A PRELIMINARY STUDY ON TOTAL VOLATILE ORGANIC COMPOUND (TVOC) CONCENTRATIONS IN PUBLIC BUSES IN BANGKOK

การศึกษาเบื้องต้นความเข้มข้นของสารอินทรีย์ระเหยง่ายทั้งหมดในรถโดยสารสาธารณะในกรุงเทพมหานคร

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Abstract

Recently, some new buses made in China have been purchased to give the transportation services in Bangkok due to their lower price. Unfortunately, volatile air pollutants emitted from material in new motor vehicles was little concern. The objective of this study was to conduct a preliminary survey of total volatile organic chemicals (TVOCs) in the cabins of some new buses used in public transportation in Bangkok. TVOCs was monitored in the air-condition buses running within Bangkok area under actual driving condition. Three buses were randomly sampled from three routes, i.e. the route number 8, 539 and 542. All of sampling buses were manufactured in year 2007 using EURO II diesel engine criteria. In addition, a used bus made in Japan (from route number 515) was randomly selected for a background comparison. The results of the monitoring showed that all four buses contained TVOCs concentrations ranging from 1.40-3.74 mg/m^3, which exceeded the US EPA maximum allowable indoor air concentration standard of 0.20 mg/m^3. TVOCs found in the new buses were higher than the used one because newer material of in-vehicle ornament would possibly release much more TVOCs. There may be the relationship between the mileage (or driving duration) and TVOCs level, however, too few samples were taken might not be enough to prove any relationship. Besides, emission for other sources such as fuel leakage and infiltration of contaminated from ambient air was uncontrolled. In conclusion, the result provided important information on TVOCs concentration in the passenger cabins of public bus.

Keywords : Volatile organic compounds, VOCs, air-condition bus, indoor air pollution

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บทคัดย่อ

ปัจจุบันมีการนำเข้ารถยนต์โดยสารที่ผลิตในประเทศจีนมาใช้ในการเดินรถโดยสารประจำทางของผู้ประกอบการเอกชนด้วยเหตุผลทางราคา โดยไม่ได้คำนึงถึงปริมาณมลพิษอากาศที่เกิดจากวัสดุตกแต่งภายในรถ การศึกษานี้ จึงเป็นการสำรวจเบื้องต้นของปริมาณสารอินทรีย์ระเหยง่ายในห้องผู้โดยสารของรถโดยสารใหม่ (มีอายุการใช้งานไม่นาน) ที่นำมาใช้ในการเดินรถโดยสารประจำทางของกรุงเทพมหานคร โดยดำเนินการตรวจวัดในสภาพใช้งานจริง เลือกรถโดยสารใหม่จำนวน 3 คัน สุ่มจาก 3 เส้นทางการเดินรถ ได้แก่ สาย 8, 539 และ 542 รถทั้ง 3 คันเป็นรถรุ่นที่ผลิตในปี 2007 ตามเกณฑ์มาตรฐานเครื่องยนต์ดีเซลยูโร II นอกจากนี้ได้สุ่มรถโดยสารเก่าที่ผลิตในประเทศญี่ปุ่น (จากเส้นทางเดินรถสาย 515) เพื่อใช้เปรียบเทียบในการศึกษานี้ ตัวอย่างรถทั้ง 4 คัน ตรวจพบสารอินทรีย์ระเหยง่ายอยู่ในช่วง 1.40-3.74 มก./ลบ.ม. ซึ่งสูงกว่าค่ามาตรฐานคุณภาพอากาศภายในห้องของหน่วยงานพิทักษ์สิ่งแวดล้อมของสหรัฐอเมริกา (US EPA) ที่กำหนดไว้ไม่เกิน 0.2 มก./ลบ.ม. โดยในรถโดยสารใหม่พบปริมาณสูงกว่าในรถโดยสารเก่า คาดว่าเนื่องจากวัสดุตกแต่งภายในรถใหม่มีสารอินทรีย์ระเหยง่ายที่ระเหยจากวัสดุตกแต่งเป็นจำนวนมาก ทั้งนี้ พบความสัมพันธ์ระหว่างระยะทางที่รถได้วิ่งมาแล้ว (หรืออายุการใช้งานของรถ) กับปริมาณสารอินทรีย์ระเหยง่าย แต่ไม่สามารถระบุความสัมพันธ์ได้ชัดเจนเนื่องจากจำนวนตัวอย่างในการศึกษานี้ค่อนข้างน้อย อีกทั้ง ในการสำรวจนี้ไม่ได้ควบคุมการปนเปื้อนสารอินทรีย์ระเหยง่ายจากปัจจัยอื่น เช่น การรั่วไหลของเชื้อเพลิงหรือการแทรกซึมจากอากาศภายนอกรถที่ปนเปื้อนสารอินทรีย์ระเหยง่ายเข้าสู่ห้องผู้โดยสาร อย่างไรก็ตาม ผลการศึกษาเบื้องต้นได้ชี้ให้เห็นว่ามีการปนเปื้อนสารอินทรีย์ระเหยง่ายในห้องผู้โดยสาร

คำสำคัญ : สารอินทรีย์ระเหยง่าย, รถโดยสารปรับอากาศ, มลพิษอากาศในห้อง

Introduction

Many people living in urban area spend long periods of time travelling by bus for business, shopping, recreation, etc. The cabin of an automobile can be considered as a part of the living environment, especially urban people in dense city like Bangkok. However, little is known about the indoor air contamination due to organic compounds diffusing from the materials used in the interior of automobiles. Drivers or passengers could be directly exposed to volatile organic chemicals (VOCs) emitted as an off-gas from interior materials, fuel leakage or infiltration of contaminated ambient air[1].

Due to rapid population growth in Bangkok, public transportations are wildly expanded and more public transportation buses are required. In Thailand, a few private concessionaires are able to run the public transportations cooperating with the government, but ought to purchase their own public passenger buses to meet the demand. In order to save the investment cost, passenger buses made in China were considered because of their lower price without concerning about in-vehicle air quality in the passenger cabin. The VOCs inside the vehicle may come from the emissions from the ventilation of interior materials such as plastic moldings, carpet, seating surfaces, foam cushions, paint and sealants[2]. Moreover, internal VOCs concentration sources may infiltrate from roadway air, which related to traffic density and wind speed.

A number of studies have been conducted to measure in-vehicle air quality. According to a study[1], the result indicated that 82% of the studied vehicles had in-vehicle air quality contaminated with toluene levels exceeding the Chinese National Indoor Air Quality Standard. Also, Other researcher[2] reported that VOCs concentrations in new cars exceeded the standard for indoor VOCs. In addition, several studies referred that in-vehicle temperature could affect VOCs level. Fedoruk and Kerger[3] demonstrated that higher temperature could increase VOCs level inside car cabins. Apart from the potential long-term health effects, VOCs in new car cabins create a "new car odor", which is a nuisance to some occupants. High concentration of VOCs may evoke trigeminal responses of nasal pungency and eye irritation[4, 5].

The objective of this study was to conduct the preliminary survey of TVOCs concentrations in three passenger buses made in China under driving conditions, which was the actual condition that passengers would be exposed to indoor VOCs. Though this study is only a preliminary survey, the results could be useful for further monitoring program of in-vehicle air quality, investigation of the decreasing rate of TVOCs emissions overtime, warning announcements to the passengers and bus drivers, or evaluate health risk assessment, etc.

Material and Methods

Bus samples

In-vehicle TVOCs monitoring was conducted with the public air-condition buses running within Bangkok area under actual driving condition. The field sampling was done in one day on January 27th, 2008. Due to the limitation of budget and resources, only three buses made in China were randomly selected from three service routes, i.e. route numbers 8, 539 and 542. Both buses of the routes number 8 and 542 were using "Golden Dragon" brand, model XML6112, which was an air-condition large city bus with thirty standard seats consisted of 240 hps EURO II diesel engine. Another bus of the route number 539 was using "Higer" brand, model U90B, that was an air condition large city bus with forty one standard seats consisted of 250hps EURO II diesel engine. The interior appearance of "Golden Dragon" and "Higer" brands mostly used rubber and plastic for seat materials and plastic sheet as an interior surface as shown in Figure 1. All of three sampling buses made in China were manufactured in the year of 2007. Furthermore, to obtain base-line TVOCs level in an existing air-condition bus for a preliminary comparison, a used bus made in Japan which manufactured in the year of 2001 was also selected from the route number 515. This Japanese bus was "ISUZU" brand, which was an air-condition large city bus with thirty two standard seats consisted of 250 hps EURO II diesel engine. The interior detail of "ISUZU" mostly used synthetic leather as a seat material and metal sheet as an interior surface. The details of interior materials used in the sampling buses were concluded in Table 1.

(a) "Golden Dragon" model XML6112 [http://www.goldendragonbus.com]

(b) "Higer" model U90B [http://www.kinglong-sz.com.cn]

Figure 1: Interior materials probably the cause of VOCs emission in new air-condition buses

Table 1 Details of interior material of the sample bus

BUS (Route number)	8 (new)	539 (new)	542 (new)	515 (used)
Brand	Golden Dragon	Higer	Golden Dragon	ISUZU
No. of seat	30	41	30	32
No. of Passenger Door	2	2	2	2
Seat Material	Rubber, plastic	Rubber, plastic	Rubber, plastic	Steel, PVC, synthetic leather
Interior surface	Plastic sheet	Plastic sheet	Plastic sheet	Metal sheet
Floor	PVC, steel	PVC, steel	PVC, steel	PVC, steel
Ceiling	PVC, synthetic leather	PVC, synthetic leather	PVC, synthetic leather	PVC, synthetic leather
Curtain	Polyester	Polyester	Polyester	Polyester

Sampling and analysis

Air samples were taken within the cabins of selected passenger buses during their actual service. The air was sampling at a rear seat area of the buses to minimize effects from contaminated air outside the bus. The inlet of sampling tube was placed at the breathing zone of the passenger. Bus ID, manufactured date, driving distance (km), route way, duration of door opening during the sampling, number of passengers (sum of every 5 min) and temperature were recorded. Standard sampling and analytical methods according to NIOSH Manual of Analytical Methods[6] were employed in this study. Details of TVOCs measurement were shown in Table 2.

Table 2 TVOCs sampling and analytical methods of city bus in Bangkok

Parameter	Sampling Instruments	Analytical methods	Reference
Total VOCs	Personal Air Sample, Coconut Shell Charcoal tubes (Model Gilair-5, Gilian® Inc., USA)	Gas Chromatography with a flame ionization detector (FID) (Model 6890plus GC, Hewlett Packard Inc., US)	NIOSH 1501

Note: Detection limit of TVOCs analysis is 0.01 ug/sample

The field sampling was done in one day on January 27, 2008 between 9.00 AM - 11.00 AM, and air samples were collected one by one. TVOCs in air samples were trapped within coconut shell charcoal tubes connected to portable sampling pumps with flow rate of 200 ml/min for 20 min/sample. Then, samples were analyzed by mean of thermally desorption and gas chromatograph equipped with a flame ionization detector (FID).

Results and Discussion

Because of no national in-vehicle air quality standards available in Thailand, the US EPA maximum allowable indoor air concentration standard of TVOCs (not exceed 0.20 mg/m^3) were applied for result comparison and discussion. Table 3 summarizes the measured concentrations of TVOCs in all four air-condition buses, all of which exceeded the US EPA Standard of 0.20 mg/m^3. The highest TVOCs concentration of 3.74 mg/m^3 was found in the new bus of the route 542, which was about nineteen times higher than the US EPA standard. The average of TVOCs concentrations in three new buses was 2.89 mg/m^3, which were about two times higher than that four in the used bus (1.40 mg/m^3).

Table 3 Results of measured TVOCs concentrations in sampling buses

BUS (Route number)	Mileage (km)	Bus age (days)[(a)]	Temperature (c°)	Frequency of door open	Duration of door open (sec)[(b)]	TVOCs (mg/m^3)
8 (new)	25974	208	21.8	5	55	2.53
539 (new)	22617	196	24.7	7	103	2.41
542 (new)	20652	98	26.8	12	202	3.74
515 (used)	673574	2457	23.1	11	146	1.40
US EPA maximum allowable indoor air concentration standard of TVOCs						<0.20

Note: (a) counted since the manufactured date

(b) Summation of time of door opening during the sampling

Mileage and driving distance parameters were reflected how new of the buses were. They showed some relationship with TVOCs concentrations as shown in Figures 2 and 3. Consideration of results among the new buses, the highest TVOCs of 3.74 mg/m^3 was found in the bus route 542, which concurrently had the least mileage (20,652 m.) and bus age (98 days). In addition, TVOCs of 2.53 mg/m^3 found in the bus route number 8 was quite closed to that of 2.41 mg/m^3 in the bus route number 539 while their driving distances and bus ages were also closed to each other. However, TVOCs concentration and mileage or bus age cannot be related statistically in this study because of insufficient number of samples and lack of control variable.

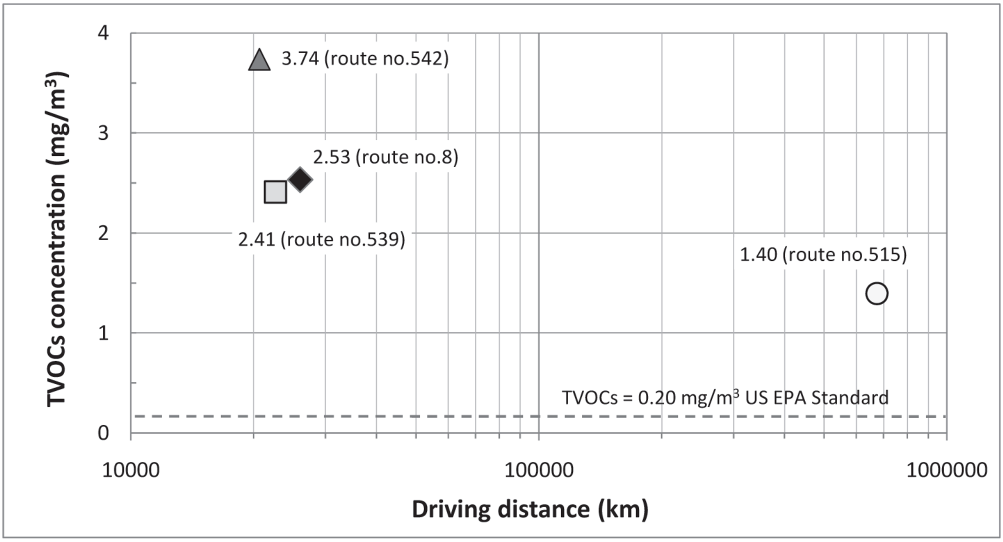

Figure 2: Measured TVOCs concentrations versus mileage

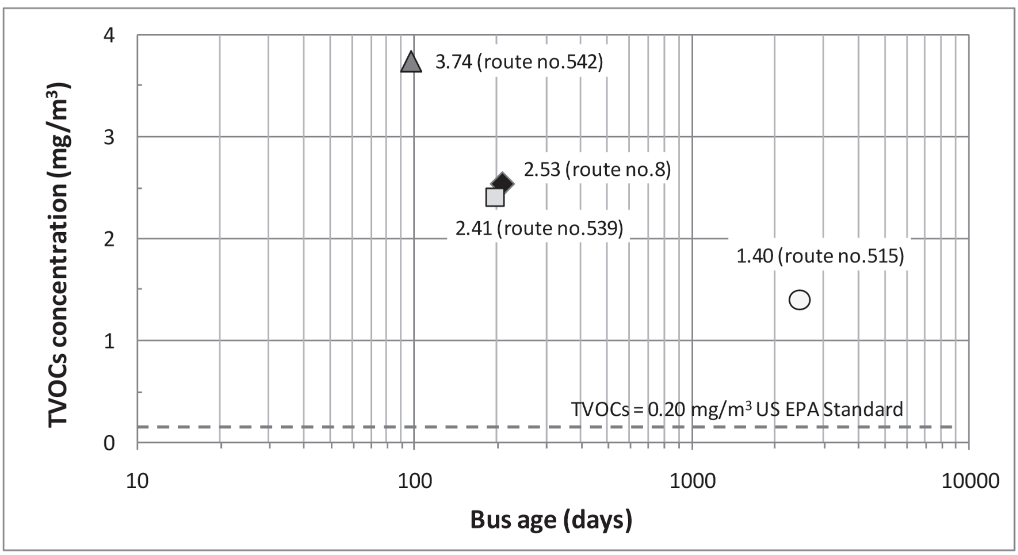

Figure 3: Measured TVOCs concentrations versus bus age

Contamination of TVOCs from outside the cabin may be occurred during door openings. Therefore, duration of each door openings during this twenty minutes sampling was also recorded, and summarized in Table 3. Unfortunately, TVOCs concentrations in this study did not show the significant relationship with duration of door opening. However, the highest TVOCs concentration was found in the bus route number 542, which had the longest duration of door opening. Moreover, temperature should theoretically affect TVOCs in the way that higher temperature could stimulate more TVOCs emission from interior materials. Likewise, the correlation between TVOCs and cabin temperature was not quite evident because of too few samples. However, the highest TVOCs concentration was found in a cabin with the highest temperature.

In comparison with other studies, the in-vehicle TVOCs concentration measured in this study were much higher than those found in Yoshida and Matsunaga[7] listed in Table 4. Three factors may contribute to the differences. The first is the difference of interior materials used in each bus may consist of high-emitting materials, such as rubber and plastic of seat materials. The second is three of sampling buses were quite new (less mileage and bus age), pollutant emission rate of newer interior material was usually greater. The third, this study measured TVOCs in the driving condition differently from others[7,8]. However, the difference would be due to the combined effects of sampling state, vehicle type, driving conditions, meteorological conditions and ambient air quality.

Table 4 Comparison of the current study with several recent studies

Study	Bus age (days)[(a)]	Driving distance (km)	TVOCs (mg/m^3)
This study (2008)	98	25,974	3.74
	196	22,617	2.41
	208	20,652	2.53
	2,457	673,574	1.40
Yoshida and Matsunaga[(7), (b)]	0	NA	14.0
	180	NA	0.80
	360	NA	0.12
Bauhof and Wensing[(8), (b)]	0	NA	7.0 – 24.0

Note: (a) counted since the manufactured date

(b) engines stopped, windows, doors and vents of the car were closed

Uncertainty of this study

- In-vehicle TVOCs levels may be related to traffic density or driving and wind speed, which were not controlled or eliminated in this study .
- The characteristic of air-conditioning could lower interior temperature, which consequently reduce in-vehicle TVOCs levels.
- This study evaluated TVOCs levels in actual driving condition, the infiltration of roadway ambient TVOCs caused by door opening could possibly contaminate samples.
- This preliminary study determined TVOCs level with only few passenger buses; therefore, statistical analysis could not be applied.

Conclusions

This study was only a preliminary investigation of in-vehicle TVOCs under actual driving conditions. The results showed that all of sampling buses have TVOCs concentrations exceeding US EPA maximum allowable indoor air concentration standard (<0.20 mg/m^3 TVOCs). This preliminary study also indicated that TVOCs in the new buses were higher than the used one, which should be due to those newer in-vehicle ornaments could emit much more TVOCs. Even TVOCs concentration in the used bus was higher than US EPA standard. Anyhow, there are some other causes of TVOCs contaminated in the passenger cabin that were still not eliminated during the sampling, such as fuel leakage or infiltration of ambient TVOCs. Statistical analysis of these results cannot take into account since this study dealt with only few samples. However, this study provides interesting information that TVOCs concentrations found in the public buses running within Bangkok area were potentially harmful to passenger's health. Hence, a more comprehensive monitoring with larger number of samples needs to be further investigated. Also, improvement of interior materials in the passenger cabin should be considered to minimize in-vehicle TVOCs emission.

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