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Lessons Learned from Countermeasures against Air Pollution in Japan

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Abstract

This paper provides a discussion of environmental issues associated with air pollution and countermeasures in developed countries, especially in Japan. In the air quality administration, there are environmental standards and emission standards. In Japan, environmental standards are considered administrative goals and there is no legal enforcement in itself. On the other hand, emissions standards are enforceable, penalties apply to people and companies that do not comply. There are two ways to manage the environment. One is a mandatory system and the other is self-management. If voluntary activities can realize a good environment, total cost including social expenses can be expected to be smaller than so called command-and-control system such as regulatory measures by the administration. In free markets where price competition is intense, there is a serious hurdle to voluntarily adopt such measures. However, it seems desirable to see the attitude of actively working as an industry.

Keywords: Air quality; Air pollution; Regulation; Air quality management

1. Introduction

After World War II, a rapid industrial restoration caused the severe pollution problems. In order to solve such pollution problems, starting with the enactment of industrial pollution prevention ordinance in Tokyo in 1959, and other prefectures such as Kanagawa and Osaka set up similar ordinances. From the 1960s, heavy industrialization was strongly promoted, and with this accompanying air and water pollution became increasingly intensified, so-called Yokkaichi asthma and Minamata disease were caused and became serious as a social problem. In 1967, the "Basic Pollution Control Law" was enacted as a law centered on the legal system to comprehensively promote pollution control measures. Since then, the "Air pollution control law", and other regulations were strengthened systematically and comprehensively. In addition, the necessity of a unified administrative agency for environmental conservation became recognized, and the environment agency was established in 1971 to comprehensively promote environmental administration including pollution control and nature conservation. In the reorganization of the central government ministry in 2001, the environment agency was upgraded to the Ministry of Environment (MOE).

2. Air quality standard and emission control

The purpose of the air pollution control law is to regulate the smoke and soot caused by business activities and to protect public health with respect to air pollution. As shown in Table 1, substances subject to the regulation of the air pollution control law are classified into "Smoke", "Dust", "Automobile exhaust gas", and "Specific substance" depending on the generation type (JEMAI editing committee, 2018). Radioactive substances released into the atmosphere had been regulated by the other laws, and they were not included in the environmental matter in Japan. However, after accident of 1 the Fukushima nuclear power plant, ambient monitoring and some limited matters concerning radioactive substances became the jurisdiction of the MOE. Regarding these atmospheric pollutants, there are limitations on the emission quantity or the concentration in the exhaust gas, respectively, which are referred to as emission standards. Apart from these regulations, there are environmental standards as administrative goals set by the government based on the Basic environment law. In Japan, the environmental standards do not directly produce a legal effect, but are considered as administrative goals, for which measures such as emission control and other regulations are taken.

Table 1. A system for regulation and control by the air pollution control law

regulated substances		Regulatory measures
Bai-en (Soot and Smoke) (Bai-en and Bai-jin are legal terms in Japanese law)	sulfur oxides	Compliance with notification and emission standards
	Bai-jin (Dust)	same as above
	Hazardous substance (Nitrogen oxides etc.)	same as above
Volatile organic compounds	(Precursor of photochemical smog)	same as above
Fun-jin (Dust) (Fun-jin is a legal term in Japanese law)	general dust	Notification
	specific dust (asbestos)	Notification
Mercury and its compounds		Compliance with notification and emission standards
Hazardous air pollutants	(21 substances for heavy metals and organic compounds, for example, benzene)	Recommendation
Specific substances	(28 substances such as ammonia, hydrogen fluoride, hydrogen cyanide, etc.)	Instructions in case of an accident

3. Regulation for stationary sources

Based on the air pollution control law, emission standards for the facilities to generate soot and smoke (nitrogen oxides (NO_x), sulfur oxides (SO_x), dust, etc.) were established to provide appropriate regulations. In addition, in areas where a good atmospheric environment is difficult to be ensured by only the emission standard of the individual facility unit, the total amount of NO_x and SO_x is regulated by the business unit of the factory.

As for SO_x the regulation for individual facility commenced in 1968 and was subsequently strengthened several times. From 1974, the total pollution load control which is similar to the state implementation planning in the United States was also implemented in some designated areas where control measures to only individual facility were deemed insufficient to meet environmental standards.

Concerning the preventive measures for SO_x, development of a supply system of low sulfur content oil and installation of flue gas desulfurization equipment were main technology. In 1987 there were a total of 43 heavy oil desulfurization units throughout Japan with a total processing capacity of 214,000 kL/day. There were also about 1800 flue gas desulfurization units throughout Japan in 1987 with a total processing capacity of 170 × 10^5 Nm^3/hr. SO_x emissions had dropped sharply from 1970 with the implementation of these measures, and concentrations in the ambient air also dropped substantially in proportion to the reduction of emission levels (Shiozawa *et al*., 1990). The remarkable SO_2 air pollution in many industrial areas was almost solved by the 1980s as shown in Figure 1. The achievement rate of SO_2 environmental standard was 99.5% in 1986, and it reached 100% in 2016. Similar measures were also taken for the nitrogen oxides and dust problems. By implementing these measures, NO_2 and PM_{10} achievement rate of environmental standards for 2016 has reached 100%.

In Japan, a majority of thermal power plants using petroleum or coal are equipped with flue gas denitration equipment, an electrostatic precipitator and flue gas desulfurization equipment. Here, Table 2 shows the cleanliness of flue gas from thermal power plants compared with overseas. The biggest reason why large-scale environmental measures had become possible at such power plants was in Japan's unique electricity tariff system. Japan is an island country and is not connected to foreign countries by power transmission lines. Electric power companies could monopolize the area, and the electricity rates were also authorized by the government. In this case, the cost related to environmental measures was also approved. Therefore, although the achievement was due to the efforts of the power company, it can be said that the biggest contribution was the patience of the people who tolerated high electricity rates.

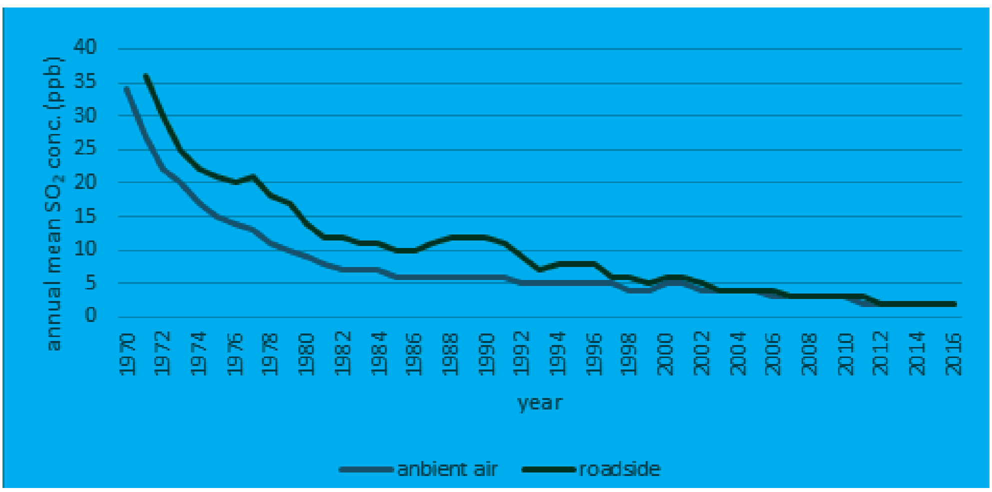


Figure 1. Trend of SO_2 annual mean concentrations in Japan

Table 2. Comparison of air pollutant emissions per generation of electricity in 2012

	Japan	U.S.	mean of six countries (United States, United Kingdom, Germany, France, Italy, Canada)
SOx(g/KWh)	0.2	0.6	1.13
NOx(g/KWh)	0.2	1.1	1.25

(Source: JEMAI Editing committee, 2018, P.533)

Technical problems of the desulfurization

Hydrodesulfurization is a method of producing low-sulfur fuel by decomposing sulfur compounds in feedstock oil into hydrocarbons and hydrogen sulfide. Sulfur compounds are reacted with hydrogen under high temperature (350 - 450 °C), high pressure (15MPa) and catalyst. It can be applied to kerosene and light oil in the same way as heavy oil. There are direct desulfurization and indirect desulfurization for hydrodesulfurization of heavy oil. Direct desulfurization is a method of hydrodesulfurizing atmospheric-distillation residual oil. Atmospheric-distillation residual oil contains polycyclic aromatic sulfur compounds that are difficult to be desulfurized. In addition, it contains asphaltenes and heavy metal organic compounds such as vanadium and nickel which cause a decrease in catalytic activity. Therefore, in direct desulfurization, operating conditions such as pressure and reaction temperature are severe, and the life of the catalyst is short. Indirect desulfurization is a method of hydrodesulfurizing only the vacuum-distillation gas oil that has been separated in advance. However, since the heavy oil is prepared together with the vacuum-distillation residual oil which is not desulfurized, the sulfur content is higher than that of the direct desulfurization. In Japan, both are used, and the total production capacities are almost half.

The desulfurization unit is one of the most dangerous unit among refineries because it uses highly flammable hydrogen in a high-temperature and high-pressure atmosphere and produces highly toxic hydrogen sulfide. Therefore, its operation requires high technology and all safety measures. Even so, many cases of accidents have been reported to date, and the development of safety measures is also in progress. For example, Act on the prevention of disaster in petroleum industrial complexes and other petroleum facilities was enacted.

Emergency measures for stationary sources

The air pollution control law stipulates the following: that is to say, the prefectural governor must monitor the situation of air pollution in article 22. In the case of article 23, when air pollution becomes significant and serious health hazards are expected, the governor is required to take appropriate measures against the Baien (soot and smoke) emitters. The enforcement ordinance of the Air pollution control law stipulates the standards for emergency situations in article 23 of this law. A summary of the criteria shown in Appendix 5 of article 11 of the enforcement ordinance is shown in table 3.

Kawasaki City was one of the most polluted areas in Japan. There were a lot of steel mills, refineries, and thermal power plants in the coastal area, and there were many asthma patients. For this reason, the city had built a comprehensive monitoring network system that connects the seven standard air pollution monitoring stations and the major 42 plants in the city, and began operations in earnest since 1972. There were 42 large factories, which covered almost 95% of sulfur oxide emissions in the city. A total of 272 source monitoring devices such as oil flow meters, flue sulfur dioxide densitometer, and gas flow meters and so on have been arranged in these 42 plants in order to provide an immediate understanding of the emissions for all factories. Some prefectures and major cities such as Kawasaki have established agreements with major factories and determined measures to be taken when warnings or alerts are issued. In general,

Table 3. Standards for the warning of sulfur oxides (Appendix 5 of article 11 of the enforcement ordinance of the Air pollution control law)

warning level	higher than 0.20ppm, more than 3 hours higher than 0.30ppm, more than 2 hours and others
alert level	higher than 0.50ppm, more than 3 hours higher than 0.70ppm, more than 2 hours

they have reduced sulfur oxide emissions by about 10 - 20% by suspending the operation of low-importance facilities and/or switching to high-quality fuels. In Kawasaki city, where a warning was issued on May 26, 1973, we can see how the emissions have decreased from one hour after the issuance, as shown in Figure 2.

Since then, further measures have been taken, and warnings or alerts for sulfur oxides have not been issued for more than 30 years. However, similar warnings for photochemical smog have been issued occasionally, even recently.

There are many air pollution monitoring stations in Japan. By 2008, the total number of monitoring stations had reached nearly 2000 as shown in Figure 3. One of the reasons for having too many stations is the provisions of Article 22 and Article 23 of the air pollution control law. In addition, by using subsidies in return for the acceptance of nuisance facilities, a number of monitoring stations were set up around the facility that would cause air pollution. However, for small-scale local governments, maintenance and management of the monitoring stations, such as updating of measuring instruments, became a major economic burden.

4. Economic impact of environmental measures and changes in industrial structure

One of the most important reasons why such a dramatic reduction in SO_2 could be achieved may be the so - called public health law enactment. "The law on pollution health damage compensation (Public health law) is a law that stipulates payment for medical expenses and compensation for lost profits for persons certified as polluted patients in designated areas. This law was enforced in 1974. The total amount of levies of the public health law had become too large, as shown in Figure 4. For this reason, it was revised by a strong request of the industry in 1987, such as terminating new patient certifications, but the same compensation was continued for already certified patients.

Park (2007) considered the homogeneous system of other countries and compared the tax rate of SO_x emissions and the fee rate of public health legal levy. Here, quoting from Park (2007), the comparison results are shown in table 4. It is understood that the public health legal levy of Japan is remarkably high even internationally. There are also environmental economics studies that calculate the marginal reduction cost and consider whether the reduction in emissions is due to the incentive for public health legal levies, for example, Imura (1988) and so on. However, there was the problem of regional monopoly and unique electricity tariff system as mentioned above with thermal power plants that were the largest consumers of heavy oil at that time. These circumstances cannot be explained by a simple economic model, and papers which were deeply drilling down this problem could not be found.

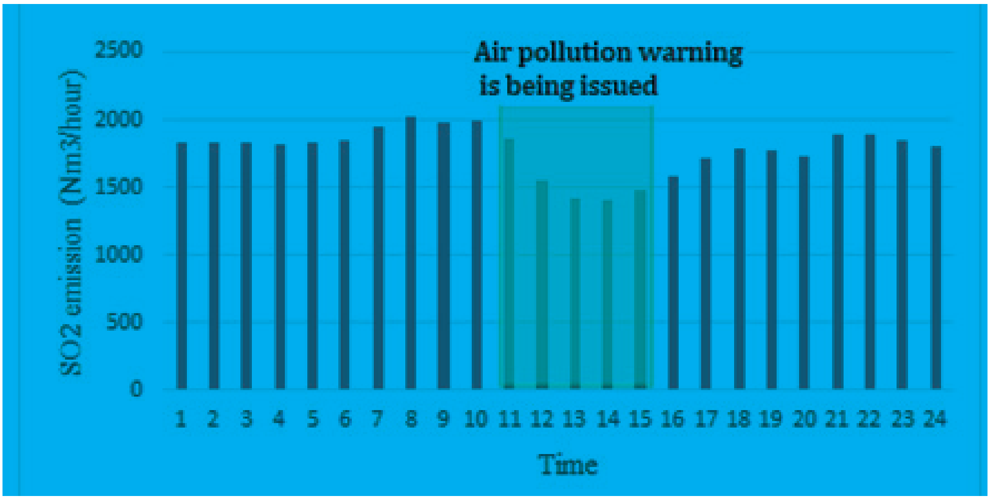
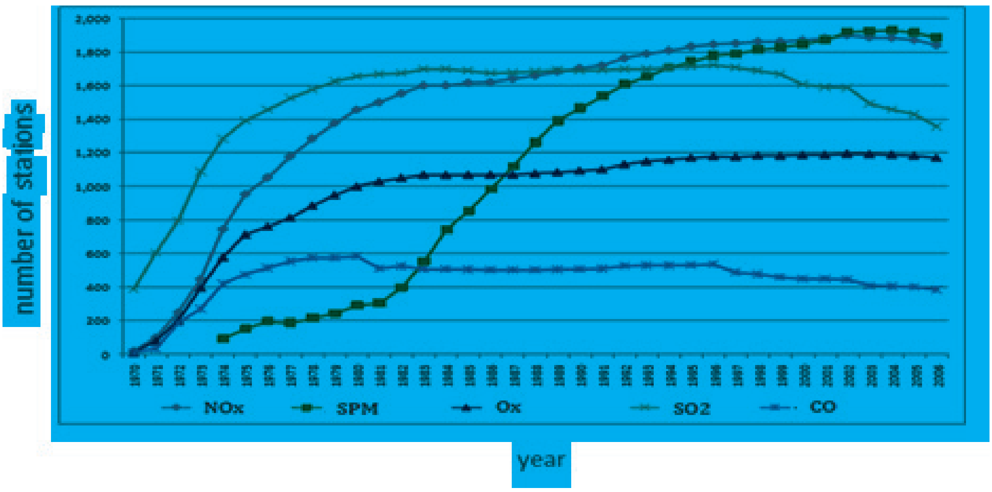
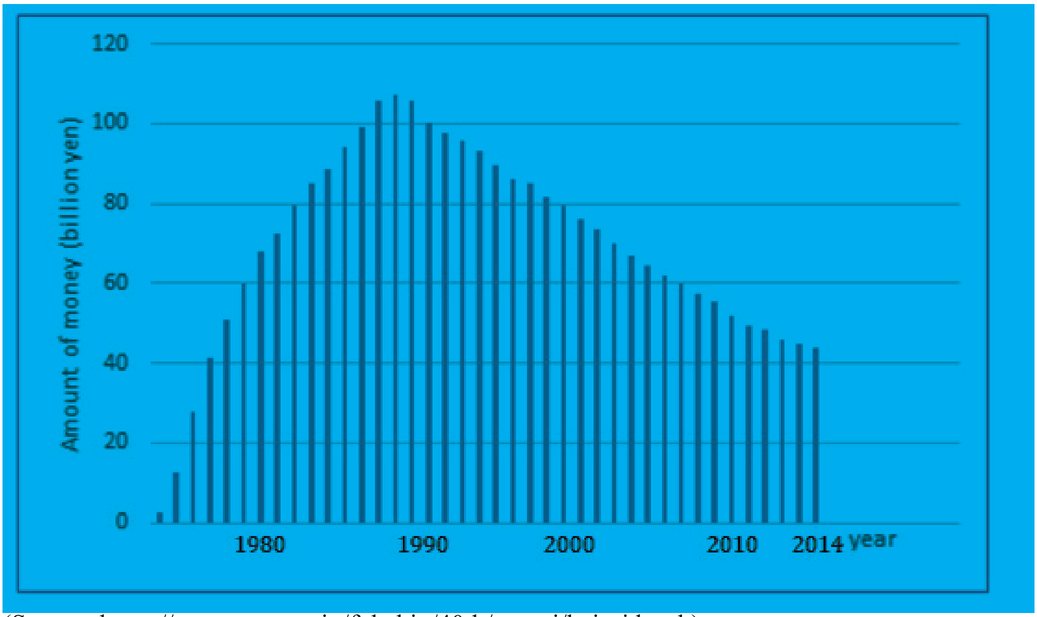


Figure 2. Hourly SO_2 emissions of Kawasaki city on May 26, 1973 when air pollution waning was issued.



(Source: Iwata, G., Current Status and Issues of Air Pollution Continuous Monitoring, Conf. Japan Soc. Atmos. Env., 2008, www.jsae-net.org/KANTO/info/080613_5ppc.pdf)

Figure 3. Number of air quality monitoring stations



(Source: https://www.erca.go.jp/fukakin/40th/ayumi/kaisei.html)

Figure 4. Annual trend of the total amount of levies of the public health law

Table 4. Comparison of taxes, levies, and permitted prices relating to SOx emissions in each country

country		Price (yen/kgSO_2)
Sweden	Sulfur tax	339
Norway	Sulfur tax	299
France	Pollution charge	3~4
USA	Permit price	12~17
Japan	Public health law levy	741~1877(Designated area)

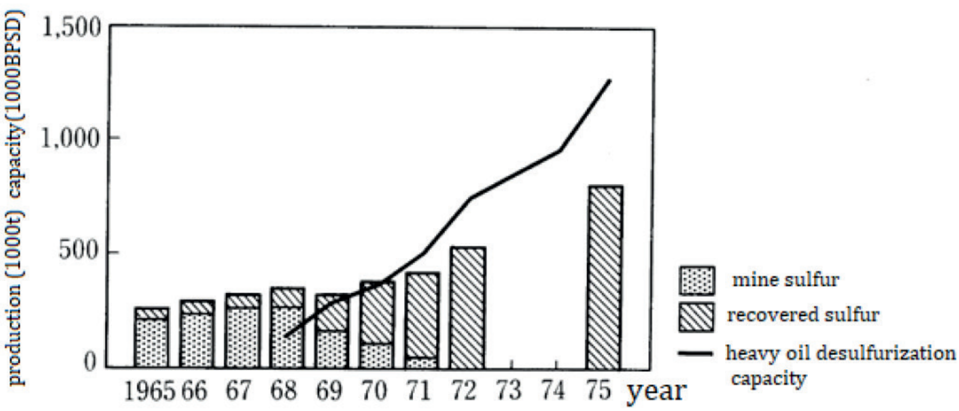
(Source: Park, 2007)

The OECD had announced the evaluation on Japanese environmental policy in 1991. Among them, even in the case of enormous pollution prevention investment in Japan, the macroeconomic impact such as a decrease in employment due to it was said to be negligible. In addition, considering the indirect benefits, it could be concluded that the profit was probably winning. In this regard, the Environment Agency was evaluating the effects of pollution control investment of 5.3 trillion yen (1970 price conversion) from 1965 to 1975 using a quantitative economic model. Again, compared to the absence of pollution control measures during this period, pollution control investment would decrease (trade) surplus by 300 billion yen, but gross national product would increase by 0.9%. In this regard, it is necessary to pay attention to the fact that many equipments such as desulfurization/denitration equipment did not procure from overseas but contributed to the demand increase of domestic pollution control equipment industries (Kobayashi, 1990).

In addition, the existing base of some industries, such as sulfur mines, had been completely destroyed by desulfurization byproducts. (Those with negative prices that would otherwise be waste if not used) (Figure 5). And recently, several hundred thousand tons of sulfur are exported to China and other countries a year, since recovered sulfur more than domestic demand is produced. According to the material flow data of mineral resources released by the Japan Oil, Gas and Metals National Corporation (JOGMEC), the most recently published domestic supply of sulfur in 2010 was about 2 million tons. Meanwhile, domestic demand as a raw material for synthetic fiber and sulfuric acid production was 0.64 million tons. And, 1.26 million tons were exported.

5. Regulation on automobiles

Regulation of automobile emissions in Japan began as administrative guidance of the Ministry of Transport in 1966. After that, legal grounds were established by the establishment of the air pollution control law in 1968. Initially it was only measures for carbon monoxide, but NO_x countermeasures became a central issue in the 1970s. In the late 1980s, significant air pollution in industrial areas was almost eliminated, and major problems on air pollution were shifting to measures against automobile emissions. In order to ensure the environmental standard of nitrogen dioxide in the area where the air pollution by automobiles exhaust was severe, “ Act on special measures to reduce the total amount of nitrogen oxides discharged from automobiles in specific areas” (The Automotive NO_x Act, in subsequent revisions, regulations on particulate matter were added, and it became the NO_x - PM Act) was promulgated in 1992. The law stipulates that prefectural governors should formulate a nitrogen oxide priority implementation plan or a particulate matter priority implementation plan. However, the governor had not been given the authority to directly regulate the automobile exhaust. For this reason, the plan formulated by the prefecture remained in limited response, such as the call for voluntary self-restraint of automobile use by many businesses and individuals. It was considered that the PM2.5 problem had not been considered as important as it is today, even when the exhaust of diesel vehicles was denounced (about 1990 - 2000) as a cause of health damage in roadside areas. It can be seen from Figure 1. that the concentrations of not only air pollutant NO_x and PM but also SO_2 were significantly different between residential areas and roadsides before around 2000. After that, the SO_2 concentrations in the roadside were decreasing to the same level as in the residential area. Figure 1. shows that it took long time for the compulsory regulation



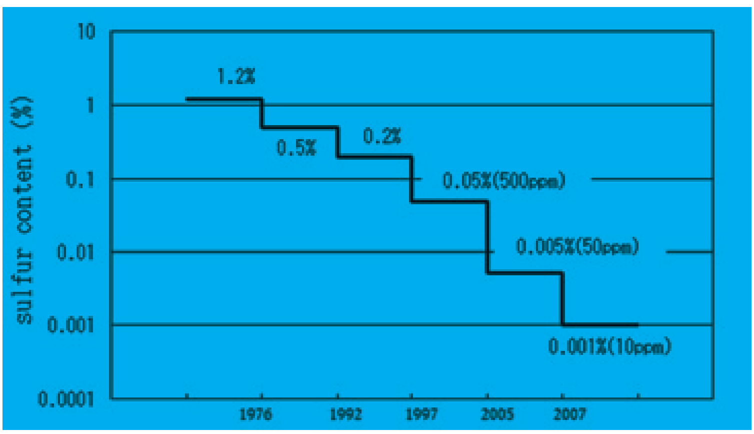
(Source: Okamoto, 2005)

Figure 5. Enhancement of petroleum desulfurization equipment and annual change of sulfur production

to move, and the countermeasure had been delayed. In facilities that were subject to the Public health law, it was more economical to use expensive low-sulfur heavy oil than paying an extremely high public health law levy. On the other hand, even though light oil desulfurization is technically easier than heavy oil desulfurization, its start was significantly delayed. Since there was no economic incentive to remove sulfur in light oil using as fuel for diesel vehicles, a circumstance that capital investment did not move until the stage where regulation by laws became certain. It seems that voluntary environmental management was not effective for measures to reduce the pollutants in diesel vehicle exhaust gas.

Technical issues of automotive exhaust gas countermeasures

The following three methods are effective as measures against emissions for gasoline vehicles: (1) Three-way catalyst, (2) Optimization of air fuel ratio, and (3) Exhaust gas recirculation. The biggest obstacle to implementing these measures was the presence of lead as antiknock agent contained in gasoline. However, in Japan, we had established the above technologies (1) to (3) by promoting lead countermeasure in gasoline ahead of the world. And this became the driving force to establish the dominance of Japanese cars' environmental measures (Okamoto, 2003). On the other hand, diesel vehicles could not use such technologies (1) and (3) above) because they contained a lot of sulfur in the fuel oil. For this reason, effective means was limited such as adjustment of ignition timing and adjustment of compression pressure up to the early 1990s, and it was difficult to simultaneously reduce both nitrogen oxides (NO_x) and particulate matter (PM). Then, when one of the NO_x and the PM is reduced, the other is increased. For this reason, in Japan where emphasis was placed on NO_x countermeasures, the regulation of the PM had become moderate as compared with Europe and the United States. The latest trends in emissions countermeasures for diesel vehicles include a method of burning in a high PM condition to remove particles with a filter or a method of burning in a high NO_x condition to remove NO_x by a catalyst. At this time, removal of sulfur in diesel oil is indispensable in either case. In line with the 1995 revision of the air pollution control law, the Secretary of the Environment Agency (the predecessor of the MOE) decided to set an allowance for substances contained in automobile fuels. To this end, the "Law on ensuring the quality of petroleum, etc." was enacted, and from the following year, automobile fuel quality regulations began (Kobayashi, 2019). Recent trend of regulation on sulfur content in fuel oil is shown in Figure 6.



(Source: Osaka prefecture, www.pref.osaka.lg.jp/attach/5004/00201015/01-7gaiyo.doc)

Figure 6. Allowable limit for automobile fuel

6. Regulation on chemical substances

In order to understand the air pollution caused by harmful air pollutants, the MOE conducts monitoring of hazardous air pollutants. Meanwhile, administrative guidance for each company is not based on the air pollution control law but is entrusted to the other laws under the jurisdiction of the Ministry of Economy, Trade and Industry (METI). For many chemical substances, emission standards by the air pollution control law are not indicated. Of course, the MOE grasps the concentration of chemical substances in the environment and requires the industry to respond as necessary, but it is not due to the compulsory emission standards.

The chemical substance management law is under the jurisdiction of the METI (METI, 2018). This law is mainly based on the Pollutant Release and Transfer Registers (PRTR) system and the Safety Data Sheets (SDS) system. It aims to promote improvement of voluntary management of chemical substances by business operators and to prevent the environmental pollution in advance. When a business entity releases and/or transfers target chemical substances, it is obliged to grasp the amount and report it to the regulatory authorities. The relevant organizations will publish their aggregated data, and anyone can request disclosure for contents notified by the business operator. Under this SDS system, businesses are obliged to provide the information (SDS) when transferring and/or providing target chemical substances to other business operators. Under the chemical substance management law, the METI and the MOE have jointly estimated and totaled the released and transferred amounts of chemical substances. According to the submitted notifications in FY2015, 378,000 tons in total of the chemical substances were released or transferred, down by 1.3% from the previous year (METI, 2017). The compiled data by business operator will be available on the METI and MOE websites. This law does not regulate the release of target chemical substances into the environment. The purpose of this law is to help business operators grasp the releases of chemical substances and to support their own self-management of chemical substances. Based on this idea, notification of PRTR and distribution of SDS is mandatory. However, this law does not prescribe provisions for measures to reduce emissions.

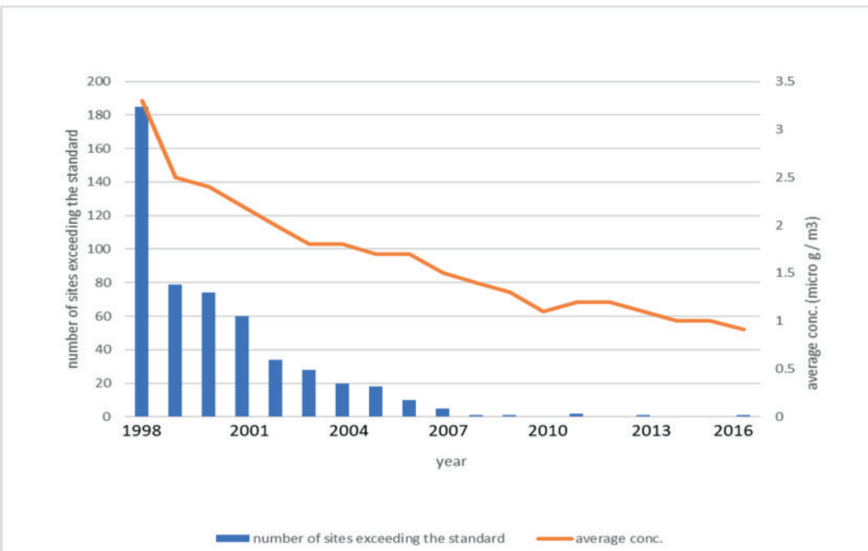


Figure 7. Annual mean Benzene concentrations and number of sites exceeding the standard

Regarding the prevention of air and water pollution, administration has been involved in both environmental standards and emission standards. In other words, we have implemented emissions regulations so that we can achieve environmental standards by determining the upper limit of concentration in the environment. However, regarding the regulation of hazardous chemical substances such as benzene announced in 2001, it was decided to achieve the environmental standard by only voluntary activities in each company (METI, 2001). This means that it is the responsibility of the business operator to grasp the relationship between the concentration in the environment and the amount of emissions, and to take appropriate measures. In 2001 when this regulation started, there were 60 monitoring stations that failed to achieve the environmental standard, but in 2016 it has decreased to one station as shown in Figure 7. (MOE, 2018b).

A tool for self-management of chemicals

The METI had developed an air quality prediction model, METI-LIS that can be used as a tool to support business operators' voluntary management activities. This model is not a regulatory model that installation of the facility is not permitted when calculated concentration value exceeds a certain reference value. The aim is to make it possible for operators to understand the relationship between the emissions of their facilities and the environmental concentrations surrounding them, thereby evaluating the effectiveness of their environmental measures. Therefore, we thought the AERMOD model of the US.EPA was not appropriate. To some extent, it is important to be able to reproduce various atmospheric diffusion phenomena, even if we specify the location and time. Although the AERMOD incorporates a sophisticated atmospheric boundary layer meteorological module, it was not sufficiently discussing to what extent the atmospheric diffusion phenomenon in such a situation was reproduced. The METI-LIS also emphasizes the downdraft by a low-rise building and employs a submodule similar to the ISC3 model. However, this is not the Huber-Snyder's algorithm, but a Kouchi-Okabayashi's algorithm (Kouchi et al., 2004). The source and executable METI-LIS programs and some related documents can be downloaded from the JEMAI's homepage with free of charge (JEMAI, 2018).

7. Prevention of health effects by other harmful substances

In Japan, many mesothelioma patients came from workers in the factory dealing with asbestos and also residents around the factory. As a result, air pollution caused by asbestos has become a major social problem. In response to this problem, the air pollution control law was amended in 1996.

Next, in response to ratification of the "Minamata Convention on Mercury", the air pollution control law was amended in 2015. Regarding coal-fired power plants and others regulated by this convention, notification of mercury emission facilities, compliance with mercury emission standards, measurement of mercury concentration, etc. were obligated. In 2016, monitoring results for mercury in atmospheric environment (MOE, 2018b) are shown in Table 5.

Table 5. Mercury concentrations in atmospheric environment in 2016

	number of sampling sites	Number of sites exceeding guideline value *	mean (unit)	
general ambient air	214	0	1.9	$ngHg/m^3$
near stationary source	18	0	2	$ngHg/m^3$
road side	39	0	1.8	$ngHg/m^3$
total	271	0	1.9	$ngHg/m^3$

* The guideline values are not environmental standard, but numerical values that serve as guidelines for reducing health risks due to harmful air pollutants in the environment. As for the mercury, this value is 40 ngHg/m3.

8. Monitoring results of atmospheric environment

The prefectures monitor air pollution situation at the general environmental monitoring stations and automobile exhaust gas monitoring stations (roadside stations) according to the air pollution control law. The data is gathered in real time by "Air Pollutants Wide Area Monitoring System" and information is provided on the internet site. Some of these data are shown in Table 6.

According to the amendment of the air pollution control law of 1996, countermeasures against hazardous air pollutants, which may harm human health by long-term exposure, have been institutionalized. Since 1998, local governments have monitored the priority substances according to the air pollution control law. There are 21 substances to be monitored. They were measured at about 400 sampling sites nationwide. Among them, the monitoring results of the four substances for which environmental standards are set are included in Table 5. Along with the amendment of the air pollution control law in 2013, monitoring of radioactive materials was started, and radiation dose rates were measured at approximately 300 locations nationwide. (MOE, 2018a).

Table 6. Status of air pollution in 2016

pollutant	type of monitoring site	number of stations	Achievement rate	environmental standard
NO_2	general ambient	1243	100%	Daily mean is less than 0.04 ~0.06ppm
	roadside	393	99.7%	
PM10	general ambient	1296	100%	Daily mean is less than 0.1mg/m^3
	roadside	388	100%	hourly data is less than 0.2mg/m^3
Oxidant	general ambient	1143	0.1%	hourly data is less than 0.06ppm
	roadside	29	0%	
SO_2	general ambient	957	100%	Daily mean is less than 0.04 ppm
	roadside	51	100%	hourly data is less than 0.10ppm
CO	general ambient	57	100%	Daily mean is less than 10ppm
	roadside	228	100%	8-hrs mean is less than 20ppm
PM2.5	general ambient	785	88.7%	Daily mean is less than 35µg/m^3
	roadside	223	88.3%	annual mean is less than 15µg/m^3
Benzene		402	99.8%	Annual mean is less than 3 µg/m^3
trichlorethylene		356	100%	Annual mean is less than200 µg/m^3
tetrachloroethylene		358	100%	Annual mean is less than200 µg/m^3
dichloromethane		363	100%	Annual mean is less than150 µg/m^3

(Source: https://www.env.go.jp/press/files/jp/108676.pdf)

*As for the hazardous air pollutants such as benzene, annual mean is not calculated from 8760h monitored data, but the mean value of more than 12 samples (more than one sample for each month).

9. Concluding remarks

In developed countries including Japan, strict eyes have been directed to companies, especially on the environmental problems, and many advanced companies have been actively working on environmental measures. Many major companies establish ISO 14001 certified environmental management systems and operate them. And they are trying to show the attitude that they are actively working on environmental measures. For example, major chemical industries are taking the responsible care and other related initiatives. If such voluntary activities can realize a good achievement, total cost including social expense can be expected to be smaller than so called command-and-control system such as regulatory measures by the administration. Regarding the regulation of hazardous chemical substances announced in 2001, it was intended to achieve the environmental standards by voluntary activities in each company. Comparing the legal regulation by the government with the voluntary management at each company, voluntary management is more cost effective. However, there are many difficulties in adopting independently and voluntarily such measures that seriously hurdles in markets where price competition is severe. In other words, situations where such voluntary management is accepted may be limited. However, it seems desirable to show a positive attitude to act proactively as the industry, such as working on the sustainable development goals (SDGs).

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