한국대기환경학회 2000 추계학술대회 논문집
Proceeding of the 31st Meeting of KOSAE (2000)
Korean Society for Atmospheric Environment

BA5) 터널 측정을 통한 비메탄계 탄화수소의 자동차 배출계수 산정

Determination of vehicle emission factor of NMHC from a tunnel study

나광삼[ab] · 김용표[c] · 김영성[a] · 문일[b]
[a]한국과학기술연구원 지구환경연구센터, [b]연세대학교 화학공학과,
[c]이화여자대학교 환경공학과

Introduction

The vehicle emissions of primary air pollutants are described by the emission factor (EF), defined as the emitted mass (g) of a compound per distance (km) and vehicle. The EF can be determined by exhaust measurements from single vehicles in dynamometric tests. However, the EF of a large number of vehicles has to be measured to obtain the representative results for actual road traffic emissions. Road traffic emissions can also be determined by exhaust measurements of driving vehicles or in tunnel measurements. The compositions of the hydrocarbon species in the tunnel air are broadly representative of a large number of vehicles and fuel types used in urban areas. Additionally, tunnel measurements have the advantage of quickly obtaining composite samples (Na and Kim, 2000a). Taking into account the strong points, we chose tunnel measurements in this study.

The present study was carried out in the Sangdo tunnel. Since this tunnel is located in Seoul, the capital of Korea, this measurement is expected to help further understanding of the characteristics of vehicle emissions in urban area. The main purpose is the measurement of EF of a large number of individual volatile organic compounds in Seoul. The EF was calculated for the total vehicle classes without any classification of vehicles. Here we described the results of the EF calculated from 10 hourly samples. We further compared the results of the speciation of organic exhaust emissions with results from the previous tunnel study conducted during the wintertime.

Experimental

The measurements were performed from 29 to 31 May 2000. The tunnel is a two-bore tunnel with two-lanes per bore, 566 m long, 9 m wide, and 7 m high. The cross sectional area of the tunnel is 57 m^2 and volume of the tunnel inside is 32,400 m^3. The tunnel has a slight upgrade at the entrance and a slight downgrade at the exit. The tunnel is located in Sangdo village and connected with Han River Bridge. Heavy traffic usually begins at 07:30 am and continue to 08:30 am. The composition and number of vehicles passing through the tunnel were determined by direct counting. A total of 6,076 vehicles were counted during the study period. The traffic counts were split into four classes: 62.8% were identified as gasoline-fueled vehicles, 24.0% of diesel-fueled vehicles, 11.6% of butane-fueled vehicles, and 1.7% of gasoline-fueled motorcycles. This composition is in good agreement with the data of vehicle registration in Seoul. Grab sampling were conducted by use of 6 L SUMMA polished stainless steel canister under high vacuum of 10^{-4} Torr. Sampling runs of 30 min duration were conducted simultaneously between 07:00 am and 08:30 am at the entry and the exit site. During this time period, passing vehicles experienced various driving conditions with start, moving, and stop. The entry site is 50 m from the tunnel entrance. The sampling sites were separated by a distance of 250 m. Total ten samples were collected for the two sites. The range of sampling time was chosen to represent mixed characteristics of various driving conditions. Sampling position is 1.8 and 2.0 m from the ground level and passing vehicles. Air speed in the tunnel was monitored by a portable anemometer at the sampling site 200 m away from the entrance to the tunnel. The analytical methodology has been outlined previously (Na and Kim, 2000b).

Emission factors for traffic within a tunnel can be calculated per unit of fuel consumed or per vehicle-mile-traveled (Fraser et al., 1998). To determine the mass of a constituent i produced by passing vehicles in the tunnel, we assumed that an element volume of the tunnel is a steady-state plug flow reactor (PFR). The mass balance on the control volume can be written in this form:

[accumulation]=[input]-[output]+[generation by passing vehicles]-[loss by reaction]

or

$$V\frac{dC_i}{dt} = C_{i,in}\nu_{in} - (C_{i,in}\nu_{in} + d(C_i\nu)) + (r_{i,generation}dV) - (r_{i,loss}dV) \quad (1)$$

If steady state is assumed, accumulation term can be set to zero. Since photochemical activity is not active in the early morning, the term of loss by reaction can be neglected. Hence, eq. (1) can be reduced to

$$r_{i,generation}\,dV = d(C_i\nu) \quad (2)$$

If eq. (2) is integrated under the condition of consistent volumetric rate, we can finally obtain

$$M_{i,generation} = \nu t(C_{i,out} - C_{i,in}) \quad (3)$$

Here, M_i is a mass of a compound i produced by passing vehicles in mg, C is a concentration in mg m^3, ν is volumetric flow rate of tunnel air in m^3 s^{-1}, and t is total sampling time in second. Given the traffic count N (number of vehicles) and distance L between sampling sites), one can obtain an emission rate E_i in mg veh-kilometer for a species i of interest:

$$E_i = \frac{M_i}{NL} \quad (4)$$

Results and discussion

Emission factors are highly variable over the study period, with an average reproducibility for total NMHC of 50.1%. The emission factors of NMHC are generally comparable to those of Thiais (Tousty and Bonsang, 2000) and Fort McHenry tunnels, but higher by about a factor of 2 in the Tuscarora tunnel (Sagebiel et al., 1996). The emission factor of n-butane is the highest value measured at 89.8 mg veh-mile, followed by ethylene which is emitted at a rate of 50.1 mg veh-mile^{-1}, and toluene of 50.0 mg veh-mile^{-1}. Note that isoprene, the main compound emitted from biogenic source, is 1.1 mg veh-mile^{-1} of emission factor. Fort McHenry and Tuscarora tunnels also released at the same order of magnitude. It shows that isoprene is a little bit produced by combustion of vehicle fuels.

Fig. 1 shows the effects of vehicle speeds on emission factor. A global decrease of the total NMHC emission factor with increasing vehicle speed during the experiment was found, with a minimum emission rate for the maximum average speed (~60 km h^{-1}) through the tunnel which was measured when traffic density was light. This trend has already been observed from the previous study by Na and Kim (2000b). Additionally, our result was consistent with that of Touaty and Bonsang (2000). However, this finding will need further measurements with more detailed vehicle speeds and distributions in order to be more clearly parametrized.

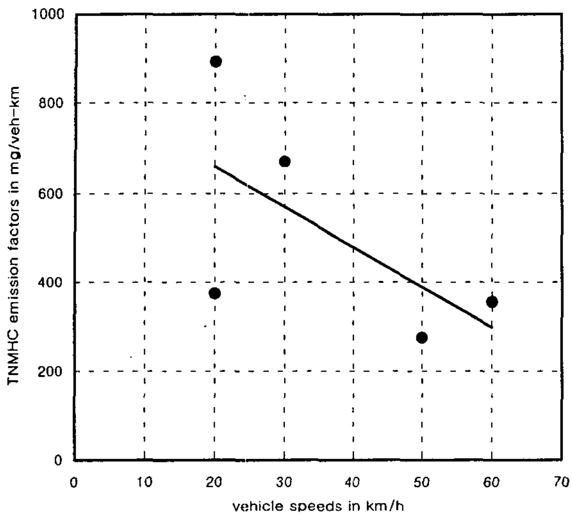

Fig. 1. Influence of vehicle speeds on emission factors of total non-methane hydrocarbon.

Reference

Fraser, M. P., G. R. Cass, and B. R. T. Simoneit (1998) Gas-phase and particle-phase organic co emitted from motor vehicle traffic in a Los Angels roadway tunnel. Environ. Sci. Technol. 32, 205

Na, K. and Y. P. Kim (2000a) Non-methane hydrocarbon concentrations in a traffic tunnel in Seoul of Korean Society for Atmospheric Environment (submitted).

Na, K. and Y. P. Kim (2000b) Seasonal characteristics of ambient volatile organic compounds in Atmos. Environ. (accepted).

Sagebiel, J., B. Zielinska, W. R. Pierson, and A. W. Gertler (1996) Real-world emissions and ca reactivities of organic species from motor vehicles. Atmos. Environ. 18(12), 79-87.

Touaty, M. and B. Bonsang (2000). Hydrocarbon emissions in a highway tunnel in the Paris area Environ. 34, 985-996.