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A territory wide survey on indoor particulate level in Hong Kong

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Abstract

Airborne particulates are a major air pollution problem in Hong Kong. Very high outdoor airborne particulate levels have been recorded in the outdoor monitoring stations managed by the Hong Kong Environmental Protection Department (HKEPD). However, information on the concentrations of indoor total suspended particulate (TSP) and particulate matters of aerodynamic size less than 10 μm (PM_{10}) has been scarce. In view of this, a territory-wide survey was conducted from September 1996 to January 1997 to investigate the indoor airborne particulate levels in 50 residential apartments in Hong Kong. In this study, 50 residential premises were selected in 18 districts of Hong Kong covering both public housing and private housing. Two Mini-Vol sampling pumps were located at each site to collect both 24 h TSP and PM_{10} samples in filters which were analyzed by gravimetric method using a precision mass balance. The living habits, ventilation characteristics and other indoor activities were recorded in a survey form. The TSP level varied from 37.5 $\mu g\ m^{-3}$ to 227.1 $\mu g\ m^{-3}$ and the PM_{10} level varied from 35.1 $\mu g\ m^{-3}$ to 161.6 $\mu g\ m^{-3}$, which were much higher than the levels measured in western countries. PM_{10}/TSP percentages varied from 49.7 to 100% (average 85.0%) which were also higher than the data obtained in other overseas studies. A high proportion of respirable content in the indoor environment indicated that there is a significant contribution from indoor activities on the residential premises, e.g. smoking, incense burning and cooking, etc. The findings have been useful for evaluating long term policy regarding environmental protection in the domestic environment. © 1998 Elsevier Science Ltd. All rights reserved.

Keywords: Indoor and outdoor; Particulate; PM_{10}; TSP

1. Introduction

Studies of indoor particulate level on residential premises have been conducted by many researchers in different parts of the world. Early work conducted by Spengler et al. [1] in the US showed that mean PM_{10} level in 35 homes with non-smokers was 24.4 $\mu g\ m^{-3}$, in 15 homes with one smoker 36.5 $\mu g\ m^{-3}$ and in 5 homes with two smokers as high as 70.4 $\mu g\ m^{-3}$. The corresponding outdoor level was 21.1 $\mu g\ m^{-3}$. An investigation was conducted by Colome et al. [2] at 10 homes in Southern California on both indoor and outdoor PM_{10}. The mean 24 h indoor PM_{10} concentration measured was 42.5 μm^{-3} while the correlated outdoor level was 60.8 $\mu g\ m^{-3}$. Over 50% of the outdoor measurement and nearly 30% of the indoor measurements exceeded the 24 h California State Standard (50 $\mu g\ m^{-3}$). In another similar report by Kado et al. [3] the indoor to outdoor PM_{10} ratio was found to be about 0.46.

Measurements have also been conducted in similar Asian cities such as Taipei. Li [4] reported mean indoor PM_{10} level of 83 $\mu g\ m^{-3}$ and outdoor level of 107 $\mu g\ m^{-3}$ in 15 homes in the Taipei urban area. Correlation of indoor PM_{10} to TSP has been studied by Kamens et al. [5]. In their report the average PM_{10}/TSP ratio at three US homes was 63%. PM_{10}/TSP ratio as high as 86% has also been reported in the study conducted by Raiyani et al. [6] for houses in India where the influence of cooking activities was investigated.

In Hong Kong, outdoor particulate levels are monitored on a daily basis but not much information has been reported for particulate level in the indoor environment [7]. A pilot study on indoor particulate levels was conducted from September 1996 to January 1997 on 50 residential premises located all over Hong Kong. Both total suspended particulate (TSP) and particulate matters with size less than 10 μm (PM_{10}) were measured on a 24 h basis. Mean TSP and PM_{10} levels at different districts

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were evaluated and correlation was also drawn between the indoor and outdoor particulate levels obtained from outdoor database developed by the Hong Kong Environment Protection Department.

2. Measurement

Fifty residential premises were selected for this study. The premises formed a rough representation of the population living in private and public housing among the 18 districts in Hong Kong. In the survey, 29 private premises and 21 public premises were selected. Public premises refer to those housing estates managed by the Hong Kong Government for families usually with lower income. A questionnaire was designed for collection of site information. The information included district, building type, building age group, elevation of premises (number of floors from ground level), room size, room height, room volume and indoor finishing materials. The area of the premises varied from 5 m^2 (a very small room) to 140 m^2 (classified as a luxurious apartment in Hong Kong). The elevation of the premises varied from the ground floor to the 35th floor. The questionnaire also included information on the indoor activities and ventilation characteristics, date of measurement, window opening frequency, ventilation and fan operation characteristics, house keeping details, adjacent environment and meteorological conditions during measurement.

Measurement started in late September 1996 and ended in mid January 1997. Two Airmetric Mini-Vol Samplers were used in each test. One was for TSP and the other one was for PM_{10}. Each was drawn at an air sampling flow rate of 5 l per min. (l min^{-1}) and the duration of each test was 24 h. The particulates were collected by the filters in the sampling pumps. The samplers were located at the site for 24 h and the tests were completed on the following day. The sampling flow rates of the samplers were calibrated by a Primary Flow Calibrator (Trademark Gilibrator), manufactured by Gilian Instrument Corp. It was a bubble type flow calibrator with three interchangeable flow cell assembles: low range, standard range and high range. The standard range was used for the flow calibration in this study. Flow calibration was conducted once every three tests. Whatman Grade QM-A Quartz Filters were used in collecting the particulate samples and analysis was carried out later in the laboratory. Standard filter conditioning and weight measurement were followed in the gravimetric tests. The sampling points were at the breathing zone (1.5 m from floor) and were located in the middle of the living room. During the tests, occupants continued to stay on the premises and all their living habits remained unchanged. The cyclones attached at the sampling inlets of the sampling pumps were cleaned after four samplings were taken, following the procedure shown in the maintenance manual, which suggested that at least one cleaning should be done for every seven samples. The sampling pumps were tested in the laboratory after ten samplings were taken to ensure that the flow rate was correct and no air leakage existed.

For quality control purpose, five of the sites were selected for duplicate tests and the selection was made so that premises in different districts were included. Four sampling pumps were used in each duplicate test. Two were for TSP measurement and two were for PM_{10} measurement. Blank tests were performed on five filters.

3. Results and discussion

The number of occupants on each premises varied from one to six. Among these 50 premises, 10% had smokers, 24% carried out incense burning and 56% had cooking activities. The percentage of these sites that had cleaning activities during the sampling period was 56, 24% were located near construction sites and 42% near automobile sources (main roads). Premises located near industrial areas amounted to 8%. Since the study was conducted from September to January, rain did not occur very frequently. Only 6% of the measurements were done while it was raining outside. Air conditioning was used in 12% of the sites during the measurement period and 4% of the sites had their windows closed all the time.

Table 1 shows the PM_{10} and TSP levels at each site, as well as the ratio of PM_{10} to TSP (%). Mean temperature and relative humidity of the indoor environment during the sampling period were also recorded. The indoor temperature varied from 16.7 to 29.0 C and the relative humidity varied from 32.8 to 81.0%. PM_{10} level varied from as low as 35.1 $\mu g\ m^{-3}$ to as high as 161.6 $\mu g\ m^{-3}$. TSP level varied from 37.5 to 227.1 $\mu g/m^3$. PM_{10}/TSP ratio varied from 49.7 to 100%. Based on the results at these 50 sites, mean and standard deviation of PM_{10} level on Hong Kong residential premises have been found to be 78.8 and 25.9 $\mu g\ m^{-3}$ respectively. Mean and standard deviation of TSP level were 93.9 and 33.2 $\mu g\ m^{-3}$ respectively. The mean indoor PM_{10}/TSP ratio was 85.0%, and the standard deviation was 9.7%. Those sites showing very high indoor particulate levels, e.g. Sites 9, 12, 20, 28, 29 and 46, were found to be either very close to (within 200 m measured at ground level) construction sites, or to major highways, or main roads.

Outdoor particulate levels at different districts are also included in Table 1 for comparison [7]. These values were obtained from the outdoor air monitoring stations managed by the Hong Kong Environmental Protection Department located in different districts.

Figure 1 shows the percentage of the residential premises within different ranges of indoor PM_{10} and TSP levels. From Fig. 1 and Table 1, it was found that none of the sites had PM_{10} or TSP values higher than the 24 h

Table 1
Indoor and outdoor airborne particulate levels on each premises

Site No.	District	Indoor					Outdoor			Indoor/Outdoor	
		PM_{10} Level ($\mu g\ m^{-3}$)	TSP Level ($\mu g\ m^{-3}$)	PM_{10} TSP (%)	Mean Temp (°C)	Mean R.H. (%)	PM_{10} Level ($\mu g\ m^{-3}$)	TSP Level ($\mu g\ m^{-3}$)	PM_{10}/ TSP (%)	$(PM_{10})_{in}/(PM_{10})_{out}$ (%)	$(TSP)_{in}/(TSP_{out}$ (%)
1	Central and Western	83.0	101.1	82.09	28.7	60.4	31	54	57.41	267.69	187.20
2	Central and Western	35.1	37.5	93.67	28.1	44.3	65	117	55.56	54.04	32.05
3	Wan Chai	74.3	86.1	86.29	26.6	62.9	61	106	57.55	121.82	81.24
4	Wan Chai	84.4	114.3	73.84	22.9	60.4	122	170	71.76	69.18	67.24
	Wan Chai (D)	73.0	86.1	84.79							
5	Eastern	60.9	63.9	95.31	29	56.7	64	117	54.70	95.14	54.61
6	Eastern	56.9	72.2	78.85	26.2	56.8	65	117	55.56	87.61	61.73
7	Eastern	74.2	117.2	63.35	20.8	41.2	79	136	58.09	93.99	86.18
8	Eastern	56.8	60.1	94.51	21.4	60.4	86	127	67.72	66.05	47.32
9	Eastern	125.0	127.8	97.83	28.2	62.4	65	117	55.56	192.31	109.21
10	Southern	72.8	87.9	82.81	28.5	66.7	54	79	68.35	—‡	—‡
11	Southern	84.4	99.6	84.76	18.3	55.6	40	64	62.50	—‡	—‡
12	Yau Tsim Mong	116.0	127.8	90.77	27.4	62.3	94	153	61.44	123.39	83.51
13	Yau Tsim Mong	75.7	105.5	71.77	24.1	55.8	72	124	58.06	105.15	85.07
14	Yau Tsim Mong	75.7	94.2	80.33	26.8	62.8	94	153	61.44	80.49	61.56
15	Sham Shui Po	101.9	120.1	84.85	24.1	55.6	117	188	62.23	87.09	63.88
	Sham Shui Po (D)	91.9	120.8	76.08							
16	Sham Shui Po	68.4	83.5	81.94	28.6	64.7	35	110	31.82	195.50	75.92
17	Sham Shui Po	130.4	139.8	93.28	19.5	48.7	86	142	60.56	151.63	98.45
18	Kowloon City	75.4†	75.0	100.52	28.3	49.9	72	113	63.72	104.71	66.37
19	Kowloon City	87.4	99.6	87.68	16.7	42.4	85	140	60.71	102.77	71.16
20	Kowloon City	116.2	138.9	83.66	23.1	41	83	128	64.84	139.99	108.51
21	Wong Tai Sin	79.7	81.9	97.31	28	56.4	65	89	73.03	122.67	92.07
22	Wong Tai Sin	65.5	77.6	84.37	28	57.4	56	99	56.57	116.99	78.43
23	Wong Tai Sin	50.7	51.4	98.74	27.5	69.9	55	88	62.50	92.26	58.40
24	Wong Tai Sin	76.5	93.1	82.18	23.2	47.9	88	139	63.31	86.90	66.95
25	Kwun Tong	81.1	92.3	87.83	27.4	62.3	72	113	63.72	112.59	81.68
26	Kwun Tong	63.9	68.9	92.74	22.7	47.8	94	139	67.63	67.98	49.57
27	Kwun Tong	94.6	109.9	86.12	20.5	49.4	83	128	64.84	114.01	85.84
28	Kwun Tong	161.6	227.1	71.16	21.5	60.2	83	128	64.84	194.70	177.41
29	Kwun Tong	119.4	153.8	77.60	22.7	56.3	62	109	56.88	192.55	141.13
30	Kwai Tsing	64.5	67.0	96.27	18.2	34.8	88	120	73.33	73.30	55.83
31	Kwai Tsing	58.2	71.8	81.12	21.5	73	63	105	60.00	92.44	68.37
32	Kwai Tsing	63.5	84.7	74.97	24.2	69.9	59	89	66.29	107.63	95.17
	Kwai Tsing (D)	66.7	81.9	81.44							
33	Kwai Tsing	91.7	131.9	69.56	20	44.8	81	121	66.94	113.23	108.97
34	Tsuen Wan	48.0	96.7	49.69	27.6	52.8	40	62	64.52	120.11	155.96
35	Tseun Wan	95.9	112.5	85.27	18.3	55.7	82	118	69.49	116.98	95.34
36	Tuen Mun	54.2	63.9	84.78	28.2	56.4	78	176	44.32	69.44	36.30
37	Tuen Mun	87.5	109.7	79.75	27.9	53.8	78	176	44.32	112.18	62.34
38	Tuen Mun	51.4	61.1	84.09	25.3	67.7	78	176	44.32	65.88	34.72
39	Yuen Long	60.9	73.6	82.72	27.3	81	62	100	62.00	98.21	73.61
40	Yuen Long	106.3	109.9	96.72	21.3	32.8	121	232	52.16	87.83	47.36
41	North	40.5	44.4	91.22	26.3	58.9	79	133	59.40	51.27	33.38
42	North	99.0	121.6	81.41	21.2	43.8	105	183	57.38	94.29	66.45
	North (D)	101.3	116.7	86.80							
43	Tai Po	59.4	66.1	89.97	28.1	61	59	97	60.82	100.76	68.11
44	Tai Po	86.5	88.9	97.28	25.9	47.1	92	134	68.66	93.99	66.33
45	Shatin	80.1	96.7	82.81	28.6	54.6	45	75	60.00	177.94	128.93
46	Shatin	113.6	124.5	91.19	27.9	68.6	58	83	69.88	195.79	150.04
47	Shatin	90.5	106.9	84.64	18.4	58	120	162	74.07	75.43	66.02
48	Shatin	44.4	59.7	74.42	26.8	61.7	33	56	58.93	134.68	106.65
49	Sai Kung	64.5	65.5	98.47	21.4	54.6	45	75	60.00	—‡	—‡
	Sai Kung (D)	61.1	62.1	98.39							
50	Islands	37.8	47.2	80.11	22.4	53.3	—‡	—‡	—‡	—‡	—‡

D = Duplication Test. † Indicates a higher PM_{10} level than TSP level. This was probably due to equipment inaccuracy when the TSP level was close to PM_{10} level. ‡ Sample size less than 3.

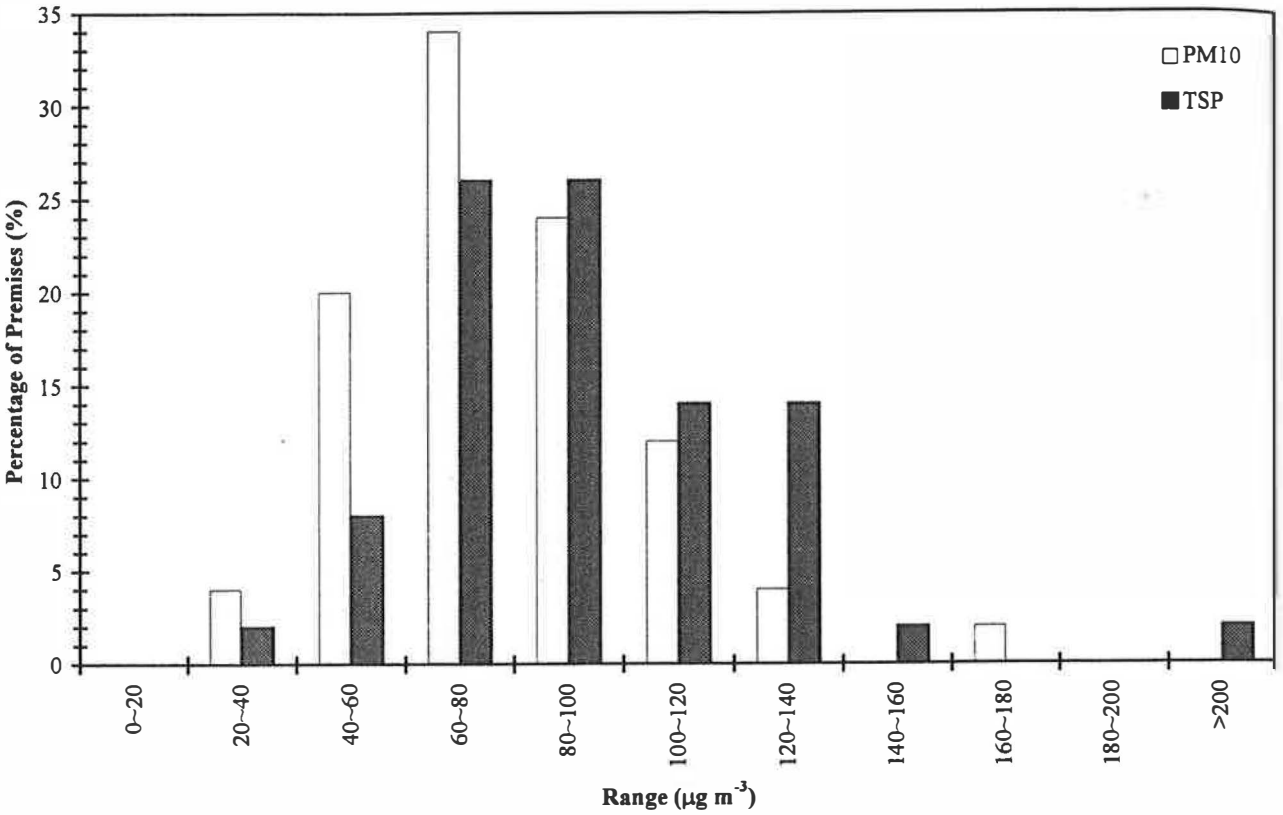

Fig. 1. Percentage of residential premises in different ranges of indoor PM_{10} and TSP levels.

level, as set in the interim indoor air quality guideline developed by the Hong Kong Environmental Protection Department (HKEPD) [8], which are 180 $\mu g\ m^{-3}$ for 24 h PM_{10} and 260 $\mu g\ m^{-3}$ for 24 h TSP. If the 24 h survey figures were extrapolated to the annual figures as shown in HKEPD guideline, i.e. 55 $\mu g\ m^{-3}$ for 1-year PM_{10} and 80 $\mu g\ m^{-3}$ for 1-year TSP, it was found that only 8 out of the 50 sites (16%) fell within the 1-year PM_{10} guideline and 18 out of the 50 sites (36%) fell within the 1-year TSP guideline. Indoor particulate level consists of two components: the indoor generated component and the outdoor contribution. The outdoor particulate level varies throughout the year and the outdoor particulate level in summer is lower than that in winter, as shown in the HKEPD outdoor database. The indoor generated component may also very due to the change of living pattern in different seasons. For examples, cooking and house cleaning activities may very in different seasons. In summer, windows may be closed most of the time due to the use of air-conditioning units and less outdoor particulate will be drawn in. In winter and spring, windows may be opened more often for natural ventilation. All our measurements were conducted in winter and the indoor particulate content might consist of a greater contribution from the outdoor sources which also existed in higher concentration in winter. The indoor particulate level in summer will not be the same as that in winter. In view of this comparing the 24 h survey data with the 1-year guideline may not be appropriate.

Mean and standard deviation of PM_{10} and TSP at each district are summarized in Table 2. The mean values at each district are shown in Fig. 2. Some districts were grouped together since not enough samples were available for analysis. Mean outdoor particulate levels in each district are also shown and the average of all districts were 73.3 and 120.5 $\mu g\ m^{-3}$ for PM_{10} and TSP respectively. It was found that Kwun Tong had the highest indoor PM_{10} (mean = 104.1 $\mu g\ m^{-3}$) and TSP levels (mean = 130.4 $\mu g\ m^{-3}$). The result agreed with the high outdoor particulate levels in this district. Based on the information collected from the site survey, the window opening frequencies at these sites (25–29) were from moderate to frequent, indicating that impact of outdoor air to indoor air was important. Indoor particulate level consists of indoor generated component and outdoor sources. More frequent window opening will bring in more outdoor particulates. Sai Kung district had the lowest indoor PM_{10} level (mean = 50.3 $\mu g\ m^{-3}$) and TSP level (55.5 $\mu g\ m^{-3}$). This was also predictable due to the low outdoor particulate level as shown in Table 1. (In Table 2, Sai Kung district was grouped into the category of 'Others' together with 'Islands' and as no outdoor data in Islands was obtained, the outdoor particulate level of Sai Kung district was not shown in Table 2.)

Table 2
Mean and standard deviation of particulate level at different districts

District	No. of Premises	Mean Indoor PM_{10} Level ($\mu g\ m^{-3}$)	Mean Indoor TSP Level ($\mu g\ m^{-3}$)	Standard Deviation of Indoor PM_{10} ($\mu g\ m^{-3}$)	Standard Deviation of Indoor TSP ($\mu g\ m^{-3}$)	Mean Indoor PM_{10}/TSP (%)	Mean Outdoor PM_{10} ($\mu g\ m^{-3}$)	Mean Outdoor TSP ($\mu g\ m^{-3}$)	Mean Outdoor PM_{10}/TSP (%)
Central and Western, Wan Chai	4	67.8	81.2	22.1	29.9	83.45	69.8	111.8	62.4
Eastern	5	74.8	88.2	29.0	31.8	84.81	71.8	122.8	58.5
Southern	2	78.6	93.8	—§	—§	—¶	—¶	—¶	—¶
Yau Tsim Mong, Sham Shui Po	6	93.8	111.8	25.1	21.3	83.90	83.0	145.0	57.2
Kowloon City, Wong Tai Sin	7	78.8	88.2	20.2	27.1	89.29	72.0	113.7	63.3
Kwun Tong	5	104.1	130.4	38.0	62.4	79.84	78.8	123.4	63.9
Kwai Tsing Tsuen Wan	6	70.7	93.9	19.0	25.0	75.29	68.8	102.5	67.1
Tuen Mun, Yuen Long, North	7	71.6	83.1	26.0	29.3	86.15	85.9	168.0	51.1
Tai Po, Shatin	6	79.1	90.5	24.3	24.6	87.41	67.8	101.2	67.0
Others (Sai Kung, Islands)	2	50.3	55.5	—§	—§	90.64	—¶	¶	¶

Mean indoor PM_{10} level = $78.8 +/- 25.9\ \mu g\ m^{-3}$ of the 50 sites. Mean indoor TSP level = $93.9 +/- 33.2\ \mu g\ m^{-3}$ of the 50 sites. § Sample size less than 3. ¶ Data not available.

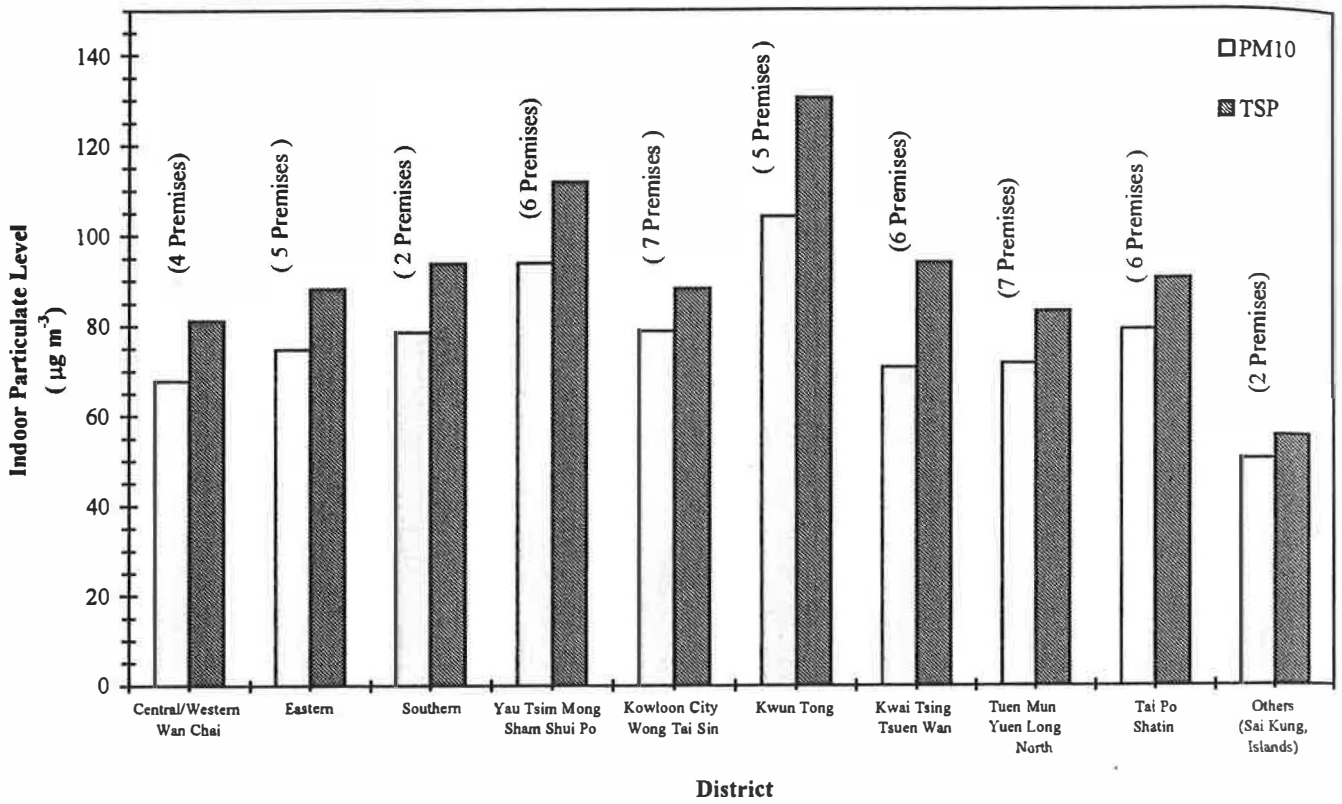

Fig. 2. Mean indoor PM_{10} and TSP levels at different districts.

The percentage of residential premises for different ranges of PM_{10}/TSP ratio is shown in Fig. 3. The PM_{10} to TSP ratio varied from 49.7 to 100%. The mean outdoor PM_{10} to TSP ratio was 62.6% from September 1996 to January 1997 according to the HKEPD outdoor database. The indoor ratio has been found to be higher than the outdoor ratio suggesting that the indoor environment might consist of more particulates of size less than 10 μm aerodynamic diameter, whereas the fraction of large particles was smaller. It has been found that 32% of the premises showed PM_{10}/TSP percentage in the range of 90–100%. The premises which had a PM_{10}/TSP ratio higher than 80% amounted to 78% and 94% of the premises had a PM_{10}/TSP ratio higher than 70%.

From Table 2, the mean indoor PM_{10}/outdoor PM_{10} ratio of the residential premises was 116.4% with 46.1% standard deviation. The mean indoor TSP/outdoor TSP was 84.4% with 36.5% deviation. These values indicate that indoor PM_{10} level is higher than outside even when the outdoor air has a higher total suspended particulate content than indoors. This result confirmed our argument that indoor activities led to more particulates of size less than 10 μm. It should be noted that apart from the outdoor component coming into the indoor environment through ventilation, the indoor particulate also consisted of the dust directly generated in the indoor environment from indoor sources and also the dust brought back into the indoor air from floor, wall or other surfaces during cleaning activities.

The influence of smoking and incense burning was also investigated and it was found that mean PM_{10} and TSP levels of those sites with smoking or incense burning were 96.6 and 118.3 $\mu g\ m^{-3}$ respectively. These levels were about 23 and 26% higher than the mean PM_{10} and TSP levels on all the premises respectively. Burning incense in houses for religious functions is quite common in Asian cities like Hong Kong. Information on the mutagenic properties, particle size spectrum and generation characteristics of incense smoke can be found in ref [9].

The mean PM_{10} and TSP levels for the premises in public buildings were 85.5 and 101.2 $\mu g\ m^{-3}$, and the corresponding standard deviations were 30.5 and 41.4 $\mu g\ m^{-3}$ respectively. The mean of PM_{10} and TSP levels for the premises in private buildings were 73.9 and 88.5 $\mu g\ m^{-3}$, and the corresponding standard deviations were 21.3 and 25.1 $\mu g\ m^{-3}$ respectively. Public premises seemed to show higher indoor particulate levels. The percentage of public premises that had smoking and cooking activities was roughly the same as that of the total sample. However, 38% of the public premises had incense burning and this percentage was higher than that of the total sample (24%). A greater level incense burning in public premise might be one of the factors for the higher indoor particulate levels.

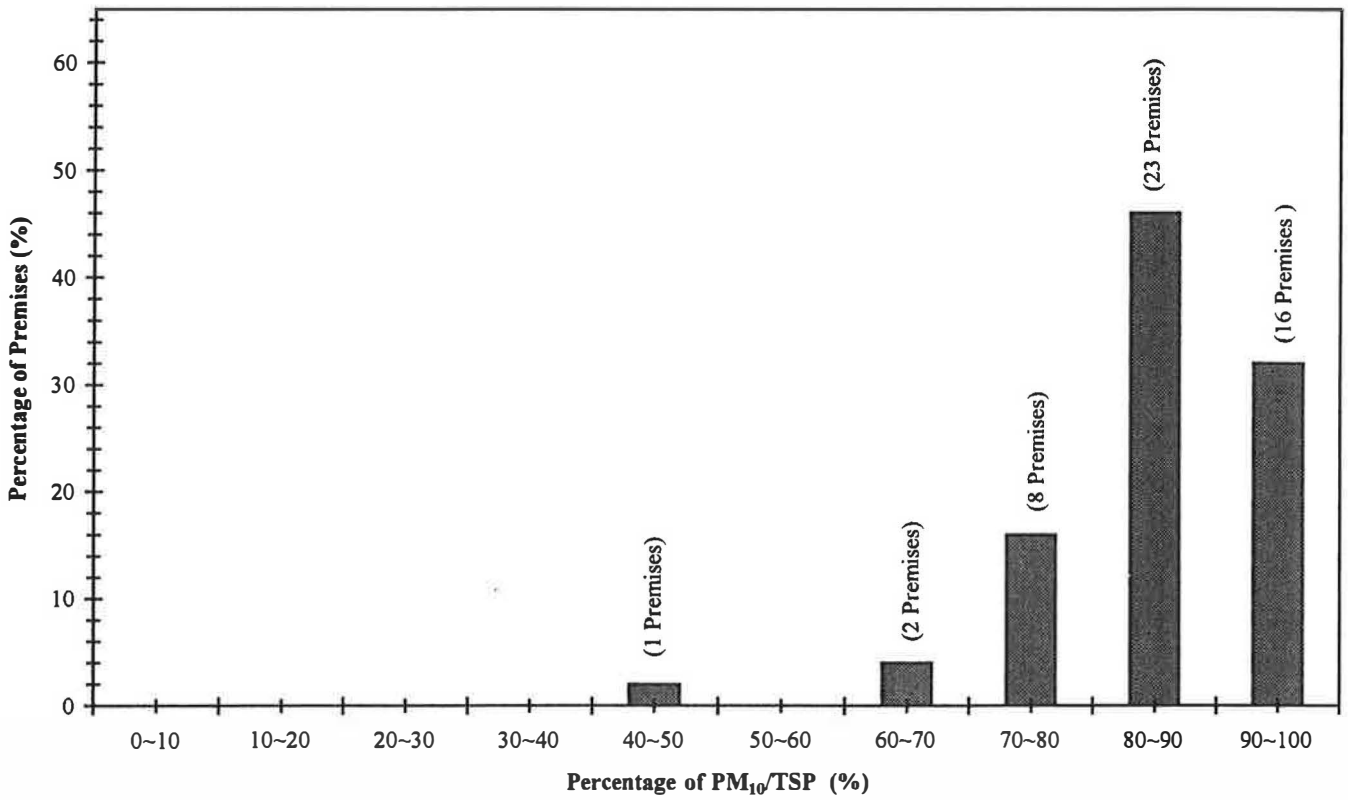

Fig. 3. Percentage of residential premises in different ranges of PM_{10}/TSP ratio.

The indoor PM_{10} and TSP levels in Hong Kong have been found to be relatively high in some districts compared to countries such as the US. The PM_{10}/TSP ratio was also found to be higher than those in other overseas countries. This might be due to the difference of the composition of the particulate matter in Hong Kong and in other western countries (e.g. differences in cooking habits, incense burning, etc.). Detailed conclusion requires further information on the chemical composition of the particulate matters. A more detailed study of the size distribution and component analysis of the indoor particulate may reveal more information about whether indoor sources or outdoor contribution due to infiltration are the principal contributors to the indoor particulate levels. Quantification of ventilation rates of the premises is also required. For the premises with air-conditioning units in use, the ventilation rate consists of both the fresh air intakes from the air-conditioning units as well as infiltration due to building leakage. The performance of filters in the air-conditioning units, together with other aerosol removal devices such as indoor air cleaners are all important parameters in understanding indoor airborne particulate levels in the domestic environment.

4. Quality control

The results of the duplicate tests are summarized in Table 3. The percentage difference of the five duplicate tests for PM_{10} varied from 2.1 to 13.5%, and from 0.6 to 24.7% for TSP. The differences were satisfactory except at site 4 where a large discrepancy was observed. It has been noticed that there was interior renovation work going on at site 4 during the testing period and the dust loading might have been very unstable during this test. Thus it was not surprising that there was a significant variation in the duplicate readings for this site. If site 4 was not included in the duplicate tests, the mean difference was 4.9 and 3.3% for PM_{10} and TSP respectively.

The results of the blank tests are summarized in Table 4. Among the five tests, the difference varied from 0.000 to 0.027%. The results were considered to be satisfactory.

5. Conclusion

Indoor particulate levels on 50 residential premises were studied in this project. Mean indoor PM_{10} level was 78.8 μm^{-3} and the standard deviation was 25.9 μm^{-3}. Mean indoor TSP level was 93.9 μm^{-3} and the standard deviation was 33.2 μm^{-3}. The mean indoor PM_{10}/TSP ratio was 85.0% and the standard deviation was 9.7%. The indoor particulate levels were also compared to the outdoor particulate levels obtained from HKEPD database. The mean indoor PM_{10}/outdoor PM_{10} ratio was 116.4% and the standard deviation was 46.1%. The mean indoor TSP/outdoor TSP ratio was 84.4% and the standard deviation was 36.5%.

Table 3
Results of duplicate tests

Site Number	PM_{10} level 1st Filter ($\mu g\ m^{-3}$)	PM_{10} level 2nd Filter ($\mu g\ m^{-3}$)	% difference in duplicate tests	TSP level 1st Filter ($\mu g\ m^{-3}$)	TSP level 2nd Filter ($\mu g\ m^{-3}$)	Difference in duplicate tests%
4	84.4	73.0	13.5%	114.3	86.1	24.7
15	101.9	91.9	9.8%	120.1	120.8	0.6
32	65.3	66.7	2.1%	84.7	81.9	3.3
42	99.0	101.3	2.3%	121.6	116.7	4.0
49	64.5	61.1	5.3%	65.5	62.1	5.2

Reading of Site 4 was dropped due to influence from renovation work. Mean% difference for the PM_{10} duplicate tests = 4.9%. Mean% difference for the TSP duplicate tests = 3.3%.

Table 4
Results of the blank tests

Blank Test Sample	First Meas. (g)	Second Meas. (g)	Difference between blank tests %
1	0.14781	0.14777	0.027
2	0.48420	0.14841	0.007
3	0.14738	0.14738	0.000
4	0.14861	0.14865	0.027
5	0.14828	0.14826	0.013

Mean% difference of the blank tests = 0.0148%.

Indoor particulate level depends on both the outdoor contribution and the generation from the indoor activities such as incense burning, smoking and cooking. An increase in window opening frequency seemed to bring in more outdoor particulate and the PM_{10}/TSP ratio was reduced. However, more samples and the use of source apportionment technique would be required in order to come up with a more solid conclusion.

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