DEVELOPMENT PARADIGM OF INDOOR AIR QUALITY IN PRESCHOOL ENVIRONMENT: A REVIEW

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ABSTRACT

The reviews on the subject of school environments emphasized that indoor air quality (AIQ) is often inadequate in classrooms causing increased risk for asthma and other health-related symptoms in preschool environment. It is most pronounced in developed countries. The paper summarizes and explores the peer-reviewed literature on IAQ in preschools environment and to explicit the importance of IAQ in refurbished pre-school by reviewing the previous studies on exposure of pupils towards poor IAQ in the classrooms. The existing reviewed data emphasizes on impact of CO2, CO, VOC, Air Velocity, Relative Humidity and temperature on children’s health and performance while performing assessment on existing standards (ASHRAE, NIOSH, ACGIH and OSHA). The study found that, most of the children are exposed to the inadequate environment during their time in the classroom which is not complying with the established standard. Expectantly, this paper is comprehensive to determine the sufficient information and as a reference for further data collection to assess the IAQ in refurbished preschools.

Keywords: Indoor Air Quality, Refurbished Kindergarten, Development, Review

1. INTRODUCTION

Coverage for preschool education in Malaysia has improved dramatically over the last 15 years, from 17 percent of 4-6 years in 1981 to 41.5 percent in 1995. The goal was 65 percent by the year 2000 and expected that the 1996 Education Act will be amended to make preschool as well as primary school compulsory (UNESCO, 2000). This progress has encouraged more private preschool center to set where it involved various type of refurbished building.

Indoor air quality in schools can have a substantial impact on children’s health, as an important environment where children may be exposed to pollutants and allergens (Zhang et al. 2006). School provides a major indoor environment for children away or apart from their home. Children may spend 10 hours per day at school, and at least 10 hours per year (Zhang et al. 2006) depending on the time that they arrive at the school and the time they leave the school.

As of 1996 there were 88 thousand kindergartens through 12th grade public schools in the United States providing daily housing for almost 46 million students and 2.7 million teachers as well as for extracurricular programs, daycare centers, and community programs (USDE, 2000). There is evidence that many school districts in the United States (GAO, 1995) and schools in other countries have significant and serious indoor environmental problems. From the educational standpoint, the indoor air quality and ventilation in school buildings may affect the health of the children and indirectly affect learning performance. Surprisingly, given the magnitude of the school population, information on indoor air quality in preschools is very limited.
2 OBJECTIVES

This study embarks on the following objectives

2.1 Assemble, evaluate, and summarize existing measurement data on ventilation, Carbon Dioxide (CO2) concentrations, Carbon Monoxide, and key indoor air pollutants most likely to be related to these symptoms, (e.g., volatile organic compounds (VOCs) and Air Velocity, Relative Humidity
2.2 Identify the most commonly reported building-related health symptoms involving schools;
2.3 Summarize existing information on causal relationships between pollutant exposures and health symptoms in schools.

3 LITERATURE REVIEW

3.1 INDOOR AIR QUALITY

Many factors affect indoor air pollution levels such as maintenance activities, the presence of contaminant sources (e.g., building materials, furnishings and equipment), the levels of contamination outdoors, the season, indoor humidity and temperature, and ventilation rates (Hall et al. 1995). Concentrations of specific contaminants in indoor air can often be considerably higher than concentration levels outdoors (Research Triangle Institute 1995). Indoor contaminants include formaldehyde, volatile organic compounds (VOCs), particles, pesticides, radon, fungi, bacteria, and nitrogen oxides. In addition to indoor air contaminants, occupants can experience similar discomfort and health symptoms similar to those attributed to indoor contaminants due to indoor environmental factors such as lighting levels, daylighting, and noise.

Often, the presence of both indoor contaminants and other indoor environmental factors makes it difficult to identify direct causes of occupant discomfort and health symptoms. While much attention is given to reactive measures regarding indoor air quality, little research is available to guide the construction and renovation of Pre-schools building to optimize good indoor air quality and minimize the potential for contamination and future problems. The Washington State Department of Health recently conducted a survey that revealed that 33 of 132 (25%) schools constructed or remodeled within the last five years had experienced indoor air quality (IAQ) problems. The survey found that the average cost to address these IAQ problems was $134,750. Because buildings and building systems are interconnected, it can be very difficult to identify specific causes of IAQ problems.

Generally, HVAC systems and water damage to the building envelope are the most common sources of building-related IAQ problems (Washington State Department of Labor and Industries 1993). Other causes of IAQ problems can be attributed to various phases of the building process including poor site selection, choice of materials, roof design, poor construction quality, improper installation or any number or combination of other factors. It is also important to make the distinction between items that are the cause and those that merely aid in distribution of contaminants because IAQ problems must be addressed at the source to eliminate the unwanted result. Cleaning the pathway between the source of a particular contaminant and an occupant does not adequately address the problem. In most cases, a remedy is required for both the source of the problem as well as the pathway to the occupant (Hall et al. 1995).

Poor ventilation was another common issue that affected school occupants. Low ventilation rates generally increase the risk for health symptoms. There is also a consistent relationship between health symptoms and ventilation rates or CO2 concentrations. Seppanen (1999) found that some increases in ventilation rates up to 20 LS-1 per person decreased
The prevalence of SBS symptoms or improved perception of IAQ. Wargocki (2002) also found that air-conditioned buildings may increase risk of SBS systems compared to those that are naturally ventilated.

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>SAMPLE</th>
<th>AREA OF FOCUS</th>
<th>RESULT/RECOMMENDATION</th>
</tr>
</thead>
</table>
| (Daisey et al. 2003) | Scientific literature published in journals and conference proceedings as of 1999 | School Building related health symptoms | • Classrooms are not adequately ventilated.  
• Consistent relationship between ventilation rates or CO2 concentrations and health symptoms.  
• Exposure to VOCs, molds, microbial VOCs and allergens measured in floor dust are related to asthma, SBS and other respiratory symptoms |
| (Mendell and Heath 2005) | Scientific literature through 2003 | School environments effect on academic performance | • Studies link indoor dampness and microbiological pollutants to asthma exacerbation and respiratory infection, which are associated with reductions in performance and attendance.  
• Evidence links low ventilation rates to reduced performance. |
| (Seppanen et al. 1999) | Reviewed 21 studies with 30,000 subjects. | CO2, ventilation rate and human health responses | • Ventilation rates below 10 LS-1 per person associated with significant worsening of one or more health or perceived air quality outcomes.  
• 1/3 of carbon dioxide studies indicate decrease risk of SBS symptoms with decreasing CO2 levels below 800 ppm. |
| (Wargocki et al. 2002) | peer-reviewed papers by EUROVEN scientific committee | Ventilation, CO2 and health symptoms of occupants | • Ventilation associated with comfort (perceived air quality), health and productivity.  
• Air-conditioned buildings may increase risk of SBS systems compared to those naturally ventilated.  
• Improper maintenance, design and functioning of air conditioning systems contribute to perceived prevalence of SBS symptoms |
3.2 MEASUREMENTS OF VENTILATION RATES AND CO2 CONCENTRATIONS IN SCHOOLS

3.2.1 Ventilation Rates

Ventilation rates have rarely been measured in schools, although inadequate ventilation is often suspected to be an important condition leading to reported health symptoms. ASHRAE Standard 62-2007 (ASHRAE, 2007) recommends a minimum ventilation rate of 8 L/s-person (15 cfm/person) for classrooms. Given typical occupant density of 33 per 90m2 (1000 ft2) and a ceiling height of 3m (10 ft), the current ASHRAE standard would require an air exchange rate of about 3 air changes per hour (ACH) for a classroom.

Turk, et al. (1989) reported ventilation measurements made in 6 non-complaint schools in the U.S. Northwest - 2 in Portland, and 4 in Spokane, WA. Schools ranged from 3 - 25 years in age, 1 - 3 stories; all had mechanical ventilation systems of some type. Ventilation rates, calculated on a whole building volume basis, ranged from 4.5 L/s-person to 31 L/s-person. The whole or average building rate, however, includes unoccupied areas such as hallways and gymnasiums, and, as the authors point out, this average rate overestimates the local ventilation rate of occupied classrooms. For example, in one of the elementary schools, the whole building ventilation rate was 4.5 L/s-person while the ventilation rate in an occupied classroom was only 1.6 L/s-person.

Turk, et al. (1993) also reported ventilation rates measured in 2 schools in Sante Fe, which were being mitigated for high radon concentrations. Twelve pre- and post-radon mitigation ventilation rates were below 3 ACH with one exception. Nielsen (1984) reported ventilation measurements made in a random selection of 11 schools in Denmark. Measurements were made in 2 classrooms for 3 consecutive days. The average ventilation rate was 6.4 L/s-person with a range of 1.8 - 15.4 L/s-person.

Croome, et al(2007) in his research of eight primary schools in United Kingdom revealed that pupils work and performance increased 7% in addition due to the intervention the fresh air supply from 0.3-0.5 to 16L/s per person. This is supported by Mendel and Heath (2005), where the poor ventilation rates for the adult population could be expected that not only the comfort and health, but also the learning performance of school children are affected by the poor environmental conditions in classrooms. By improving classroom conditions can substantially improve the performance of school works by children (Wargocki, 2005).

3.2.2 CO2 Concentrations

Carbon dioxide concentrations are often used as a surrogate of the rate of outside supply air per occupant. Indoor CO2 concentrations above about 1000 ppm are generally regarded as indicative of ventilation rates that are unacceptable with respect to body odors. Concentrations of CO2 below 1000 ppm do not always guarantee that the ventilation rate is adequate for removal of air pollutants from other indoor sources (Seppänen et al., 1999; Apte et al., 2000).

It is difficult to adequately characterize indoor CO2 concentrations since they are a function of occupant density and ventilation rate, both varying as a function of time. Grab samples or other short-term measurements may be inadequate to provide information on the long-term ventilation conditions in schools.
The most common building factors associated with indoor environmental complaints are related to the Heating Ventilation and Air Conditioning (HVAC) systems. The recommended ventilation rate for a classroom is 15 cfm/person with a specified maximum occupancy of 50 persons per 1000 ft² for schools (Sahlberg et al. 2002). The ASHRAE 62.1-2007 ventilation standard provides outdoor air requirements for classrooms of 15 cubic feet per minute (CFM) per person. ASHRAE Standard 55-2004 provides the thermal comfort guideline for temperature and relative humidity.

According to Bayer (2002), the ventilation rate for schools with desiccant cooling systems (humidity control) averaged 15 cfm/person, whereas conventional HVAC system schools averaged only 5 cfm/person. This study cited inadequate HVAC maintenance and poor design as causes for poor indoor air quality from HVAC systems. Students occupying rooms with old air handling unit filters reported more symptoms from the eyes, nose and throat than students with newer filters (Smedje et al. 2002). HVAC systems can cause indoor air quality problems and/or distribute contaminants throughout a building. Table 3.2 presents findings from literature relative to measurements of CO₂, ventilation and other measures of the indoor conditions in classrooms and schools. Specifically, the findings determined whether ASHRAE recommended concentration of 1,000 ppm CO₂ and ventilation rate of 15-cfm/person were met. Results from only two study met the ventilation guidelines, and 14 of the 16 studies failed to meet the ventilation guidelines. Two studies met the ventilation guidelines with desiccant systems, but failed to meet the guidelines with conventional HVAC systems. The data indicates that, most often, mechanically ventilated and unoccupied rooms meet standards for CO₂, whereas naturally ventilated and occupied rooms did not. When new schools were compared to old schools, measurements were relatively equal.

High levels of CO₂ can result from inadequate ventilation systems, inadequate air exchanges from the opening and closing of windows and doors, and overcrowded classrooms. Occupied and air conditioned rooms measured higher levels of CO₂ than rooms cooled with ceiling fans. Rooms with desiccant active control systems met standards for ventilation, while rooms with conventional HVAC systems did not (Bayer et al. 2002). Other study findings indicate that low ventilation rates were associated with worsening health or perceived air quality outcomes. Also, the literature associates increases in CO₂ with decreased attendance (Shendell et al. 2004).

Brennan et al. (1991) reported mid-afternoon CO₂ measurements in a non-random study of 9 U.S. non-complaint schools. Concentrations ranged from about 400 to 5,000 ppm (mean = 1480 ppm). CO₂ concentrations exceeded the 1000 ppm ASHRAE ventilation standard in 74% of the rooms. The average CO₂ concentrations for 3 non-complaint schools in Alberta, Canada were below 1000 ppm although some measurements exceeded this concentration (Cousins and Collett, 1989). In one portable classroom the average CO₂ concentration was 1950 ppm. The number of classrooms studied at each school was not provided.

Smedje, et al. (1996, 1997) reported average and ranges of indoor CO₂ concentrations for 96 classrooms in 38 Swedish schools randomly selected from a population of 130 schools; 61% of them had mechanical supply and exhaust air systems while the remainder had natural ventilation. Concentrations averaged 990 ppm CO₂ for the 38 schools, but were above 1000 ppm for 41% of the measurements (maximum = 2800 ppm).

In general, CO₂ measurements in schools suggest a significant proportion of classrooms probably do not meet the ASHRAE Standard 62-2007 for minimum ventilation rate, at least part of the time. The particular concern is the potential for increased risks of contracting certain
communicable respiratory illnesses, such as influenza and common colds in classrooms with low ventilation rates (Fisk 2001).

Table 3.2 Measuring CO₂ (ppm) and Ventilation (cfm/person)

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>SAMPLE</th>
<th>CO₂ ventilation guidelines met</th>
<th>CO₂ (ppm) or ventilation (cfm/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M. Ismail et.al, 2010)</td>
<td>3 schools 9 classrooms</td>
<td>Yes</td>
<td>638.27-698.60 ppm, 555.50-647.60 ppm, 545.60-675.00 ppm</td>
</tr>
<tr>
<td>(Bartlett et al. 2004)</td>
<td>39 schools</td>
<td>No</td>
<td>1080 ppm</td>
</tr>
<tr>
<td>(Bayer et al. 2002)</td>
<td>10 schools</td>
<td>Yes - desiccant</td>
<td>Desiccant (15 cfm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No - HVAC sys.</td>
<td>HVAC system &lt; 5 cfm/person</td>
</tr>
<tr>
<td>(Butala and Novak 1999)</td>
<td>24 schools</td>
<td>No</td>
<td>4000 ppm</td>
</tr>
<tr>
<td>(Dautel et al. 1999)</td>
<td>10 schools 2 districts</td>
<td>No</td>
<td>1461 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>79% exceeded standard</td>
</tr>
<tr>
<td>(Fox et al. 2003)</td>
<td>7 classrooms</td>
<td>No</td>
<td>1017-1735 ppm</td>
</tr>
<tr>
<td>(Fox et al. 2005)</td>
<td>3 schools 7 classrooms</td>
<td>No</td>
<td>1,387, 644, and 1,455 ppm</td>
</tr>
<tr>
<td>(Godwin and Batterman, 2007)</td>
<td>9 schools 64 classrooms</td>
<td>No</td>
<td>533-1552 ppm</td>
</tr>
<tr>
<td>(Grams et al. 2003)</td>
<td>7 Schools</td>
<td>No</td>
<td>1316 ppm</td>
</tr>
<tr>
<td>(Lee and Chang 1999)</td>
<td>5 schools 5 classrooms</td>
<td>No</td>
<td>&gt; 1000 ppm</td>
</tr>
<tr>
<td>(Norback et al. 2000)</td>
<td>12 schools 12 Classrooms</td>
<td>No</td>
<td>1,150 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Range 760 – 1620 : 84% did not meet standard</td>
</tr>
<tr>
<td>(Ramachandran et al. 2005)</td>
<td>2 schools 5 classrooms</td>
<td>Yes</td>
<td>Old school (509 ppm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>New school (512 ppm)</td>
</tr>
<tr>
<td>(Research Triangle Institute International 2003)</td>
<td>67 schools 384 classrooms</td>
<td>No</td>
<td>1,070 ppm portable classrooms (1,064 ppm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>traditional classrooms (1074 ppm)</td>
</tr>
<tr>
<td>(Shendell et al. 2004)</td>
<td>22 schools 436 classrooms</td>
<td>No</td>
<td>45% of classrooms &gt; 1,000 ppm</td>
</tr>
<tr>
<td>(Shin et al. 2005)</td>
<td>1 test chamber 1 classroom</td>
<td>No</td>
<td>without ventilation (1790 - 2190 ppm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with ventilation (1032 - 1536 ppm)</td>
</tr>
<tr>
<td>(Zuraimi and Tham, 2008)</td>
<td>104 Childcare Center</td>
<td>Yes-Natural Ventilation</td>
<td>Natural Ventilation (463-509 ppm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No-Air-Condition</td>
<td>With air-condition (Mean 1184 ppm : range 995-1337 ppm)</td>
</tr>
</tbody>
</table>
3.2.3 TEMPERATURE AND RELATIVE HUMIDITY

Table 3.3 presents findings from literature reviews relative to measurements of temperature and relative humidity in classrooms and schools. In some cases, the studies collected data for both indoor and outdoor conditions. The literature referenced standards for acceptable comfort measurements of temperatures below 23 °C and 30% - 60% relative humidity. Recorded temperatures generally met this comfort range, although temperature was difficult to control in naturally ventilated (Lee and Chang 2000). Typically, 1/3 of all recorded cases in a study exceeded the standard for temperature if any temperature in the study exceeded the standard. Sacrificing ventilation achieved acceptable relative humidity levels in some cases (Fischer and Bayer 2003). Several investigators found correlations between measured conditions, bacteria or contaminants and humidity, occupied rooms and ventilation (Bayer et al. 2002b).

Bayer (2002) found that without active humidity control systems, ventilation rates of 5 cfm/person create greater than 70% relative humidity levels for extended periods of time. Attempts to control indoor humidity by lowering ventilation rates and space temperature increases contaminant concentrations, energy usage, and costs (Fischer and Bayer 2003). Desiccant systems had the best ventilation rates, which improved IAQ in qualitative (perception) and quantitative (objective) measures (Bayer et al. 2002b). Most desiccant systems accommodate high efficiency filtration in a central location using fans. One outcome noted from the literature ties the results to student attendance. Fischer (2003) reported that conventionally conditioned schools had approximately 9% higher absenteeism than desiccant conditioned schools. Another factor noted relates to cost. The operating cost for desiccant systems is approximately $15-20K less than conventional systems.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sample</th>
<th>Temperature (°C)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M. Ismail et.al, 2010)</td>
<td>3 schools 9 classrooms</td>
<td>27.9-26.47</td>
<td>71.90-88.45</td>
</tr>
<tr>
<td>(Dautel et al. 1999)</td>
<td>2 districts 10 schools</td>
<td>n/a</td>
<td>53</td>
</tr>
<tr>
<td>(Bayer, 2003)</td>
<td>10 schools</td>
<td>22.8 - 25</td>
<td>Conventional schools (58) at 15cfm/person (70)</td>
</tr>
<tr>
<td>(Grams et al. 2003)</td>
<td>7 schools</td>
<td>21.7</td>
<td>50.7</td>
</tr>
<tr>
<td>(Lee and Chang 1999)</td>
<td>5 schools 5 classrooms</td>
<td>17.2 - 23.</td>
<td>Indoor (55.5 - 75.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Outdoor (53.5 - 83.6)</td>
</tr>
<tr>
<td>(Mysen et al. 2005)</td>
<td>2 classrooms</td>
<td>14.0 - 19.4</td>
<td>n/a</td>
</tr>
<tr>
<td>(Norback et al. 2000)</td>
<td>12 schools 12 classrooms</td>
<td>22 Range (21 – 25)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>in 54% of schools</td>
</tr>
<tr>
<td>(Ramachandran et al. 2005)</td>
<td>2 schools 5 rooms</td>
<td>Old school (22.3) New school (21.3)</td>
<td>Old school (37.3) New School (39.0)</td>
</tr>
<tr>
<td>(Research Triangle Institute 1995)</td>
<td>384 schools 1133 classrooms</td>
<td>Temperatures below 20 more frequently than traditional classrooms</td>
<td>Traditional classrooms (45.9) portables (46.8)</td>
</tr>
<tr>
<td>(Shendell et al. 2004)</td>
<td>7 schools 2 portable</td>
<td>portables (19.5 - 24.1) traditional (19.4 -23.8)</td>
<td>portables (51.8 - 57.9) traditional (49.1 - 55.5)</td>
</tr>
<tr>
<td>(Zuraimi and Tham, 2008)</td>
<td>104 Childcare Center</td>
<td>27.9-28.7</td>
<td>66.9-70.9</td>
</tr>
</tbody>
</table>
3.3 INDOOR POLLUTANTS
3.3.1 Volatile Organic Compounds

The most commonly measured pollutants in schools were total volatile organic compounds (TVOCs), formaldehyde, and biological contaminants. VOCs are suspected as one of the causes of SBS. Measured values of TVOC can vary significantly depending upon the sampling and analysis methods used (Hodgson, 1995). Particularly high TVOC concentrations, above 1 to 2 mg/m³, indicate the presence of strong VOC sources and/or low ventilation.

Organic pollutants account for the vast majority of pollution found in air. Indoor air in residences, offices, public access buildings and transportation vehicles often contain volatile organic compounds (VOC) at levels in order of magnitude higher than those outdoors (Edwards et al. 2001, Jones 1998) from emitting sources such as cleaning products, vehicle emissions and electronic appliances. Jones (1998) has found levels of most VOC can be five (5) to ten (10) times higher indoors than outdoors, and sometimes indoor levels can be more than 100 times higher than outdoor levels (American Lung Association 2002).

TVOCs cover a broad spectrum of chemical classes with different physicochemical and biological properties with inhalation a prominent route of exposure due to their volatility although many TVOCs can quite readily be absorbed through the skin (Henrich-Ramm et al. 2000). TVOC that can be found in several sources (Grimsrud 2004). Data in the published technical literature provide the following guidance in the interpretation of VOC air sampling results. This guidance includes the following:

a) TVOC concentrations in non-compliant buildings are typically in the range of 200-500µg/m³ (AQS 1995).

b) Recently renovated spaces may have TVOC levels of up to 30,000µg/m³ (30mg/m³). With adequate ventilation, these levels can decrease to below 1000µg/m³ within a 30-day period (AQS 1995).

c) Based on an extensive literature review, analysis of health related data and a survey of unpublished measurements, means concentration of individual VOC in established buildings were generally found to be less than 50µg/m³, with most below 5µg/m³ (Brown 1994).

d) Mean TVOC concentrations in established public buildings were found to be in the range of 70-410µg/m³ (Brown 1997).

TVOC concentrations in two Southeastern US schools with reported humidity and mold problems ranged from about 1 to 23 mg/m³ in one school and averaged 1.6 mg/m³ in another (Bayer and Downing, 1992). Black and Worthan (1995) reported average TVOC concentrations of 0.45 and 0.2 mg/m³ under unoccupied and occupied conditions, for a problem school in Washington State after mitigation. Casey, et al. (1995) reported TVOC measurements made in two Las Vegas, NV elementary schools during the cooling season. The ventilation systems for the classrooms had been disabled for unknown reasons and the only means of ventilation was infiltration. TVOC levels before the installation and operation of heat recovery ventilators (HRVs) ranged from 0.8 to 2.0 mg/m³. With the HRVs operating, concentrations of TVOC were reduced to 0.75 mg/m³ and 0.45 mg/m³ in the two classrooms.

Cavallo, et al. (1993) reported TVOC concentrations for ten non-complaint schools in Italy. The median concentration reported for the Italian nurseries and kindergartens was 3.6 mg/m³ and lower for primary and secondary schools (0.26 mg/m³), but the upper end of the range was very high, 13.6 mg/m³. The average TVOC for 10 French schools was 0.98 mg/m³ (Laurent, et al., 1993). Norback (1995) reported the range of average TVOC concentrations from
36 classrooms in 6 Swedish primary schools to be quite low, 0.07 to 0.18 mg/m3. Median TVOC (excluding limonene) concentrations were 0.19 mg/m3 (range 0.10 to 0.23 mg/m3) in a study of 10 Swedish non-complaint schools, and 0.11 mg/m3 (range 0.07 to 0.21 mg/m3) in 11 schools with higher prevalence of SBS symptoms, while outdoor concentrations averaged about 0.09 mg/m3 (Willers et al., 1996). Mean indoor and outdoor kindergarten TVOC concentrations were 0.09 mg/m3 and 0.05 mg/m3, respectively.

### 3.3.1 Carbon Monoxide

Carbon monoxide reacts 210 times more strongly with blood hemoglobin than oxygen to form carboxyhaemoglobin, COHb where it performs the acute toxicity among human. The recommend value for safety CO is 10 ppm for 8-hour exposure (DOSH, 2005). The ACGIH recommend the limit for carbon monoxide is 25 ppm averaged over 8-hour. The EPA National Emissions Standard is 9 ppm for 8 hours and 40 ppm for one hour.

Often, sources of elevated level of CO and other combustion by-products are encountered in one, or combination of the following scenarios;

i. Vehicle exhaust in a building (air intake to a building located at street level in a busy alley or an automobile left running in a garage)

ii. Poorly vented gas-fired hot water heater

iii. Air from a leaking exhaust duct of furnace flue

iv. Combustion by-products vented closed to an air intake for a building

v. Poorly sealed wood burning stove

vi. An insufficient amount of oxygen supplied to a gas-operated space heater

vii. Poorly tuned forklift trucks

viii. Poorly vented and insufficient replacement air in a building with natural gas and wood burning fireplaces (e.g., tight building with little or no air coming from outside to replace the air discharged through the chimney)

ix. Gas fired heaters in air handling units

x. Industrial combustion gases from an associated building

(Source: Hess-Kosa, 2000)

Indoor sources in building: e.g. gas stove, smoking, building characteristic, natural ventilation and high rise building will increase personal CO exposure (Alm et al., 2000). However, studies on 104 childcare center in Singapore have the adequate indoor CO concentration 1.0-1.2 ppm in dominantly natural ventilation classrooms and 0.9-1.4 ppm for dominantly air conditions classrooms (Tham and Zuraimi, 2008). They found that only outdoor concentration was found to be the determinant in their standard errors. While, IAQ studies for 3 primary schools in Malaysia revealed the same, where the outdoor combustion generated activities i.e. automobiles exhaust from attach garage, nearby roads or parking area are believed to be the sources of CO concentration (M.Ismail et al., 2010). The measured concentration CO ranged between 0.61 to 4.09 ppm, well below the Malaysian Code of practice (DOSH, 2005) recommended value of 10 ppm for an 8-hour of exposure.

### 3.4 Indoor Air Quality Related Health

The symptoms associated with indoor air quality problems are similar to those of allergies or colds. They are often non-specific symptoms rather than clearly defined illnesses (Hall et al. 1995). In general, occupants of a building diagnosed with sick building syndrome (SBS) suffer from such symptoms. SBS symptoms include eye, nose, and throat irritation,
dryness of mucous membranes and skin, nose bleeds, skin rash, dry or itchy skin, difficulty breathing or chest tightness, mental fatigue, headache, cough, hoarseness, wheezing, nausea, and dizziness (U.S. Department of Labor 1994). SBS describes an illness with symptoms that occur while in a specific building but subside when away from the building. The symptoms may worsen or only appear in specific zones or rooms. A Swedish study reported the following (Sahlberg et al. 2002):

1) general symptoms were more prevalent at high temperatures,
2) eye symptoms and tiredness were more common at low lighting,
3) headaches were more common for lower levels of daylighting,
4) eye symptoms were related to the total air concentration of bacteria,
5) a relationship between observed building dampness and SBS-symptoms, but only in schools with an air exchange rate below the median value (<1.8 ach)

In contrast to SBS is Building Related Illness (BRI), which attributes illness to environmental agents in the indoor air. These specific environmental agents produce symptoms that allow for illness diagnosis. An example of a BRI with life-threatening consequences is Legionnaire’s disease, which is a severe pneumonia associated with the {\textit{Legionella}} species of bacteria. Such illnesses result from uncontrolled sources of contaminants and poor building maintenance (Sahlberg et al. 2002).

The prevalence of asthma and allergies, especially in children, rose over the past decade (Akinbami and Edelman 2006). After the home, school is the most important indoor environment for children. This is especially noteworthy because individuals with asthma or allergies are potentially more susceptible to indoor air contaminants (Research Triangle Institute 1995). Children may be more susceptible to indoor air pollution than adults. The U.S. Environmental Protection Agency attributes this to the greater volume of air inhaled by children relative to their body weight, and thus a greater mass of pollutant uptake per body weight (U.S. Environmental Protection Agency 1996). One study positively associates respiratory infections in schoolchildren with viable molds in air, viable bacteria, and 3-methylfuran (Norback et al. 2002).

Table 3.4 presents findings from literature reviews relative to associations between health and the environment of classrooms. Specifically, the table outlines findings on the health symptoms and environmental factors that affect health. In most cases, the literature indicates that such correlations do exist. The literature found a connection between health and the environment in all studies. The most significant findings related to allergens, asthma, cold/cough, respiratory infections, nasal patency and other SBS symptoms. Several studies also associate mold allergens with the presence.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sample</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dautel et al. 1999)</td>
<td>2 districts 10 classrooms</td>
<td>Significant correlations: Allergen and irritant scores. Allergen score to condition of HVAC filter. Condition of HVAC filter to irritant score</td>
</tr>
<tr>
<td>(Karlsson 2002).</td>
<td>35 classrooms</td>
<td>Rate of children reporting dissatisfaction with indoor air quality correlated positively with allergen levels.</td>
</tr>
<tr>
<td>(Meklin et 32 schools</td>
<td></td>
<td>Common colds significantly more common in</td>
</tr>
</tbody>
</table>
The present paper supports on previous studies of IAQ for schools in various countries. Anxiously, majority of schools are exposed to the inadequate IAQ due to insufficient ventilation, maintenance activities, the presence of contaminant sources (e.g. building materials, furnishings and equipment), the levels of contamination outdoors, the season, indoor humidity and temperature, and ventilation rates. These conditions will lead to the SBS symptom and affecting the children performance as they are sensitive to any changes surrounding them. The peered researches indicate that 14 of 16 studies failed to meet the CO2 ventilation guidelines. Yet, I is difficult to endure the characteristic indoor CO2 as it often used as a surrogate of the rate of outside supply air per occupant and a function of occupancy and ventilation rate.

In valuating the Temperature and relative humidity, the previous researches shown most of the cases exceeded the standard of temperature and relative humidity. Yet, the fact is Malaysia is located in tropical region which experience a hot and humid climate, it will affect the results of immediate classroom. The TVOCs and CO2 in selected researches shows quite low, where it will no affecting much the IAQ of the classroom.

### DISCUSSIONS OF FINDINGS

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Norback et al. 2002)</td>
<td>12 schools</td>
<td>Lower degree of nasal patency found at higher concentrations of total molds.</td>
</tr>
<tr>
<td>(Norback et al. 2002)</td>
<td>10 schools</td>
<td>Respiratory infections more common at higher concentration of viable bacteria and viable molds.</td>
</tr>
<tr>
<td>(Sahlberg et al. 2002)</td>
<td>38 schools</td>
<td>General symptoms higher at higher room temperature.</td>
</tr>
<tr>
<td>(Seppanen et al. 1999)</td>
<td>21 studies</td>
<td>Ventilation rates below 10 LS-1 per person were associated with significant worsening of one or more health or perceived air quality outcomes.</td>
</tr>
<tr>
<td>(Smedje and Norback 2001)</td>
<td>39 schools</td>
<td>Asthma more common at higher concentrations of formaldehyde and total molds in the classroom air</td>
</tr>
<tr>
<td>(Wargocki et al. 2002)</td>
<td>105 peer-reviewed papers</td>
<td>Ventilation strongly associated with comfort (perceived air quality) and health (SBS symptoms, inflammation, infections, asthma, allergy, short-term sick leave).</td>
</tr>
</tbody>
</table>
4.0 RESEARCH NEEDS/CONCLUSIONS

This review shows that the state of knowledge regarding IAQ in schools is limited. With the possible exception of the early NIOSH investigations not reported in the peer-reviewed literature, there has been no consistent approach to evaluations of IAQ and health outcomes in schools. Many of the existing studies lack the rigor and quality necessary to adequately address the problem. In addition, although there is some effort to identify the IAQ problems in schools, there are no programs currently in place to improve the indoor environmental quality in schools especially the refurbished one.

More studies are needed in which relations between symptoms and measured exposures to multiple specific pollutants are investigated. Furthermore, quantitative information is needed on exposure-health response relationships for specific pollutants suspected to cause health symptoms, in order to provide a sound basis for setting standards for refurbished pre-school and for insuring cost-effective mitigation measures. Finally, although there is evidence that many schools are not adequately ventilated, the extent of the problem is not known. Careful and thorough measurements of ventilation rates and/or CO2 levels in a representative sample of schools would provide much needed information on the fraction of schools with this problem. In closing, although more studies are needed to determine the extent of IAQ problems in schools, evidence shows that ventilation rates in new and existing schools often do not meet the minimum ASHRAE guidelines, and this may be related to significant increases in symptoms among children and teachers in schools. It is clear that programs should be put in place to ensure that all pre-schools provide necessary ventilation. Expectantly, this paper is comprehensive to determine the sufficient information and as a reference for further data collection to assess the IAQ in refurbished preschools.

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