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Measuring quantity of indoor/outdoor suspended air particle matter in Southern Taiwan

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Abstract

Many invisible pollutants such as dust and toxic aerosols had released into the atmosphere in southern Taiwan. The air affecting our heart and lung function was named aerosols (particulate matter, PM). As long as the particles inhaled into the lungs, they stayed in the alveoli and were hard to be discharged. Whether they were toxic or non-toxic substances, they might cause a direct or potential harm to the body. When PM size inhaled became smaller, the probability of discharge would be lower. Therefore, it was suggested that people should avoid inhaling them. Moreover, because of the poor quality of the air, it was easy to accumulate dust at home. It might not only cause eyes itchy but more likely physical discomfort and other respiratory diseases, especially carpeted room in the house. Literature had demonstrated that the distribution of PM size was 0.1~10 μm. Only PM10 was considered to have negative impacts on human respiratory system. The quantity of patients would increase accompanied by the concentration of PM2.5.They had a positive and significant correlation. However, fewer studies compared the size and composition of indoor/outdoor space of PM. Responding this problem would benefit practice and academia. Consequently the purpose of this study was to explore the size of PM and its composition in indoor/outdoor spaces; to clarify the difference between the indoor spaces contained carpet and none carpet; and finally some more recommendations would be offered. The research tools were made by Aerotrak Company (9310-02 model) series. PM size detection was to 0.3, 0.5, 1.0, 3.0, 5.0 and 10.0 in Desktop Particles Calculator. This study had a total of six groups of samples, respectively, in NPUST campus different locations within the space for the actual number of PM. Each sample for 10 seconds and each sample of 30 times, the interval time was only 3 seconds (as far as possible reduce the impact of the time difference). Six groups of samples were dealt at different time to sample the actual the quantity of PM. Sampling data showed that the average quantity of outdoor PM was accumulated to 447,920; the average quantity of indoor was accumulated to 258,756; and 297,743 was accumulated in an indoor carpeted room. Research results showed that the average quantity of PM outside was larger than the interior space. It was almost to 2 times. Moreover, the average quantity of PM in the carpeted room was much larger than none-carpeted one. As long as PM inhaled into the lungs, the body would directly or potentially be harmed, and when the smaller size of the particle was met, the probability of discharging the particles would be lower. Human should avoid inhaling those particles as possible.

Key words: Indoor/outdoor, particulate matter, PM, particle size, the average quantity of PM.

Introduction

Many invisible pollutants such as dust and toxic aerosols had released into the atmosphere in southern Taiwan. The air affecting our heart and lung function was named aerosols (particulate matter, PM). As long as the particles inhaled into the lungs, they stayed in the alveoli and were hard to be discharged. Whether they were toxic or non-toxic substances, they might cause a direct or potential harm to the body. When the particle size inhaled became smaller, the probability of discharge would be lower. Therefore, it was suggested that people should avoid inhaling them. Moreover, because of the poor quality of the air, it was easy to accumulate dust at home. It might not only cause eyes itchy but more likely physical discomfort and other respiratory diseases, especially carpeted room in the house.

PM integrated polychlorinated biphenyls (PCBs) and dioxins, resulting in a threat to human health in a outdoor environment [1, 2, 4, 5]. Thus, it has attracted many scientists to investigate the composition of ingredients of suspended particulates (such as PCBs) and its impacts on human health [5].The other pollutants, PAHs, could potentially impact human health when indoor concentration changed between 0.44 and 2.09 ng m^{-3}. Further, it has been evidenced that it was 3.7 to 4.3 times in industrial areas comparing to residential areas so that many advices were suggested to the government for this finding [14,15]. Moreover, volatile organic compounds (VOCs) and polycyclic aromatic species of PM could release benzene, toluene, xylems and styrene in the carpeted interior [18, 19]. The significant difference of its concentration could be found in autumn and winter. It would increase to 75% in those seasons in the same type of carpet [18,19, 21.

Past studies had indicated that the use of sources of meteorological satellite remote sensing of aerosols in urban areas[16,17]. The steam locomotive exhaust gas, wind, waste incinerator flue gas and bio-aerosols could be included [3, 5-7,10,15-17, 20]. The results revealed it was particularly serious when the vehicles use two-stroke engine [13,15]. A variety of pollutants (e.g. benzene, CO, Pb, OCS, NOx, SO_2, SPM and inert dust, etc.) would be emit on those engines [13, 15]. The damages of PM were mainly focused on the circulatory system, respiratory and cardiovascular problems[11]. Total suspended particulates (TSP) of emissions

number (PM_{10}~$PM_{2.5}$) and particles could affect human and animal health and rest [22]. However, not all of the particle size of the suspended particles could harm human health. Research has indicated that the size of particle aerosols below $PM_{10}$was considered to be reparable to respiratory system [11].The number of patients would increase accompanied by the concentration of $PM_{2.5}$ and they had a positive and significant correlation [11,12]. This means that it could be discharged when its size is ranging from PM_{10} to $PM_{2.5}$ and when size is below $PM_{2.5}$ particulates would affect adversely health in the human body.

Specifically, previous studies did not compare the size and composition of indoor/outdoor space of PM, responding this problem would benefit practice and academia. In sum, to explore the size of PM in different spaces and to provide some advices could fill up the gap of theory and improve the quality of the air and thus reduce the probabilities of its harming on human health. Consequently the purpose of this study was to explore the size of PM and composition in indoor/outdoor spaces; and to clarify the difference between the interior space contained carpet and none carpet; and finally some more recommendations would be offered.

Materials and Methods

The experimental tools used in this study were made by Aerotrak Company (model 9310-02) series (Fig. 1). It contained a Desktop Particles Calculator and its detection range of the PM size ranging from 0.1 to 1.0 µm PM. According to the default model, totally six sets of PM samples, 0.3, 0.5, 1.0, 3.0, 5.0 and 10.0 were tested [8,9]. The aerosol particles were collected from different locations within the NPUST campus (Fig. 2). Considering to the experimental safety, the sampling of the experiment was conducted during daytime. The samples of outdoor space were collected on the grass out of the EP101 and other samples of indoor space were in CE411 classroom in NPUST campus. Furthermore, carpeted samples were collected at LB202 classroom in NPUST's library.

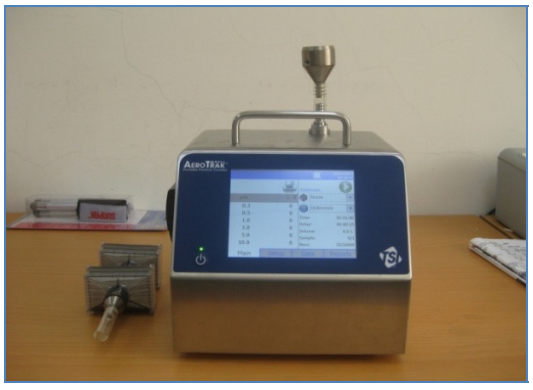


Figure 1. Aerotrak (9310-02 models) Desktop Particles Calculator for this study.

Figure 2. The actual sampling locations on NPUST campus in southern Taiwan.

It's noted that the environmental factors of outdoor space, e.g. no wind ground and sampling was met under a natural addition, were controlled when collecting the samples. Again, the sampling for indoor environment could be met at the same time. This study conducted the sampling 10 seconds/time. The interval of sampling was 3 s. It took 387 s for collecting samples each site and totally 1,161 s was used for three spaces. A total of 30 times per sample group was made in order to test the differences of actual condition of PM for six groups' samples.

Moreover, virtual number was made for data analysis. Data from CE411 classroom (indoor/non carpeted space) was set as the first group, the grass outside EP101 (outdoor space) was set as the second group, and LB202 classroom (indoor/ carpeted space) was then set as the third group.

Beside, this study adopted SPSS version 12.0 statistical software package to analyze the data. Each setting of data for indoor had set of 30 samples. ANOVA analysis was adopted to confirm if the characteristic of PM quantity sampling from three different locations were significantly different or not.

Finally, this study adopted scanning electron microscope (SEM) with 15.0 kV and magnification of 5000 times to clarify PM's shape. For minor exterior shape of PM, we further made the analysis for the composition of the main elements. This tool helped us to understand the basic characteristics of the distribution of aerosols in southern Taiwan.

Results

The samples were collected from four independent spaces at the same time, indoor/outdoor space, carpeted room/non carpeted space. The results are presented by these two groups (e.g. indoor/ outdoor space and carpeted room/non carpeted space).

The comparison of indoor/outdoor space: The outdoor space used in this study was set on the grass outside EP101 museum in NPUST campus. Totally 30 samples were valid and Table 1 presents the average values of the first 10 groups. The results revealed the quantity of PM was 440,000~460,000. The average quantity of PM cumulated in outdoor space was 447,920 (Table 1, Fig. 3).

Table 1. Sampling particle number at outdoor space on the grass outside EP101 museum in NPUST campus.

Zone Name	Sample Time (sec)	Size (µm)	Cumul (No.)	Size (µm)	Cumul (No.)	Size (µm)	Cumul (No.)	Size (µm)	Cumul (No.)	Size (µm)	Cumul (No.)	Size (µm)	Cumul (No.)
EP101	10	0.3	454459	0.5	144635	1	24275	3	1175	5	213	10	21
EP101	10	0.3	454849	0.5	144856	1	24181	3	1183	5	207	10	15
EP101	10	0.3	445694	0.5	145417	1	24300	3	1147	5	162	10	17
EP101	10	0.3	461821	0.5	149252	1	24910	3	1327	5	234	10	33
EP101	10	0.3	444778	0.5	142055	1	24077	3	1288	5	217	10	29
EP101	10	0.3	452822	0.5	146670	1	25164	3	1520	5	324	10	65
EP101	10	0.3	457712	0.5	149756	1	24723	3	1287	5	245	10	36
EP101	10	0.3	456749	0.5	150675	1	24928	3	1423	5	291	10	37
EP101	10	0.3	460635	0.5	149551	1	24995	3	1523	5	312	10	60
EP101	10	0.3	451131	0.5	145892	1	24853	3	1380	5	283	10	56

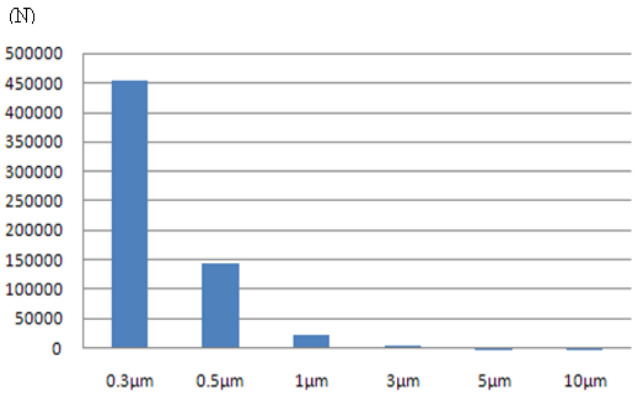


Figure 3. The cumulative average number of particles of different size at outdoor space on the grass outside EP101 museum in NPUST campus.

The indoor space was set at CE411 classroom in Institute of Technology (no carpet indoor space) in NPUST. Totally 30 samples were valid and Table 2 presents the average values of the first 10 groups. The results showed that the quantity of PM was 250,000~260,000. The average quantity of PM cumulated in indoor space was 258,756 (Table 2, Fig. 4).

Table 2. The number of particles sampled at CE411 classroom in Institute of Technology in NPUST (no carpet indoor space).

Zone Name	Sample Time (sec)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)
CE411	10	0.3	263183	0.5	22091	1	1855	3	56	5	18	10	6
CE411	10	0.3	261739	0.5	21973	1	1834	3	71	5	19	10	8
CE411	10	0.3	262866	0.5	21499	1	1871	3	72	5	21	10	8
CE411	10	0.3	261097	0.5	21246	1	1862	3	64	5	14	10	4
CE411	10	0.3	266241	0.5	21597	1	1938	3	59	5	18	10	6
CE411	10	0.3	262157	0.5	21732	1	1969	3	59	5	12	10	5
CE411	10	0.3	262777	0.5	21535	1	1939	3	63	5	19	10	8
CE411	10	0.3	262835	0.5	20936	1	1858	3	73	5	19	10	10
CE411	10	0.3	258933	0.5	20708	1	1931	3	62	5	16	10	3
CE411	10	0.3	259149	0.5	20619	1	1854	3	79	5	19	10	3

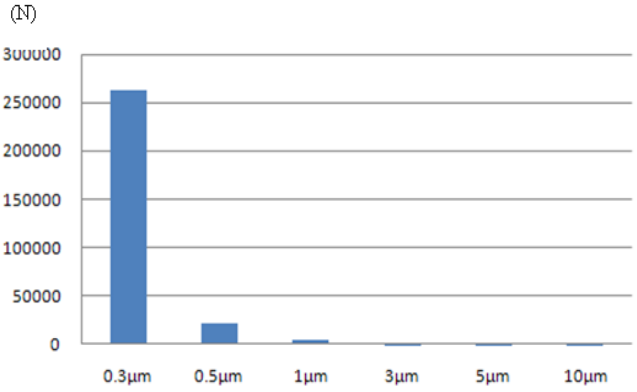


Figure 4. The cumulative average number of PM of different size at the indoor space (no carpet indoor space) was CE411 classroom in Institute of Technology.

In general, the average quantity of PM cumulated in outdoor space was higher than that of indoor space.

The comparison of carpeted space/none carpeted space: The carpeted indoor space was set at LB202 in NPUST's library. Totally 30 samples were valid. The results showed that the quantity of PM was 310,000~290,000. The average quantity of PM cumulated in indoor space was 307,743 (Table 3, Fig. 5).

Table 3. The number of particles sampled at LB202 classroom (carpeted indoor space) in NPUST library.

Zone Name	Sample Time (sec)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)	Size (μm)	Cumul (No.)
Lib2F	10	0.3	312685	0.5	43603	1	7021	3	634	5	202	10	52
Lib2F	10	0.3	295993	0.5	41312	1	6648	3	559	5	186	10	53
Lib2F	10	0.3	301957	0.5	41507	1	6430	3	530	5	167	10	41
Lib2F	10	0.3	299034	0.5	40434	1	6346	3	536	5	155	10	34
Lib2F	10	0.3	303580	0.5	40010	1	5974	3	497	5	140	10	36
Lib2F	10	0.3	298100	0.5	38812	1	5080	3	396	5	121	10	33
Lib2F	10	0.3	298237	0.5	38861	1	5341	3	411	5	140	10	30
Lib2F	10	0.3	299562	0.5	39472	1	5733	3	475	5	141	10	33
Lib2F	10	0.3	295287	0.5	38096	1	4951	3	415	5	130	10	28
Lib2F	10	0.3	296359	0.5	37045	1	4124	3	275	5	78	10	27

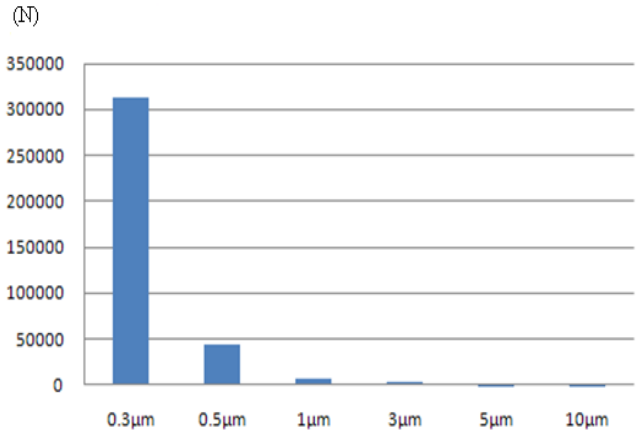


Figure 5. The cumulative average number of particles of different size at the indoor space (carpeted) LB202 classroom in NPUST library.

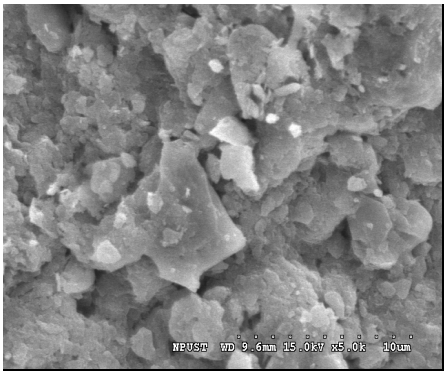
The ANOVA analysis: In order to compare the differences between indoor/outdoor space and carpeted room/non carpeted space, one-way ANOVA analysis was adopted. The results of carpeted room/non carpeted space showed that the F values were significant (8170.038>F0.001(2,87) = 7.48, p^{***}= 0.000<0.001) indicating that the quantity of PM of those groups had significant statistical difference (Table 4). The quantity of PM in carpeted room was much higher than in non carpeted space.

The comparison of PM's shape: This study adopted scanning electron microscope (SEM) with 15.0 kV and magnification of 5000 times to clarify PM's shape. The results of outdoor space/indoor

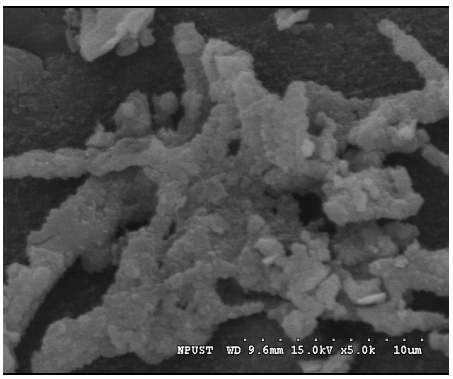
Table 4. One-way ANOVA (three groups).

SV	SS	DF	MS	F	Sig.
Between	59856219 0875.756	2	29928109 5437.878	8170. 038	.000
Within	31869440 74.867	87	36631541 .090		
Total	60174913 4950.622	89			

space showed that the appearance of the PM's shape in outdoor space was rounding granular (Fig. 6a). However, it was relatively long fibrous in indoor space (Fig.6b). In sum, the appearances of the PM's shape adopted in this study were different.



a. PM_{10} (EP101)



b. PM_{10} (CE411)

Figure 6. SEM photograph of the appearance of fine particle shape in a) outdoor space and b) indoor space.

The components of PM: Approximately O, Si, K, and Fe were the components of PM in outdoor space setting (Table 5, Fig. 7). Furthermore the content of Fe was highest indicating that the surface soil in southern Taiwan might contain a lot of Fe and it's typical in acidic soil.

Moreover the results of the components of PM in indoor space setting are listed in Table 6. The results showed that O, Si, K, Ca and Ti would be the components of PM (Fig. 8). More specifically Ti was first evidenced to be the component of PM. It was seldom found in related research. This study argued that the reason might be the selection of sampling place adopted from CE411 classroom.

Table 5. Analysis of elements in sampling particles at NPUST on the grass outside EP101 museum.

Element	Weight%	Atomic%	Date
O	17.61	38.37	2-Mar-2014
Si	9.44	11.72	2-Mar-2014
K	16.35	14.58	2-Mar-2014
Fe	56.60	35.33	2-Mar-2014
Totals	100.00	100.00	

Standard : O SiO_2 2-Mar-2014 12:00 AM; Si SiO_2 2-Mar-2014 12:00 AM, K MAD-10 Feldspar 2-Mar-2014 12:00 AM; Fe Fe 2-Mar-2014 12:00 AM

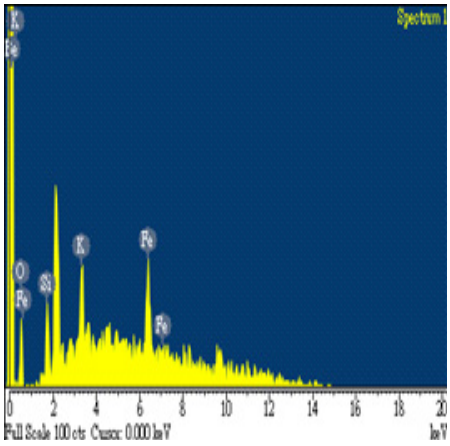


Figure 7. Elements contained in particles at NPUST on the grass outside EP101 museum.

Table 6. Analysis of elements in sampling particles at NPUST in CE411 classroom.

Element	Weight%	Atomic%	Date
O	46.40	68.85	2-Mar-2014
Si	4.67	3.94	2-Mar-2014
K	11.71	7.11	2-Mar-2014
Ca	17.01	10.08	2-Mar-2014
Ti	20.21	10.02	2-Mar-2014
Total	100.00	100.00	

Standard: O SiO_2 2-Mar-2014 12:00 AM; Si SiO_2 2-Mar-2014 12:00 AM
K MAD-10 Feldspar 2-Mar-2014 12:00 AM;
Ca Wollastonite 2-Mar-2014 12:00 AM; Ti Ti 2-Mar-2014 12:00 AM

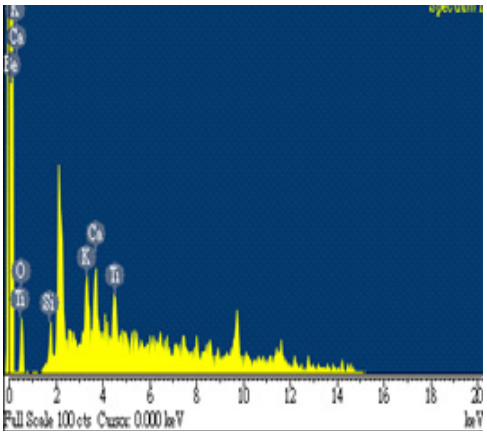


Figure 8. Elements contained in particles at CE411 classroom in Institute of Technology.

Discussion and Conclusions

(1)Comparing to indoor samples, the average quantity of outdoor particles ones were much larger than the indoor particles two times.

(2)Regarding to different kinds of indoor space particles, the average quantity of carpeted room samples significantly exceed non carpeted one. The carpeted area in a room should be declined or controlled and human should carefully consider when decorating the fixed carpets.

(3)The significant difference could be found between indoor/ outdoor and carpeted/non carpeted when calculating the quantity of particle matter based on the results of one-way ANOVA.

(4)When the size of particle was becoming smaller, the quantity of particle matter would increase much more. In order to maintain the quality of the air, people who stay/live in a carpeted room need to clean the air conditioning facilities more frequently.

(5)The shape of the particles in outdoor space revealed more likely granular round and long fibrous could be found in indoor space after adopting SEM. Future study could compare the appearance of particles' shapes in different environments.

(6)With considering to the particle components of outdoor samples, the higher content of Fe indicated that the surface of the soil in hilly southern Taiwan contains a lot of Fe and it has become a typical acidic soil. Further study could explore the difference of particle components in different environments.

(7)As regarding to the particle components of indoor samples, Ca and Ti were evidenced to be the particle components but Fe wasn't. This finding might be caused due to the data collected from one of a lab. Future study could redo it in other space and have a comparison of the results.

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