Vehicular emission exposures of public transport commuters and pedestrians in commercial districts, Hong Kong

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Abstract

Vehicular emission is the dominate air pollution source in Hong Kong. Commuters are exposed to vehicular emission during their daily commuting trips. Hong Kong has a convenience public transport system comprising buses, subway, railway, tram, taxis and ferry. This system overall carries just over 10 million passenger trips per day. A survey on public transport exposure of commuters and pedestrians has been conducted in commercial districts of Hong Kong. The exposures were surveyed according to different commuting traffic modes. 1 bus route, 3 lines of Mass transit Railway, 1 tram routes and 19 fix points set up on roadside pavement in two commercial districts were monitored in the survey. Four criteria pollutants, CO, NOx, O3 and THC were selected as target pollutants. The vehicular emission exposures of bus, tram commuters and pedestrians were relatively high while exposures of Mass Transit Railway commuter were low. Compare to other metropolitan survey results in other parts of the world and the Hong Kong Air Quality Objectives, vehicular emission exposure levels of public transport commuters and pedestrians were low in commercial districts of Hong Kong. They were within acceptable levels.

1 Introduction

Vehicular emission is a major air pollution source in modern metropolis. The vehicular pollutant concentrations received by the commuter were higher during commuting times than other times (Akland et al. [1]). CO is a typical vehicular emission pollutant. It was usually selected as indicator in some surveys on commuter exposures for budget limit (Petersen and Allen [2]). Recently, Other criteria pollutants such as NOx, THC (total hydrocarbons), O3 and many kinds of VOCs (volatile organic compounds) related to vehicular
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emission were getting more attention for their potential hazard to health (Lofgren et al. [3]). 24 kinds of volatile aromatic hydrocarbons were analyzed in a commuter exposures study conducted in Boston (Chan et al [4]). Selection of typical commuting routes and traffic patterns are important in the study of commuter exposures. Different methods have been used in the selection of survey routes. Flachsbart et al. [5], Fernandez-brmauntz and Ashmore [6] had selected some major traffic corridors that connected different activity centers and zones of the metropolises as the typical commuting routes in Washington, D.C. and Mexico city. The General knowledge of the traffic patterns, along with some other factor such as traffic volume were used by Petersen and Allen [2] to select the typical commuting routes in Los Angeles Area. Questionnaire surveys were conducted by Chan et al. [7], [8] to establish the commuting patterns of office workers and students in Taipei city. The traffic modes used by commuters varied among countries and cities. In developed countries, private car and public transport were the major traffic modes investigated in the commuter exposures studies (Flachsbart et al. [5], Dor et al. [9]). In developing countries, public transport, motorcycle, bicycle and on foot were the major traffic modes investigated in the commuter exposures studies (e. g. Fernandez-brmauntz and Ashmore [6], Chan et al. [10], Chan et al. [11]).

Hong Kong with more than 6 million population has a comprehensive and convenient public transport system. It is a diverse multi-modal transport system, comprising an electrified Kowlong-Canton Railway, a Mass Transit Railway (MTR), a Light Rapid Transit, a tram, franchised buses, public light buses, taxis, various residential coach services, a funicular cable tram and ferry services, extended to almost every part of the territory [12]. In 1993, the overall public transport services carried about 10.10 million passengers per day. The service proportion of Railway, MTR, Light Rapid Transit, tram, buses, light buses, taxis, residential coach and ferry services were 5.7%, 21.1%, 2.9%, 3.5%, 34.2%, 16.7%, 12.6%, 0.8% and 2.3% respectively. In 1993, the number of private car was 0.26 million in Hong Kong. If each car took two trips per day and each trip carried two passengers on an average, these private cars could carried about 1.04 million passengers per day. The service proportion of private car were much small than public transport system.

Study about public transport commuter and pedestrian exposures to vehicular emission has been conducted in commercial districts of Hong Kong. The exposures of commuter by four transport modes (bus, MTR, tram and on foot) were surveyed. The survey results are summarized in this paper.

2 Field study

Four kinds of criteria pollutant related to vehicular emission (CO, NOx, O3 and THC) were measured in the study on public commuter and pedestrian exposures in commercial districts of Hong Kong. Air samples in different kinds of commuting microenvironments were collected at respiratory level by Tedlar
sampling bag with portable sampling pump (SKC Inc.). The air samples were sent immediately to laboratory for analyses of the four pollutant concentrations. CO concentration was measured by Gas Filter Correlation CO Analyzer (Model 48, Thermo Environmental Instruments Inc., detection limit: 0.1 ppm, precision: ± 0.1 ppm). NO, NO\textsubscript{2} and NO\textsubscript{x} concentrations were measured by Chemiluminescence NO-NO\textsubscript{2}-NO\textsubscript{x} Analyzer (Model 42, Thermo Environmental Instruments Inc., detection limit: 0.5 ppb, precision: ± 0.5 ppb). O\textsubscript{3} concentration was measured by U. V. Photometric O\textsubscript{3} Analyzer (Model 49, Thermo Electron Instruments, detection limits: 2 ppb, precision: 2 ppb). THC concentration was measured by APHA-300E Ambient HC Monitor (HORIBA Ltd., detection limit: 0.1 ppm, precision: ± 0.1 ppb). Only average concentration for the sampling period could be analyzed by sample bag. For monitoring temporary variation of pollutant concentrations in different kinds of commuting microenvironment, an electrochemical voltametric sensing portable CO monitor (Model 4148, Interscan Co., detection limit: 0.1 ppm) was used to monitored CO concentration continuously when the air sample was collected by the sample bag. The continuous monitoring values of the portable CO monitor were recorded by a portable data logger (Metrosonics dl-714). The data logger was programmed to store 15 seconds average values. All instruments were calibrated regularly with standard gas samples (Hong Kong Oxygen & Acetylene Co. Ltd.) during field survey period.

Instead of selecting routine commuting routes, commuter exposure levels were surveyed according to exposure in different traffic and commuting modes in our study. The average exposures of commuter could be assessed by combining the exposure levels cumulated in various traffic modes and commuting pattern. This method is generally used in simulating human exposure models. The survey of commuter exposures conducted according to traffic and commuting modes could cover larger area than the survey only conducted along some routine commuting routes. This survey approach provides extensive representation of the commuting exposure levels throughout the whole city. The survey results may also be as a data base to developed commuter exposure model.

The various routes and microenvironments of bus, MTR, tram and roadside pavement were described below. The survey of various roadside pavement microenvironments were conducted in two central commercial districts (Central, Mongkok). 19 fix monitoring points were set up on different kinds of roadside pavement. They were located on heavy traffic road sides, bus stops, bus terminals, road junctions, elevated pedestrian corridors and entrances of MTR respectively. MTR connects major commercial areas in Hong Kong. All three lines of MTR (Tsuen Wan line, Kwun Tong line, Island line) were selected. Each trip time of these lines were between 22 to 30 min. Bus route 1 (Chuk Yuen Estate to Star Ferry) running north-south passing through the central commercial district of Kowloon was selected. Each trip time of the route was about 45 min. 1 route of east-west oriented tramway in Hong Kong.
island (Causeway Bay to Western Market) passing through the central area was selected. Each trip time of the route was about 45 min.

The survey of roadside pavement microenvironments were conducted from Nov., 1994 to Jan., 1995. The survey of pavement microenvironments were conducted 3 days for each fix monitoring point. The air was sampled 3 times a day (8:30-9:30, 12:30-13:30, 16:30-17:30). The traffic volume of the road was counted during the sampling period. The survey of bus, MTR and tram microenvironments were conducted from Nov., 1995 to Mar., 1996. 8 monitoring trips were conducted for each line or route of bus, MTR and tram. 4 trips were conducted in the morning commuting peak time (8:30-9:30) and another 4 trips were conducted in the evening commuting peak time (17:30-18:30). The sampling time in the vehicle was equal to one trip time. The sampling time at fix monitoring points were 1 hr.

3 Results and discussion

Statistical results of the survey are shown in table 1. The CO concentration measured in bus and tram was relatively high. It ranged from 1.4 to 3.7 ppm. The average value was 2.2 ppm for bus and 2.1 ppm for tram. The CO concentrations measured on roadside pavements varied with site location and road traffic condition. It ranged from 0.2 to 5.7 ppm. The average value was 1.8 ppm. The CO concentrations measured in MTR were lower and more stable than that measured in tram and pavement. It ranged form 0.8 to 2.2 ppm. The average value was 1.5 ppm. Compare to other metropolises, the CO exposure level of commuter by public traffic modes in Hong Kong was low. The bus commuter CO exposure level in Hong Kong is much lower than that in Mexico city (30.2 ppm, Fernandez-brmauntz and Ashmore [6]), Taipei (11.6 ppm, Liu et al. [13]), Denver (8.2 to 10.0 ppm, Ott et al. [14]), and Washington, D.C. (4 to 8 ppm, Flachsbart et al. [5]). The average tram commuter CO exposure level in Hong Kong is much lower than that in Mexico city (25.6 ppm). The average MTR commuter CO exposure level in Hong Kong is much lower than that in Mexico city (20.6 ppm).

The NO concentration measured in bus was the highest. It ranged from 303 to 1122 ppb. The average value was 712 ppb. The NO concentration measured in tram was second with a range from 110 to 941 ppb and an average value of 464 ppb. The NO concentrations measured on pavements varied widely from 2 to 1247 ppb. The average values was 320 ppb. The NO concentration measured in MTR was the lowest. It ranged from 71 to 329 ppb. The average value was 173 ppb.

NO$_2$ is only a very small part of primary NO$_x$ of vehicular emission. The NO$_2$ concentration measured in bus was the highest also. The average value was 111 ppb. The average NO$_2$ exposure level of bus commuter in commercial district is higher than the NO$_2$ exposure level of automobile driver in urban area of Raleigh (83 ppb, Chan et al. [4]). The average NO$_2$ exposure
level of tram and on foot commuter were 80 and 74 ppb respectively in Hong Kong. They are similar to NO₂ exposure level of automobile driver in urban area of Raleigh. The NO₂ concentration measured in MTR was low. The average value was 32 ppb.

### Table 1 Statistics results of the survey

<table>
<thead>
<tr>
<th>Traffic modes</th>
<th>Traffic modes</th>
<th>Bus</th>
<th>MTR</th>
<th>Tram</th>
<th>On foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling time(min)</td>
<td>20-45</td>
<td>22-30</td>
<td>45</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Sample Number</td>
<td>12</td>
<td>24</td>
<td>8</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>CO (ppm)</td>
<td>Min</td>
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<td>0.8</td>
<td>1.4</td>
<td>0.2</td>
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<tr>
<td>Max</td>
<td>3.7</td>
<td>2.2</td>
<td>3.5</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.2</td>
<td>1.5</td>
<td>2.1</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>NO (ppb)</td>
<td>Min</td>
<td>303</td>
<td>71</td>
<td>110</td>
<td>2</td>
</tr>
<tr>
<td>Max</td>
<td>1122</td>
<td>329</td>
<td>941</td>
<td>1247</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>712</td>
<td>173</td>
<td>464</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>NO₂(ppb)</td>
<td>Min</td>
<td>55</td>
<td>19</td>
<td>43</td>
<td>28</td>
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<tr>
<td>Max</td>
<td>369</td>
<td>56</td>
<td>106</td>
<td>160</td>
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</tr>
<tr>
<td>Average</td>
<td>111</td>
<td>32</td>
<td>80</td>
<td>74</td>
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<tr>
<td>NOₓ(ppb)</td>
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<tr>
<td>O₃(ppb)</td>
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<td>7</td>
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<td>Average</td>
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<td>11</td>
<td>15</td>
<td></td>
<td></td>
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<tr>
<td>THC (ppm)</td>
<td>Min</td>
<td>1.8</td>
<td>2.2</td>
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</tr>
<tr>
<td>Max</td>
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<tr>
<td>Average</td>
<td>2.9</td>
<td>2.9</td>
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</tr>
</tbody>
</table>

O₃ is not the primary vehicular emission pollutant. The average O₃ concentration measured in MTR, tram and pavement ranged from 11 to 15 ppb. The O₃ concentration was low and its variation with traffic modes was small in commercial districts of Hong Kong.

The THC concentrations measured in tram and MTR were low. The average values were all 2.9 ppm and approached to background concentration level in Hong Kong.

Some typical temporal variation of CO concentration measured in MTR and tram are shown in figure 1. The temporal CO concentration measured in tram showed a cyclic variation. The time of cycle was about 3 to 4 min. It was identical with the cycle that the tram traversed through junctions. The trams were not air-conditioned in Hong Kong. The windows of the tram were opened during the trips. The air exchange in the tram was fast when the tram was moving. The CO concentration in the tram with open windows was affected by the driving mode (idle, accelerating, cruise, and decelerating) of the vehicle fleet. MTR in commercial area of Hong Kong is under ground. It is a closed
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tunnel with a ventilation system. MTR are all air-conditioned, so that, the temporal CO concentration measured in MTR varied slowly.

![Figure 1 temporal variation of CO concentration measured in MTR and tram](image)

Figure 1 temporal variation of CO concentration measured in MTR and tram

Compared to 1 hr average Hong Kong Air Quality Objectives (30.0 mg·m⁻³ (26.2 ppm) for CO, 0.30 mg·m⁻³ (159.5 ppb) for NO₂, 0.24 mg·m⁻³ (122.3 ppb) for O₃), the public transport commuter and pedestrian exposures to vehicle emission were low in commercial districts of Hong Kong. The concentrations of vehicular pollutant emission measured in various commuting microenvironment were within acceptable level except a few NO₂ concentration measured in bus microenvironment which were over the standard value of the Hong Kong Air Quality Objectives.

4 Conclusion

The public transport commuter and pedestrian exposures to vehicular emission were surveyed according to traffic modes and commuting modes in commercial districts of Hong Kong. The survey results could be used as a data base to develop commuter exposure model in Hong Kong.

The bus commuters, tram commuters and pedestrians exposed to relatively higher CO, NO and NO₂ concentration while the exposures level of MTR commuters were low. O₃ is not a primary pollutant of vehicular emission. No obvious differences of O₃ concentrations were measured among these four kinds of commuting microenvironments.

The temporal CO concentration measured in tram with windows opened showed a cyclic variation. The cyclic time varied with the frequency of that tram passing through junctions. It was affected by driving mode. The CO concentration measured in MTR varied slowly.

Compare to other metropolises survey results in other parts of the world and the Hong Kong Air Quality Objectives, vehicular emission exposure levels
of public transport commuter and pedestrian were low in commercial districts of Hong Kong. They were within acceptable levels.

References


