MEASURING INDOOR AIR QUALITY PERFORMANCE IN MALAYSIAN GOVERNMENT KINDERGARTEN

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ABSTRACT

Children require good indoor environment since indoor air quality (IAQ) is very important for their growth and wellbeing. Studies around the world have found that indoor air quality affected these sensitive groups more compared to adults. In IAQ of kindergarten buildings especially in Malaysia is unknown as research on this matter is limited. The failure to identify and establish IAQ status can increase the chance of long-term and short-term health problems. Therefore, the IAQ of two government kindergartens in Malaysia was studied in this research. In these studies, all factors were considered including temperature, relative humidity (RH), airflow rate and the amount of carbon dioxide (CO2), nitrogen dioxide (NO2), formaldehyde and volatile organic compound (VOC). One case study is located in the rural area of Rembau, Negeri Sembilan and the other one is located in the city centre area of Kuala Lumpur. Measurements were taken continuously in a period of three daysin order to establish the IAQ pattern. Furthermore, a comparison with an established benchmark was conducted to identify rooms for improvement. It is anticipated that findings from this research would provide some advancement towards improving existing Malaysian policies and standards. This research could also spur other research activities concerning IAQ.

Keywords: Indoor Air Quality, kindergarten , building performance, environment

Introduction

Nowadays indoor air quality (IAQ) has received great attention from people all over the world (Law et.al, 2001). According to Lee and Chang (2000) , people spend 90% of their daily life inside buildings. Therefore, a clean, healthy and comfortable IAQ is vital in order to avoid health problems. Similarly, a healthy IAQ is vital for the health of children and the aged as they are more sensitive towards indoor air pollutants (Lee and Chang, 2000). For children, it is easy for them to be exposed to contaminated indoor air since they breathe greater volumes of air compared to adults (Torres, 2000). Moreover, according to Torres (2000), it was found that children spent only around 23% of their time indoors such as in kindergartens and schools. Thus, a healthy IAQ is crucial for their growth. This is because, children are susceptible towards poor indoor air quality that can cause health problems that are sometimes difficult to recognize (USEPA, 1996). This is due to the low metabolism level of children, delaying the effects of adolescent health problems until they are older (REF). Besides that, more attention towards IAQ level inside kindergartens needs to be considered seriously because from the study conducted by the Canadian Lung Association CLA (2002), ¼ or 10% of school absenteeism was caused by asthma . In addition, school absenteeism and medication for asthmatic children increase proportionately with the deterioration of the respiratory systemcaused by the high amount of particulate matter inside the schools (Peter et al., 1997).

According to Paul (1994), schools have four times the number of occupants per square foot as office. Therefore, when children breathe high amounts of polluted air, it will produce more polluted air than the fresh air intake. In real conditions, indoor air is 10 times as polluted as the outdoor air (REF). The failure to identify and establish indoor air pollution status can increase the chance of long-term and short-term health problems such as reduction in productivity and learning environment and comfort (ASHRAE, 2001). Due to this fact, an IAQ study was carried out at selected kindergartens in Malaysia. This study is timely as and there is a pressing need to determine the actual IAQ status especially in the schools, where our nation’s so-called future leaders are trained (Ismail et al., 2010).

Indoor Air & Performance in Schools

IAQ refers to the nature of conditioned air that circulates throughout the space or area where we work and live, that is, the air we breathe during most of our lives (Cheng, 2002). IAQ is not only for comfort, which is affected by temperature, humidity and odors but also by harmful biological contaminants and chemicals present in the conditioned space (Cheng, 2002). Most people control the environment in their homes to a certain degree to provide comfort and health. They will not use freshly painted rooms until the smell has gone away. Besides that, according to PDHengineering (2005), IAQ is defined as the characteristic of the indoor air inside a building that consist of pollutants and thermal (which is temperature and relative humidity) concentration that can give effect towards health, comfort and performance of building occupants.

Indoor environment quality (IEQ) is the sum of all environmental factors that effect the occupants including lighting, noise, odors, humidity, temperature, rate of ventilation as well as the rate of exposure to chemical and biological agents (Torres, 2000). IAQ is one of the components that contribute to the quality of the indoor environment in schools (Torres, 2000). On the other hand, indoor air pollutants cause a combined physical, chemical and biological effect on the occupants and limit that adequacy ofventilation systems (REF). Indoor air pollutant comes from the outdoors, mechanical ventilation and air-conditioning (MVAC), building equipment and furnishing as well as human activities (Torres, 2000). Based on a study by Armstrong Laboratory (1992), there are three most frequent causes of unacceptable IAQ firstly, inadequate design or maintenance of heating, ventilation and air-conditioning (HVAC) systems. Secondly, a shortage of fresh air intakes into buildings and finally, a lack of humidity control.

Children and senior citizens have been categorized as sensitive toward indoor air pollution. These sensitive groups are more affected by polluted indoor air rather than ambient atmospheric air (Ismail et al., 2010). Furthermore, overcrowded classrooms will cause poor IAQ resulting in adverse health problems (Lei et al, 2005). This happen because, the metabolic rate per kilogram of body weight of children is much higher than adults (REF) and their respiratory rate is proportionately greater as they breathe in much more air pollution (Yassi et al., 2001). Surprisingly, the number of occupants per square foot in schools is four times that of offices (REF). In addition, schools contain a variety of pollution sources such as lab chemicals, cleaning agents, chalk dust and mold. Furthermore, teachers and students often work more closely in classrooms than people in other types of buildings. According to Tanner (2000), there should be a certain limit to the number of students per square feet or meters in indoor classrooms. Table 1 below shows the result from that research:

There are many factors that can contribute to the indoor air quality problems. Several of researchers carry out with several of factor that causes into IAQ problems. But the various factors are more or less the same for each other. Based on the study done by Armstrong Laboratory (1992), there are three most frequent causes of unacceptable indoor air quality (IAQ). Firstly, there is inadequate design or maintenance of the heating, ventilation, and air-conditioning (HVAC) system. Second, a shortage of fresh air comes inside the building and finally, lack of humidity control.

Material & Methods

For the purpose of this research, two government kindergartens were selected as case studies. They are located in Rembau, Negeri Sembilan (rural location) and Kuala Lumpur (city center location). The rationale behind the selections is that the physical environment and the size of population of each location is different. Below are descriptions of each case study:

i. One unit of government kindergarten which is naturally ventilated and located in the rural area of Rembau, Negeri Sembilan (Abbreviated as TK)

ii. One unit of government kindergarten which is naturally ventilated and located at in the city center of Kuala Lumpur with high population density (Abbreviated as TS)

Six indoor air characteristics were measured by using a MultiRAE meter as well as a Formaldehyde meter. The measurements are more focused on the indoor air rather than outdoor air at both kindergartens. There are six measurement items which are formaldehyde, nitrogen dioxide (NO^2), volatile organic compound (VOC), carbon dioxide, CO^2, relative humidity (RH) and temperature. In order to increase the accuracy of data collection, data collection work was carried out at both kindergartens for three consecutive days. All collected data at certain points inside the kindergartens, were recorded every 30 minutes for 8 hours from 7 am to 3 pm. This is to observe if there were extreme changes in the IAQ. Although class started at 8 am, measurements were taken from 7 am to ensure that readings are stable when kids enter the classroom. Furthermore, measurements were taken beyond the end class of class at noon until 3 pm to observe the indoor air characteristics in the evening. Measurements were gathered and compared with existing benchmarks created by the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE, 2001, 2007), the Department of Safety and Health (DOSH, 2005), the US Environmental Protection Agency (USEPA, 2008), the Occupational Health and Safety Administration (OSHA, 1999) and the World Health Organization (WHO, 2000).

Results & Discussion

Data analysis between government kindergarten buildings focused more on the performance of their IAQ. Comparisons were made to distinguish which kindergarten holds more of the six hazardous gasses as shown in Figure 1 to 6.

a) Formaldehyde

Figure 1 above shows the Formaldehyde concentration between both kindergartens. Based on the graph, it shows that the emission of formaldehyde at TS is higher than at TK especially between 9.30 am until 1.30 pm. It is evident that before 8.30 am there was no formaldehyde emission. However, between 11.30 am to 12.00 pm the rate of emission increased sharply at TS and dropped to zero in the evening. The amount of formaldehyde emission at TK only increased to 0.01 parts per million (ppm) at 9am. At other times, it was 0 ppm.

b) Nitrogen Dioxide, NO_2

Figure 2 above indicates the nitrogen dioxide, NO_2 concentration at both TK and TS. From the average reading, both kindergartens show the same data which is 0 ppm.

c) Volatile Organic Compound, VOCs

Figure 3 shows the concentration of VOCs at TS which was higher than at TK. This is probably caused by the factors of different locations and surrounding activities. As explain before, TS is located in Kuala Lumpur near a main road. Meanwhile TK is located in rural Rembau, Negeri Sembilan which is not as busy as Kuala Lumpur.

d) Carbon Dioxide, CO_2

According to Figure 4, the CO_2 concentration at both TK and TS is very similar throughout the day as the number of occupants is similar. TK has 19 occupants at one time while TS has 15 occupants. The emission of carbon dioxide, CO_2 by kids at both case studies were at a normal stage because the graph did not show huge differences of CO_2 concentrations.

e) Relative Humidity (RH)

Figure 5 above shows the RH level at both TK and TS. The level of RH between these two kindergartens was similar. Between 7.00 am to until 9.00 am, the level of RH in both TK and TS kindergarten were between 65% and 75% which were the highest throughout the day.

f) Temperature

Figure 6 indicates the indoor temperature at both TK and TS kindergarten. Measurements showed that the indoor temperature for both TK and TS were similar throughout the measurement period. Between 7.00 am to 9.00 am, temperature increased at both kindergartens from 28 degree Celsius to 29 degree Celsius. Then, from 9.00 am to 12.00 pm the indoor temperature at TK were recorded to be higher than TS's temperature level. This is believe due to students at TK are having more activities and movement which released more heat, thus increase the temperature inside the building.

Comparison with Benchmark

Benchmarking is one of the measures that can be done in order to evaluate IAQ performance. This is important as it will provide the indication of the level of efficiency in terms of indoor environmental level. For this study, result was compared with established benchmarks created by ASHRAE,(2001, 2007), WHO (2000), OSHA (1999) and DOSH (2005). The performance comparisons are presented below.

Figure 7 shows that formaldehyde concentration at both TK and TS did not exceed the maximum standard by OSHA which is 1.00 ppm (OSHA, 1999). Both kindergartens also recorded readings below OSHA's minimum which is 0.04ppm (OSHA, 1999). Therefore, formaldehyde concentration at both kindergartens was acceptable and not harmful. As indicated in Figure 8, the amount of NO_2 at both kindergartens was 0 ppm and below the standard of 1.00 ppm set by WHO (2000). As for VOCs (Figure 9), readings at TS exceed the ASHRAE 2001 standard which is 0.1mg/m3. This is due to the location of TS near to a main road at the city center of Kuala Lumpur. Meanwhile, VOC readings at TK were below the standard at an average of 0.08 mg/m3. This is because TK is located at the rural area that not expose to the many vehicles. CO_2 concentration at TS exceeded the existing benchmark of 1000 ppm at 1005.9 ppm as shown in Figure 10. This is because TS is located inside the grounds of an elementary school (Sekolah Kebangsaan) with, higher number of students compared to TK with only one room of pupils. According to Figure 11, the RH level of both kindergartens did not exceed the maximum standard set by ASHRAE, 2007 which is 65%. This is because Malaysia is located in the tropical region with hot and humid climate which affected the thermal comfort levels of the students. From Figure 12, it can be seen that both kindergartens had temperature readings that exceeded ASHRAE 2007 standards. This scenario happened due to the fact that Malaysia is hot and humid climate as this gives a high temperature and disturbance to the thermal comfort of the children.

In all, the overall IAQ at both kindergartens complied to the selected benchmarks. As for TK, from 6 elements measured, 5 complied to the benchmarks, whereas 1 element (temperature) exceeded the benchmark. Meanwhile, out of 6 elements measured at TS, 3 of them complied to the benchmarks whereas another 3 did not. Only the VOC rate of 0.54 mg/m^3 exceeded the benchmark. Furthermore, CO_2 concentration at TS exceeded the permissible limit of 1000 ppm . Similarly, temperature readings at TS exceeded ASHRAE 2007 standards. Nevertheless, attendance at both TK and TS was 100%.

Conclusion

From the data collection it can be found that the CO_2 concentration at TK and TS is proportional to their indoor temperature. In opposite, the RH rate is inversely proportional to the temperature and CO_2 concentration. Comparisons with benchmarks recognised that the current state of IAQ in both kindergartens showed that overall, the IAQ at both kindergartens complied to the selected benchmarks. Despite the findings from this study, more studies with larger samples of case studies are needed to determine the extent of IAQ problems in kindergartens in Malaysia. This research evidently shows that at least, VOC, CO_2 and temperature at the selected kindergartens did not meet the minimum benchmarks and this may be related to significant increases in symptoms of health problems among children and teachers at both kindergartens. Therefore programs should be put in place to ensure that all kindergartens provide necessary improvements to tackle the issue of poor IAQ.

References

Ambu S., Chu W.L., Mak J.W., Wong S.F., Chan L.L., and Wong S.T., (2008) Environmental Health and Building Related Illnesses, Science, Medicine and Education, Vol. 2:1, pp.11-18

Armstrong Laboratory (1992) Occupational and Environmental Health Directorate, Armstrong Laboratory, Brooks Air Force Base, Texas.

ASHRAE (2001) *Ventilation for Acceptable Indoor Air Quality, Standard 62*, American Society for Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA.

ASHRAE (2007) *Ventilation for Acceptable Indoor Air Quality, Standard 62.1*, American Society for Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA.

Cheng, C.Y (2002) Indoor Air Quality, Course No. C-3005 PDHengineer. [Retrieved February 10, 2011 from http://www.pdhengineer.com/Course%20Web/Civil%20Courses/indoor_air_quality.htm]

CLA (2002), Learning about Lungs: Quick Facts and Statistic, Canadian Lung Association. Canada

DOSH [Department of Safety and Health] (2005) *Code of Practice on Indoor Air Quality. ISBN: 983-2014-51-4, JKKP: GP(1)05/2005.* Ministry of Human Resources Malaysia.

Ismail M., Sofian N.Z.M. and Abdullah, A.M. (2010), Indoor Air Quality in Selected Samples of Primary Schools in Kuala Terengganu, Malaysia, Environment Asia 3, 22 (special issues), pp.103-108.

Law, A. K. Y., Chau C. K. and Chan, G. Y. S, (2001) Characteristics of bioaerosol profile in office buildings in Hong Kong, Building and Environment, Vol 36:4, pp 527-541

Lee, S.C and Chang, M. (2000) Indoor and Outdoor air quality investigation at schools in Hong Kong, Chemosphere Vol 41:1-2, pp 109-113.

Lei I.F.M., (2005) Recommended Practice for Good Indoor Air Quality in Macao Schools. Macao Polytechnic Institute.

Paul H., (1994), Clean Air, Efficient Energy Use. American Association of School Administrators 15.

PDHengineer (2005). EPA Indoor Air Quality Building Education and Assessment Guidance- I Beam: Course No M-600, Houston. [Retrieved November 27, 2010 from http://www.pdhengineer.com/courses/bd/M-6001.pdf]

Peters A, Dockery DW, Heinrich J, Wichmann HE., (1997) Short-term effects of particulate air pollution on respiratory morbidity in asthmatic children. European Respiratory Journal. Vol. 10:4, pp. 872–879.

Tanner, C.K. (2000). Minimum Classroom Size and Number of Students per Classroom, The University of Georgia, School Design and Planning Laboratory. [Retrieved March 20, 2008 from http://www.coe.uga.edu/sdpl/research/territoriality.html]

Torres, V. M. (2000) Indoor air quality in schools. Austin, TX: University of Texas, Texas Institute for the Indoor Environment.

USEPA (1996) Indoor Air Quality Basics for Schools. United States Environment Protection Agency, U.S.

USEPA (2008), Clean Air Act, United States Environmental Protection Agency, Washington DC: U.S. Government Printing Office.

WHO (2000) *Air quality guidelines for Europe*. 2nd ed. World Health Organization, WHO Regional Publications, European Series No. 91, Copenhagen.

Yassi A, Kjellstrm T, Kok TD, Guidotti TL, (2001). Basic Environmental Health, New York: Oxford University Press.

Appendix

Table 1: The number of student in classroom

NO. OF STUDENTS PLUS 1 TEACHER	ELEMTARY SCHOOL (SQFT, M2)	SECONDARY SCHOOL (SQFT, M2)
10	539 (50.13)	704 (65.47)
11	564 (52.45)	768 (71.42)
12	637 (59.24)	832 (77.38)
13	686 (63.80)	896 (83.33)
14	735 (68.36)	960 (89.28)
15	784 (72.91)	1024 (95.23)
16	833 (77.47)	1088 (101.18)
17	882 (82.03)	1152 (107.14)
18	931 (86.58)	1216 (113.09)
19	980 (91.14)	1280 (119.04)
20	1029 (95.70)	1344 4.99)

Source: Tannner (2000)

Table 2: Common factors associated with indoor air pollution

Common Factors Associated With Indoor Air Pollution	
Inadequate ventilation	52%
Contamination from inside the building	16%
Contamination brought in from outside the building	10%
Microbiological contaminants	5%
Building material contamination	4%
Cause not determined	13%

Source: Ambu et al. (2008)

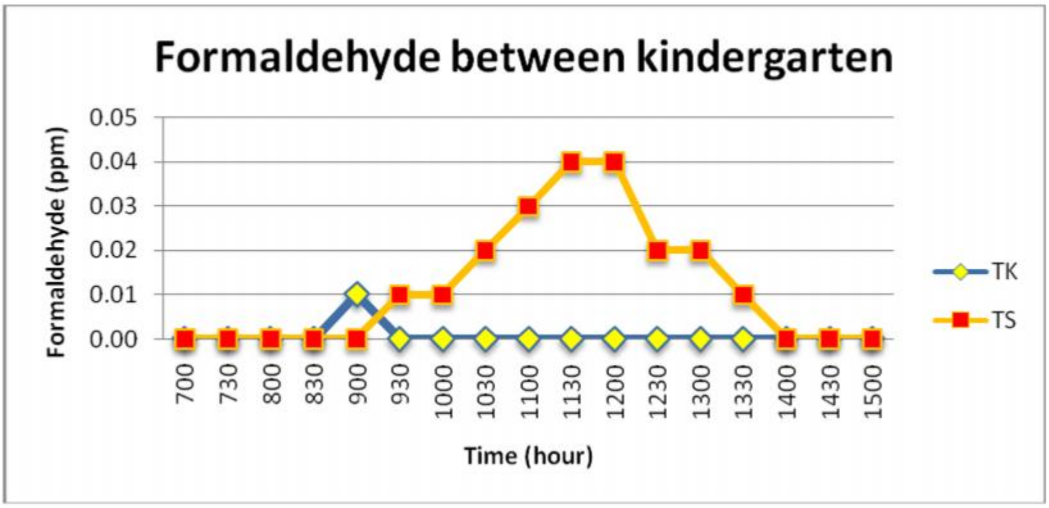

Figure 1: Formaldehyde pattern in two case studies

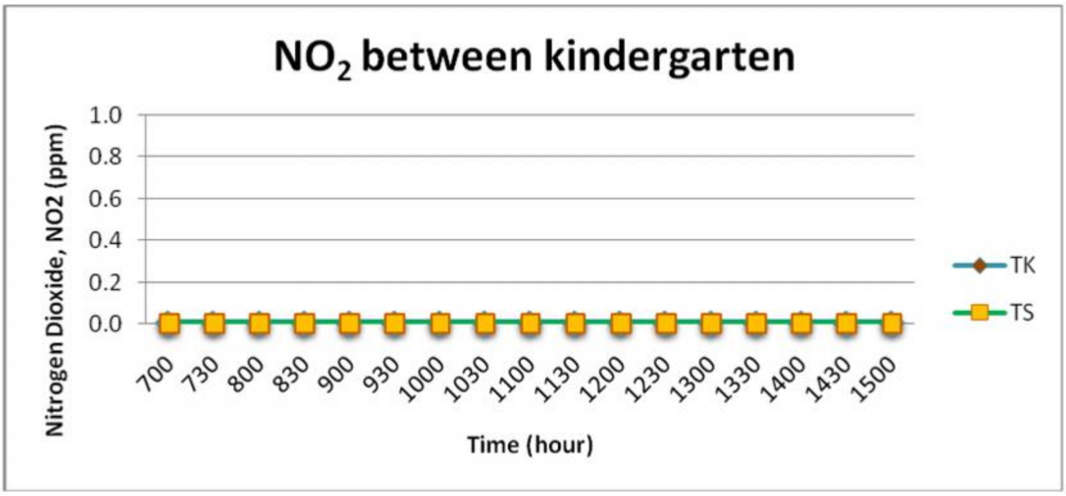

Figure 2: Nitrogen Dioxide pattern in two case studies

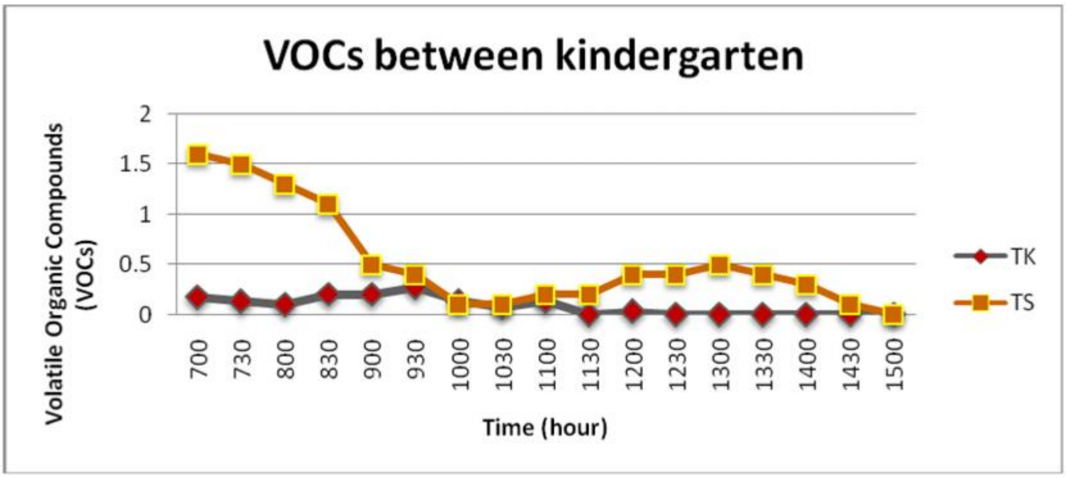

Figure 3: Volatile Organic Compound, VOCs pattern in two case studies

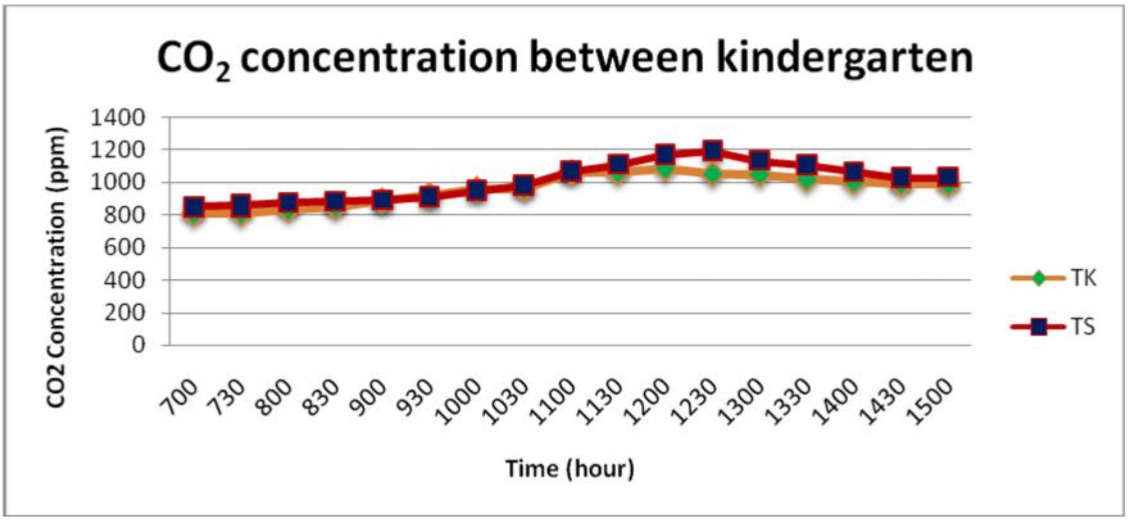

Figure 4: Carbon Dioxide, CO_2 pattern in two case studies

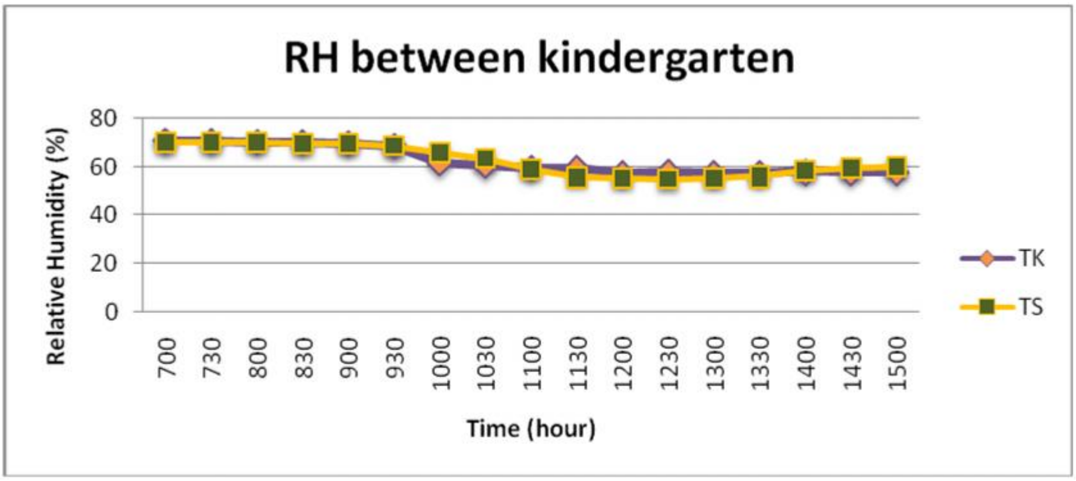

Figure 5: RH pattern in two case studies

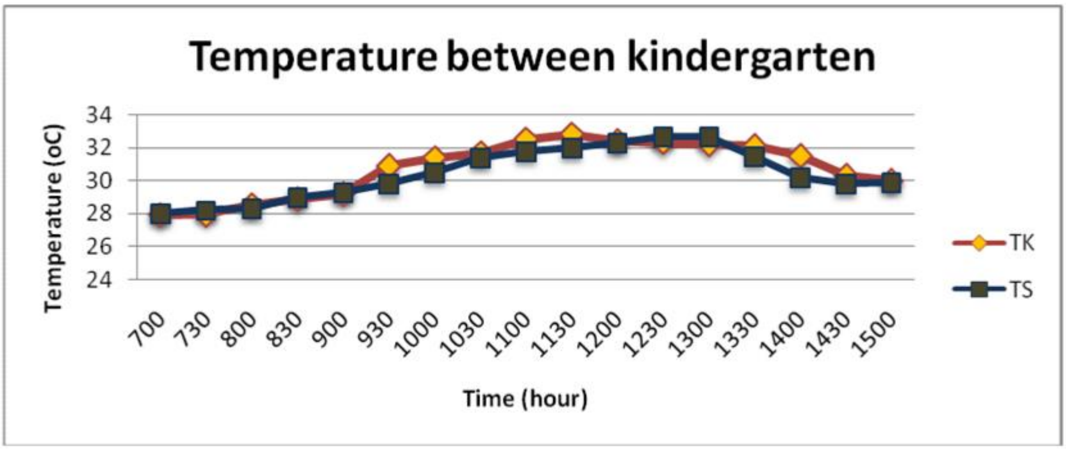

Figure 6: Temperature pattern in two case studies

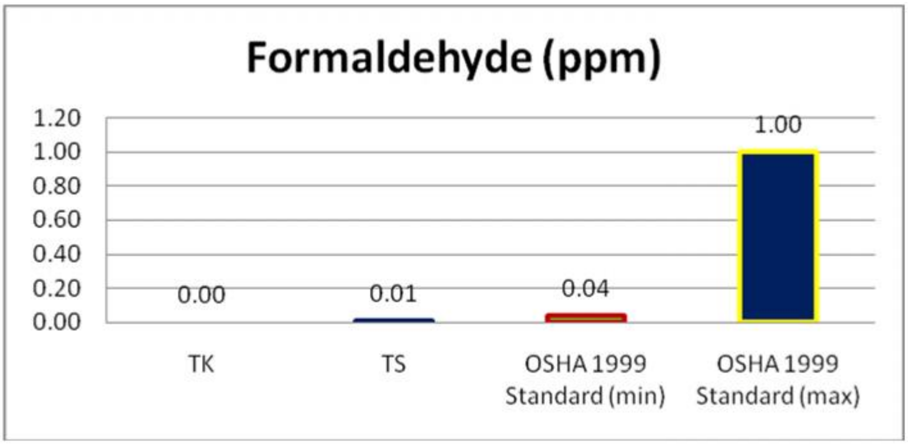

Figure 7: Formaldehyde against OSHA 1990

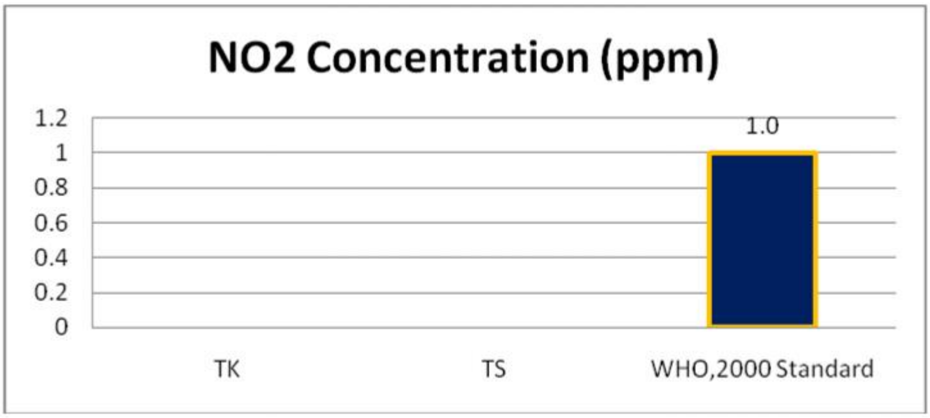

Figure 8: NO_2 Concentration against WHO 2000

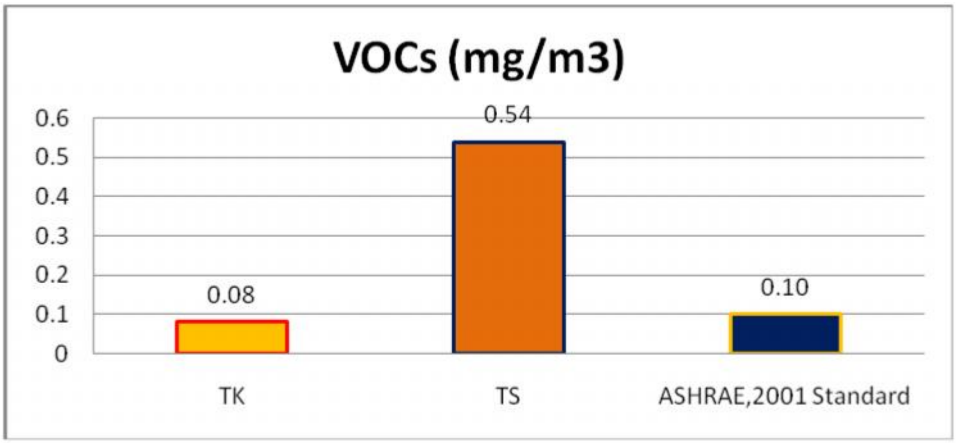

Figure 9: VOCs rate against ASHRAE 2001

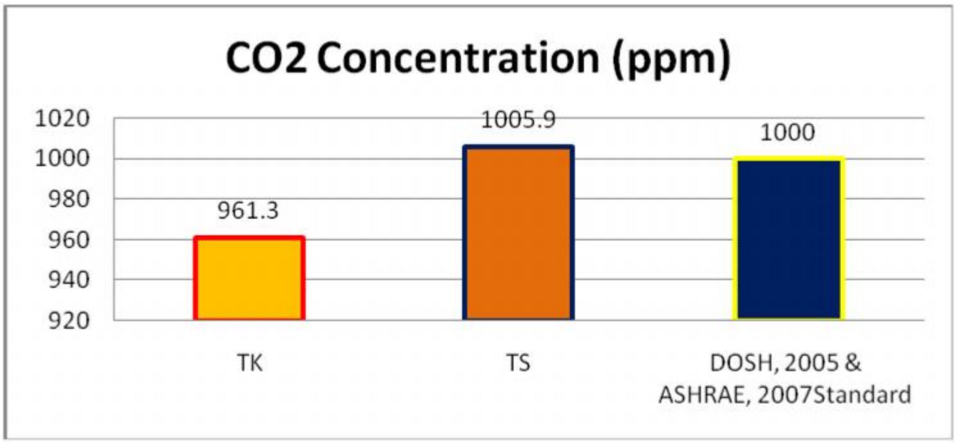

Figure 10: CO_2 concentration against DOSH 2005 & ASHRAE 2007

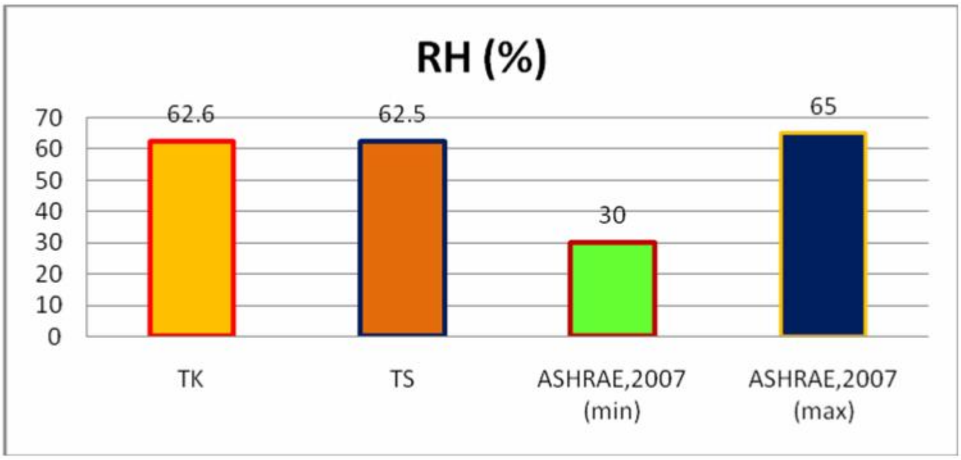

Figure 11: RH rate against ASHRAE 2007

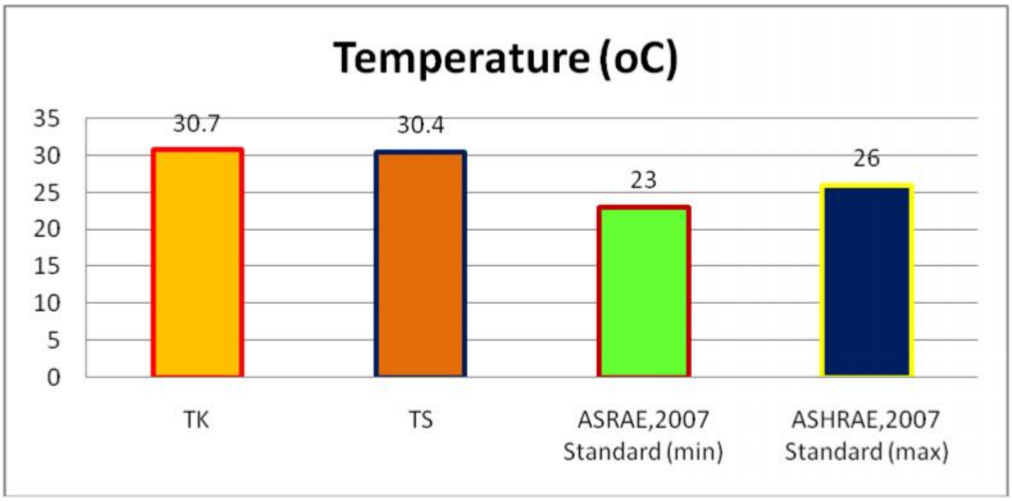

Figure 12: Temperature rate against ASHRAE 2007