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Analysis of Reduction Strategies for Air Pollutants Discharged from Emission Sources and their Impact on the Seoul Metropolitan Area

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ABSTRACT

The Korean government enacted the "Special Law for Improving Air Quality of Metropolitan Area" in 2003. According to this plan, Korean government plan to lower the concentrations of PM_{10} and NO_x to 40 μg/m^3 and 22 ppb, respectively, by 2014. In this study, we analyze emission reduction strategies to lower their concentration. Emission reduction for the supply of mass energy and regenerative energy are compared with several scenarios. According to the results, 713 t/y of NO_x and 165 t/y of PM_{10} will be reduced by enhancing the number of households supplied by local heating and air conditioning. And also 5 t/y of PM_{10} and 312 t/y of NO_x will be reduced by replacing conventional energy with solar energy by 2014.

Key words: Area source, Emission, Reduction, Mass energy, Regenerative energy, NO_x, PM_{10}

1. INTRODUCTION

Korea has kept a high economic growth policy since the 1970's and joined the OECD group as a result. However, air quality has reached a serious level with the increase in industrial development. The Korean government has tried eagerly to improve the air pollution situation using various environmental policies such as fuel regulations and stronger emission standards. Concentrations of TSP, SO_2, and Pb were noticeably reduced in ambient air after the policies were put into effect. However, concentrations of PM_{10}, NO_x and O_3 were not improved (Konkuk University, 2006). Concentrations of PM_{10} and NO_x (Fig. 1) were 69 μg/m^3 and 38 ppb, respectively, in the metropolitan area in 2001. This was equivalent to 1.9-3.6 times the value of OECD countries.

It is estimated that 1,940 persons died in 2000 from PM_{10}-related illnesses in Seoul city. The Korean government enacted the "Special Law for Improving Air Quality of Metropolitan Area" in 2003 and plans to lower the concentrations of PM_{10} and NO_x to 40 μg/m^3 and 22 ppb, respectively, by 2014. Emissions from point, area and line sources must be reduced to accomplish this goal (MOE, 2005).

In this study, we discuss reduction strategies of emissions, especially from area sources. We evaluated the impact of these reductions. A proper reduction strategy can be established only on the basis of studies such as this.

2. EMISSION REDUCTION STRATEGY

Maximum permissible emissions were set to reach the target concentrations by 2014. Emission reduction amounts are given in Table 1. 24,603 t/y of NO_x and 436 t/y of PM_{10} must be reduced by 2014. Initially, the status of emissions was studied to evaluate reduction potential. Then several alternative reduction strategies were discussed.

2.1 Estimation of Emissions from Area Source

Our target area was composed of Seoul city, Inch-

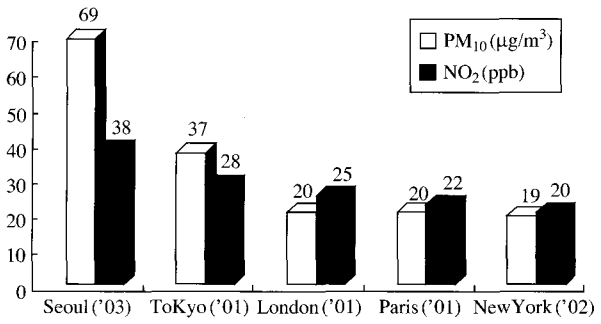

Fig. 1. Status of air pollution in Seoul city.

eon city and a part of Gyonggi-Do province. Contribution rates of emission sources to air quality in the metropolitan area are described in Fig. 2. Emissions from area sources are estimated in Table 1. According to Fig. 2 and Table 1, emissions are affected mainly by line and area sources. This study specifically discusses how to reduce emissions from area sources. According to Table 1, 58% of NO_x emissions and 48% of PM_{10} emissions need to be reduced by 2014. Maximum permissible emissions for 2014 are given in Table 2.

2.2 Plan to Reduce Emissions

The Korean government has made plans to reduce emissions from area sources. The effectiveness of the plans is currently unknown. Only if the plan is effectively executed will the target emission reductions be obtained. Therefore, several scenarios of reduction strategies were compared to see whether they will reach the reduction goal in the target year.

Table 1. Estimation of emissions from area sources without any reduction measures. (unit: t/yr)

	2001	2005	2009	2014
SO_x	14,519	11,175	8,871	8,539
NO_x	33,528	38,637	48,059	59,682
VOC	173,832	206,793	244,943	292,828
PM_{10}	883	753	716	729

Table 2. Maximum permissible emissions in 2014. (unit: t/y)

Division	NO_x	PM_{10}
Emission in 2014 (without reduction measures)	353,943	17,385
Maximum permissible emission	145,412	9,000
Amount to be reduced (reduction % of emission rom area sources)	24,603 (14%)	436 (5%)

2.2.1 Reduction Measures

Several measures to reduce emissions from area sources have been already implemented. These include fuel regulation, promotion of supplied local heating and air conditioning, strengthened NO_x management and management of energy demand.

Table 2 shows maximum permissible emissions to reach target concentrations of air quality by 2014. According to Table 2, by 2014, 24,603 t/y of NO_x and 436 t/y of PM_{10} have to be reduced using these measures (KEI, 2004). Several measures for area sources are listed in Table 3 (KEMCO, 2005). Supplying local heating and air conditioning and replacement of conventional energy with solar energy were considered the main reduction measures in this study.

2.2.2 Scenarios for Emissions Reduction

Several scenarios for supplying local heating and air conditioning and enhancement of solar energy usage were considered to compare the reduction effects of these measures.

How supply rate is determined and enhanced is important. We hypothesized three scenarios: Scenario 1: supply 105,000 households per year; Scenario 2: supply 92,000 households per year; Scenario 3: supply 85,000 households per year (see Table 4).

We considered only solar energy in the regenerative energy category. The supply rate of solar energy is 100,000 households per year from 2001 to 2010 on the basis of the 2nd national energy master plan (MOCIE, 2002). But the rate is 100,000 households

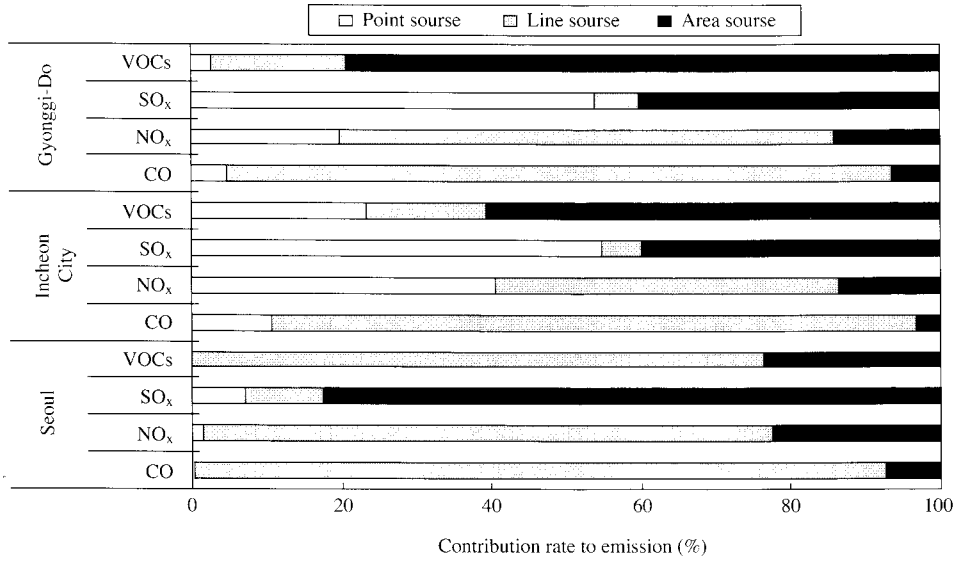

Fig. 2. Contributions to emissions from point, area and line sources in metropolitan areas in 2001.

Table 3. Reduction measures to lower emission levels.

Reduction measures	Reduction strategies
Local heating & air conditioning	Enhancement of local heating & air conditioning and revitalization of CES
Strengthening NO_x management	Diffusion of low NO_x-boiler and strengthening LNG management
Demand management	Enlargement of solar power plant Intensification of standard for heating & air conditioning indoors Intensification of standard and certification for environment-friendly buildings Strengthen management and regulation levels for emission dispersed Regulate solvent-content for general use of oil and paint Regulate use of cut-back asphalt

Table 4. Scenarios for enhancing the supply rate for mass energy.

Analysis of reducing effect	Basis
Scenario A	2002 Ministry of Commerce「The plan of supply for mass energy」 - Supply of 105,000 households/y until 2014
Scenario B	Actual supply of local heating & air-conditioning from 1995 to 2004 for 10 years - Supply of 92,000 households/y until 2014
Scenario C	Actual supply of local heating & air-conditioning from 2002 to 2006 for 5 yrs - Supply of 85,000 households/y until 2014

Table 5. Scenarios for enhancing supply rate for regenerative energy.

	Basis
Scenario D	- Consider 100,000 households - Consider duplication amounts (low NO_x boiler) - Number of households in metropolitan area: 46% of whole country (2001) - Replacement ratio: 0.77%
Scenario E	- Consider 100,000 households - Consider duplication amounts (low NO_x boiler) - Number of households in metropolitan area: 46% of whole country (2001) - Replacement ratio: 0.51%
Scenario F	- Consider 100,000 households+30,000 commercial facilities - Consider duplication amounts (low NO_x boiler) - Number of households in metropolitan area: 46% of whole country (2001) - Replacement ratio: 0.66%
Scenario G	- Consider 100,000 households +30,000 commercial facilities - Consider duplication amounts (low NO_x boiler) - Number of households in metropolitan area: basis of overall house supply plan: 54.3% of whole country (basis in 2001) - Replacement ratio: 0.78%

and 30,000 commercial facilities on the basis of the 2nd technical development and supply & usage plan for regenerative energy. We hypothesized four scenarios (Table 4) on the basis of these two plans.

3. EVALUATION OF IMPACT OF REDUCTION MEASURES

Emission reduction amounts were summarized for each reduction measure. Their impacts were divided into two parts: mass energy and regenerative energy.

3. 1 Mass Energy

We hypothesized three scenarios for reducing emissions (see Table 3). Emissions reduction for the metropolitan areas is most important because the abovementioned reduction measures are being implemented to improve the air quality of the metropolitan area. It was necessary to determine the percent replace-

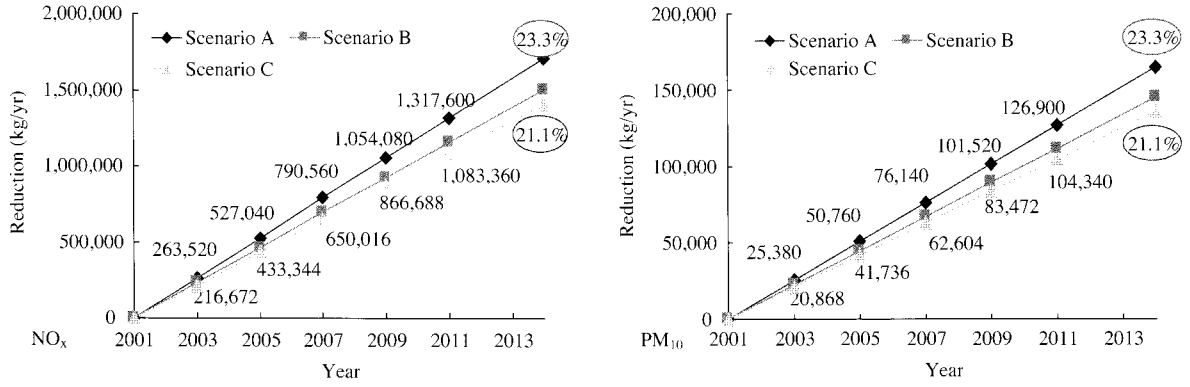

Fig. 3. Comparison of reduction amounts of PM_{10} and NO_x for three scenarios.

Table 6. Reduced amounts for three scenarios.

Division	Year	2001	2003	2005	2007	2009	2011	2014
Scenario A	Households supplied (thousands)	0	180	360	540	720	900	1,170
	NO_x (t/y)	0	263.5	527.0	790.6	1,054.1	1,317.6	1,712.9
	SO_x (t/y)	0	26.6	53.3	79.9	106.6	133.2	173.2
	PM_{10} (t/y)	0	25.4	50.8	76.1	101.5	126.9	165.0
Scenario B	Households supplied (thousands)	0	158	316	474	632	790	1,027
	NO_x (t/y)	0	231	463	694	925	1,157	1,504
	SO_x (t/y)	0	23	47	70	94	117	152
	PM_{10} (t/y)	0	22	45	67	89	111	145
Scenario C	Households supplied (thousands)	0	148	296	444	592	740	962
	NO_x (t/y)	0	217	433	650	867	1,083	1,408
	SO_x (t/y)	0	22	44	66	88	110	142
	PM_{10} (t/y)	0	21	42	63	84	104	136

ment ratio of the conventional system with local heating and air-conditioning (below LHA) to estimate reduction amounts. The national supply plan is not categorized for each local autonomous entity, nor is it for the metropolitan area. Therefore, the concept of area ratio (whole country area versus target area (designated by the special law)) was introduced to calculate the replacement ratio and reduction amounts. We divided the total number of households supplied by local heating and air conditioning by the number of households supplied in the metropolitan area and the number supplied in other areas on the basis of this concept. Results are given in Table 6 and Fig. 3. Replacement ratios ranged from 21.1% to 23.3%. Reduction amounts of NO_x were 1,713 t/y, 1,504 t/y and 1,408 t/y for scenarios A, B and C in 2014, respectively. PM_{10} was reduced by 165 t/y, 145 t/y and 136 t/y for scenarios A, B and C in 2014, respectively.

Table 7. Reduction amounts of NO_x and PM_{10} by 2014.

(unit: t/y)

	NO_x	SO_x	PM_{10}	VOC
2014 emissions (without measures)	400.9	2,343	623	2,583
Scenario D	302	18	5	19
Scenario E	204	12	3	13
Scenario F	264	15	4	17
Scenario G	312	18	5	20

3.2 Regenerative Energy

Four scenarios were compared for regenerative energy (see Table 5). There are many types of regenerative energy, but only reductions using solar energy were discussed in this paper. Replacement ratios for solar energy and reduction amounts were computed by Equation (1).

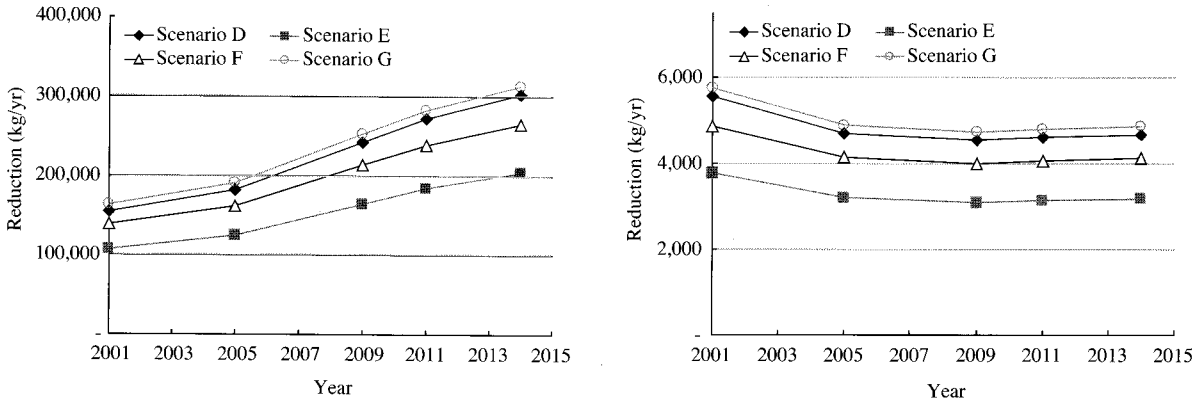

Fig. 4. Comparison of NO_x and PM_{10} in four scenarios using solar energy.

$$ERf = p \times ERi, \quad (1)$$

where ERf=amount of emission reduction in 2014, p (replacement ratio)=(number of households supplied by solar energy)/(number of total households in metropolitan area) × 100,

ERi=emission amount in 2014.

Results are described in Table 7 and Fig. 4. It was estimated that 204-312 t/y of NO_x and 3-5 t/y of PM_{10} will be reduced by 2014. If the replacement ratio increases 50 1.0%, the amount of NO_x and PM_{10} will be reduced to 400.5 t/y and 6.2 t/y, respectively.

4. CONCLUSION

In the present study, emission reduction strategies and their impacts were analyzed and reduction scenarios of emissions were compared. Results were summarized as follows:

(1) Emissions were reduced by enhancing the number of households supplied by local heating and air conditioning. Reduction amounts were estimated at 1,713 t/y of NO_x and 165 t/y of PM_{10} by 2014.

(2) A total of 5 t/y of PM_{10} and 312 t/y of NO_x will be reduced by replacing conventional energy with solar energy by 2014. The emission reductions will be larger in the future, because the use of renewable energy, such as geo-thermal energy and wind energy, will continue to be developed

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