Policies

Diesel Vehicle Emission Control Devices

Date 2017-03-28 **Category** Transportation **Updater** hyelyn

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Date

2017-03-28

Last Update

2017-04-10

Policy Implementation Period

Located at the heart of the Korean Peninsula, Seoul is surrounded by high mountains including Bukhansan, Dobongsan, and Gwanaksan, thus forming a sort of basin which inhibits air dispersion by weak winds. Recently, along with the population increase in the metropolitan area, air pollutants generated by China's industrialization have affected the region. With regard to the condition of Seoul's artificial environment, its population has increased sharply since 1965, with more than 10.36 million inhabitants as of 2014. Meanwhile, the number of automobiles, the main cause of air pollution, increased from 450,000 in 1985 to 3,010,000 in 2014, showing a 6.7-fold increase.

Aside for days when yellow dust storms occur, the annual PM10 concentration in Seoul has shown a decreasing trend since 2003, with a fine-dust concentration of 44 $\mu g/m^3$ as of 2014. Fine dust shows a seasonal pattern: its concentration is highest in the spring due to frequent yellow dust storms, followed by winter, which is characterized by a highly stagnant atmosphere frequency caused by heating and radiative cooling. The concentration of fine dust is lowest in the summer, when there is a high amount of rainfall.

To prevent the environmental damages caused by fine dust, protect public health, and create a comfortable living environment, the national government has established air quality standards and ensured adequate maintenance of air quality in Seoul despite the ongoing changes in local environmental conditions. In 1993, fine dust (PM10) was included in the national air quality standards for the first time.

In addition, with the revision of the Environmental Policy Framework Act on December 4, 2006, an enhanced standard (compared to previous environmental standards) that has been applied since January 1, 2007, while ultra-fine dust (PM2.5) was added as a new evaluation item in 2015.

Table 1. National and Seoul Air Quality Standards

Item	National standard	Seoul standard	Method of measurement
Sulfur dioxide (SO_2)	0.02ppm/year 0.05ppm/day 0.15ppm/hour	0.01ppm/year 0.04ppm/day 0.12ppm/hour	Ultraviolet fluorescence
Fine dust (PM10)	50$\mu g/m^3$/year 100$\mu g/m^3$/day	50$\mu g/m^3$/year 100$\mu g/m^3$/day	Beta absorption
Fine dust (PM2.5)	25$\mu g/m^3$/year 50$\mu g/m^3$/day	25$\mu g/m^3$/year 50$\mu g/m^3$/day	Weight concentration method or an equivalent method of automatic measurement
Nitrogen dioxide (NO_2)	0.03ppm/year 0.06ppm/day 0.10ppm/hour	0.03ppm/year 0.06ppm/day 0.10ppm/hour	Chemical luminescence
Ozone (O_3)	0.06ppm/8hour 0.1ppm/hour	0.06ppm/8hour 0.1ppm/hour	UV photometric
Carbon monoxide (CO)	9ppm/8hour 25ppm/hour	9ppm/8hour 25ppm/hour	Non-dispersive infrared analysis
Lead (Pb)	0.5$\mu g/m^3$/year	0.5$\mu g/m^3$/year	Atomic absorption spectroscopy
Benzene (C6H6)	5$\mu g/m^3$/year	5$\mu g/m^3$/year	Gas chromatography

In 2003, the Special Act on Seoul Metropolitan Air Quality Improvement was established to improve the air quality in the capital area, which encompasses Seoul, Incheon, and Gyeonggi province. Based on this, the Seoul Metropolitan Air Quality Control Master Plan was established in 2005, and air quality improvement targets of PM10 40 $\mu g/m^3$, NO_2 22 ppb were implemented by 2014.

The detailed promotion plans of the Seoul Metropolitan Air Quality Control Master Plan included automobile management, including the production and operation of cars, and traffic demand management; total load management for large establishments; pollution source management for small- and medium-sized enterprises and towns; and eco-friendly energy and urban management projects.

The 2nd Seoul Metropolitan Air Quality Control Master Plan was established and announced in December 2013. The 2nd Special Measures for the Seoul Metropolitan Air Quality Improvement, covering the period from 2015-2024, switched the policy direction from managing the concentration targets to reducing the risks to public health. According to the provisions of the Special Act on Seoul Metropolitan Air Quality Improvement, Seoul′s action plan for the 2nd Seoul Metropolitan Air Quality Management was established in 2014 to promote the 2nd Seoul Metropolitan Air Quality Control Master Plan; and detailed plans for reducing air pollutants at the sources of pollution have been implemented to ensure eco-friendly traffic demand control by installing diesel particulate filters (DPFs) to diesel vehicles to reduce pollution, post-management, strengthening of the allowable-emission criteria, adoption of low-pollution vehicles, exhaust gas management, dissemination of the weekly no-driving day program, and review of the restrictions on driving diesel vehicles in the event of failure to comply with such low-pollution measures. To reduce the volume of pollutants discharged by businesses, the total pollutant control systems allocate yearly total allowable emissions and manage them within the range of the amounts allocated to large businesses. In the case of small- and medium-sized businesses, such measures as the distribution of eco-friendly energy and the expansion of the clean-energy supply have been implemented by strengthening the permissible-emission standards.

The Seoul Metropolitan Government targets a 20% reduction of ultra-fine dust in 2015 as an important policy objective, and strived to reduce the annual PM2.5 pollution level of 25 $\mu g/m^3$ to 20 $\mu g/m^3$.

Background Information

Regarding the atmospheric environment of the capital area, the concentration of fine dust, which could cause lung cancer and premature death, is twice that of Tokyo. The social costs due to air pollution amount to a staggering KRW 12 trillion per year, with the number of premature deaths caused by fine dust estimated to reach 20,000 per year by 2024. As fine dust - which, as mentioned earlier, is harmful to the human body - is mainly generated by diesel vehicles, it is necessary to implement measures aimed at reducing the level of fine dust in the atmosphere in Seoul by targeting diesel vehicles; therefore, measures targeting diesel vehicles with the aim of reducing fine dust levels have been promoted in air quality management areas such as Seoul, Gyeonggi, and Incheon, based on the Special Act on Seoul Metropolitan Air Quality Improvement.

According to the OECD, in 2002 the level of fine-dust (PM10) pollution in Seoul was the worst of all large cities in the OECD countries. To host the 2002 World Cup event in a more pleasant environment, the South Korean government actively promoted policies and research on the spread of non-pollutant or low-pollutant vehicles. The Seoul Metropolitan Government proceeded with projects to replace diesel buses with CNG buses and to transform medium- and large-sized old diesel vehicles into low-pollutant ones. A project for installing an emission reduction device to diesel vehicles was also included in the project of turning old diesel vehicles into low-pollutant ones.

Meanwhile, Seoul′s PM10 and NO_2 concentrations in 2003 were 69 $\mu g/m^3$ and 38 ppb, respectively, i.e. 1.9~3.6 and 1.4~1.9 times higher than in major OECD cities, respectively. The social costs incurred by the capital area as a result of damages caused by such air pollution were estimated at KRW 10 trillion in 2000, and the number of deaths in Seoul caused by fine dust was estimated to have amounted to 1,940 in the same year. To reduce the high fine-dust concentration in the city's air, the Seoul Metropolitan Government established the Seoul Metropolitan Air Quality Control Master Plan, which comprises various improvement measures including the introduction of the Total Industrial Site Volume Control System (TISVCS) by the end of 2003, the spread of low-pollutant vehicles, and the management of exhaust gas emissions from vehicles.

Some years before 1995, the number of registered vehicles in Seoul showed a rising trend of more than 10% per year due to rapid industrialization and rising incomes, although the growth rate slowed down from 1995 onward. The total number of vehicles in South Korea was a miniscule 40,000 in 1965, yet by 1997 the number had surpassed 10 million, representing an increase of more than 250 times in just 30 years. As of 2014, the total number of vehicles in the city stood at 20.12 million, and the air pollution problem caused by exhaust gases continues to become increasingly serious. In particular, 8.96 million vehicles, i.e. about 44.5% of all vehicles in South Korea, are concentrated in the capital area (Seoul, Gyeonggi, Incheon). Notably, 15% of these vehicles are concentrated in Seoul, which also has a very high population density. As such, the air pollution caused by vehicle pollutants has become an extremely important issue in large cities.

Table 2. Increase in the number of vehicles in the entire country/in Seoul

(Unit: 1,000)

	1975	**1980**	**1985**	**1990**	**1995**	**2000**	**2003**	**2006**	**2009**	**2012**	**2013**	**2014**
Entire country	201	528	1,113	3,395	8,469	12,060	14,587	15,895	17,325	18,871	19,401	20,118
Seoul	85	207	446	1,194	2,043	2,441	2,777	2,857	2,955	2,969	2,974	3,014

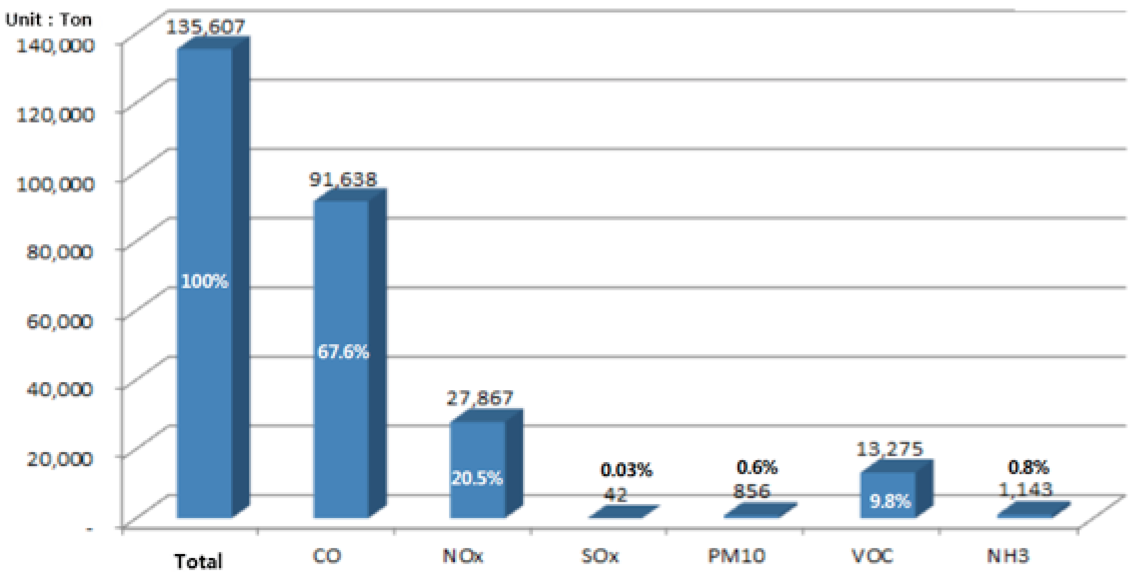
By the end of 2014, diesel vehicles accounted for 33.1% of all vehicles in Seoul, showing a relatively higher figure than in other countries. The main reason for this is that diesel oil is cheaper than gasoline oil due to the country's industrial and energy policy, and the fuel efficiency of diesel vehicles is slightly superior. In other countries, such as the United States, Japan, and Germany, diesel vehicles account for only 3%, 13%, and 18% of all vehicles, respectively. Due to the continuous improvements made to engines and emission control technologies, however, the supply of diesel vehicles has increased due to their significant economic benefits.

Table 3. Number of registered vehicles by type

(Unit: 1,000)											
Division	**1994**	**1996**	**1998**	**2000**	**2004**	**2006**	**2009**	**2010**	**2012**	**2013**	**2014**
Total	1,932	2,168	2,199	2,441	2,780	2,857	2,954	2,981	2,969	2,974	3,014
Diesel vehicles	433	473	471	542	797	848	854	863	899	937	997
Gasoline/gas vehicles	1,499	1,695	1,728	1,899	1,983	2,009	2,100	2,118	2,070	2,037	2,017

In 2011, air pollution emissions from vehicles amounted to 135,637 tons, including 52% of total emissions, 81% of CO_2 emissions, 45% of nitrogen oxide (NOx) emissions, and 49% of fine-dust emissions.

Figure 1. Pollutant emissions from vehicles



– Source : National Institute of Environmental Research

The 1st Special Measures for Seoul Metropolitan Air Quality aimed to secure a good degree of visibility of the open sea at Incheon from Namsan Mountain in the center of Seoul on a clear day. To that end, a budget of about KRW 4 trillion originating from both the National Treasury and local funds was executed over a period of ten years (2005-2014). Ninety percent of the total budget was allotted to an old-diesel-vehicle exhaust gas reduction project, and an action plan was formulated and implemented with the aim of turning old diesel vehicles into low-pollutant ones. The improvement target was set at 40$\mu g/m^3$ PM10 (Tokyo) and 22ppb NO_2 (Paris).

The 2nd Special Measures for Seoul Metropolitan Air Quality sought to realize a healthy century of cleaner air, under which efforts would be made to achieve this goal from 2015 to 2024. The improvement targets were set at 20$\mu g/m^3$ PM2.5, 30$\mu g/m^3$ PM10, 21ppb NO_2, and 60ppb O_2, and the focus was expanded to include gasoline and gas cars in addition to diesel vehicles.

In the case of specific diesel vehicles, cars whose emission warranty period has expired in accordance with Article 46 of the Clean Air Conservation Act, light cars and passenger cars whose emission warranty period has expired in accordance with No. 3, Annexed Table 5 of the Enforcement Regulations of Clean Air Conservation Act, and vehicles whose emission warranty period has expired in accordance with No. 5, Title 4, were excluded from the enforcement regulations of the Clean Air Conservation Act, as shown below.

Table 4. Enforcement Regulations of the Clean Air Conservation Act

Specific diesel vehicles		**Specific diesel vehicles (excluding some vehicles)**	**Excluded vehicles**	
No.1 Until December 31, 2000	No.2 January 1, 2000- June 30, 2002	No.3 From July 1, 2002	No. 4 From January 1, 2006	No.5 From January 1, 2009
All diesel vehicles	All diesel vehicles	<Exclusions> - Light cars (less than 800cc) - Passenger cars weighing less than 2.5 tons and with a capacity of fewer than 8 passengers	All diesel vehicles	All diesel vehicles

Annex Table 18 of the Enforcement Regulations of the Clean Air Conservation Act regulates the exhaust gas application period according to the production period of diesel vehicles.

Table 5. Enforcement Regulations of the Clean Air Conservation Act

Production period	Application period	Vehicle type				
Up until December 31, 1997		Passenger cars	Small trucks			
	February 2, 1991-December 31, 1992					
	January 1, 1993-December 31, 1995	5 years, 80,000㎞				
	January 1, 1996-December 31, 1997	5 years, 80,000㎞	40,000㎞			
January 1, 1998-December 31, 2000		Light cars	Passenger cars	Small trucks	Heavy-duty vehicles	
	January 1, 1998-December 31, 1999	60,000㎞	5 years, 80,000 ㎞	60,000㎞	-	
	January 1, 2000-December 31, 2000	5 years, 80,000㎞	5 years, 80,000 ㎞	5 years, 80,000㎞	2 years, 40,000 ㎞	
January 1, 2001-June 30, 2002		Light cars	Passenger cars	Multi-purpose cars	Mid-sized cars	Large cars
	January 1, 2001-June 30, 2002	5 years, 80,000㎞	5 years, 80,000 ㎞	5 years, 80,000㎞	5 years, 80,000 ㎞	2 years, 80,000㎞
July 1, 2002-December 31, 2005		Light cars	Passenger car 1/ passenger car 2	Passenger car 3/ truck 1/ truck 2	Passenger car 4/ truck 3	Construction machinery
	July 1, 2002-December 31, 2002	5 years, 80,000㎞	5 years, 80,000 ㎞	5 years, 80,000㎞	2 years, 80,000 ㎞	
	From January 1, 2003	5 years, 80,000㎞	5 years, 80,000 ㎞	5 years, 80,000㎞	2 years, 160,000 ㎞	1 year, 20,000 ㎞
January 1, 2006-December 31, 2008		Light cars	Small passenger cars	Small trucks/mid-sized passenger cars/trucks	Large/ ultra-large passenger cars/trucks	Construction machinery
		5 years, 80,000㎞	5 years, 80,000 ㎞	5 years, 80,000㎞	2 years, 160,000 ㎞	1 year, 20,000 ㎞
From January 1, 2009		Light/small/mid-sized passenger cars/trucks	Large passenger cars/trucks	Ultra-large passenger cars/trucks	Construction machinery motors	
		10 years, 160,000㎞	5 years, 80,000 ㎞	6 years, 200,000㎞	7 years, 500,000 ㎞	1 year, 20,000km
From January 1, 2013		10 years, 160,000㎞	6 years, 300,000㎞	7 years, 700,000㎞	10 years, 8,000 hours	
From January 1, 2016		10 years, 160,000㎞	6 years, 300,000㎞	7 years, 700,000㎞	10 years, 8,000 hours	

The Importance of the Policies

The rapid increase in the number of automobiles in Seoul accounts for 52% of the air pollution, and automobiles are currently considered the main source of air pollution. Fine dust, excluding the inflow from outside, is generated mostly by diesel-powered vehicles. The more fuel an automobile consumes, the more air pollutants it releases into the air, which inevitably has an adverse effect on the air quality in Seoul. Air pollutants from the transport sector account for more than 70% of all air pollutant emissions; and among such air pollutants, those originating from automobiles are increasing gradually.

Air pollution has a highly negative effect on people's health and causes damage to properties and ecosystems. Furthermore, the damages caused by the increase in air pollutant emissions also tend to accumulate. As this problem cannot be contained within an individual city but spreads to the surrounding areas, the seriousness of the problem is increasing accordingly. It is only natural for the number of automobiles to increase as people's incomes and the transportation of goods increase, but Diesel Particulate Filters (DPFs) must be installed in diesel vehicles in order to significantly reduce the emission of air pollutants from such vehicles.

Air quality in Seoul has improved substantially considering that the concentration of PM10 decreased from 60 ㎍/㎥ in 2004 to 45 ㎍

/㎥ in 2015. More recently, however, it has been increasing slightly due to the influx of air pollutants from neighboring countries in Northeast Asia, including China. The NO_2 concentration has decreased slightly or shown no change since 2008. The implementation of Phase 1 of the Seoul Action Plan on Air and Environmental Improvement is considered to have lowered the pollution level near the city streets, and to have increased visibility.

The visibility (distance) data show a significant improvement owing to the better PM10 concentration in Seoul's air. Visibility improved from 12.3 km in 2004 to 13.1 km in 2013 on average. The number of days with over 20 km of visibility have also increased significantly - from 76 days in 2007 to 202 days in 2010, 274 days in 2012, and 205 days in 2013.

Seoul, however, still needed to get the owners of diesel vehicles to follow the emissions reduction plan. Since January 2011, the authorities have implemented a series of administrative measures including the imposition of fines on diesel vehicle owners who failed to follow the plan within six months of notification, with the aim of inducing their participation in the effort.

Results of the Project in terms of the Adoption of Diesel Emission Control Devices

1) Promotion of the pilot project

Seoul carried out the In-Use Diesel Vehicle Emission Reduction Pilot Project in 2004, installing 280 DPFs and 150 DOCs (diesel oxidation catalysts) in its official vehicles and public transit buses, and converting 450 vehicles into LPG (liquefied petroleum gas) vehicles, for a total of 880 units. The costs of DPF installation were fully shouldered by the government, while those for DOC installation and LPG conversion were shouldered evenly by the government and the city.

2) Full-scale implementation

After the pilot project period, the full-scale project began in earnest in 2005. With 50% of the project expense shouldered by the government and 50% by the city, the project has thus far covered a total of 12,130 diesel vehicles, including the installation of 7,789 DPFs and 1,490 DOCs, the conversion of 2,814 vehicles into LPG vehicles, and the early disposal of 37 vehicles. In addition, around 70-95% of the installation costs have been supported since 2006.

3) Mandatory installation

In 2008, the city made it mandatory to install low-emission devices in all diesel vehicles over seven years old and weighing over 3.5 tons. The policy included support for 70-95% of the installation costs, with 50% coming from the government and 50% from the city.

In 2009, the city extended the coverage of the In-Use Diesel Vehicle Emission Reduction Project to diesel vehicles over seven years old and weighing over 2.5 tons. It shouldered 70-95% of the installation costs, with 50% provided by the government and 50% by the city.

Policy Objectives and Processes

The objective of the In-Use Diesel Vehicle Emission Reduction Project is to protect the health of Seoul's ten million plus inhabitants from air pollution, and to create a more pleasant environment by installing low-emission devices in diesel vehicles, remodeling the engines of such vehicles into LPG engines, and encouraging the owners of old diesel vehicles to dispose of their vehicles early. The city plans to complete the project by 2019, and to maintain a safe level of air quality by completing the installation of low-emission devices and by carrying out other measures for dealing with the 380,000 or so diesel vehicles in the city that were manufactured before 2005.

Table 6. Seoul Air Quality Improvement Targets

Division	2014	2024
PM_{10}	40$\mu g/m^3$	30$\mu g/m^3$
$PM_{2.5}$	-	20$\mu g/m^3$
NO_X	22ppb	21ppb
Remarks: The target year for ultra-fine dust ($PM_{2.5}$) was set as 2018 in order to achieve the target earlier than planned.		

Main Policy Contents

By 2015, the city, through its In-Use Diesel Vehicle Emission Reduction Project, had installed low-emission devices such as DPFs in 150,948 diesel vehicles.

According to the Special Act on Seoul Metropolitan Air Quality Improvement and local by-laws, the city made it mandatory (from January 1, 2008) to install low-emission devices in diesel vehicles that were over seven years old and weighed over 2.5 tons, and whose low-emission guarantee period (2 years for vehicles weighing over 3.5 tons, and 5 years for vehicles weighing under 3.5 tons) had expired. The government and the city shouldered around 83-96.5% of the installation cost. Likewise, the aforementioned devices had to be installed in diesel vehicles over seven years old and weighing between 2.5 and 3.5 tons starting in January 2009.

In particular, between 2013 and 2014, the city installed PM-NOx simultaneous-reduction devices in 106 large diesel buses as part of the Nitrogen Oxide (ultra-fine-dust inducer) Reduction Demonstration Project. After analyzing the results of the demonstration project, the city started expanding the scope of the project.

Although the long-term effectiveness of the Diesel Vehicle Emission Reduction Device Installation Project has yet to be evaluated, it can be said that the air quality in Seoul has been improving based on the data obtained thus far, which point to a decrease in the number of days with 100$\mu g/m^3$ or more of ultra-fine dust in the air, and an increase in the number of days with no more than 30$\mu g/m^3$ of ultra-fine dust in the air. Moreover, the number of high-emission-vehicle reports, which indicates the citizens′ perception of the level of air pollution in the city, has decreased dramatically.

The Diesel Vehicle Emission Reduction Device Installation Project was planned to be implemented from 2005 to 2024 with the aim of improving the air quality in the capital area. Since 2009, it has been implemented in five other metropolitan cities including Busan, Daejeon, Daegu, Gwangju, and Ulsan.

It is very important to ensure that the installed emission reduction devices function as intended. Recognizing the importance of inspecting such devices, the city has encouraged the manufacturers to inspect the devices regularly and formed the city's own inspection team. The team examines vehicles fitted with an emission reduction device, and issues orders for device improvement or disposal to people whose vehicles fail the inspection.

The owners of vehicles fitted with an emission reduction device can receive free after-sales (A/S) services during the 3-year warranty period (3 years or 160,000 km for DPF models, and 3 years or 80,000 km for DOC or LPG remodels). Also, the owners of vehicles fitted with a class 1 emission reduction device can receive a free filter cleaning service each year at more than forty cleaning centers in the capital area.

According to the Special Act on Seoul Metropolitan Air Quality Improvement, vehicles fitted with an emission reduction device should be operated for at least two years after its installation, excepting unavoidable situations such as natural disaster, fire, or theft. Moreover, vehicle owners are required to return the device to the Korea Automobile Environmental Association upon disposing of their vehicles.

If an owner removes the device without a valid reason before the mandatory operation period, or fails to return it, the owner must return the subsidy.

To handle complaints regarding the emission reduction devices, the manufacturers of the devices operate their own A/S call centers and cleaning centers. In the event of a dispute between an owner and a manufacturer, the city will act as the arbiter.

The primary reason why DPFs have been disqualified on account of their under-performance, and become subject to a removal order, is that operating the vehicle amid a severe environment falls outside the certification criteria. Other reasons include the lack of post-management by the manufacturer and failure to maintain a vehicle on the part of the owner. Theoretically, the DPF can reduce the amount of exhaust emissions by more than 80%. Therefore, vehicle owners should do their best to maintain the device at its optimal performance level.

Once a vehicle owner removes the device from the vehicle, he or she is no longer qualified to receive the corresponding benefits and subsidies. Thus, the car owner is obliged to pay the environment improvement charges and must regularly submit the vehicle to an exhaust emissions test. Moreover, the manufacturer has to return the subsidy.

Realizing the broad characteristics of air pollution, Seoul, Incheon, and Gyeonggi province decided to cooperate with one another starting in 2010 to maximize the improvement of their air quality, after collecting the opinions of experts and citizens. The subject vehicles are diesel vehicles that weigh over 2.5 tons and are over 7 years old, and for which no corrective measures have been taken within 6 months of receiving Seoul's emission reduction order, or those that have not passed the total emission gas test. Any of the three aforementioned local governments can impose a fine of KRW 200,000 after a one-month warning period on the owners of vehicles that are not fitted with an emission reduction device and which are identified on their respective jurisdictional roads. Moreover, they have set up an unmanned enforcement system using CCTVs on their main roads (e.g. Olympic Expressway), and have tightened their control over vehicles that are not fitted with emission reduction devices.

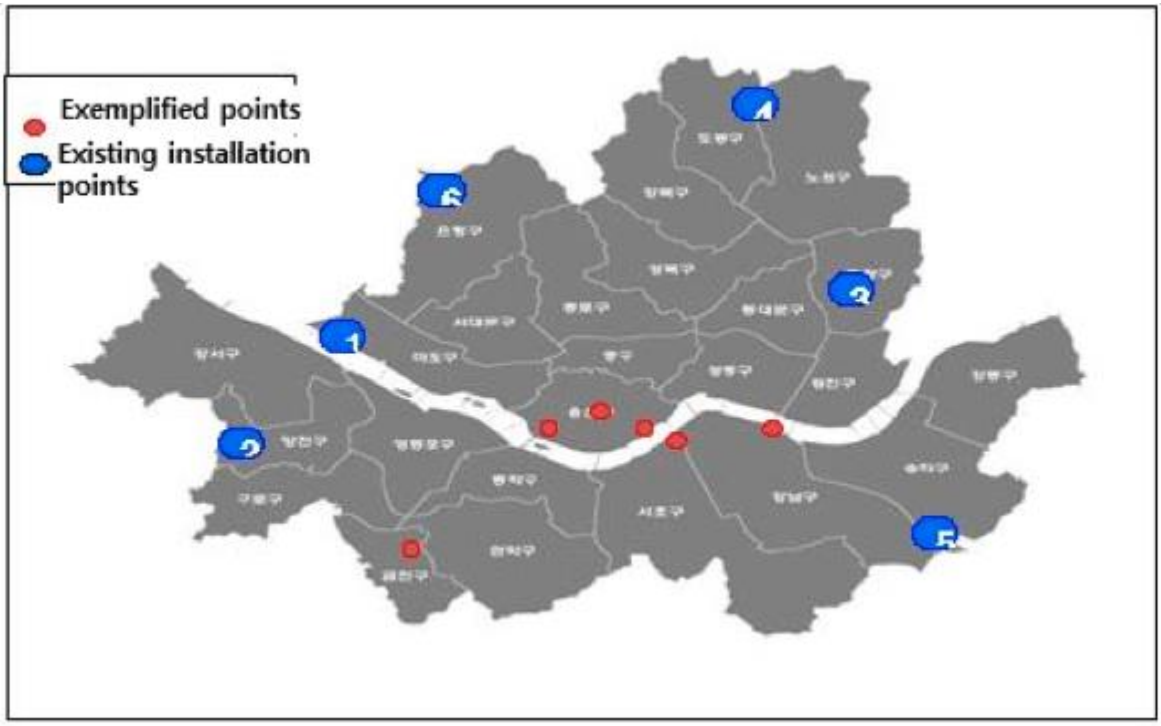
- Current status of the installation of the Driving Restriction Monitoring System (in operation since March 2012)

- 24 camera installations at 7 different spots on Seoul's main roads.

- Implementation of the Driving Restriction Monitoring System (2014)

- 746 vehicles have been caught; 679 vehicles have been issued with warnings; and fines have been imposed on 67 vehicles.

Figure 2. Status of vehicle travel restriction system installations



The DPF is generally installed in medium- and large-sized diesel vehicles, and can eliminate more than 70% of the exhaust gas emissions by collecting pollutants such as PMs and depositing them in a catalyst-coated filter before converting them into CO_2 or vapor. The partial diesel particulate filter (p-DPF) is installed in small- and medium-sized diesel vehicles (weighing no more than 3.5 tons), and is equipped with a catalyst that converts pollutants into hazardless substances without a collection process, thus exempting the p-DPF from any post-management measures. The DOC is installed in small diesel vehicles; but its installation has been suspended since 2010 due to its low cost-to-benefit performance ratio of 10.20% in reducing ultra-fine-dust emissions. Since the full-scale implementation of the emission reduction project in 2005, with the focus on public transit buses and business vehicles, DPFs have been installed in 89,423 diesel vehicles, and it is expected that they will be installed in a further 6,600 vehicles per year until 2019. According to the Special Act on Seoul Metropolitan Air Quality Improvement and local by-laws, the owners of diesel vehicles that weigh more than 2.5 tons and are over 7 years old, and whose low-emission warranty period (2 years for vehicles weighing at least 3.5 tons; 5 years for vehicles weighing less than 3.5 tons) has expired can obtain government and city subsidies of 90-95% of the implementation cost of any emission reduction measure, such as the installation of an emission reduction device.

Table 7. Status of DPF devices and subsidy (amount, effects)

Division			Government fund (KRW 1,000)	Deductible (KRW 1,000)	Target	Emission reduction effects	
						PM (HC)	NOx
DPF	Natural large-sized		5,575	511	Large-sized: More than 11,000 cc Mid-sized: 6,000-11,000 cc Small-sized: Less than 3,000 cc	More than 80%	-
	Natural medium-sized		5,232	477			
	Complex large-sized		10,056	959			
	Complex medium-sized		7,809	737			
	Complex small-sized	Van	3,672	401			
		Truck	3,764	330			

The city conducts frequent inspections of diesel vehicles to check that their emission reduction device is working properly and that their emission level is within the normal range. If any abnormality is found, the city orders correctional measures and monitors their fulfillment. If any device is found to be no longer usable, the city freely provides a refurbished device in an attempt to promote the continuous use of the emission reduction device and to maintain the vehicle's optimal performance.

Diesel vehicles registered in Seoul and the metropolitan area (excluding compact cars and passenger cars) whose low-emission guarantee period has expired under the Clean Air Conservation Act are designated as "specific diesel vehicles" and are monitored with stricter emission standards than with the general emission standards for in-use vehicles.

A specific diesel vehicle is allowed to operate only if it passes a detailed inspection and falls within the specified emission level range. If it does not satisfy the standard, the owner of the vehicle must install an emission reduction device (DPF, p-DPF, or DOC), replace the vehicle's engine with a low-emission model, or dispose of the vehicle.

When installing an emission reduction device in a specific diesel vehicle, its smoke concentration has to meet the certification criteria for an emission reduction device. If the device does not meet the standard, it can only be installed after fixing and re-testing to ensure that it meets the standard. Only vehicles whose smoke concentration level meets the in-use vehicle emission standard are allowed to be disposed of early.

Generally speaking, DPFs are installed in medium- to large-sized vehicles; p-DPFs are installed in mid-sized vehicles, or such vehicles are converted into vehicles with LPG engines; and DOCs are installed in small vehicles, or such vehicles are converted into vehicles with LPG engines. Since 2010, however, the installation of DOCs has been suspended, and small p-DPFs have been installed in small vehicles instead.

The Korea Automobile Environmental Association (KAEA) is in charge of giving the subsidies for the maintenance expenses.

When the manufacturers submit an application for reimbursement of the maintenance expenses along with the relevant supporting documents to the KAEA, the latter screens the applications and then releases the funds to the device manufacturers. The maintenance cost shouldered by the association includes an annual KRW 300,000 cleaning charge for 3 years for a DPF during the warranty period, and a KRW10,000 monitoring charge.

Certain benefits, including exemption from the environmental improvement charges and exemption from the precise emission test, are granted to vehicle owners who join the low-emission initiative. The only compulsory condition for receipt of the benefits is that the vehicle in question should be operated for at least two years after the installation of an emission reduction device.

Post-management of an installed device is also very important. Since the initiation of the project, the city has realized the importance of post-management and has thus encouraged the manufacturers to focus on it too. The city has conducted inspections of vehicles fitted with an emission reduction device by forming an inspection and monitoring team to that end. The team has also issued correctional or removal orders whenever necessary.

Technical Details

As mentioned earlier in this paper, DPF stands for “diesel particulate filter.” This device traps particulates discharged from the vehicle engine in its filter, and then burns them (recycling) in the engine. Through this repetitive trapping and recycling of particulates, the device can eliminate more than 80% of the vehicle’s emissions, and thus has an excellent advantage over other devices in terms of performance. DPFs, in most cases, are installed in medium- to large-sized vehicles. For small vehicles, DPFs were not available until 2007 due to the technological limitations of such devices. The four technologies presented below are the internationally accepted post-treatment technologies whose reliability, durability, and cost effectiveness have proven that they are practical to use in reducing the air pollutant emissions of modern diesel vehicles.

-The technology traps particulates (e.g. soot) from a vehicle’s exhaust and eliminates them through a burner and/or heater.

-The continuously regenerating trap (CRT) is to be continuously cleaned or “regenerated” to maintain above a certain temperature with the catalyzed diesel particulate filter (CDPF).

-The diesel oxidation catalyst (DOC) oxidizes gaseous matters in the exhaust gas (e.g. hydrocarbons, CO, NOx) and particulate matter (PMs) in the exhaust gas (e.g. soluble organic fractions) using catalysts. It works similarly to the three-way catalytic converter in a gasoline engine.

-The technology oxidizes harmful exhaust gases and PMs by systematically controlling the engine control technology, catalyst post-treatment technology, and additive technology.

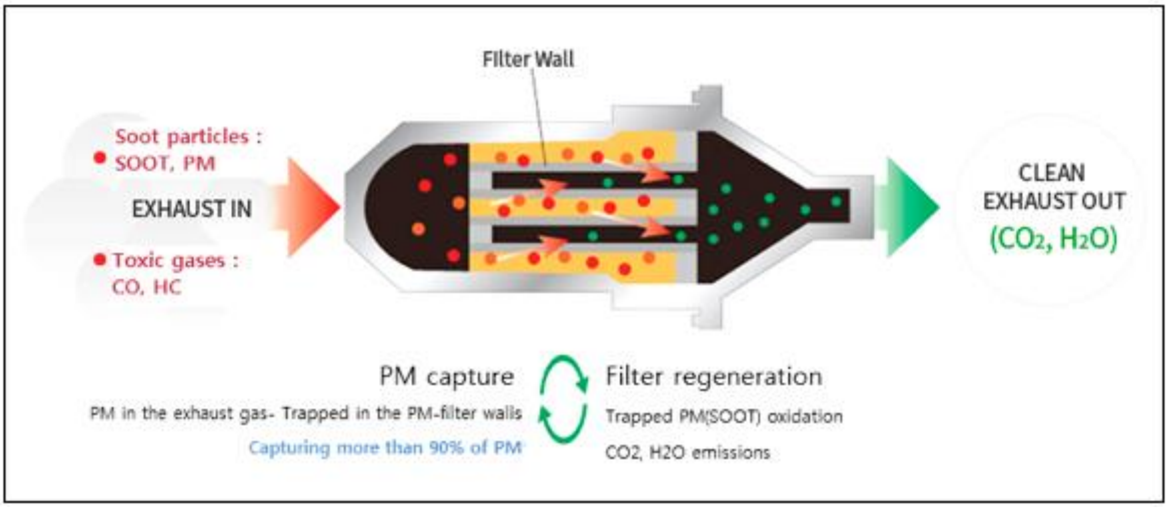
Table 8. Types of diesel emission control devices

Division	Pollutant reduction efficiency of device	Warranty period	Target pollutants	Remarks
First-class	More than 80%	3 years or 160,000 km	Particulate matter (PM_{10}), nitrogen oxide (NOx)	Diesel particulate filter (DPF)
Second-class	More than 50%	3 years or 80,000 km		Partial diesel particulate filter (p-DPF)
Third-class	More than 25%	3 years or 80,000 km		Diesel oxidization catalyst (DOC)

1) First-class emission control device (DPF: diesel particulate filter)

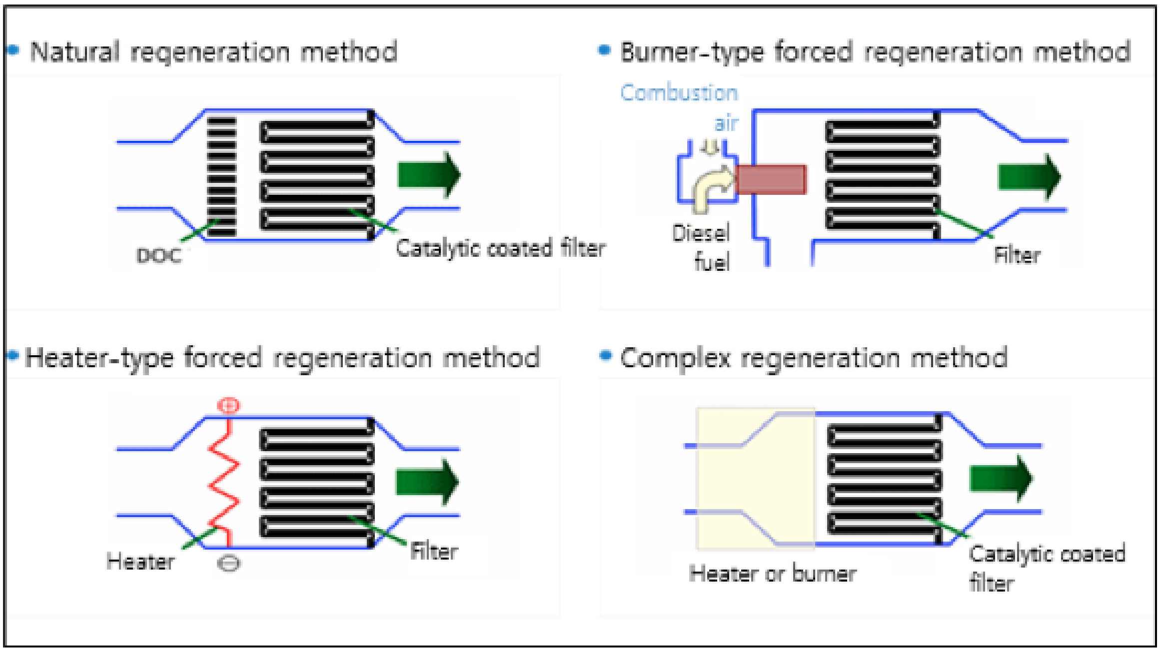
The DPF traps PMs in the exhaust gas at the catalytic filter and eliminates them by burning them at a temperature of over 550^{0}C. It reduces the soot contained in the exhaust gas of a diesel engine. Soot consists of carbon and is produced by the incomplete combustion of coal, oil, wood, or other fuels. If it is excessively accumulated, it can reduce the fuel efficiency and performance of a vehicle. DPFs are categorized in terms of the way that the heat for burning PMs is generated.

Figure 3. How the DPF works



(Source: Korea Automobile Environmental Association, http://www.aea.or.kr/main_business/technology.php)

Figure 4. DPF method of regeneration



(Source: Korea Automobile Environmental Association, http://www.aea.or.kr/main_business/technology.php)

PMs are classified according to the heat supply system required for combustion, as shown below.

Table 9. Heat supply system by generative method

Type	Heat supply system	Applicable vehicles
Natural regeneration	Engine exhaust heat	High-speed vehicles
Forced regeneration	Electric heater or auxiliary fuel injection	Low-speed vehicles
Complex regeneration	Mixed use of natural- and force-regeneration methods	Low- and high-speed vehicles

Exhaust gas is burned again by the oxidation catalyst located at the opening of the DPF, which decreases the size of the PM. These small PMs penetrate the filter and are released into the air, while other larger PMs are trapped in the filter and accumulate there through a repetitive process until the engine control system sprays the fuel to be burned into the DPF. This burning fuel increases the temperature in the DPF, and the heat burns the accumulated PMs again, making them smaller.

The process of spraying fuel so as to make large PMs smaller is called “regeneration.” There are different ways of setting the timing of regeneration, one of which is achieved through the difference in pressure between the front and back of the filter (pressure difference sensor). Each vehicle manufacturer has a different set point for the pressure difference; some check engine performance regularly based on its mileage to see how negatively the PMs affect performance due to the filter clogging and the resultant increased pressure in the exhaust system. Once it detects a certain level of engine underperformance, it sprays fuel into the DPF. Other manufacturers use an additional piece of equipment (scanner) to set the regeneration timing. The pressure difference sensor and mileage methods are applied differently according to the engine control system type, vehicle type, and DPF manufacturer.

The ways of increasing the temperature in the DPF to a degree that is sufficient to burn the PMs accumulated in the filter are most important and vary considerably. Some spray extra fuel into the PDF, some use additives, some use an electric heater, and others use an extra burner. Due to the cost issue, the most common method consists of spraying extra fuel into the DPF so as to increase the temperature beyond the regeneration point while checking the temperature with an exhaust gas temperature sensor. Some manufacturers, however, use additives for such a purpose.

Although the DPF reduces PM emissions into the air, it has various limitations in that it increases costs, decreases fuel efficiency, and has short durability. Many studies have pointed out that the average lifespan of the fuel-spraying DPF in terms of mileage is around 100,000 km.

2) Second-class emission control device (p-DPF: partial diesel particulate filter)

Rolled like a cylinder with a paired layer of flat foil and corrugated foil, the p-DPF has a partially open structure. Therefore, exhaust gas passes through the space between the flat foil and the corrugated foil. The p-DPF does not reduce the engine power or fuel efficiency because PMs are not accumulated on the filter, unlike the wall-flow-type filter. Moreover, periodic management of the filter is unnecessary because ashes do adhere to it.

Figure 5. Structure of the p-DPF

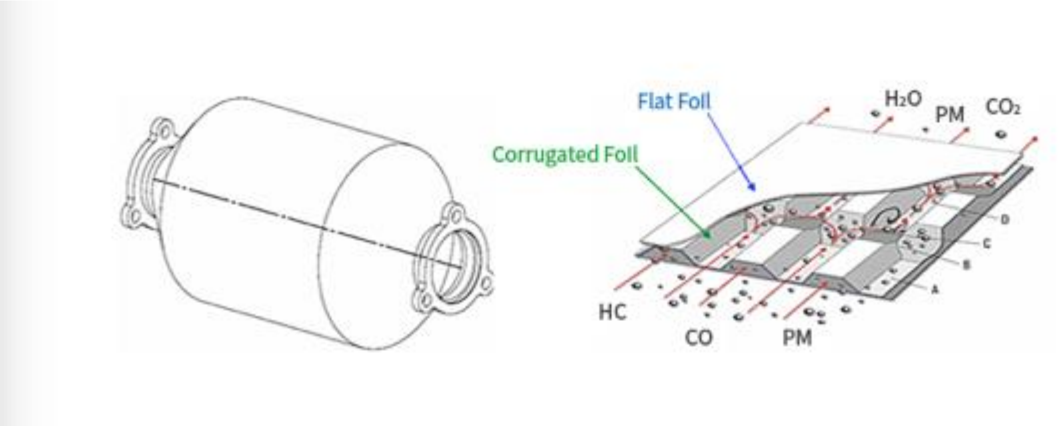
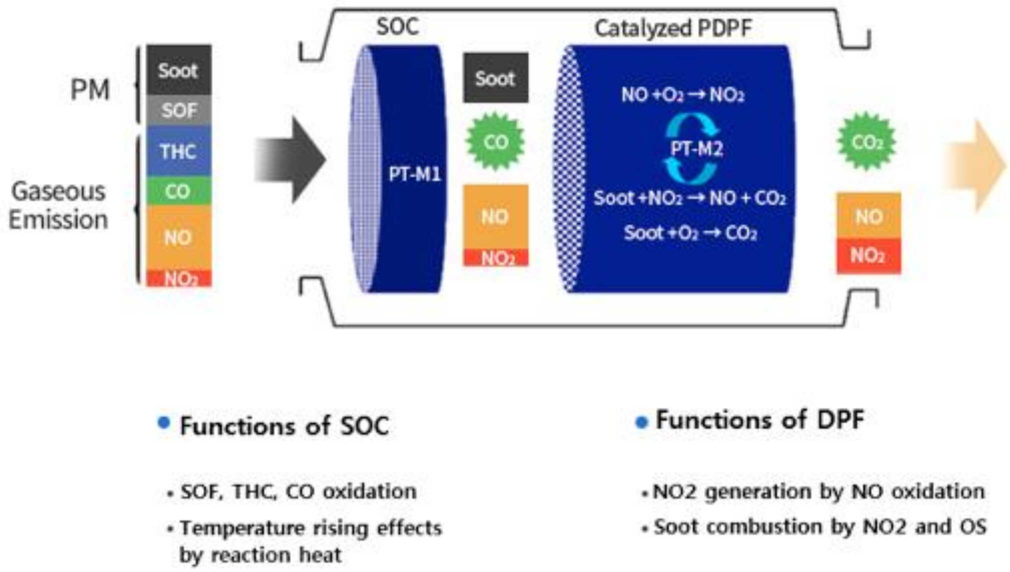


Figure 6. How the p-DPF works



3) Third-class emission control device (DOC: diesel oxidation catalyst)

When exhaust gas passes through the DOC, it reacts with the catalyst. During this catalytic reaction, the DOC purifies the exhaust gas by oxidizing the gaseous matter (e.g. HC, CO) and PMs (e.g. lubricant components, incompletely combusted fuels, SOFs).

Figure 7. How the DOC controls emissions

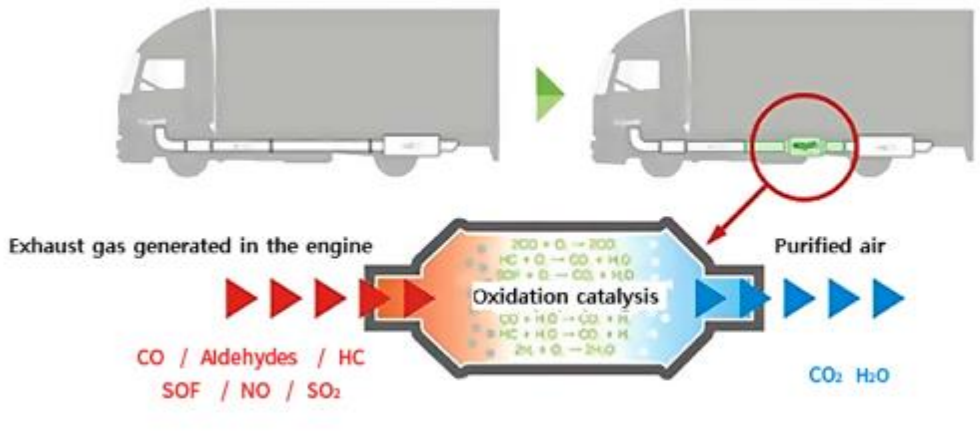
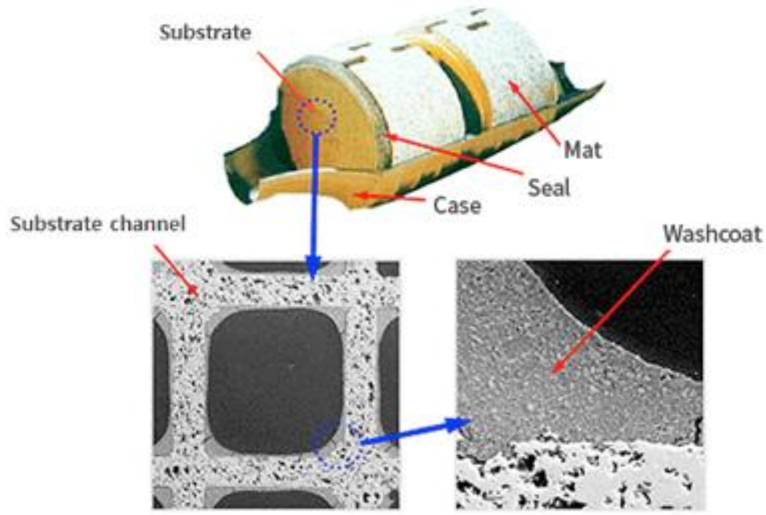


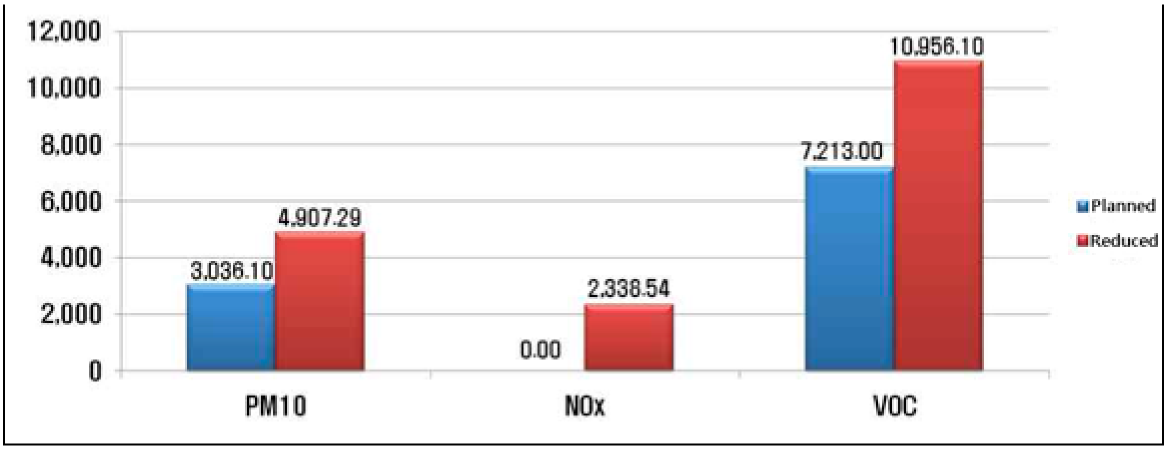
Figure 8. Structure of the DOC



Policy Effects

Launched in 2000, the low-pollution vehicle project has demonstrated the effect of reducing the PM10 emissions of vehicles in Seoul by 4-22%. The concentration of PM10 measured from an air quality measurement network installed along the roadsides of Seoul has continuously been reduced through the years since 2005, to around 53 μg/m^3 in 2014. This is almost similar to the annual environmental standard of PM10 (50 μg/m^3); as such, it can be seen that the environmental standard was met not only at the general air quality measurement station (45.8 μg/m^3 in 2014) but also at roadside air quality measurement stations. In addition, the number of days with a high density of more than 100 μg/m^3 has decreased, while the number of days with a low density of more than 30 μg/m^3 has increased. Therefore, fine-dust pollution in Seoul has decreased, and the number of reported vehicles discharging exhaust fumes has been sharply reduced. It cannot of course be concluded that these improvements were obtained solely through the low-pollution vehicle project, but the project has been evaluated as having played a major role in achieving such results.

Figure 9. Reduction of pollutants by emission control devices (2007-2009) (Unit: ton)



Source: Analysis of the air quality improvement effects of pollution control measures (2011)

To reduce the amount of NOx in the air, the Seoul Metropolitan Government implemented a pilot project from 2013 to 2017 in which a NOx reduction device was fitted on 444 vehicles, including the installment of a PM-NOx simultaneous-reduction device to old construction machinery and large trucks, in order to verify the feasibility of such a measure, and then expanded the project to beyond 2015.

Table 10. Average exhaust gas reduction ratio achieved by the NOx reduction pilot project

Project title/exhaust gas	CO reduction	NO_X reduction	PM reduction
Three-way catalytic converter	82.2%	88.4%	60.1%
PM-NO_X simultaneous-reduction device	85%	70%	80%

Challenges and Solutions

The project to install an emission control device to diesel vehicles, conducted with the aim of reducing fine-dust emissions, was evaluated as having been somewhat effective in reducing diesel vehicles' fine-dust emissions. The level of carbon dioxide (CO_2) pollution in Seoul, however, continued to exceed the environmental standards without showing a clear trend of improvement. Given that a significant portion of the NOX emissions in Seoul was still being discharged by diesel vehicles, it was judged necessary to execute a low-pollution diesel vehicle project that would take into account not only the reduction of fine dust but also of NOX.

In this regard, the Seoul Metropolitan Government proceeded with the project of installing PM-NOX simultaneous-reduction devices to 444 vehicles in 2013, including old construction machinery and large trucks, and has been expanding and promoting the project after the verification of its effects since 2015.

관련 자료

Seoul seeks strategies for cooperation on air quality improvement with 13 major Northeast Asian cities

The first Seoul – Beijing Agreement for Better Air Quality

첨부파일

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