Estimation of VOC emission factors of gasoline car

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ABSTRACT

In this study, we estimate benzene, toluene, ethyl benzene, m,p-xylene and o-xylene emission factor from different 30 cars by using simple sampling equipment. Considering the effect of cold start, the benzene emission factor was estimated. Comparing with the emission factor in a few decades ago, the emission factor in 2008 drastically decreased.

KEYWORDS

VOC emissions, emission factor, cold start, hot start

INTRODUCTION

Air pollutions by suspended particle matter and photochemical oxidant are improved compared with a few decades ago in Japan. But the effects for human health and ecosystem by air pollutions are still concerned. One of the air pollution concerned is VOC (volatile organic compound) into exhaust gas from cars. Generally VOC amounts in exhaust gas are measured by a chassis dynamometer. But it was reported that VOC amounts in real car running were considerably different from the measurement by a chassis dynamometer[1)]. A few measurements of VOC amounts in real car running were performed. We measured VOC amounts of different 30 cars in real car running by using the gas sampling equipment, and estimated the emission factor of benzene, toluene, ethyl benzene, m,p-xylene and o-xylene

GAS SAMPLING EQUIPMENT

The outline of the gas sampling equipment is shown in Fig.1. The gas sampling equipment consists of sampling needle, Drain separator, sampling tube and pump. Each part is connected by Teflon tube. The sampling needle is inserted into tail pipe of the cars. The drain separator absorbs water vapor of exhaust gas for using centrifugal force. The sampling tube is made of stainless steel and its inner radius is 11.5mm. Activated carbon of 1 g, which size is from 500 μm to 840 μm is filled up in the sampling tube. The sampling needle is inserted into tail pipe and exhaust gas is sucked by the pump. The flow rate is 3.5ml/min. Then several VOC components are analyzed by

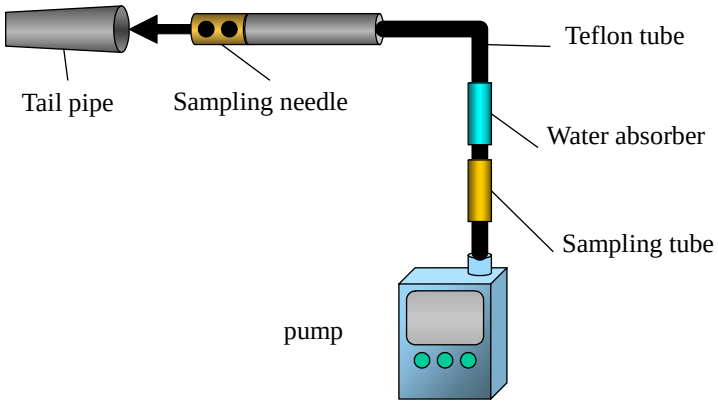

Fig.1 Outline of portable gas sampling equipment

GC/MS. VOC components analyzed are benzene, toluene, ethyl benzene, o-xylene, and m, p-xylene.

MEASUREMENTS

The gas sample equipment is installed as shown in Fig.2. In this measurement, 30 different cars were used. The measurements were performed in cooperators' commutation. Each sampling time was different but was about 20 minutes. In the measurement, the pump was run when a car stopped by a signal, but pump was stopped at a traffic jam. After finishing the measurement, the both sides of the sampling tube were wrapped by sealed tape.

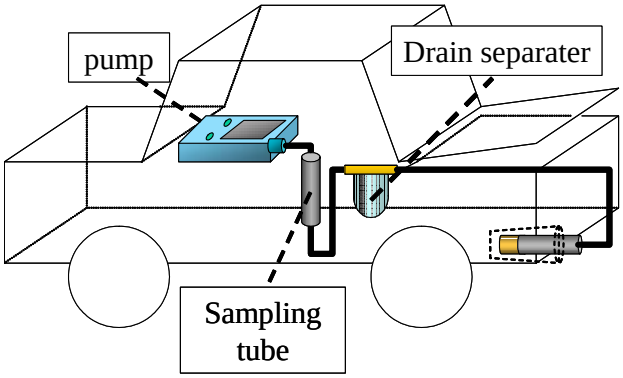

Fig.2 Installation of gas sampling equipment

VOC absorbed by activated carbon in sampling tube was extracted by carbon disulfide from activated carbon and was analyzed by GC/MS. Emission factors were determined by equations (1), (2), and (3).

$$C = \frac{cvd}{qt} \quad (1)$$

$$Q = CV\Omega \quad (2)$$

$$E_0 = \frac{Q}{2L} \quad (3)$$

where C is VOC concentration in exhaust gas (ml/L), c is VOC concentration in analyzed liquid solution (ppm), d is density of VOC (g/cm3), v is volume of analyzed liquid solution(ml), q is sampling flow (l/min), t is sampling time (min), Q is VOC emission(mg), V is volume of aerodynamic volume displacement (L/r), Ω is engine rotations (r/min), L is mileage (km), and E_0 is emission factor(mg/km).

RESULTS

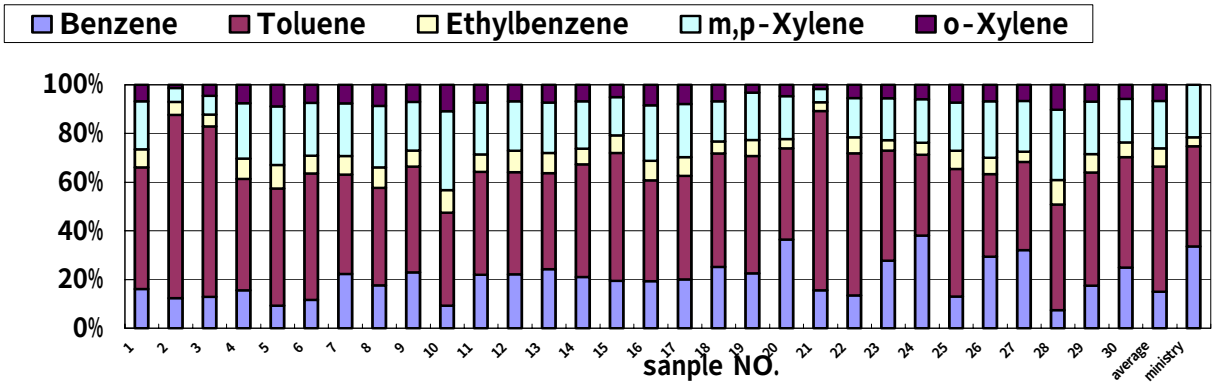

Fig.3 The constitution of VOC for each measurement

The constitution of VOC for each measurement is shown in Fig.3. Each constitution is almost same as Ministry of Environment data.

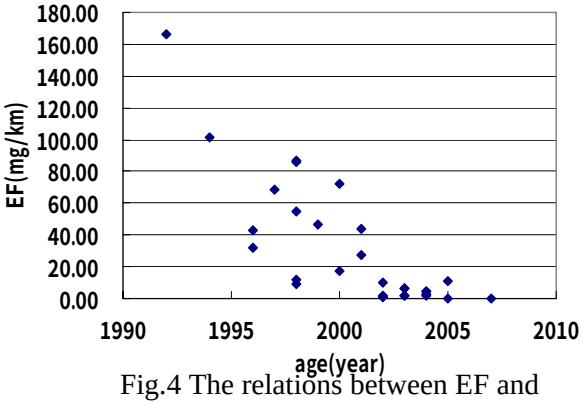

Fig.4 The relations between EF and car age for benzene

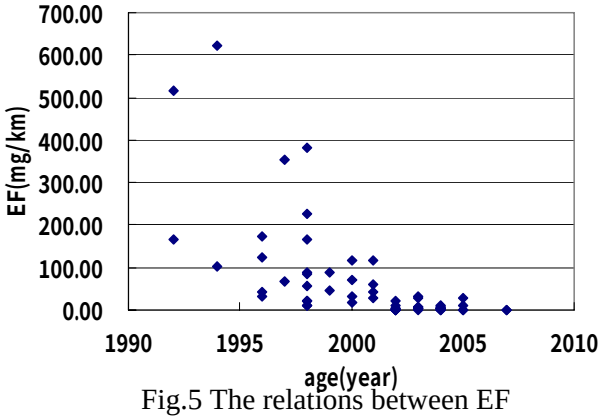

Fig.5 The relations between EF and car age for toluene

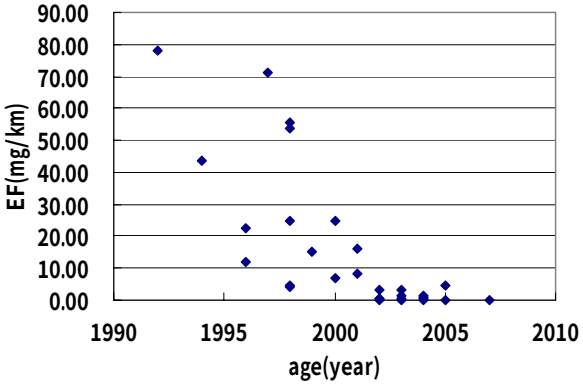

Fig.6 The relation between EF and car age for ethylbenzene

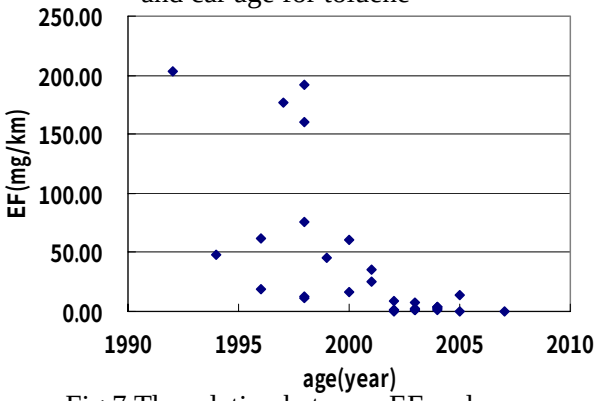

Fig.7 The relation between EF and car age for m,p-xylene

The relations between emission factor and car age for benzene, toluene, ethyl benzene, m,p-xylene, and o- xylene are shown in Fig.4, Fig.5, Fig.6, Fig.7, and Fig.8. From these results, VOC emission factors obviously depend on car age. After 2004, emission factors became close to 0. But the emission factor in 1980s were about 100 times higher than in 2005.The number of the samplings was only 30 and the values varied widely. However it was enough to estimate the emission factors in the future. In order to estimate the average emission factors in any year, the ratio of the number of car age must be considered. The accumulated ratio of car age in 2005 is shown in Fig.9. In order to estimate the emission factors in the future, it was assumed that the distribution of Fig.9 didn't change throughout the future.

VOC emissions of cold start (when engine is not warmed) are larger than hot start. It was reasonable that the driving start presumed cold start. If cold start was until the initial 4km from the driving start, the emission factors in hot start were expressed by

$$E = \frac{LE_0}{L + 4(r_c - 1)} \qquad (4)$$

$$\Delta_c = 4(r_c - 1)E \qquad (5)$$

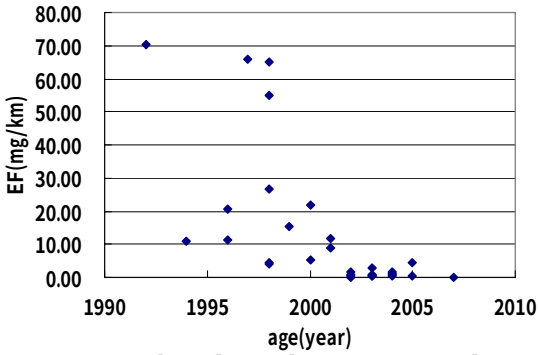

Fig.8 The relation between EF and car age for o-xylene

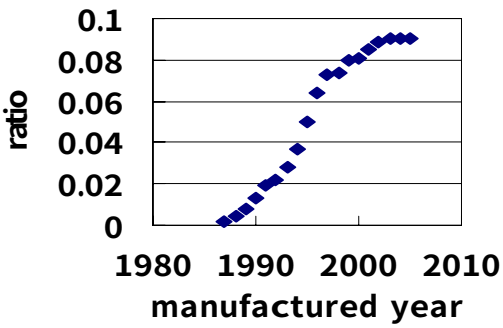

Fig.9 The ratio of the number of the car(2005)

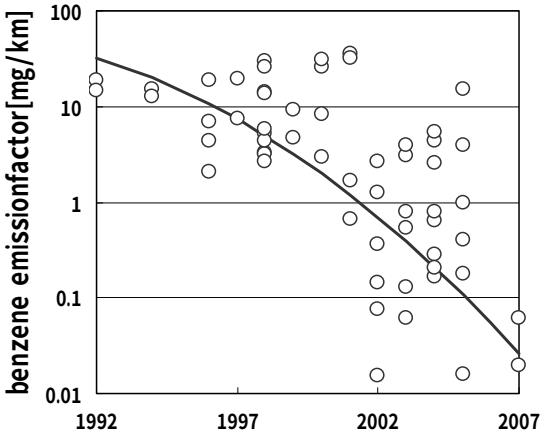

Fig.10 benzene emission factor(hot start)

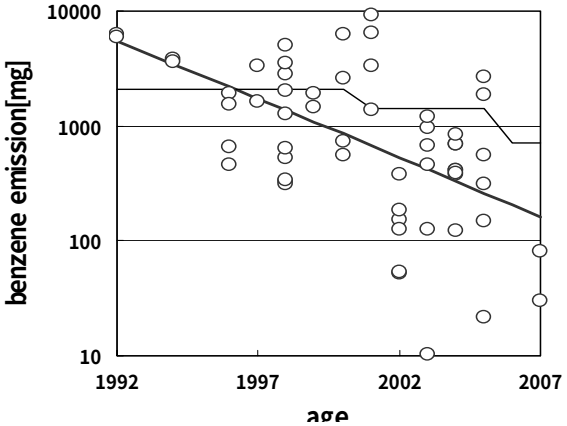

Fig.11 benzene emissions at cold start

where E is emission factor at hot start (mg/km), r_c is emission ratio between cold start and hot start until the initial 4km and Δ_c is amounts increased by cold start. Fig. 10 shows the emission factor at hot start for benzene. Fig. 11 shows the benzene emission amount increased by cold start. It was found that the emission factor and the benzene emission of new cars drastically decreased.
Next, the emission factor for benzene was estimated varying the ratio of car of cold start as shown in Fig.11. Shi[2)] reported that benzene emission factor of gasoline car was 12.3 mg/km in 2002. From Fig.11, this emission factor corresponded with the ratio of 2% and the benzene emission factor in 2008 was 3 mg/km. It was suggested that the decrease of benzene addition into gasoline and the regulation of exhaust gas induced the decrease of the emission factor.

CONCLUSIONS

We measured VOC amounts of different 30 cars in real car running by using the gas sampling equipment and obtained the emission factor for benzene, toluene, ethyl benzene, m,p-xylene and o-xylene. The emission factor were strongly depends on car age. Considering the effect of cold start, the benzene emission factor was estimated. It was found that the emission factor and the benzene emission of new cars drastically decreased. The emission factor for benzene was estimated varying the ratio of car of cold start. From the emission factor in 2002, it was found that this ratio was 2%. It was suggested that the decrease of benzene addition into gasoline and the regulation of exhaust gas induced the decrease of the emission factor.

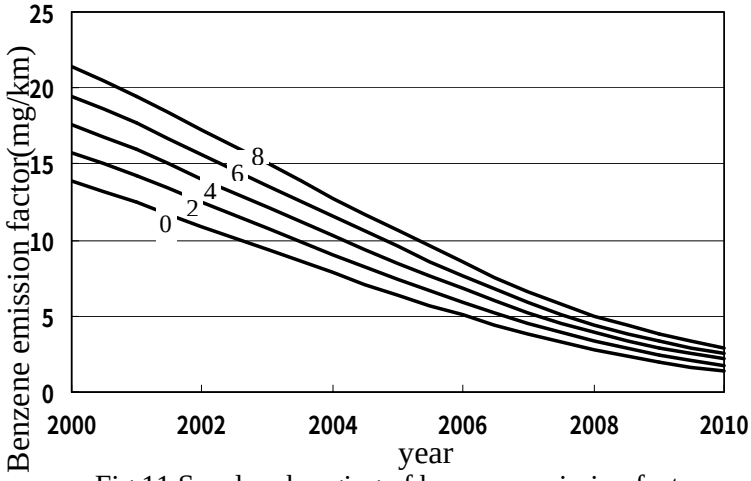

Fig.11 Secular changing of benzene emission factor

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