VOCs Emissions and Reduction Potential in Solvent Utilization

- A Case Study -

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Y. Sunwoo, Y.I. Ma, Y.J. Kim, H.M, J.Y. Yoo, H.M Kim, S.H. Kim, J.S. Nam, J.H. Kim, H.K. Sung, D.G Kim[1)], J.H. Hong[1)]

Department of Environmental Engineering, Konkuk University, Korea
1) Environmental Cap Research Department, National Institute of Environmental Research, Korea

bluesky@konkuk.ac.kr

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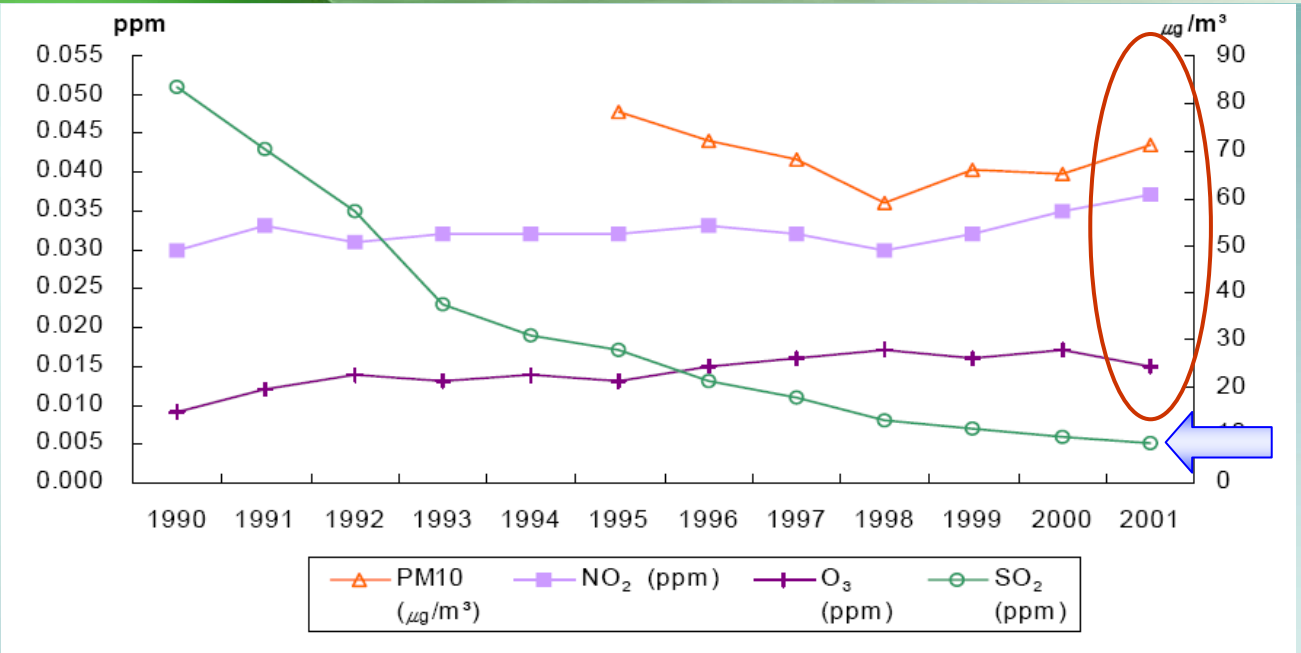
Introduction - Background 1

Trend of air quality in Seoul



- **Rapid decrease and achievement of air quality standard for SO_2**
- In spite of various efforts, PM_{10}, NO_2, and O_3 conc. on steady increase

O_3 is especially serious in SMA

In 2004, 48% of short-term O_3 air quality standard exceedances and 64% of O_3 alarms in all of Korea occurred in SMA

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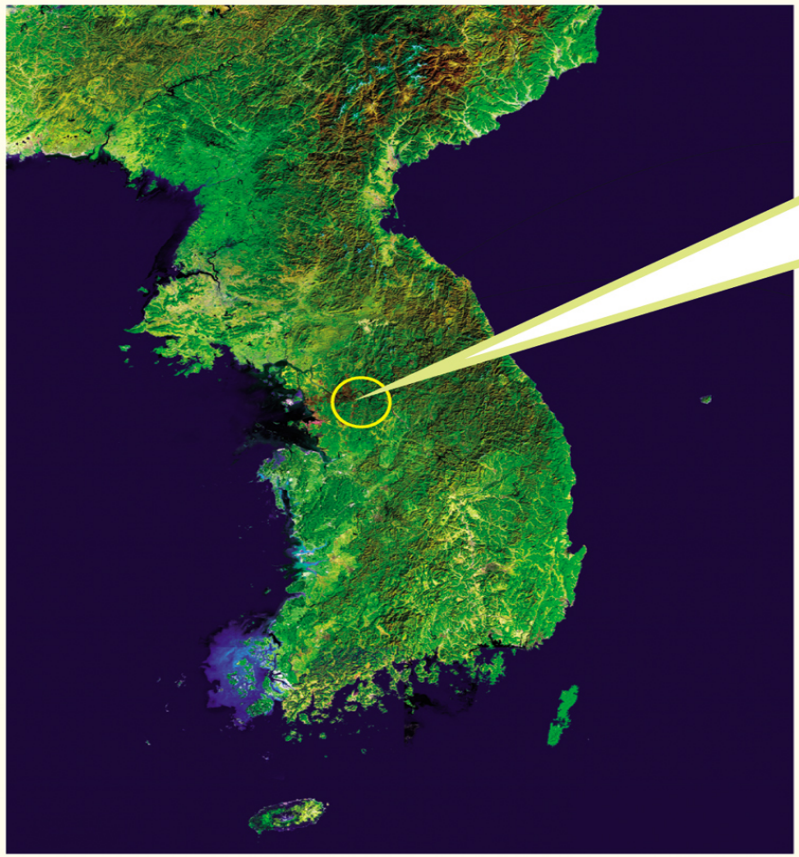
Special Measures for Metropolitan Air Quality Improvement

Seoul Metropolitan Air Quality Management District (SMAQMD)



Special Act for Seoul Metropolitan Air Quality Improvement

- **"Framework for Special Act" developed by Korean government in 2005**
  - **Includes general reduction program and reduction rates of VOCs emissions for O_3**
    - Reduction programs
      - Installation of VOCs recycling system for Stage II at gas station
      - Increase usage of ECO paint (low VOCs content and VOC-free paint)
      - Suppression of cutback asphalt usage for asphalt paving
      - etc.
    - Reduction rate : 38.7 % of VOCs emissions in 2001

Introduction

Purpose of this study

For the success of the "Special" Act and VOCs emission reductions

⇨ **Emissions estimating methods for specific sources must be developed**

Air pollutant emission inventory has already been developed by the Clean Air Policy Support System (CAPSS)

⇨ **Source-specific emission reduction programs must be developed**

So, in this study

- **Development of VOCs emission factor and estimation of emissions at certain sources**
  - **Dry cleaning, metal degreasing, and printing facilities**
- **Research of source-specific reduction programs and estimation of reduction potential**

Dry Cleaning Facilities

Dry Cleaning Facilities

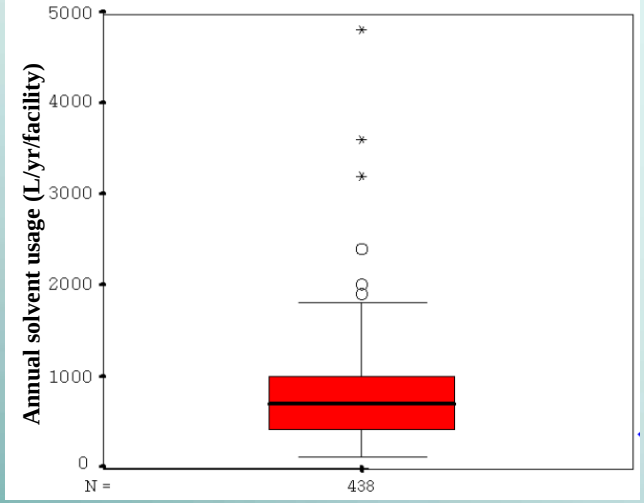
VOCs emissions estimation method : mass balance

VOCs emissions (kg VOCs/yr)
= annual net solvent usage per facility × number of facilities

Estimation of annual solvent usage

Obtained via on-site questionnaire survey

A total of 891 facilities were visited and number of “valid” results was 438



Annual solvent usage per facility :
792.7 L/facility/yr (610.4kg/yr/facility)

Dry Cleaning Facilities

Estimation of annual disposed solvent

- Obtained through laboratory evaporation simulation experiment of waste filter

→ **Amount of annual disposed solvent : 0.82 kg/yr/facility**

Ignore emissions from used waste filters

VOCs emission factor for dry cleaning facility : 610.4 kg/yr/facility)

VOCs emissions from dry cleaning facilities in 2001

Region	VOCs emissions (ton/yr)
Seoul	4,878
Incheon	1,137
Gyounggi province	3,832
Seoul Metropolitan Area	9,856

Metal Degreasing Facilities

Metal Degreasing Facilities

VOCs emissions estimation method : mass balance

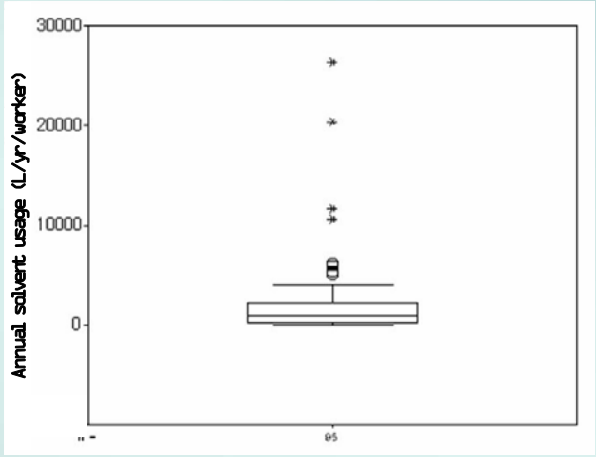
VOCs emissions (kg VOCs/yr)
= annual solvent usage per worker × number of workers

Estimation of annual solvent usage

Obtained via site visitation and mail questionnaire survey

→ A total of 790 facilities were targeted and number of "valid" results was only 95

	Annual solvent usage		
	Per facility (kg/facility/yr)	Per machine (kg/machine/yr)	Per worker (kg/yr/worker)
Average	4,011.5	1,980.6	223.1
Standard deviation	8,112.4	3,643.4	314.6



Topic 1 : Development of Emission Factors and Estimation of Emissions

Metal Degreasing Facilities

VOCs emission factor for metal degreasing facility : 223.1kg/yr/worker)

cf.) Emission factor used in CAPSS : 39.5 kg/yr/employee

Activity data :
number of workers at metal plating and metal heat treatment industry

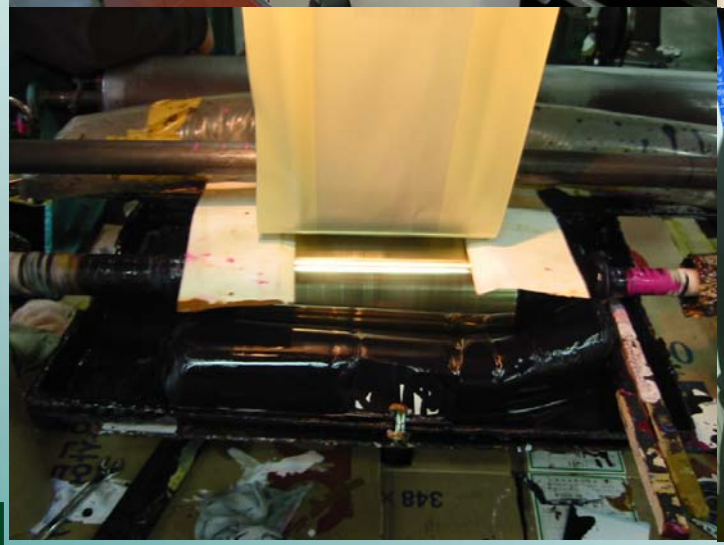
cf.) CAPSS : entire 5 sub-categories related to metal industry

VOCs emisssions from metal degreasing facilities in 2001

Region	VOCs emissions (ton/yr)
Seoul	126
Incheon	913
Gyounggi province	1,305
Seoul Metropolitan Area	2,344

Topic 1 : Development of Emission Factors and Estimation of Emissions

Printing facilities



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Topic 1 : Development of Emission Factors and Estimation of Emissions

Printing Facilities

VOCs emissions estimation method : mass balance

$$E_i = (I_i C_i + V_i D) \times A_i$$

E = VOCs emissions from printing facilities (kg VOCs/yr)
I = annual ink usage per facility or worker (kg/yr/facility or worker)
C = solvent content of ink (%)
V = annual solvent usage per facility or worker (L/yr/facility or worker)
D = density of solvent (kg/L)
A= activity data (total number of facilities or workers)
i = printing method.

Estimation of annual ink and solvent usage

- Obtained through site visitation and mail questionnaire survey

→ A total of 3,100 facilities were targeted and number of “valid” results was 137

Printing Facilities

Correlation between ink/solvent usage and number of workers

Printing Method		Annual ink usage	Annual solvent usage
Master Printing	r	0.179	0.18
	p	0.18	0.17
	N	59	59
Offset Lithography	r	0.788	0.713
	p	1.07E-11	4.47E-08
	N	44	44
Screen Printing	r	0.226	0.281
	p	0.38	0.28
	N	17	17
Rotogravure	r	0.854	0.889
	p	1.32E-05	1.80E-06
	N	17	17

- **Total number of workers was adopted as activity data for offset and rotogravure**
- **Total number of facilities was adopted as activity data for master and screen**

Printing Facilities

Estimation of solvent content of printing ink

- Obtained through laboratory evaporation experiment and literature

Typical parameter used in developing emission factor for printing facilities

Printing method	Solvent content of ink (%)	Annual ink usage (kg/yr)	Density of Solvent (kg/L)	Annual solvent usage (L/yr)
Master printing	37	287.9	0.879	130.6
Offset lithography	24	259.4	0.879	211.6
Screen printing	41	1,450.8	0.852	1,290.5
Rotogravure	63	3,266.7	0.867	2,751.8

VOCs emission factor for printing facilities w.r.t printing method

Printing method	Emission factors (This study)	Emission factor (CAPSS)
Master printing	499.6 (kg/yr/facility)	0.4 (kg/yr/cap)
Offset lithography	248.3 (kg/yr/worker)	
Screen printing	1,694.3 (kg/yr/facility)	
Rotogravure	4,443.8 (kg/yr/worker)	

Printing Facilities

VOCs emissions from printing facilities w.r.t printing method for 2001

Region	Master printing	Offset lithography	Screen printing	Rotogravure	Total
Seoul	1,651	2,826	888	1,898	7,236
Incheon	129	18	105	324	576
Gyunggi province	497	267	862	5,817	7,443
Seoul Metropolitan Area	2,277	3,110	1,855	8,039	15,282

CAPSS vs. This Study

Comparison of VOCs emissions (ton/yr, 2001)

Sources	CAPSS	This study	Difference
Dry cleaning	9,856	9,856	0
Metal degreasing	18,245	2,344	-15,901
Printing	45	15,282	15,237
Total	28,146	27,482	- 664

- Results of this study were already adopted in CAPSS
- Curtailment of activity data range and development of EF
- Correction of error in activity and development of EFs

Topic 2 : Estimation of Emissions Reduction Potential

Estimation of VOCs emissions for 2014

Dry cleaning facilities

- Using predicted activity data through linear regression analysis for 1995 ~ 2004

Metal degreasing and printing facilities

$$E_{future,\,s} = E_{base,\,s} \times G_s \times R_s$$

E_{future} = emissions in 2014 (ton/yr)
E_{base} = emissions in base year (base year is 2001; ton/yr)
G = growth factor (rate of energy demand increase)
R = regulation factor
s = source

Rate of energy demand increase

	Annual average increasing rate (%)	
	`02 ~ `10	`11 ~ `20
Assembly metal industry (for metal degreasing facilities)	3.9 ~ 4.7	3.1 ~ 3.7
Manufacturing industry (for printing facilities)	2.1 ~ 2.8	1.1 ~ 1.7

Topic 2 : Estimation of Emissions Reduction Potential

Estimation of VOCs emissions for 2014

Dry cleaning facilities

- Using predicted activity data through linear regression analysis from 1995 ~ 2004

Metal degreasing and printing facilities

$$E_{future,\,s} = E_{base,\,s} \times G_s \times R_s$$

E_{future} = emissions in 2014 (ton/yr)
E_{base} = emissions in base year (base year is 2001; ton/yr)
G = growth factor (the rate of energy demand increase)
R = regulation factor
s = source

VOCs emissions in 2001 and estimated VOCs emissions for 2014

	VOCs emissions in 2001	VOCs emissions for 2014
Dry cleaning	9,856	10,387
Metal degreasing	2,344	3,757 ~ 4,098
Printing	15,282	19,439 ~ 21,187

Source-Specific Emission Reduction Program and Its Effect

Source-specific emissions reduction program

- Obtained through literature analysis

Effect of source-specific emissions reduction program

- Estimated through modification of emission factors

Most appropriate source-specific emission reduction program and its effect

Source	Emissions reduction program	VOCs emissions for 2014 in SMA (tons)	
		Without program	With program
Dry cleaning	Installation of solvent recycling system	10,387	748 ~ 2,347
Metal degreasing	Replace solvent with water-soluble alternative	3,757 ~ 4,098	1,233 ~ 1,352
Printing	Reduction of VOC content in printing inks	19,439 ~ 21,187	12,851 ~ 15,451

Summary and Conclusion

- VOCs emission factors were developed and its emissions were estimated for certain sources in the solvent utilization category
  - VOCs emission factor is 610.4 kg/yr/facility for dry cleaning and 223.1 kg/yr/worker for metal degreasing
  - For printing facilities, emission factors developed w.r.t. printing method are 499.6 kg/yr/facility for master printing, 1,694.3 kg/yr/facility for screen printing, 248.3 kg/yr/worker for offset lithography and 4,443.8 kg/yr/worker for rotogravure
  - VOCs emissions were estimated to be 9,856 tons, 2,344 tons and 15,282 tons, respectively, for the above 3 categories in SMA for 2001
- Source-specific reduction program for these sources and its effect were also studied
  - VOCs emissions for 2014 are estimated to be 33,583 ~ 35,672 tons
  - The most appropriate reduction programs are deemed to be installation of solvent recycling system for dry cleaning, switching to water-soluble solvent for metal degreasing and reduction of VOCs content in printing ink for printing facilities
  - Reduction potential for these sources are estimated to be 16,522 ~ 18,751 tons

Future Work

- Development of VOCs emission factors and estimation of emissions from coating and consumer solvent categories
- Development of VOCs emission factors and estimation of emissions from manufacturing processes
- Finding duplicate and/or omitted sources
- Development of monthly allocation of VOCs emissions
- Speciation of source-specific VOCs emissions

Acknowledgement

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Thank you for your attention