for Global Environment and Economics, 1991) tries to show (with rather simplified assumptions) that the cost-effectiveness relation of pollution control measures has been positive in a balanced, long-term view, particularly when considering pollution-related damage in Yokkaichi, Minamata and the Jinzu River region (cadmium pollution causing Itai-Itai disease) and the costs which would have been incurred for compensation payments if no abatement measures had been taken. A so-called trial calculation of costs for SO₂ abatement and for damage repair in the absence of measures shows, according to the authors, that projected damage expenses would have been ten times greater than pollution control costs. This study also revealed that there was no adverse impact on macro-economic variables – to the contrary, the economy seems to have benefited from technological progress combining low pollution and high productivity. Other studies (cf. OECD 1977: 68ff., Nishijima 1992: 12, Kato 1993) seem to confirm this finding, indicating that progress in environmental technologies had been stimulated in the 1970s by strict air pollution control policies in two directions: end-of-pipe technologies (FGD, denitrification) and integrated technologies (energy conservation, increased energy efficiency). Because of the rapid progress in air pollution abatement technology, Japan (together with the United States and Germany) is now among the world's leading exporters of emission abatement equipment (Kaizu & Hiratsuku 1992, OECD 1992). Finally, with respect to the criterion "efficiency", one should bear in mind that cost effectiveness was not at all an important target when a systematic air pollution control policy was initiated. Instead, the dominant aim was to reduce pollution as fast as possible. *Cross-medial pollution shifting* is relatively low; gypsum produced by FGD units is almost totally saleable. Catalysts of SCR units are, to a certain degree, recyclable. However, some of the more complex policies (e.g., changes in industrial structure, energy-mix policies) lead to considerable, though not quantifiable problem shifting: "pollution export" (e.g., transferral of high-pollution industries under strict regulation in Japan to foreign countries with weaker environmental standards), nuclear waste, and pollution from "high-tech" industries are prominent examples. For a very long time, from the late 1960s until recently, however, the achievements have shown a high degree of *sustainability*: total SO₂ and NO₂ emissions from stationary sources have been decreasing steadily while the economy has prospered. There have also been *bonus effects* for the environment from measures implemented in the course of energy conservation and industry policy as well as the policy to strive for a more balanced fuel-mix. Finally, the *benefits to the environment* (human health and the living environment) brought about by these achievements are evident as far as one can tell from epidemiological studies and state-of-nature surveys.

The conclusion can therefore be drawn that, on the basis of the evaluation criteria used here, the achievements in controlling SO_x and NO_x emissions from

stationary sources show, *grosso modo*, a positive balance. In an international comparative perspective, no other country has achieved such enormous reductions so early (at a time when many other countries had just begun discussing and institutionalizing a systematic environmental policy) and in such a short period of time. However, even this "best case" is not free of faults, the most serious one probably being that, through economic growth, reduction rates in some industrial branches are levelled down, stagnate (as in power generation), or even rise. These trends indicate that the Japanese approach to coping with environmental problems is essentially still an end-of-pipe or, in other words, technocratic approach.

6. Interpretation and Conclusion

Because of the innumerable interdependencies among Japan's various policy instruments directly and/or indirectly influencing air pollution control measures, it is generally impossible to isolate exactly the achievement rate of one single instrument. This task is further complicated by the influence of "complementary" and "meta"-instruments, such as liability rules, financial support measures, and administrative guidance and by changes in the relative influence of some instruments over time. This basic problem should be kept in mind when reading the following qualitative, rather simple interpretation masking a rather complex reality.

When looking at the policy instruments for air pollution control at stationary sources, one can with a certain degree of plausibility assert that the (nationally) regulated emission standards and the ambient air quality ceilings for SO₂ and NO₂ as well as the instruments designed to combat heavy air pollution (e.g., the total pollutant-load control system, sulphur content limits, regional environmental pollution control programmes) and the modification (the "fine-tuning") of these instruments by local governments have proven effective in a range from medium to high. The administrative compensation system for health impairments through air pollution created a general emission-reducing incentive that varies in intensity depending on regional conditions and the industrial sector concerned. For some high-pollution plants, it can be assumed that the heavy burden imposed by SO₂ levies has provided a strong incentive to reduce emissions.

Instruments that are more indirectly related to air pollution control, such as energy conservation, changes in the primary energy structure and industry policies (especially a shift from heavy industries to knowledge-intensive branches), have proved highly effective, especially when considering the long-term effects (cf. Jänicke, Mönch & Binder 1992).

In general – and this might come as a surprise to whoever has followed the lengthy debate on deregulation and the structural weaknesses of regulatory poli-

cies – the Japanese case shows that conventional regulatory policy instruments actually have a high potential effectiveness which can be realized if the framework conditions for policy programming, implementation and enforcement are suitable and favourable. The so-called anti-pollution agreements and the sophisticated environmental monitoring and reporting system are clearly among these framework conditions. The anti-pollution agreements provide responsible authorities and citizen groups with the flexible means – often lacking in other countries – to adapt general rules and standards to specific cases, striving for the best practicable environmental option. They also allow for fast and flexible reaction to loopholes in more general regulations and progress in environmental technology. The monitoring and reporting system provides the very basis for the rational planning of environmental policies, quick response to unforeseen developments, and with respect to the regulatees, the systems works as a general pollution-prevention mechanism. Both instruments are not only "supporting" instruments but also instruments "in their own right" in that they effect measures and developments positive for the environment and which are not covered by the arsenal of regulatory instruments.

In a more generalized interpretation of the effects of the afore-mentioned "framework-building" (or "meta-") instruments, one can say that decentralization (anti-pollution agreements) and transparency (monitoring and reporting system) seem to be basic elements of an effective environmental policy. A third basic element must be added here: the element I labelled as "parity of legal weapons" in environmental conflicts. This goes back to the "Four Major Pollution Trials" initiated in the late 1960s by pollution victims. The four trials involved two cases relating to "Minamata Disease" caused by mercury pollution, the Itai-Itai case relating to cadmium pollution, and one case dealing with respiratory diseases caused by air pollution, especially sulphur dioxide from several industrial plants forming a so-called kombinato in the city of Yokkaichi. The plaintiffs won all four trials because the judges departed from prevailing legal opinion, changing it in favour of the citizen. Some of the new principles that have decisively marked Japanese environmental policy since then are:

- The use of statistical or epidemiological proof of causality instead of strictly scientific proof of cause and effect between a certain concentration of toxic substances and the damage being claimed;
- The non-consideration of fault or negligence in deciding liability, the so-called "principle of strict liability";
- The recognition of each polluter's broad liability for interacting emissions: the "principle of joint liability";
- The introduction of rigorous standards of caution to be applied even to activities where danger was merely postulated rather than demonstrated;

- The far-reaching alleviation of the victim's burden when it comes to establishing the legal and actual basis for a claim to compensation: the principle of "reversing the burden of proof" in certain circumstances.

In some cases, the firms involved had to pay enormous sums in compensation. The court decisions have had profound political impact because government and industry feared that stricter liability principles could precipitate a wave of disputes, which would seriously have hampered corporate decision-making, and made long-term planning of industrial policy – one of the cornerstones of Japan's economic policy – all but impossible.

The relatively high effectiveness of policy instruments and "meta-instruments" (basic elements conditioning the framework of conventional instruments in favour of environmental protection) was the result of certain unique developments and events in Japanese society in the 1960s and 1970s as well as of certain characteristics of its political culture and political system. There was very strong pressure on government and industry from victims' organisations, anti-pollution groups (mushrooming in the late 1960s and early 1970s) who were later to win support from the general public. The media assumed the role of pollution watchdog in the public interest reporting every day on pollution problems, and heavily criticizing government. The environmental movement was supported by scientists and lawyers, the latter working partly free of charge. So-called progressive local governments emerged and spread throughout the country, seeking strict environmental regulations and measures, sometimes in direct confrontation with the central government; the number of progressive governments (formed by political parties in opposition to the Liberal Democratic Party or by independents) increased – especially in large municipalities persons campaigning on a strict environmental platform came to power. In this respect, the environmental movement contributed decisively to the "democratization" of Japan's local government system. There also was pressure from abroad on the Japanese government: Richard Nixon, then president of the United States, criticized Japan's unfair trade policy (goods not reflecting real prices because of "ecological dumping"); at the first U.N. World Environment Conference in Stockholm in 1972, the Japanese government "lost face". The widespread coverage of the Yokkaichi, the Minamata and the Itai-Itai pollution cases had drawn the attention of both public and government to toxic substances in effluents and to air pollution from stationary sources; this explains that SO₂ in particular had played such a dominant role in the inception of a systematic air pollution control policy.

All in all, one can say that pollution conflicts aided a process of social and political modernization in Japanese society. The process of change towards a more environmentally responsive and effective policy-making by the central government was aided by the traditionally close interrelationship between key bu-

reaucrats, industry leaders and leading persons of the then ruling party (LDP). A centerpiece in the relationship between these groups is a cooperative instead of adversarial approach, or, to be more precise, the predominance of cooperative policy formulation and decision-making style and the endeavour to return to this pattern of government-business relation after phases of highly adversarial relationships.¹⁰ Equally important in a broader sense is the very capability of state officials to take a leading role in designing and enforcing fundamental strategies shaping a whole society. Finally, a new stage was entered in cooperation among the various conflicting groups on environmental and economic goals resulting not only in a return to cooperative government-business relations based on the acknowledgement of environmental protection measures as a national goal, but also leading to a new system of relationships between central and local governments: the central government maintained its power and competence for controlling the scope, direction and speed of economic growth policy and of environmental policy, whereas local governments received increased competence for managing environmental pollution matters within their administrative boundaries.

To sum up, it can be said that well organized public pressure at several levels was the main stimulus for the development of a sophisticated, diverse pollution control approach within which negotiated pollution control agreements – a social invention – initially played a decisive role. With respect to the various components of this approach, it is not possible to single out "the" most decisive one.¹¹ However, when focusing on the phase of *policy*-making (after the issue had been pushed on the political agenda), the most decisive factors have been the creation of new basic conditions restructuring the environmental conflict arena (described above as "basic elements") as well as conventional policy instruments (strict regulations based on negotiations, etc.); for that phase, the central government (especially the Environment Agency) must be considered as the main actor. The key to the successful reduction in SO₂ and NO₂ emissions from stationary sources seems to be the capability and capacity (or: will and skill) of the Japanese government to respond to the tremendous social pressure by establishing and implementing a goal-oriented configuration management, as one might call it.

10 Cooperation with a problem-solving orientation generally takes place in advisory councils (shingikai), usually composed of ex-bureaucrats, representatives of business groups, university professors, and other experts, and also – but as a clear minority – of representatives of public interest groups.

11 This is in keeping with the results of a study on a comparably (or even more) complex policy area, namely industrial policy: "In short, the distinctiveness of Japanese industrial policy emerges from a complex configuration of factors, no one of which can possibly be singled out as decisive" (Okimoto 1989).

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