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Indoor air quality level influence sick building syndrome among occupants in educational buildings

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ABSTRACT

In educational facilities, good and healthy indoor air quality is critical to ensure students' focus and academic activities can be carried out efficiently. The goal of this study was to evaluate the link between indoor air quality level with sick building syndrome and health complaints among occupants. A cross-sectional study was conducted which involved 513 occupants. A modified MM040Na questionnaire was used in this study. Occupants' workspaces were monitored for indoor air quality. The score obtained from the questionnaire and environmental factors were tested using statistical analyses incorporating test of differences namely Chi–Square, t-test, and non-parametric analysis. Logistic regression was conducted to evaluate relationship between exposure and occupants' complaint. Results shows that some indoor air pollutants (carbon dioxide, formaldehyde, and particulate matter) are related to overall sick building syndrome (Odd Ratio, OR=1.348, 2.493, 1.958 respectively). General score of sick building syndrome (SBS) shows significant relationship with air motion (OR=2.220) and air flow (OR=2.515). Mucosal score of SBS suggest exposure risk towards indoor factors namely formaldehyde (OR=2.799), while dermal effect was associated from the exposure of Particulate (OR=2.88), carbon dioxide (OR=4.000), and air flow (OR=2.679). In educational environments, indoor contaminants have an impact on reported symptoms.

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1. INTRODUCTION

The new model for the design of modern educational buildings encourages engineers and architects to create stable, mechanically fitted constructions. The primary purpose of the indoor mechanical ventilation was to provide sufficient airflow to ensure comfort for the occupants. Over recent years, the transmissibility of infectious diseases has brought educational structures to the notice of the occupants and building managers. Occupants are sometimes sensitive to their workspace in the indoor environment, and this indoor condition can cause the spread of disease from virus, bacterial and fungal form. In the last ten years, Malaysia has implemented an indoor air quality self-regulation strategy by implementing the indoor air quality industry code of practice (ICOP-IAQ) in year 2010 [1]. The self-regulation provides building owners and employees with the ability to safe keep their healthy workplaces, particularly indoor workplaces.

In order to understand the state of the indoor environment in a specific building, a thorough investigation should be conducted with regard to the spatial condition of each location and the workspace of the occupants. The regular indoor air quality study emphasis on sampling areas but does not really look at individual monitoring at desk level or near the breathing zone of the occupants. Area monitoring may somehow offer a representative result on the condition of the total occupants rather than the holistic nature of the summary complaint. This area monitoring may lead to bias that are not suitable for deep diagnostic approach of any indoor air quality problems investigation. In addition, the description of the exposure and health effects investigation at individual levels are very important to establish a meaningful relationship between indoor air quality and health effects [2]. Thus, the exposure and outcome analysis which collected at individual levels are important in determining the epidemiology of sick building syndrome (SBS).

The new industrial code of practice (ICOP-IAQ, 2010) has been revised and focuses on three main parameters, namely biological pollutants, chemical and physical parameters. Previous studies also suggest that the use of a semi-quantitative factor during the preliminary investigation of indoor air quality problems could give sufficient insight into the general condition or actions of pollutants in the building of interest [3]. Generally, in Malaysia's normal mechanical ventilation, the fan coil unit (FCU) is one of the most common equipment used to supply adequate air flow and comfort indoor air. Engineers are faced with quite a challenge when designing the FCU for a heavily occupied room due to the fact that the number of occupants may vary due to pre-existing conditions and indoor activities [4]. The FCU was unable to cope with the dilution process when the extremely concentrated carbon dioxide was present indoors. The use of the Air Handling Unit with dedicated fresh air intake is therefore proven to be the ideal mechanical system for educational buildings, because the design is effective of diluting, filtering and processing clean air in the large classroom.

Occupants in any building faced many challenges with the un-controlled ventilation setting. This includes varying temperature which can lead to dissatisfaction and distraction during working hours. Similarly, with students, when they use the indoor spaces, they need comfortable indoor condition to ensure that they can focus on the study material. Student performance is somehow linked to the indoor environment and this is the reason most of the occupants have varying perspectives through individual assessment and somehow lead to the psychological condition, mental health and respiratory illness [5]. The majority of problems with indoor air quality contribute to poor or inadequate ventilation [6] that can generate bad pollutants circulation within indoor spaces and travel along in the centralized system. A greater number of symptoms appear as a result of bad indoor conditions, and this led to a high number of absences especially during the initial start-up of the ventilation system. In addition, the indoor environment is becoming worse where there is non-visible source of the contaminants that can cause bad health issues especially to the occupants with pre-existing medical conditions such as asthma, allergic disease and chemical sensitivity [7]. Chemical exposure within poorly circulated indoor environment operated by mechanical ventilation may led to the decrease of students' performance, distracting focus during teaching and learning process and somehow, relate to the increase of stress levels [5]–[7].

In new modern building design, ventilation system and maintenance protocol were the key to ensure the health of the occupants remain similar before they enter and study inside the building. Engineers usually focus on the comfort where the main ideas were to maintain the temperature and humidity levels, within indoor environment. These include concerns of temperature and thermal comfort [8] the moisture, dampness problem [9] and particle dispersion indoors [10]. There are other factors that are likely to be important in causing symptoms among occupants, including ergonomic problems [11], working with photocopier machine [12] environmental tobacco smoke [13], [14] and total volatile organic carbon (TVOC), aldehyde and combustion products [15]–[18]. However, the indoor environment condition not only due to these factors (temperature and humidity), but thus researchers also need to understand the other exposure that may impact the occupants (students) in order to established epidemiological evidence for managing the risk and the indoor environment factors. Therefore, this study was aimed at developing empirical evidence in exploring the relationship between independent variables, namely socio-demographic factors, environmental exposure to indoor pollutants with the dependent variables namely as health symptoms, and indoor exposure-related health problems. The outcome from this study will be further used in the estimation of the health risk assessment tools that can help building managers to rectify any indoor air quality complaints in educational building.

2. RESEARCH METHOD

2.1. Study design

A cross-sectional study was carried out in educational buildings in the Klang Valley, Malaysia (four storey building). Students from each classroom of this institution were invited to participate during the study period (data collected by random allocation in the choice of courses at overall educational facilities). The building owners, safety and health officers or building management present briefed them all at a General Meeting and advised them. Written and oral information was given, and written consent was provided to all participants. The study took place after the peak season and before the fasting season from July 2018 until January 2020. In their own workplace, all participants were questioned. Figure 1 provides a summary of the data collection process.

2.2. Questionnaire and survey form

Participants were asked to complete a modified extended MM040NA questionnaire that was typically used to evaluate indoor air symptoms [4]. The questionnaire also includes items similar to those published by the Department of Occupational Safety and Health (DOSH), Malaysia, in its Code of Practice on IAQ for Malaysian Use (Department of Occupational Safety and Health, 2010). This questionnaire contains four components: i) perceived indoor environment (contains 12 environmental perceptions) – this section was not discussed in this article; ii) sick building syndrome (SBS) symptoms and health problems (17 symptoms including six primary respiratory and mucosal health problems); iii) supplementary question (temperature perception, washing, noise and air quality); iv) and thermal comfort concern (thermal sensation score). Specific demographic statistics have also been collected to identify any confounding factors in this study. The symptoms score was calculated on the basis of the 17 question where "yes, often (every week)"= two mark, "yes, sometimes (every week)"= one mark, and "no, never"= zero mark. An additional mark will be given in each of the 17 questions if the respondent is informed that the symptoms have been triggered by a live indoors. Health concern score was recorded as "Yes"= mark as two, "No"= mark as zero and the issue continues or happens within 12 months and a mark is added. Health complaints include six issues: asthma, hay fever, allergic symptoms to the eyes or nose, eczema, respiratory or eye irritation due to environmental tobacco smoke (ETS) or strong smell and illness (such as cold). Health complaints score computational is then summed up as zero to six, indicating the number of cumulative health complaints that the inhabitants have had as they stay indoors.

The SBS symptoms in this questionnaire included five questions on general symptoms (fatigue; feeling heavy; headache; nausea or dizziness; and difficulty concentrating), four questions on mucosal irritation (itching, burning, or irritation of the eyes; irritated, stuffy or runny nose; hoarse, dry throat; and cough), three on skin symptoms (hot or flushed facial skin; scaling or itching; These were combined, giving three additional general (zero to ten), mucosal (zero to eight), dermal (zero to six) and other symptoms (zero to eight) respectively. Participants also answered questions about gender, age, type of study areas, study hours, smoking status, length of computer usage, educational status, class name, and floor level. Additional objective health assessment referred to as the symptomatic break time stability test (SBUT) was performed. This method evaluates the amount in the second of the eye lid that is opened before it blinks. This method has been widely used in the European study to assess the condition of the indoor environment and the effects on eye health. The complete questionnaire used in this study can be accessed through the Open Science Platform link as follows: https://osf.io/rja5g.

2.3. Objective indoor environmental exposure monitoring

Indoor climate was investigated in each of the selected 513 respondent’s workspace areas (near the desk and away from the source of pollutants) as according to occupational hygiene approach 1. There are 10 classes randomly selected from the whole institution which comprises 30 to 80 students per class. The randomization was using simple random sampling via computer generated number by allocating more than 30 available classes in this selected educational institute. Environmental monitoring (exposure assessment) strategies divided into three components (the symbol) namely, first, chemical airborne such as Formaldehyde (HCHO), Total volatile organic compounds (TVOCs), carbon dioxide (CO_2), carbon monoxide (CO), secondly, physical parameters including ventilation elements such as temperature (Temp), relative humidity (RH), air movement (Air Mot), and volumetric flowrate (CFM). The third components include particulate matter and particulate count such as particulate matter$_{2.5}$ ($PM_{2.5}$), particle count matter size$_{0.3}$ ($PM_{0.3}$), particle count matter size$_{0.5}$ ($PM_{0.5}$) and particle matter count size$_{5.0}$ (PM_5).

All data collected was performed at a logging point in each of the respondents’ desk, 110 cm from the floor and air samples were collected at minimum of three periodical time slots (morning, noon and evening). A specific checklist was used in the data collection process. Respondents’ data was collected purposively according to the permission obtain and ethical clearance given by the respondents and management office. Each respondent was marked as sequence with the A until F for the row and each column identified as numbers 1 until 80, e.g. A1, A2, B1, F3. The use of this technique was to understand the spatial variation of indoor measurement, ventilation and health complaint within each of the classrooms and overall performance of the ventilation system. In ventilation estimation (Cubic Feet Minute, CFM of air supply from diffuser), the nearest location to the students will be selected and the data was according to the numbers of students within indoor environment.

Air temperature (°C), RH (%), and air movement (m/second) were used for physical work environment monitoring. Carbon dioxide (CO_2; ppm), carbon monoxide (CO; ppm), TVOCs (ppm), formaldehyde (ppm), ozone (ppm), and airborne dust – assessed as particulate matter with an aerodynamic diameter of 2.5 $\mu g/m^3$ ($PM_{2.5}$ $\mu g/m^3$) – were monitored. Data were logged according to the occupational hygiene technique, namely surrogate partial period grab samples. The samples were collected in 30 minutes at four time slots (morning, afternoon, evening, and late evening) to avoid spatial temporal differences in the data collection process (making the data more representative). The use of different measurement throughout different time slot was crucial to ensure the representativeness of the data collected represents the condition of the air being supply by the mechanical ventilation. This method was also explained and guided by the Department Occupational Safety and Health [1]. Data were logged continuously using the following instruments: i) Temperature (^oC), relative humidity (%), carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde (HCHO), total volatile organic carbon (TVOCs): indoor environment quality (IEQ) Meter with 8-Channel IAQ meter with multiple sensors, IEQ ChekTM brand Bacharach (New Kensington, Pennsylvania) with Data Logger and Internal Pump - SD Card applications: ii) Air velocity and draft: TSI Velocicalc Plus 8385 (hot wire) with LOGDAT2 (TSI Inc, Shoreview, MN, USA), measuring range of air velocity (0.01–3.00 m/second): iii) Airborne dust ($PM_{2.5}$ $\mu g/m^3$): Digital Dust Meter direct reading instrument: iv) Particle mass counter with difference size ($PM_{0.3}$, $PM_{0.5}$ and PM_5 $\mu g/m^3$), KANOMAX Model 3888 (Japan).

The instruments were calibrated according to the stated procedures from the instrument suppliers and manufacturers' specification. For real-time monitoring, a special sensor – photoionization detector – was used in the IEQ Chek^{TM} monitoring devices. Precautions were taken when using the real-time photoionization detector instrument as the readings could be affected by the presence of other non-VOCs, such as anesthetic or disinfecting gases. For calibration of the real-time monitors, isobutylene (2-methylpropene) was used as the reference calibration gas [1]. Measurements within the classroom were registered as 5-minute averages throughout the monitoring period between 8:00 AM and 5:00 PM for monitoring day. The concentrations of the airborne chemicals collected at three different time were calculated using the eight hours time weighted average (TWA) formula [1], [19]. The flow of research summarized in Figure 1.

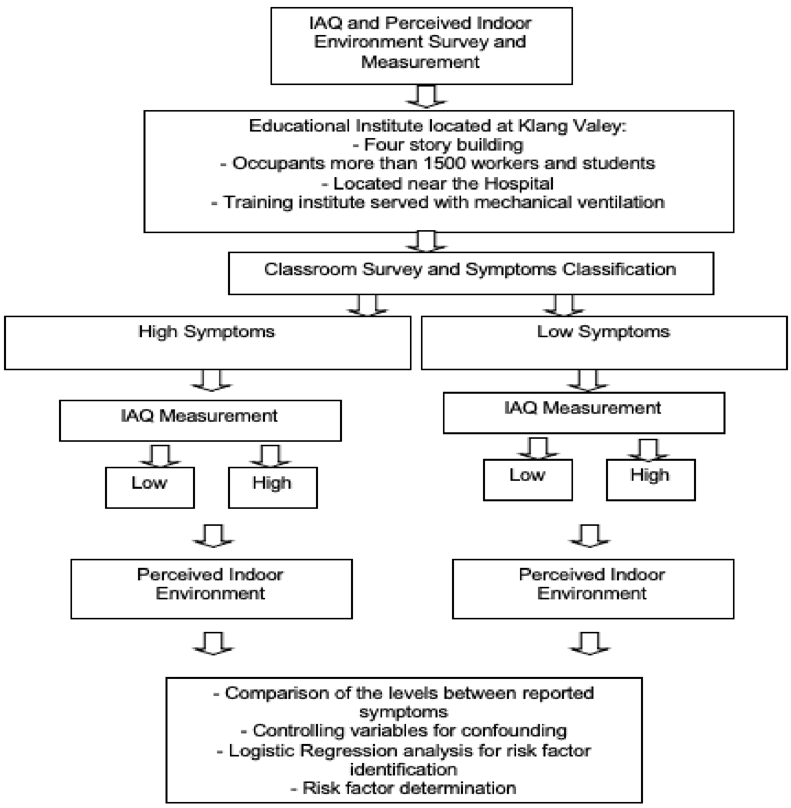

Figure 1. Flow diagram of the study related to exposure and outcome of indoor air pollutants

2.4. Statistical procedure

The computational method of the questionnaire was divided into three parts, namely the score calculation (SBS and health complaint), the second part, the environmental perception calculation (complementary score and other variables), the third part, the class or category description based on objective measurement and the calculated values for the regression analysis. Calculation of score can be calculated as summation of overall environmental score (minimum of zero to 20, based on 12 question and maximum score of 2 for each question), SBS score (minimum of zero to 34, based on 17 question and maximum score of 2 for each question), SBS Adjusted score (minimum of zero to 51, based on SBS score plus 17 for each question if the respondents' complaint the symptoms was due to the indoor factors). All calculation syntax algorithms can be retrieved at Open Science Framework: https://osf.io/w38zt.

Categorical values were compared in the groups using Pearson's chi-squared test, and continuous variables were compared using Student's t-test and ANOVA for more than two groups' comparison approach. Kendall Tau statistics was deployed for the violated ANOVA assumption. SBS symptoms score were computed and classify according to the severity group and assigned as low and high symptoms. Similar approach was applied to the health complaint score based on six reported health issues. Due to the measurement of airborne pollutants were recorded lower than the standard specifies by DOSH, centre of the data (mean or median) had been used as classification approach in determining the acceptability condition group. Logistic regression was performed for dichotomized responses concerning symptoms, and health complaints, univariate and controlling for floor levels and size of the classroom. Analysis was also stratified by gender and selected demographic factors. SPSS version 25.0 (IBM) was used for the analysis, and the significance level was set at 0.05. The potential cofounders found in the analysis were controlled statistically.

2.5. Ethics

Ethical approval for this study was obtained from the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (Ref. No: KKM.NIHSEC. P18-1489(6) dated 24 July 2018). This study also registered with the National Medical Research Register (NMRR ID: NMRR-17-3449-39116 (IIR).) The Institut Latihan Kementerian Kesihatan Malaysia (ILKKM) Sungai Buloh provides official permission to use the buildings for this indoor air quality study. All respondents who participate in this study were asked to complete the patient information sheet (PIS) as according to the NMRR standard operating procedure.

3. RESULTS AND DISCUSSION

A total of 513 (100%) invited respondents participated in this study. All demographic indicators in Table 1 show a significant difference in relation between the compositions of the group. The characteristics of the workspace are described in Table 2. The majority of the respondent chosen stayed on the fourth floor, as the architecture of the institute comprises the main class in the upper part of the building. All factors were statistically differed when compare with the characteristics of the buildings. In general, the age of the respondent can be considered to be around 29 years old with a minimum duration of spending in specific classrooms of around five to six months. This average suggests the period of indoor exposure of around one semester in a similar or not identical class.

Overall, the data collected showed that almost all demographic, social and building variables were significantly different. Due to the major differences in non-indoor air quality variables, the researcher decide to test all non-air quality and perception related indoor air quality (IAQs) to be statistically controlled. This approach will show the true environmental factors to be responsible for possibly causing sick buildings and health complaints. Our statistical approach was supported by a number of indoor air quality researchers [9], [20]. The analysis of the characteristics was important in order to understand the similarity and any emerging demographic factors that indirectly influence this indoor air quality research. Males were reported to be higher than women, who explain the lower symptoms reported in general. This is because males tend to be less reactive than females [21], [22]. Our finding, however, suggests that this gender factor was not the emphasis, due to the fact that it was used for statistical control to classify environmental factors as an estimate. Smoking or vaping prevalence in this study was reported lower (14.0%) as compared to other higher institution in Malaysia (29.0%) [23], [24]. Current findings suggest that the reason for lower prevalence was due to the anti - smoking campaign that exists within the institute and is being implemented to higher standards.

3.1. Health status of respondents due to indoor exposure

Based on the previous study, the majority of researchers concentrate on the symptoms of sick building syndrome (SBS), where this study follows a similar approach with addition of health status or health index assessment. Such health complaints involve six major indoor-related complaints that are highly related to the bad or good indoor environment in particular non - industrial settings. All six questions were asked with the additional question whether or not the symptoms were related to the present indoor situation. Table 3 shows the potential status of a health concern related to the indoor air environment in this study. All reported complaints in Table 3 were further calculated as total scores, which were referred as the Health Index.

Table 1. Demographic data of the respondents

Variable		Frequency	Percentage (%)	Statistics^
Class	1	52	10.1	
	2	57	11.1	
	3	41	8.0	
	4	72	14.0	
	5	50	9.7	19.11*
	6	52	10.1	
	7	45	8.8	
	8	55	10.7	
	9	33	6.4	
	10	56	10.9	
Gender	Male	317	61.8	28.54*
	Female	196	38.2	
Contact lens	No	408	79.5	178.97*
	Yes	105	20.5	
Computer use	0-2 hours	310	60.4	
	2-4 hours	110	21.4	170.33*
	> 4 hours	93	18.1	
Educational	PMR	1	0.2	
	SPM	183	35.7	439.79*
	University/College	296	57.7	
	Others	33	6.4	
Smoking	No	441	86.0	265.42*
	Yes	72	14.0	

Note: N= 513; ^Chi square value; *significant at p<0.05; PMR = Penilaian Menengah Rendah (Lower Secondary Assessment); SPM = Siji Pelajaran Malaysia (Malaysia Certificate of Education)

Table 2. Educational, workspace characteristics, age and duration of spend indoors

Variables		Freq	%	Statistics^
Floor	2nd Floor	16	3.1	635.19*
	3rd Floor	58	11.3	
	4th Floor	439	85.6	
Type of class	Shared room	440	85.8	262.55*
	other	73	14.2	
Activities	Mostly in building	498	97.1	454.74*
	Assignment outside building	15	2.9	
Designation	Students	506	98.6	485.38*
	Others	7	1.4	
Frequency indoors	Less than 30hw/	378	73.7	115.11*
	More than 30hw/	135	26.3	
Spaciousness	Spacious	95	18.5	233.42*
	Enough spacious	334	65.1	
	Not enough spacious	84	16.4	
	Mean (SD)	Median	IQR	
Age (years)	28.96 (5.38)	29.00	24 – 33	
Duration^^	5.85 (5.42)	4.00	2 – 8	

Note: Freq=Frequency; % =Percentage (prevalence); ^^Duration spend indoors in month; IQR=inter quartile range; ^Chi square value; *significant at p<0.05

In the current research, chronic and health-related indoor diseases such as asthma, irritation, allergenicity and infection were combined with the revised MM040Na Questionnaire. The findings of this study show that the eye and nose allergic and sensitivity to exposure to second-hand smoke are the highest prevalence of health effects possibly associated with the indoor environment. Compared to the previous school, total asthma registered lower in this study, where this study shows 4.5% where the previous study shows more than 10% of the samples reported diagnosed with asthma [25], [26]. In addition to the health complaints, lower health issues related to hay fever, and skin issues (Eczema) where both of the prevalence recorded less than 10%. In addition to the health consequences, the primary concern was eye and nasal allergens, along with eye and nose irritation due to second-hand smoke. This allergic reaction is also caused by the indoor penetration to microbial volatile organic compounds (MVOC) due to the exposure of large numbers of biological pollutants [15]. This research, however, did not focus on this parameter and the primary source of TVOC suggest coming from the use of teaching and learning material including markers, posters and paint.

Table 3. Health status of respondents

Variables		Freq	%	Statistics^
Asthma	No	490	95.5	425.13*
	Yes, Indoors	23	4.5	
Hay Fever	No	476	92.8	375.67*
	Yes, Indoors	37	7.2	
Eye and nose allergic	No	443	86.4	271.21*
	Yes, Indoors	70	13.6	
Eczema	No	489	95.3	421.49*
	Yes, Indoors	24	4.7	
Irritation eye, nose and respiratory due to SHS	No	439	85.6	259.70*
	Yes, Indoors	74	14.4	
Cold infection	No	456	88.9	310.33*
	Yes, Indoors	57	11.1	

Note: SHS=Secondhand smoker; Freq=Frequency; %=Percentage (prevalence); ^Chi square value; *significant at $p<0.05$; Yes, indoors – compute based on the reported complaint due to the indoors.

In this study, second-hand smoke exposure indicates a significant highlight when, there is a potential comfort and health issue. The main source of second-hand smoke from smokers who use tobacco products during the study period is second-hand smoke [27]. The health effects of second-hand smoke can vary, including asthmatic attacks [5], [26] [28], particle dispersion that effects eye [8], [24], [26], and respiratory discomfort from nearby non-smoker due to exposure to the tar, nicotine and carbon monoxide [10], [29]. After the survey conducted, data analysis suggests the classification of the symptoms and health score categorized into two parts namely as low and high symptoms. Because of indoor air quality parameters, the use of this method has been shown to be adequate and effective in predicting SBS and health-related illness [30].

3.3. Environment, sick building syndrome and health index

All data collected was further categorized as a mean or median index score. Cut - off values have been identified on the basis of the tabulation of data in this study, as shown in Table 4 of this article. The classification of low and high symptoms was based on the overall evaluation of the data tabulated in this study. Information of the computational method and syntax available online via the Open Science Framework: https://osf.io/w38zt.

Based on the result in Table 5, all dependent variables, namely environmental score (Env. Cat), SBS score (SBS Cat), general SBS score (General Cat), mucosal SBS score (Mucosal Cat), dermal SBS score (Dermal Cat), other SBS score (Others Cat), symptomatic break time stability test (SBUT Cat) and health index (HI Cat) showed similar proportions of low and high symptoms. Details of inferential statistics show that all the components were statistically different, except for SBS Cat and General Cat. The highest proportion reported in this survey was in the others cat high symptom group, which reported more than 61.2% in the high group. Comparison of the levels of pollutants according to the different type of symptoms levels reported in this study was found to be meaningful for future research. This was the fact that the levels exist between the low and high symptoms can be use as estimator to establish triggering risk factors before the severe symptoms emerge. This technique was similar as suggest by previous study on Environmetric where researcher able to predict the source of pollutants based on classified region of indoor air pollutants in risk assessment protocols [3], [31].

Indoor chemistry and physical parameters of indoor air quality have been reported in Table 6. All data collected in this study showed a normal tabulation for the graphical tabulation system (Histogram, Scatter Plot and Box Plot). Particle count sizes 0.3, 0.5 and 5 microns have been reported to be the reference basis for the spatial dispersion of the airborne chemical being transferred from one space to another. There are eight related parameters discussed in this section were environmental score, SBS score, general SBS score, mucosal SBS score, dermal SBS score, other SBS score, SBUT Score and Health Index. All these dependent variables or health outcomes were classified as high and low symptoms on the basis of cut-off as set out in Table 4 of this article.

Table 4. Environment, sick building syndrome score and health index

Variable*	Mean	SD	Median	IQR 25th	IQR 75th	Min	Max	Cut Off^
Env. score	6.75	2.67	7	5	9	0	12	>6.8
SBS score	8.37	3.89	9	6	11	0	17	>8
General score	3.31	1.47	4	2	4	0	5	>3
Mucosal score	2.03	1.25	2	1	3	0	4	>2
Dermal score	1.16	1.08	1	0	2	0	3	>1
Others score	1.87	1.22	2	1	3	0	5	>1
SBUT (second)	23.64	20.14	17	11	30	1.03	158	<23
Health index**	6.19	11.07	1	0	10	0	51	N/A

Note: Env.= Environmental perception score; SBS= Sick building syndrome; *variables were computed where at least one symptom reported to be present at least once a week; SBUT= Symptomatic Break Time Stability test (measurement conducted in second); **Health Index= calculation was based on the positive reported symptoms (believe) cumulative score due to environmental exposure; ^Cut off= determination value to represent high or low symptoms/health risk events based on epidemiological data tabulated (SBUT, lower indicate poor eye performance due to high indoor pollutants). Health Index (N/A) was analyzed individually by each symptom

Table 5. Health index according to the categorical cut off sets

Variable	Low Frequency	Low %	High Frequency	High %	Stat^
Env. Cat	226	44.1	287	55.9	7.253*
SBS Cat	252	49.1	261	50.9	0.158
General Cat	247	48.1	266	51.9	0.704
Mucosal Cat	315	61.4	198	38.6	26.684*
Dermal Cat	325	63.4	188	36.6	36.587*
Others Cat	199	38.8	314	61.2	25.78*
SBUT Cat	340	66.3	173	33.7	54.365*
HI Cat	226	44.1	287	55.9	7.253*

Note: Env. = Environment; Cat = Category; HI = Health index; ^Chi Square test (Goodness of fit); *Significant at p<0.05

3.4. Relationship between indoor chemical exposure, physical parameters and sick building syndrome symptoms (SBS total score)

The first phase in the logistic regression analysis for this study was to identify the possible confounding of demographic or social factors that may influence the logistic regression model. The health effect status of the model was described as a categorical variable that is more than or less than the level set in the cut-off as shown in Table 4. Exposure of indoor environmental pollutants was determined by the levels set for mean or median levels as presented Table 6. Focusing on logistic regression model, there were five tables detailing the results that can be differentiated by different dependent variables. The logistic model was statistically controlled for demographic and social factors such as gender; type of room, use of contact lenses, floor, space, time spent indoors, smoking, computer use and education.

For SBS Total score, there have been a number of factors including indoor air quality parameters that may have risk factors affecting SBS as shown in Table 7. The indoor air quality parameters were significantly associated with the SBS Total score for formaldehyde, $PM_{2.5}$, carbon dioxide and air flow. It indicates that the level of indoor air quality is likely to result in a high level of risk associated with the SBS complaint. This finding suggests that aldehyde, particulate matter and ventilation (including dilution of CO_2 factors) pose a significant risk to the growth of a high number of SBS reporters.

3.5. Relationship between indoor chemical exposure, physical parameters with sick building syndrome symptoms (general, mucosal, dermal, others and SBUT)

Among the overall symptoms, the SBS score can further be classify according to the human region of health effects namely “General” which comprises feeling related to general neurological condition such as dizziness, fatigue and headache. Besides, the other region of health effects related to indoor symptoms can be further down towards the “Mucosal” region, which comprises nose, mouth and irritation to the eye. Then the “Dermal” areas are related to the skin health, ear and additional irritation effects towards indoor chemicals.

Additional "Others" score includes stress and additional health complaint that usually related to the workspace environment including ergonomic risk elements.

For the Mucosal Score, there were two indoor air quality parameters and two perceived indoor environment factors that influence the complaint towards mucosal region. Formaldehyde and TVOC (aldehyde compound or organic elements) show positive relationship in increasing risk of mucosal irritation or health effects as shown in Table 8. Toxicological and chemical study suggest, the TVOC and Formaldehyde are classified as organic compounds which mainly composed form the free radical elements in the chemical structure and their chemical reaction could react to the irritative mechanism on human respiratory health [32], [33]. This compound reacts with temperature in influencing the chemical dispersion. Based on this study, it suggests the reaction towards the humidity and air flow where, higher relative humidity may increase the possible organic compound to be airborne as compared to lower humid areas. This idea was supported by previous study [24], [34]. As mention by previous researcher [33], [35], [19] there was a significant relationship exist between the chemical TVOC dispersion with the temperature condition within indoor spaces. Findings from this investigation suggest lower mucosal symptoms will be appearing in the condition of low $PM_{0.3}$ and high air movement (good ventilation). Idea of this had been supported by previous study indicate higher ventilation rate able to control the particulate levels indoor [36], [37].

Dermal score shows positive relationship with the factor of indoor air quality high in the context of $PM_{2.5}$, carbon dioxide, and air flow as shown in Table 9. For dermal score, slight high levels of TVOS levels will possibly increase the risk of dermal symptoms. The result, however, was contradicted with the levels of temperature, where the assumption of higher temperature will make the higher TVOCs. The levels of temperature were not significantly differed in big gap. Findings from this classified symptoms and levels of pollutants can help hygienist to understand the source of the pollutants and possible mitigation plan in reducing such exposure. Similar approach also had been discussed previously by [38] where the levels of TVOCs was significantly related with the temperature levels.

Table 6. Environmental exposure of indoor air pollutants (IAP) and physical parameters

Variable (unit)	Mean	SD	Median	IQR	
				25th	75th
Formaldehyde (PPM)	0.02	0.02	0.01	0.01	0.02
PM2.5 (µg/m3)	50.53	36.39	40.00	20.00	70.00
TVOC (PPM)	0.10	0.06	0.09	0.06	0.13
PM0.3 (µg/m3)	4.27E+07	1.42E+07	4.61E+07	2.76E+07	5.46E+07
PM0.5 (µg/m3)	2.91E+06	2.52E+06	1.73E+06	1.28E+06	3.39E+06
PM5.0 (µg/m3)	3.33E+04	2.03E+04	2.78E+04	1.73E+04	4.32E+04
Air movement (ft/m)	36.75	39.81	18.00	12.00	41.00
Temperature (oC)	25.23	2.13	25.10	24.30	26.50
Relative humidity (%)	64.86	8.22	66.70	58.80	71.20
Carbon dioxide (PPM)	832.09	291.53	780.00	611.50	891.50
Carbon monoxide (PPM)	3.45	2.58	3.00	1.00	6.00
Volumetric flowrate (cfm)	70.69	55.64	60.75	27.50	88.13

Note: PM= Particulate matter; PPM = Part per million; All data was normally tabulated by graphical test (histogram and detrended Q-Q plot)

Table 7. Logistic regression model for SBS total score and selected independent variables (indoor chemical exposure)

Variables	B	S.E.	Wald	Sig.	pOR	95% CI	
						Lower	Upper
Constant	-5.83	1.783	10.69	0.001	0.003		
HCHO category	0.914	0.384	5.647	0.017*	2.493	1.174	5.297
PM2.5 category	0.672	0.325	4.267	0.039*	1.958	1.035	3.706
Carbon dioxide category	1.383	0.553	6.248	0.012*	3.987	1.348	11.794
Air flow category	1.358	0.346	15.373	p<0.001*	3.887	1.972	7.661

R square= 0.267 (Cox & Snell), 0.356 (Nagelkerke)
Model $\chi 2$ (Omnibus test) = 100.84, p<0.001
Model $\chi 2$ (Hosmer and Lameshow) = 6.045, p= 0.642
Classification table accuracy (%) = 74.8
Adjusted odd ratio (Epidemiological risk) = 95% CI > 1 (Risk condition)

Note: pOR= Prevalence odd ratio; controlling for gender, type of room, use of contact lenses, floor, spaciousness, time spend indoor, smoking, computer use and education

The other SBS score shows positive relationship with the carbon dioxide and air flow as shown in Table 10. Additional regression analysis was conducted on the SBUT parameters to understand the relationship with the indoor air quality parameters. Result indicates that Relative Humidity significantly a risk factor for SBUT condition for IAQ parameters as presented Table 11. Additional Other SBS score, indicate temperature and air flow significantly differ. Lower ventilation (measured by volumetric flowrate) suggests the increase of temperature and thus increases chemical dispersion which led to high complaints related to other condition. In addition to the health investigation SBUT classification show significant different for particulate parameters [39], [40]. This suggests high particulate count will lead to lower SBUT. When the particulate high, the eye irritate more and thus lead to the poor ability to maintain single tear film. Lower particulate count helps maintain the tear film break which suggest higher SBUT (longer time for eye can be hold before blink) [18].

Table 8. Logistic regression model for mucosal SBS score and selected independent variables

Variables	B	S.E.	Wald	Sig.	pOR	95% CI	
						Lower	Upper
Constant	-5.123	1.77	8.38	0.004	0.006		
HCHO category	1.029	0.411	6.271	0.012*	2.799	1.251	6.262
TVOC category	-1.08	0.502	4.619	0.032*	0.34	0.127	0.909

R square= 0.266 (Cox & Snell), 0.360 (Nagelkerke)
Model $\chi 2$ (Omnibus test) = 100.342, p= 0.001
Model $\chi 2$ (Hosmer and Lameshow) = 3.872, p= 0.868
Classification table accuracy (%) = 72.9
Adjusted odd ratio (Epidemiological risk) = 95% CI>1 (Risk condition)

Note: pOR= prevalence odd ratio; controlling for gender, type of room, use of contact lenses, floor, spaciousness, time spend indoor, smoking, computer use and education

Table 9. Logistic regression model for other SBS score and selected independent variables

Variables	B	S.E.	Wald	Sig.	pOR	95% CI	
						Lower	Upper
Constant	-4.633	1.685	7.565	0.006	0.01		
CO_2 category	1.403	0.556	6.367	0.012*	4.067	1.368	12.093
AF category	1.242	0.349	12.635	p<0.001*	3.462	1.746	6.867

R square= 0.228 (Cox & Snell), 0.308 (Nagelkerke)
Model $\chi 2$ (Omnibus test) = 83.988, p<0.001
Model $\chi 2$ (Hosmer and Lameshow) = 15.649, p= 0.048
Classification table accuracy (%) = 73.5
Adjusted odd ratio (Epidemiological risk) = 95% CI>1 (Risk condition)

Note: CO_2= Carbon dioxide; AF= Air flow; pOR= prevalence odd ratio; controlling for gender, type of room, use of contact lenses, floor, spaciousness, time spend indoor, smoking, computer use and education

Table 10. Logistic regression model for dermal SBS score and selected independent variables

Variables	B	S.E.	Wald	Sig.	pOR	95% CI	
						Lower	Upper
Constant	-7.809	1.841	17.999	0	0		
PM2.5 category	1.058	0.329	10.313	0.001*	2.88	1.51	5.491
CO_2 category	1.386	0.549	6.365	0.012*	4.00	1.362	11.741
Air flow category	0.985	0.337	8.575	0.003*	2.679	1.385	5.181

R Square= 0.206 (Cox & Snell), 0.206 (Nagelkerke)
Model $\chi 2$ (Omnibus test) = 75.065, p<0.001
Model $\chi 2$ (Hosmer and Lameshow) = 6.108, p= 0.635
Classification table accuracy (%) = 71.7
Adjusted odd ratio (Epidemiological risk) = 95% CI>1 (Risk condition)

Note: CO_2= Carbon dioxide; pOR= prevalence odd ratio; controlling for gender, type of room, use of contact lenses, floor, spaciousness, time spend indoor, smoking, computer use and education

3.6. Relationship between selected objective measurement of IAQ and subjective perception with the health complaint (health index)

The results of the regression analysis of this study had been summarized in Table 11, which gives an understanding of the risk reasons for sick building syndrome and the health effects. The overall SBS is highly related to the movement of formaldehyde, particulate matter, carbon dioxide and air flow. For the general SBS ranking, the ventilation factors have a major impact. These findings have been supported by previous study, which shows that the ventilation system affects the occupants' complaint with usual symptoms such as headache, nausea and some health problems [3], [14], [41]. For mucosal mainly associated with exposure to aldehyde compounds, similar findings reported in the previous study [34], [42]-[44] . The score on dermal and other complaints was contributed by particulate, and ventilation. This evidence also similar with reported by [8] where the SBUT was the only result of the relative humidity relationship. This is because the eye was purely based on the indoor moisture content. Table 12 shows logistic regression model for SBUT SBS score and selected independent variables.

3.7. Methodological considerations

This study was carried out in an educational environment and certain bias could exist, as information was collected on the symptoms and interpretation of the workplace using the same questionnaire. The report, however, is strongly supported by objective measures to complement the perceived indoor and airborne chemical monitoring with physical air quality monitoring. This work also has other major strengths, since it monitors the primary environmental factors (gas, chemical and physical indoor environments) for analysis, which likely represent the main potential issues in a teaching environment with mechanical ventilation indoors. The participation rate was also high, reducing the likelihood of selection bias. This study was conducted in a college student population. The results are likely representative of other similar educational building designs in the Klang Valley (Malaysia as a tropical climate country) (high occupants and equipment for mechanical-climate classrooms) and similar workplaces in every tropical area with similar high humidity and temperature patterns.

Table 11. Summary of logistic regression model for independent variables (IVs) and dependent variables (DVs)

Variable (DVs)	IAQ factor (IVs) – Human factors/chemical agents	IAQ factors (IVs) – ventilation factors/mechanical system
SBS total	HCHO, PM2.5,	CO_2, Air Flow
General SBS score	N/A	Air Mot, Air Flow
Mucosal SBS score	HCHO, TVOC	N/A
Dermal SBS score	PM2.5,	CO_2, Air Flow
Other SBS score	N/A	CO_2, Air Flow
SBUT score	RH	N/A

Note: N/A= Not applicable; HCHO= Formaldehyde, PM2.5= Particulate matter 2.5, CO_2= Carbon dioxide, TVOC= Total volatile organic compounds, Air mot= Air movement/motion, Air flow, RH= Relative humidity

Table 12. Logistic regression model for SBUT SBS Score and selected independent variables

Variables	B	S.E.	Wald	Sig.	pOR	95% CI	
						Lower	Upper
Constant	-0.074	1.629	0.002	0.964	0.929		
RH category	-0.872	0.304	8.214	0.004*	0.418	0.23	0.759

R square = 0.167 (Cox & Snell), 0.228 (Nagelkerke)
Model $\chi2$ (Omnibus test) = 59.267, p= 0.005
Model $\chi2$ (Hosmer and Lameshow) = 3.816, p= 0.873
Classification table accuracy (%) = 71.7
Adjusted odd ratio (Epidemiological risk) = 95% CI > 1 (Risk condition)

Note: RH= Relative humidity; pOR= Prevalence odd ratio; controlling for gender, type of room, use of contact lenses, floor, spaciousness, time spend indoor, smoking, computer use and education

The work has other major strengths in that it monitors the main environmental factors of the indoor environment (gas, chemical and physical indoor environments) for study, which likely represent the key problems in an indoor mechanical ventilated educational building environment. The participation rate was also high, reducing the likelihood of selection biases. This study was conducted in a group of university students. It is probable that the findings are representative of other similar education buildings designs in Klang Valley (Malaysia as the tropical climate country) and similar workplaces in any tropical region that have a similar high humidity and temperature pattern.

The study provides information on air quality levels indoors and their health impacts in an educational facility alone. Certain types of educational workplace may also have different challenges, including psychosocial environments, different outdoor conditions, various building designs, ventilation, the interaction of different races and different interactions between sex and the environment. In this study, the statistical assessment examined several confounders that were statistically tracked during the data analysis process. Gender, room size, use of contact lenses, floor, space, time, smoking, computers and educational levels are some of the confounders.

4. CONCLUSION

The main sources of factors influencing the SBS in educational areas was the physical working environment, air movement, air flow as well as poor venting dilution (high carbon dioxide as an indicator) and relative humidity. The main factors influencing the mucosal and irritative effects are chemical airborne dispersion (particulate, formaldehyde and TVOC). Perception of air quality in surface observation and building conditions showed relationship patterns with overall SBS symptoms among occupants.

Any important recommendations should be considered by facility managers, maintenance workers, building designers, architects and interior designers during order to maintain, or create an appropriate indoor environment in order to prevent extreme, indoor symptoms that will reduce productivity. New buildings should use low emission VOC paint. In the construction planning phase, an improvement in the fresh air intake should be considered to prevent CO penetration within the installations. From this analysis, a model of symptoms of exposure can be determined which should be used as primary indicators for temperature, RH and air movement. Some changes to the range indicated by the current standard would probably cause IAQ problems. Due to the nature of chemicals/gases, TVOCs and formaldehyde should be considered as secondary parameters for assessment and measurement. Other toxins contain CO_2, CO, pollen and microbials.

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REFERENCES

[1] Department of Occupational Safety and Health, “Industry code of practice on indoor air quality 2010,” *Ministry of Human Resources Department of Occupational Safety and Health*, pp. 1–50, 2010. Link: https://www.dosh.gov.my/index.php/legislation/codes-of-practice/chemical-management/594-02-industry-code-of-practice-on-indoor-air-quality-2010/file. Access date: 20 November 2021.

[2] Kishi, Reiko, Dan Norbäck, and Atsuko Araki, "Current topics in environmental health and preventive medicine," *Indoor environmental quality and health risk toward healthier environment for all*. Springer, 2020.

[3] A. Syazwan *et al.*, “Analysis of indoor air pollutants checklist using environmetric technique for health risk assessment of sick building complaint in nonindustrial workplace,” *Drug, Healthcare and Patient Safety*, vol. 4, no. 1, pp. 107–126, 2012, doi: 10.2147/DHPS.S33400.

[4] A. I. Syazwan *et al.*, “Gender, airborne chemical monitoring, and physical work environment are related to indoor air symptoms among nonindustrial workers in the Klang Valley, Malaysia,” *Therapeutics and Clinical Risk Management*, vol. 9, no. 1, pp. 87–105, 2013, doi: /10.2147/TCRM.S39136.

[5] M. A. H. Suryadhi, K. Abudureyimu, S. Kashima, and T. Yorifuji, “Effects of household air pollution from solid fuel use and environmental tobacco smoke on child health outcomes in Indonesia,” *Journal of Occupational and Environmental Medicine*, vol. 61, no. 4, pp. 335–339, 2019, doi: 10.1097/JOM.0000000000001554.

[6] Mendell, M., and Heath, G., Indoor air quality & student performance (No. 402-K-95-001). *Washington: Indoor Environments Division Office of Radiation and Indoor Air.* United States Environmental Protection Agency (USEPA), 2003.

[7] I. Annesi-Maesano, N. Baiz, S. Banerjee, P. Rudnai, and S. Rive, “Indoor air quality and sources in schools and related health effects,” *Journal of Toxicology and Environmental Health - Part B: Critical Reviews*, vol. 16, no. 8, pp. 491–550, 2013, doi: 10.1080/10937404.2013.853609.

[8] P. Wolkoff, “Indoor air humidity, air quality, and health – an overview,” *International Journal of Hygiene and Environmental Health*, vol. 221, no. 3, pp. 376–390, 2018, doi: 10.1016/j.ijheh.2018.01.015.

[9] D. Norbäck *et al.*, “Respiratory symptoms and fractional exhaled nitric oxide (FeNO) among students in Penang, Malaysia in relation to signs of dampness at school and fungal DNA in school dust,” *Science of the Total Environment*, vol. 577, 2017, doi: 10.1016/j.scitotenv.2016.10.148.

[10] N. Ahmad and M. H. Hassim, “Assessment of indoor air quality level and sick building syndrome according to the ages of building in Universiti Teknologi Malaysia,” *Jurnal Teknologi*, vol. 76, no. 1, pp. 163–170, 2015, doi: 10.11113/jt.v76.3995.

[11] J. Sethi, J. Sandhu, and V. Imbanathan, “Effect of body mass index on work related musculoskeletal discomfort and occupational stress of computer workers in a developed ergonomic setup,” *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology*, vol. 3, no. 1, p. 22, 2011, doi: 10.1186/1758-2555-3-22.

[12] B. P. Singh, A. Kumar, D. Singh, M. Punia, K. Kumar, and V. K. Jain, “An assessment of ozone levels, UV radiation and their occupational health hazard estimation during photocopying operation,” *Journal of Hazardous Materials*, vol. 275, pp. 55–62, 2014, doi: 10.1016/j.jhazmat.2014.04.049.

[13] B. E. Boor, M. P. Spilak, J. Laverge, A. Novoselac, and Y. Xu, “Human exposure to indoor air pollutants in sleep microenvironments: A literature review,” *Building and Environment*, vol. 125, 2017, doi: 10.1016/j.buildenv.2017.08.050.

[14] M. S. Jaakkola and J. J. K. Jaakkola, “Office equipment and supplies: a modern occupational health concern?,” *American Journal of Epidemiology*, vol. 150, no. 11, pp. 1223–1228, 1999, doi: 10.1093/oxfordjournals.aje.a009949.

[15] A. Araki *et al.*, “The relationship between exposure to microbial volatile organic compound and allergy prevalence in single-family homes,” *Science of the Total Environment*, vol. 423, pp. 18–26, 2012, doi: 10.1016/j.scitotenv.2012.02.026.

[16] Bas, Ed. Indoor air quality: *A guide for facility managers*. CRC Press, 2003.

[17] O. Geiss, S. Tirendi, J. Barrero-Moreno, and D. Kotzias, “Investigation of volatile organic compounds and phthalates present in the cabin air of used private cars,” *Environment International*, vol. 35, no. 8, pp. 1188–1195, 2009, doi:

10.1016/j.envint.2009.07.016.
[18] D. Norbäck, J. H. Hashim, Z. Hashim, V. Sooria, S. A. Ismail, and G. Wieslander, “Ocular symptoms and tear film break up time (BUT) among junior high school students in Penang, Malaysia – Associations with fungal DNA in school dust,” *International Journal of Hygiene and Environmental Health*, vol. 220, no. 4, pp. 697–703, 2017, doi: 10.1016/j.ijheh.2017.01.016.
[19] A. I. Syazwan *et al.*, “Development of an indoor air quality checklist for risk assessment of indoor air pollutants by semiquantitative score in nonindustrial workplaces,” *Risk Management and Healthcare Policy*, vol. 5, no. May 2014, pp. 17–23, 2012, doi: 10.2147/RMHP.S26567.
[20] A. P. Jones, “Indoor air quality and health,” *International Journal of Environmental Research and Public Health*, vol. 14, no. 11, p. 1286, 2017, doi: 10.3390/ijerph14111286.
[21] J. V. Bakke, B. E. Moen, G. Wieslander, and D. Norbäck, “Gender and the physical and psychosocial work environments are related to indoor air symptoms,” *Journal of Occupational and Environmental Medicine*, vol. 49, no. 6, pp. 641–650, 2007, doi: 10.1097/JOM.0b013e31806e5fa0.
[22] K. Tähtinen, S. Lappalainen, K. Karvala, J. Remes, and H. Salonen, “Association between four-level categorisation of indoor exposure and perceived indoor air quality,” *International Journal of Environmental Research and Public Health*, vol. 15, no. 4, 2018, doi: 10.3390/ijerph15040679.
[23] J. Kang and K. Il Hwang, “A comprehensive real-time indoor air-quality level indicator,” *Sustainability (Switzerland)*, vol. 8, no. 9, pp. 1–15, 2016, doi: 10.3390/su8090881.
[24] M. I. Mitova *et al.*, “Comprehensive air quality assessment of the tobacco heating system 2.2 under simulated indoor environments,” *Atmosphere*, vol. 12, no. 8, pp. 10–12, 2021, doi: 10.3390/atmos12080989.
[25] Y. Y. Lu *et al.*, “Evaluation of volatile organic compounds and carbonyl compounds present in the cabins of newly produced, medium-and large-size coaches in China,” *International Journal of Environmental Research and Public Health*, vol. 13, no. 6, pp. 1–16, 2016, doi: 10.3390/ijerph13060596.
[26] M. D. Eisner, J. Klein, S. K. Hammond, G. Koren, G. Lactao, and C. Iribarren, “Directly measured second hand smoke exposure and asthma health outcomes,” *Thorax*, vol. 60, no. 10, pp. 814–821, 2005, doi: 10.1136/thx.2004.037283.
[27] K. H. Lim *et al.*, “Using the theory of reasoned action to predict smoking intention among non-smoking secondary school going adolescents in Peninsular Malaysia,” *Malaysian Journal of Public Health Medicine*, vol. 21, no. 2, pp. 8–13, 2021, doi: 10.37268/mjphm/vol.21/no.2/art.521.
[28] P. P. Heng, F. Daud, K. H. Lim, and M. Mohd Yusoff, “Susceptibility to e-cigarette initiation among tobacco product naïve adolescents in Malaysia: Findings from the tobacco and e-cigarette survey among Malaysian adolescents (TECMA),” *Tobacco Induced Diseases*, vol. 19, no. November, pp. 1–9, 2021, doi: 10.18332/tid/142900.
[29] R. Pitarma, G. Marques, and B. R. Ferreira, “Monitoring indoor air quality for fnhanced occupational health,” *Journal of Medical Systems*, vol. 41, no. 2, pp. 1–8, 2017, doi: 10.1007/s10916-016-0667-2.
[30] S. M. Saad *et al.*, “Development of indoor environmental index: Air quality index and thermal comfort index,” *AIP Conference Proceedings*, vol. 1808, 2017, doi: 10.1063/1.4975276.
[31] T. Kowalkowski, R. Zbytniewski, J. Szpejna, and B. Buszewski, “Application of chemometrics in river water classification,” *Water Research*, vol. 40, no. 4, pp. 744–752, 2006.
[32] R. L. Doty, J. E. Cometto-Muñiz, A. A. Jalowayski, P. Dalton, M. Kendal-Reed, and M. Hodgson, *Assessment of upper respiratory tract and ocular irritative effects of volatile chemicals in humans*, vol. 34, no. 2. 2004.
[33] X. Zhang, X. Li, Z. Wang, G. Deng, and Z. Wang, “Exposure level and influential factors of HCHO, BTX and TVOC from the interior redecoration of residences,” *Building and Environment*, vol. 168, no. October 2019, p. 106494, 2020, doi: 10.1016/j.buildenv.2019.106494.
[34] L. Pommer *et al.*, “Class separation of buildings with high and low prevalence of SBS by principal component analysis,” *Indoor Air*, vol. 14, no. 1, pp. 16–23, 2004, doi: 10.1111/j.1600-0668.2004.00203.x.
[35] Y. C. Chien, “Variations in amounts and potential sources of volatile organic chemicals in new cars,” *Science of the Total Environment*, vol. 382, no. 2–3, pp. 228–239, 2007, doi: 10.1016/j.scitotenv.2007.04.022.
[36] C. K. H. Yu, M. Li, V. Chan, and A. C. K. Lai, “Influence of mechanical ventilation system on indoor carbon dioxide and particulate matter concentration,” *Building and Environment*, vol. 76, pp. 73–80, 2014, doi: 10.1016/j.buildenv.2014.03.004.
[37] A. Leavey, N. Reed, S. Patel, K. Bradley, P. Kulkarni, and P. Biswas, “Comparing on-road real-time simultaneous in-cabin and outdoor particulate and gaseous concentrations for a range of ventilation scenarios,” *Atmospheric Environment*, vol. 166, pp. 130–141, 2017, doi: 10.1016/j.atmosenv.2017.07.016.
[38] J. H. Park, P. L. Schleiff, M. D. Attfield, J. M. Cox-Ganser, and K. Kreiss, “Building-related respiratory symptoms can be predicted with semi-quantitative indices of exposure to dampness and mold,” in *Indoor Air*, Dec. 2004, vol. 14, no. 6, pp. 425–433, doi: 10.1111/j.1600-0668.2004.00291.x.
[39] V. Van Tran, D. Park, and Y. C. Lee, “Indoor air pollution, related human diseases, and recent trends in the control and improvement of indoor air quality,” *International Journal of Environmental Research and Public Health*, vol. 17, no. 8, 2020.
[40] L. Morawska *et al.*, “Airborne particles in indoor environment of homes, schools, offices and aged care facilities: The main routes of exposure,” *Environment International*, vol. 108, no. April, pp. 75–83, 2017, doi: 10.1016/j.envint.2017.07.025.
[41] R. M. Babadjouni *et al.*, “Clinical effects of air pollution on the central nervous system; a review,” *Journal of Clinical Neuroscience*, vol. 43, pp. 16–24, 2017, doi: 10.1016/j.jocn.2017.04.028.
[42] M. J. Jafari *et al.*, “Effect of ventilation on occupational exposure to airborne biological contaminants in an isolation room,” *Tanaffos*, vol. 14, no. 2, pp. 141–148, 2015.
[43] D. Menzies, J. Popa, J. A. Hanley, T. Rand, and D. K. Milton, “Effect of ultraviolet germicidal lights installed in office ventilation systems on workers' health and wellbeing: Double-blind multiple crossover trial,” *Lancet*, vol. 362, no. 9398, pp. 1785–1791, 2003, doi: 10.1016/S0140-6736(03)14897-0.
[44] T. Takigawa *et al.*, “A longitudinal study of aldehydes and volatile organic compounds associated with subjective symptoms related to sick building syndrome in new dwellings in Japan,” *Science of the Total Environment*, vol. 417–418, pp. 61–67, 2012, doi: 10.1016/j.scitotenv.2011.12.060.

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