7th International Building Physics Conference

IBPC2018

Proceedings

SYRACUSE, NY, USA

September 23 - 26, 2018

Healthy, Intelligent and Resilient
Buildings and Urban Environments

ibpc2018.org | #ibpc2018

Field experimental investigation of temperature, humidity and solar radiation impacts on Formaldehyde Emission from interior furnishing material (particle board): A Preliminary Study

Alula Yadete[1,*], Fitsum Tariku[1,2] and Doug Horn[2]

[1]British Colombia Institute of Technology (BCIT), Canada.

[*]*Corresponding email: alula_a@outlook.com*

ABSTRACT
Some part of indoor space components such as furniture and surfaces (like walls and floor carpet) contains contaminants and emit them over time. The emission is affected by different environmental factors like temperature, relative humidity, and solar radiation. As a result, three field experiments are conducted to assess the impact of these environmental factors on Formaldehyde emission. This study referred to previous literature on measuring volatile compound emission from wood stain using balance scale. Consequently, a similar test setup (balance scale) is adopted to investigate formaldehyde emission from test sample which is exposed to solar radiation in fully controlled test buildings. Two identical particle-board test samples are prepared and one of them placed inside a test building in which the window is fully covered whereas the other test sample is installed in a building which is not covered so that it is exposed to solar radiation to the maximum extent. Moreover, Formaldehyde meter captures the concentration inside the test room release from the test sample. The result shows that the test room with 23ºC depicts slightly more formaldehyde in comparison to a room with 18ºC. Whereas, both rooms with 50% and 70% RH shows similar Formaldehyde concentration between 20 ppb and 25 ppb.

KEYWORDS
Formaldehyde, solar radiation, RH, Temperature, emission rate.

INTRODUCTION
The indoor environment is consisting of different components which contains chemical compounds harmful to the dwellers [1]. Although various measures are taken to minimize the indoor components with high pollutant sources, there are still some components such as particle board that produce formaldehyde which is deemed harmful [2]. The emission rate is found impacted by different indoor environmental elements such as temperature and relative humidity [3]. The impact of these environmental elements has been investigated by various studies [4].

The impact of temperature on formaldehyde emission from a laminated particleboard floor was found low at both 23ºC and 29ºC; however, the high initial concentration found influencing the emission which gradually decreased at 50ºC [5]. Moreover, the impact of temperature on the emission further extended to investigate the impact on components of parameters that depict the emission of formaldehyde from particle board and found to have a significant effect on both diffusion coefficient and partition coefficient [6]. Whereas, the remaining component initial (imitable) concentration found affected by the relative humidity [7]. The combined effect of temperature and relative humidity studied and found having a significant influence on formaldehyde emission [8].

However, most of these researches were done in a climate chamber which is different from the field experiment where the measurement is conducted under a real environment (more

dynamic). Besides, there is insufficient research in the area where solar radiation is influencing particle emission. Therefore, this study incorporates the effect of solar initiated formaldehyde emission in addition to temperature and relative humidity to get insight on formaldehyde emission in a full-scale test building simulating study room or small office.

METHOD

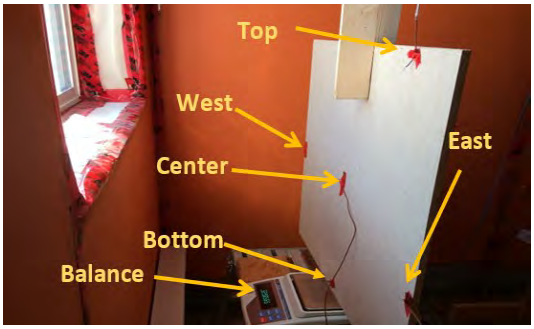
Field experimental measurement method is used to conduct this study. Two identical experimental test buildings with an overall dimension of 12 ft x 16 ft x 10 ft are used to carry out these tests. Both buildings have two (3 ft by 4 ft) windows on their south and north walls. These two buildings are exposed to a similar climatic environment as shown in Figure 1. The indoor condition in both buildings are set to maintain 21^{o}C room air temperature, and 50% RH in 100% recirculated air ventilation at 5 cfm. Then three separate measurements are conducted to study the impact of solar radiation, temperature, and relative humidity on Formaldehyde emission from particle board. Two type of measurement is conducted in the test rooms. First, the Formaldehyde concentration in the air, the second weight loss of the test samples as a result of mass exchange using balance scale. Moreover, two-weeks of data measurement is reviewed, and single day data is reported for each case in the result and discussion section.

A) South Test Building (STB) B) North Test Building (NTB)

Figure 1: Whole Building Research Laboratory (WBPRL).

The experimental set up for the first test case arranged to examine the impact of solar radiation on Formaldehyde emission from particle board test sample. Two test samples are prepared from a single sheet of particle board, a building material which is known to have and release formaldehyde. The samples have similar dimensions and size. Due to the balance maximum weight capacity, the test samples are limited to have 0.7 m x 0.7 m surface area and 11 mm thickness. One of the test samples is exposed to solar radiation inside south test building (STB) where the window is not covered as shown in Figure 1 (A). The other test sample is placed inside the north test building (NTB) in which the window is fully covered with aluminum foil to block solar radiation reaching inside the test room as shown in Figure 1 (B). Besides, the mass loss from the test samples due to formaldehyde emission is measured using balance scale as shown in Figure 2 B. The off-gassed formaldehyde concentration in the test room is measured using formaldehyde sensor as illustrated in Figure 2 A.

A) Formaldehyde meter

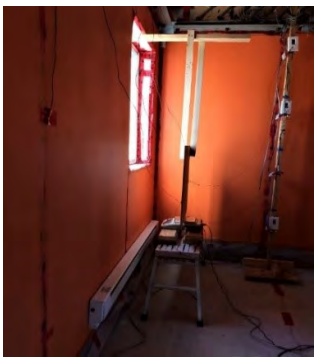


B) A test sample (window not covered)

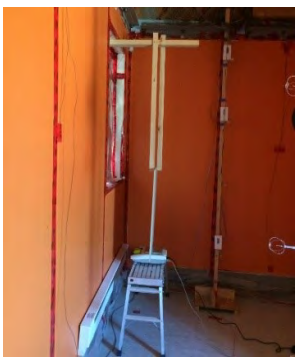
Figure 2: Formaldehyde meter and Thermocouples on the surface of test sample: Window not covered

The buildings are first flushed with high ventilation rate 1.1ACH (30 cfm) before each test. The ventilation rate then changes to 5 cfm and the background Formaldehyde concentration is measured. Following that the two samples are introduced into the test room, and the measurement carried out. The test samples are prepared and installed as illustrated in Figure 2. As illustrates in Figure 2 B, two balances are used to measure the mass change over the measurement period. The maximum capacity of the balances is 4100g for the balance in the NTB and 6100g in the STB. The initial mass of the samples is 3257.922 g in STB and 3261.722 g in NTB. In addition, five thermocouples are installed on the surface of the sample to identify the part of the sample under solar radiation as shown in Figure 2 B.

The experimental set up is rearranged for the experiments to investigate the effect of indoor air temperature and relative humidity on Formaldehyde emission separately. As a result, a full-size particle board (5/8'' x 49'' x 97'' CARB II / E1 PB) is mounted in both test rooms as shown in Figure 3 B, where the windows of both test buildings are not covered but the solar radiation doesn't reach on the samples. In the test where the impact of temperature is investigated, the setpoint temperature in North Test Building (NTB) is at 18°C and in the South Test Building (STB) is at 23°C keeping the same relative humidity (50%). For the last test in which the effect of relative humidity is investigated involves setting both test rooms at 21°C but different relative humidity (NTB at 50% and STB at 70%). Moreover, a single formaldehyde meter is used to measure the formaldehyde concentration in the test room by switching the sensor between the test buildings. The sensor is switched every other day for the second test which investigates the impact of temperature; whereas, for the last test case, it is switched every three and half days.



STB: Window not covered



NTB: Window covered

A) Solar radiation test

NTB and STB window not covered

B) RH and temperature test

Figure 3: Test samples in the test building.

RESULTS and DISCUSSIONS

Temperature distribution

Figure 4 shows the temperature reading from five thermocouples on the surface of the test sample over 24 hours period where the impact of solar radiation on formaldehyde emission measurement is conducted. As depicted in the figure the temperature raised during the daytime when the sun radiates on it. The maximum temperature reading on the sample was over 30ºC. Whereas, the average sample temperature at the pick is over 26ºC which is more than 5ºC relative to the average room temperature (20ºC).

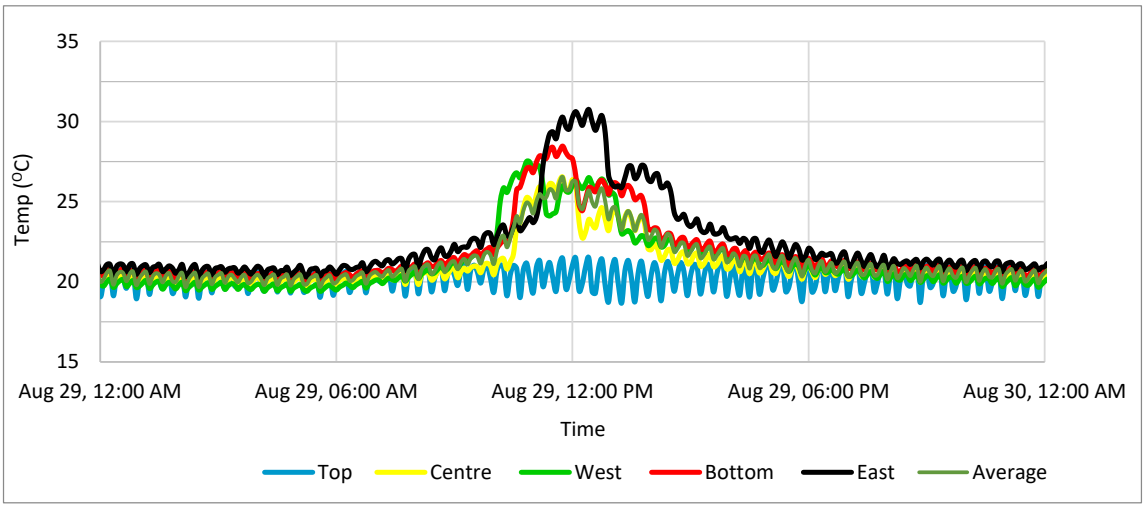


Figure 4: Sample surface temperature distribution: window not Covered.

Case 1: Impact of Solar radiation on formaldehyde emission

The formaldehyde meter measurement shows the formaldehyde concentration in the test room is between 10 ppb and 12.5 ppb throughout the measurement period as illustrated in Figure 5, despite the average sample surface temperature rise 5ºC more than the room temperature due to solar radiation. This finding suggests that the sample in this test is discharging a small amount of particle (Formaldehyde) into the test room. As a result, the attempt to measure the emitted particle is not successful. It is because the maximum capacity of the balances limits the sample size. Moreover, since the sample size relative to the test room volume and temperature rise on the sample surface is small, that might explain why the balances do not capture the mass change.

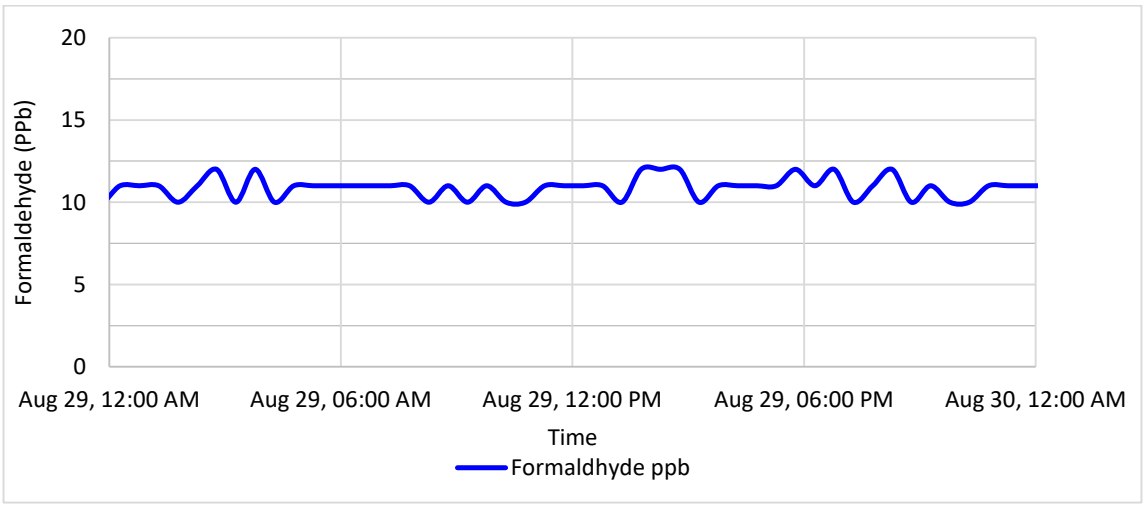


Figure 5: Formaldehyde emission due to solar radiation.

Case 2: Impact of Temperature on formaldehyde emission

The formaldehyde concentration in the test rooms with 23°C and 18°C both rooms with 50% RH is illustrated in Figure 6. As indicated in the figure the average formaldehyde concentration is around 15 ppb in a test room with 23°C. Whereas, the average formaldehyde concentration in a test room where the temperature is 18°C, is around 12.5 ppb. Overall, the room with 23°C show marginally more formaldehyde concentration compares to a room with 18°C. This result indicates that the formaldehyde emission is slightly affected by the temperature.

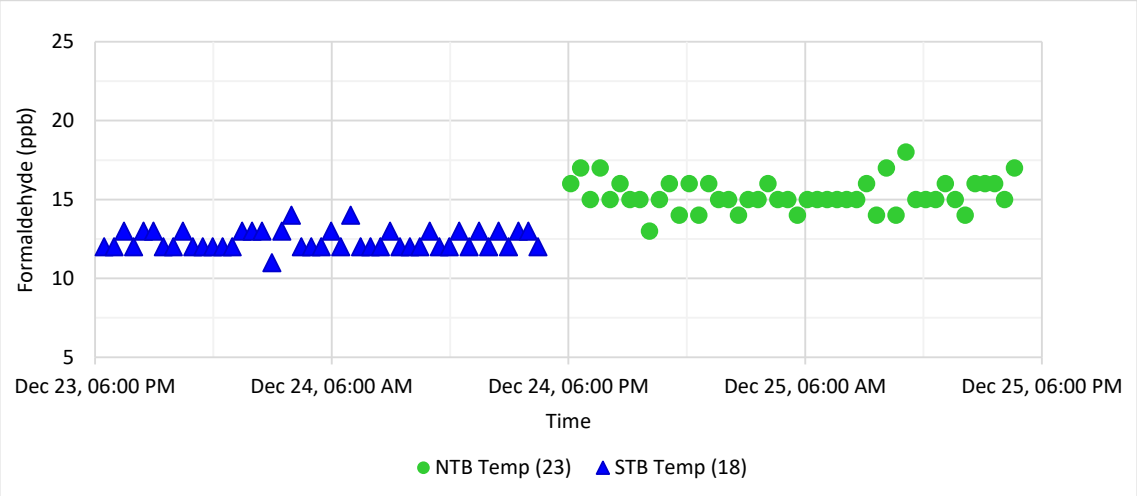


Figure 6: Formaldehyde concentration profile with two different indoor temperature (18°C and 23°C).

Case 3: Impact of RH on Formaldehyde Emission

Figure 7 shows the formaldehyde concentration in test rooms both with similar room temperature (21°C) and different relative humidity (50% and 70%). The formaldehyde measurement in a room with 70% relative humidity shows slightly scattered values. Whereas, in a room with 50% relative humidity depicts smooth trend. However, the formaldehyde concentration in both rooms remains between 20 ppb and 25 ppb. Overall, both test rooms demonstrate similar formaldehyde concentration despite their relative humidity difference.

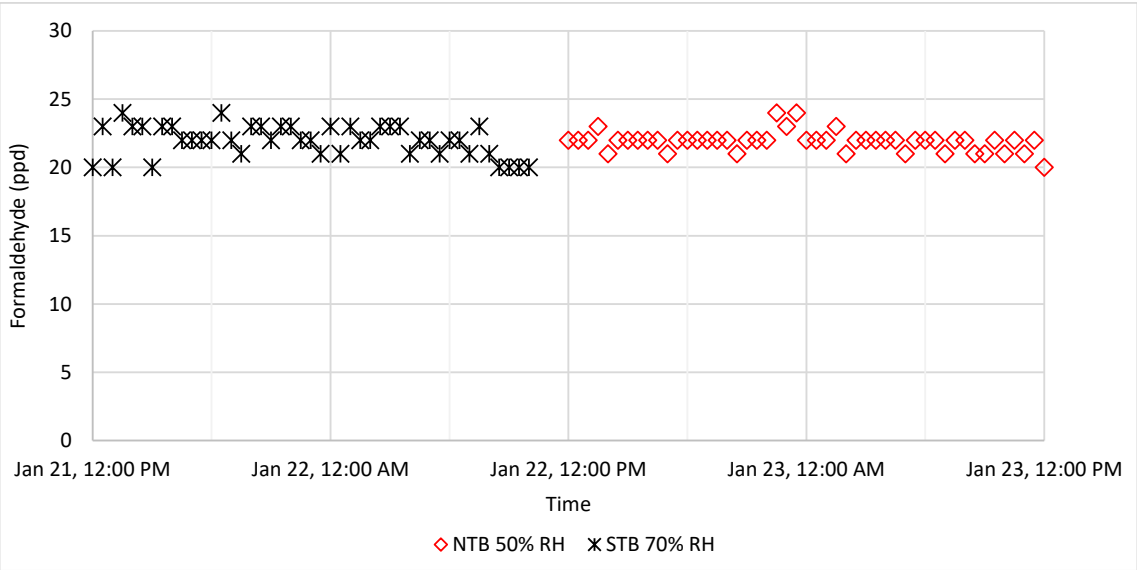


Figure 7: Formaldehyde concentration profile with two different RH (50% and 70%).

CONCLUSIONS

This project conducts three set of experiments investigating the effect of temperature, relative humidity and solar radiation on formaldehyde emission from a particleboard test samples in full-scale field experimental test buildings. Similar formaldehyde concentration (between 20 ppb and 25 ppb) is found in both test rooms with 50% and 70% relative humidity. Whereas, in the case of temperature, the formaldehyde concentration in the test room with 23°C is slightly higher than the room with 18°C. The preliminary study indicates that the mass change measurement is found very low and further study is recommended to find material that yields measurable mass change due to emission.

Acknowledgment

This project is funded by Natural Science and Engineering Council Canada (NSERC), Canada Research Chair (CRC) and school of Constriction and the Environment at the British Columbia Institute of Technology (BCIT).

REFERENCES

1. Ye, Wei, et al. "Indoor air pollutants, ventilation rate determinants and potential control strategies in Chinese dwellings: a literature review." *Science of the Total Environment* 586 (2017): 696-729.
2. Tang, Xiaojiang, et al. "Formaldehyde in China: production, consumption, exposure levels, and health effects." *Environment international* 35.8 (2009): 1210-1224.
3. Liang, Weihui, and Xudong Yang. "Indoor formaldehyde in real buildings: Emission source identification, overall emission rate estimation, concentration increase and decay patterns." *Building and Environment* 69 (2013): 114-120.
4. Jiang, Chuanjia, et al. "Formaldehyde and volatile organic compound (VOC) emissions from particleboard: identification of odorous compounds and effects of heat treatment." *Building and Environment* 117 (2017): 118-126.
5. Wiglusz, Renata, et al. "The effect of temperature on the emission of formaldehyde and volatile organic compounds (VOCs) from laminate flooring—case study." *Building and environment* 37.1 (2002): 41-44.
6. Zhang, Yinping, et al. "Influence of temperature on formaldehyde emission parameters of dry building materials." *Atmospheric Environment* 41.15 (2007): 3203-3216.
7. Liang, Weihui, Mengqiang Lv, and Xudong Yang. "The effect of humidity on formaldehyde emission parameters of a medium-density fiberboard: Experimental observations and correlations." *Building and Environment* 101 (2016): 110-115.
8. Liang, Weihui, and Xudong Yang. "Indoor formaldehyde in real buildings: Emission source identification, overall emission rate estimation, concentration increase and decay patterns." *Building and Environment* 69 (2013): 114-120.