Sick building syndrome and its effect on health of students and teachers in selected educational buildings in Bandung

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Abstract. This study investigates the current conditions of indoor air quality, focusing especially on formaldehyde and TVOC, and their effects on health among occupants in the educational buildings located in the city of Bandung. A total of 120 respondents were interviewed and 40 rooms were measured from September to November 2018. The results indicated that around 50% of the respondents in the buildings showed some degrees of chemical sensitivity risk. More than 60% of the measured formaldehyde levels in the buildings exceeded the WHO standard, 0.08 ppm. The respondents studying in rooms with higher mean formaldehyde values tended to have higher multiple chemical sensitivity risk scores.

1. Introduction
Indoor air quality (IAQ) and its effects on health of occupants have been studied in many parts of the world over the last several decades [1]. In developing countries, however, most of the IAQ studies focused on the issues of exposure to biomass combustion, and thus there are relatively few studies investigating IAQ in educational buildings such as schools [2]. Schools are the buildings where students learn and prepare their future almost all day long. Therefore, the health and sustainability of schools are important. Nevertheless, in response to rapid population growth and urbanization, the construction of buildings, including educational buildings, using modern building materials is thriving in developing countries – but without sufficient standards or regulations for the building materials as well as minimum ventilation rates. This study investigates the current conditions of IAQ, focusing especially on formaldehyde and TVOCs, and their effects on health among students and teachers in educational buildings of Indonesia. This paper presents the results of a case study conducted in the city of Bandung in 2018.

2. Methodology
Field investigations consisting of face-to-face interviews and measurements were conducted in four schools, including kindergarten (TK), elementary school (SD), junior high school (SMP), senior high school (SMA) and a university (PT) in Bandung from September to November 2018 (Table 1). This period includes part of dry season. A total of 120 respondents were interviewed and 40 rooms were measured. The schools were located in Indonesia University of Education complex (Figs. 1-2). These educational buildings were newly renovated since 2005 (see Table 4).

The interviews were conducted using a questionnaire form comprising the Quick Environmental Exposure and Sensitivity Inventory (QEESI) developed by Miller & Prihoda [3] and several additional...
questions, amongst others: cleaning habits, window-opening behaviour and socio-economic factors. Formaldehyde (FMM-MD, Shinyei) and TVOCs (ToxiRAE Pro, RAE Systems) were measured on top of air temperature and RH for approximately three days in classroom and multi-purpose room of respective buildings. The interval time of measurement was 1 min for TVOC and 30 min for the other parameters. Multiple chemical sensitivity (MCS), which was recommended to replace idiopathic environmental intolerance (IEI) in the World Health Organization/International Programme on Chemical Safety (WHO/IPCS) workshop, is defined as an acquired disorder with multiple recurrent symptoms, being associated with diverse environmental factors tolerated by the majority of people, and not explainable by any known medical or psychiatric disorder [4]. Miller & Prihoda [3] developed the QEESI to differentiate between chemically sensitive people and normal people.

|                | TK | SD | SMP | SMA | PT | Total |
|----------------|----|----|-----|-----|----|-------|
| Questionnaire  | 24 | 24 | 24  | 24  | 24 | 120   |
| IAQ Measurement|  8 |  8 |  8  |  8  |  8 |  40   |

Table 1. Number of samples.

Figure 1. Views of (a) TK, (b) SD (c) SMP, (d) SMA and (e) PT.

Figure 2. Measurement in class rooms at (a) school and (b) PT.

The QEESI consists of the following five scales [3]: chemical intolerance (to what extent certain odor or exposures make one sick); other intolerances (to what extent a variety of other exposures make
one sick); the severity of symptoms (to what extent one experiences certain symptoms); the masking index (whether there is ongoing exposure from routinely used products); and life impact (to what extent the sensitivity affects certain aspects of life). Each scale is composed of ten questions, and each question is scored from 0-10, except for the masking index, which is scored as ‘yes: 1’ or ‘no: 0’. Miller & Prihoda [3] suggested ranges for the scales and interpretation guidelines. The criteria for the risk criteria (degree to which MCS is suggested) are shown in Table 2. However, masking index and life impact are not utilized due to different study purpose.

Table 2. MCS risk criteria.

| Degree to which MCS is suggested | Symptom Severity Score | Chemical Intolerance Score |
|----------------------------------|------------------------|-----------------------------|
| Very suggestive                  | ≥ 40                   | ≥ 40                        |
| Somewhat suggestive              | ≥ 40                   | < 40                        |
| Not suggestive                   | ≥ 40                   | < 40                        |
| Problematic                      | < 40                   | ≥ 40                        |
| Not suggestive                   | < 40                   | < 40                        |

3. Result and Discussion

3.1 Multiple chemical sensitivity (MCS) risk

The final calculated results of MCS were analysed by respective school levels (Fig. 3). As shown, only 21.9% of respondents show some degrees of intolerances in schools, but the percentage of problematic respondents is significantly higher in the PT, which is 48.8% (p<0.01). The percentages of problematic and very suggestive respondents in PT are more than twice than other schools.

Fig. 4 shows the detailed results from QEESI. As illustrated in Fig. 4a, the respondents show high degrees of intolerance particularly to tobacco/smoke, diesel/gas, insecticide and paint. Overall, the magnitudes of intolerance in the PT are significantly higher than those in schools for most kinds of chemicals (p<0.01). Nevertheless, if only problematic respondents of which MCS risks range from ‘problematic’ to ‘very suggestive’ are analysed (i.e. the right figures of Fig. 4), the magnitudes of intolerance in the PT are not higher than those of schools (Fig. 4a). Rather, the intolerance to new furnishings is higher in schools than that in the PT.

On average, symptoms scores (Fig. 4b) are high in terms of stomach and intestines (2.8/3.8), emotion (1.8/3.4), muscles (3.7/3.4), head-related (2.6/3.3), cognition (2.2/3.1), skin-related (1.7/2.9) and airway or mucous membrane (1.9/2.9). Significant differences between the two groups can be seen in most of the items, except for muscles. The average symptoms score for the muscles in schools is significantly higher than that of PT even among the problematic respondents (p<0.01).

The above results imply that although most of the factors affecting MCS risk are similar among problematic respondents of buildings, a few different factors also can be seen in the groups, such as intolerance to new furnishings and symptoms on muscles.

3.2 Factors affecting MCS risk

We conducted correlation analyses to identify the factors affecting MCS risk scores in educational buildings respectively using the Spearman’s test or Chi-square test depending on types of variable. Table 3 summarises the surveyed personal attribute variables and their relations to the MCS risk scores respectively. First, it is found that the female respondents tend to obtain higher MCS risk scores in the PT (p<0.05). In contrast, the increases in age and household income tend to increase the MCS risk in schools (p<0.05, p<0.01). Second, the occupation of respondents has significant relationship with MCS in schools: in particular, government officers and retired respondents tend to have higher MCS risk scores. The increase in stress level increases MCS risk scores in both groups. Meanwhile,
those who have a medical history of asthma, eczema and other kinds of allergy tend to have higher MCS risk scores in schools.

Figure 3. Results of MCS risk.

Figure 4. Results of QEESI. The left figure shows those of all samples and the right indicates those of only problematic respondents (MCS risk: ‘Problematic’ to ‘Very suggestive’). The error bar indicates a standard deviation, and, hereafter, ** shows 1% significant level, whereas * indicates at 5% level.

Table 3. Personal attributes and their relations to MCS risk.

| Variables        | School | p   | PT  | p   | Total | p   |
|------------------|--------|-----|-----|-----|-------|-----|
| Gender [%]       |        |     |     |     |       |     |
| Male             | 45.4   | .474 | 43.1 | .032 | 44.2  |     |
| Female           | 54.6   | .068 | 56.9 | .809 | 55.8  |     |
| Age [%]          |        | .000 |     |     |       | .031|
| <20              | 50.3   | .496 | 68.0 |     | 58.2  | .000|
| 20-29            | 13.0   |     | 16.0 | .046 | 14.5  |     |
| 30-39            | 17.7   |     | 5.9  |     | 13.4  | .000|
| 40-49            | 15.0   |     | 4.7  |     | 9.4   | .000|
| >50              | 4.0    |     | 5.4  |     | 4.5   | .000|
| Income [%]       |        |     |     |     |       | .000|
| <1500US$         | 56.4   |     | 49.5 | .750 | 53.1  |     |
| 1500-4500        | 24.8   |     | 10.2 | .750 | 18.3  | .000|
| >4500-750        | 9.4    |     | 14.5 |     | 12.1  | .000|
| >7500            | 9.4    |     | 25.8 | .740 | 16.5  | .017|
| Stress [0-10]    | 1.1    |     | 5.3  | .798 | 3.9   | .987|
| Asthma [%]       | 13.6   | .017 | 16.4 | .740 | 15.5  | .987|
| Allergy [%]      | 30.6   | .387 | 34.5 | .143 | 31.7  | .698|

Table 4. Personal attributes and their relations to MCS risk.

| Variables        | School | p   | PT  | p   | Total | p   |
|------------------|--------|-----|-----|-----|-------|-----|
| Age of building  |        |     |     |     |       |     |
| [years]          |        | .017 | .252 | .987 | 3.8   | .065|
| No. of windows in class [%] | .000 | .750 | 47.4 | .049 | 1.05 | .049|
| No. of windows in multipurpose room [%] | .000 | .750 | 47.4 | .049 | 1.05 | .049|
| Modification [%] | 71.1   | .387 | 69.8 | .387 | 71.1  | .387|
| Water leakage [%] | .387 | 27.6 | .143 | 50.4 | .387 | 27.6 | .143|
Table 4 presents the surveyed building attribute variables and their relations to the MCS risk scores. As shown, overall, the increases in number of windows in rooms increase the MCS risk in schools (p<0.01). Nevertheless, the duration of opening windows obtains a significant relationship with MCS risk only for all samples (p<0.01). Furthermore, in schools, the ownership level of air-conditioning (p<0.01), the history of modification (p<0.05), the number of furniture in the class room (p<0.05) and the frequency of cleaning rooms (p<0.05) have significant relationships with MCS risk.

Table 5 shows indoor air quality and their relation to the MCS risk scores. As shown, outdoor air quality (OAQ) has a significant relationship with MCS risk (p<0.05). However, IAQ and humidity have week relationship with MCS risk (p>0.05).

3.3 IAQ Measurement
Outdoor weather conditions differed between dry and wet seasons. During the dry season, the outdoor air temperature ranges from 25.1-36.3°C with an average temperature of 29.9°C, whereas the RH ranges from 34-86% with an average of 64%. Meanwhile, the average outdoor temperature dropped to 28.1°C while the average RH increased up to 77% during the wet season.

Table 5. Indoor air quality and their relations to MCS.

| Variables           | School p | PT p | Total p |
|---------------------|----------|------|---------|
| Smell/Odor [%]      | .024     | .160 | .064    |
| IAQ [%]             | .93      | .56  | .24     |
|                       | (Rather) |      |         |
| Clean               | 42.1     | 42.3 | 42.2    |
| Neutral             | 46.7     | 43.8 | 45.4    |
| Dirty               | 11.2     | 13.8 | 12.4    |
| OAQ [%]             | .089     | .148 | .027    |
|                       | (Rather) |      |         |
| Clean               | 38.8     | 33.8 | 36.5    |
| Neutral             | 43.4     | 54.6 | 48.6    |
| Dirty               | 17.8     | 11.5 | 14.9    |
| Humidity            | .51      | .128 | .07     |
| [%]                 | (Rather) |      |         |
| Dry                 | 31.3     | 30.7 | 31.0    |
| Neutral(Rather)     | 42.7     | 48.0 | 45.1    |
| Humid               | 26.0     | 21.3 | 23.8    |

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Figure 5. Statistical summary of IAQ.

Figure 6. Formaldehyde levels by different MCS risk groups.
In the dry season, the measured indoor air temperatures range from approximately 29-32°C in schools, while those in PT ranges from 27-31°C. Air-conditioning was used in most of the rooms in the buildings of PT. The indoor RH does not exceed 70% even in schools during most of the period in the dry season partially due to the increased indoor air temperatures. In contrast, indoor RH maintained very high values, up to 87% in schools during the wet season, while the indoor air temperatures were decreased to approximately 27-29°C.

The mean and maximum formaldehyde and TVOCs during the measurement periods were illustrated respectively in Fig. 5. These values were calculated based on the measured 30 min temporal average values, and therefore even the maximum values over the measurement period can be comparable with major international/domestic standards on IAQ. Overall, the average values of both formaldehyde and TVOCs are higher in the PT than those in schools except for the average maximum values of TVOCs, although a significant difference is found only for the mean values of formaldehyde (p<0.01). For example, the maximum values of formaldehyde range up to approximately 0.172 ppm with an average of 0.081 ppm in schools, while those in the PT range from approximately 0.048-0.183 ppm with an average of 0.115 ppm, which is higher than the WHO standard, 0.08 ppm. Meanwhile, the maximum values of TVOCs range up to approximately 5.21 mg/m3 with an average of 2.59 mg/m3 in schools, while those in PT range up to approximately 7.40 mg/m3 with an average of 2.90 mg/m3.

Figs. 6-7 present cumulative frequencies of formaldehyde and TVOCs respectively. As shown in Fig. 6, overall, the formaldehyde concentrations are higher in the PT than those of schools especially in terms of mean values. It should be noted that extremely high maximum values of formaldehyde were, however, obtained in both groups. This means that the background formaldehyde concentrations are apparently higher in the PT than schools, but there are some exceptional cases in schools which the formaldehyde levels are intermittently very high. Nevertheless, the result indicates that a large proportion of occupants in the PT are routinely exposed to a high concentration of formaldehyde. As shown in Fig. 6b, more than 60% of the measured formaldehyde levels in the PT exceed the WHO standard, whereas about 20% exceed the standard in schools.

As shown in Fig. 7, the measured TVOC levels are not so different among schools. Overall, the measured TVOC levels are divided into two opposites. Although approximately 60% of the rooms obtain relatively low TVOC levels with mean values of less than 400 μg/m3, the rest of the rooms obtain high values, up to 8,000 μg/m3 on average. All schools contain several extreme cases in which the maximum values range from 8,000 up to 21,800 μg/m3.

3.4 Influence of IAQ levels on MCS risk

We analysed the differences of mean values of formaldehyde and TVOCs respectively between the two different MCS risk groups: ‘not suggestive’ and ‘problematic’ to ‘very suggestive’. As shown in significant differences are found in terms of formaldehyde in both schools and PT for mean and
maximum values respectively. As expected, the respondents living in rooms with higher formaldehyde values tend to have higher MCS risk scores. Nevertheless, the opposite tendency can be seen for the maximum formaldehyde values in schools. This is probably because there were some exceptional cases in which the formaldehyde levels were intermittently very high as discussed before. In other words, this result implies that the long-term routinely exposure to formaldehyde would be more influential to the occupants’ chemical intolerance than by the intermittent but high exposures. In contrast, significant differences cannot be seen in the TVOC results. However, basically, the higher TVOC level is the higher the MCS scores would be, except for the maximum values in schools.

The usage green building materials is more necessary to avoid toxic emission influence students’ health. In addition, the indoor air circulation would be the key for good indoor air quality. Passive and active air circulation should be considered more when the people design the educational buildings to make the healthy buildings and more sustainable environmental education. Therefore, students can learn and prepare their future well.

4. Conclusions

This research is probably the first attempt to assess the IAQ conditions and their effects on health in educational buildings of Indonesia. The key findings from the case study of Bandung are as follows:

1. There was a significant difference in mean values of MCS risk among educational buildings. Around 50% of the respondents in the PT showed some degrees of chemical sensitivity risk, indicating possible spread of sick building syndrome.

2. On the other hand, significant differences were not found in the results of TVOC measurement among educational buildings. This implies that there are other IAQ problems even in schools, which cannot be measured by the degree of chemical intolerance.

3. Although most of the factors affecting MCS risk were similar among the problematic respondents of both two groups, there were a few different factors on the other hand. The chemical intolerance to new furnishings, symptoms on muscles and passive smoking were higher in schools, whereas the masking factor of scented products was higher in the PT instead.

4. Various kinds of personal and building attributes were found to affect MCS risk scores, but the influential factors were quite different among buildings, except for the degree of stress. For example, in schools, the increases in age and household income increased MCS risk scores. Moreover, those who have a history of allergic diseases tended to record higher MCS risk. In contrast, in the PT, the female respondents tended to obtain higher MCS risk. In schools, more factors are associated with personal and building attributes than the PT.

5. The average maximum values of formaldehyde were 0.081 ppm in schools and 0.115 ppm in the PT, which are higher than the WHO standard, 0.08 ppm. It was found that the background formaldehyde levels were apparently higher, but there were some exceptional cases in which the formaldehyde levels were intermittently very high. On the other hand, the measured TVOC levels were not so different between the groups, ranging very widely up to 22 mg/m3 in maximum value.

6. The respondents living or studying in rooms with higher mean formaldehyde values tended to have higher MCS risk scores. It was suggested that the long-term routinely exposure to formaldehyde would be more influential to the occupants’ chemical intolerance, which was particularly seen in the PT, than by the intermittent but high exposures.

7. The usage of green building materials is necessary and the indoor air circulation would be the key for good IAQ.

Acknowledgements
This research was supported by a grant from LPPM UPI through Penelitian Unggulan UPI scheme (contract: 339/UN40.D/PP/2018). We also would like to thank the students who kindly supported our survey.
References

[1]  Tham K W 2016 Indoor air quality and its effects on humans-A review of challenges and developments in the last 30 years *Energy and Buildings* **130** 637-50  https://doi.org/10.1016/j.enbuild.2016.08.071

[2]  Joshi S M 2008 The sick building syndrome *Indian J. of Occupational and Environmental Medicine* **12** 61-4 DOI: 10.4103/0019-5278.43262

[3]  Miller C S and Prihoda T J 1999 The environmental exposure and sensitivity inventory (EESI): a standardized approach for measuring chemical intolerances for research and clinical applications *Toxicology and Industrial Health* **15** 370-85  https://doi.org/10.1177/074823379901500311

[4]  Heo Y, Kim S H, Lee S K and Kim H A 2017 Factors contributing to the self-reported prevalence of multiple chemical sensitivity in public facility workers and the general population of Korea *J. of UOEH* **39** 249-58  https://doi.org/10.7888/juoeh.39.249