Journal of Environmental Science International
23(4); 673~679; April 2014

pISSN: 1225-4517 eISSN: 2287-3503
http://dx.doi.org/10.5322/JESI.2014.4.673

ORIGINAL ARTICLE

Characteristics of Fine Particle and Metallic Elements at School Classroom in Summertime

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Abstract

This study aims to investigate the indoor air quality by analyzing PM_{10} concentration and metallic elements collected from high school(classroom, science room, assembly room). PM_{10} concentration of a classroom, a science room, and an assembly hall during the research period was 87.7 $\mu g/m^3$, 75.3$\mu g/m^3$, 64.6$\mu g/m^3$, respectively. Si of PM_{10} had highest concentration with 15,427 ng/m^3 followed by Na which had 7,205 ng/m^3, and the order was Si>Na>Ca>Mg>Fe>K in the classroom. PM_{10} concentration of a classroom and a science room was each 104.8 $\mu g/m^3$ and 75.3 $\mu g/m^3$ during the semester and PM_{10} concentration of a classroom and an assembly hall was each 80.9 $\mu g/m^3$ and 64.6 $\mu g/m^3$ during the summer vacation. Based on PM_{10} and metallic concentration at a classroom on day of week, the concentration of Friday was highest with 112.0 $\mu g/m^3$, and that of Monday was lowest with 65.3 $\mu g/m^3$.

Key words : PM_{10} concentration, Metallic elements, Classroom, Science room, Assembly hall

1. Introduction

Indoor environmental quality in schools is a very important element in providing a healthy and comfortable learning environment where it has an effect on health, productivity, performance and comfort for students and teachers in a variety of ways (Daisey et al., 2003). Particulate matter is considered one of the main pollutants that exist inside school buildings that could affect students' health. Poor indoor environment quality in schools has a great influence on the performance and attendance of students. The exposure to contaminants in such indoor environments may lead children to develop potential health consequences as they are more susceptible to air pollutants than adults because they breath higher volumes of air relative to their body weights and their tissue and organs are growing(Mendell and Health, 2005).

Poor indoor environments in schools may be attributed to three primary causes: i) unexistence or inadequate operation and maintenance of ventilation systems, ii) infrequent and unthoroughly cleaned indoor surfaces, and iii) a large number of students in relation to room area and volume, with constant re-suspension of particles from room surfaces.

As school-aged children spend approximately 80% of their daytime in school and may be regarded as particularly vulnerable to potential health hazards, more precise data on exposure to air pollution in this setting is urgently required. Many invisible particles such as asbestos powder, chalk powder, and textile dust harm human bodies in classrooms full of activities.

Some offices of education in Korea not only measure the air quality of elementary, middle, and

Received 6 January, 2014; **Revised** 2 April, 2013;
Accepted 4 April, 2014
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high schools and provide faculty with training sessions on the importance of air quality inside the classroom but also carry out a regular checkup on particulate matters at least once a year. In addition, they try to promote clean environment for students by taking necessary measures to supplement facilities in case the measured value of indoor air quality exceeds 100 $\mu g/m^3$, the guideline.

Thus, this study aims to determine the indoor air quality by analyzing concentration of particulate matters and metallic elements collected from high school in Busan using mini volume air sampler(made by U.S. Air Metrics) in July and August, 2013.

2. Measurement and methods

Sampling was done in July and August, 2013 at high school located in Bukgu, Busan in which efficient measurement of indoor particulate matters and convenient supervision of observation instruments were ensured. Using two mini volume air samplers, the sampling was done in a classroom, a science room, and an assembly hall from 9 a.m. to 9 p.m. for 12 hours during the semester and from 9 a.m. to 9 a.m. of the next day for 24 hours during the summer vacation for which students took supplementary classes in the morning and either left for home or had study hall in the afternoon.

For measurements of PM_{10}, mini volume air sampler was used with 5.0 ℓ /min of inlet air flow and 47mm Quartz Fiber filter for 12 hours or 24 hours. This sampler proceeds measurements with high degree of vacuum and air flow, provides convenient portability and consistent operation without pulse. It adopts the media injection method that separates particles less than 10 ㎛ through inertia collision method. MINI PUMP (Model MP-603T) was utilized for filter sampling. This instrument has 5 ℓ /min of maximum air inlet and accordingly enables to adjust wide range of air flow. It can be used to collect both toxic and normal gas. Filters used in this study are Quartz Fiber filter(QMA, 47 mm, No. 1851-047, Whatman Co.). Filters were first dried for two days at minimum using an automatic dry/up desiccator (SIBATA DUV-12) with constant temperature(20℃) and humidity (50%) and then weighed thought a electronic microbalance (Saritorious microbalance, Germany) with sensitivity up to 0.01 ㎎ to measure mass concentration of PM_{10} before and after sampling of particles.

To analyze trace elements in the filter sample, all analysis procedures were in compliance with the Air Pollutant Analyzing Procedure Standard. For analysis of trace elements, ultrasound wave extraction method was adopted to preprocess the filter before the elements analysis. The extraction was performed in a way that with 6 ㎖ mixture of 1.3 M nitric acid and 2.23 M hydrochloric acid (1:1) is added to a beaker where a filter is contained and then an ultrasound wave extractor retrieve solution from the beaker for 2 hours with 28 KHz. After the ultrasound treatment, the beaker will be filled with distillated water up to 20 ㎖ so the resulting concentration of nitric acid-hydrochloric can be 0.31 M and 0.67 M(1:1) extracts. After the ultrasound wave preprocessing of the filter, the extracts pass through syringe filter(PVDF, Whatman Co. pore size 0.45 ㎛). Then using ICP/AES (ICP-IRIS, Thermo Jarrell Ash Co., USA), Al, Ca, Fe, K, Mg, Na and S were analyzed. Using ICP/MS, Ba, Cd, Cr, Co, Cu, Mn, Ni, Pb, Sr, Ti, V and Zn were quantified.

3. Results and discussion

3.1. Characteristics of concentration of particulate matters in the school

Table 1 shows concentration of PM_{10} measured in domestic and foreign schools as well as concentration of PM_{10} in a classroom, a science room, and an assembly hall covered in this study. Using two mini volume air samplers, the sampling was done simultaneously in a classroom and science room from 9 a.m. to 9 p.m., 4 times for 12 hours. Another sampling was done in a classroom and an assembly room from 9 a.m. to 9 a.m. of the next day, 10 times for 24 hours within the period of supplementary classes during the summer vacation. The total number of measurement was 14 times for a class, 4 times for a science room, 10 times for an assembly room.

PM_{10} concentration in the classroom was 87.7 ㎍/m^3 which was lower than 100 ㎍/m^3, the limit value of the Korean Air Quality directive. Meanwhile, PM_{10} concentration in a science room and an assembly hall were each 75.3 ㎍/m^3 and 64.6 ㎍/m^3 which were lower than 87.7 ㎍/m^3, PM_{10} concentration in the classroom. The cause of high concentration of particulate matters in the classroom lied in increase of students' activities and lack of frequent ventilation. The domestic research on particulate matters in the classroom were done mainly from 2002 to 2008, most of which showed concentration distribution of 50.5∼82 ㎍/m^3. The cases in foreign countries regarding the concentration of particulate matters show that Netherlands and Germany have less than or equal to 80 ㎍/m^3, while both Palestine and Greece have over 200 ㎍/m^3 which is very high.

3.2. Characteristics of metallic element concentration in PM_{10} in the school

Table 2 shows PM_{10} concentration and metallic concentration within them, which were measured in a classroom, a science room, and an assembly room in the school. In the classroom, Si of PM_{10} had the concentration of 15,427 ng/m^3 which was highest followed by Na which had the concentration of 7,205 ng/m^3. The entire order was as follows: Si>Na>Ca>Mg>Fe>K. That is, the concentration of Si originated from soil was highest, followed by the concentration of Na affected by the ocean. Of the analyzed 19 metallic elements, most of them such as Ca, Fe, K, Mg, Si were originated from soil except for Na.

Considering that such soil-oriented metallic elements harm human bodies, it is important to get rid of them attached to clothing or shoes that have been to playgrounds or off-roads in order to decrease concentration of particulate matters. Also, it is very

Table 1. Indoor school PM_{10} concentration in this study and other regions

Location	Type	Concentration(㎍/m^3)	Reference
Busan	classroom(n=14)	87.7±17.3	This study
Busan	science room(n=4)	75.3±18.3	This study
Busan	assembly hall(n=10)	64.6±14.0	This study
Busan	preschool	75.3	Kim et al.(2006)
Korea	Library	78.4	Nam et al.(2002)
Gyeongido	classroom	70.7	Choi et al.(2006)
Chungnam	classroom	53.4±31.6	Cho et al.(2008)
Chungnam	stateroom	50.5±60.2	Cho et al.(2008)
Korea	classroom	82±47	Sohn et al.(2006)
Korea	science room	71±35	Sohn et al.(2006)
Korea	computer room	72±40	Sohn et al.(2006)
Netherlands	classroom	77.8	Janssen et al.(1999)
Portugal	classroom	83	Almeida et al.(2011)
Palestine	classroom	349.5±196.6	Elbayoumi et al.(2013)
Germany	classroom(summer)	71.7	Fromme et al.(2007)
Greece	classroom	236.1	Diapouli et al.(2007)

effective for students to voluntarily beat the dust off at the building entrance before they get into the classroom. Another good way is to put the dust-free pads in front of the classroom entrance.

The high Na concentration is due to seawater constituents that moved into the continent on the wind from the coast near Busan. The sea-salt that contributes to PM_{10} concentration in Busan is known to be approximately 10%(Jeon et al., 2010). Co, Cd, Pb, Cr are anthropogenic elements including volatility and could not only fatally damage nerve system but also cause cancer if accumulated excessively. The fact that these harmful elements are found albeit very small indicates the need for improvement of indoor environment.

Compared to the research findings of Nam et al.(2002) on metallic elements of particulate matters at school classrooms in Korea, all elements measured in this research except for Cd and Zn had higher concentration. Meanwhile, compared to the findings of Janssen et al.(1999) conducted in Netherlands, Cr, Fe, Mn, Si of the entire 11 elements covered in this study had higher concentration. Especially, the concentration of Si, the soil-oriented element, was approximately 4 times higher, which was deemed to be caused by the difference of two environment such as playground and classroom entrance. Also, compared with the findings of Almeida et al.(2011) in Portugal, metallic elements such as Ba, Co, Cr, Na in our study had higher concentration.

The concentration of Na was especially high, which seemed to be due to the geographical difference of two research areas: Busan near the ocean and Portugal, the land. Also, it should be noted that the concentration of Co and Cr, the artificial elements, were relatively high.

3.3. Characteristics of PM_{10} concentration and metallic

Table 2. Summary of metallic element concentrations of PM_{10} at this study and other sites. The unit of mass concentration is $\mu g/m^3$, while all the rest are ng/m^3

	This study classroom (n=14)	This study science room(n=4)	This study assembly hall(n=10)	Nam et al.(2002)	Janssen et al.(1999)	Almeida et al.(2011)
PM_{10}	87.71	75.3	64.6	78.4	77.8	83
Al	402.6	550.7	276.5	316.9		
Ba	38.56	53.84	27.68	36.9		36.9
Ca	2248.9	2905.3	1493.9	2196.0	3322	14000.7
Cd	0.55	0.58	0.41	1.6		
Co	1.19	1.89	0.97			0.71
Cr	51.02	101.9	47.59	12.0	17	10.8
Cu	16.43	20.90	17.39	9.6	19	
Fe	629.2	877.3	466.3	91.6	614	996
K	467.1	586.7	308.1	75.7	536	1181
Mg	710.0	1057.3	521.9	38.6		
Mn	24.95	28.13	19.22		16	
Na	7205.9	10648.0	5446.9	1081.6		1749
Ni	15.94	30.27	16.15	12.5		
Pb	30.69	24.09	23.71	26.2	71	
Si	15427.5	23588.0	11678.8		3992	
Sr	4.28	5.14	2.77		15	
Ti	23.06	32.26	16.32	7.4	235	
V	132.1	187.6	106.9	0.7		
Zn	88.39	43.69	52.40	830.4	142	94.15

concentration depending on activities at each place

The present study selected a classroom, a science room, and an assembly room to determine the characteristics of PM_{10} concentration and metallic concentration depending on activities at each place(Table 3). Using two mini volume air samplers, the sampling was done in a classroom and a science room from 9 a.m. to 9 p.m., 4 times for 12 hours. Another sampling was done in a classroom and an assembly room from 9 a.m. to 9 a.m. of the next day, 10 times for 24 hours within the period of supplementary classes during the summer vacation.

Table 3. PM_{10} concentration($\mu g/m^3$) in school. The n is sample number

	n=4		n=10	
	Classroom	Science room	Classroom	Assembly hall
PM_{10}	104.8±8.7	75.3±18.3	80.9±13.8	64.6±14.0

PM_{10} concentration in the classroom during the semester was 104.8 $\mu g/m^3$, which was very high exceeding the indoor air quality criteria of maintenance while the PM_{10} concentration in the science room was 75.3 $\mu g/m^3$, showing 40% less concentration. This directly shows that the classroom where students spend all day long and have a lot of activities has more PM_{10} concentration than the science room where students drop off only when they have a class. Thus, students' activities have a great influence on particulate matters, which asks for additional management and measures to improve the indoor air quality of classroom.

Also, the PM_{10} concentration of the classroom where students take supplementary classes in the morning and either have study hall or leave for home was 80.9 $\mu g/m^3$, and of the assembly hall where students use only for indoor physical and extracurricular activities was 64.6 $\mu g/m^3$. PM_{10} concentration of the classroom is by no means low even allowing for the fact that students take a class in the morning and either have study hall or leave for home. PM_{10} concentration of the classroom was below the maintenance criteria of indoor air quality but still considered to be harmful to human bodies. On the other hand, PM_{10} concentration of the assembly hall was only about a half of 100 $\mu g/m^3$, the standard PM_{10} concentration, due to the low frequency of usage during the vacation. This shows that the indoor air quality of the assembly hall is in good condition.

Fig. 1 shows the ratio of PM_{10} and metallic elements concentration measured in a classroom and a science room during the semester, and in a classroom and an assembly hall during the vacation. If the ratio of PM_{10} concentration in the classroom divided by that in the science room exceeds 1, it means that the former is higher.

Fig. 1(upper) shows that PM_{10} concentration of the classroom is approximately 40% higher than that of the science room. Specifically, the classroom had Ca, K, Sr, Zn with 20% higher metallic concentration and had Al, Ba, Cd, Co, Cu, Mg, Na, Pb, Si, Ti, V with slightly higher or similar metallic concentration compared to the science room. On the other hand, the science room had Cr, Fe, Mn, Ni with higher concentration. Fig. 1(lower) that compares the classroom with the assembly hall shows that PM_{10} concentration of the classroom is 25% higher than that of the assembly hall, indicating that more activities in the classroom might have caused higher PM_{10} concentration in the assembly hall.

The classroom had Cd, Mn, Pb, Zn with 20% higher metallic concentration and had Co, Cr, Cu, Ni with less metallic concentration compared to the assembly hall. Meanwhile, Co, Cr, Cu, Ni which are emitted from the anthropogenic source were found to have higher concentration in the assembly hall than in the classroom, but the amount of such metallic elements was too small to make the assembly hall more vulnerable. Especially, Zn concentration was found to be double in the classroom. Comparing the classroom with the special objective room and the classroom with the assembly hall, the PM_{10} concentration of the classroom was 40% higher than that of the special objective room and 25% higher than that of the assembly hall. The amount of heavy metal concentration in the classroom was higher than that in that special objective room and the assembly hall, asking for proper management and measures.

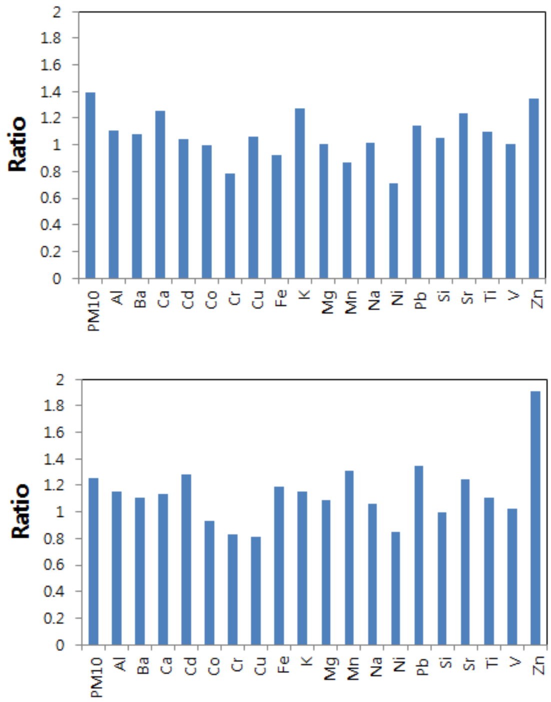

Fig. 1. Classroom/science room concentration (upper) and Classroom/assembly hall (lower) ratio in school.

3.4. Characteristics of PM_{10} concentration and metallic concentration on day of week

Table 4 shows PM_{10} concentration and metallic concentration which were measured 14 times in a classroom during the research period on day of week. Then entire 14 times were composed of two Mondays, three Tuesdays, five Wednesdays, three Thursdays, and one Friday. PM_{10} concentration of Friday was 112.0 $\mu g/m^3$, the highest, and that of Monday was 65.3 $\mu g/m^3$, the lowest. The metallic concentration included in particulate matters of Friday was higher than that of any other days. It seems that Friday had higher PM_{10} concentration due to increased group movements and activities during the HR & Club activity time. Meanwhile, the concentration of Pb and Zn were found to be higher on Thursday than on Friday.

4. Conclusions

We came to the following conclusions based on the analysis of metallic concentration included in particulate matter using mini volume air samplers at a classroom, a science room, and an assembly hall of a high school located in Bukgu, Busan during the summer of 2013.

1. PM_{10} concentration of a classroom, a science room, and an assembly hall during the research period was 87.7 $\mu g/m^3$, 75.3$\mu g/m^3$, 64.6$\mu g/m^3$, respectively, having the PM_{10} concentration of the classroom as the highest.

Table 4. Weekly PM_{10} and metallic element concentration at classroom in school. The unit of mass concentration is $\mu g/m^3$, while all the rest are ng/m^3

	PM_{10}	Al	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Si	Sr	Ti	V	Zn
Mon	65.3	302	30.2	1711	0.08	0.86	40.0	10.7	463	175	575	17.8	5938	12.2	7.62	12261	2.98	17.0	108	28.7
The	95.3	415	41.4	2233	0.34	1.26	53.2	13.9	583	495	772	23.3	7966	17.7	22.2	16575	4.22	23.2	140	68.8
Wed	90.8	457	41.4	2805	0.36	1.37	57.9	15.9	699	524	785	23.6	7966	16.5	20.9	17499	5.04	26.5	140	78.8
Thu	84.3	342	33.7	1724	0.89	0.96	41.7	18.1	612	448	583	29.2	5964	14.6	54.5	12542	3.63	19.4	124	134
Fri	112.0	613	61.4	3125	1.48	1.80	81.0	30.3	853	656	1088	30.5	10736	22.7	50.8	24325	5.89	35.9	190	79.5

2. Based on the analysis of metallic concentration included in particulate matter during the research period, Si of PM_{10} had highest concentration with 15,427 ng/m^3 followed by Na which had 7,205 ng/m^3, and the order was Si>Na>Ca>Mg>Fe>K in the classroom. In other words, Si, the soil-oriented, had highest concentration and Na, the ocean-oriented, had the second highest concentration. Of the 19 analyzed metallic elements, most of them such as Ca, Fe, K, Mg, Si were soil-oriented excluding Na.

3. According to the PM_{10} concentration and metallic concentration during the research period, PM_{10} concentration of a classroom and a science room was each 104.8 $\mu g/m^3$ and 75.3 $\mu g/m^3$ during the semester and PM_{10} concentration of a classroom and an assembly hall was each 80.9 $\mu g/m^3$ and 64.6 $\mu g/m^3$ during the summer vacation. The classroom had more Ca, K, Sr, Zn than the science room and had more Cd, Mn, Pb, Zn than the assembly hall.

4. Based on PM_{10} and metallic concentration at a classroom on day of week during the research period, the concentration of Friday was highest with 112.0 $\mu g/m^3$, and that of Monday was lowest with 65.3 $\mu g/m^3$. The metallic elements concentration included in PM_{10} was highest on Friday as well.

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