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Removal of VOC from waste gas by an oil scrubber

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Removal of VOC from waste gas by an oil scrubber and the aqua clean system using oil instead of water was studied. Toluene, trichloroethylene and ethanol were used as VOCs. Soy bean oil, rape seed oil, high vacuum oil and turbo oil were used as oils. For comparison with VOC-oil system, ethanol – water system was also studied. VOC from waste gas was well removed by oil scrubber and the aqua clean system.

1. Introduction

Recently much attention has been paid to environment. Volatile organic compound (VOC) is used in many industries. In order to keep clean environment, VOC must be removed from waste gas. There are many methods for VOC treatment such as adsorption (Bandosz 2008, Zhao et al. 1998), combustion (Gervasini et al. 1996) and decomposition by ozone and electric discharge (Chang and Chang 2004). VOC can't be recycled by combustion and decomposition. The active carbon and zeolite are often used for adsorption of VOC. The active carbon and zeolite are good in the ability for adsorption of VOC, but they adsorb only little quantity of VOC. Therefore, the active carbon and zeolite are not suitable for removal of high concentration of VOC. It is expected that the oil scrubber can absorb high concentration of VOC and that VOC absorbed can be recycled. Moreover, it is expected that waste plant oil from homes can be used as an oil for the oil scrubber. Nippon SC developed the aqua clean system for treatment of smoke and exhaust gas from large kitchens of restaurants. The aqua clean system is an efficient water scrubber and is used to clean up smoke and exhaust gas from kitchens. In this work, removal of VOC from waste gas by oil scrubbers and the aqua clean system using plant oil instead of water was studied and the results were analyzed and discussed.

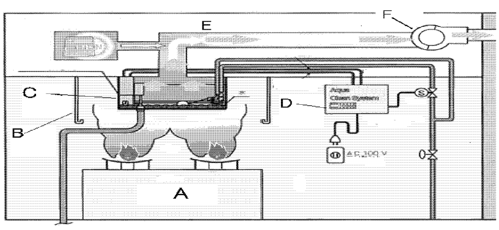

Fig.1 The aqua clean system in a kitchen.
A = range, B = hood, C = water scrubber,
D = water controller, E = duct, F = blower

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2. The aqua clean system

Fig.1 shows a schematic diagram of the aqua clean system in the kitchen. The smoke from the range A is sucked into the water scrubber C and cleaned up. The aqua clean system can eliminate possibility of fire and remove bad fume and mists, because of use of water.

3. Experimental

Fig.2 shows a schematic diagram of the 3- stage oil scrubber. In Fig.2, A means air flow meter. B means vaporizer of VOC. C means oil scrubber. D and E mean gas sampling point at inlet and outlet of the oil scrubber, respectively. The scrubbers are made of $1 dm^3$ messcylinder. Air at room temperature was used as a gas. Toluene, trichloroethylene and ethanol were used as VOCs. The concentration of VOC in the air was measured by FID or a handy VOC sensor (VOC-201H produced by Iable - Biott). Salad oil, rape seed oil, high vacuum oil and turbo oil were used as oils.

Fig.3 shows a schematic diagram of the aqua clean system used in this experiment. The dimension of the apparatus used was 65cm W x 60cm D x 100cm H. A means vaporizer of VOC. B means oil scrubber. C means filter. D means blower. The maximum flow rate of air is $13.1 m^3 / min$. The air which contained toluene was sucked into the shallow (about 7cm deep) salad oil bath B from the bottom of the oil scrubber by the blower. In the oil bath the air stirred up the oil like a shallow bubble column at large gas velocity and toluene was absorbed into the oil. All experiments were done at room temperature. The experimental conditions were Q_G = 9.4 – 12.5

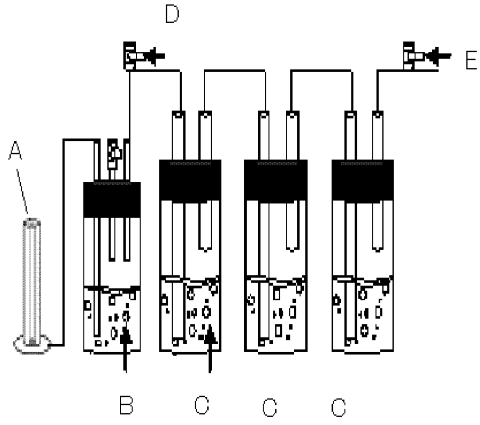

Fig.2 The 3-stage oil scrubber

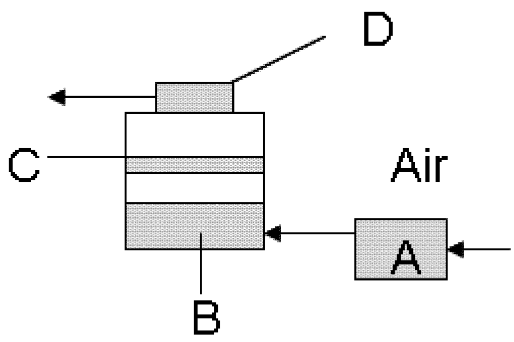

Fig.3 The aqua clean system used

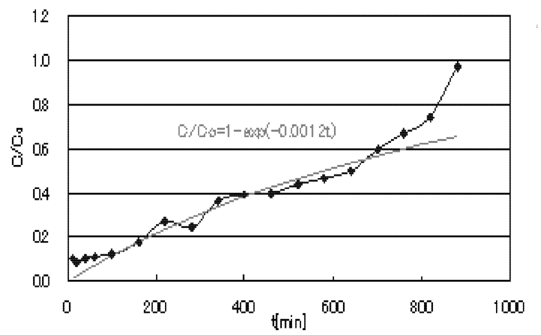

Fig.4 Toluene - soy bean waste oil system

m^3/min, C_o=120-700 ppm and V_{oil} =16-22 dm^3. The depth of clear oil in the oil scrubber is in the range of 65 - 80mm. Q_G means flow rate of air. C_o and C mean concentration of VOC at inlet and outlet of the oil scrubber, respectively. V_{oil} means volume of oil. ppm means 10^{-6} mole fraction.

4. Experimental results and discussions

4.1 Toluene system

Fig.4 shows C / C_o for toluene-soy bean waste oil system by the 1-stage oil scrubber. The experimental conditions are Q_G = 1.5 L/min, C_o = 11100 ppm and V_{oil} = 570 mL. C / C_o increased with time.

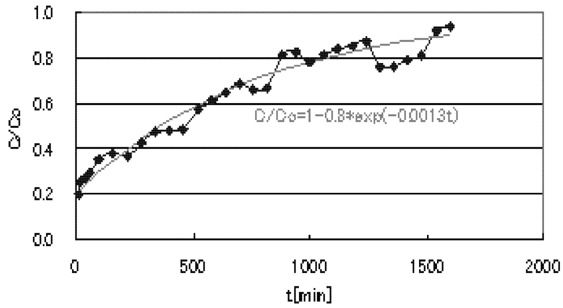

Fig.5 Toluene - high vacuum oil system by the 1-stage scrubber

Fig. 5 shows C / C_o for toluene-high vacuum oil system. C also increased with time. The experimental conditions are Q_G = 1.5L/min, C_o = 26300 ppm and V_{oil} = 570 mL. C increased with t.

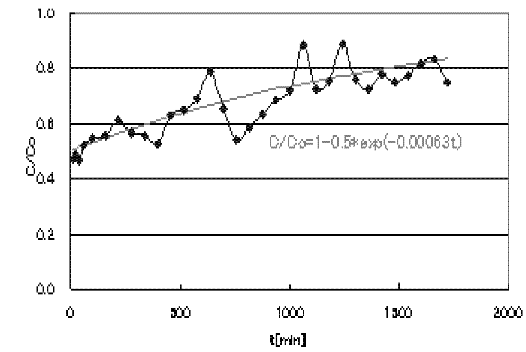

Fig.6 Toluene-regenerated high vacuum oil

Fig.6 shows C / C_o for toluene-regenerated high vacuum oil. The experimental conditions are Q_G=1.5 L/min, C_o= 25900 ppm and V_{oil}=560 mL. Removal of Toluene became worse than that by new oil.

Fig.7 shows C / C_o for toluene- rape seed oil system. The experimental conditions are Q_G = 4 L/min, C_o = 2124 ppm, V_{oil} = 1524 mL and the 3-stage oil scrubber. C/C_o was very low till at t = 1000min. After at t = 1000 min, C/C_o increased rapidly with t.

Fig.8 shows C / C_o for toluene-turbo oil system by the 2-stage scrubber. The experimental conditions are Q_G = 4 L / min, C_o = 6883 ppm and V_{oil} = 1242 mL. C / C_o increased with t.

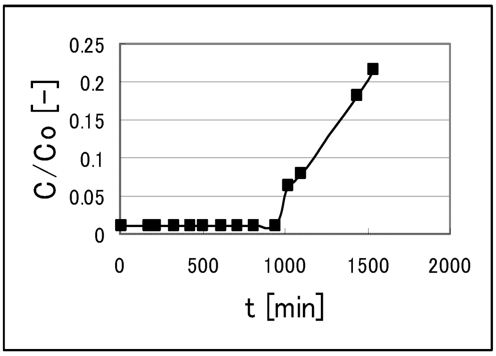

Fig.7 Toluene-rape sedd oil system by the 3-stage oil scrubber

4.2 Trichloroethylene - soy bean oil system

Fig.9 shows C / C_o for the 1- stage trichloroethylene - soy bean oil system. The experimental conditions are Q_G = 5 L/m, C_o = 211.3 ppm and V_{oil} =540 mL. C / C_o was nearly 20-30% till at 200 min and then increased rapidly with t.

Fig.10 shows C / C_o vs. t for the 3-stage trichloroethylene-soy bean oil system. The experimental conditions are Q_G=5 L/m, V_{oil}=1590 mL and C_o = 307.5 ppm. C/C_o was very low till at t = 260 min and increased rapidly with time.

Fig.11shows volume V of liquid (= oil + trichloroethylene) in the oil scrubber. The experimental conditions are the same as those in Fig.10.

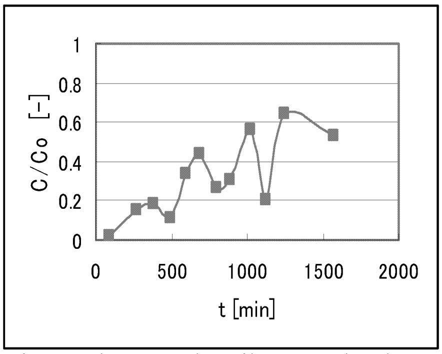

Fig.8 Toluene-turbo oil system by the 2 – stage oil scrubber

4.3 Ethanol – water system

For comparison with VOC-oil system, ethanol-water system was studied. Fig.12 shows C / C_o for the 1- stage ethanol - water system. The experimental conditions are Q_G = 5 L/m, C_o = 211.3 ppm and V_{oil} =540 mL. C / C_o was nearly 15 % till at 1000 min and then increased rapidly with t. Fig.13 shows V vs. t. V increased with time. V means volume of (ethanol+ water).

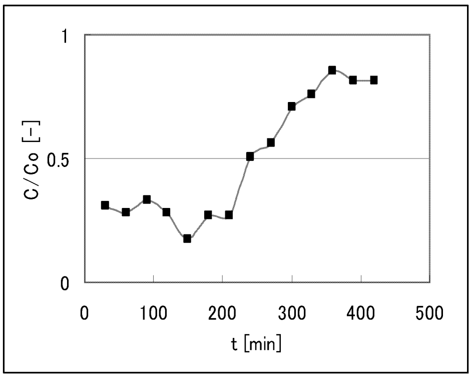

Fig.9 Trichloroethylene-soy bean oil by the 1-stage oil scrubber

4.4 Removal of toluene by the aqua clean system

Figs.14 and 15 show examples of the results. The horizontal axis means run number. The vertical axis means C [ppm]. Fig.14 shows the results for C_{in}=about 200ppm, H_{oil}=65mm, Q_G = 10.5 m^3 / min. The removal efficiency R was 40-41%.

Fig.15 shows the results for C_{in}=650-680ppm, H_{oil}=65mm, Q_G=10.5m^3/min and R=51-53%. The removal efficiency of toluene is not so large. The reason why the removal efficiency is not so large may be because air flow rate is too large and oil scrubber is too shallow (60-80mm).

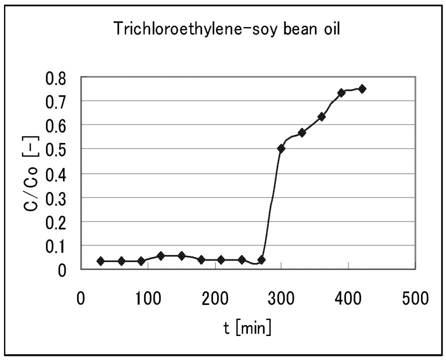

Fig.10 Trichloroethylene-soy bean oil by the 3-stage oil scrubber

Conclusion

1) Removal efficiency by the 3-stage oil scrubber was much larger than that by the 1-stage oil scrubber.
2) Removal efficiency was very large till at the critical time, however, after the critical time, the removal efficiency decreased.
3) Removal efficiency of toluene by the aqua clean system was nearly 50%.

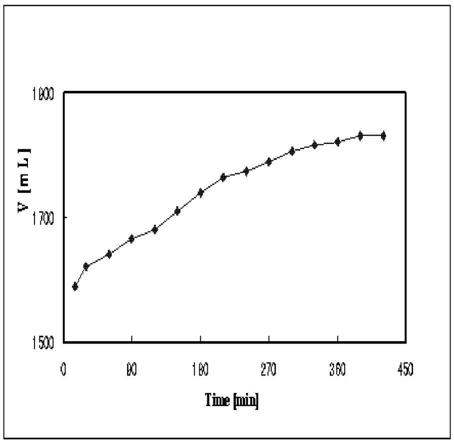

Fig.11 V vs. t for trichloroethylene-soy bean oil by the 3-stage oil scrubber Q_G=5 L/m, V_{oil}=1590 mL and C_o = 307.5ppm

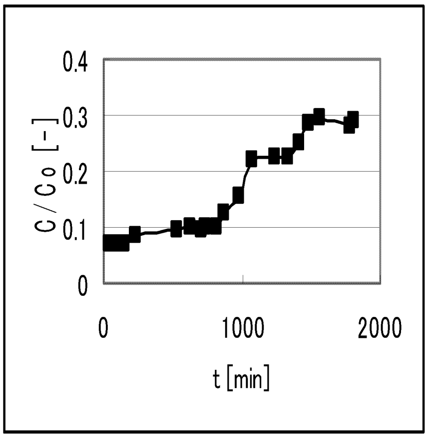

Fig.12 Ethanol – water system Q_G = 5 L/m, C_o = 211.3 ppm and V_{oil} =540 mL.

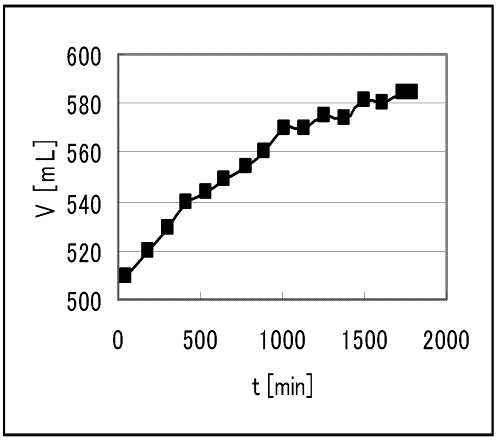

Fig.13 V vs. t for ethanol – water system The experimental conditions are the same as those in Fig.12.

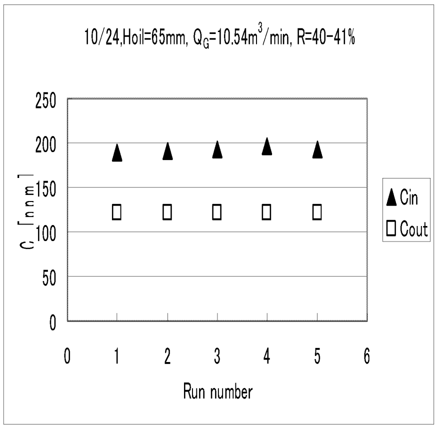

Fig.14 C vs. t for toluene – salad oil system by the aqua clean system. C_{in}=about 200ppm, H_{oil}=65mm, Q_G = 10.5 m^3 / min.

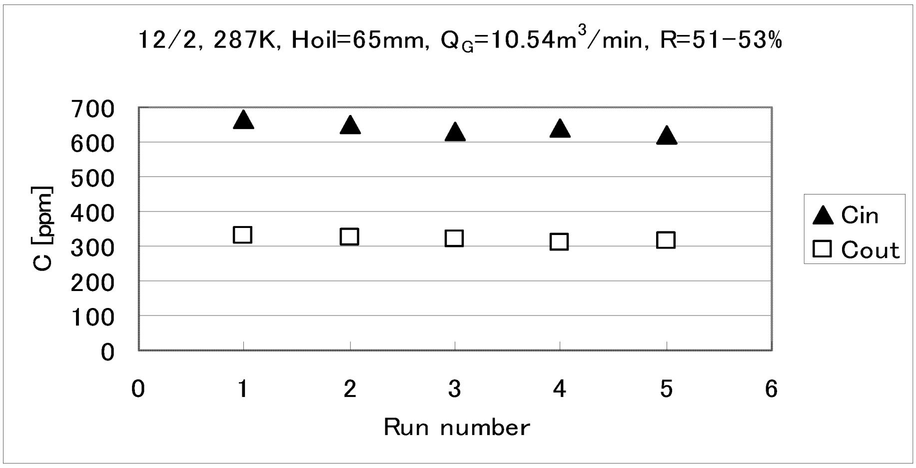

Fig.15 C vs. t for toluene – salad oil system by the aqua clean system.

Nomenclature

C = concentration of VOC in the air at outlet of oil scrubber or concentration [ppm]
C_o = concentration of VOC in the air at inlet of oil scrubber [ppm]
C_{in} = concentration of VOC in the air at inlet of oil scrubber [ppm]
C_{out} = concentration of VOC in the air at outlet of oil scrubber [ppm]
H_{oil} = depth of oil scrubber [cm]
Q_G = gas flow rate [L/min]
R = removal efficiency defined by $(1-C_{out}/C_{in})$ [-]
t = time [min]
V = volume [mL]
V_{oil} = volume of oil [mL]

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