Emissions of PAHs and mutagenicities in PM$_{2.5}$ from motorcycles

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Abstract

In this study, PM$_{2.5}$ (particulate matter with aerodynamic diameter less than 2.5 μm) for two kinds of motorcycles (carburetor and fuel injection types) are collected from diluted exhausts. The emission characteristics of PM$_{2.5}$-associated polycyclic aromatic hydrocarbons (PAHs) and mutagenicities are investigated. The organic extracts of PM$_{2.5}$ are tested for mutagenicity using the Ames assay test with TA100 strain of Salmonella typhimurium and studies are performed both with and without metabolic activation to account for direct and indirect acting mutagens. PAHs are analyzed by gas chromatograph/mass spectrometer. The measured mutagenicity emission factors, i.e. number of revertants per kilometer (rev/km) with metabolic activation for the new fuel injection, used fuel injection, new carburetor and used carburetor motorcycles are 78 × 10$^{3}$, 118 × 10$^{3}$, 132 × 10$^{3}$ and 115 × 10$^{3}$ rev/km, respectively. The mutagenicity emission factors with metabolic activation are higher than the corresponding values without metabolic activation as expected. The average PAH emission factors are 12.3, 16.3, 25.5 and 26.5 μg/km for the new fuel injection, used fuel injection, new carburetor and used carburetor motorcycles, respectively. The trends are similar for mutagenicity and PAH emission factors and the new fuel injection motorcycle has the lowest mutagenicity and PAH emission factors. The correlation coefficients between PAHs and mutagenicity emission factors are higher with metabolic activation (0.59) than that without metabolic activation (0.31).

Introduction

There is an increased concern about human exposure to air particulate matter (PM) originating from vehicle traffic. Combustion processes in vehicle engines produce a wide variety of PM in urban areas, and are a significant source of particles with diameters smaller than 2.5 μm (PM$_{2.5}$) (Lightthly et al., 2000). Motor vehicles are also a significant emission source of polycyclic aromatic hydrocarbons (PAHs). Some PAHs are potential mutagens and carcinogens, and are probably a significant cause of cancer.

Numerous studies have been conducted on PM and PAH emissions for diesel vehicles. However, only limited studies have focused on motorcycles (Yang et al., 2005). Since diesel PM and motorcycle PM differ significantly, it is not possible to infer that motorcycle PM would exhibit different biological effects than diesel PM. To control and mitigate PM$_{2.5}$ and associated PAHs and mutagenicities with a view of reducing health and environmental risks, a good understanding of their contribution from motorcycle emissions is necessary.

Materials and Methods

Two 4-stroke carburetor motorcycles and two 4-stroke fuel injection motorcycle were tested in this study. New and used motorcycles were tested for both motorcycle types. The test fuel used was a commercial fuel produced by the Chinese Petroleum Company with an octane number of 95, the most widely used unleaded gasoline in Taiwan. The test motorcycles were driven on a Schenck GS-530 GS chassis dynamometer. The European driving cycle is conducted in this study. Diluted exhaust gas was extracted by the Apex Instruments source sampling system (Model MC-500) (Fig. 1). Apex Instruments’ cyclone was attached to the probe to determine particulate emissions at 2.5 μm (Fig. 2).

The European driving cycle (ECE) is the legislative cycle used for automotive emission certification in Taiwan. One complete test cycle (780 s) includes idle time (240 s), acceleration (168 s), cruising (228 s) and deceleration (144 s). Four different cruising speeds (15, 32, 35 and 50 km/h) are applied in these tests (Fig. 3).

The collected PM$_{2.5}$ sample was Soxhlet-extracted and analyzed for PAHs by gas chromatography/mass selective detector (GC/MSD). Half of the extracted eluent was evaporated to complete dryness by high-purity nitrogen. The residue was subsequently re-dissolved in 1 mL of dimethylsulfoxide (DMSO) for mutagenicity testing. Mutagenicity testing was performed by Ames assay test following the procedure described by Maron and Ames (1983).

Results and Discussion

Emission factors of PM$_{2.5}$ were calculated from the mass of PM$_{2.5}$ emitted, divided by the mileage traveled during the whole driving test. The average PM$_{2.5}$ emission factors measured in this study were 1.38, 3.18, 7.02 and 8.48 mg/km for the new and used fuel-injection motorcycles, and new and used carburetor motorcycles, respectively. PM$_{2.5}$ emission factors of used motorcycles were higher than those of new ones for all test motorcycles. The results indicate that deterioration of the engine would lead to the higher PM$_{2.5}$ emissions.

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The emission factors of mutagenicities without metabolic activation (−S9) are 2.03 × 10$^{4}$, 1.14 × 10$^{4}$, 8.05 × 10$^{4}$ and 1.04 × 10$^{5}$ rev/km for the new fuel injection, used fuel injection, new carburetor and used carburetor motorcycles, respectively. With metabolic activation (+S9), the mutagenicity emission factors are 7.77 × 10$^{4}$, 1.18 × 10$^{5}$, 1.32 × 10$^{5}$ and 1.15 × 10$^{5}$ rev/km, respectively (table 1). The mutagenicity emission factors are higher for the used fuel-injection motorcycle than the new one. With metabolic activation, the mutagenicity emission factors are higher than the corresponding values without metabolic activation. Higher values in the assay with S9 are expected due to the contribution of both direct (−S9) and indirect ( +S9) acting mutagenicity; whereas, in assays without S9 only the direct-acting component contributes (Fig. 4).

Table 1. Mutagenicity emission factors of the test motorcycles (rev/km).

<table>
<thead>
<tr>
<th></th>
<th>motorcycles</th>
<th>With S9</th>
<th>Without S9</th>
</tr>
</thead>
<tbody>
<tr>
<td>New fuel injection</td>
<td>7.77 × 10$^{4}$</td>
<td>2.03 × 10$^{4}$</td>
<td></td>
</tr>
<tr>
<td>Used fuel injection</td>
<td>1.18 × 10$^{5}$</td>
<td>1.14 × 10$^{5}$</td>
<td></td>
</tr>
<tr>
<td>New carburetor</td>
<td>1.32 × 10$^{5}$</td>
<td>8.05 × 10$^{4}$</td>
<td></td>
</tr>
<tr>
<td>Used carburetor</td>
<td>1.15 × 10$^{5}$</td>
<td>1.04 × 10$^{5}$</td>
<td></td>
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</tbody>
</table>

Fig. 4. Emission factors of mutagenicity (FI: Fuel injection; Cb: Carburetor).

References