



Study of particulate at the roadside microenvironment in different land use areas in Hong Kong

L.Y. Chan, W.S. Kwok & C.Y. Chan

Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

Email: 97980906R@polyu.edu.hk

Abstract

The major source of particulate air pollution in Hong Kong is vehicle emission. The study employed Microenvironment monitoring technique to assess the exposure of pedestrians to respirable suspended particulate (RSP) at roadside. A total of 62 roadside sites in 14 districts representing four different land use categories were selected. They covered most urbanized and densely populated area. MINIVol portable samplers were used for RSP sampling. The range of roadside exposure for 24-hour average RSP was from 46.03 to 337.4 $\mu\text{g}/\text{m}^3$ and the average of RSP was 112.95 $\mu\text{g}/\text{m}^3$. Due to the different characteristics of land use, the average concentration and temporal variation were different. The field data was compared with the data of Environmental Protection Department (EPD) measured at low roof top and at a street level station.

1 Introduction

Hong Kong is a densely populated city with 6 million people. The hilly topography and concentration of residential, commercial and industrial activities in limited built-up areas create complex microenvironments. The main built up area and urban centres are situated on both sides of Victoria Harbor (Figure 1). There are also new satellite towns in the New Territories with growing population and traffic.

Particulate pollution is serious in Hong Kong. According to Hong Kong Government statistics, the Air Quality Objective (AQO) for particulates



has been exceeded by 30 to 40% in recent years in areas with heavy traffic³. Each year Hong Kong's 423,966 licensed vehicles discharge 5,900 tons of particulates into the atmosphere, while only 400 tons come from industrial sources. The pollutants emitted by road traffic have found to be the main contributor to local air pollution in Hong Kong¹. The present study aims at the study of the exposure level of respirable suspended particulate at the roadside microenvironment in different land use districts.

2 Field Study

A total of 60 roadside sites in 14 districts were selected. The location, area type, number of site in each district and microenvironment condition were shown in figure 1 and table 1. They cover most of the urbanized and densely populated area. The selection criteria was based upon the type of land use, the traffic flow and the population distribution. They can be classified into (1) urban and industrial area, (2) urban and residential area, (3) urban and commercial area and (4) new town.

Figure 1 Metropolitan area of Hong Kong and the sampling location

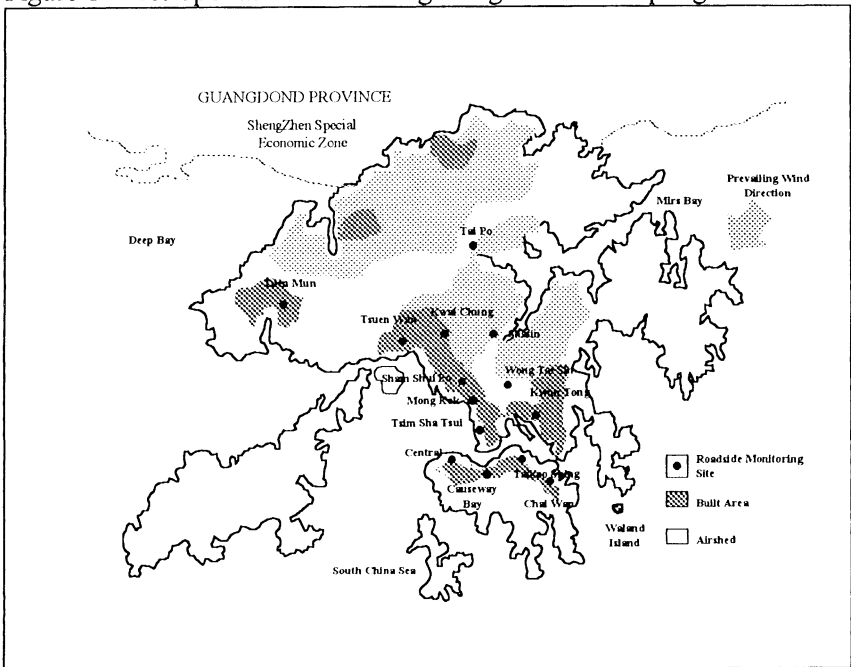


Table 1 Description of sampling location

Area Type	District	no. of site	Microenvironment condition
Urban Residential	Mong Kok (MK)	5	density populated, heavy traffic
	Sham Shui Po (SSP)	5	flow, mainly van, public light
	Wong Tai Sin (WTS)	2	bus, taxi and bus.
	Taikoo Shing (TKS)	2	Upper class private housing estate, low traffic flow
Urban Commercial	Central (C/W)	6	high rise building, high traffic
	Causeway Bay (CB)	4	flow, mainly taxi and private
	Tsim Sha Shui (TSS)	5	car, mixed industrial and residential
Urban Industrial	Kwai Chung (KC)	5	moderate traffic flow, mainly
	Chai Wan (CW)	2	good vehicles and vans
	Tsuen Wan (TW)	5	
	Kwun Tong (KT)	3	
New Town	Shatin (ST)	8	mixed commercial & residential use (airshed area), moderate traffic flow
	Tai Po (TP)	2	residential use (airshed area), moderate traffic flow
	Tuen Mun (TM)	6	residential use, moderate traffic flow

The sites were further classified according to the road condition. They are traffic light, bus stop, road junction and normal traffic. The selection of the site was also based on accessibility for sample collection. Consideration was taken to avoid the influence of immediate local sources such as unpaved roads, railroads, construction sites and emission sources from factory and restaurant.

MINIVOL Portable Air Samplers (AIRMETRICS) were used for RSP sampling. The flow rate of MINIVol is generally lower than the flow rates used by high volume air samplers. The lower flow rate results in a greater deviation in accuracy at low concentration of particulate matter where precision can be lost through the handling and weighing of a minute particulate sample. However, at high particulate concentrations the sampler produces results that are precise and comparable to reference method samplers. Thus, it is suitable for particulate sampling in Hong Kong's urban roadside environment since the pollutant level is quite high. The battery operated and lightweight MINIVol is ideal for monitoring in areas without power.

The experiment was conducted from mid January to mid February 1997. The sampling duration was 24 hours in two weekdays and one Sunday for each sampling site. All MINIVOL samplers were mounted on light pole about 1m from the roadside and 3.5m above ground.

A flow of 5 liters per minute (lpm) was used. The flow rates were checked again at the end of the study. Included in the daily quality control reviews were checking for battery power, flow rate, volume of air sampled, elapsed time, leaks, and unusual filter conditions including damage, odor, discoloration, or loose particles on the filter. Any abnormal conditions were corrected and noted on the field forms.

An open top balance (Mettler AE163) with accuracy of 0.01 mg was used to weigh the filter paper which was conditioned in an electronic desiccator before and after sample collection for 24 hours. The balance was placed on top of a concrete bench with anti-vibration table. The filter was stored flat on the petri dish and covered after conditioning or weighing.

To study the performance of the MINVOL sampler, one RSP high volume sampler and one RSP mini-volume sampler were operated at the HKPU road side site in the same period in order to determine the correlation between the two samplers. The samplers were placed on the pavement at about 0.5 metre from the roadside where 24- hour samples were collected.

3 Result and Discussion

A total of 180 PM₁₀ samples were collected during the roadside study. Overall, 94.4 percent (170) of the samples passed the screening check. Bad samples were due to the damage of the filter paper during handling and transportation, occasionally low flow rate of the sampler, and the malfunction of the samplers.

Figure 2 RSP Concentration: Mini-volume Sampler Vs High-volume Sampler

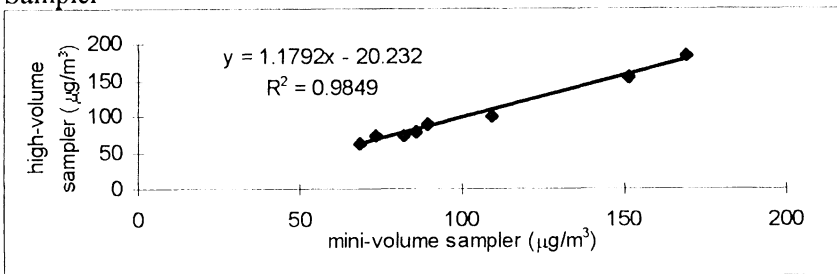


Figure 2 shows the result of the performance test for the mini-vol sampler. It was found that the average ratio of mini-volume to high-volume sampler was 1.04. The correlation coefficient (R^2) was 0.9849. That is, the correlation between portable sampler and high volume PM₁₀ sampler is

good. The result is similar to the performance test of the portable sampler reported in an overseas study². On average, the portable sampler was slightly positively biased (by about 1 to 5 $\mu\text{g}/\text{m}^3$). The accuracy was within the 10% flow audit limit. Thus, the data collected by mini-volume sampler were converted to high-volume sampler scale by $[1.1792 \times \text{RSP measured by mini-volume sampler} - 20.232]$.

Table 2 Average RSP Conc. at Different Roadside Microenvironments

Area type	District	District avg. ($\mu\text{g}/\text{m}^3$)	min. ($\mu\text{g}/\text{m}^3$)	max. ($\mu\text{g}/\text{m}^3$)	Land use type avg. ($\mu\text{g}/\text{m}^3$)
Urban Residential	MK	98.76	78.76	115.43	95.05
	SSP	133.78	87.81	182.61	
	WTS	93.27	36.43	169.70	
	TKS	54.40	25.48	93.32	
Urban Commercial	C/W	166.58	80.50	337.46	129.03
	CB	112.51	72.16	207.20	
	TSS	107.99	91.29	136.08	
Urban Industrial	KC	125.34	82.45	172.08	87.30
	CW	58.35	38.71	75.99	
	TW	84.59	31.96	159.16	
	KT	80.94	50.15	122.34	
New Town	ST	115.68	56.16	241.88	112.65
	TP	134.28	106.94	153.42	
	TM	87.98	25.63	179.90	

Statistical analysis of PM_{10} from the 14 districts are presented in Table 2. The concentration level of PM_{10} ranged from 25.48 $\mu\text{g}/\text{m}^3$ to 337.46 $\mu\text{g}/\text{m}^3$. The results were fairly symmetrically distributed with a mean of 109.50 $\mu\text{g}/\text{m}^3$ and a median of 101.62 $\mu\text{g}/\text{m}^3$. The overall mean concentration of PM_{10} was within the Hong Kong Air Quality Objective (HKAQO) (180 $\mu\text{g}/\text{m}^3$, 24-hours) and the National Ambient Air Quality Standards (NAAQS) (150 $\mu\text{g}/\text{m}^3$, 24-hours). However, the mean concentration of Central district (166.58 $\mu\text{g}/\text{m}^3$), one of the commercial area, exceeded the daily PM_{10} limit of NAAQS. Moreover, for the individual result, there were 24 exceedances of the PM_{10} daily limit of NAAQS. The exceedances were found at three districts belonging to different types of land use.

The RSP pollution level depends on the degree of urbanization, extent of industrial development and regional characteristics. Variation in RSP concentration level may due to difference in traffic flow and different types of land use. In densely populated urban areas, such as Mong Kok and



Sham Shui Po, goods vehicles and large buses are the principal contributors to vehicular emissions but taxis play an important role in less polluted areas such as Taikoo Shing. In this study, the 14 selected districts can be classified into four categories of land use. The characteristics of the four land use categories and the variation of pollutant levels within each category are described below.

Fourteen sampling points covering four districts, Wong Tai Sin, Sham Shui Po, Monk Kok and Taikoo Shing were the urban residential category. Except some upper class private residential area, such as Taikoo Shing, residential area in Hong Kong is usually highly populated and the residential flats are very closed to the roads. The maximum district average of RSP was $133.79 \mu\text{g}/\text{m}^3$ in Sham Shui Po. The minimum district average of RSP was $54.4 \text{ ng}/\text{m}^3$ in Taikoo Shing. All the selected district in this category have heavy vehicle flow except Taikoo Shing. Van, public light bus, taxi and buses are the major transport in this area.

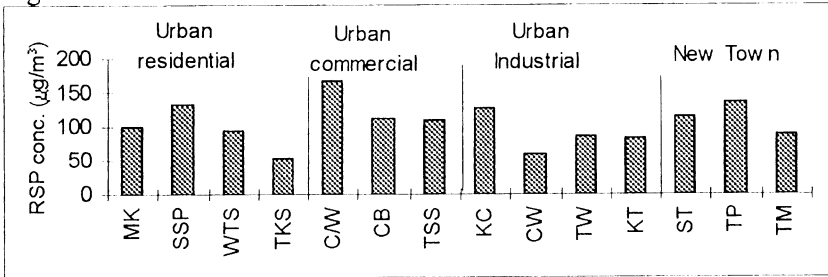
The tall, dense high-rise buildings characterized the Central, Causeway Bay and Tsim Sha Tsui urban commercial districts. The average RSP concentration level ranged from $107.99 \mu\text{g}/\text{m}^3$ to $166.58 \mu\text{g}/\text{m}^3$. They have heavy traffic volume with large proportion of taxi and private cars. Urban canyon effect was found at Central and Causeway Bay due to the high-rise buildings. The particulate pollutants are trapped between the buildings which cause poor dispersion. Thus, high concentration occurs at the urban canyon when junctions are the only ventilation outlet for dispersion of pollutants. Central had the highest average RSP concentration ($166.58 \mu\text{g}/\text{m}^3$) among all districts due to the canyon effect, heavy traffic, frequent stops and congestion. There were also contribution from the numerous construction sites nearby. Hence, it had the highest average RSP concentration level.

The roads at the selected districts in the industrial category were all surrounded by low-rise factories. The roads at the industrial area are intended for local distributors and are narrow. The average RSP concentration level ranged from $58.35 \mu\text{g}/\text{m}^3$ to $125.34 \mu\text{g}/\text{m}^3$. Traffic is mainly dominated by goods vehicles and vans, and traffic volume is comparative low. Many goods vehicles park at roadside for loading of goods and usually occupied one traffic lane. Busy traffic periods for industrial area are always at the working hours and the traffic volume is very low at other times. The RSP concentration of industrial area is the lowest.

Sixteen points covering three districts, Shatin, Tai Po and Tuen Mun were selected to represent new town category. Roads in new town are

surrounded by both old low-rise buildings and new built high-rise buildings. Traffic flow is low and the vehicle types are mainly taxi and private car. The average RSP concentrations of these three districts were $115.68 \mu\text{g}/\text{m}^3$ at Shatin, $134.28 \mu\text{g}/\text{m}^3$ at Tai Po and $87.98 \mu\text{g}/\text{m}^3$ at Tuen Mun. The high concentrations at Shatin and Tai Po are due to the topography as they are confined by hills and the dispersion effect is less.

Figure 3 The mean RSP Concentrations in Different Districts



From figure 3 we observed that the variation of the concentration of RSP within the four land use categories were quite great. The result is due to the great variation in topography in Hong Kong and the different building and traffic configuration in different districts. Moreover, samples of the same land use category might be collected in different days, so the concentration might be susceptible to the influence of short-term fluctuation in meteorological condition.

Table 4 Comparison between HKPU and EPD Data

District	EPD fixed station($\mu\text{g}/\text{m}^3$) (Jan 96 monthly avg.)	Field Study (district avg., $\mu\text{g}/\text{m}^3$)
Kwun Tong	91	80.94
Sha Tin	66	115.68
Tai Po	76	134.28
Sham Shui Po	85	133.78
Central/Western	82	166.58
Tsuen Wan	79	84.59
Kwai Chung	71	125.34
Mong Kok	98*	98.76

* roadside EPD monitoring station.

This field study result, confirm EPD report that, particulate pollution is serious in the urban areas with heavy traffic. Twenty-four out of 170 samples breaches the NAAQS. The result shows that particulate



concentration depends very much on the degree of urbanization, regional characteristics, and distance from the local emission source. There was a marked difference in particulate level in the Central district. In this built-up urban financial and commercial center, roads are surrounded by tall buildings which inevitably trap the vehicular emissions in the road canyon. Also a great proportion of vehicles on the street are diesel taxi. Particulate emission is significant since diesel engine emission contains more particulate than petrol. As all the sampling sites were at the urban ground level, which is closed to the influence of traffic impact, the effects and the concentration levels were much greater than those measured in the EPD fixed station at the roof top in the same district.

However, the RSP concentrations were lower than the EPD data in Kwun Tong. Due to the industrial land use at Kwun Tong, sampling at roof top had been influenced by the emission from the factory chimneys. At Mong Kok, the fixed station of EPD is also at ground level, so the measuring results were close. For all other districts, higher concentrations measured at roadside show that roadside particulate levels are higher than the ambient levels measured at roof-top. Similar results had been found in previous studies⁴. EPD fixed station data underestimated the pollution levels at roadside in most of the sites. More street level measurements should be carried out to assess the street level exposure of the general population in Hong Kong.

4 Conclusion

This project studied the particulate level at roadside using portable mini-volume sampler. The performance of portable mini-volume sampler was well correlated with the high-volume sampler and was estimated to be 4.59% higher. From the field data of 14 districts, pedestrians were found to expose to 24-hour average RSP ranged from 25.56 to 337.40 $\mu\text{g}/\text{m}^3$. The average RSP level was 109.50 $\mu\text{g}/\text{m}^3$. The highest average land use RSP concentration was found in urban commercial and new town category respectively. And the lowest average land use RSP concentration was recorded in urban industrial and urban residential category respectively. Also, there were variation of particulate level within each land use category related to difference in traffic flow, vehicle type, topographical and street configuration. Worst particulate air quality in Central was due to the urban canyon effect in this commercial area.



The field data was compared with the data of EPD. It was found that the average concentrations of the roadside field data at different districts were higher than the EPD data which were measured at elevated roof top stations. The underestimation of particulate level shows that the ambient air quality measured by the EPD cannot reflect the real exposure level of pedestrians on street level. Thus more monitoring station should be set up at roadside in districts with different land use category.

Acknowledgments

The authors greatly appreciate the lending of ten MINIVol samplers by AIRMETRICS for our field study.

References

1. Environmental Protection Department, Environmental Hong Kong 1996, Hong Kong, 1996.
2. Eric S. Ringler et al: *The Summer 1992 PM-10 Saturation Monitoring Study in the Ashland, KY Area*, 1992
3. Government Secretariat, *Hong Kong Environment(1993) The Hong Kong Environment: a green challenge for the community, Second review of the 1989 White Paper, pollution in Hong Kong - Time to Act, Planning, Environment and Lands Branch*, 1993.
4. Wu.Helen W.Y, A Pilot Field Study on the Exposure of Bus Drivers, Passengers and Pedestrians to Traffic-related Air Pollution, The Hong Kong Polytechnic University, M Phil. Thesis, 1991.