Journal of Sustainability Science and Management
Volume 9 *Number* 1, June 2014: 141-149
ISSN: 1823-8556

INFLUENCE OF DIFFERENT MICROENVIRONMENTS ON RESPIRABLE PARTICULATE MATTER IN PRE-SCHOOL OF KUALA TERENGGANU, MALAYSIA

M. ISMAIL* AND A. SUROTO

School of Marine Science and Environment, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu.

**Corresponding author: marzuki@umt.edu.my*

Abstract: Respirable particulate matter (RSP) is one of the major indoor air pollutants that can cause infection on respiratory system especially for children less than six years of age. As children spent almost 90% of their daily time indoor either at home or pre-schools, there is a need to identify the influence of surrounding activities on indoor RSP concentration. Failure to do so will amplify the chance of long-term and short-term respiratory system problems for these young children and reduced their learning environment and comfort. In this study, samples of RSP concentration for both indoor and outdoor at five selected pre-schools with different surrounding activities in Kuala Terengganu were collected. Sampling was conducted during learning session (8.00 am to 12.30 pm) for three consecutive working days. The results showed that there were statistically significant influence of surrounding activities ($P<0.05$) on indoor respirable particulate matter in pre-school. Coastal area had been identified as having the strongest influence ($r^2 = 0.97$) followed by heavy industry ($r^2 = 0.96$), planned residential ($r^2 = 0.91$), commercial ($r^2 = 0.88$) and rural area ($r^2 = 0.83$), respectively. We conclude our findings by confirming the imperative influence of surrounding activities on indoor concentrations of respirable particulate in selected pre-schools in Kuala Terengganu.

KEYWORDS: Different microenvironments, respirable particulate matter, children, pre-schools, Kuala Terengganu.

Introduction

Children are known as sensitive group of human being to air pollution due to the fact that their metabolic rate per kilogram of body weight is much higher than of an adult because they are still growing and small, thus will cause them to breathe in much more air pollutants in relation to their body weight compared to adult. Furthermore, children less than six years of age are much easier to be infected especially to the respiratory illness because their respiratory system is less mature (DOSH, 2005; Zhang G *et al.,* 2006; Diapoulli *et al.,* 2007; Ekmekcioglu *et al.,* 2007; C. Yoon *et al.,* 2010). Throughout their growth period, most of the children spent their time indoor, especially in home and pre-schools. For children that come from working family, they spent 6 to 7 hours daily in the classroom. ASHRAE, (2005) found that these children spent more than 90% of their daily time indoor, especially in pre-schools. From this situation, probability for children to be exposed to indoor air pollutant is higher than ambient air pollutant.

Good indoor air quality is desired for a healthy indoor environment (DOSH, 2005) and it is important especially for children wellness as they will be future leader for our nation. Children wellness is influenced by their productivity where they gain from learning session in pre-schools. A good pre-school will provide comfort environment with good indoor air quality. Thus, children can precede their daily indoor activities very well. Otherwise, children productivity might be decline and lead to poor wellness when they experienced the symptoms such as flu, bronchitis, irritations of throat and nose, rhinitis and epidemic conjunctivitis which most of them are related to bad indoor air quality (Meininghaus R *et al.,* 2003). Studies conducted by USEPA (2003) reported that poor indoor air quality had caused illness especially respiratory infections and asthma which then leading to absenteeism.

In Malaysia, the air quality status nowadays becomes less favourable due to rapid increment of urbanization, industrialization and commercialization activities (Azmi *et al.,* 2010). The air quality become poor when the RSP concentration from surrounding activities for instance commercialization, industrialization and construction increased and give significant impact on indoor RSP status (Bouhambra *et al.,* 2000; Long *et al.,* 2000; Kornartit *et al.,* 2012). Consequently, the objective of this study is to identify the influence of outdoor RSP from different surrounding microenvironment (i.e.: coastal, residential, industrial, commercial and rural area) on indoor RSP in selected pre-schools in Kuala Terengganu, Terengganu, Malaysia.

Methodology and material

Study Area

This study was conducted in pre-schools located in Kuala Terengganu (Figure 1), capital city of Terengganu state, Malaysia, covering an area of 605km^2. In Kuala Terengganu, there are sixty nine pre-schools which are public pre-schools that have same design and dimension such as equal number of windows, doors and fans inside each classroom. All of the pre-schools are using natural ventilation system which is a system of air circulation which supported by thermal buoyancy and wind forces in open buildings (Li *et al.,* 2001). In addition; the number of students in each classroom is uniform in term of age (i.e. 5 to 6 years old). For the purpose of this study, out of sixty nine pre-schools, five of them which are using natural ventilation system were selected. Selection of these pre-schools is based on different surrounding activities i.e. commercial, residential, coastal, industrial and rural areas as tabulated in Table 1.

Sampling Activity

In each pre-school, two classrooms were randomly selected for sampling activity. RSP samples were collected using Microdust Pro® meter which utilized forward light scattering technique for 5 minutes for each sampling point in order to obtain representative data. The equipment was placed at 0.8 meter above the floor, 0.5 meter away from windows and doors and also 0.5 meter away from bookshelves and out of reach of children which based on Code of Practice on Indoor Air Quality (DOSH, 2005). Sampling activity was performed during learning session at three days interval which was from 8.00 am to 12.30 pm. RSP samples were collected at nine sampling points inside (i.e. three sampling points on the left side, three sampling points in the middle and three sampling points on the right side of classroom) and six sampling points outside the classroom which is at yard of each pre-school, the area which is not frequently visited by students, respectively. The data collected were then transferred via RS232 which is a connector for data transferring from the data storage system located inside Microdust Pro into a spreadsheet i.e. MS Excel for analysis. Fitness to normal distribution and homogeneity of variance of the data were examined by using the Kolmogorov-Smirnov test for goodness of fit and Cochran's test for homogeneity of variance (Solka RR and Rohalf, 1998). Where normality and homogeneity of variance of the data were confirmed, single classification analysis of variance (ANOVA) F test was performed to compare the RSP concentration among selected pre-schools and also between indoor and outdoor RSP concentrations. In addition, inferential statistic which is regression analysis was then performed in order to determine the relationship between indoor and outdoor RSP in these five selected pre-schools.

Results and Discussion

Temporal Distribution

The profile of indoor and outdoor RSP concentration levels of selected pre-schools in

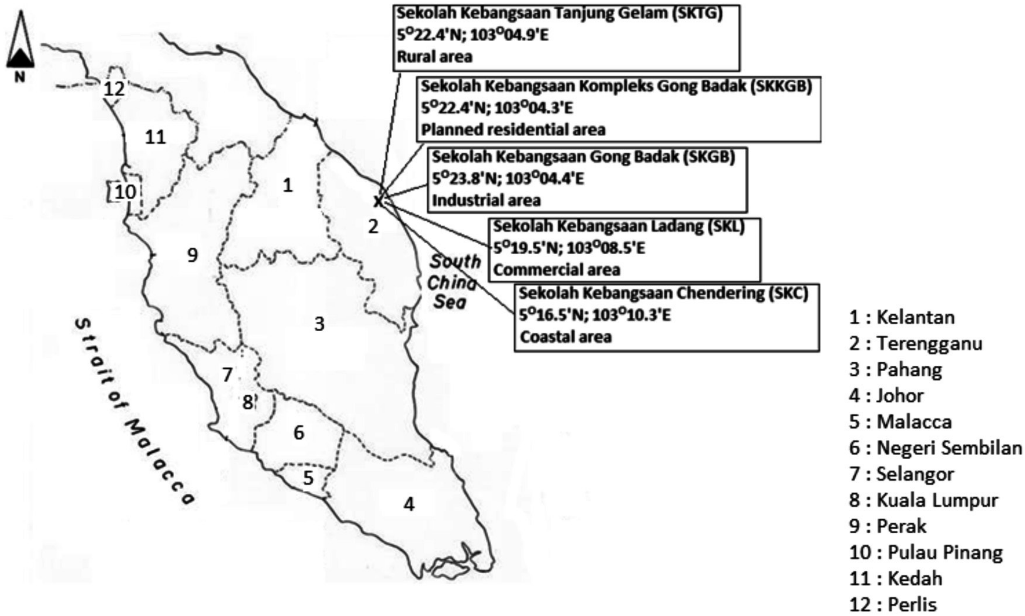

Figure 1: Map of Kuala Terengganu, Terengganu, Malaysia.

Table 1: Location of Study Areas.

Pre-schools	Surrounding activities	Latitude & Longitude
Sekolah Kebangsaan Tanjung Gelam (SKTG)	Rural (located nearby coastal area)	05°22.4’N 103°04.9’E
Sekolah Kebangsaan Kompleks Gong Badak (SKKGB)	Planned Residential	05°22.4’N 103°04.8’E
Sekolah Kebangsaan Gong Badak (SKGB)	Industrial	05°23.8’N 103°04.4’E
Sekolah Kebangsaan Ladang (SKL)	Commercial	05°19.5’N 103°08.5’E
Sekolah Kebangsaan Chendering (SKC)	Coastal	05°16.5’N 103°10.3’E

Kuala Terengganu is shown in Figure 2. The mean concentration of indoor RSP for SKKGB is (12 µg/m^3 ±16.92); SKGB (9 µg/m^3 ±8.48); SKTG (40 µg/m^3 ±48.84); SKL (33 µg/m^3 ±12.84) and SKC (19 µg/m^3 ±14.22), respectively. Meanwhile, the mean concentration of outdoor RSP concentration in SKKGB is (15 µg/m^3 ± 22.62); SKGB (11 µg/m^3 ±13.86); SKTG (29 µg/m^3 ±36.72); SKL (34 µg/m^3 ± 14.50) and SKC (17 µg/m^3 ±13.92), respectively. In general, outdoor RSP levels were higher than the corresponding indoor. Figure 3 shows the comparison of mean between indoor and outdoor of RSP concentration in each pre-school in the form of Box-and-Whisker plot. Overall, as the P-value of the F-test in the ANOVA table is 0.03 (< 0.05), there is statistically significant difference between RSP concentration of the five pre-schools at the 95% confidence level. Therefore, the results indicated that indoor

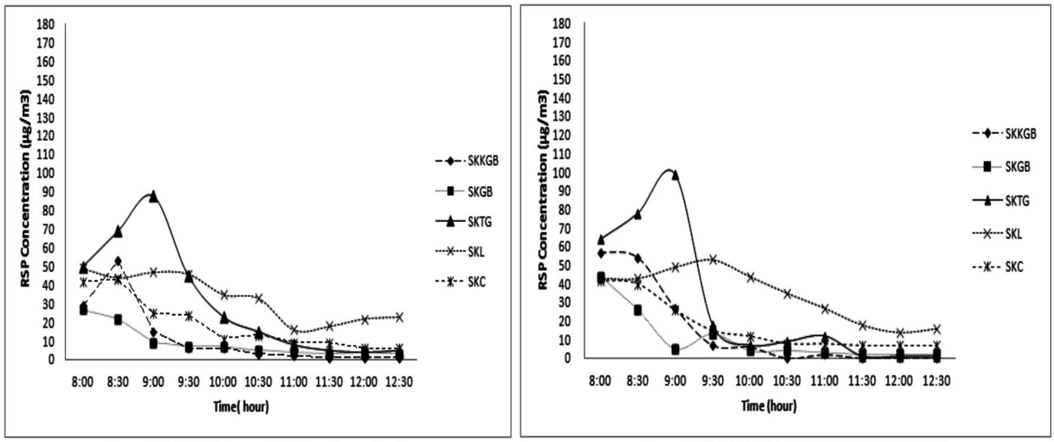

Figure 2.1 Indoor RSP Concentration in each pre-school

Figure 2.2 Outdoor RSP Concentration in each pre-school

Figure 2: Indoor and Outdoor RSP Concentrations in Each Pre-School.

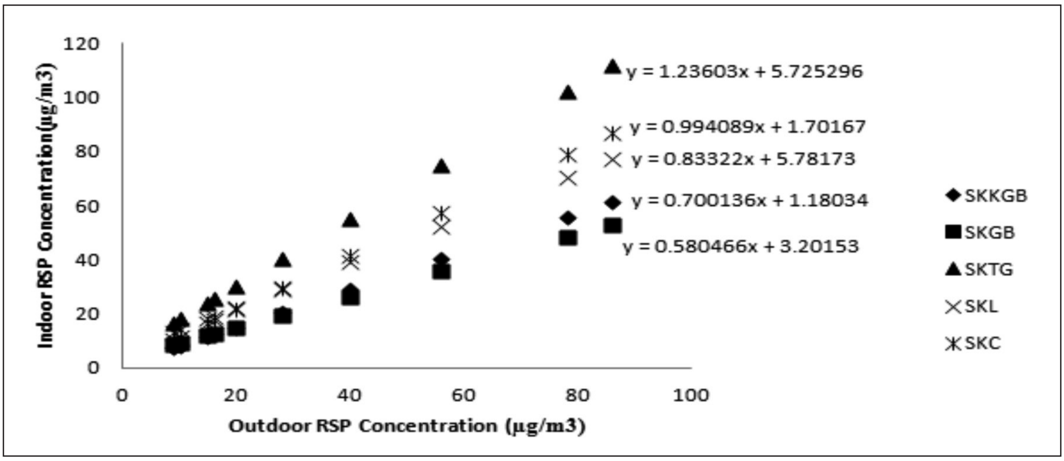

Figure 3: Box-and-Whisker Plot between Indoor and Outdoor Of RSP Concentration in Each Pre-School.

particles' concentration is greatly influenced by infiltration of outdoor air. This is expected as all the doors and windows were wide open in allowing air flow inside the classroom as no mechanical ventilation system specifically air-conditioner existed in any of the pre-schools.

The relationship between Indoor RSP (I_{RSP}) and outdoor RSP (O_{RSP}) in all pre-schools were established and resulting in the equations as shown in Figures 4. The correlation coefficients were as follows: SKC (r^2=0.97), SKGB (r^2=0.96), SKKGB (r^2=0.91), SKL (r^2=0.88) and for SKTG (r^2=0.83). Therefore, these correlations indicate an important role of the outdoor particles to the indoor concentration levels. The highest influenced of surrounding activity on indoor RSP occurred in pre-school located within the vicinity of coastal area, followed by pre-school near the industrial area, planned residential, commercial and rural area, respectively. Moreover from this study, it shows that windborne dust and sea spray are the major natural sources of RSP whereas the most important anthropogenic sources are mainly vehicular emissions and industrial flue pollutants.

Spatial Distribution

For better visualisation, spatial distributions of RSP at fixed time of 8.00 am, 10.00 am and 12.00

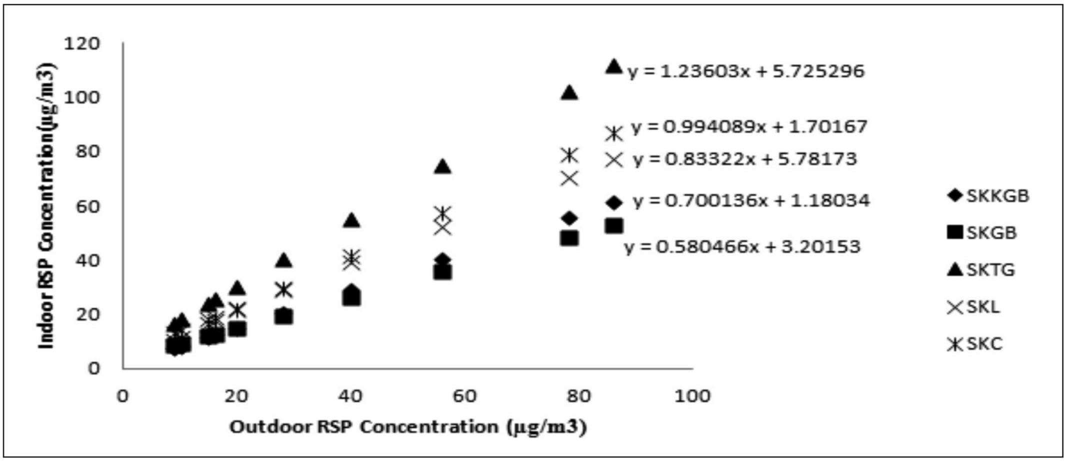

Figure 4: Indoor and Outdoor Relationship of RSP Concentration in Each Pre-School.

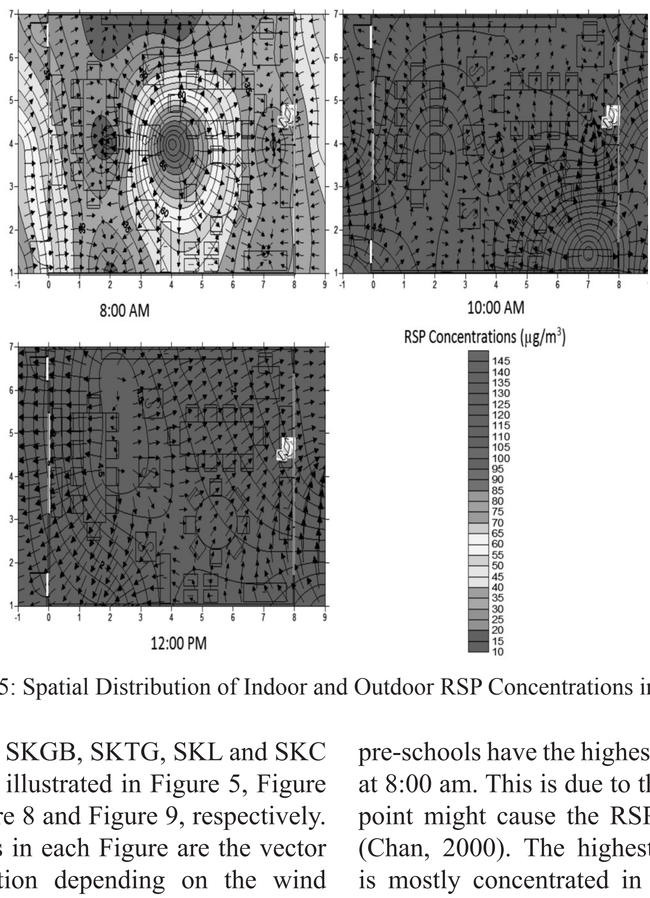

Figure 5: Spatial Distribution of Indoor and Outdoor RSP Concentrations in SKKGB.

noon in SKKGB, SKGB, SKTG, SKL and SKC pre-schools were illustrated in Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9, respectively. The small arrows in each Figure are the vector of RSP distribution depending on the wind circulation inside each classroom. Basically, the highest concentration spot will move and dispersed to the spot with lower concentration of RSP to achieve equilibrium. In general, all the pre-schools have the highest RSP concentrations at 8:00 am. This is due to the fact that high dew point might cause the RSP to be trapped in it (Chan, 2000). The highest RSP concentration is mostly concentrated in the middle of class where the children always gathered for learning activities, nearby book shelves and opening windows and doors. Furthermore, in all the classes, the highest indoor RSP concentrations

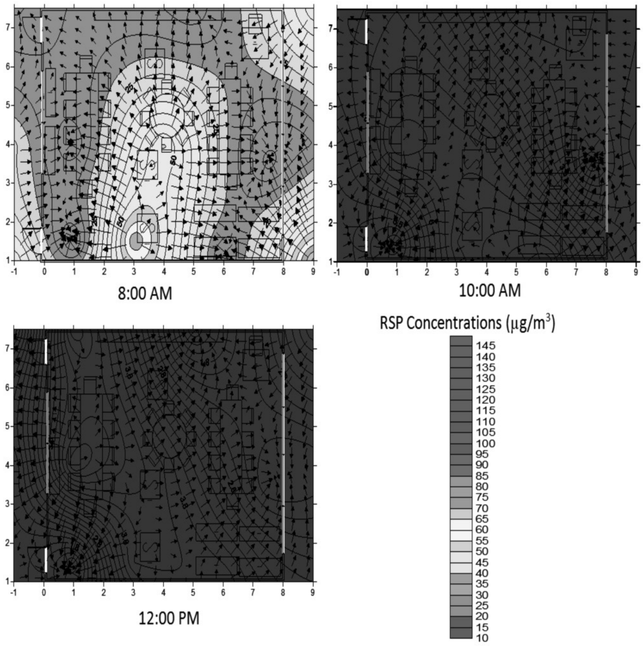

Figure 6: Spatial Distribution of Indoor and Outdoor RSP Concentrations in SKGB.

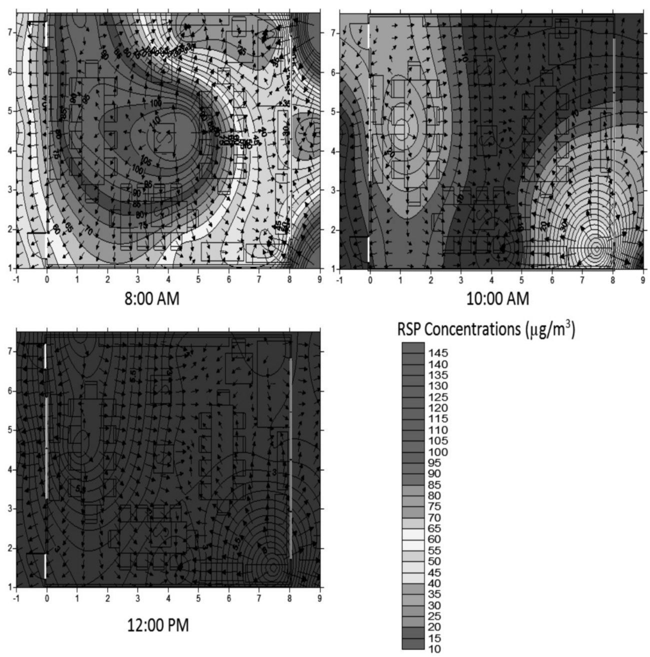

Figure 7: Spatial Distribution of Indoor and Outdoor RSP Concentrations in SKTG.

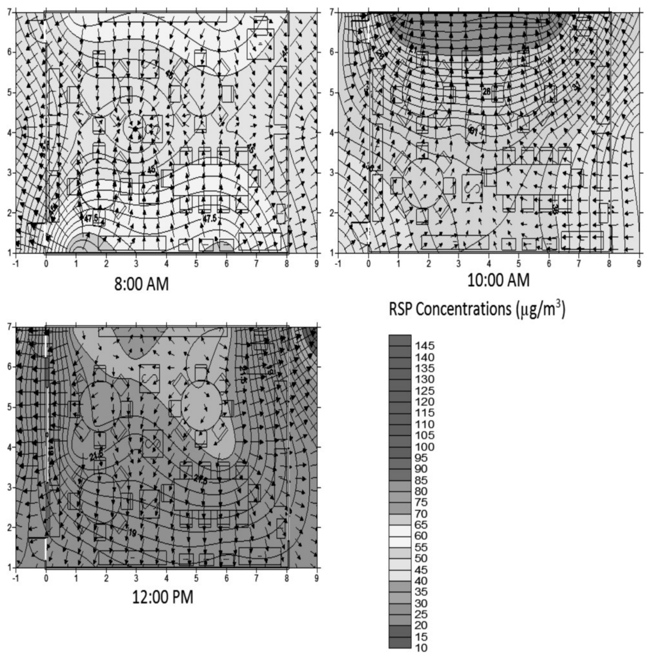

Figure 8: Spatial Distribution of Indoor and Outdoor RSP Concentrations in SKL.

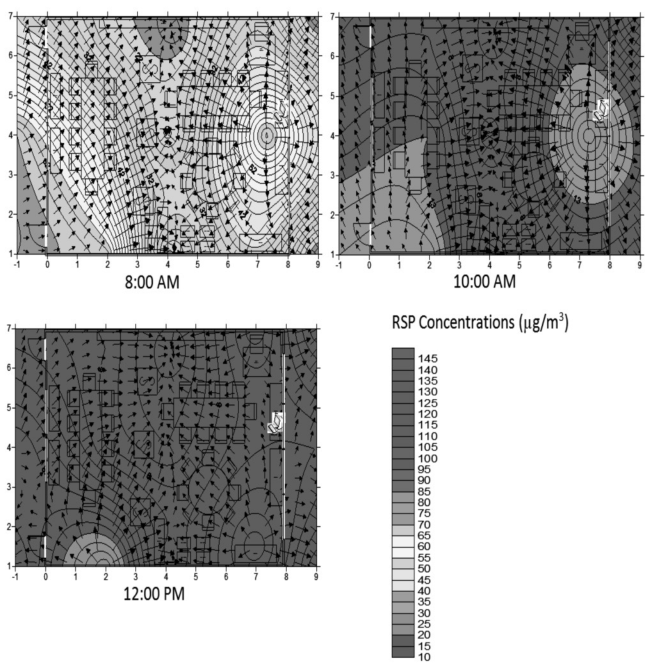

Figure 9: Spatial Distribution of Indoor and Outdoor RSP Concentrations in SKC.

were in the area located nearby the book shelves and also toys storage. The RSP concentrations reduced appreciably at 10: 00 am and 12:00 pm in each pre-school. This is because at 10:00 am, the classrooms were unoccupied due to children had gone out for their second outdoor activities during recess time. In addition, all pre-schools have the lowest RSP concentrations at 12:00 pm because during this time, some of the children have already gone home and the classrooms are less occupied i.e., only teachers and few children were left around.

Conclusion

All the selected microenvironments, there exist strong influences of surrounding RSP on indoor RSP concentrations. The highest positive correlation (r^2) occurred at pre-school within the vicinity of coastal area. An immediate action should be taken by the authority and the government to reduce the RSP concentration in these pre-schools because the protection of indoor air quality in a microenvironment is so critical and children total daily exposure must be the first priority goal in designing and implementing any development plan in the future. Therefore the following recommendations are provided for Malaysian Ministry of Education in order to improve RSP status in the future:

- Providing sufficient buffer zone area between pre-schools and its surrounding especially for pre-schools located in critical areas such as industrial, heavy traffic and coastal areas.
- Installation of air-conditioning system for existing pre-schools located in critical areas for a conducive and comfy learning environment.

Acknowledgement

The authors would like to thank the Malaysian Ministry of Education, Terengganu Education Department, and all staffs and students of SKKGB, SKGB, SKTG, SKL, and SKC for their cooperation during the sampling duration.

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