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STATUS OF EMISSION RELEASE AND ASSOCIATED PROBLEMS IN ENERGY SYSTEMS ANALYSIS

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OECD/IEA/ETSAP (Energy Technology System Analysis Project) has been started in March 1976. Since initiation of the projects, JAERI and ETL (Electrotechnical Laboratory) have been participating in the projects as operating agent of Japan. From last October, the ETSAP has initiated its Annex III programme, which pursues the problems laid down in energy-environment relationships. Main research objective of the programme is to investigate through the systems analysis "how various environmental constrains would affect the pattern of fuel and technology use and the choice and timing of implementation of abatement technologies".

In this report, we describe the status of emission release in Japan and associated problems in energy system analysis which has been investigated at the start of these research programme mentioned above.

Keywords:. Energy System Analysis, Emission Release, Emission Coefficient, Emission Control Technologies, Energy-Environment Analysis, System Analysis Methodologies, Environmental Problem, Air Monitoring Station

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This report was distributed at IEA/ETSAP Workshop held at Brookhaven National Laboratory on June 24-30, 1987.

* Electrotechnical Laboratory

環境排出の現況とエネルギーシステム分析に於ける関連諸問題

日本原子力研究所動力炉開発・安全性研究管理部
安川　茂・萬金　修一・佐藤　治
小川　茂夫*・伊原征治郎*

（１９８７年１０月１９日受理）

ＯＥＣＤ／ＩＥＡ／ＥＴＳＡＰ（経済協力開発機構／国際エネルギー機関／エネルギー技術システム分析プロジェクト）は１９７６年３月に開始され，以来日本原子力研究所は電子技術総合研究所と共に我が国に於ける当プロジェクト実務実施機関を担当してきた。当プロジェクトに於ける分析課題は昨年１０月から，環境制約と将来のエネルギー技術，燃料利用の相互関係を追求する研究を中心に据えたAnnexⅢ研究を開始した。この研究の目的は種々の環境制約がエネルギー技術と燃料の利用パターンをどの様に変え，抑制技術の利用を含めてこれらの撰択と導入時期をシステム分析を通じて明らかにしようとするものである。当研究を開始するにあたって我々は我が国の環境排出の現況を把握すると共に，システム分析との関連に於ける諸問題を検討したので報告する。

本報告書は１９８７年６月２４日，ＢＮＬ（ブルックヘブン国立研究所）で開催されたＩＥＡ／ＥＴＳＡＰ（国際エネルギー機関／エネルギー技術システム分析プロジェクト）会議において発表，配布された。
日本原子力研究所：〒３１９−１１ 茨城県那珂郡東海村白方字白根２−４
＊電子総合研究所

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1. Introduction

An analytical study on energy systems analysis of the International Energy Agency (IEA) initiated in March 1976 under the auspices of the Committee of Research and Development of the IEA. This study was reformed into an international cooperative research project, named as the Energy Technology Systems Analysis Project (ETSAP), in December 1980. Since October 1986, the Annex III programme of the ETSAP has been progressing.

The government of Japan has been participating in this study since its initiation, and till now participants of the member countries have worked on the research subjects such as the group strategy on energy R&D, the development of an analytical model MARKAL, the preparation of energy technology data base, the scenario analysis on energy technologies R&D. Also, they have been engaged in the information exchange programme on methodology and data base.

In the circumstances of recent oil glut and also of the increasing concern on acid rain and greenhause effect problems, the ETSAP has initiated its Annex III programme, which pursues the problems laid down in energy-environment relationships. Main research objective of the programme is to investigate "how various environmental constraints would affect the pattern of fuel and technology use, and the choice and timing of implementation of abatement technologies".

The programme sets up three different working tasks. The first one is to revise energy technology data base adding environmental emission data and to characterize abatement technologies. The second one is to accomodate analytical tools which are applicable to analyze environmental issues related to energy use. The MARKAL programme is considered to be a leading software among various tools. The third one is to promote the effective communication of the results within the group and if necessary outside groups.

The operating agent, the Brookhaven National Laboratory (BNL), has prepared the agent's preliminary programme of work[1] reflecting the discussions at the BNL workshop in last November. In this program, the followings are explained, i.e. the research objective, working criteria, rationale for working approach, working scope, task objectives which address technology characterization, methodology and communication, context of outside group activities, and programme plan.

This time, the IEA/ETSAP workshop and the International Forum on Energy Environment Studies (FEEST) which is a joint meeting with the members of the joint IAEA/UNEP/WHO project on "Assessing and Managing Health and Environmental Risks from Energy and Other Complex Industrial Systems", being held at BNL, would be considered as an occasion for communicating research activities among groups as well as for searching an effective way to conduct each working programme. With this understanding, in Japan, we are working upon research groups in universities and think-tanks to cooperate with this program.

The reference group responsible for conducting the IEA/ETSAP/Annex III programme in Japan is the group of which the members are Electrotechnical Laboratory (ETL)being operated by the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI), Japan Atomic Energy Research Institute (JAERI) being a public corporation under the jurisdiction of the Science and Technology Agency (STA), and semi-governmental New Energy Development Organization (NEDO).

2. Emission Releases

If we wish to study the energy-related environmental issue from its originating matter, we are forced to consider it in its revealed fields such as air pollution, water pollution, noise and vibration, offensive odors, waste disposal, ground subsidence, soil pollution on one hand and in its carries such as chemical effluents, suspended particulates, sound, heat, and radiations on the other.

However, even though we pick up one from these, for an instance, air pollution, it originates in a variety of pollutants, i.e. sulfur oxides, nitrogen oxides, carbon oxides, non-methane hydrocarbons,photochemical oxidants, suspended particles, etc., and some of these, for an instance, photochemical oxidants, are the pollutants generated secondarily and /or tertiarily. Those pollutants are directly or indirectly to cause acid rain, to raise greenhause effect, and to accelerate the destruction of an ozonic zone in the stratosphere. Overall impacts by these sources do not always relate with source strength additively but show in some case nonlinearity and mutual dependency within them. As those reasons, the background of the problem is in diverse and complex natures.

The operating agent's program suggests us that the ETSAP/Annex III research work will be focussing on air pollution, moreover, stressing on SO_2 , NO_2 , CO_2 emissions. Focussing on SO_2 , NO_2 , CO_2 , is well understandable for us from the reasons that these pollutants are key sources for acid rain problem now being requiring urgent countermeasures and also for such global problem as greenhause effect which is steadily progressing.

2.1 Present State of Monitering SO_2 and NO_2

In Japan, the promotion of environmental conservation has been executed upon individual laws, administrative guidances, ordinances, guidelines and the like which are based on the Basic Law for Environmental Pollution Control enacted in 1967. Both the Air pollution Control Law (enacted in 1968) and the Water pollution Control Law (Enacted in 1970) are examples of those. Environmental Quality Standard (EQS) is also introduced for each pollution cause.In Local areas, the provincial administrations introduce their own regulations, which are adaptable to local condition but conform to national

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To keep the EQS, both the Environment Agency and the local government administrations are responsible for year-round monitoring of pollutants in accordance with pollution control laws, For this purpose, national pollution monitoring station network and local monitoring stations have been introduced by the government and local authorities (Details are in Appedix II).

Factory owners and/or enterprisers have to monitor pollutants released from their facilities and to report their records to the associated local authorities. The local authority has a right to inspect facilities.

Sulfur dioxide (SO_2) concentration[2] in ambient air in 1984 was recorded at 1623 valid monitoring stations (a station at which monitoring is conducted for more than 6,000 hours a year) in 641 municipalities (Table 1). Annual average concentration of SO_2, which has been measured at 15 air pollution monitoring stations (Appendix 2) since 1965, is shown in Fig. 1.

As for nitrogen dioxide (NO_2) concentration[2] in ambient air, it was recorded at 1302 valid monitoring stations in 586 municipalities in 1984 (Table 2) and also at 282 valid automobile exhaust monitoring stations in 160 municipalities (Table 2). The solid line in Fig. 2 shows the annual average concentrations of NO_2 which have been measured at 15 air pollution monitoring stations and the dotted line for the average concentrations of 26 automobile exhaust monitoring stations.

Trend and current state of complicane with the EQS for SO_2 by the long-term criteria[2] is indicated in Table 1 as compliance rate (%). Here, the long-term criteria of the EQS is that the daily average readings at certain air pollution monitoring station over a year, excluding 2% of days with the highest readings (e. g., in the case that data are available for 365 days, 7 days with the highest readings are excluded, the 8th highest daily average reading is evaluated), shall not exceed 0.04 ppm and readings of any two consecutive days over the year shall not exceed 0.04ppm. The compliance rates in Table 1 indicate us that year after year the compliance with the EQS for SO_2 has been improving and recorded 99.4% in 1984. In view point of the short-term criteria, i.e. a ratio of the number of monitoring stations for which daily average reading is less than 0.04ppm in all monitoring days to the number of all valid monitoring stations, it recorded 94% in the same year.

Figure 3 shows the compliance rates[2] with the EQS for NO_2 both at air pollution monitoring stations and at automobile exhaust monitoring stations. Of air pollution monitoring stations, those for which the annual 98% value of daily average exceeds 0.06ppm, i.e. the upper limit of the EQS, have been decreasing in a few recent years but increased in 1984 and decreased again in 1985. This is due to the increases of emission in the areas of large populated cities where total emission is regulated.

Air pollution monitoring has been conducted also for those pollutants, i.e. NO_2, CO_2, photochemical oxidants, non-methane hydrocarbons, suspended particles, soots.

Among the data collected under the laws and regulations, especially the details of monitoring data for air and water pollutions are available to the public. However, the records at emission stage, most of which are reported from facility owners, are almost no publication. Aggregated data and/or partial data of them and the related information are publicized as environment-related statistics, as survey reports,etc., and appear in academic journals and/or engineering magazines, etc.

2.2 SO_2 , NO_2 Emission Coefficients

For controlling air pollutants in ambient air, we need the information on emission sources and their emission rates. Various kinds of energy facilities and related appliances and devices are those sources and they are operated in industry as well as utilized in residential and commercial sector and also in transportation sector. To know the quantity of an environmental pollutant in relation to its source, information and data concerning on kinds, installation, operation situation, environmental countermeasures of the related facilities and devices should be collected and analyzed beforehand.

As for emission release form fixed sources in industry, relevant information and data have been collected widely from factory level to business proprietor utilizing "Questionaire for Emission of Air pollutant". The collected information have been utilized to prepare a data base for emission coefficients. The data base is compiled in accordance with such indices as kinds of emissions, kinds of energy-related facilities and devices (Details are in Table 3), sectors of industry (Table 3), prefectures of instalation, quantity of emissions released. Emission release and emission coefficient depend on availability of facility, its fuels, and degree of emission control, so that tabulations have also been made for those variables.

As far as fixed sources in residential and commercial sector are concerned, similar approach has been taken. For moving sources in transportation sector, data base has been prepared for motor vehicles, ships, and airplanes. Emission releases from motor vehicles are estimated from those data,i. e. traffic volumes measured by traffic sensors, emission coefficients which are evaluated from the measuring data of volumes of automobile exhaust gas, of fuel consumption rates, of fuel components, and the constitution of number of motor vehicles which have adopted countermeasures.

For emission releases from ships so-called ship-indices (which reflect various activities of ships in harbors) and the emission coefficients (which are prepared from the monitoring data of air pollutants in special harbors) are major factors.

Emission releases from air planes are estimated from such data as emission coefficients, total number of air planes which are in access of landing and/or take-off. To the evaluation of emission coefficients, type of airplanes, difference of engines, operation modes both on a runway and on flying (which is further divided into approach, take-off (including taxiing and idling), and climb) are reflected, and original data of emission coefficients for airplanes are based on "Compilation of Air Pollution Emission Factors" prepared by the US Environmental Protection Agency.

2.3 Emissions for Study

Energy-environment systems analysis in the ETSAP/Annex III program will treat not only the present energy-environment system but also future systems. From this reason, it is necessary to prepare data base both for energy technologies and for control technologies which are not utilized at present but will be utilized in the future.

In order to maintain the environmental quality within the national EQS, the regulation of environmental pollutions should be tighten in those area where the emission concentration becomes possibly high. Especially in such area as highly possible emission concentration, not only such regulation as commonly applied in nation wide but also regulation for area-wide total pollutant load control (which means in turn admitting nonlinear emission coefficient with operating activity because emission rate will be roughly inversely propotional to the activity to keep total emission within some limited quantity.) as well as fuel regulation should be applied. This suggests us the fact that an analysis of relationship between emission sources and pollutant concentration can be made only if we have a well documented information on emission sources which are disaggregated by region, by facility, by fuel, and by level of regulation.

From this reason, our main interest is not in data themselves but in the approach for data acquisition, its scientific and engineering background, and the information suggesting limitations of approaches. Therefore, we will recommend such approach that some representative approaches, which can demonstrate the above, would first be addressed to exemplify the problem, after then, the comparative study on existing emission coefficients and other necessary data will be made.

3. Emission Control Technologies

There are many countermeasures for pollution controls. As for direct countermeasures, we can expect the followings: fuel switching to low sulfur and nitrogen content fuels; burner improvement; fuel cleaning by such technologies as gasification & liquefaction; oil refinery; desulfurization of heavy oil; hydro-cracking of heavy oil; flue-gas treatments such as desulfurization, denitrification, filterization, etc.

As indirect countermeasures, we can consider the followings: fossil fuel substitution by nuclear and renewable energy; electrification through fuel cell and electric automobil; hydrogen utilization in fuel cleaning and upgrading, electric power storage, automobils. Energy consevation technologies are also categorized in this frame. Efficiency improvement in electric power generation, improvements of heat utilization in building by thermal insulation, co-generation, heat pump have also benefit to reduce emission release through reduction in fossil fuel use.

Furthermore, such countermeasres as direct energy saving promoted by energy conservation campaign by people, improvement of fuel utilization efficiency of end-use technologies, shifts of both production mix and transportation mode in industry and transportation sectors to less eneregy-intensive structure and mode, collecting flue-gas, such as carbon dioxide, at exit of exhaust gas and converting it into fuel material again, which can be in recysle use, will also contribute to the reduction of pollutants.

Howener, practice of the above countermeasures should be made considering relative effectiveness among them.

3.1 Present Status of Countermeasures for SO_2 and NO_2

As for SO_2 emission control, such countermeasures as importation of low sulfur content fuel, desulfurization of heavy oil and desulfurization of flue-gas have been implemented. Concerning the flue-gas desulfurization, wet limestone-gypsum technology is widely used at present, and by this more than 90% of sulfuroxide in flue-gas can be removed. But, this method consumes much of water on one hand and produces excessive plaster on other hand. To solve these disadvantages, a dry-system desulfurization technology is now underdeveloping. With this technology, SO_2 in flue-gas can be recovered as simple sulfur through activated charcoal. Practical desulfurization facilities have been operating since 1970, and number and capacities of the facilities[2] have steadily increased (Fig. 4)

As for NO_2 emission control, it is divided roughly into two categories, i.e. countermeasures for fixed sources and countermeasures for moving sources. In regard to fixed sources, there exists burner improvement and denitrification of flue-gas. For burner improvement, such technologies as two stage burning, partial recycling of flue-gas, low NOx burner are present arts of technologies.

As for denitrification of flue-gas, most of operating units employ the dry selective catalytic reduction process based on ammonia, while there are other processes such as non-catalytic reduction process, wet direct absorption and wet oxidation absorption. The denitrification efficiency of present technologies exceeds more than 80%. Historical changes in the number of denitrification units[2] installed is shown in Fig. 5

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As far as NOx emission from motor vehicles is concerned, it has been put in effect by following measures: catalytic reduction effective for CO, HC, NOx simultaneously; engine structural improvements (combution chamber,inhaling nozzle and valve); recycling a part of flue-gas; fuel jet equipment controlled by electronic devices (blast-off timing, jetted fuel volume, blast-off angle, optimization of opening and closing valve), etc.. The effects[2] of regulation on automobile exhaust are shown in Fig. 6 and the permissible limits[2] of motor vehicle exhaust gas are presented in Table 4.

3.2 Characterization of Emission Control Technologies

As seen in the above, emission control technologies have many kinds and depend on degrees of their regulations. It becomes so large job as we had experienced in the ETSAP/Annex I to make characterization of those technologies all , and a lot of time might be necessary if we will do this in the same way as in the ETSAP/Annex I. Considering the nature of our study and available information, we prefer to reduce number of technologies to be characterized rather than just collecting data, but we should carefully select technologies in order to cover major part of pollution field and countermeasures.

In actual work on technology characaterization, we can utilize several different kinds of materials such as statistics, technical reports, and in the course of working we may face some difficulty for which we can not trace its background well. In this case, it may be necessary to consult with experts outside the ETSAP groups. Before starting our work, data format should be reconsidered again, because the latest format has in part some inconsistencies and is inadaptable for those problem analyses, for an instance, both desulfurization and denitrification of flue-gas being treated not always for each of emissions but for some group of emission.

To search for the trade-off relationship between routine emissions and cost of countermeasures through the energy-envronment systems analysis, not only emission coefficients but also cost data are necessary for us. In making this data, the information on trade-off relationships among cost, emission coefficients, and level of countermeasures will serve as key factors.

We are much interested in countermeasures both for flue-gas from coal-steam electric power plants and for exhaust gas from motor vehicles, ships, and airplanes from view point of acid rain problem in long-term. And, also from the view point on green hause effect problem we are interested in fossil fuel utilization,especially in reducing coal and synthetic fuels by substitution of those fuels with less CO_2 burden fuels and/or energy sources and through CO_2 recycling use. The characterization of those technologies will be the item for mutual cooperation.

4. Systems Analysis Methodology

We are developing methodologies and data bases for energy-economy-environment system analyses through conducting the IEA/ETSAP research programme, other international cooperative research subjects, and our own subjects. We are also conducting their applications. Of these, within the research activities carried out by ETL and JAERI, which will be considered useful for the ETSAP/Annex III programme, we will report our recent activities on following subjects:

(1) Study on Energy-Environmental Analysis in ETL[3]

(2) Progress in Integrated Energy-Economy-Environment Model System Development[4]

(3) Introduction of Activities on PSA Development and Application at JAERI and PNC[5]

(4) Development in JAERI of Method and Data Base for Environmental Radiological Consequences Assessment[6].

Those reports are prepared and annexed to this report, and the report (1)-(3) are presented to the IEA/ETSAP workshop and the report[4] to the IEA/ETSAP/FEEST meeting.

5. Conclusion

The problematic area of energy-environment to be dealt with systems analysis has wide boundaries and involves various interdiciplinery problems. For challenging to those problems, we have to keep in mind the clear definition on our subject matter.

As far as the subject matter is concerned, both the ETSAP/Annex III and the operating agent working programme are proposing to study countermeasures that would be effective to acid-rain problem requiring urgent actions and to the green-hause effect problem progressing steadily. The study is aiming at accesses from scientific, engineering, and technological sides.

From this view point, our research activities in approach, methodology, and data base have to be both suitable and effective in pursuit of the problems. More complex and wider the problems become, more simple and concise approach is necessary. The key to the way relies on how to reflect our technical resources and scientific and engineering findings to the study properly.

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Refernces

(1) D. Hill;"Operating Agent's Preliminary Program of Work in IEA/ETSAP/Annex III", presented at the Workshop for the ETSAP/Annex III held at BNL (Nov. 1986).

(2) The Environment Agency of Japan; "The White Paper on the Environment" for the fiscal year 1985 (May 1985) and 1986 (May 1986) [in Japanese].

(3) S. Koyama, S. Ihara; "Study on Energy-Environmental Analysis in ETL", to be presented at the Workshop for the ETSASP/Annex III held at BNL (June 1987).

(4) S. Yasukawa, S. Mankin, O. Sato, T. Tadokoro, Y. Nakano, T. Nagano; "Progress in Integrated Energy-Economy-Environment Model System Development", to be presented at the Workshop for the ETSAP/Annex III held at BNL (June 1987).

(5) T. Harami; "Introduction of Activities on PSA Development and Application at JAERI and PNC", to be presented at the Workshop for the ETSAP/Annex III held at BNL(June 1987).

(6) T. Iijima, T. Homma, D. Togawa, S. Mitake, Y. Sakamoto; "Development in JAERI of Method and Data Base for Environmental Radiological Consequences Assessment", to be presented at the FEEST, the joint metting of the IEA/ETSAP/Workshkop and the IAEA/UNEP/WHO Project held at BNL (June 1987).

Table 1 State of Compliance with Sulfur Dioxide Environmental Quality Standard for SO_2 (based on long-term criteria)

Category \ Year	'79	'80	'81	'82	'83	'84
Number of monitoring stations	1532	1571	1586	1605	1613	1623
Number in compliance	1485	1546	1569	1596	1603	1614
Compliance rate (%)	96.9	98.4	98.9	99.4	99.4	99.4

Table 2 Compliance with the Environmental Quality Standard for NO_2 (FY 1984)

Annual 98% value for daily average \ Type of motiroring station	Air pollution monitoring station		Automobile exhaust monitoring station	
	Number of stations	Percentage (%)	Number of stations	Percentage (%)
over 0.06 ppm	43	3.3	75	26.6
0.04-0.06 ppm	283	21.7	160	56.7
under 0.04 ppm	976	75.0	47	16.7
Total	1302	100.0	282	100.0

Table 3-1 Facilities for Emission Data Preparation

Facilities	Use
Boiler	Electric power generation Industrial use Space heating Others
Gas generator	Industrial gas, consummer gas production
Gas heater	Industrial process
Roasting furnace	Sulfuric acid production Cu, Zn, Pb production
Sintering furnace	Iron making Nonferous metal production Inorganic material production
Smelting furnace Melting pot crucible	Steel making, steel casting Al refineing, Al casting, glass production Other refineing and casting
Coke oven	Cake production
Blast furnace	Iron making, nonferrous metal making
Basic oxygen furnance	Steel making, nonferrous metal making
Soaking pit	Steel making
Heat treatment furnace	Metal production
Oil furnace	Chemical products production
Catalyst regenerator	Chemical plants
Calciner	Lim, dolomite, carbone, bricks, china and porcelain, and others
Kiln	SP, NSP, L types and others
Reaction furnace	Inorganic chemical products, food treatment, and others
Drying furnace	For various uses
Electric furnace	By resistance, induction, arc, and ultrared ray
Refuse incinerator	Industrial and urban refuses
Others	Reforming, reactioning, distilling, evaporating, drying, bleaching, plating, enriching processes

Table 3-2 Industrial Category for Emission Data Preparation

1. Agriculture, Forestry and Fishery
2. Minings
3. Foods
4. Textiles
5. Lumber and Woods
6. Pulp and Paper
7. Chemicals
8. Petro. & Coal Products
9. Rubber & Leather
10. Ceramics & Clays
11. Iron & Steel
12. Non-Ferrous Metals
13. Fabiricated Metal Products
14. Machinery
15. Other manufactures
16. Construction
17. Transportation & Communication
18. Services
19. Electric Supply
20. Gas Supply

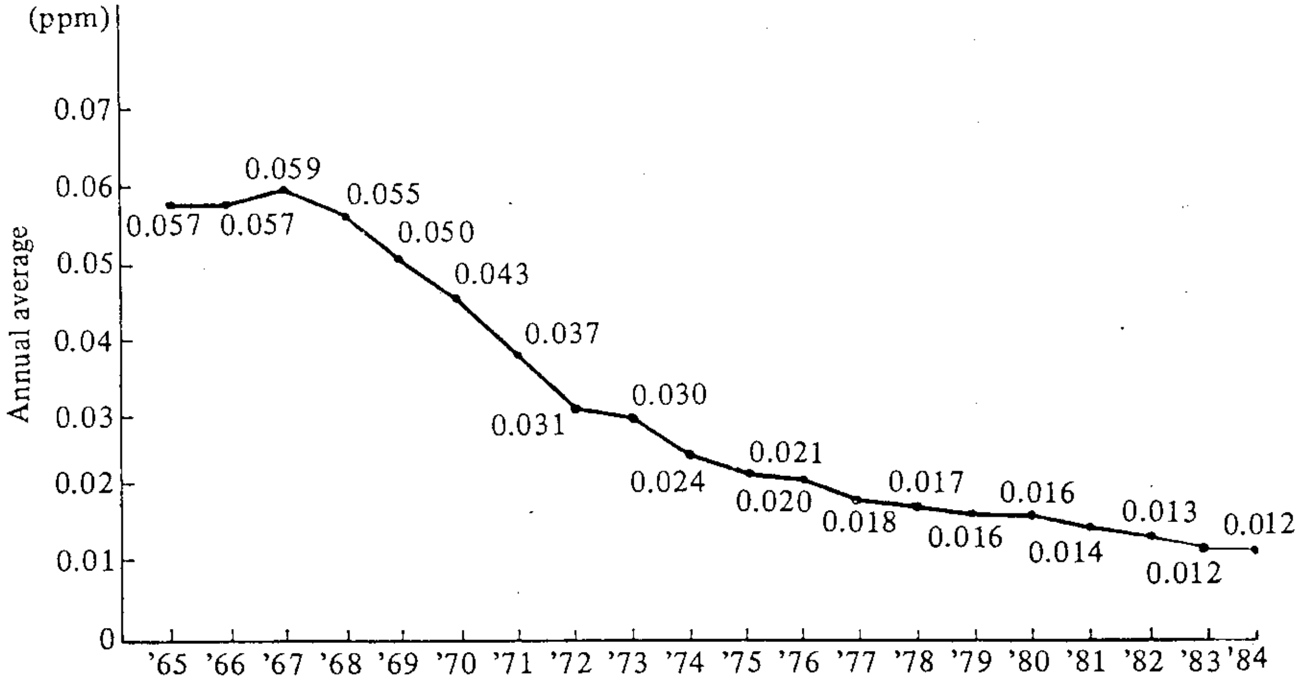
Table 4 Permissible Limits of Motor Vehicle Exhaust Gas

					Application date: New model vehicle	Application date: Existing model vehicle	Standards (maximum permissible limits)
Gasoline- or LPG-fueled vehicle	Carbon monoxide (CO)	New vehicle	Control by driving cycle	4-mode	September 1, 1966	September 1, 1967	3.0% for gasoline-fueled ordinary-sized motor vehicle and small-sized motor vehicle
				4-mode	September 1, 1969	January 1, 1970 April 1, 1970**	2.5% for gasoline-fueled ordinary-sized motor vehicle and small-sized motor vehicle **for truck and bus
				4-mode	January1, 1971		1.5% for LPG-fueled ordinary-sized motor vehicle and small-sized motor vehicle 3.0% for mini-sized motor vehicle
				10-mode	April 1, 1973	December 1, 1973	26.0 g/km for gasoline-fueled passenger car, 18.0 g/km for LPG-fueled passenger car (all vehicles except heavy-duty vehicle)
				Gasoline 6-mode			1.6% for gasoline-fueled vehicle, 1.1% for LPG-fueled vehicle (heavy-duty vehicle)
				10-mode	April 1, 1975	December 1, 1975	2.7 g/km for passenger car, 17.0 g/km for truck and bus (all vehicles except heavy-duty vehicle)
				11-mode		(April 1, 1976)	85.0 g/test for passenger car, 130.0 g/test for light-duty vehicle (all vehicles except heavy-duty vehicle)
			Idling		August 1, 1970		4.5%
							5.5%
		Vehicle in use	Idling		October 1, 1972		4.5%
	Hydro-carbon (HC)	New vehicle	Blow-by gas control		September 1, 1970	January 1, 1971	Installation of blow-by gas recirculation device
			Fuel evaporative gas control		July 1, 1972	April 1, 1973	Installation of fuel evaporative emission control device (2.0 g/test)
			Control by driving cycle	10-mode	April 1, 1973	December 1, 1973	3.8 g/km for gasoline-fueled vehicle, 3.2 g/km for LPG-fueled vehicle (all vehicles except heavy-duty vehicle), 22.5 g/km for mini-sized motor vehicle with two-stroke engine
				Gasoline 6-mode			520 ppm for gasoline-fueled vehicle, 440 ppm for LPG-fueled vehicle (heavy-duty vehicle)
				10-mode	April 1, 1975	December 1, 1975 (April 1, 1976)	0.39 g/km for passenger car, 2.7 g/km for truck and bus, 15.0 g/km for truck of mini-sized motor vehicle with two-stroke engine (all vehicles except heavy-duty vehicle)
				11-mode			9.5 g/test for gassenger car, 17.0 g/test for truck and bus, 70.0 g/test for truck of mini-sized motor vehicle with two-stroke engine (all vehicles except heavy-duty vehicle)
		Vehicle in use	Device installation		May 1, 1973		Installation of HC/NOx reduction device and adjustment of spark timing
			Idling		January 1, 1975		1,200 ppm for passenger car and bus with four-stroke engine, 7,800 ppm for passenger car and bus with two-stroke engine, 3,300 ppm for passenger car and bus with special structure engine
					June 1, 1975		1,200 ppm for truck with four-stroke engine, 7,800 ppm for truck with two-stroke engine, 3,300 ppm for truck with special structure engine
	Nitrogen oxides (NOx)	New vehicle	Control by driving cycle	10-mode	April 1, 1973	December 1, 1973	3.0 g/km (all vehicles except heavy-duty vehicle) 0.5 g/km for mini-sized motor vehicle with two-stroke engine
				Gasoline 6-mode			2,200 ppm for heavy-duty vehicle
				10-mode	April 1, 1975	December 1, 1975 (April 1, 1976)	1.6 g/km for passenger car, 2.3 g/km for truck and bus, 0.5 g/km for mini-sized motor vehicle with two-stroke engine (all vehicles except heavy-duty vehicle)
				11-mode			11.0 g/test for passenger car, 20.0 g/test for truck and bus, 4.0 g/test for mini-sized motor vehicle with two-stroke engine (all vehicles except heavy-duty vehicle)

Table 4 (Continue)

Gasoline- or LPG-fueled vehicle	Nitrogen oxides (NOx)	New Vehicle	Control by driving cycle	10-mode	April 1, 1976	March 1, 1977 (March 31, 1978)	0.84 g/km for passenger car with EIW of 1 ton or less, 1.2 g/km for passenger car with EIW of more than 1 ton and passenger car of mini-sized motor vehicle with four-stroke engine, 0.5 g/km for mini-sized motor vehicle with two-stroke engine	
				11-mode			8.0 g/test for passenger car with EIW of 1 ton or less, 9.0 g/test for passenger car with EIW of more than 1 ton and passenger car of light motor vehicle with four-stroke engine, 4.0 g/test for mini-sized motor vehicle with two-stroke engine	
				Gasoline 6-mode	August 1, 1977	April 1, 1978	1,850 ppm for heavy-duty vehicle	
				10-mode	April 1, 1978 (April 1, 1981)	March 1, 1979 (April 1, 1981)	0.48 g/km for passenger car	
				11-mode			6.0 g/test for passenger car	
				10-mode	January 1, 1979 (April 1, 1981)	December 1, 1979 (April 1, 1981)	1.4 g/km for truck and bus (light-duty vehicle) 1.6 g/km for truck and bus (medium-duty vehicle and mini-sized motor vehicle)	
				11-mode			10 g/test for truck and bus (light-duty vehicle) 11 g/test for truck and bus (medium-duty vehicle and mini-sized motor vehicle)	
				Gasoline 6-mode			1,390 ppm for truck and bus (heavy-duty vehicle)	
				10-mode	January 1, 1981 (April 1, 1983)	December 1, 1981 (April 1, 1983)	0.84 g/km for truck and bus (light-duty vehicle)	
				11-mode			8.0 g/test for truck and bus (light-duty vehicle)	
				10-mode	December 1, 1981 (April 1, 1984)	November 1, 1982 (April 1, 1984)	1.26 g/km for truck and bus (medium-duty vehicle)	
				11-mode			9.5 g/test for truck and bus (medium-duty vehicle)	
				10-mode	January 1, 1982 (April 1, 1984)	December 1, 1982 (April 1, 1984)	1.26 g/km for mini-sized motor vehicle	
				11-mode			990 ppm for heavy-duty vehicle	
				Gasoline 6-mode			990 ppm for heavy-duty vehicle	
		Vehicle in use	Device installation		May 1, 1973		Installation of HC/NOx reduction device and adjustment of spark timing	
Diesel-powered vehicle	CO, HC, NOx	New vehicle	Control by driving cycle	Diesel 6-mode	September 1, 1974	April 1, 1975	CO 980 ppm, HC 670 ppm, NOx 590 ppm (1,000 ppm for direct injection type)	
	NOx				August 1, 1977	April 1, 1978	500 ppm (850 ppm for direct injection type)	
					April 1, 1979 (April 1, 1981)	March 1, 1980 (April 1, 1981)	450 ppm (700 ppm for direct injection type)	
					January 1, 1982 (April 1, 1984)	December 1, 1982 (April 1, 1984)	390 ppm for IDI passenger car	
					October 1, 1982 (April 1, 1984)	September 1, 1983 (April 1, 1984)	390 ppm for IDI vehicle	
					August 1, 1983 (April 1, 1985)	July 1, 1984 (April 1, 1985)	610 ppm for DI vehicle	
	CO, HC NOx			10-mode	October 1, 1986 (April 1, 1988)	September 1, 1987 (April 1, 1988)	CO: 2.7 g/km HC: 0.62 g/km NOx: 0.98 g/km (EIW of 1,250 kg or less) 1.26 g/km (EIW of more than 1,250 kg)	passenger car with manual transmission
					October 1, 1987 (April 1, 1989)	September 1, 1988 (April 1, 1989)		passenger car with automatic transmission
	Particulates (Diesel smoke)	New vehicle	Full-load test		July 1, 1972		Rate of contamination 50%	
		Vehicle in use	No-load acceleration test		January 1, 1975			

Notes:
1. Light-duty vehicle – an ordinary car or small-sized car weighing less than 1,700 kg.
2. Medium-duty vehicle – an ordinary car or small-sized car weighing 1,700 up to 2,500 kg.
3. Heavy-duty vehicle – an ordinary car or small-sized car, excluding passenger car, weighing more than 2,500 kg.
4. "All vehicles except heavy-duty vehicle" – all vehicles except truck and bus weighing more than 2,500 kg.
5. Application date in the parentheses is applied to the imported cars.



Note: Annual average is the quotient of the sum of all one-hour values per year divided by the total measured hours.

Fig. 1 Changes in Annual Average Concentration of SO_2 (Average of 15 air pollution monitoring stations)

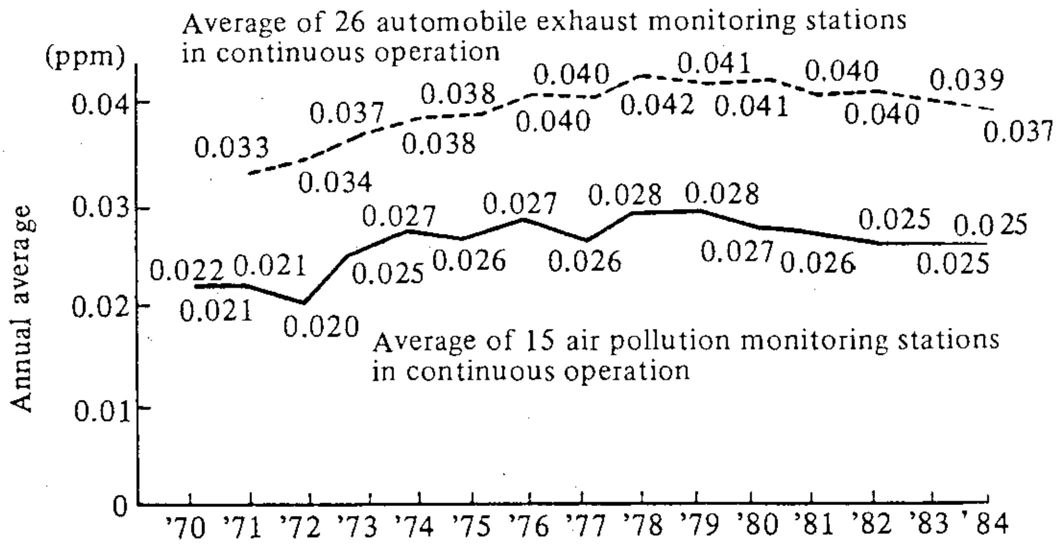
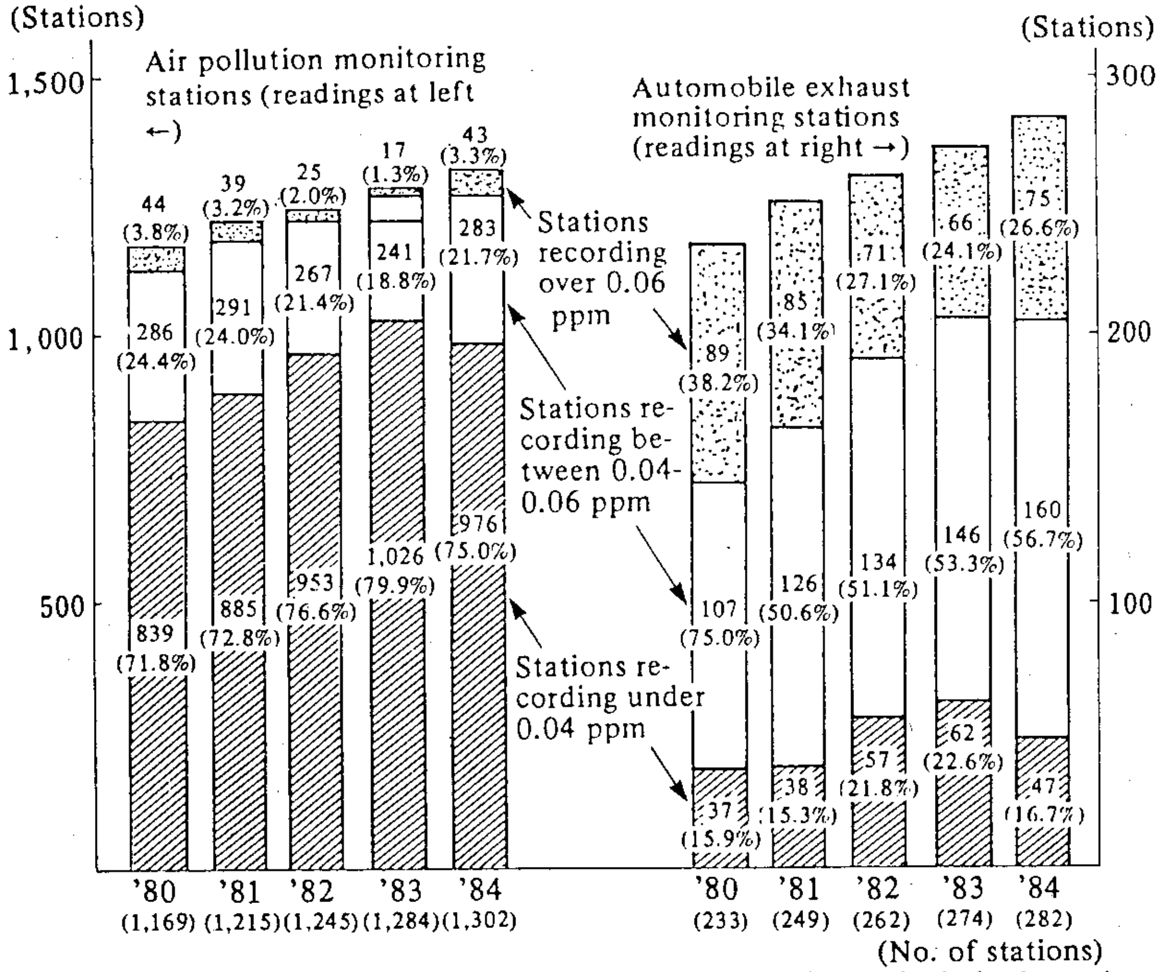


Fig. 2 Changes in Annual Average Concentration of NO_2



Notes:
1. The automobile exhaust monitoring stations do not include those the sampling inlets are located in the driveway.
2. The figures in parentheses indicate the ratio of number of the given monitoring stations to number of all pollution monitoring stations.
3. The concentration level is annual 98% value of daily average.

Fig. 3 Compliance Rate with Environmental Quality Standards for NO_2

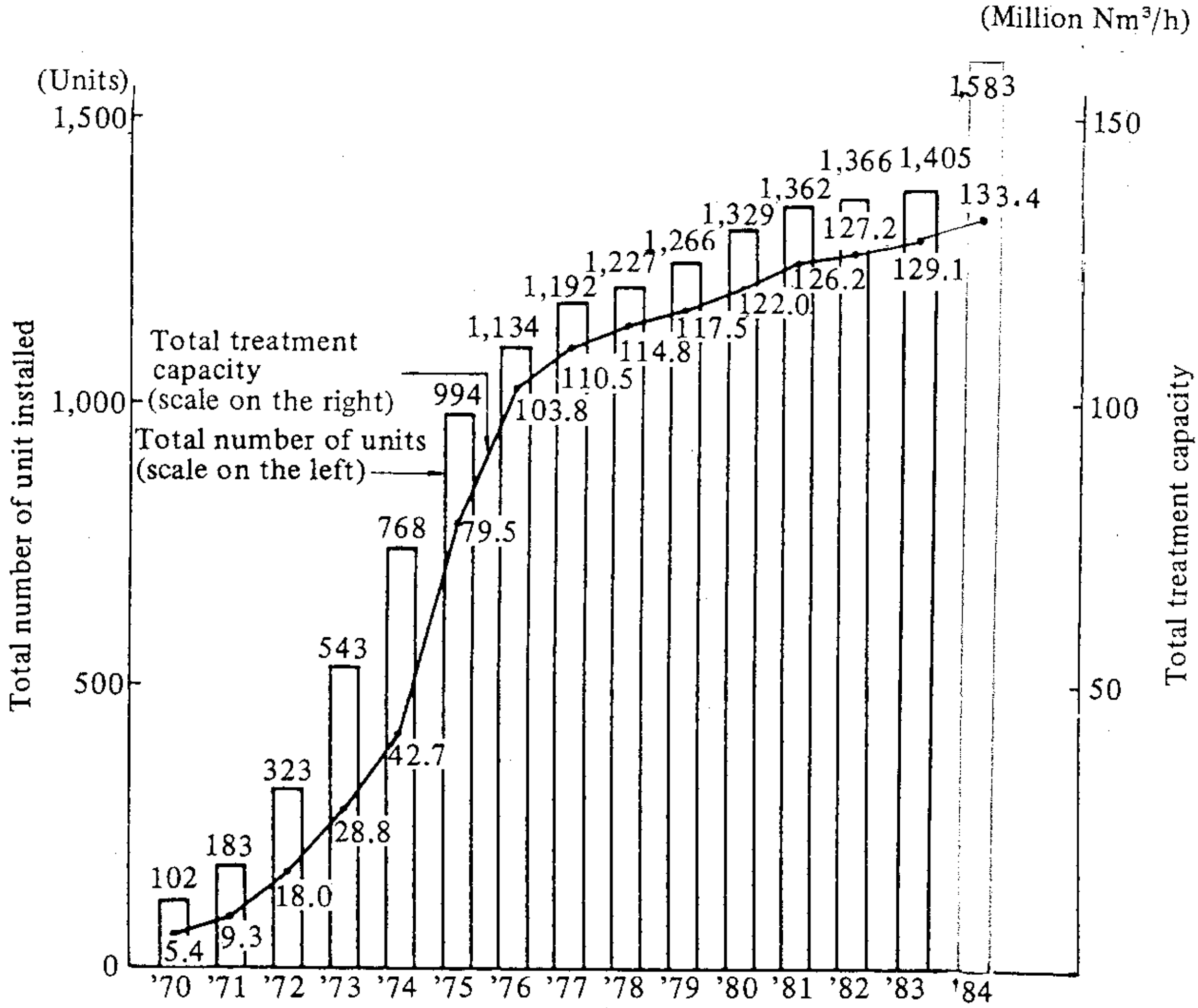
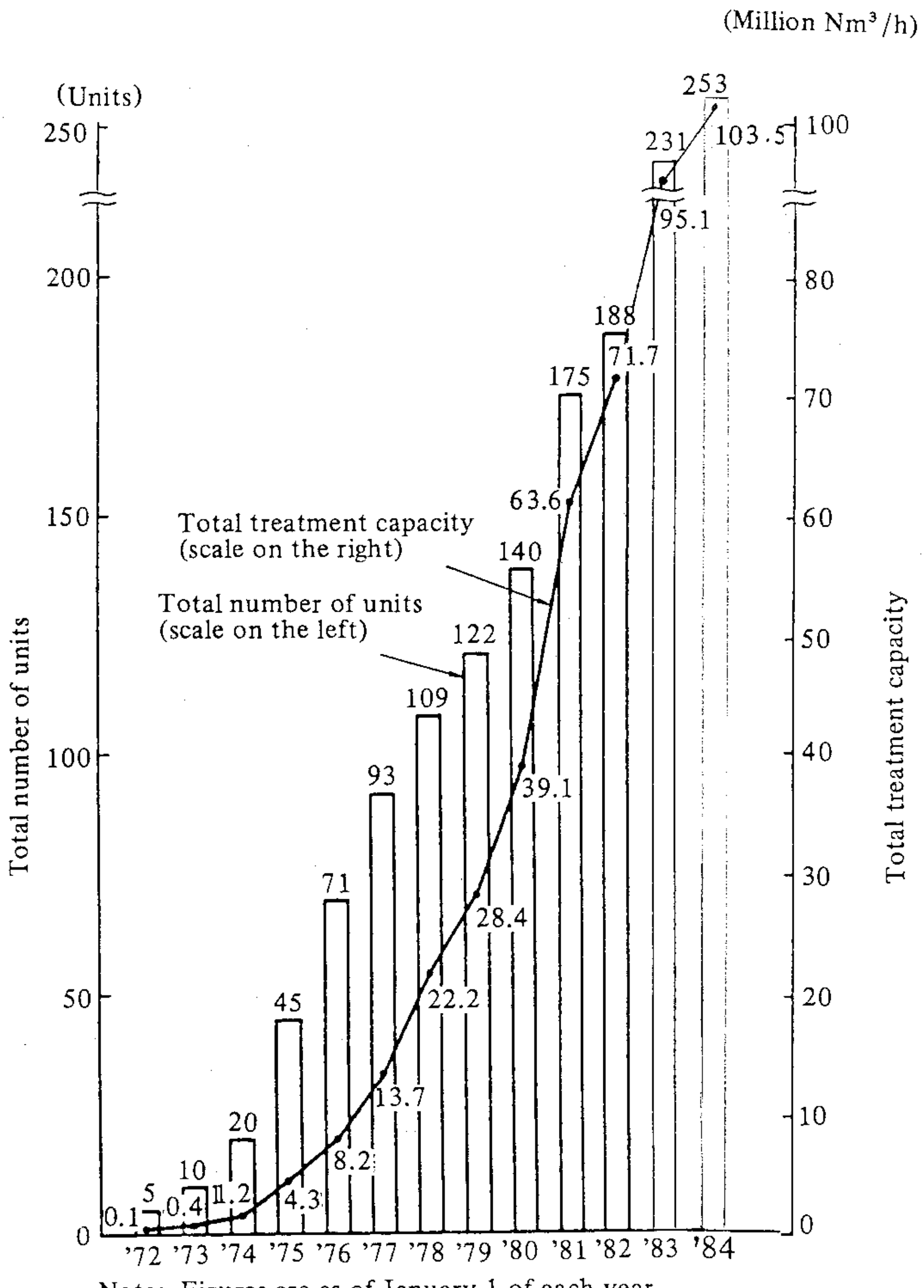
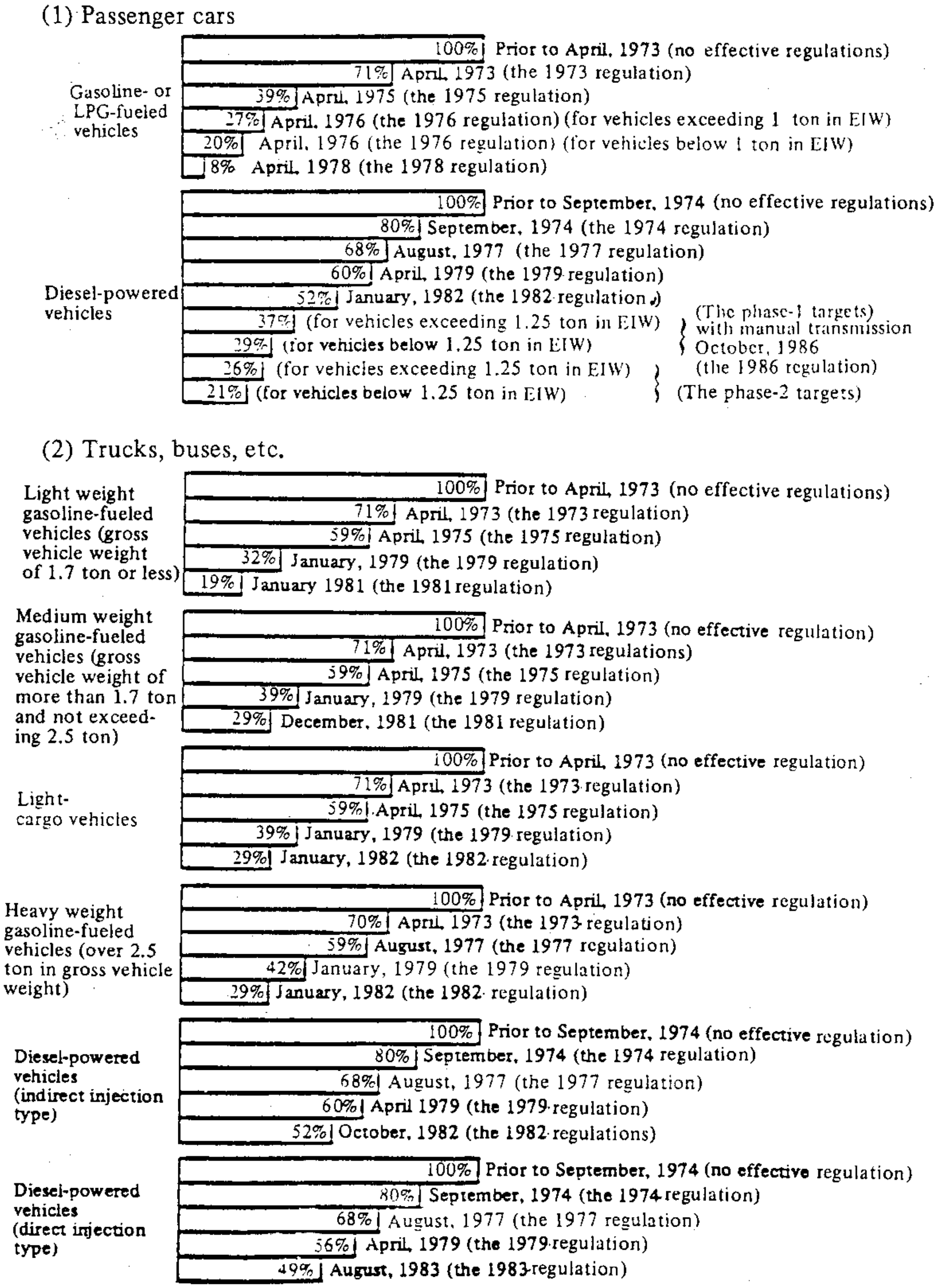


Fig. 4 Changes in the Number and Total Capacities of Flue Gas Desulfurization Units



Note: Figures are as of January 1 of each year.

Fig. 5 Changes in the Number of Denitrification Units Installed



Note: EIW is the abbreviation for equivalent inertia weight.

Fig. 6 Effects of Regulation on Automobile Exhaust (Average values of NO_X emissions)

APPENDIX 1 AN OUTLINE OF THE AIR POLLUTION CONTROL LAW

A-1.1 Air Quality Standards

The national standards of the ambient air quality in Japan have been established by the Basic Law for Environmental Pollution Control. The air quality standards stipulated in the law for five pollutants and their measuring methods are summarized in Table A-1.

Table A-1 Ambient Air Quality Standards *)

Substance	Standard values	Measuring methods
Sulfur dioxide	Daily average of hourly values shall not exceed 0.04 ppm, and hourly values shall not exceed 0.1 ppm	Conductometric method
Carbon monoxide	Daily average of hourly values shall not exceed 10 ppm, and average of hourly values in eight consecutive hours shall not exceed 20 ppm.	Nondispersive infrared analyzer method
Suspended[1] particulate matter	Daily average of hourly values shall not exceed 0.10 mg/m^3, and hourly values shall not exceed 0.20 mg/m^3	Weight concentration measuring methods based on filtration collection, or light scattering method, or piezoelectric microbalance method of β-ray attenuation method yielding values having a linear relation with the values of the above method
Nitrogen[2] dioxide	Daily average of hourly values shall be within the range between 0.04 ppm and 0.06 ppm or below.	Colorimetry employing Saltzman reagent (with Saltzman's coefficient being 0.84)
Photochemical[3] oxidants	Hourly values shall not exceed 0.06 ppm	Absorptiometry using neutral potassium iodide solution, or coulometry

Notes:
1. Suspended particulates matter shall mean airborn particles of 10 microns or less in diameter.
2. a) In an area where the daily average of hourly values exceeds 0.06 ppm, efforts should be made to achieve the level of 0.06 ppm by 1985.
   b) In an area where the daily average of hourly values is within the range between 0.04 ppm and 0.06 ppm, efforts should be made so that the ambient concentration be maintained around the present level within the range or does not significantly exceed the present level.
3. Photochemical oxidants are oxidizing substances such as ozone and peroxiacetyl nitrate produced by photochemical reactions (only those capable of isolating iodine from neutral potassium iodide, excluding nitrogen dioxide).

*) Environment Agency ed., 'Quality of the Environment in Japan 1986.', Sansei Sougou Printing Co., Tokyo, 1986, p.248.

A-1.2 Sulfur Oxides

The emission standard for each facility is prescribed by the "K-value regulation" with which the emission levels are stipulated according to the 16 ranks of "K" constants. The ranks are ranged from 3.0 to 17.5 (smaller the stricter) corresponding to the location and the height of exhausting point of sulfur oxides. The more small ranks are forced in some areas.

The areas where factories and other business establishments are too concentrated to maintain the environmental quality standards merely with emission control over individual facilities are designated as the area-wide total pollutant load control regions. Additional regulations are imposed on those areas under an area-wide total pollutant control plan formulated by the prefectural governors. The plan imposes a more strict regulation for a newer facility and for a larger energy consuming facility. There are 24 such areas as of 1985.

In the city area where seasonal heavy local air pollution is caused by heating equipments, fuel use standards are imposed to regulate the sulfur content of fuels.

A-1.3 Nitrogen Oxides

The emission standards are prescribed according to the type and the scale of soot and smoke emitting facilities, and to the grade of fuels. These standards have been established deeming of the attainability of the most of the present fuel combustion techniques.

There are several regions in which factories and other business establishments are so concentrated that the emission control with respect to individual facilities does not provide the desired effect. In such regions the area-wide total pollutant load control on nitrogen oxides is introduced by the Cabinet Order for Implementation of Air Pollution Control Law. The law requests to take necessary measures to achieve the environmental quality standards for nitrogen dioxide. Tokyo, Yokohama, and Osaka have been designated as such region. Kita-kyushu and Kobe are carrying out the measures by their own ordinances.

A-1.4 Other Emissions

The emission standards for soot and dust are specified for each type and scale of facility under the Air Pollution Control Law. Stringent standards are stipulated for newly installed and expanded facilities in the areas suffering severe air pollution.

The permissible limits of automobile exhausts have been established in the law according to the type and the weight of vehicles, and according to the displacement of engines and the using fuels.

APPENDIX 2 THE STATUS OF AIR MONITORING IN JAPAN

(1) Numbers of Local Air Monitoring Stations as of 1985

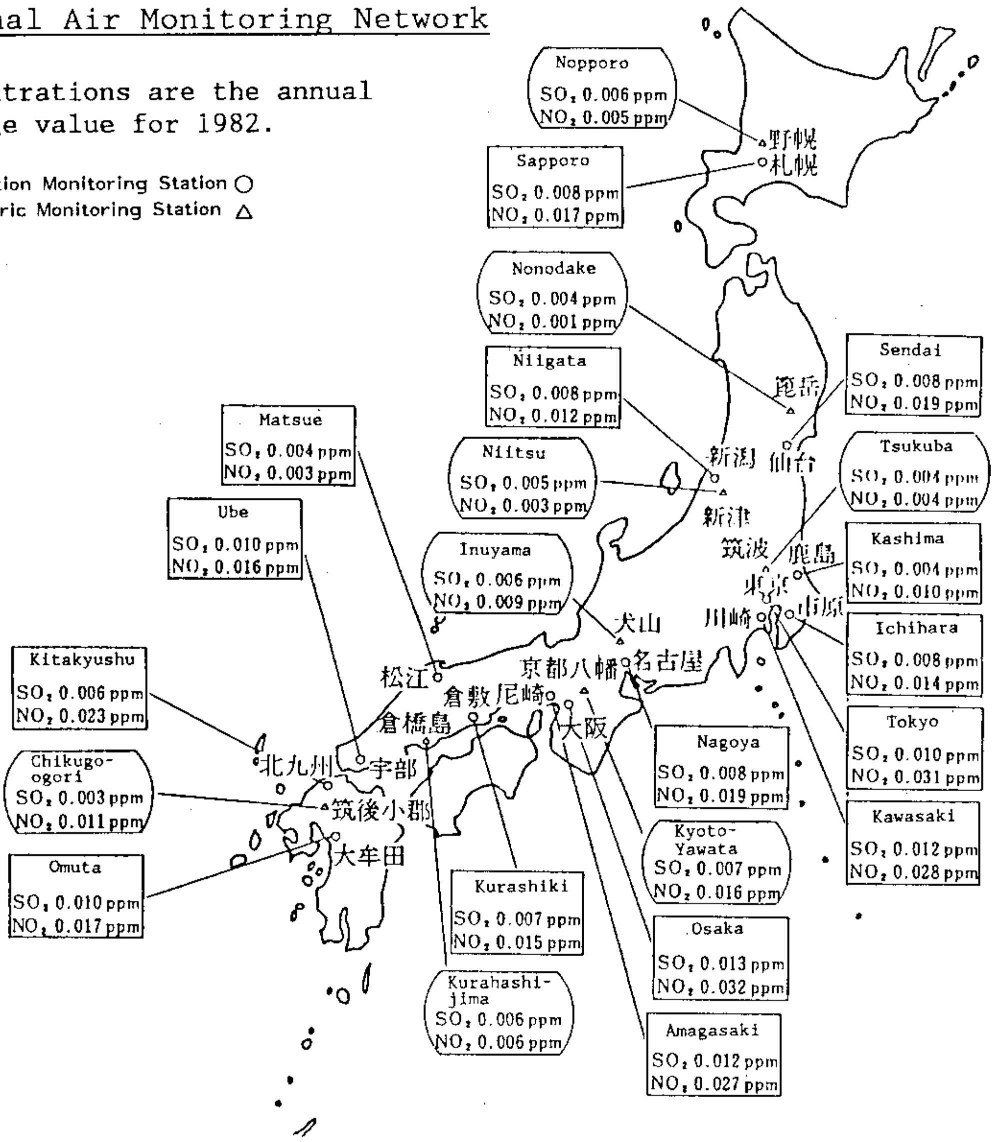
Item	Air pollution(1,647)*	Automobile exhaust(341)
SO_x	1,647	54
NO_x (NO, NO_2)	1,321	295
CO	197	317
HC		142
Non-methane HC	306	
Photo-chemical oxidants	1,021	48
Total suspended particulate matter	884	
Suspended particulate matter (diameter less than 10μm)	680	65
Wind direction and velocity	1,582	
Temperature	427	
Traffic volume		59

*) Including 108 mobile air monitoring stations.

(2) National Air Monitoring Network

°Concentrations are the annual average value for 1982.

Air Pollution Monitoring Station ○
Atmospheric Monitoring Station △



APPENDIX 3 PRESENT STATE OF ENVIRONMENTAL PROBLEMS IN JAPAN

Special attentions have been paid in Japan to the 'seven major types of pollution', namely, air pollution; water pollution; noise; vibration; offensive odors; soil pollution; and ground subsidence, and various endeavors are being made to develop their coutermeasures.

Among of those, air pollution by nitrogen oxides, water pollution in semi-closed water areas, and traffic noise are considered to be the present most pressing problems.

Acid rain is recognized not so urgent as in some other countries. However, establishment of its monitoring system is going to be accelerated since there have been observed low pH rainfalls frequently in a year, and acidification of some lakes and ponds have been discovered.

Other types of environmental issues to be remarked are those of agricultural chemicals and waste disposals. The use of agricultural chemicals have been tightly controlled under the Agricultural Chemicals Regulation Law since 1971 and any big problem has not been posed up to the present. On the other hand the disposal of domestic wastes and industrial wastes is still problematic.

Followings are the brief summary of the present state of the seven major pollutions.

(1) Air Pollution

Sulfur dioxide: Fig. A-1(a) shows the changes in the annual average atmospheric concentration of SO_2 which have been measured at 15 air pollution monitoring stations (see APPENDIX 2) since 1965. The concentration was its maximum at 0.059 ppm in 1967 and has decreased to 0.012 ppm in 1984. There were 1,623 stations monitoring SO_2 in the atmosphere in 1984, and 99.4% of them showed the average concentration in compliance with the ambient air quality standard for SO_2 (see APPENDIX 1).

Nitrogen dioxide: Fig. A-1(b) shows the annual average concentrations of NO_2. The solid line and the dashed line indicate respectively the average of the 15 stations and that of the 26 automobile exhaust monitoring stations. The average NO_2 concentration in 1984 was 0.025 ppm for the 15 stations and 0.037 ppm for the 26 stations. There were 1,302 air pollution monitoring stations and 282 automobile exhaust monitoring stations recording validly NO_2 concentration in 1984. Among of them, 43 air pollution monitoring stations (3.3%) and 75 automobile exhaust monitoring stations (26.6%) were known to have exceeded the upper limit of the ambient air quality standard for NO_2 (see APPENDIX 1). Most of those stations were located in the metropolitan area of Tokyo, Osaka, and Kobe prefectures, and it was suggested that the pollutant emission from automobiles was not decreased as it had been planned.

Nitrogen monoxide: Fig. A-1(c) shows that the annual average concentration of NO had been continuously decreased since 1971 to 1983 but that the concentration in 1984 stayed at the same level as in 1983.

Carbon monoxide: Air pollution by CO is ascribed to the automobiles, and the annual average concentration measured at 15 automobile exhaust monitoring stations is shown in Fig. A-1(d).

It was 6.0 ppm in 1971 and decreased to 2.5 ppm in 1984. The concentrations recorded in 1984 at all 293 valid automobile exhaust monitoring stations and at all 192 valid air pollution monitoring stations complied with the ambient air quality standards described in the Table A-1 of APPENDIX 1.

<u>Photochemical oxidants</u>: As shown in Fig. A-1(e), both the frequency of issuing an oxidant warning and the number of the reported sufferings per year decreased since 1973 to 1981 but again tended to increase after that. The Meteorological Agency is conducting analysis and forecasts of meteorological conditions that are likely to induce photochemical air pollutions.

<u>Suspended particulate matter</u>: The concentration data in 1984 were obtained at 607 monitoring stations in 199 municipalities. Only at 50.1% of those stations the measured values complied with the ambient air quality standards.

(2) Water Pollution

Pollutions in the semi-closed water areas such as lakes and ponds, inland seas, and bays and coves are the present big problems to be solved.

(3) Noise

Of all types of pollution, noise comes on top of the list in terms of the number of complaints every year (32%). Breakdown of the number of complaints by the type of noise indicates that the noise from factories and other business establishments including construction works accounts for 50%; so-called neighborhood noise in urban and suburban area for 35%; and traffic noise for 15%.

(4) Vibration

3.7% of the number of all complaints on pollution are from vibration. Breakdown by vibration source indicates that the number of complaints on vibration of factories and other business establishments accounts for 40%; construction works for 40%; and traffic and transportation for 14%.

(5) Offensive Odors

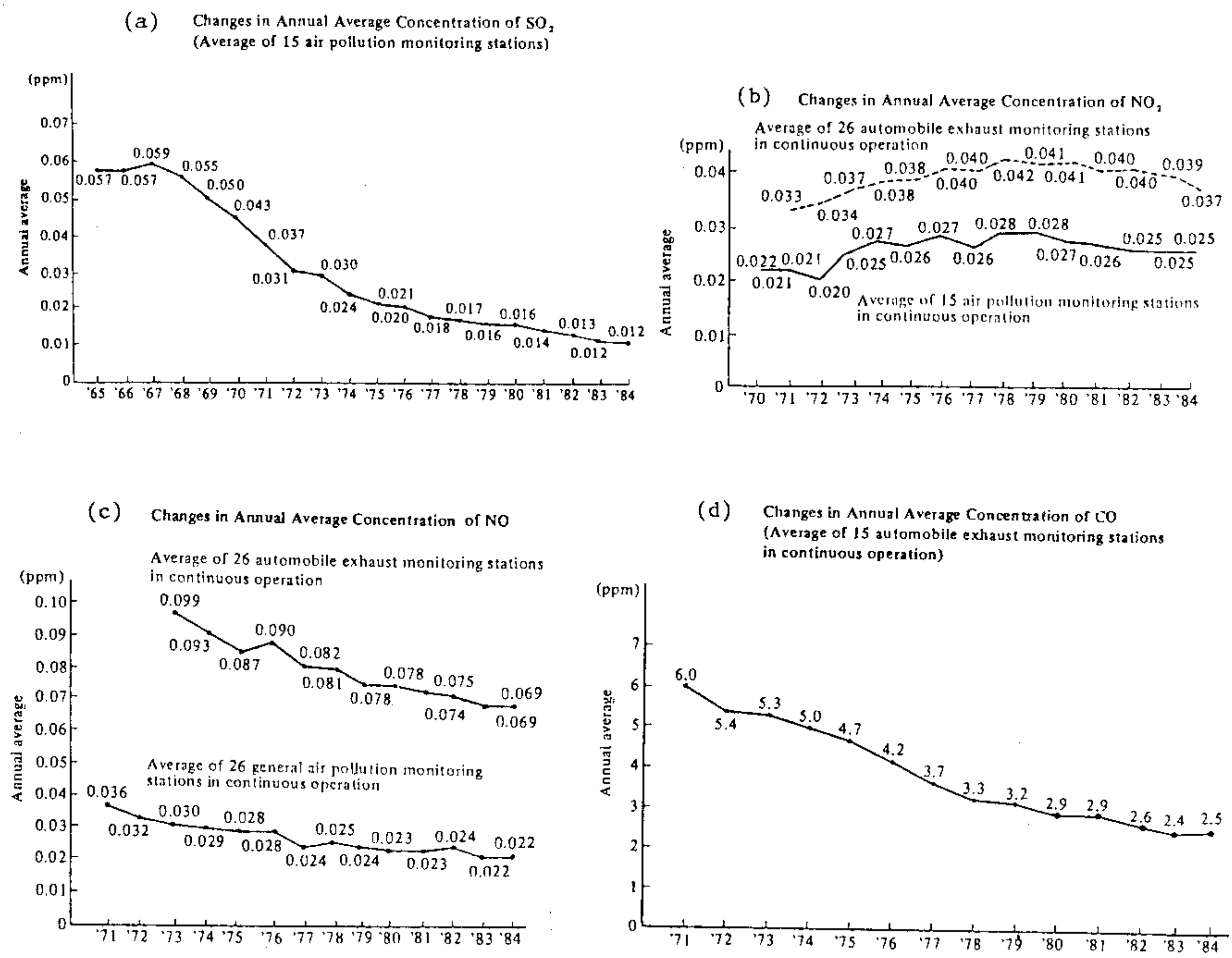
This comes on second of the list in terms of the number of complaints on pollutions (19%). Breakdown by vibration source indicates that livestock industries account for 28%; and service industries for 20%.

(6) Soil Pollution

Farmland soil pollution with heavy metals has been the primary problem. Surveys and experiments on the measures such as effects of top soil dressing on soil improvements are being carried out.

(7) Ground Subsidence

The excessive pumping up of groundwater has been the primary cause of ground subsidence. By the regulation on the pumping-up of groundwater enacted in Tokyo, Osaka, and Nagoya, the progress of the subsidences in these cities have either ceased or slowed down. In several other areas, where great quantities of groundwater is being used for snow melting, the subsidences are still in progress.



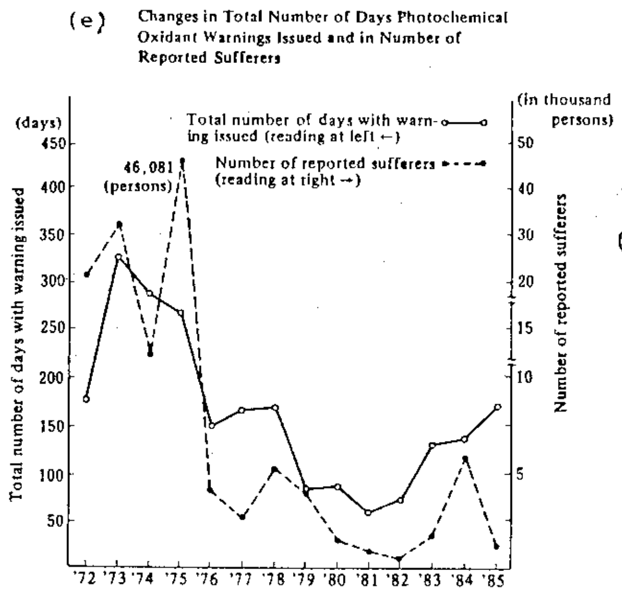


Fig. A-1 Trends of Air Pollution

(Source: Environmental Agency ed., 'Quality of the Environment in Japan 1986.', Sansei Sougou Printing Co., Tokyo, 1986, p.p.77-110. (English edition available)).