State of Air Pollution and Policy Issues in Seoul, Republic of Korea[1)]

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1) This paper was presented at the 90th. Annual Meeting & Exhibition of Air & Waste Management Association, June 8-13, 1997, Toronto, Canada.

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1. Introduction

The Republic of Korea has experienced severe environmental problems including air pollution because of the rapid urbanization and industrialization during the last three decades. The government has taken various countermeasures in order to solve the air pollution problems. The efforts to reduce the levels of sulfur dioxide (SO_2) and total suspended particulates (TSP) have been quite successful while nitorogen oxides and ozone (O_3) are emerging as more serious threats to the urban atmospheric environment due to the ever-increasing automobiles.

The spacio-temporal analyses of the air quality using the monitoring data for the last ten years clearly revealed that the air quality changed with the urban development and countermeasure policies adopted. Future policy recommendations are made based on the analyses.

2. Air Quality Status and Trends in Seoul

2.1 The Trends of Annual Air Pollution Levels

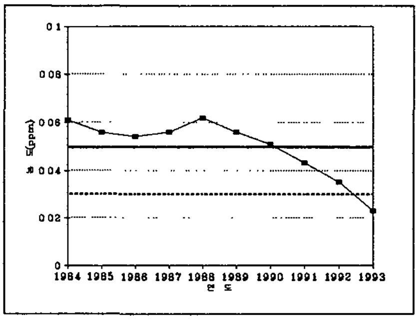
As shown in Figure 1, the annual average levels of SO_2, TSP and CO decreased by 62%, 65% and 44%, respectively, over the last decade (1984-1993), while the oxidants' level (analysed as O_3) showed 63% increase during the same period. The level of NO_2 showed a slight increase in recent years.

2.2 Monthly Variations

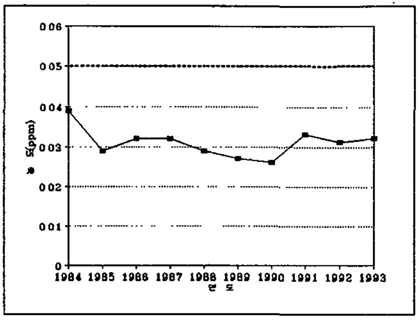
The monthly variations of air pollution level were as shown in Figure 2. The levels of SO_2, TSP and CO which are generated mainly from heating showed higher levels in winter, while those of NO_2, and HC from vehicles did not show any significant changes with season. The oxidants (measured as O_3) formed from photochemical reactions showed higher level in summer.

2.3 Diurnal Variations

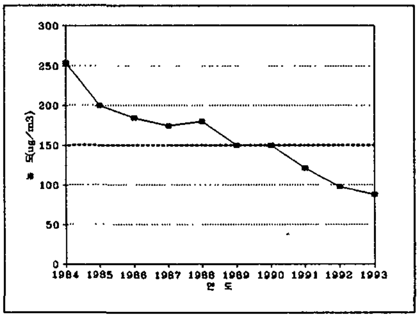
The diurnal fluctuations of air pollution level were also analyzed as shown in Figure 3. The concentrations of SO_2 and TSP remained constant during night and



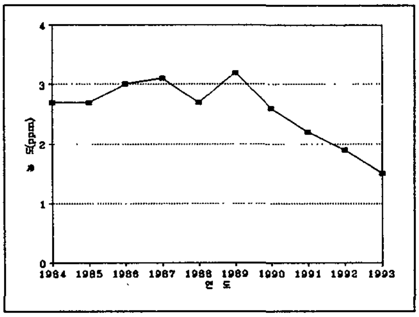
(a) SO_2



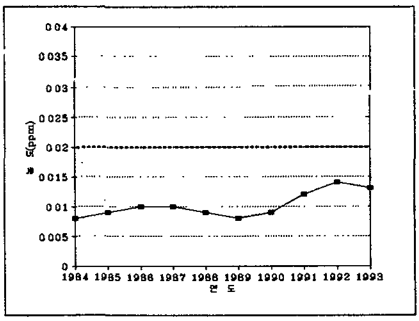
(b) NO_2



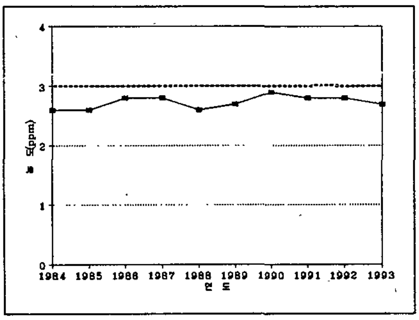
(c) TSP



(d) CO

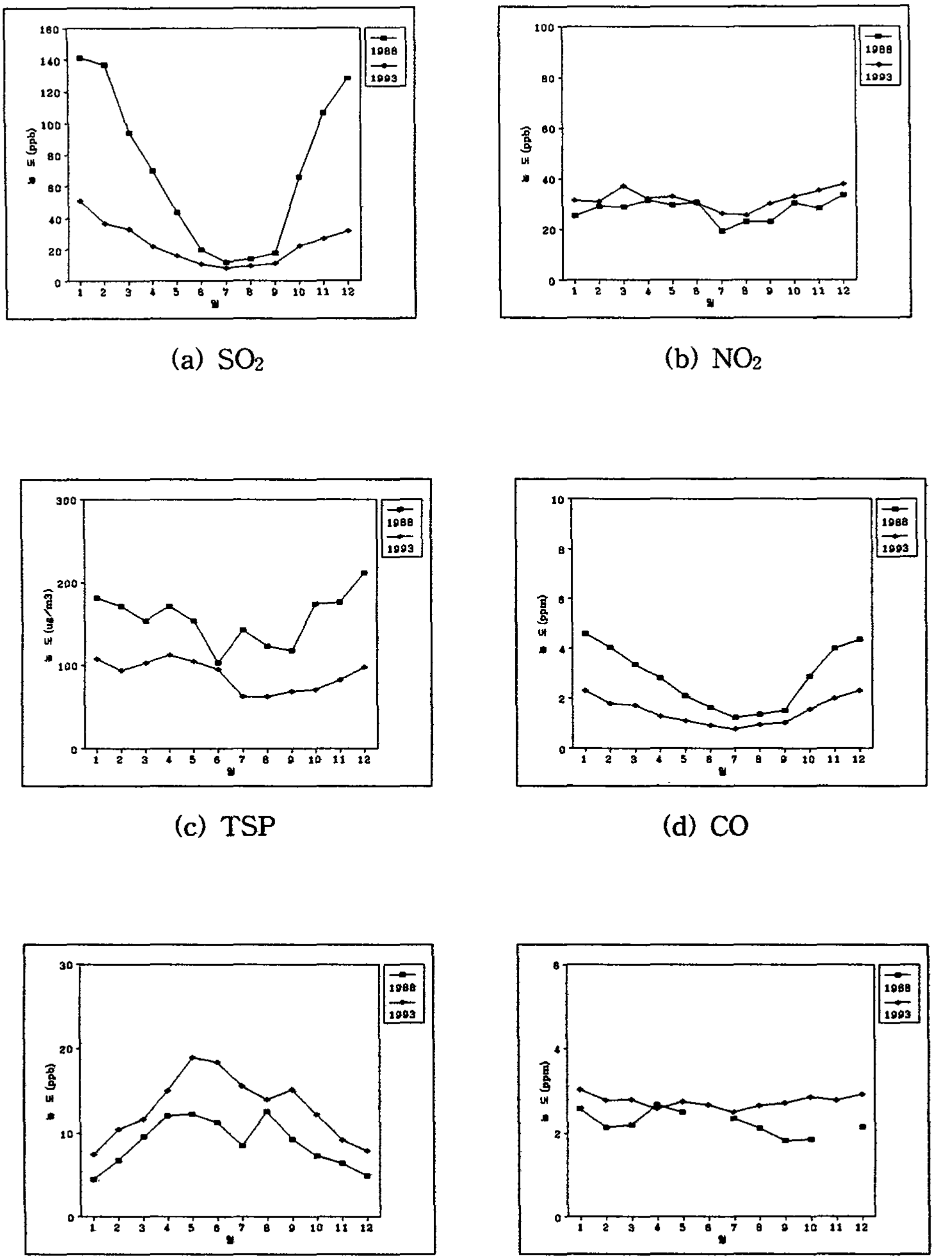


(e) O_3



(f) THC

Figure 1. The trend of air pollution in Seoul

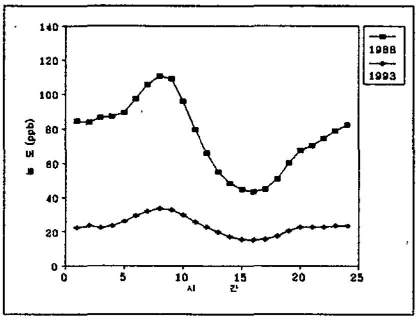


(a) SO_2 (b) NO_2

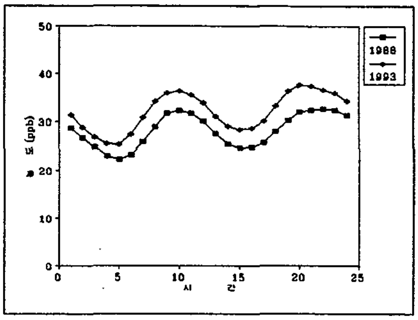
(c) TSP (d) CO

(e) O_3 (f) THC

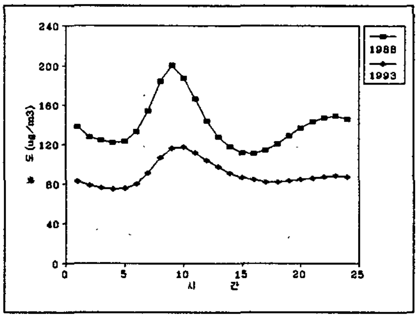
Figure 2. Monthly variations of air pollution in Seoul (1988/1993)



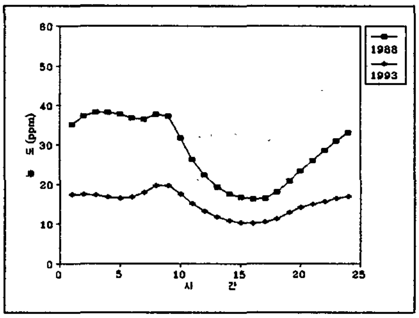
(a) SO_2



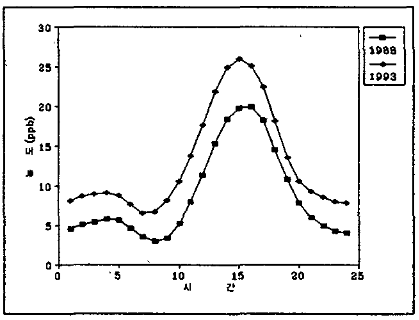
(b) NO_2



(c) TSP



(d) CO



(e) O_3

Figure 3. Diurnal variations of air pollution in Seoul (1988/1993)

reached their peaks between 8:00 and 10:00 in the moring and their minimums between 2:00 and 4:00 in the afternoon. The concentration of NO_2 started to increase with the commuting rush hours and showed two peaks: one at 10:00 AM and the other one at 8:00 PM.

2.4 Spatial Characteristics of the Air Pollution in Seoul

The spatial characteristics of the annual average pollution levels showed differences among monitoring stations. The concentration of SO_2 was high at Gileum-dong which is located in a residential area, Seongsu-dong in a mixed residential and industrial area and Mullae-dong in an industrial area. This reflects the fact that the major sources of SO_2 in Seoul are the coal briquette burning for home heating and the bunker-C oil used for industrial boilers. The concentration of NO_2 was high at Mullae-dong and Seongsu-dong which are located near industrial areas, Gwanghwamun in downtown and Jamsil-dong near Olympic Stadium; these stations are surrounded by heavy traffic. The major source of nitrogen oxides in Seoul is automobiles. The Gileum-dong station showed the highest level of SO_2 in Seoul in 1988 and 1992, but the ozone level was the lowest during the same periods. This station is situated in a middle-income residential area which uses coal briquette as a main source of home heating without heavy traffic nearby.

The SO_2 level in Seoul sharply decreased since 1988 as the fuel for heating switched from coal briquette and high-sulfur bunker oil to LNG and low-sulfur oil. The NO_2 level was higher in areas with high commercial activities and lower in residential and green areas. The NO_2 level showed peaks at rush hours and it was more distinctive in commercially-active areas. The oxidants level was highest at about 3:00 PM in all stations, and did not show significant differences among stations showing that the air mass over Seoul is quite well mixed before it reaches the full photochemical reactions in the afternoon.

2.5 Violation of the National Ambient Standards

The overall ambient air quality improved significantly for the past decade. None of the standard pollutants exceeded the long-term ambient standards (3-months average and annual average standards) in 1993. There were some monitoring stations which violated the short-term ambient standards (1-hr, 8-hr and 24-hr average). The national ambient air quality standards are as shown in Table 1.

In the case of NO_2, the number of monitoring stations which violated the 24-hour standards remained almost constant for the last ten years (5 stations in 1988, 6 in 1989, 5 in 1990, 4 in 1991 and 5 in 1992 and 1993). However, the total number of violation seemed to increase as shown in Table 2. The Gwanghwamun station violated the 24-hour NO_2 standard for six consecutive years from 1988 to 1993. The highest number of violation observed was 46 in 1991.

However, the violation of 1-hour NO2 standard showed sharp decrease since 1988 as shown in Table 3. The Gwanghwamun station violated the 1-hour ambient standards the most frequently.

The fact that the annual average and 24-hr average NO_2 levels have increased while the 1-hr peak level has sharply decreased during the last decade reflects that the sources of nitrogen oxides have been changing from high stacks to ground-level sources like automobiles. Most of the industrial plants in Seoul City

Table 1. Ambient air standards of Rep. of Korea revised in 1994

Pollutants		Current Standards	Revision in 1994
Sulfur Dioxide (SO_2)		Annual: Less than 0.03 ppm Daily : Less than 0.14 ppm 1-hr : Less than 0.25 ppm	0.05 ppm → 0.03 ppm 0.15 ppm → 0.14 ppm Newly established (1-hr)
Carbon Monoxide (CO)		8-hr : Less than 9 ppm 1-hr : Less than 25 ppm	1-month standard deleted Newly established (1-hr)
Nitrogen Dioxide (NO_2)		Annual: Less than 0.05 ppm Daily : Less than 0.08 ppm 1-hr : Less than 0.15 ppm	Newly established (Daily)
Particulate	TSP	Annual: Less than 150 $\mu g/m^3$ Daily : Less than 300 $\mu g/m^3$	
	PM_{10}	Annual: Less than 80 $\mu g/m^3$ Daily : Less than 150 $\mu g/m^3$	Newly established (Annual & Daily)
Oxidants (O_3)		8-hr : Less than 0.06 ppm 1-hr : Less than 0.10 ppm	Annual standard deleted Newly established (1-hr)
Lead (Pb)		3-Month average: 1.5 $\mu g/m^3$	
Hydrocarbon (HC)			Deleted (All)

Table 2. Number of violations against 24-hr standard of NO_2 and the station with the highest violation (1988~1994)

Year	1988	1989	1990	1991	1992	1993	1994
No. of violation	16	33	37	46	17	39	15
The worst station	Mullae	Sinseol	Kwang-hwamun	Kwang-hwamun	Bulgwang	Kwang-hwamun	Banpo

Table 3. Number of violations against 1-hr standard of NO_2 and the station with the highest violation (1988~1994)

Year	1988	1989	1990	1991	1992	1993	1994
No. of violation	63	44	14	20	5	6	3
The worst station	Kwang-hwamun	Sinseol	Jamsil	Jamsil	Bulgwang Guro	Kwang-hwamun	Hwagok

Table 4. Number of violations against 24-hr standard of TSP and the station with the highest violation (1988~1994)

Year	1988	1989	1990	1991	1992	1993	1994
No. of violation	256	257	210	136	63	38	5
The worst station	Seongsu	Seongsu	Seongsu	Seongsu Hannam	Hannam	Hannam	Oryu

have been relocated to peripherial areas during last decades and there has been an enormous increase of automobiles in Seoul. The fluctuation of ground-level concentration from high industrial stacks should be great with the weather conditions, but that from low sources like automobiles should remain quite stable.

About the TSP, the number of monitoring stations which violated the 24-hour standard showed no significant change since 1988 (11 stations in 1988, 13 in 1989, 14 in 1990, 11 in 1991, 9 in 1992 and 14 in 1993). However, the total number of violations decreased remarkably as shown in Table 4. The Seongsu-dong and Hannam-dong monitoring stations showed the highest number of violation.

Table 5. Number of violations against 1-hr standard of oxidants and the station with the highest number of violation (1988~1994)

Year	1988	1989	1990	1991	1992	1993	1994
No. of violation	169	49	94	153	222	63	251
The worst station	Sinlim	Guui	Bangi	Guui	Kwang-hwamun	Seongsu	Bangi

The level of oxidants exceeded the ambient standards in most of the monitorng stations in Seoul and this trend has been increasing. The number of monitoring stations which violated the 1-hour standard increased also: 10 stations violated the standard in 1988, 11 in 1989, 8 in 1990, 15 in 1991, 11 in 1992, 12 in 1993 and 15 in 1994. Also, the number of violations against the 1-hour standard increased remarkably as shown in Table 5. As of 1994, the number of violations in all the monitoring stations was 251.

2.6 Air Pollution Sources and Emissions

The number of air pollution sources nationwide has been increasing every year as shown in Table 6. However, the number in Seoul has been decreasing rapidly since 1991 as shown in Table 7. Especially the reduction in small-scale sources (class 4 and 5) in Seoul is remarkable: the number of class 4 sources decreased from 572 in 1990 to 211 in 1993 and that of class 5 from 2891 in 1990 to 753 in 1993. It was not so conspicuous with the large ones. This is the result of the Government's policy to relocate small- and medium-sized factories scattered within the city of Seoul to newly-developed industrial sites in the outskirts of Seoul. The classes 1, 2 and 3 are large-scale sources such as power plants, mammoth buildings, big industrial plants and so forth which are not easily relocatable. The number of sources in Seoul comprises only 5% of the national total (see Table 7).

The national total emissions of SO_2, CO and HC increased until 1990 and have been decreasing since as shown in Table 8. The major source of these three pollutants in South Korea used to be coal briquette for home heating. The total energy consumption has been continuously increasing up to the present time, but the major fuel for home heating in urban areas has been substituted by less pollutive fuels like oil and gas since 1990. The build-up of natural gas supply

Table 6. Number of air pollution sources nationwide (1984~1992)

Class	Class '1'	Class '2'	Class '3'	Class '4'	Class '5'	Total
1983	230	510	597	3041	12204	16582
1984	223	500	665	3193	13313	17894
1985	256	507	709	2846	15396	19714
1986	278	600	735	3002	16892	21507
1987	283	665	845	3287	18133	23213
1988	281	689	847	3104	19142	24063
1989	325	762	915	3116	19931	25049
1990	372	879	1010	3331	20351	25943
1991	458	1018	1157	3540	19987	26160
1992	531	1119	1227	3885	21112	27874

Class '1' : sources which use more than 10,000 TOE/year (TOE: tons of oil equivalent)
Class '2' : 〃 more than 2,000 TOE/year and less than 10,000 TOE/year
Class '3' : 〃 more than 1,000 TOE/year and less than 2,000 TOE/year
Class '4' : 〃 more than 200 TOE/year and less than 1,000 TOE/year
Class '5' : 〃 less than 200 TOE/year
Source: Ministry of Environment, Korea Environmental Year Book, 1988~1993

Table 7. Number of air pollution sources in Seoul (1990~1993)

Class	Class '1'	Class '2'	Class '3'	Class '4'	Class '5'	Total
1990	27(7.3)[a]	153(17.4)	178(17.6)	572(17.2)	2891(14.2)	3821(14.7)
1991	28(6.1)	135(13.3)	156(13.5)	342 (9.7)	753 (3.8)	1414 (5.4)
1992	21(4.0)	110 (9.8)	131(10.7)	263 (6.8)	699 (3.3)	1224 (4.4)
1993	25	103	108	211	753	1200

a: Figures within ( ) mean the ratio of the number of sources in seoul to the national total in %.

system and district heating system using waste heat from power plant, dissemination of oil boilers for home heating, supply of low-sulfur oil and other policies the Government launched to clean up the air seemed to be effective. The reduction of these emissions in Seoul began earlier: the Government began to put special efforts in Seoul in 1988, which was the year of Seoul Olympic. The national total emission of TSP began to drop from 1992. The major source of TSP in the nation is industrial stacks and the stricter control of industrial emissions seemed to be the cause of the reduction. However, the major source of TSP in Seoul is automobiles. The Government tightened the emission standards for the exhaust gases from gasoline cars to the world-class level effective from 1988, the

Table 8. Emission of air pollutants (1984~1993)

(Unit: 1,000 ton)

Pollutants	SO_2		CO		HC		NO_2		TSP.	
	Korea	Seoul	Korea	Seoul	Korea	Seoul	Korea	Seoul	Korea	Seoul
1984	1226	169	1330	445	96	28	755	149	274	50
1985	1352	162	1361	450	137	32	723	158	342	52
1986	1241	168	1449	514	146	35	782	172	342	54
1987	1041	172	1479	508	162	37	837	174	352	53
1988	1401	177	1476	536	196	45	876	110	390	55
1989	1446	151	1530	482	191	39	1122	219	386	45
1990	1611	138	1991	640	272	69	926	127	420	49
1991	1598	123	1760	532	200	59	878	127	431	43
1992	1613	97	1630	452	164	42	1067	126	392	24
1993	1572	56	1290	316	145	32	1187	113	390	18

Source: Ministry of Environment, Emission of Air Pollutants, 1988~1993

Seoul Olympic year, and thus the emission began to drop since (see Table 8).

The NO_2 emission in the nation is still increasing because of the difficulty in control technology and the lack of proper governmental policy. However, there seems to have been a slight reduction of emission in Seoul City until 1990, which can be attributed by the relocation of industrial plants to newly developed industrial bases in satellite cities. The emission in Seoul has been stabilized since 1990 because the relocation of industrial plants has been balanced by the increase of traffic within Seoul (see Table 8).

In Seoul City, transportation is the major emission source for CO, HC, NO_2 and TSP as illustrated in Table 9. The contribution of transportation to these emissons is rising sharply because of rapid increase in automobiles and tighter control over stack emissions: in 1991, the transportation was responsible for 58.9% of the CO emission, 65.9% of the HC emission, 76.3% of the NO_2 emission and 35% of the TSP emission, but in 1993, just in two years, the percentages rose to 75.2%, 98.3%, 87.3% and 79.4%, respectively (see Table 9).

The major source of SO_2 in Seoul is the burning of coal briquette for home heating. The coal consumption in 1993 for home heating was reduced to less than a half that in 1991, but the contribution percentage remained the same, in the vicinity of 70%. This is so because the total SO_2 emission halved also due to the upgrading of the petroleum fuel.

Table 9. Emission of air pollutants by sector (Seoul, 1991~1993)

(Unit: 1,000 ton)

Sector		Heating	Industrial	Transportation	Power Plant	Total
	SO_2	84317(68.4)	16084(13.1)	16918(13.7)	5902(4.8)	123221(100.0)
	NO_2	15094(11.9)	4382(3.4)	97105(76.3)	10656(8.4)	127237(100.0)
1991	TSP	25749(60.5)	1211(2.8)	14905(35.0)	709(1.7)	42574(100.0)
	CO	217054(40.9)	513(0.1)	313775(58.9)	539(0.1)	531881(100.0)
	HC	19962(33.8)	98(0.2)	38919(65.9)	104(0.1)	59083(100.0)
	SO_2	66525(68.3)	14883(15.3)	11382(11.7)	4527(4.7)	97317(100.0)
	NO_2	16083(12.7)	4204(3.3)	97894(77.4)	8250(6.6)	126431(100.0)
1992	TSP	3834(16.3)	1053(4.5)	18149(76.9)	540(2.3)	23576(100.0)
	CO	157158(34.8)	529(0.1)	293486(65.0)	473(0.1)	451646(100.0)
	HC	4832(11.5)	100(0.2)	37114(88.1)	101(0.2)	42147(100.0)
	SO_2	40167(71.7)	9268(16.6)	6070(10.8)	476(0.9)	55981(100.0)
	NO_2	9833(9.2)	3006(2.8)	93541(87.3)	728(0.7)	107108(100.0)
1993	TSP	2971(16.1)	752(4.1)	14596(79.4)	75(0.4)	18394(100.0)
	CO	77530(24.6)	449(0.1)	237437(75.2)	277(0.1)	315693(100.0)
	HC	477(1.5)	27(0.1)	31008(98.3)	27(0.1)	31539(100.0)

Source: Ministry of Environment, Emission of Air Pollutants, 1992~1994

3. Policy Issues

3.1 Problems of Seoul's Air Quality

As shown above, there have been remarkable improvements in the air qualities of sulfur dioxides (SO_2), total suspended particulates and carbon monoxide (CO) because of the reduced use of coal briquette, the upgrading of oils and relocation of industries. However, nitrogen oxides (NO_x) and oxidants (as O_3), which are associated with automobiles, do not show any improvement. Especially the photochemical smog is posing more serious problem year after year: the smog was observed for 20 days over Seoul in July 1994 and the highest ozone level recorded at Kwanghwamun station in August in the same year reached 3 times the national 1-hr average standard.

The fine particulates, PM10, has been monitored since 1995. The annual average level of PM10 in Seoul in 1995 was nearing the national ambient standard, 80 $\mu g/m_3$. Anyang City, a satellite city of Seoul, violated the standard. The levels in most of the major cities in South Korea were very close to the national standard:

some above the standard and some below it. These fine particles are believed to be originated mainly from diesel cars, fuel combustion and waste incineration.

Therefore, the air pollution control policy in Seoul should better be focused on reducing nitrogen oxides, volatile organic compounds and fine particulates, the main source of which is automobiles.

Among automobiles diesel cars pose a much more serious problem. Diesel cars occupy 24.5% of the total vehicles in Seoul and consume 37% of the energy. Diesel exhaust gases account for 39% of CO, 36% of VOC, 80% of NO_x, 85% of SO_2 and 99% of PM10 emission from transportation in Seoul.

3.2 Measures against Air Pollution from Automobiles

3.2.1 Measures for Automobiles

The government strengthened the emission standards for automobiles using gasoline, LPG, and kerosine to fight the urban air pollution problems. The recall system for automobiles has been in effect since 1992: auto manufacturers are responsible for recalling those cars which violate the emission standards and have to fix them. Through this system, about 70,000 cars manufactured in 1995 were recalled for violating the law.

Passenger cars manufactured since July, 1987 have been equipped with catalytic converter to reduce air pollution. However, there has been no program to test the performance of the catalytic converter. The recall system could serve as a useful tool to pressure the manufacturers to install durable parts. However, only five cars have been sampled for the test each year: five cars out of 50 thousands cars sold each year means a mere 0.01%. The representativeness of the five cars sampled is questionable. It is desirable to increase the samples for the test: it is recommended to increase the number and set a ratio of the sample as to be flexible with the total sales.

As a measure to reduce the diesel exhaust, passenger cars with less than 15 seats and 1-ton trucks using diesel have been encouraged to switch the fuel to LPG, a much cleaner fuel. By the end of 1995, more than 180,000 diesel cars changed fuel. Buses in South Korea used to be low-powered; it saved energy but made serious smoke problem especially when running uphill. So the government started to introduce high-power buses in 1991 and 65.6% of the buses in Seoul were replaced by them by 1995. And a diesel/CNG engine has been developed and is being road-tested for further improvement for diesel cars.

To reduce air pollution from the cars in running, the Government has tightened the emission standards. For gasoline cars, the CO emission standard was upgraded to 2.11g/km, the HC standard to 0.25g/km and the NO_x standard to 0.62g/km in 1988. The HC and NO_x standards will be further tightened to 0.16g/km and 0.25g/km, respectively, from the year 2000. The particulate emission standard for diesel cars was upgraded to 0.08g/km in 1996 and will further be upgraded to 0.05g/km from 2000. These standards are quite comparable to those in Western countries. The exhaust gas of running cars used to be tested in idling condition, but the test is to be done on road to check the actual emission from January 1997.

The emissions of CO and HC from gasoline cars are measured in idling condition, and the particulates from diesel cars at rapid acceleration in idling. But most of the measuring equipments are old and the accuracies doubtful. In addition, because of the insufficient man power and equipments, it is impossible to monitor the exhaust gases effectively considering the number of cars increasing continuously. Therefore, it is desirable to employ a new monitoring system such as an optical remote sensing equipment which monitors the exhaust gases of 1,000~1,200 running cars simultaneously. But, it is necessary to check the economic feasibility and the credibility fully before using the equipment worth 300 million U.S. dollars.

The researches on the smoke-filtering equipment for diesel cars have been going on for a long time, and several institutes have almost completed their studies and are now testing the performances on the road.

3.2.2 Upgrading of the Fuel

Gasoline cars manufactured since 1988 use unleaded gasoline. The aromatic compounds, benzene and oxygen contents of gasoline have been improved since January 1996 as shown in table 10.

The standards for exhaust gases are as tight as those in any environmentally-conscious countries, but the standards for fuel such as the oxygen content, aromatic compounds, sulfur and bezene known as carcinogen, are much loose

Table 10. Fuel standards for automobiles

Fuel	Components	Korea[a)]	U.S.A.	Japan
Gasoline	Aromatic compounds(vol %)	≤ 50	≤ 25	-
	Bezene (vol %)	≤ 5	≤ 1	-
	Lead (g/ l)	≤ 0.013	≤ 0.026	≤ 0.013
	Sulfur (wt %)	≤ 0.10	≤ 0.03	≤ 0.01
	Oxyzen (wt %)	≤ 1.0	≤ 2.7	≤ 1.8
Diesel	10% residual carbon (%)	≤ 0.15	≤ 0.15	≤ 0.05
	Sulfur (wt %)	≤ 0.1	≤ 0.05	≤ 0.1

Source: a. Ministry of Environment, Korea Environmental Year Book, 1996

compared to those of U.S.A. or Japan. Clean cars alone cannot make clean air without clean fuel. Therefore it is desired to upgrade the fuel specification so as to push the oil refineries for further research and investment to improve the quality of fuels. At the same time the altenative fuels such as methanol, ethanol, CNG etc. need to be developed especially to improve diesel cars.

3.2.3 Traffic Management

The traffic is the most important cause of the serious air pollution in Seoul. The number of cars registered in Seoul reached 2,043,458 as of December 1995, 24.5% of which (500,343 cars) were diesel cars. The number of cars are still increasing very rapidly. The traffic poses a serious threat to air not just because of the number of the cars but also because of the mileage. The average mileage per vehicle is about 23,000km/yr in Seoul, while that for the United States of America, France and Japan is 17,000km/yr, 14,000km/yr and 10,000km/yr. These figures are for the national average: the mileage in big cities like New York City, Paris or Tokyo is much less than the national average. The per-vehicle mileage in Seoul is excessively high compared with other metropolitan cities of the world, because the transportation policy in South Korea has emphasized on expanding the supply of the traffic utilities, such as building more roads, efficient intersects and parking lots with cheap fuel costs and parking fees.

Spacious parking lots, broad roads and cheap parking fees attracted traffic to downtown Seoul, which resulted in chronic traffic jam in Seoul. According to a survey in 1992, 61% of the traffic volume in rush hour (07:00~10:00) was passenger cars, while they carried only 14.5% of the passengers. The problem is getting worse every year: the number of cars increased 30% in just three years, most of them were passenger cars. Therefore, the most important policy to review should be about discouraging the use of passenger cars for commuting. Policies like traffic congestion tax and mileage tax for gasoline, raising parking fees and so forth may be more proper to solve the transportation as well as the air pollution problem, is imposed to reduce the ratio of passengers to traffic volume, thereby dispersing the traffic volume and solving the traffic jam at the same time.

3.3 Measures against Volatile Organic Compounds

Volatile organic compounds (VOCs) are known as precursors to form oxidants including ozone with nitrogen oxides. VOCs do not mean a single chemical but thousands of volatile compounds. There are diverse sources of VOCs such as cars, painting shops, gas stations, oil storage facilities, laundromats and other industries using solvents.

While the level of oxidants in Korea is getting worse each year, the monitoring and emission inventory for VOCs, a limiting factor for oxidants, are still in the beginning stage; therefore, the data on spacio-temporal characteristics for precursors of oxidants are rare and it is very hard to understand the detailed processes of the photochemical smog episode.

Therefore, first of all, the emission inventories on VOCs should be made. To do this, firstly, VOC sources scattered around the city should be identified and monitored using instruments such as hand-carried gas chromatographies. Also preliminary works are needed to improve the format for inventories and develop the monitoring methods. At the same time, VOCs should be classified so as better to represent the local characteristics of Seoul. The management strategy for Seoul may be different from those in the U.S.A. or other countries depending on the characeristics and the level of oxidant pollution.

In addition, financial support programs like CLEAN (Califonia Loans for Environmental Assistance Now)are recommended for small businesses such as laundromats, painting shops and so forth. The CLEAN has a fund of 3 million dollars to give long-term loan to small businesses to follow the regulation of SCAQMD (South Coast Air Quality Management District).

3.4 Measures against Fine Particulates

The regulations to reduce the fine particulates from industries, coals and bunker-C oil have changed continuously, but the dust collecting equipment is essential in any cases. To control the fugutive dusts from construction sites and storage sites for coal and aggregates, those companies are required to hire an environmental manager responsible for managing the dusts and the sites should be monitored by the environmental officers. Also, to reduce dusts from roads, the Metropolitan Government is responsible for the sweeping of the roads using cleaning vehicles and operating report centers for citizens.

However, there lacks the management policy to control pollution from open burning in construction sites, roadsides and other remote areas especially in the winter season. Most citizens do not pay much attention to the open burning which is very harmful to air quality. Thus, awareness building among citizens is necessary and then legal regulations should be supplemented.

Recently, Ministry of Environnment recommended small-scale incinerators for the on-site treatment of wastes. Since waste is a low-quality fuel, smoke and fume emitted from burning the waste are harmful for the environment. Moreover, the operation of the small-scale incinerators is allowed without any control equipment such as dust collectors. This policy needs to be reviewed carefully before further dissemination.

The role of NGOs (non-governmental organizations) and citizens' group is very important in implementing the policies to clean up the air, so they need to be mobilized for efficient monitoring and cooperation from citizens.

3.5 Further Recommendations to Appease Citizens

Air pollution indices in Seoul have been improved remarkably in recent years except for nitrogen oxides and oxidants according to the monitoring data. However, most of citizens think air quality becomes worse and worse. It may be so because there are differences between the air monitored and the air citizens breathe. The air quality in the downtown Seoul has improved significantly, but the air pollution has spread to much wider areas because of the enormous growth of the satelite cities of Seoul and the relocation policy of industries to those satelite cities. Therefore the population exposed to polluted air has increased enormousely while the peak concentration in downtown has decreased. So it is time to pay attention not only to concentration but also to the area and population exposed.

Another reason people feel the air is getting worse has to do with the visibillity, which has not been improving at all despite of other air quality indices. It is suggested that the visibility be monitored and investigated to identify the cause and to find ways to solve it. The visibility itself may mean many things which are not clearly known to us. The Seoul sky may look clean only when all the air pollution problems are cleared. The Seoul citizens will not be happy about air without solving the visibility problem.

4. Conclusions

Due to the intensive economic development for the last three decades in Korea, the per-capita income has increased remarkably. However, various environmental problems have occurred with the rapid urbanization, development of the heavy chemical industries and rapid increase of vehicles.

Seoul, the capital city of the Republic of Korea with the population of 12 million in a $605km^2$ area is the representative city that has serious environmental problems. Air pollution levels in Seoul have been significantly improved after practicing various pollution reduction measures such as the supply of low-sulfur oil and clean fuel such as LNG, installing gas cleaning devices in passenger cars and others. However, the overall status of air quality in Seoul is still far from comfortable.

The temporal characteristics of air pollution in Seoul are investigated. The trend of air quality differ from pollutant to pollutant. The levels of CO, TSP and SO_2 have improved remarkbly, while the oxidants' level increased by 63% from 1984 to 1993. The monthly-average concentrations of air pollutants were also analyzed. Air pollutants generated mainly from space heating, such as SO_2 and TSP, showed higher level in winter. The level of NO_2 and HC generated mainly from automobiles, showed almost fluctuation. The oxidants which are formed by photochemical reaction, showed higher concentration in summer.

In 1993, no air pollutant exceeded the long-term ambient standards. Also, all the air pollution levels except oxidants showed a remarkable improvement with respect to violations of short-term ambient standards. Only the oxidants showed an increasing number of violations against the short-term ambient standards. Because of that, it is urgent to make measures to reduce the oxidants concentration.

It is recommended that special countermeasure policies be adopted to solve the air pollution problems associated with automobiles, fine particulates, fugitive dusts and visibility with emphasis on policies for citizens not for statistical data.

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