Emissions of Polycyclic Aromatic Hydrocarbons (PAHs) from the Use of Scented Candles and Their Resultant Excessive Cancer Risks

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INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are hazardous pollutants formed during the combustion of organic materials, including scented candles. Although several studies have investigated PAH emissions from scented candles (Andersen et al., 2021; Derudi et al., 2012, 2014; Ott and Siegmann, 2006; Salthammer et al., 2021), systematic evaluations of the influence of operational conditions and the associated health risks remain limited. This study aims to quantify the emission factors of PAHs from scented candles under various environmental conditions and to assess the resulting long-term excessive cancer risks for practitioners.

MATERIAL & METHODS

The whole study was conducted in an exposure chamber. The dimension and pattern of the exposure chamber were sketched in Fig 1. The exposure chamber was constructed by acrylic (poly (methyl methacrylate), PMMA), it can be divided into five parts including the inlet area, the scented candle placing area, the combustion area, the mixing area, and the sampling area.

The stability and uniformity of the exposure chamber were tested prior to experiments, the exposed chamber was separated into three surfaces, nine points were tested for each surface (total 27 points on three surfaces) as shown in fig 1. For testing the spatial uniformity and the stability over time, the RH and the wind speed (for calculating the ACH) were measured for each point over 3 hours continuously.

Scented candles with paraffin base wax blended with the 6% of rosemary essential oil were used to test at three different environmental conditions, including three relative humidity (RH) conditions (60%, 75%, and 90%), and three air exchange rates (0.5 ACH, 1.0 ACH, and 2.0 ACH). For each testing condition, three repeat measurements were conducted, the candle were weighted before and after the experiments for calculating the emission factor (EF). For PAHs sampling, both gas- and particle-phase (total 22 species PAHs) were collected by using a filter cassettes sampler and a XAD-2 sorbent tube, respectively. For excessive lung cancer risk associated with the use of scented candles, the unit risk of 8.7x10-5(ng/m3)-1 for BaP was adopted.

RESULTS

The stability test results of the exposure chamber were shown in Fig 2. The results showed that the system reached steady state in 10 minutes, the air exchange rate and RH were very stable. The uniformity results of the RH and ACH were shown in Table 1 and 2, respectively. For both uniformity test results , the relative standard deviation (RSD) of each test surface (first, second, and third surface) was less than 10%; in addition, the deviations between each test surface and the target value were less than 6%.

For scented candles operated under 75% RH but different ACH, the $EF_{Total\text{-}PAH}$ followed the trend: 0.5 ACH > 1.0 ACH ≈ 2.0 ACH. This indicates that a higher air exchange rate provides more oxygen, promoting more complete combustion and resulting in lower PAH emissions. Conversely, under a constant ACH of 1.0, but varying RH conditions, the $EF_{T\text{-}PAHs}$ showed the trend: 60% RH > 75% RH > 90% RH. This suggests that higher humidity might hinder complete combustion, leading to increased PAH emissions.

Assuming the scented candle (1ACH, 75% RH) was used for 4 hours/day over 40 years, the estimated 95%-tile excessive lung cancer risk was 1.02×10^{-3}. The above results indicate that scented candles should be used with caution, particularly should prevent from long-term exposures in indoor environments with low ACHs and high RHs.

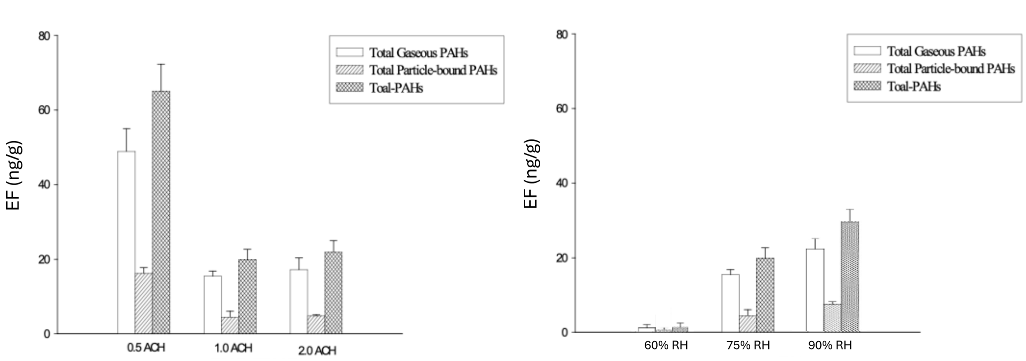

Figure 3. Emission factors in: (a) different ACHs under 75% RH, (b) different RHs under 1ACH

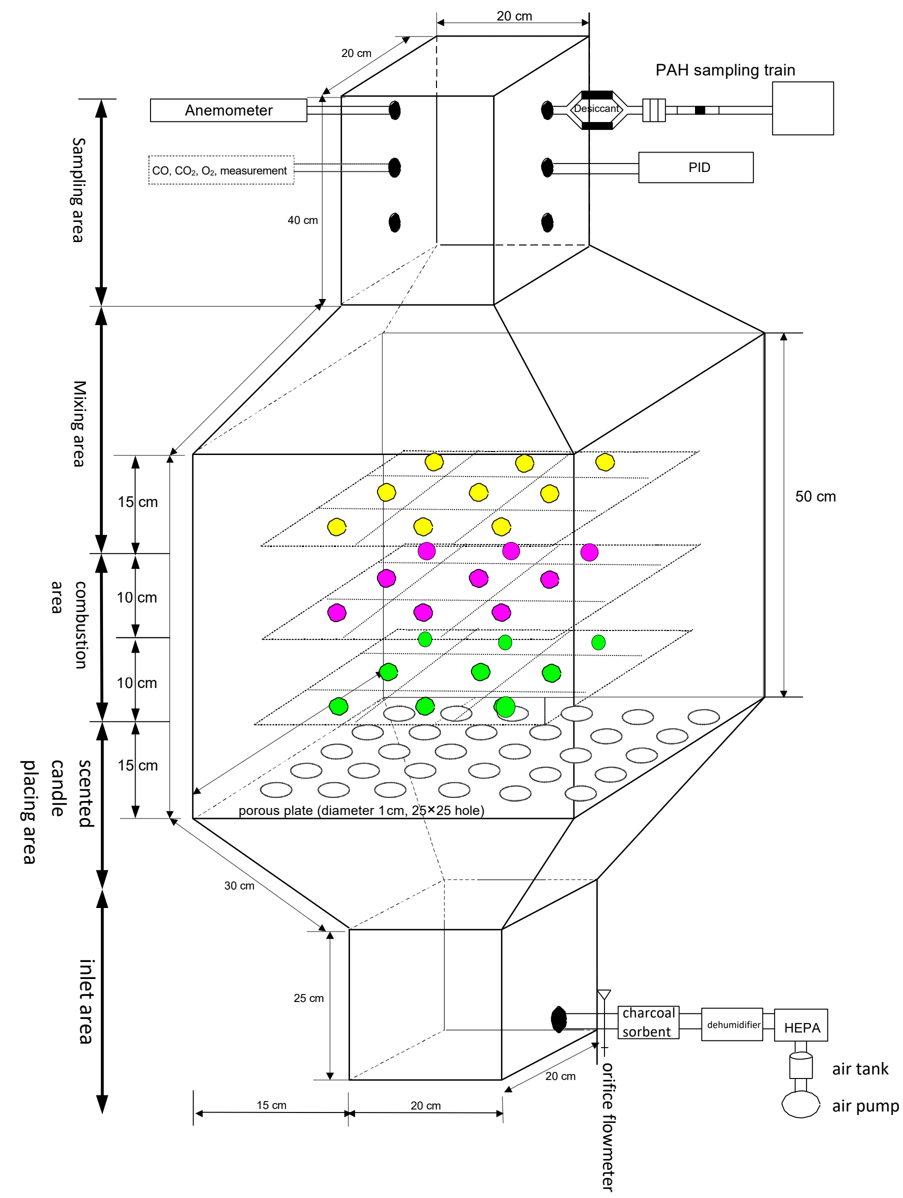

Figure 1. Exposure chamber and the test points for stability and uniformity

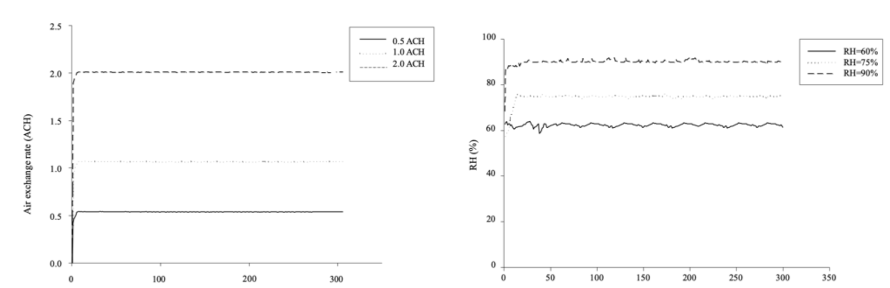

Figure 2. Stability results of: (a) air exchange rate at RH=75%, (b) relative humidity at 0.5 ACH

Table 1. Uniformity test results of different relative humidity at 1 ACH

RH (Mean±SD)	surface		
	1st	2nd	3rd
60%	61.4±5.48	61.3±3.77	60.6±4.14
75%	75.3±6.82	74.1±5.29	76.0±6.61
90%	90.9±3.64	90.4±4.83	89.4±6.70

Table 2. Uniformity test results of different air exchange rate at RH=75%

ACH (Mean±SD)	surface		
	1st	2nd	3rd
0.5	0.55±0.03	0.53±0.04	0.56±0.02
1	1.13±0.03	1.02±0.02	1.07±0.02
2	2.11±0.04	2.16±0.02	2.08±0.03