1981 -2000 Emission Trends and the Influence by Economic Crisis in Korea

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ABSTRACTS

In this paper, it was developed annual emission trends of sulfur dioxides(SO_2), nitrogen oxides(NOx), carbon monoxide(CO) and volatile organic compounds(VOC) during 1981 - 2000 period, and analyzed how a Korean economic crisis influenced an air pollution emission trends. This paper documents the methods and data sources that were used to develop the emission trends data and presents a discussion of the major factors producing these trends.

It was applied emission estimation methodologies and emission factors reported recently by U.S. EPA and CORINAIR. And the emissions were calculated from major source categories, fuel combustion, on-road vehicles, non-road mobile sources, solvent utilization and waste treatment. It is calculated emission from industry, heating and electricity production by the fuel consumption. The emissions from motor vehicles included hot and cold start emission and evaporative emission were considered. Activity data of construction equipments, farming machine, air flight and railroad vehicles were accounted for the emission estimation from non-road mobile sources. And also it is calculated an emission by waste incineration and landfill treatments. Analytical limitations and future improvements are described in the conclusion section.

INTRODUCTION

It has been a continuous economic growth in Korea after 1970's, and the air pollution emission has been increased by industrial developments. GNP per capita in Korea was exceeded $10,000 in 1995, but GNP fell rapidly to $ 6,700 in 1998 by an influence of an economic crisis in 1997 as shown Figure 1. This 1998 GNP fall-down was corresponding as -35 percent to the last year, 1997. This change was due to a depression of industrial and economic activities. This depression effected on air pollution emissions from many source categories.

In Korea, there were many changes in social environments and environmental protection policy; fuel substitution policy, economic development and crisis. Therefore, air pollution emission trend was greatly changed during 1981 - 2000 period in Korea. In this paper, it was developed annual emission trends of sulfur dioxides(SO_2), nitrogen oxides(NOx), carbon monoxide(CO) and volatile organic compounds(VOC) from various source category during these 20 years. And disaggregated emission was analyzed how an economic crisis influenced an air pollution emission sectors. This paper documents the methods and data sources that were used to develop the emission trends data and presents a discussion of the major factors producing these trends.

EMISSION ESTIMATION METHODOLOGIES

Fuel Combustion

The emissions from fuel combustion were produced by major source categories, industry, heating and electricity production. It was calculated as the product of annual fuel consumption and emission factors. It was applied emission factors studied recently in Korea and AP-42.

Mobile Sources

In mobile sources, source categories are considered as on-road vehicle; passenger car, buses, trucks and motorcycles, and non-road vehicle; construction equipments, farming machine, ships, air flight and railroad vehicles.

The emission of pollutants from motor vehicle was split into two basic types; tail-pipe and evaporative emissions. Tail-pipe emission was calculated by two methodologies; NOx, CO, VOC were calculated as the product of emission per kilometer traveled (g/km) with vehicle speed and annual VKT. The emission of sulfur dioxide was calculated as the product of annual fuel consumption and emission per unit mass of fuel consumed. And tail-pipe emissions were consisted of hot emission and cold start emission. The hot emission was calculated by emission factors studied by Korean Motor Vehicle Emission Research Laboratory in 2001. The cold start emission and evaporative emission were estimated by CORINAIR methodology with Korean environmental factors.

As the non-road mobile sources, the emission from construction equipments, farming machine and railroad vehicles were calculated by estimation methodologies recommended in NONROAD model and emission factors studied in Korea. The emission from air flight and their ground supporting equipments was calculated by methodologies and emission factors used in EDMS model. And activity data of these sources like as equipment operation days, vehicle kilometer traveled and the numbers of LTO(Landing and Take Off) by engine types per year were accounted for emission estimation.

Waste Treatment

The waste incineration emits many criteria pollutants, and landfill treatment emits a methane and VOC. Waste incinerator was categorized into 3 types by capacity, and emission from incinerator was calculated by factors reported in Korea. VOC emission from landfill site was estimated by U.S. EPA methodology(Landfill Gas Emission Model). The input values of methane emission potential(Lo) and landfilled waste decay factor(k) for this model were 50 m^3-CH_4/refused-waste(Mg) and 0.035 /year in consideration of a characteristics of Korean municipal waste.

Solvent Utilization

VOC is a principal component in the chemical and physical atmospheric reactions that form ozone and other photochemical oxidants. Surface paintings are the dominant source of VOC. And VOCs are released from various point and area sources. Those sources are gasoline station, dry cleaning, degreasing, graphic arts, consumer solvents, etc. These VOC emissions were estimated by CORINAIR methodology and activity data compiled as an amount of solvent consumed or the population or employee of related industry. VOC emissions refer to anthropogenic releases only in this study.

EMISSION TRENDS IN 1981-2000 AND SOURCE SECTOR SPLIT

Source sector split

The national total emissions by source category for SO_2, NOx, CO and VOC in 2000 are displayed in Table 1. The source categories for official report constitute simply tier 1 before 2000 in Korea, industry, electric generation, heating and transport. In this study, the source categories are disaggregated shown in Table 1; fuel consumption, on-road-vehicle, non-road vehicle, waste treatment, oil storage and transport, solvent utilization and industrial process. The disaggregated emission in 2000 for SO_2, NOx, CO and VOC is shown in Figure 2 through Figure 5.

Figure 2 is a pie chart showing 2000 SO_2 emissions by source category. Fuel combustion contributes the majority SO_2 emission representing 79 percent, and the fuel combustion for industry contributes the 37 percent of total national SO_2 emissions in 2000.

Figure 3 is a pie chart showing 2000 NOx emissions by source category. On-road vehicles account for 44 percent of total national NOx emissions in 2000. Trucks are a major contributor to the on-road vehicles NOx emissions. And non-road vehicles contribute the 22 percent of total national NOx emissions in 2000.

Motor vehicles are the dominant contributor to the CO emission as shown in Figure 4. On-road vehicles contribute the majority CO emissions representing 73 percent, and passenger cars contribute the 32 percent of total national CO emissions in 2000.

As shown Figure 5, solvent utilization is the dominant source of VOC, corresponding to 64 percent of total national VOC emissions in 2000. The surface painting is the major contributor to the VOC emissions from solvent utilization. On-road vehicle contributes the 14 percent of total national VOC emissions in 2000.

On-road vehicles are a major contributor to the national total emissions. They account for approximately 44 percent of NOx emissions and 73 percent of CO emissions within the all source categories.

Emission trends and changes in 1997-1998

The development of SO_2, NOx, CO and VOC emissions over Korea during the 1981- 2000 period is given in Figure 6, 7, 9, 10. These annual emission trends are as follows;

The trends of Sulfur dioxides(SO_2) emission is characterized by relatively high emission in the middle 1990's and a gentle decrease in the late 1990's shown as Figure 6. And the 38 percent decrease in 2000 from the 1981 level. This decrease is due to the low-sulfur oil policy and fuel substitution from coal to natural gas in 1990's.

With regard to NOx, the total emission in 2000 shows approximately 4 times than to the 1981 emission level. Changes in emissions over this period are shown in Figure 7. From 1991 to 2000, NOx emissions increased by 90 percent. This increase is made mainly by explosive vehicle transport increase. The numbers of motor vehicles rise to 12 million in 2000, this value is 21 times than those of vehicles in 1981 as shown in Figure 8.

Figure 9 shows historical trends in CO emission by principal source categories. Total CO emissions peaked in 1988 and decreased steadily thereafter. This decrease is due to the fuel substitution from coal to natural gas for heating in 1990's.

Before 1991, VOC emissions from source category of solvent utilization, oil storage and transport could not be calculated by a lack of activity data. The annual VOC emissions after 1991 show an upward trend shown as Figure 10. It exhibits an approximate 44 percent increase between 1991 and 2000. A significant decrease in VOC emission occurred between 1997 and 1998 as a result of economic crisis in Korea.

As shown the trends of air pollutants emission, many changes of emission were made in Korea during 1981 - 2000 period, these changes were due to economic developments, explosive vehicle transport increase and fuel substitution. Especially, the change of NOx, VOC emission from 1997 to 1998 shows a significant fall-down. This change is believed because Korean economic crisis in 1997 influenced an air pollution emission.

The changes of national emissions by source category for SO_2, NOx, CO and VOC between 1997 and 1998 are displayed in Table 2. The reduction of SO_2 emission during this period was 192,861 ton/yr, and NOx emissions reduced by 205,823 ton/yr. These SO_2 and NOx emission decrease in 1998 are corresponding as -19%, -14% to the 1997 emission. This change was due to a depression of industrial and economic activities, especially made in vehicle transport and construction activity. So SO_2, CO, VOC and NOx emission reduction from on-road vehicles (buses and trucks) and non-road vehicles (construction equipment) was made more than those from other sources. And VOC reduction was accelerated by solvent consumption decrease of painting activities.

CONCLUSION

The national total emissions by source category for SO_2, NOx, CO and VOC were estimated during 1981-2000 in Korea. The emission estimation methodologies of U.S. EPA and CORINAIR were applied for this study. In this study, the source categories were disaggregated as more detailed; fuel consumption, on-road-vehicle, non-road vehicle, waste treatment, oil storage and transport, solvent utilization and industrial process. And the disaggregated emissions of Korean totals in 2000 were analyzed.

As shown the trends of air pollutants emission, many changes of emissions were made in Korea during 1981 - 2000 period, these changes were due to economic developments, vehicle transport increase and fuel substitution policy. Especially the emission changes during 1997 - 1998 period show significant fall-down.

This change is believed because Korean economic crisis in 1997 influenced an air pollution emission. It was due to a depression of industrial and economic activities, especially made in vehicle transport and construction activities. So emission reduction from on-road vehicles (buses and trucks) and non-road vehicles (construction equipment) was made more than those from other sources.

In this study, the emission source categories in tier 2 are not sufficient yet, especially about industrial process, solvent utilization etc. It is needed to reduce an uncertainty of emission data and to improve source categories through the future studies.

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Figure 1. The annual trends of GNP per capita in Korea

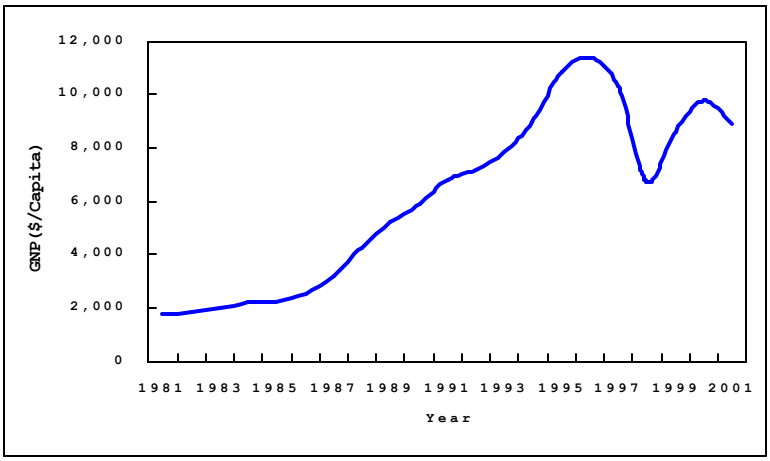


Figure 2. The 2000 national SO_2 emissions by principal source categories in Korea

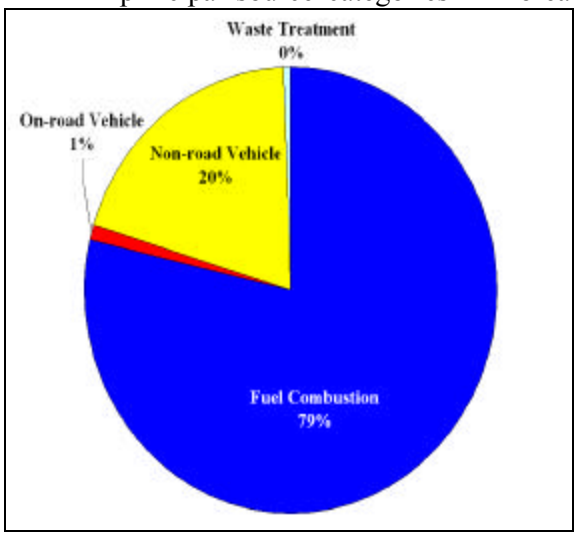


Figure 3. The 2000 national NOx emissions by principal source categories in Korea

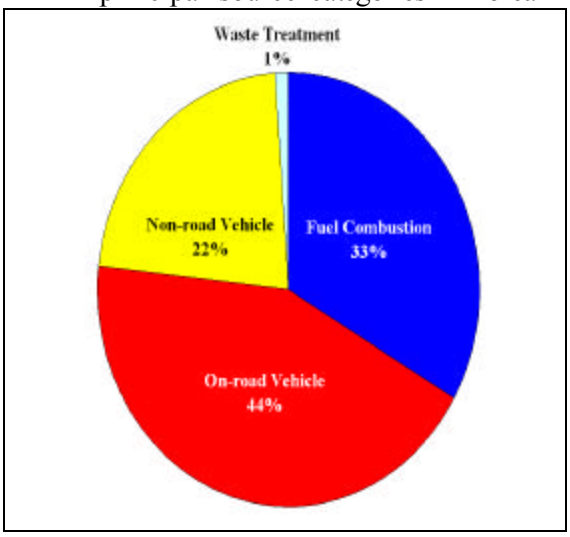


Figure 4. The 2000 national CO emissions by principal source categories in Korea

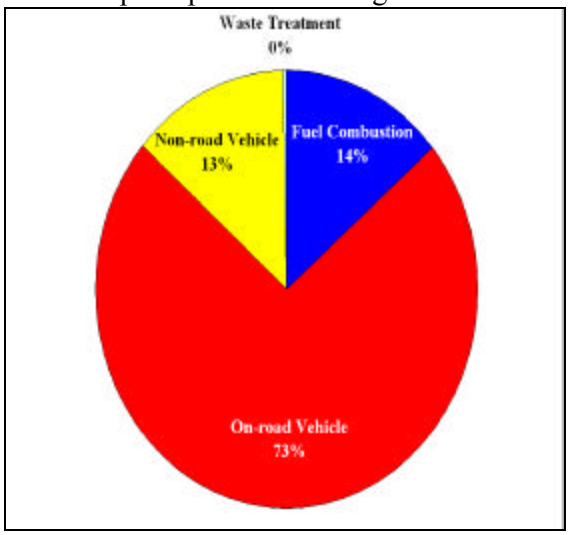


Figure 4. The 2000 national VOC emissions by principal source categories in Korea

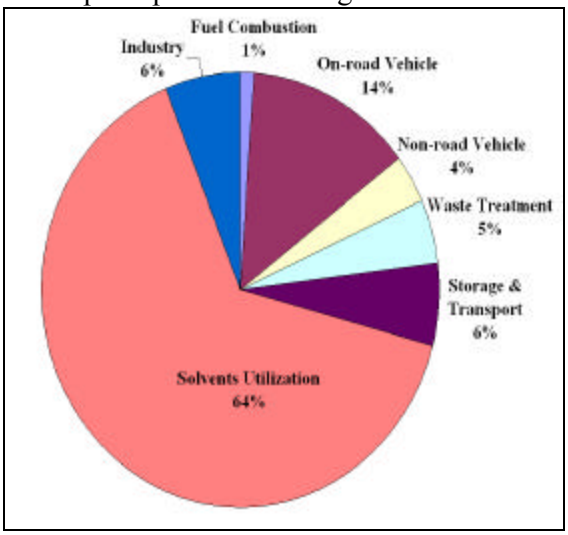


Figure 6. The annual emission trends of SO_2 in Korea (1981-2000)

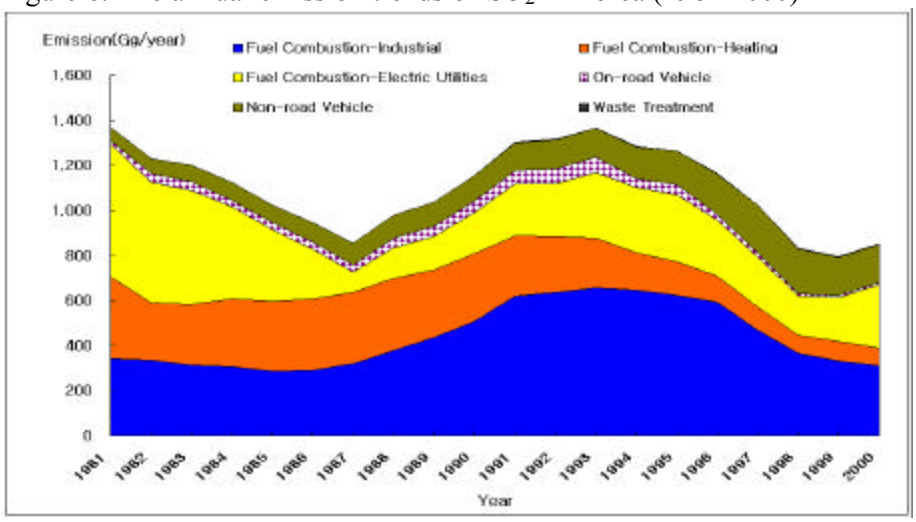


Figure 7. The annual emission trends of NOx in Korea (1981-2000)

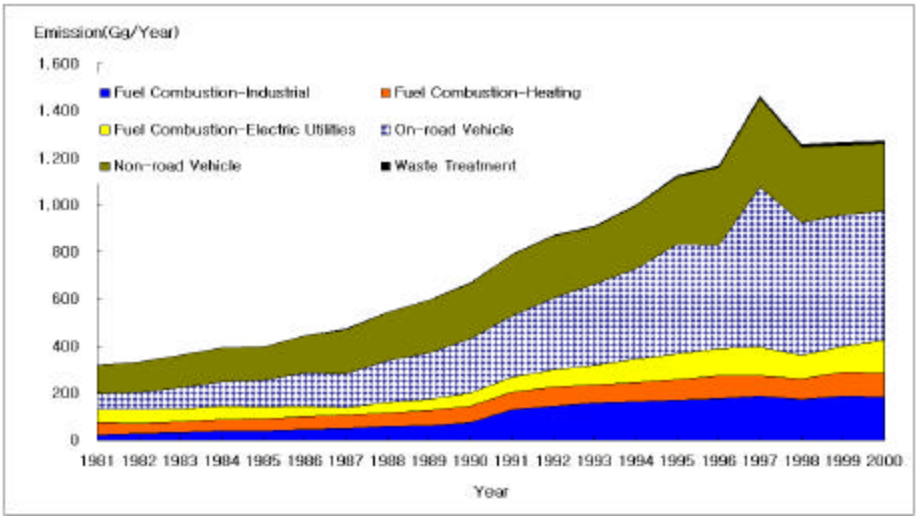


Figure 8. The annual trends of motor vehicles operated in Korea

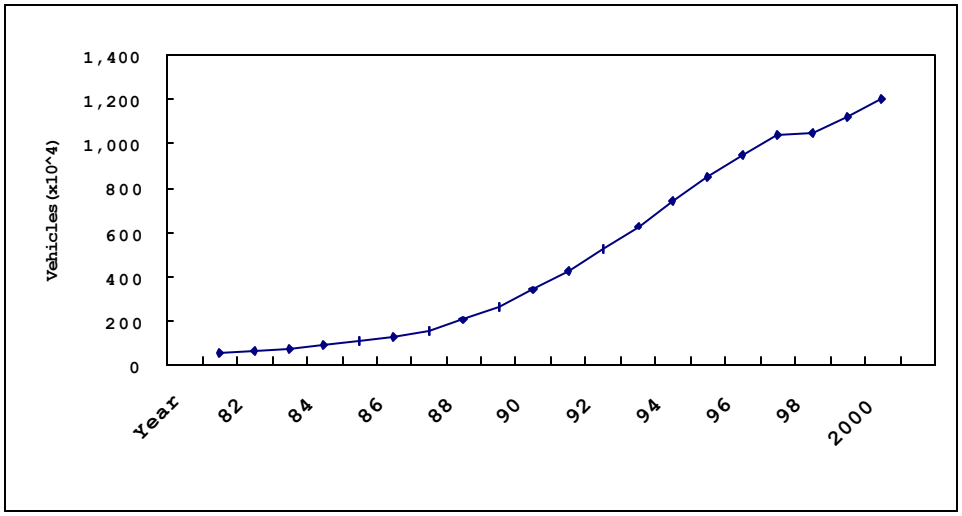


Figure 9. The annual emission trends of CO in Korea (1981-2000)

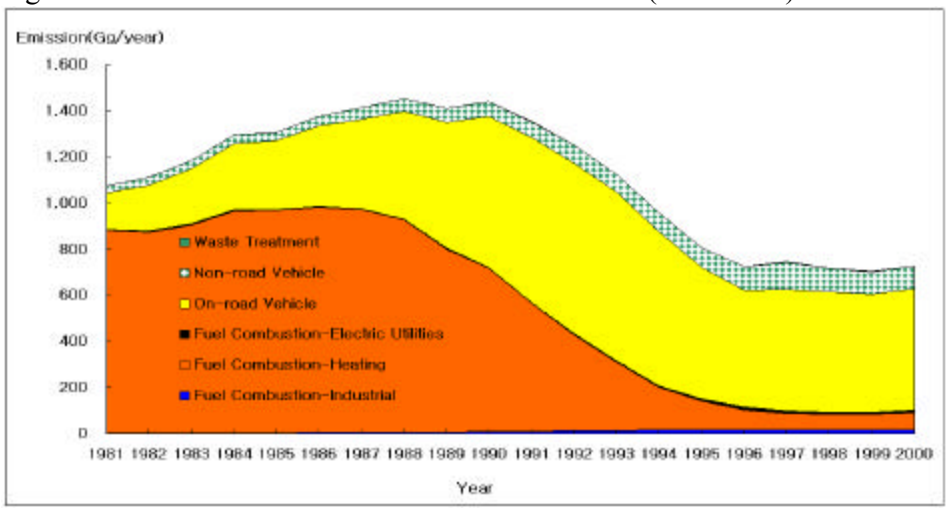
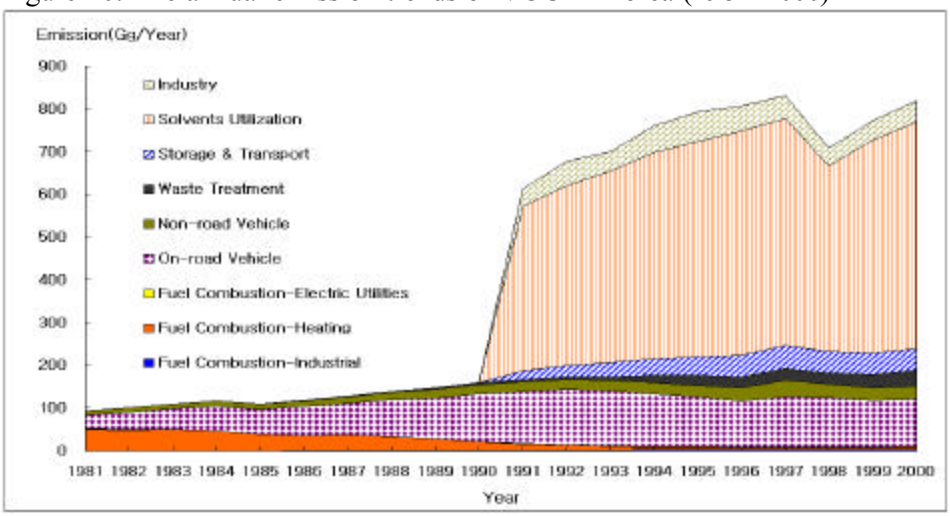


Figure 10. The annual emission trends of VOC in Korea (1981-2000)



* Before 1991, VOC emissions from source category of solvent utilization, oil storage and transport could not be calculated by a lack of activity data.

Table 1. 2000 national emissions by principal source categories in Korea (ton/yr).

		CO	NOx	SO_2	VOC
Total		728,290	1,271,049	851,046	809,309
Fuel combustion	Sum	100,647	425,159	668,495	10,142
	Industrial	16,821	183,435	309,344	2,815
	Heating	72,080	103,267	78,815	5,141
	Electric	11,745	138,457	280,336	2,186
On-road vehicles	Sum	526,212	547,884	9,978	111,374
	Passenger car	227,506	65,904	712	33,783
	Bus	66,086	115,094	3,809	11,680
	Truck	88,380	365,749	5,457	24,788
	Motorcycles	144,240	1,138	0	41,123
Non-road vehicles	Sum	99,580	285,211	168,939	24,085
	Railroads	50,044	18,904	488	2,970
	Marine vessels	10,101	173,660	149,076	10,189
	Aircraft	10,101	5,098	230	329
	Agricultural	10,379	23,267	13,458	2,832
	Construction	18,955	64,282	5,686	7,765
Waste Treatment	Sum	1,851	12,795	3,634	37,696
	Incineration	1,851	12,795	3,634	27,334
	Landfill	0	0	0	10,363
Storage & Transport					51,017
Solvent utilization	Surface coating				305,819
	Others				223,167
Industrial process					50,655
Others					12,656

Table 2. The change of emissions by source categories in Korea from 1997 to 1998 (ton/yr).

		CO	NOx	SO_2	VOC
Total		-25,960	-205,823	-192,861	-123,319
Fuel combustion	Industrial	-683	-13,034	-100,671	-231
	Heating	-3,169	-1,338	-25,198	-39
	Electric	-2,004	-18,880	-45,767	-482
On-road vehicles	Passenger car	-393	-3,238	518	-144
	Bus	-15,527	-44,136	-4,608	-3,170
	Truck	-5,894	-70,766	-7,075	-2,612
	Motorcycles	18,046	140		5,185
Non-road vehicles	Railroads	-155	-372	-9	-68
	Marine vessels	-1,563	-11,735	-5,651	-761
	Aircraft	-1,459	-739	-29	-187
	Agricultural	-748	-1,579	-933	-235
	Construction	-12,525	-40,033	-3,757	-5,267
Waste treatment	Incineration	113	-114	318	-1,373
	Landfill				474
Storage & Transport					-5,120
Solvent utilization	Surface coating				-87,151
	Others				-9,363
Industrial process					-12,202