

Japan's Experience with Short-Lived Climate Pollutants The Case of Black Carbon



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Ministry of the Environment, Japan

Institute for Global Environmental Strategies

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List of Acronyms

ABC	Atmospheric Brown Cloud
ACP	Asian Co-benefits Partnership
APCAP	Asia Pacific Clean Air Partnership
AR5	Fifth Assessment Report
BC	Black Carbon
CAA	Clean Air Asia
CCAC	Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants
CH ₄	Methane
DPF	Diesel Particulate Filter
DSS	Dust and Sandstorm
EANET	Acid Deposition Monitoring Network in East Asia
EC	Elemental Carbon
EQS	Environmental Quality Standard
ESP	Electrostatic Precipitator
FY	Fiscal Year
HFCs	Hydrofluorocarbons
IBAQ	Integrated Programme for Better Air Quality
IPCC	Intergovernmental Panel on Climate Change
MAFF	Ministry of Agriculture, Forestry and Fisheries
MOEJ	Ministry of the Environment of Japan
NO _x	Nitrogen Oxides
O ₃	Tropospheric Ozone
PM	Particulate Matter
PM ₁₀	Particulate Matter equal to or less than 10 µm in diameter.
PM _{2.5}	Fine Particulate Matter; Particulate Matter that is equal to or less than 2.5 µm in diameter
SLCPs	Short-Lived Climate Pollutants
SNAP	Supporting NATIONAL Planning for action on SLCPs
SO ₂	Sulphur Dioxide
SO _x	Sulphur Oxides
SPM	Suspended Particulate Matter
TMG	Tokyo Metropolitan Government
TSP	Total Suspended Particulates
UNEP	United Nations Environment Programme
WHO	World Health Organization
WMO	World Meteorological Organization

Executive Summary

Reducing short-lived climate pollutants (SLCPs) is a win-win solution to confronting the dual problems of local air pollution and climate change. The aim of this report is to facilitate further global SLCP reduction efforts by sharing Japan's experiences that helped to limit SLCPs, especially black carbon (BC) – a component of particulate matter (PM).

The average annual concentration of suspended particulate matter (SPM) has significantly decreased in Japan over the last 40 years. This improvement has been accomplished through various policy measures introduced by national and local governments. In 2012, the attainment rate of the environmental quality standard for SPM was 99.7%.

This report discusses major policy measures implemented by the Japanese government to control BC emissions from both stationary and mobile sources, including: (1) the regulation of soot and dust from stationary facilities; (2) the stepwise development of vehicle emissions standards and fuel quality standards to address diesel emissions; and (3) special vehicle emissions control measures introduced in highly populated metropolitan areas.

The report also presents two examples of metropolitan-level undertakings, one involving industrial emissions and the other vehicle emissions. The case of Kawasaki is considered for its pioneering emissions reduction measures for industrial pollution. Tokyo's innovative regulation of diesel vehicles is also discussed. In both cases, ambient SPM concentrations have decreased significantly, suggesting the effectiveness of the efforts.

The report also outlines technologies used to control soot emissions from industrial sources and diesel emissions, both of which have become more stringent in order to keep up with strengthening national and local standards.

Finally, the report touches on international initiatives relating to the regulation and reduction of SLCPs, with a focus on Japan's involvement.

The primary messages of the report can be summarised as follows:

- The national emissions standards on soot and dust under the Air Pollution Control Act have been key policies in reducing BC emissions from stationary sources. Efforts by

municipal governments, such as Kawasaki, have also yielded good results. In fact, Kawasaki's innovative approach to address total emissions has more ambitious targets than the national ambient standard. Kawasaki introduced regulations on multi-pollutants by addressing not only primary SPM pollutants but also precursor sources of SPM – a process known as a basket regulation.

- Diesel vehicle emissions standards have progressively strengthened through revisions in diesel fuel standards to lower the maximum content of sulphur. These policies were supplemented by regulations focusing on highly populated metropolitan areas under the Law Concerning Special Measures for Total Emission Reduction of Nitrogen Oxides from Automobiles in Specified Areas (Automobile NO_x and PM Law). In addition, the Tokyo Metropolitan Government adopted regulations facilitating the reduction of diesel emissions from new and used vehicles in Tokyo and neighbouring prefectures.
- Technologies to control soot and diesel emissions have improved steadily in response to these national and local policies. For stationary sources, advanced devices such as bag filters and electrostatic precipitators (ESPs) have been introduced and widely distributed. Vehicle emissions control technologies have been upgraded for both the combustion process and after treatment.
- There is still room for improvement: despite the reduction in SPM concentration, attainment rates of the environmental quality standards for fine particulate matter (PM_{2.5}) still fall below 50% in Japan. A government advisory body is currently in the process of recommending that the government further strengthen emissions controls in order to address PM_{2.5}.
- Japan is committed to working collectively to improve air quality throughout Asia by building on its experience with international cooperation. In addition, Japan will continue efforts to bridge air quality management with climate mitigation, thus maximizing co-benefit opportunities.

1. Introduction

1.1 Background and purpose of the report

Governments across the globe are paying more attention to air pollution than ever before. This growing attention is in no small part because their citizens are suffering more from air pollution than ever before. In June 2014, the United Nations Environment Assembly identified air pollution as a priority requiring immediate action from the international community.¹ According to the World Health Organization (WHO), around seven million people died as a result of exposure to air pollution in 2012.²

At the same time, concerns over climate change are increasing. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) noted that “Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems”.³

With concerns over the local and global impacts of air pollution on the rise, reducing short-lived climate pollutants (SLCPs) is being seen more and more as a win-win solution to confronting the twin challenges of air pollution and climate change. In a 2011 report, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) concluded that immediate and multiple benefits, including air pollution reductions and climate mitigation, would be achieved by targeting black carbon (BC) and ozone precursors.⁴

To facilitate the introduction of measures to reduce SLCPs in other parts of the world, this report goes over Japan’s efforts to limit BC emissions, one of the primary SLCPs. In discussing these experiences, the report focuses chiefly on attempts to control soot and dust emissions from industrial sources and diesel vehicles. The report also covers Japan’s efforts to promote international cooperation relating to air pollution and climate change mitigation.

Serious air pollution problems accompanied Japan’s rapid industrialization in the 20th century. Japan introduced various policies at the national and local levels to try and reduce the emissions of these pollutants. These policies and measures supported the development of emissions reduction technologies and eventually led to improvements in air quality.

Hopefully Japan’s experience can provide useful lessons for other countries still undergoing rapid development, and subsequently contribute to cleaner air in these locales and climate change mitigation worldwide.

1.2 SLCPs and co-benefits

SLCPs are “agents that have relatively short lifetimes in the atmosphere – a few days to a few decades – and a warming influence on climate”.⁵ The major SLCPs are BC, methane (CH₄), tropospheric ozone (O₃), and some hydrofluorocarbons (HFCs). As shown in Table 1, SLCPs not only have adverse impacts on human health, agriculture and ecosystems, but also a warming effect on the climate. Due to these multiple negative impacts, reductions of SLCPs can bring multiple benefits in a relatively short timeframe. These multiple benefits are known as co-benefits when they include a reduction in pollutants that contribute to climate change.⁶

Table 1 Short-Lived Climate Pollutants

(Table developed based on CCAC Homepage)

Short-lived Climate Pollutants	Anthropogenic sources	Lifetime in Atmosphere	Impacts
Black Carbon (BC)	diesel cars and trucks residential stoves forest fires agricultural open burning industrial facilities	Days	ice and snow melting rainfall patterns human health
Methane (CH ₄)	natural processes coal mines natural gas and oil systems landfills	12 years	climate system (direct) human health (indirect) ecosystems (indirect)
Tropospheric Ozone (O ₃)	not emitted directly but formed by sunlight-driven oxidation of ozone precursors	Weeks	atmospheric warming agricultural production human health
Hydrofluorocarbons (HFCs)	air conditioning refrigeration solvents foam blowing agents aerosols	15 years	atmospheric warming

1.3 International initiatives

A number of international networks and programs have been established to strengthen the management of air and climate change pollutants. For air quality management, existing regional frameworks include, among others, the Acid Deposition Monitoring Network in East Asia (EANET), the ASEAN Agreement on Transboundary Haze, the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia (Malé Declaration), and the Joint Forum on Atmospheric Environment in Asia and the Pacific (Joint Forum). These initiatives differ from one another in terms of regional coverage and thematic scope. However, while their objectives relate strongly to the management SLCPs, none of them address SLCPs as their primary focus.⁷

The first global effort to address SLCPs was launched in 2012 with the establishment of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC). CCAC is a voluntary partnership with participation from governments, intergovernmental organisations, civil society, and the private sector.

1.4 Measures for BC reduction

SLCPs are emitted from various sources, and there are a number of ways to reduce their emissions. The UNEP/WMO report examined a subset of approximately 2,000 separate measures addressing SLCPs and selected those most likely to provide the combined co-benefits of climate change mitigation and air quality improvement. Table 2 lists the measures identified as most effective when it comes to reducing BC emissions,⁸ one of the main SLCPs and the focus of this report. Some of the measures listed in the table are already integrated into each country's domestic climate and air pollution policies, though they are often not explicitly labelled as "SLCP" policies.

Table 2 Key abatement measures for BC

(Sources: UNEP and WMO, 2011; UNEP 2011)

Sector	Measure
Transport	1. Standards for the reduction of pollutants from vehicles (including diesel particle filters), equivalent to those included in Euro-6/VI standards, for road and off-road vehicles
	2. Elimination of high-emitting vehicles in road and off-road transport
Residential	3. Replacing lump coal by coal briquettes in cooking and heating stoves
	4. Pellet stoves and boilers, using fuel made from recycled wood waste or sawdust, to replace current wood-burning technologies in the residential sector in industrialized countries
	5. Introduction of clean-burning (fan-assisted) biomass stoves for cooking and heating in developing countries ^{1,2}
Industry	6. Substitution of traditional biomass cookstoves with stoves using cleaner-burning fuels (e.g., liquefied petroleum gas or biogas) ^{2,3}
	7. Replacing traditional brick kilns with vertical shaft brick kilns ³
Agriculture	8. Replacing traditional coke ovens with modern recovery ovens
	9. Ban on open burning of agricultural waste ²
<p>1. Motivated in part by its effect on health and regional climate, including its impact on areas of ice and snow</p> <p>2. For cookstoves, given their importance for black carbon emissions, two alternative measures are included</p> <p>3. Zigzag brick kilns would achieve comparable emission reductions to vertical-shaft brick kilns</p>	

1.5 BC and Particulate Matter

BC is one of the components of particulate matter (PM), which represents a broad class of chemically and physically diverse substances. PM can be described by its size, formation mechanism, origin, chemical composition, atmospheric behaviour, and method of measurement.⁹

PM is principally characterised as discrete particles spanning **several orders of magnitude in size** as shown in Table 3.

Table 3 Categories of PM by Size

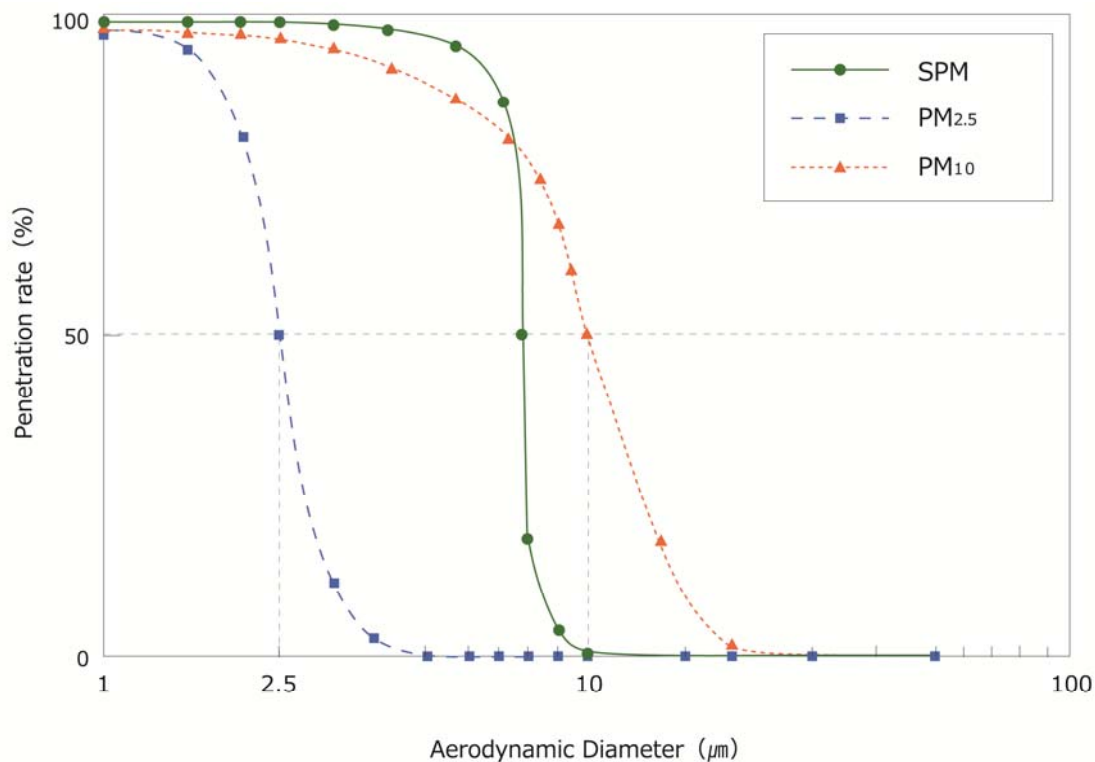
(Source: Sekiguchi, 2010¹⁰)

TSP	Total Suspended Particles. All particles that are suspended in the air (all aerosols).
SPM	Suspended Particulate Matter. Particles that pass through an inlet with a 100% efficiency cut off at 10 μm aerodynamic diameter.
PM ₁₀	Particulate matter equal to or less than 10 μm in diameter. Particles that pass through an inlet with a 50% efficiency cut off at 10 μm aerodynamic diameter.
PM _{2.5}	Particulate matter that is equal to or less than 2.5 μm in diameter. Particles that pass through an inlet with a 50% efficiency cut-off at 2,5 μm aerodynamic diameter.

It should be noted that SPM differs from PM₁₀. While both measure particles at 10 μm aerodynamic diameter, the cut-off rates are different. SPM is approximately equivalent to PM₇ if the same criterion is applied (Figure1).¹¹

Figure 1 Penetration rates for PM_{2.5}, PM₁₀, and SPM

(Source: Kasahara and Tohno, 2007¹², with some modification)



PM can be also categorised by its **origin** or **generation mechanism** as shown in Table 4.

Table 4 Categories of PM by origin and generation mechanisms

(Source: NIES¹³)

Origins	Generation mechanisms
Anthropogenic	Soot and dust generated by the combustion of fuel or other items or by the use of electricity as a source of heat
	Particles generated or dispersed as a result of crushing or sorting materials or any other mechanical process, or as a result of the accumulation of such materials
Natural	Dust and sandstorm (DSS), volcanic ash
Secondary formation	Transformation of gaseous substances to PM through processes such as photochemical chemical reactions in the atmosphere

Another characterisation of PM is based on **chemical composition**. Fine particles are generally composed of sulphates, nitrates, chloride and ammonium compounds, organic and elemental carbon, and metals.¹⁴ Elemental carbon (EC) is also used to refer to soot or BC.¹⁵ Because of this overlap, this report will use the terms **EC, soot and dust**, and **BC interchangeably**.¹⁶

2. Japan's Experience in BC reduction

2.1 Overview of history of air pollution in Japan

Japan's air pollution problems have tracked closely to the country's industrialization and urbanization. During periods of very rapid economic development during the late 1950s into the 1970s, air pollutants from industrial sources such as soot and dust and sulphur oxides (SO_x) caused serious health issues and elicited strong concern from the general public. From the late 1970s to early 1980s, ambient concentrations of SO_x were significantly reduced due to various control measures on stationary sources. However, nitrogen oxides (NO_x) emitted from factories, urban small-scale sources, and automobiles remained a significant problem. As automobiles proliferated from late-1980s into the 2000s, major air pollution concerns shifted to mobile source emissions including NO_x and suspended particulate matter (SPM).¹⁷ Over the past decade, the ambient concentration of SPM has fallen thanks to the various policy measures introduced below. The remaining challenges relate to pollutants with more complex formulation mechanisms, such as photochemical oxidants (ozone) and fine particulate matter (PM_{2.5}).

2.2 Ambient concentrations of particulate matter

For SPM, an environmental quality standard (EQS) was set in 1973 indicating that the daily average for hourly values not exceed 100 µg/m³, and hourly values not exceed 200 µg/m³.¹⁸

In 2012, the EQS was attained in 99.7% of the ambient air quality monitoring stations (1,316 stations) and 99.7% of the roadside air quality monitoring stations (393 stations). As shown in Figure 2, the annual average concentration fell drastically during the latter half of 1970s. After a fluctuating trend during 1980s and gradual decline during 1990s, the concentration started to fall steadily again around 2000.

EQSs for PM_{2.5} were established in 2009 as:

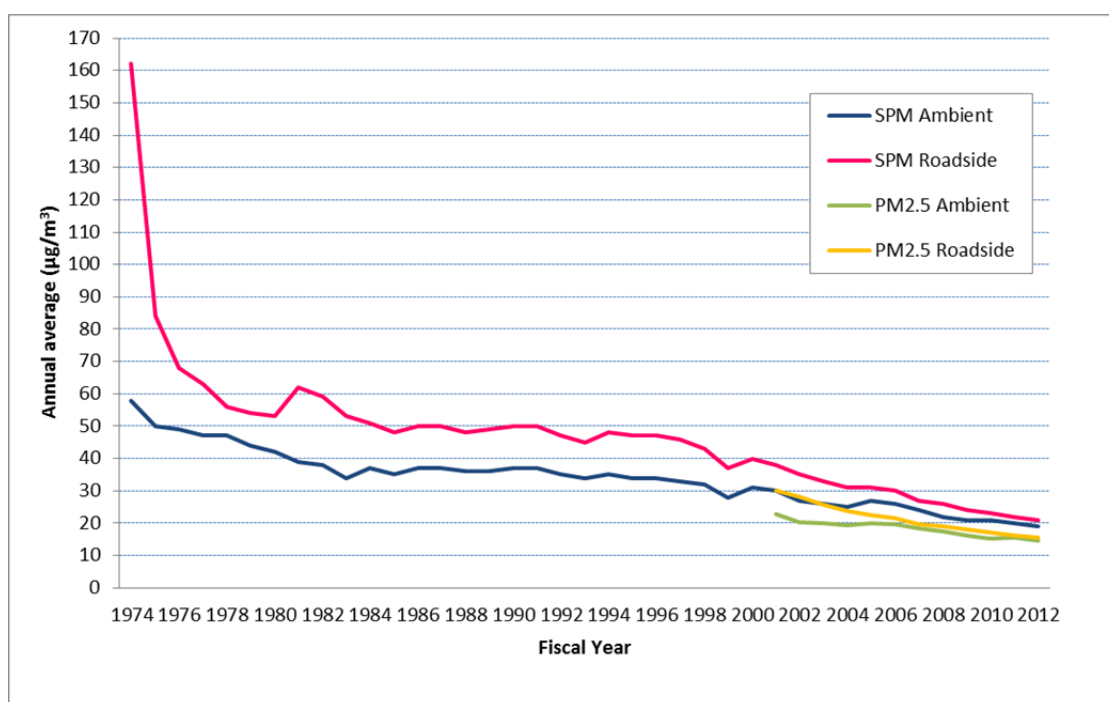
"The annual standard for PM_{2.5} is less than or equal to 15.0 µg/m³. The 24 hour standard, which means the annual 98th percentile values at designated monitoring sites in an area, is less than or equal to 35µg/m³."

Following the establishment of the PM_{2.5} EQSs, a system to continuously monitor them based on the Air Pollution Control Act was launched in fiscal year (FY) 2010.¹⁹ Because of the recent implementation of the program, the number of monitoring stations is still limited compared to those monitoring SPM. For now, many new PM_{2.5} monitoring stations remain under development.

According to data collected from the 312 ambient air quality monitoring stations and 123 roadside air quality monitoring stations in FY 2012, the annual standard (15.0 µg/m³) was attained in 61.5% of the ambient monitors (192 stations) and 45.5% of the roadside monitors (56 stations). As for the daily standard (35 µg/m³), the attainment rate was 44.6% for the ambient monitoring (139 stations) and 38.2% for the roadside monitoring stations (47 stations).

Figure 2 Annual average concentrations of SPM and PM₁₀

(Source: MOEJ²⁰)



Note: Data for PM_{2.5} from 2001 to 2009 are drawn from experimental monitoring.

2.3 Policy Measures to Reduce BC

This section discusses the major policy measures implemented by the Japanese government to control emissions-related BC from both stationary and mobile sources. First,

it presents an outline of the soot and dust regulations from stationary facilities and the subsequent emissions reductions. Second, it goes over the stepwise development of vehicle emissions standards and fuel quality standards for diesel vehicles. Third, it summarises vehicle emissions control measures introduced in highly populated metropolitan areas – an effort that resulted in the steady reduction of SPM in the designated areas.

Emissions reductions of soot and dust from stationary sources

Emissions standards are the backbone of most air pollution policies. The Air Pollution Control Act, enacted in 1968, set emissions standards for air pollutants from stationary sources (factories or workplaces), including SO_x, NO_x, soot and dust, and hazardous substances.

Emissions standards can be categorised as follows:

- **Emissions standard** : Maximum permissible limits prescribed for each type and size of facility. The Ministry of the Environment of Japan (MOEJ) sets the standards at the national level.
- **Special emissions standard** : stricter standards applied in lieu of the emissions standards in areas where air pollution has occurred or is likely to occur at levels exceeding the limits prescribed by a Cabinet Order (SO_x, soot and dust). The MOEJ establishes the special standards.
- **More stringent prefectural emission standard** : Emissions standards stricter than both the above-mentioned standards in areas where a prefecture finds national emissions standards to be insufficient to protect human health or living conditions (soot and dust, hazardous substances). Prefectural governments set these standards.
- **Standards for controlling the total emissions** : Maximum permissible limits prescribed for specific large-scale factories in areas where it is difficult to attain the EQSs using only the emission standards (SO_x and NO_x). Areas are designated by the national government while standards are prescribed by the prefectural government.²¹

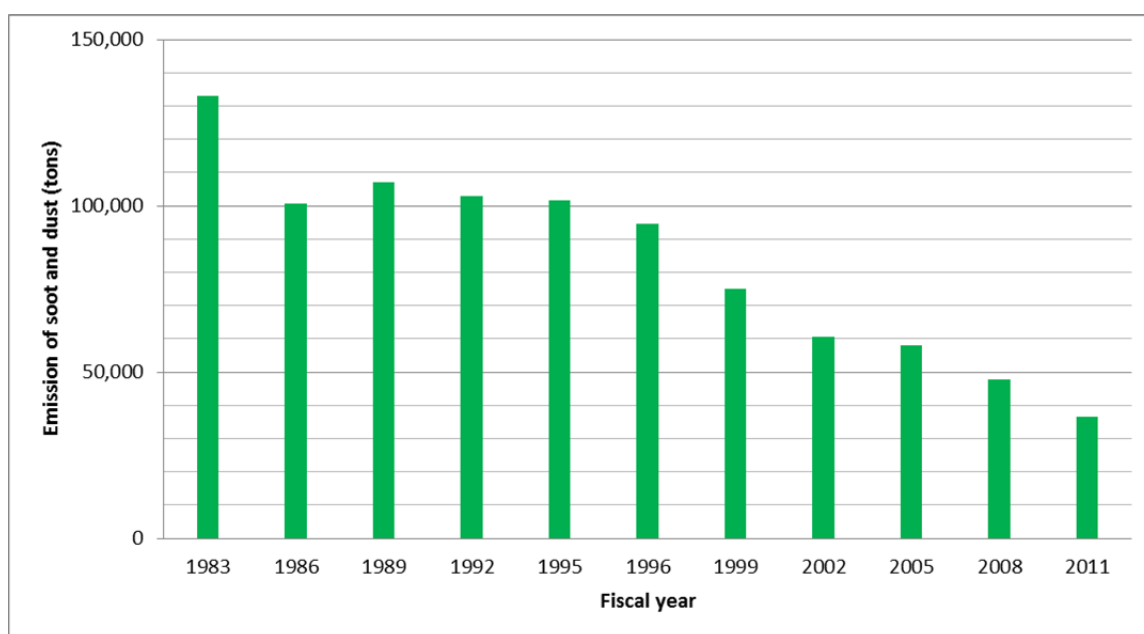
Regulations on soot and dust emissions have been implemented according to provisions in the Air Pollution Control Act. The emissions standards for soot and dust are set as the limit of concentration (g/m³) based on the type and size of the facility.²² The types of regulated facilities have been expanded over the years to include small sized boilers (1985), gas

turbines and diesel engines (1988), and gas engines and gasoline engines (1991). In addition, emissions regulations on soot and dust from waste incinerators were tightened in 1998. Coupled with the emissions regulation on dioxins, the more stringent regulation on waste incinerators resulted in a significant reduction of soot and dust emissions²³.

Annual emissions of soot and dust (Figure 3) indicates that soot and dust emissions have decreased as regulations have taken hold, with emissions falling by approximately half between FY 1999 and FY 2011.

Figure 3 Annual Emissions of Soot and Dust

(Source: MOEJ²⁴)



Note: National comprehensive emission surveys are conducted every three years, with exceptions in 1995 and 1996.

The electricity industry represented the largest source of soot and dust emissions in FY 2011 with 5,583 tons, or 15%, of the total. It was followed closely by the steel industry with 5,317 tons, still 15% of the total, and then ceramics, clay and stone product manufacturers with 3,110 tons, or 9% of the total.

As for the facility type, boilers represented the major source, accounting for approximately half of the total emissions (44%).

Control of Emissions from Diesel Vehicles

Vehicle emissions standards are prescribed by the Minister of the Environment and are based on the Air Pollution Control Act. These standards have been tightened following recommendations by the Central Environment Council.²⁵

Figure 4 shows the different phases of emissions standards for PM from diesel vehicles. As a result of the tightening of these standards, the emissions limit has been reduced from 1% to 10% compared to the initial regulation depending on the vehicle type.

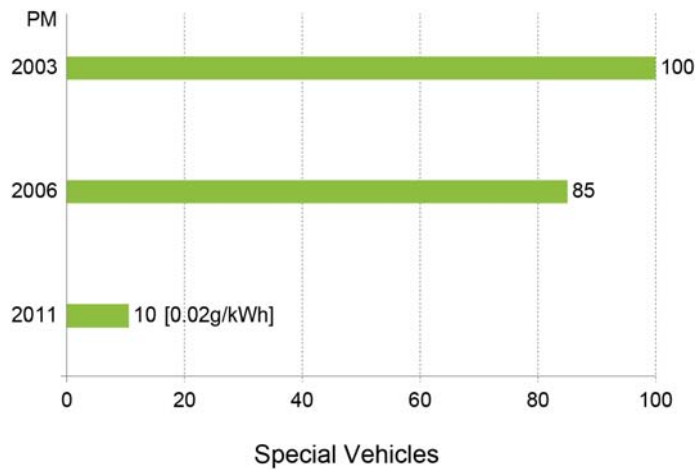
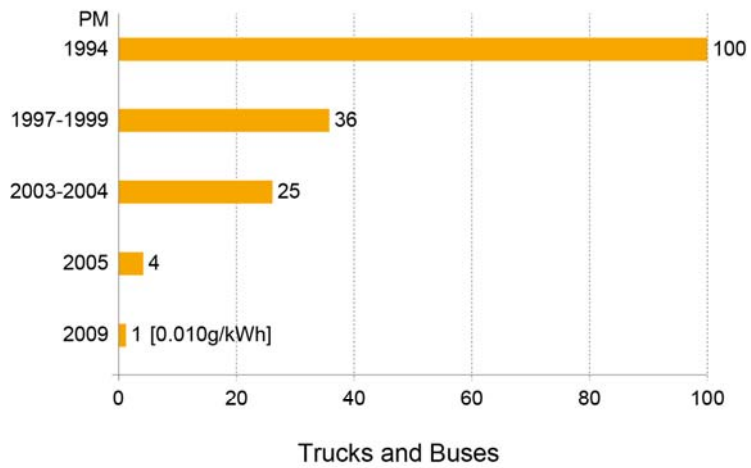
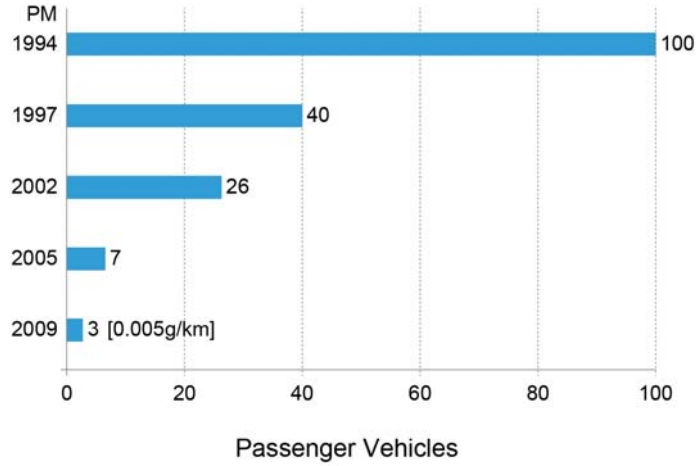
For example, the emissions standards for heavy-duty trucks and buses (>3.5t) have been strengthened as follows:

- 1994: Short-term regulation (0.7g/kWh)
- 1998: Long-term regulation (0.25g/kWh)
- 2003: New short-term regulation (0.18g/kWh)
- 2005: New long-term regulation (0.027g/kWh)
- 2009: Post new long-term regulation (0.01g/kWh)

Due to the implementation of stricter standards, almost all new diesel vehicles are equipped with diesel particulate filters (DPF).

Figure 4 PM Vehicle Emission Standards from Diesel Vehicles

(Source: MOEJ²⁶)



Improving fuel quality is necessary to make vehicle emissions regulations stricter. The combustion of diesel fuels with high sulphur content not only generates pollutants such as SOx and sulphates but also deteriorates the catalysts that remove pollutants from exhaust gas. In addition, DPFs cannot properly process high-sulphur diesel fuels. Because of these factors, lowering sulphur content in diesel fuels is crucial for achieving vehicle emissions reductions.²⁷

Since the 1990s, Japan has taken a series of steps to tighten standards on sulphur content in diesel fuels (Figure 5). In 1997, the limit of sulphur content was lowered from 2,000 ppm to 500 ppm (0.05% by weight). In 2005 the standard was further tightened to 50 ppm and in 2007 it was made even more stringent to 10 ppm, so called “sulphur-free”.

The step-by-step reduction of sulphur content in diesel fuel enabled the installation of after-treatment devices necessary to strengthen vehicle emissions standards.

Figure 5 Regulation on sulphur content in diesel fuel

(Source: MOEJ²⁸)

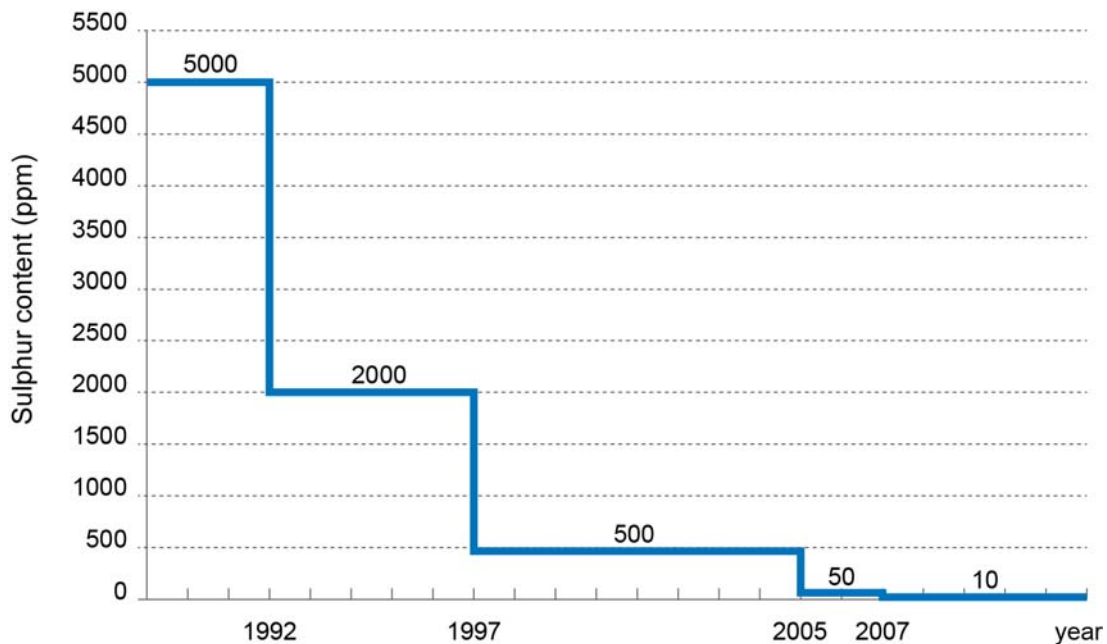


Figure 6 shows long-term reductions in ambient concentrations of elemental carbon (EC) in particulate matter smaller than 2.1 µm as measured from an ambient monitoring station in the Kudan Area of Tokyo. The major updates on vehicle emissions and fuel standard

regulations are also shown in the graph. The reduction in EC concentration indicates the contributions that these regulations have made in improving local air quality.²⁹

Figure 6 Ambient concentration of EC in particles

(Source: JAMA³⁰)



Automobile NOx and PM Law

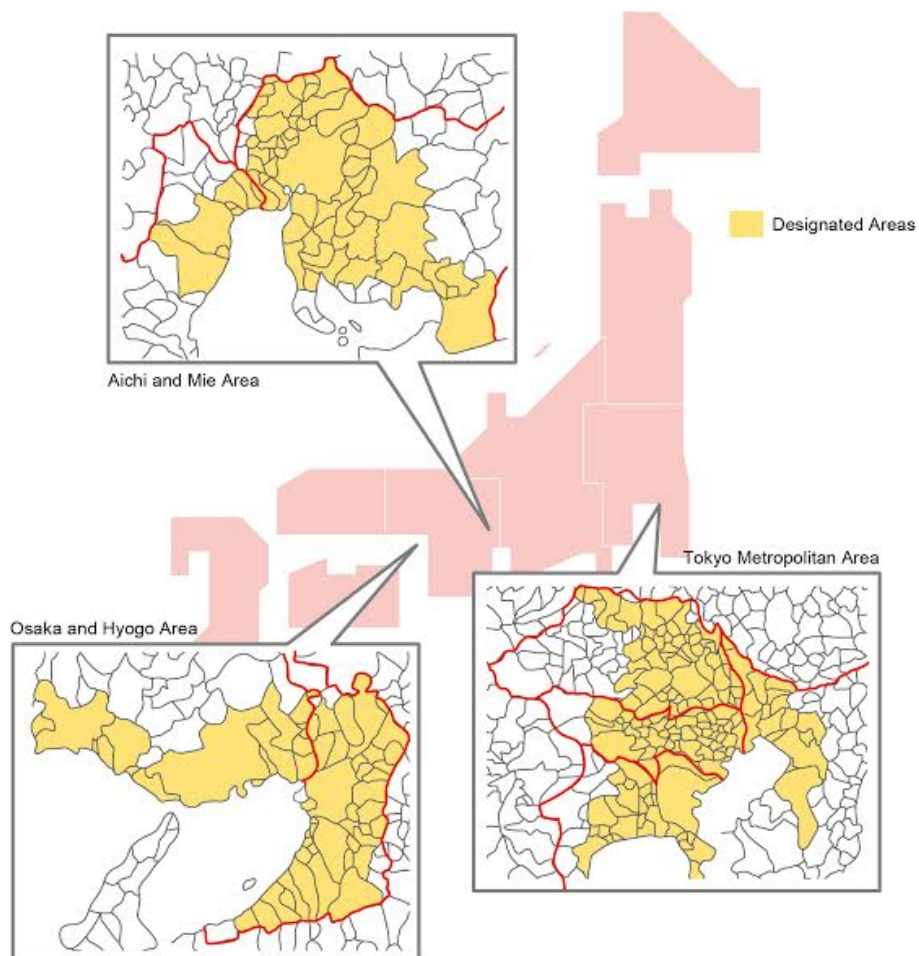
In a further effort to reduce pollution from vehicles in highly populated and congested metropolitan areas, the Law Concerning Special Measures for Total Emission Reduction of Nitrogen Oxides from Automobiles in Specified Areas (Automobile NOx and PM Law) was enacted in 2001. The new law added PM to the air pollution control system established under the previous Automobile NOx Law.

The Automobile NOx and PM Law designated cities in three metropolitan areas (Tokyo Metropolitan Area, Osaka/Hyogo Metropolitan Area, and Aichi/Mie Metropolitan Area) (Figure 7) for implementation of the following measures:

- ① **Development of basic policies and plans for area-wide emissions reductions** of NOx and PM as emitted from vehicles (general framework for countermeasures).
- ② **Regulation of in-use vehicles** (with a ban on the use of vehicles not meeting specified emission standards for trucks, buses, and diesel vehicles; applies only to the vehicles registered in the designated areas).
- ③ **Reduction of emissions by business operators** (large business operators must develop vehicle management plans).³¹

Figure 7 Areas Designated under the Automobile NOx and PM Law

(Source: MOEJ and MLIT³²)

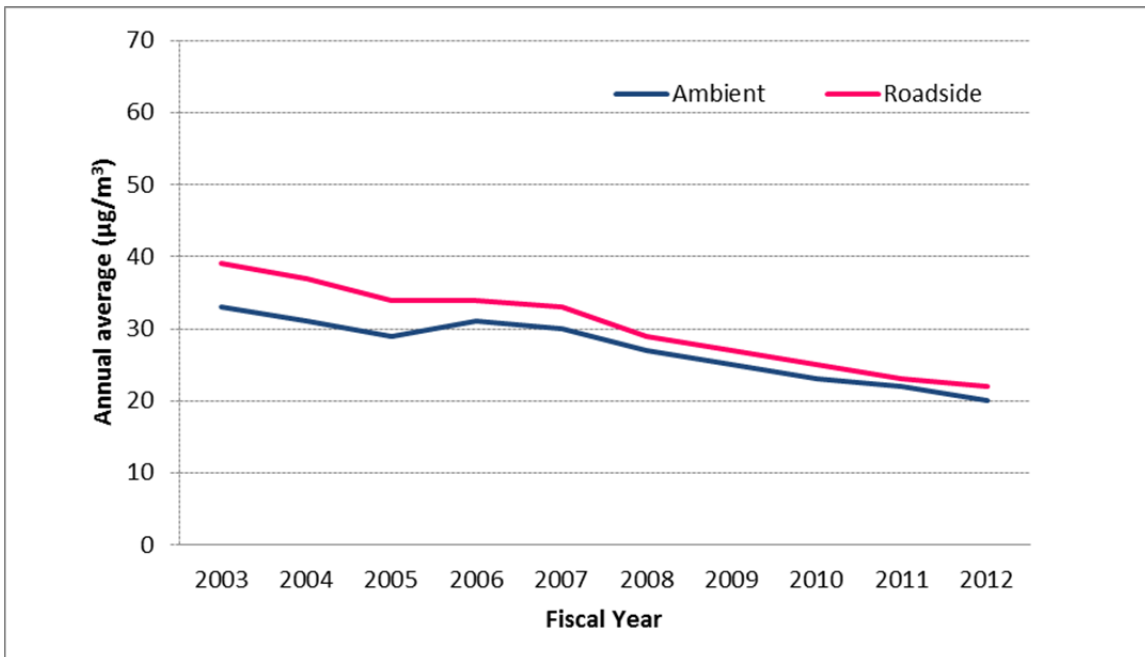


The Law was partially amended in 2007 to introduce measures to address **localised pollution** and **incoming traffic from outside the designated areas** (these updates came into effect in 2008).

As a part of the **basic policies for area-wide emissions reductions**, a goal was set “to attain EQSs in most monitoring stations in the designated areas by 2010.” This goal has been achieved, and annual average concentrations of SPM in the designated areas – which include 294 ambient air quality monitoring stations and 165 roadside monitoring stations – have shown gradual but steady improvement as illustrated in Figure 8.³³

Figure 8 Annual Average Concentration of SPM in Designated Areas under the Automobile NOx and PM Law

(Source: MOEJ³⁴)



3. Japanese City and Metropolitan Government Experiences: Selected Case Studies

This chapter summarises two examples of local government's efforts to reduce emissions of black carbon (BC), one involving industrial emissions and the other involving vehicle emissions. The case of Kawasaki is presented first as an example of a city that has pioneered industrial pollution emissions reduction measures. Tokyo's innovative policy measures for diesel vehicles are also discussed. In both cases, ambient concentrations of suspended particulate matter (SPM) have improved, indicating the effectiveness of the efforts.

3.1 Control on industrial pollution in Kawasaki

Kawasaki experienced rapid industrial development during the 1950s, with industrial emissions increasing accordingly. With the Adverse health effects on residents becoming ever more apparent, the city enacted the Pollution Prevention Ordinance (the Old Ordinance) in 1960.

Ten years later in 1970, the city reached an agreement with 39 local industries to set non-legally binding actions for air pollution control; this was known as **the air pollution control agreement**. This agreement was eventually adopted nationwide and has come to be viewed as an innovative measure for motivating local-level compliance. Based on the agreement, included industries were required to:

- Prepare and implement an air pollution prevention plan to reduce emissions of air pollutants
- Respond to warnings for atmospheric levels of sulphur dioxide (SO₂) over the prescribed limits by controlling the amount of production
- Regularly report fuel type and sulphur content.³⁵

In 1972 the Pollution Prevention Ordinance, which also played a key role in pollution control in Kawasaki, was enacted and promulgated. This ordinance synthesised a variety of regulations developed by the city, including those regulating air pollution, water pollution, noise, and more. Based on the ordinance, the city set its own **environmental target values** for air pollutants. For SPM, the environmental target was set as a daily average under 75 µg/m³ per hour with an annual average not exceeding 12.5 µg/m³.³⁶ The target was more ambitious than the national environmental quality standard (EQS) set at 100 µg/m³ per hour or less.

For each of these pollutants, Kawasaki set **area emissions limits** by taking into account the locations and emissions status of each of the emissions sources, such as factories. In order to achieve the **environmental target values** and **area emissions limits**, the city introduced the **total emissions control system**, otherwise known as the “Kawasaki-method”. Under the **total emissions control system**, different emissions standards were set for each facility based on the simulated results of ambient concentrations from an atmospheric dispersion model (Box 1). Kawasaki’s pioneering total emissions control system played an important role advancing pollution controls at both the national and local levels.³⁷

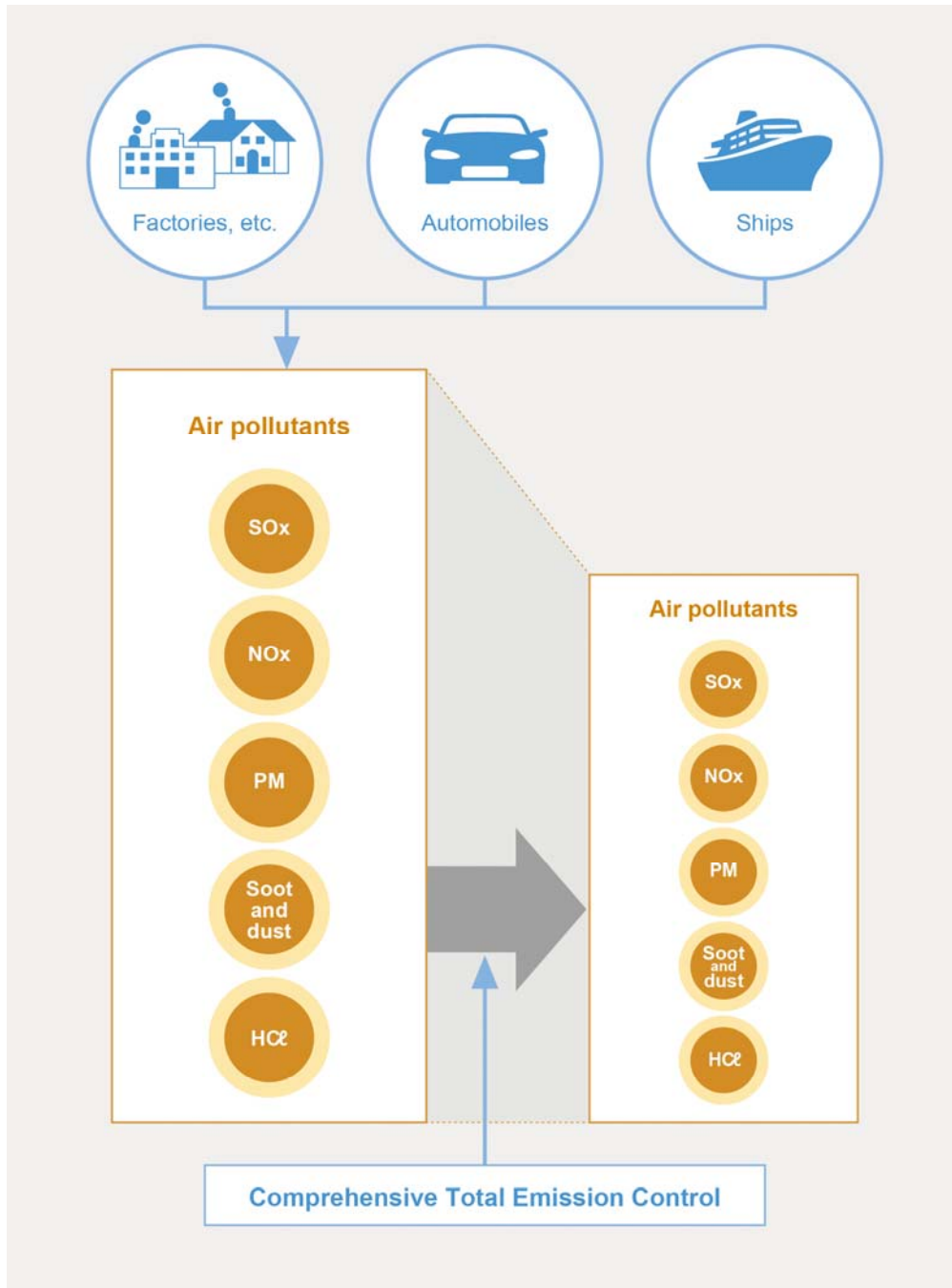
Box 1 Key elements of the Kawasaki-method³⁸

- **Environmental Target Values:** set by the city in order to protect citizens’ health and surrounding environment.
- **Area Emissions Limits:** set to achieve environmental target values. The area emissions limits differ from area to area based on the status of pollution.
- **Emissions standards:** set for each facility to maintain the area emissions limits. Based on simulated results of ambient concentrations from an atmospheric dispersion model.

As Kawasaki’s environmental problems became more complex, the city enacted the Ordinance for Conservation of Living Environment, including Pollution Prevention in 1999. This ordinance contains measures to improve air quality, including the introduction of a **comprehensive total emissions control** (also known as a **basket regulation**) to reduce SPM. The basket regulation was comprehensive in that it not only addressed the primary sources of SPM, soot and dust, but also its precursors: sulphur oxides (SO_x), nitrogen oxides (NO_x), and hydrogen chloride (HCl) (Figure 9). Under the regulation, emissions standards related to PM were newly established for business facilities over a certain size. The regulation was extended to cover existing facilities in 2005.³⁹

Figure 9 Comprehensive total emission control

(Source: Kawasaki City⁴⁰)



As a result of these basket regulations, annual emissions of soot and dust from factories decreased, and ambient concentrations of SPM began to fall correspondingly (Figure 10 and 11). The attainment status has had a fairly good track record since 2004, with every ambient monitoring station meeting the EQS except for the years 2006 and 2010.

Figure 10 Annual Emissions of Soot and Dust from Factories in Kawasaki

(Source: Kawasaki City⁴¹)

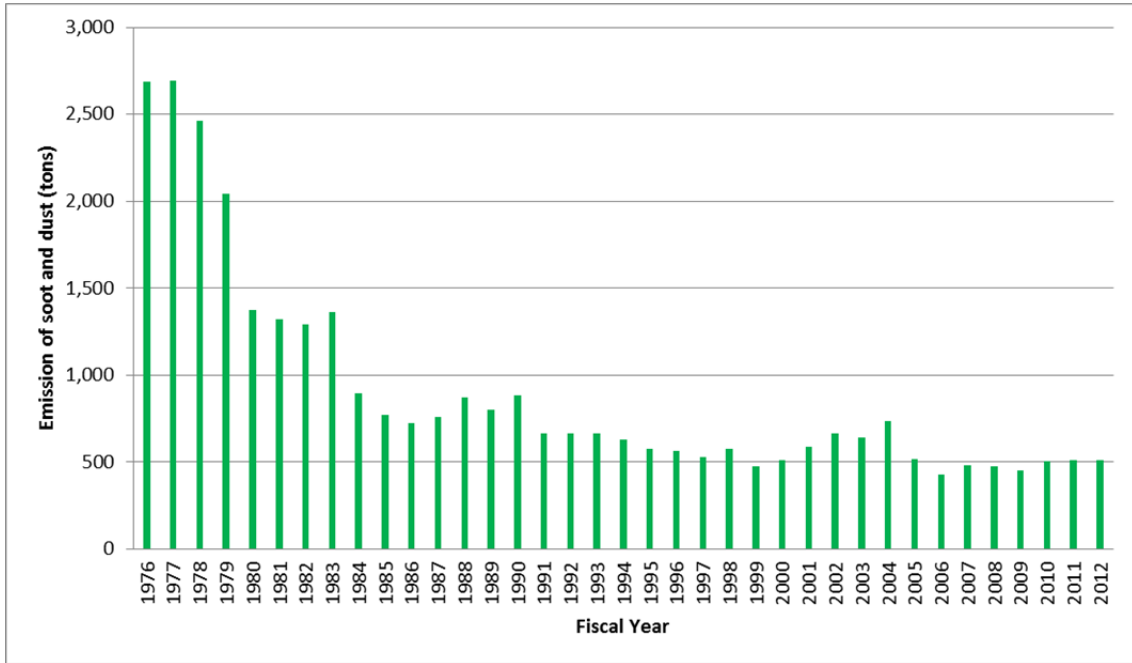
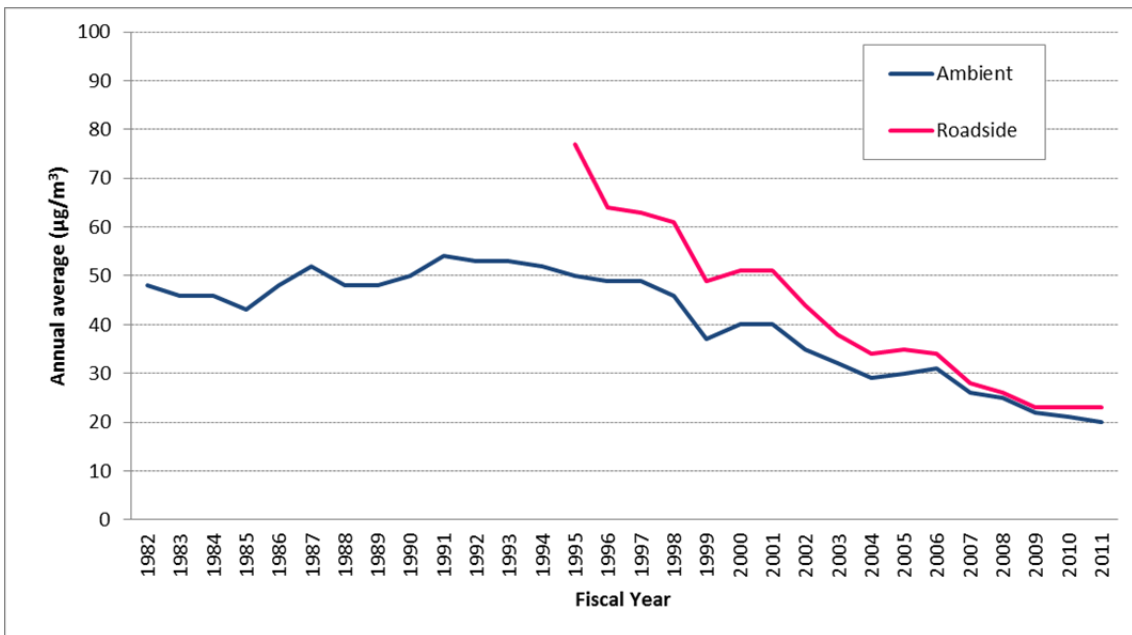


Figure 11 Annual Average Concentrations of SPM in Kawasaki

(Source: Kawasaki City⁴²)



3.2 Diesel Emissions Control in Tokyo

In October 2003, the Tokyo Metropolitan Government (TMG) introduced regulations on diesel vehicle emissions through a revision to the Tokyo Metropolitan Environmental Security Ordinance. Before the new regulations were implemented, the environmental standard for SPM had never been attained at any monitoring station in Tokyo.

To reverse this trend, the TMG launched the **"Say No to Diesel Vehicles"** campaign in August of 1999. The campaign aimed to initiate a debate on vehicle pollution control policies and called for behavioural changes related to vehicle use. Five policy measures were proposed as an initial first step (STEP1) (Box 2).

Box 2 Five Policy Measures (STEP1)

Proposal 1:	Do not ride on, purchase, or sell diesel-powered passenger vehicles in Tokyo.
Proposal 2:	Switch from business-use diesel vehicles to gasoline equivalents whenever such alternatives are available.
Proposal 3:	Achieve early development of emissions purification devices and their subsequent installation on diesel vehicles.
Proposal 4:	Rectify the preferential taxation system that imposes lower excise taxes on diesel fuel than on gasoline.
Proposal 5:	Achieve early development of vehicles that comply with the new long-term regulation on diesel emissions (planned to be enforced around 2007) to help enable accelerated implementation.

Based on data gathered in STEP1, TMG developed a report "Countermeasures for Diesel Vehicles: Tokyo's Choices" outlining its basic stance on future regulations for diesel vehicles. TMG also launched the "Say No to Diesel Vehicles STEP 2" campaign, which proposed "Nine Measures to Challenge Diesel Emissions" (based on the original Five Proposals) and "Five Actions for Promoting Debate and Initiatives" (Box 3).

Box 3 Nine Measures to Challenge Diesel Emission (STEP2)

(Provisions to be incorporated to the Ordinance)	
Measure 1:	Install DPF to large cargo vehicles and busses (Proposal 3)
Measure 2:	Restrict the use of diesel vehicles that do not meet the equivalent emissions standard for gasoline vehicles, and an obligation to replace them (Proposals 1 and 2)
Measure 3:	Promote the use of automobiles that generate lower pollution
Measure 4:	Disclose environmental information regarding automobiles (Early realisation of system reform)
Measure 5:	Rectify the preferential excise tax system on diesel fuel (Proposal 4)
Measure 6:	Enhance the sulphur content regulation on diesel fuel, and accelerate the implementation of the new long-term regulation (Proposal 5)
Measure 7:	Rectify the emissions testing method, which is not reflective of the actual driving conditions in Tokyo
Measure 8:	Enhance the vehicle registration system with an environmental perspective, and tighten controls on soot discharge in automotive emissions (establish a long-term strategy)
Measure 9:	Establish of a long-term strategy that encompasses the introduction of fuel-cell vehicles and a modal shift

The Tokyo campaign garnered considerable public attention and the national government decided to accelerate implementation of the long-term regulations for new vehicles in consequence.⁴³

In addition, in December 2000, the TMG enacted a ban across Tokyo **on the use of diesel vehicles out of compliance with PM emissions standards** as a part of the Ordinance on Environmental Preservation to Secure the Health and Safety of Citizens of the Tokyo Metropolitan Area (commonly known as the Environmental Preservation Ordinance) (Table 5). This was unprecedented in the country for two notable reasons: It was to the first policy to be employed **by a local government regulating the use of diesel vehicles**, and it regulated **not only new vehicles, but also in-use vehicles**. Neighbouring prefectures soon followed suit and comparable ordinances were adopted by Saitama Prefecture (July 2001), Chiba Prefecture (March 2002) and Kanagawa Prefecture (September 2002).

Table 5 Summary of the Regulation: TMG Environmental Preservation Ordinance

(Source: TMG⁴⁴)

Date of application	October 1, 2003
Substance controlled	Particulate matter (PM) emitted by diesel vehicles
Target area	Tokyo Metropolitan area (Islands excluded)
Banned activity	The driving of diesel vehicles that do not comply with PM emission standards
Target vehicles	Trucks and vans, buses and special purpose vehicles (e.g., refrigerated trucks). * Passenger cars exempt.
Grace period	Seven years
Designated device	Vehicles are considered compliant if fitted with a PM reduction device designated by the governor.
Penalties	Business owners and the persons in charge of fleet operations are responsible. Violators are subject to fines of up to 500,000 yen and their names could be published.

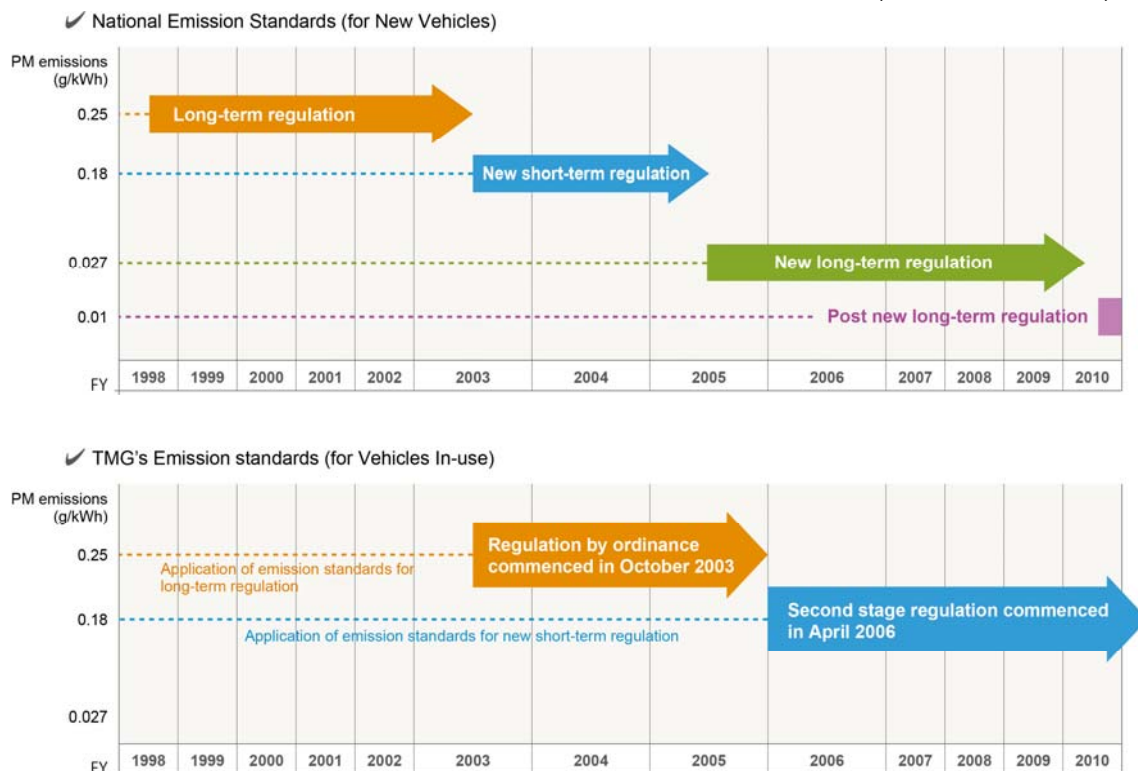
In order to facilitate smooth implementation of the new regulation, a campaign was rolled out one year before the enforcement date in which inspectors visited and instructed all companies owning more than twenty vehicles how to comply with the regulations. In addition, the TMG introduced programs to support compliance by small- and medium-sized businesses, including **subsidies for purchases of emissions reduction devices** and **low interest loan systems for purchasing vehicles** that met the state-of-the-art regulation.⁴⁵

The ban on the use of non-compliant diesel vehicles came into effect across Tokyo and the three neighbouring prefectures on October 1, 2003.

The 2003 regulations were intended to correspond with the national long-term PM emissions regulations for new vehicles. The PM regulation was further strengthened in 2006 by applying the values for national short-term regulations (Figure 12).

Figure 12 National PM Emission Standards (for New Vehicles) and the TMG's PM Emission Standards (for Vehicles in Use)

(Source: TMG 2014⁴⁶)



To ensure effective enforcement of the vehicle regulations, inspection officers (Vehicle G-men) were designated under the Tokyo Metropolitan Environmental Security Ordinance (see photograph below). To identify violating vehicles, inspections were conducted on the street, at distribution centers, and via video recordings throughout the region.⁴⁷

On-road inspection

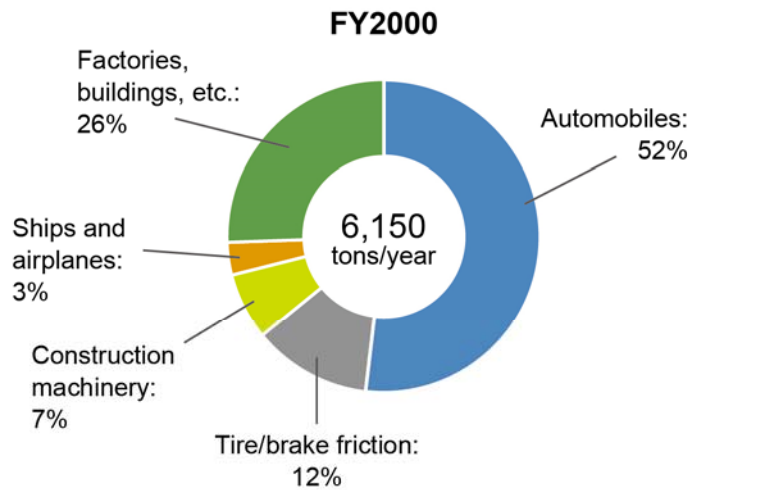
(Source: TMG)



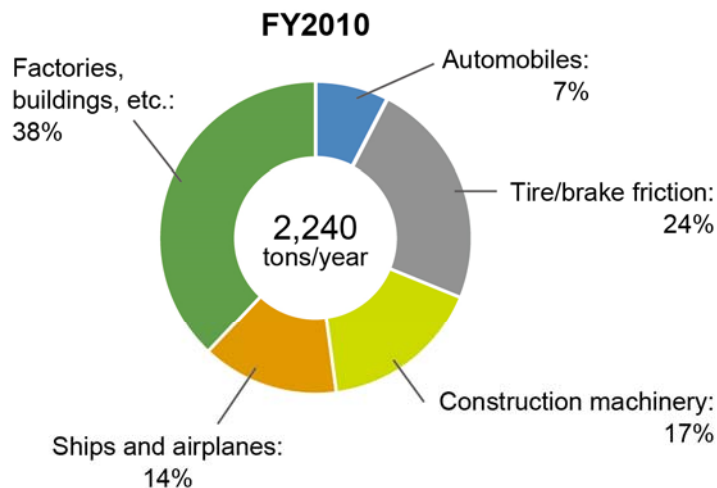
Emissions of PM in Tokyo fell from 6,150 tons in 2000 year to 2,240 tons in 2010. In addition, the ratio of the emissions from automobiles to the total PM emissions yielded a significant decrease over the decade (Figure 13).

Figure 13 PM Emissions in Tokyo

(Source: TMG 2014⁴⁸)



- * Automobile emissions do not include engine startup emissions.
- * Emissions from factories include condensed dust (PM).
- * Automobile emissions do not include ground dust (PM) stirred up by passing automobiles.

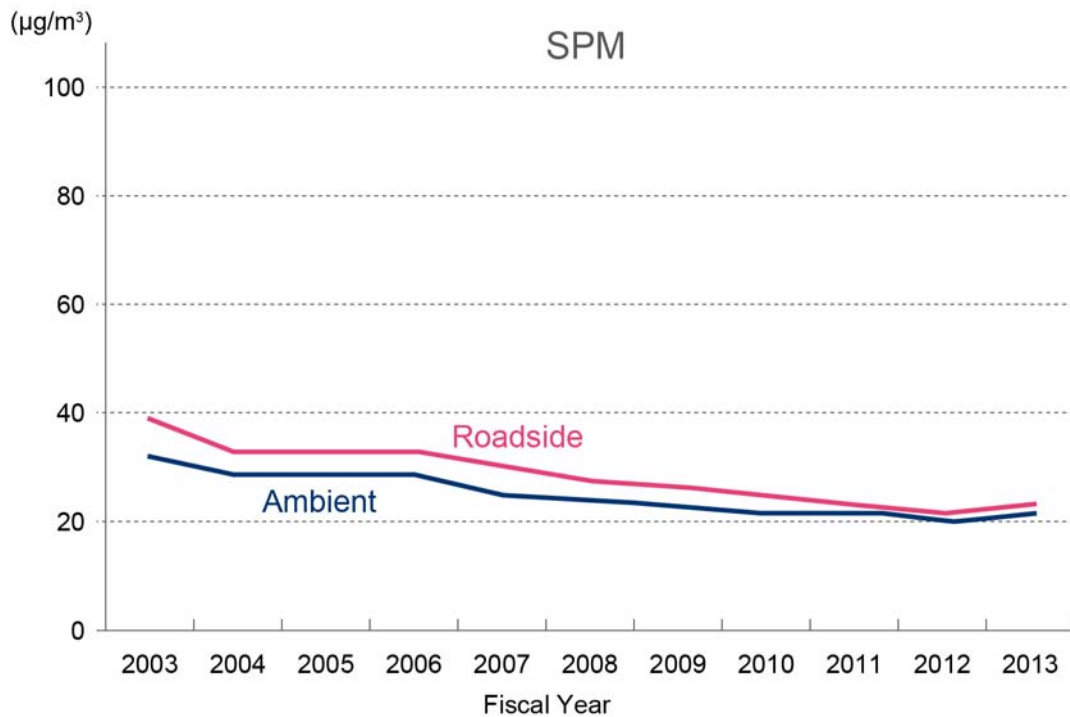


- * Secondary generated PM is not included.
- * Since the values for each item are rounded, there may be a rounding error for the total amount.

SPM annual average concentrations have been gradually falling over the past ten years, though FY 2013 showed an increase (Figure 14). The differences in values between ambient air monitoring stations and roadside air pollution monitoring stations have also begun to converge.

Figure 14 Annual Average Concentrations of SPM in Tokyo

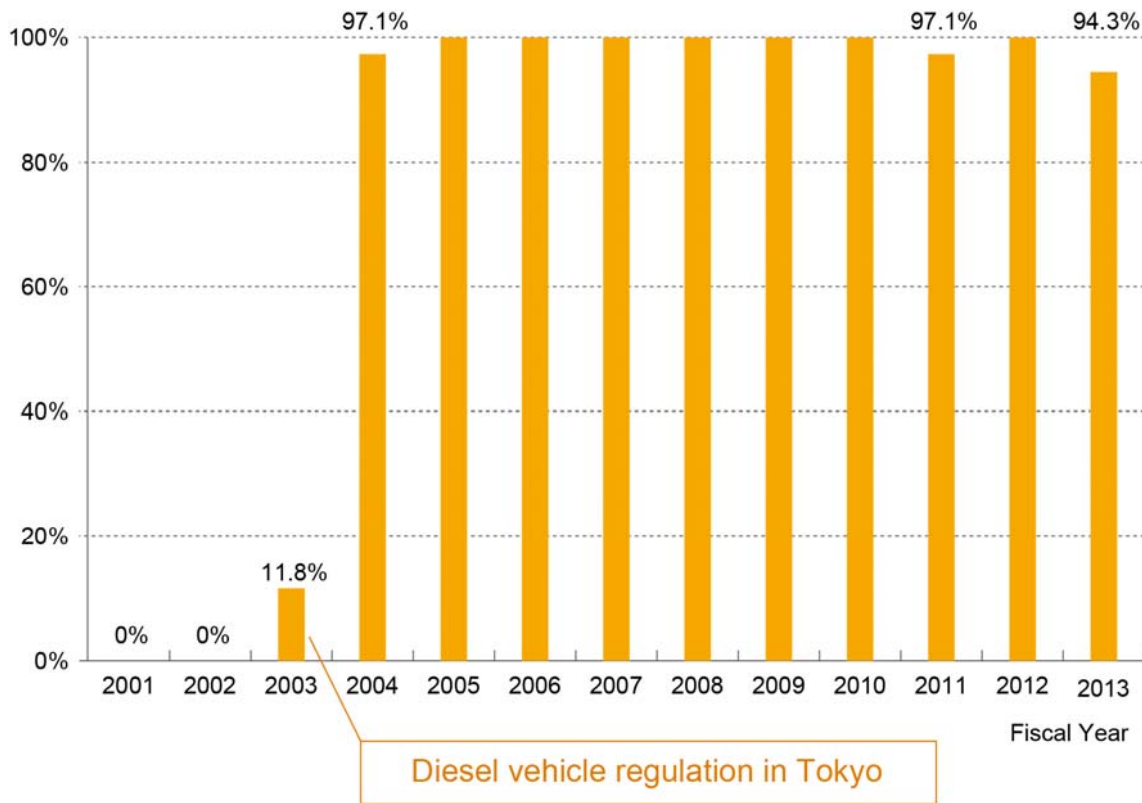
(Source: TMG 2014⁴⁹)



The attainment rate of the air quality standard for SPM significantly improved after the implementation of the regulations. In FY 2004, just one year after going into effect, the rate reached 97.1%, and only one roadside monitoring station failed to meet the standard (Figure 15).

Figure 15 Achievement Ratio of Environmental Standards for SPM Concentrations at Roadside Air Pollution Monitoring Stations

(Source: TMG 2014⁵⁰)



4 Examples of Pollution Control Technologies in Japan

In order to keep up with Japan's increasingly strict national and local dust and soot and diesel emissions regulations, Japan has introduced increasingly advanced emission control technologies. This section looks at how technologies to curb dust and soot emissions, as well as technologies to reduce diesel emissions, have evolved, including recent technological advances.

4.1 Dust Collection Technologies

Dust collection involves removing and collecting particles from treated waste gases. The air pollution control devices used in this process are generally applied in the final stage of a production process.

In Japan, dust collection technologies have improved dramatically since the end of World War II as public interest in controlling air pollution has grown, helping them keep pace with the increasingly stringent standards on dust emissions.

Initially, installing centrifugal collection apparatuses such as cyclones and dust cleaning apparatuses like scrubbers was sufficient to meet emissions standards. However, newer standards required higher-performing devices equipped with more sophisticated equipment such as bag filters and electrostatic precipitators (ESPs). High-pressure and high-temperature technologies were developed and made more energy efficient by utilising exhaust heat. Examples of these high-temperature dust collectors include ceramic filters and packed-bed filters.⁵¹

Dust collectors can be grouped into six types based on how they extract particles from waste gas: gravity, inertial, centrifugal, cleaning, filtration and electrostatic. These vary in their dust collecting capacities and in their manufacturing and operation costs. Types are selected based on the conditions of their use and depending on the nature of the waste gas (Table 6).⁵²

Table 6 An Overview of Dust Collectors

(Source: NIES⁵³)

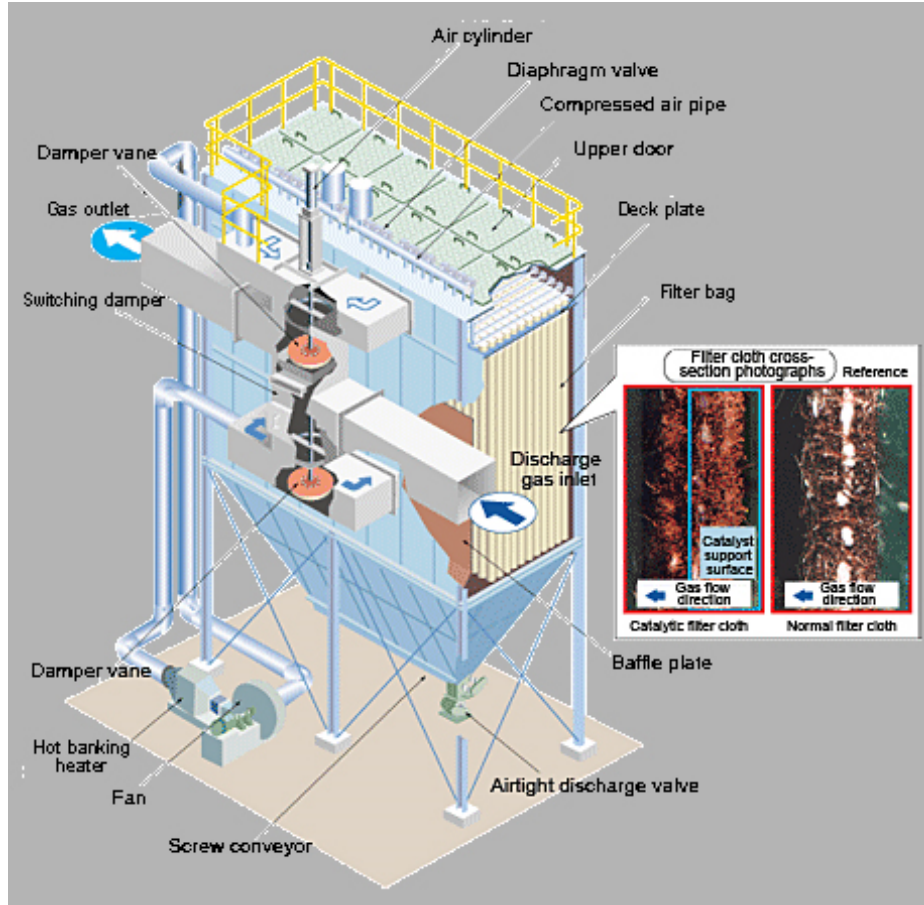
Type	Design	Principle	Used For
Gravity	Sedimentation chamber	Prompts gravity-induced natural sedimentation, then separates and collects particles in waste gas.	-
Inertial	Louver	Uses the tendency of a particle with mass to move straight with inertia (no matter how the gas flow changes its direction) to separate and collect particles.	-
Centrifugal	Cyclone	Adds a swirling flow to waste gas to generate a centrifugal force and extract particles from the gas.	(•Cement kiln)
Cleaning	Venturi	There are reservoir and pressured water types of cleaning dust collectors. The former stores water in a collection chamber, bringing it into contact with the waste gas to collect and remove particles.	(•Coal-fired thermal boiler)
Filter	Bag Filter	Particles are collected on the surface of a filter.	•Electric furnace for steel manufacturing •Waste combustion furnace
Electrostatic	-	Particles in waste gas are given a charge using direct current high voltage, then Coulomb's force (force effected between two charged particles) is used to capture particles on a collection pole.	•Coal-fired thermal boiler •Furnace in steel mill •Cement kiln

※In the "Used For" column, facilities in parenthesis refers to one that is used for supplementary purposes such as pre-operation treatment.

In recent years, bag filters and ESPs have become the primary abatement technologies. The use of bag filters (shown in Figure 16) has spread rapidly as they demonstrate a high particle capture rate.⁵⁴ The efficiency of bag filters depends on whether the filter material of the bag is well suited to the gas temperature, humidity, gas composition, and other characteristics of the dust. Fabric bag filters are widely used in dust collection systems involving industrial processes with a medium or low quantity of gas.⁵⁵

Figure 16 Structure of Bag Filter

(Source: Hitachi Plant Construction, Ltd. ⁵⁶)



Alternatively, ESPs are widely used for larger scale facilities. It is common practice for industries to operate at a lower temperature in order to apply these methodologies with high particle capture rates.⁵⁷

4.2 Diesel Vehicle Emissions Control Technologies

Japanese emissions standards for particulate matter (PM) and nitrogen oxides (NOx) have been gradually strengthened via a phased approach. To meet these tighter regulations, emissions control technologies have been continually improved upon.

Emissions control technologies can be categorized into either “engine improvement” (structure and combustion capacity) or “after treatment”. It is worth noting that there is a trade-off between NOx and PM controls, whereby reductions in one pollutant can

sometimes lead to increases in the other. Furthermore, NO_x may impair the fuel efficiency of diesel engines. Reducing a significant amount of PM, therefore, requires both the improvement of engine technology and the development of better after-treatment technologies.

The Japanese automobile industry has developed technologies that can both curb emissions and improve engine efficiency, including high-pressure injection that improves combustion capacity. The industry has also implemented after-treatment technologies such as Continuously Regenerating Type Diesel Particulate Filter (DPF). Examples of these removal technologies as developed by the Japanese automobile industry are presented in Figure 17. The latest electronic control technologies have further accelerated the process of enhancing both combustion capacity and after treatment pollution removals, resulting in significant reductions of both PM and NO_x.⁵⁸

Figure 17 PM emission reduction strategies and control measures

(Source: JAMA⁵⁹)

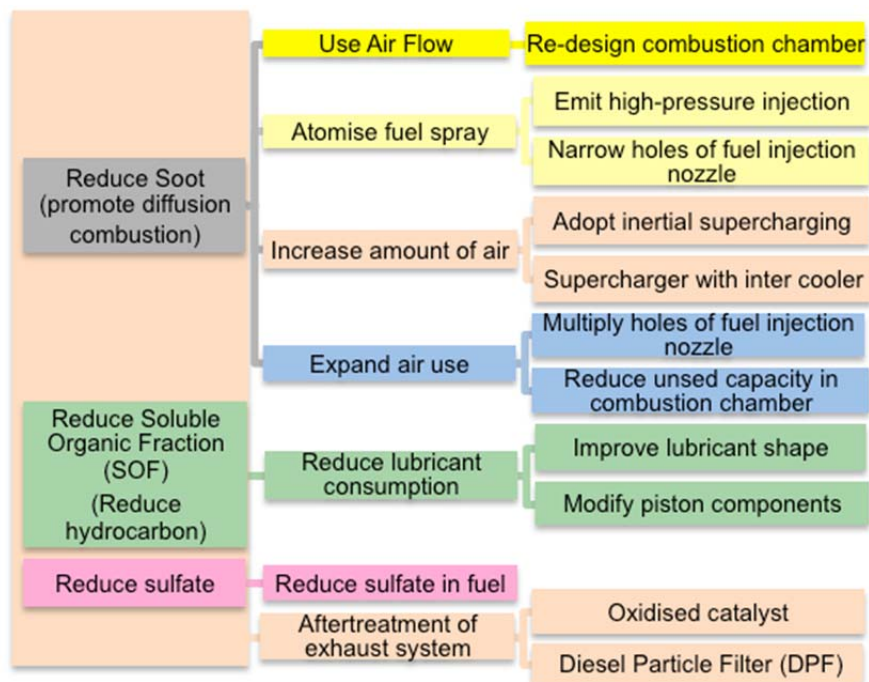
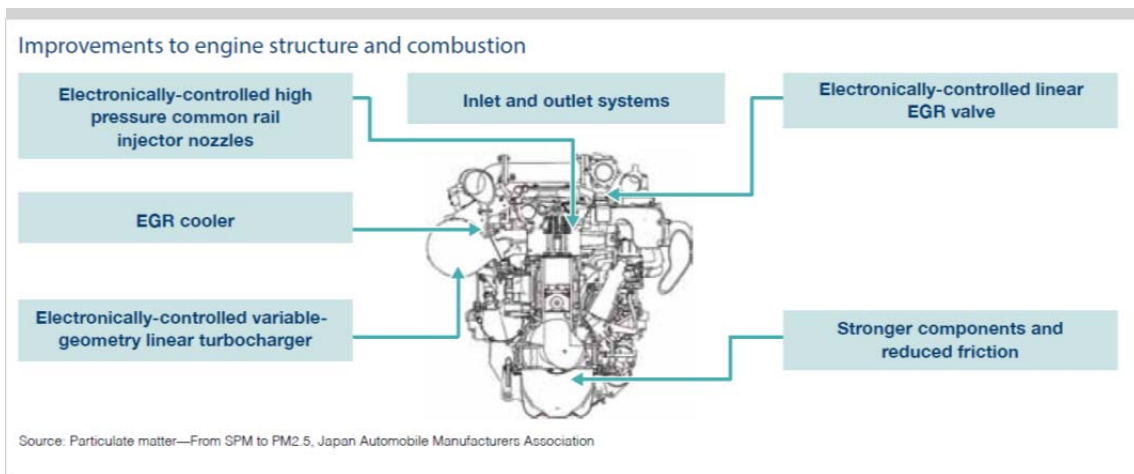


Figure 18 shows how the structure and combustion of engines have improved thanks to these advances. Vehicle exhaust contains carbon particles in the form of soot that has yet to be combusted. In order to reduce these soot emissions, it is important to promote the mixture of fuel and air in the combustion process by increasing the amount of air, utilising air flow, atomising fuel spray, and otherwise improving air use.⁶⁰

Figure 18 Improvements to Engine Structure and Combustion

(Source: MOEJ⁶¹)

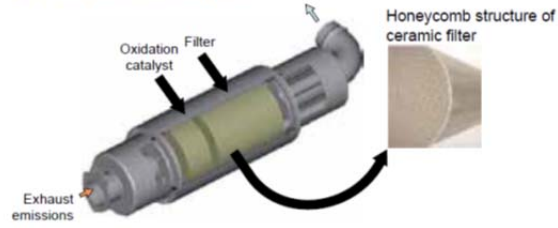


DPFs, which capture PM in the exhaust gas through filtration mechanisms, are highly effective in controlling solid particulate emissions in the after-treatment process.⁶² In Japan, almost all new diesel vehicles are now equipped with DPFs, of which filter substrates are the key components.⁶³ These filters, which need to be resistant to high temperatures, are commonly made from porous ceramics in Japan. In order to prevent the filters from clogging, collected particles are removed using an oxidation catalyst. Overall, DPFs are comprised of filters, catalysts, and a fuel additive control. Figure 19 illustrates a sample DPF structure.⁶⁴

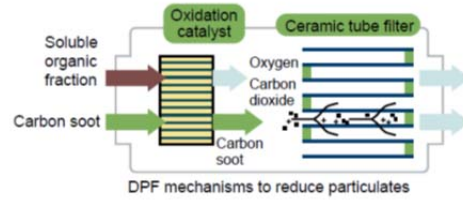
Figure 19 Example of DPF structure

(Source: MOEJ⁶⁵)

DPF structure (example)



Source: Particulate matter—From SPM to PM2.5,
Japan Automobile Manufacturers Association



5. Japan's International Cooperation

The international community has identified air pollution as a top priority requiring immediate action by world governments.⁶⁶ Many of the most polluted cities are located in Asia and emissions of air pollutants, including black carbon (BC), are expected to rise as these economies continue to grow and demand more energy. To help address the urgent problem of air pollution, Japan is involved in various international initiatives as described below.

EANET

The Acid Deposition Monitoring Network in East Asia (EANET) was launched in 1998 as a regional cooperative initiative to promote environmental sustainability and protect human health in East Asia.

Japan has supported EANET both financially and technologically, an effort the Japanese government plans to continue since EANET offers a framework to promote regional cooperation for the improvement of the air quality management.⁶⁷

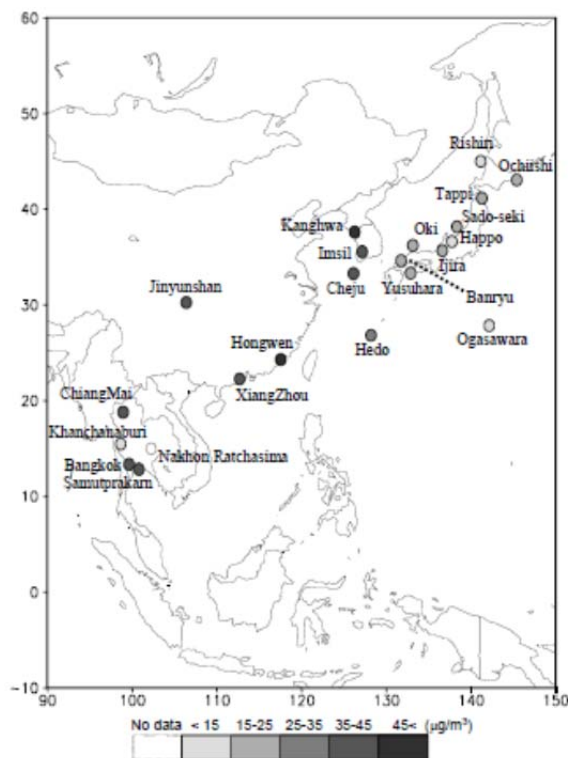
EANET monitors four environmental media – wet deposition, dry deposition, soil and vegetation, and inland aquatic environments. For dry deposition, measurements are conducted for:

- Gases: concentrations of sulphur dioxide (SO₂), nitrogen dioxide (NO₂), ozone (O₃) and others, and
- Particulate components.⁶⁸

Figure 20 shows levels of annual PM 10 concentrations at EANET monitoring sites in 2012, an example of the monitoring results.

Figure 20 Levels of annual PM10 concentrations at EANET monitoring sites in 2012

(Source: EANET 2013⁶⁹)



IBAQ

In July 2014, the Ministry of the Environment of Japan (MOEJ), in conjunction with Clean Air Asia (CAA), launched the Integrated Programme for Better Air Quality (IBAQ) in Asia. The IBAQ addresses the growing issue of air pollution in the Asia through an integrated approach contributing directly to more liveable and healthier cities.

Major IBAQ initiatives include:

- (1) Creation of the **Guidance Framework for Better Air Quality in Asian Cities**, an authoritative document for policymakers and other decision-makers on how to address key urban air quality issues in Asia.
- (2) Support of the **Fifth Governmental Meeting on Urban Air Quality in Asia** held in Colombo, Sri Lanka in November 2014.

- (3) **Implementation of the Guidance Framework** through the development of collaborative action plans at the local and regional levels and further **capacity building**.
- (4) **Technical support for air quality monitoring of fine particulates (PM2.5)**, and assistance with the assessment and utilization of such data.⁷⁰

APCAP

In June 2014, the MOEJ and UNEP launched the Asia Pacific Clean Air Partnership (APCAP), which brings together multiple regional initiatives to provide clear policy options and best available science to help countries manage air pollution. A special emphasis is placed on the other co-benefits of the reductions in air pollution, recognised as improved health, food and water security, and climate change mitigation.⁷¹

Components of the APCAP include:

- (1) **Reinforcing air quality assessments to help determine gaps in countries' capacity to address air pollution**

A science panel has been established to develop a science-policy synthesis report on air pollution with data aggregated at the sub-regional and regional levels to aid in this pursuit.

- (2) **Joint Forum on Clean Air in Asia and the Pacific**

The forum, comprised of various initiatives on air pollution, provides a platform for sharing the latest scientific data, international guidelines, and relevant information on atmospheric science, in order to assist policymakers in setting targets to improve air quality.

CCAC

The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) works to identify actions that reduce key short-lived climate pollutants (SLCPs), and that will ensure rapid delivery of scaled-up climate and clean air benefits. CCAC has introduced seven sector-based initiatives with the goal of substantially reducing SLCPs worldwide, and engaging high-level stakeholders. The Coalition has also launched three additional crosscutting efforts to accelerate emissions reductions of all SLCPs.⁷²

As a member of CCAC, Japan has been actively involved in the following sector specific and crosscutting initiatives:

(1) Mitigating SLCPs from the Municipal Solid Waste Sector

Supporting the mitigation of SLCPs in the municipal solid waste sector is Japan's primary interest in CCAC. Japan is working with several cities in Asia such as Cebu, Philippines to develop solid waste management plans. Japan is also helping support development of a tool to measure methane reductions, which will then be used by CCAC to demonstrate the mitigation's impacts.

(2) Supporting National Planning for action on SLCPs (SNAP)

Japan is also working with SNAP to help countries in Asia develop and implement National Action Plans (NAP) related to SLCPs. Bangladesh developed the first NAP in Asia.

(3) Regional Assessments on SLCPs

Regional Assessments are intended to provide policymakers with a more precise understanding of the opportunities for mitigating SLCPs than can be offered in other broader-scale reports. Japan is not only interested in supporting CCAC Regional Assessments but also in bridging CCACs work on SLCPs with other similar work done by the Atmospheric Brown Cloud (ABC) initiative and the science panel established by APCAP. This entails making sure there are strong communication channels across different air pollution policy and science initiatives, and helping to support the integration of findings from each of these initiatives into relevant publications.

(4) Addressing SLCPs from Agriculture

While the three above initiatives are supported chiefly by the MOEJ, the Ministry of Agriculture, Forestry and Fisheries (MAFF) is also considering working on the agricultural initiative. For this initiative, Japan is interested in promoting sustainable rice cultivation that can help reduce methane emissions.

ACP

The Asian Co-benefits Partnership (ACP) was formally launched at the 2010 Better Air Quality conference in Singapore with the support of 100 participants and the MOEJ.

The ultimate goal of the ACP is to support the mainstreaming of co-benefits into sector-based development plans, policies, and projects throughout Asia. The ACP serves as an interactive platform to improve information sharing and stakeholder coordination on co-benefits in Asia.

The partnership's major functions include:

- **Information sharing and knowledge management**, including generation and dissemination.
- **Enhancing communication** amongst ACP members.
- Developing **co-benefit policies and projects** in Asia.
- Strengthening **regional cooperation** to promote co-benefits.

6. Conclusion

The adoption of policy measures and technologies at national and local levels in Japan has contributed to the reduction of BC emissions and ambient concentrations of PM.

The core policies to reduce BC emissions from stationary sources were the national emissions standards on soot and dust under the Air Pollution Control Act enacted in 1968. In addition, efforts have been made by municipal governments to reduce emissions. In the case of Kawasaki, the city government set area emissions limits and facility emission standards to achieve ambient air quality targets that were more ambitious than the national EQS. The city further introduced regulations on multi-pollutants by addressing not only the primary sources of SPM but also its precursors (basket regulation).

Regarding mobile sources, vehicle emissions standards were set under the Air Pollution Control Act, with those relating to diesel vehicles having been progressively strengthened over time. In order to enable the implementation of more stringent emission standards, diesel fuel standards have been revised to lower the maximum sulphur content. These policies have been complemented by regulations focusing on highly populated metropolitan areas under the Automobile NO_x and PM Law; regulations that require the development of basic policies and plans for area-wide emissions reductions. In addition, initiatives by the Tokyo Metropolitan Government facilitated the reduction of diesel emissions not only in Tokyo but also in the neighbouring prefectures. The ban on the driving of heavy-duty diesel vehicles that are out of compliance with PM emissions standards was the first policy measure in the country to regulate in-use vehicles. The user costs of associated with the ban were moderated by subsidies for purchases of emissions reductions devices, low interest loans for new vehicles, and easily manageable inspections on the street and at distribution centers.

In response to these national and local policies, technologies to control soot and diesel emissions have steadily improved. For stationary sources, high-performance devices equipped with more sophisticated equipment such as bag filters and electric dust collectors have been widely introduced to meet the stringent standards. Vehicle emissions control technologies also have been upgraded to keep pace with the tightened standards. The latest electronic control technologies have accelerated the process of enhancing combustion capacity and after treatment. As a result, almost all new diesel vehicles are

equipped with DPFs in Japan.

Japan still has room for improvement. While the attainment rates of the EQS of SPM have improved significantly to more than 90% at both ambient and roadside monitoring stations, those of PM_{2.5} are still below 50% according to current data. In 2015, the Expert Meeting on PM_{2.5} of the Central Environment Council, an advisory body to the Minister of the Environment, released a report suggesting the government of Japan should further strengthen emissions controls to address PM_{2.5}.

Japan is also committed to working collectively to better air quality throughout Asia, further building on its track record of international cooperation. In addition, Japan will continue pursuing efforts to bridge air quality management with climate mitigation in an effort to maximise co-benefits.

Notes

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⁴ UNEP/WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone Summary for Decision Makers. P4.

⁵ CCAC. Definitions. <<http://www.unep.org/ccac/Short-LivedClimatePollutants/Definitions>>.

⁶ Ministry of the Environment Japan (MOEJ) and Secretariat of the Asian Co-benefits Partnership (ACP) (2014). Asian Co-benefits Partnership White Paper 2014. Bringing Development and Climate Together in Asia. pp 6-7.

⁷ Ibid. p29-30.

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¹¹ Committee on Assessment of Health Effects of Fine Particulate Matters (2008) Report (in Japanese).

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¹³ National Institute for Environmental Studies (NIES). Soot Removal Technologies (in Japanese) <<http://tenbou.nies.go.jp/science//description/detail.php?id=34>>

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¹⁶ It should be noted that the strict definition among those terms are still under discussion in the academic field. For example, see: Buseck, P. R., Adachi, K., Gelencsér, A., Tompa, É., & Pósfai, M. (2012). Are black carbon and soot the same?. Atmospheric Chemistry and Physics Discussions, 12(9), 24821-24846.

¹⁷ Nishio, T. (2013) Japan's Experience in Air pollution Control (in Japanese). Presented at

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¹⁸ MOEJ. Environmental Quality Standards in Japan - Air Quality.

<<http://www.env.go.jp/en/air/aq/aq.html>>. The unit used in the original document was microgram (0.10 mg/m³ for daily average , and 0.20 mg/m³ for hourly values) .

¹⁹ In Japan, the government's fiscal year starts on 1 April and concludes on 31 March.

²⁰ MOEJ (2014) Air Quality Status during Fiscal Year 2012 (in Japanese). <

<http://www.env.go.jp/press/press.php?serial=17974>>

²¹ MOEJ. Overview of the Air Pollution Control Act (in Japanese).

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²² MOEJ. List of emission standards for soot and dust and NOx (in Japanese).

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²³ Expert Meeting on Fine Particulate Matters (2015) Mid-term Report on Domestic Emission reduction Measures of Fine Particulate Matters (in Japanese).

²⁴ MOEJ (2014) Overview of the Comprehensive Survey on Emissions of Air Pollutants (Data from Fiscal Year 2011) (in Japanese) <<http://www.env.go.jp/press/press.php?serial=18034>>.

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