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Estimation of VOCs Emissions from Small-Scale Surface Coating Facilities in Seoul

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Abstract

Purpose: VOCs (volatile organic compounds) are all the organic compounds that react with solar rays and increase the concentration of ozone in the troposphere and are partially also known as carcinogens. The adsorption using activated carbon is usually applied to remove VOCs. **Research design, data and methodology:** The 20 places of surface coating facilities were selected to evaluate the emission amount of VOCs in Seoul. In addition, the removal efficiency of VOCs in 25 places of automobile coating facilities was evaluated. **Results:** The average emission amount of VOCs was 10.903 kg/hr from automobile coating facilities, while 3.520 kg/hr from other surface coating facilities. The removal efficiency in adsorption with the combustion catalytic process has the mean value of 87.9% and the regeneration efficiency of activated carbon has the mean value of 95.0%. **Conclusions:** The removal efficiency in adsorption with the biofiltration process has the mean value of 89.8% and the regeneration efficiency of activated carbon has the mean value of 94.8%. The removal efficiency in the plasma catalyst process has the mean value of 79.3%.

Keywords : VOCs, Adsorption, Combustion Catalytic Oxidation, Biofiltration, Plasma Catalyst

JEL Classification Codes : I10, I30, I31

1. Introduction

Volatile Organic Compounds (VOCs) refer to organic compounds that increase surface ozone concentration by reacting with nitrogen oxides in the air by sunlight (WHO, 1989). In addition, most of the VOCs are highly volatile, so they are emitted in the form of steam and generate ozone by photochemical reactions. As a result, they not only cause smog in the city, but most of them cause carcinogenic substances and odors, adversely affecting human health (Baek, 1996).

The various VOCs are newly included in the subject of environmental regulation, and the substances that have been regulated so far are being further strengthened. Therefore, more effective and economical VOCs treatment technology is required, and the development of an efficient adsorbent regeneration process is becoming more necessary in terms of environment and economy.

This study aimed to identify the actual situation of VOCs emission generated from automobile coating facilities and other surface coating facilities, which were VOCs generating facilities in Seoul, and to identify the efficiency of the prevention facilities through the VOCs removal efficiency according to the treatment method of each newly improved VOCs prevention facility. In addition, we intended to provide basic data for Seoul's VOCs reduction measures by identifying the efficiency of facilities.

2. Materials and Methods

2.1. Target Facilities

This study was conducted on several types of surface coating facilities located in Seoul. Samples were collected from 1) 10 automobile coating facilities equipped with only conventional activated carbon filters, 2) 10 other surface coating facilities, and 3) automobile coating facilities registered as newly improved prevention facilities after the ordinance on air pollution emission standards was amended and promulgated.

The treatment methods for VOCs were largely divided into methods of recovering and reusing VOCs and methods of decomposing them (Korea Ministry of Environment, 2000). The installation and operation of a recovery facility would be efficient when the recovery value of the emitted VOCs was sufficient. However, it was appropriate to select a decomposition facility when VOCs were not a single substance but a mixture or hazardous substance or have no recovery value. Currently, VOCs prevention facilities installed in Seoul were selected as decomposition facilities.

In this study, the VOCs emissions of 20 small-scale surface coating facilities were first calculated. In addition, the efficiency of each prevention facility was analyzed for 13 activated carbon adsorption and combustion catalytic oxidation treatment methods, 7 adsorption and biofiltration treatment methods, and 5 plasma catalyst treatment methods among newly installed surface coating facilities in Seoul.

2.2. Sampling

The VOCs sampling in the activated carbon adsorption process was collected in the state of spraying with about 2L paint thinner in the surface coating facility. The samples were collected from the VOCs measurement port installed at the final outlet, the front and rear of the prevention facility corresponding to the primary treatment facility, and the front and rear of the VOCs recycle facilities by using a decompression sample handy sampler. Also, they were collected in Tedlar bags specified in the Official Test Method on Air Pollution for 10L containers.

2.3. Sample Analysis

After sampling, the concentration of BTEX was measured in the shortest time using a portable GC equipped with a PID detector, Photovac Voyager Portable GC (Perkin Elmer Co, USA), to ensure the accuracy of the sample. The calibration was performed using the VOCs standard gas sample based on toluene. In addition, the removal efficiency of VOCs was calculated by measuring the total hydrocarbon (THC) concentration with a portable measuring device, a flame ionization detector, Photovac Micro-FID (Photovac, USA).

3. Results & Discussion

3.1. VOCs Emission

In Korea's VOCs emission source and emission data, it was reported that the VOCs emission rate of the surface coating facilities occupied a considerable portion at 40.4%. Among the various types of surface coating facilities located in Seoul, automobile manufacturers and other manufacturers subject to management as air pollutant emission facilities used activated carbon filters as prevention facilities to reduce VOCs emissions, but still, a significant amount of VOCs was emitted into the atmosphere without being removed. The VOCs emissions from these facilities were also not accurately identified. Therefore, in this study, 10 automobile coating facilities and other surface coating facilities with poor VOCs prevention facilities were selected and VOCs emissions were calculated by using **Equation 1:**

$$VOCs\ emissions(ppm) = \sum VOCs \times gas\ flow\ rate \times 10^{-3} \quad (1)$$

where ΣVOCs is VOCs emission concentration for each component (mg/L), and gas flow rate is emission gas flow rate (Sm3/hr).

As shown in **Figure 1**, the VOCs emitted from automobile coating facilities ranged from 7.106 to 15.411 kg/hr, and the VOCs emitted from surface coating facilities in other surface coating facilities ranged from 0.142 to 8.989 kg/hr. The average emission from automobile coating facilities was 10.903 kg/hr. On the other hand, other surface coating facilities were found to be 3.220 kg/hr, about 3.4 times more VOCs emitted from automobile coating facilities (Choi, 2000).

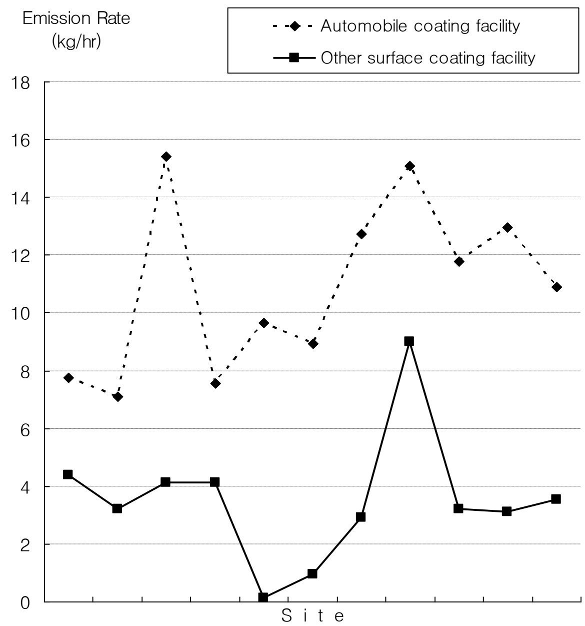

Figure 1: The Trends of VOCs Emission Amount from Automobile and Other Surface Coating Facilities

3.2. Treatment Efficiency According to VOCs Prevention Facilities

To calculate the VOCs removal efficiency at the surface coating facilities newly installed in Seoul, the THC concentration discharged from treatment according to the regeneration-processing method (activated carbon adsorption and combustion catalytic oxidation, activated carbon adsorption and adsorption with biofiltration, and plasma catalyst) was measured and the removal efficiency was also calculated. In the adsorption and combustion catalytic oxidation treatment method, VOCs emitted from surface coating facilities were adsorbed in the activated carbon adsorption facility, and in the catalytic incineration facility, which is an activated carbon regeneration facility, auxiliary fuel was mainly used for platinum catalyst, and heating and regeneration are performed at about 320 to 430 ℃ (Stenzel, 1993). This method has the advantage that the activated carbon can be used continuously without frequent replacement. The VOCs removal efficiency of this treatment method was shown in Table 1. The treatment and regeneration method proceeds according to an activated carbon adsorption and combustion catalytic oxidation regeneration method, an activated carbon adsorption and regeneration method using microorganisms, and a plasma catalyst method. Among them, in the combustion catalytic oxidation regeneration method, a method of heating and regenerating at about 320 to 430 ℃ was used in a catalytic incineration facility, which was an activated carbon regeneration facility, mainly using auxiliary fuel for a platinum catalyst.

Table 1: The Removal Efficiency of VOCs in Adsorption with Combustion Catalytic Oxidation

Site	Control technology			Regeneration technology		
	INLET (ppm)	OUTLET (ppm)	Removal efficiency (%)	INLET (ppm)	OUTLET (ppm)	Removal efficiency (%)
1	195.6	39.0	80.1	196.1	14.0	92.9
2	102.5	14.8	85.6	29.6	1.2	95.9
3	54.1	11.8	78.2	49.7	1.5	97.0
4	76.8	7.5	90.2	26.7	0.9	96.6
5	84.9	9.2	89.2	69.6	1.1	98.4
6	102.4	3.2	96.9	20.7	1.0	95.2
7	126.1	6.4	94.9	31.1	1.3	95.8
8	120.8	8.5	93.0	39.8	1.0	97.5
9	161.4	20.1	87.5	57.6	1.1	98.1
10	61.4	9.4	84.7	67.1	1.4	97.9
11	73.8	15.6	78.9	173.6	3.7	97.9
12	158.9	23.5	85.2	111.8	15.0	86.6
13	397.1	6.4	98.4	161.2	23.4	85.5

Table 2: The Removal Efficiency of VOCs in Adsorption with Biofiltration

Site	Control technology			Regeneration technology		
	INLET (ppm)	OUTLET (ppm)	Removal efficiency (%)	INLET (ppm)	OUTLET (ppm)	Removal efficiency (%)
14	199.4	3.0	98.5	492.5	37.3	92.4
15	146.3	6.6	95.5	898.2	0.6	99.9
16	175.7	29.5	83.2	24.2	2.0	91.7
17	145.2	13.6	90.6	720.9	10.3	98.6
18	134.1	7.4	94.5	79.3	8.1	89.8
19	185.0	33.2	82.1	309.5	15.1	95.1
20	153.3	24.6	84.0	727.3	26.0	96.4

The removal efficiency of VOCs by activated carbon adsorption was 78.2 to 98.4%, and the removal efficiency in the regeneration facility was 85.5 to 98.4%. The inside view of the regeneration facility was shown in **Figure 2**. In the adsorption and biofilter treatment method, the process was the same as the adsorption and combustion catalytic oxidation treatment method (Leson et al., 1991). The adsorption and microbial regeneration treatment method was the same as the adsorption and combustion catalytic oxidation treatment method, but only the desorbed VOCs were absorbed into the biofilm of the carrier, the absorbed pollutants were decomposed using microorganisms, and then discharged into the atmosphere. In addition, it has the advantage that activated carbon can be used continuously without frequent replacement, and the removal efficiency calculated in this facility was shown in **Table 2** and the inside view of the regeneration facility was shown in **Figure 3**.

Figure 2: The View of VOCs Control System with Combustion Catalytic Oxidation

Figure 3: The View of VOCs Control System with Biofiltration

As a result, the removal efficiency range of the prevention facility was 82.1 to 98.5%, and the removal efficiency range of the regeneration facility was 89.8 to 99.9%.

The **Table 3** showed the result of the removal efficiency of VOCs with a plasma catalyst treatment method, which has the advantage of being able to destroy explosive compounds at low temperatures, having a short residence time, and operating at low temperatures, but showing a rather low removal efficiency in the range of 49.6 to 97.0% depending on the conditions.

Table 3: The Removal Efficiency of VOCs with Plasma Catalyst

Site	Control technology		
	INLET (ppm)	OUTLET (ppm)	Removal efficiency(%)
21	302.6	10.1	96.7
22	394.2	12.0	97.0
23	54.1	11.6	78.6
24	113.6	57.2	49.6
25	58.6	14.9	74.6

The trends of the 3 representative treatment methods installed in surface coating facilities in Seoul were shown in **Figure 4**, and it could be seen through the figure that the efficiency of the plasma treatment method was low, while the treatment efficiency of the adsorption combustion catalyst method and the adsorption biofilter treatment method was stable.

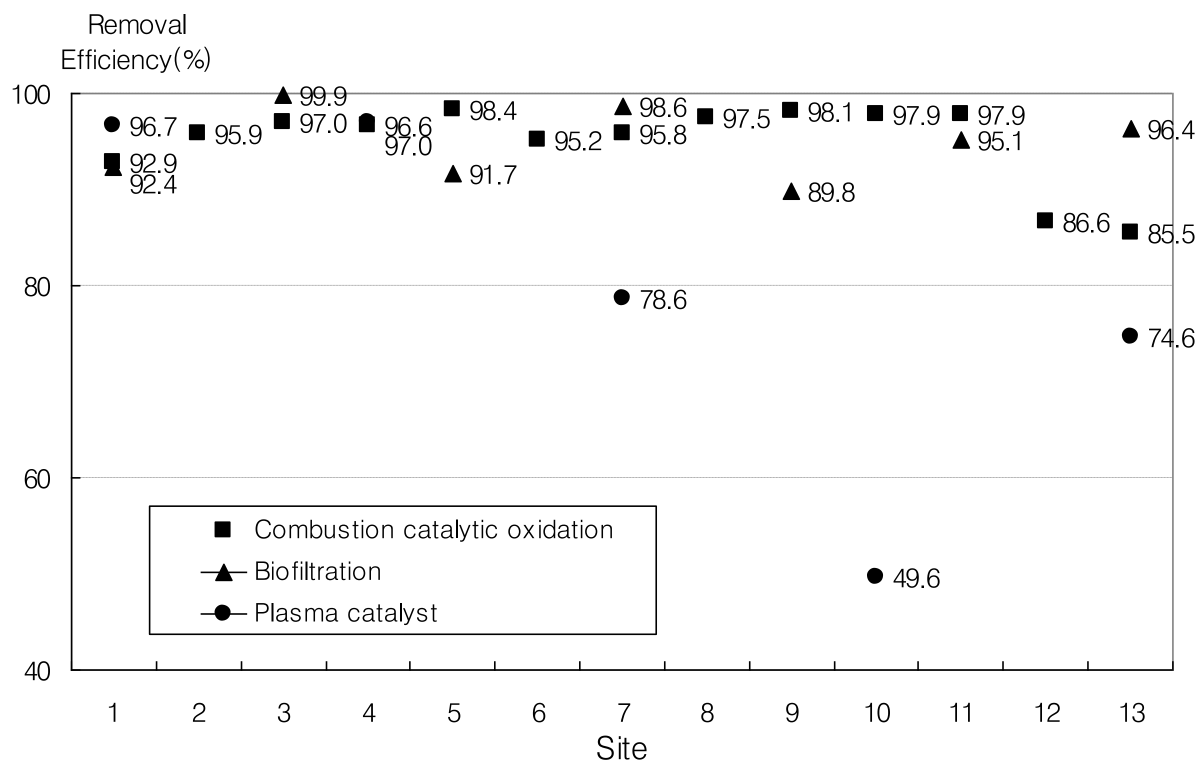

Figure 4: The Removal Efficiency of Various VOCs Regeneration Systems at Automobile Coating Facilities

4. Conclusion

The results of calculating the efficiency by measuring the VOCs emission from automobile coating facilities in Seoul and other surface coating facilities were shown in this study. In addition, the concentration of VOCs before and after the improvement of the prevention facility was measured, and the results of calculating the efficiency were as follows.

1. The annual average emission of VOCs from automobile coating facilities was 10.903 kg/hr, which was about 3.4 times higher than that of 3.520 kg/hr from other surface coating facilities.

2. In the activated carbon adsorption-combustion catalytic oxidation method with the addition of a regeneration facility, the activated carbon adsorption capacity was 87.9% on average and the regeneration capacity was 95.0% on average.

3. In addition, the activated carbon adsorption-microbial treatment method showed an average of 89.8% in activated carbon adsorption capacity slightly higher than the combustion catalytic oxidation method, and a regeneration capacity of 94.8%, which was similar to that of the combustion catalyst method.

4. The plasma catalyst method was easy to manage because there was no activated carbon, but the treatment capacity was 79.3% on average, which was slightly lower than other methods.

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