

Supplementary Materials: Volatile organic compounds in primary schools in Ho Chi Minh city, Vietnam: Characterization, sources and health risk assessment

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Table S1. Building and classroom characteristics.

| Char-acter-istics. | S1 | S2 | S3 | S4 |
|--|---------------------|---------------------|---------------------|---------------------|
| Locations | urban | urban | urban | urban |
| Building age (years) | 13 | 29 | 12 | 27 |
| Building type | commercial building | commercial building | commercial building | commercial building |
| Building material | brick/concrete | brick/concrete | brick/concrete | brick/concrete |
| Renovation/repainting work (within the last 2 years) | annual | annual | annual | annual |
| Area (m ²) | 7577 | 2939.6 | 2379 | 3393 |
| Room ventilation openings | no | no | no | no |
| Air conditioning system | partly | partly | partly | partly |
| Water damage | no | no | no | no |
| Paint peeling | yes | no | no | yes |
| Mold | no | no | no | no |
| Kitchen/eating room | yes | yes | yes | yes |
| Proximity to heavy traffic roads | across the street | across the street | across the street | across the street |
| Nearby dry-cleaners | no | no | no | across the street |
| Trees in schoolyard | yes | yes | yes | yes |
| Classrooms | 30 | 20 | 32 | 30 |
| Classroom area (m ²) | 54.4 | 36 | 40.4 | 48 |
| Number of students (per classroom) | 40 - 50 | 40 - 50 | 40 - 50 | 40 - 50 |
| Floor material | concrete | concrete | concrete | concrete |
| Use of pesticides | unknown | unknown | unknown | unknown |
| Use of air fresheners | yes | yes | yes | yes |
| Frequency of cleaning | daily | daily | daily | daily |
| Use of bleach/cleaner/ toilet deodorizer | yes | yes | yes | yes |
| Use of board/markers/chalk | yes | yes | yes | yes |
| Use of electronic devices (TV, PC, camera) | yes | yes | yes | yes |

Table S2. List of VOCs monitored in this study

| No. | Compound | Chemical class |
|-----|-------------------------|-------------------------|
| 1 | 1,2,3-Trimethylbenzene | Aromatic hydrocarbon |
| 2 | 1,2,4-Trimethylbenzene | |
| 3 | 1,3,5-Trimethylbenzene | |
| 4 | Benzene | |
| 5 | Butylbenzene | |
| 6 | Cumene | |
| 7 | Diethylbenzenes | |
| 8 | Ethylbenzene | |
| 9 | Ethyltoluene | |
| 10 | Naphthalene | |
| 11 | m/p-Xylenes | |
| 12 | o-Xylene | |
| 13 | Styrene | |
| 14 | Toluene | |
| 15 | Nonane | Alkane |
| 16 | Decane | |
| 17 | Undecane | |
| 18 | Dodecane | |
| 19 | Tridecane | |
| 20 | Tetradecane | |
| 21 | Hexadecane | |
| 22 | Hexanal | Alkanal |
| 23 | Heptanal | |
| 24 | Octanal | |
| 25 | Nonanal | |
| 26 | Decanal | |
| 27 | Benzaldehyde | Aromatic aldehyde |
| 28 | Homomenthyl salicylate | Ester |
| 29 | 2-Ethylhexyl salicylate | |
| 30 | Butyl acetate | |
| 31 | 2-Ethylhexanol | Alcohol |
| 32 | Limonene | Cyclic terpene |
| 33 | Pinene | |
| 34 | Terpinene | |
| 35 | Tetrachloroethylene | Chlorinated hydrocarbon |
| 36 | 1,4-Dichlorobenzene | |

Table S3. Comparison of VOC profile among the schools using the Kruskal-Wallis test

| Compound | S1 | S2 | S3 | S4 |
|-------------------------|-----------|-----------|-----------|-----------|
| 1,2,3-Trimethylbenzene | bc | ab | a | c |
| 1,2,4-Trimethylbenzene | bc | ab | a | c |
| 1,3,5-Trimethylbenzene | b | a | a | b |
| Benzene | a | b | a | b |
| Butylbenzene | a | ab | b | a |
| Cumene | b | a | b | b |
| Diethylbenzenes | b | a | a | b |
| Ethylbenzene | c | a | b | ab |
| Ethyltoluene | b | a | a | b |
| Naphthalene | a | a | b | b |
| m/p-Xylenes | c | a | b | ab |
| o-Xylene | c | a | bc | b |
| Styrene | a | a | b | a |
| Toluene | b | a | a | b |
| Nonane | b | a | a | a |
| Decane | a | ab | b | c |
| Undecane | a | ab | b | c |
| Dodecane | a | ab | b | c |
| Tridecane | a | ab | a | b |
| Tetradecane | a | ab | a | b |
| Hexadecane | b | a | a | a |
| Hexanal | b | b | a | b |
| Heptanal | a | ab | a | b |
| Octanal | ab | a | b | c |
| Nonanal | b | a | a | b |
| Decanal | ab | a | ab | b |
| Benzaldehyde | a | a | a | b |
| Homomenthyl salicylate | a | ab | c | b |
| 2-Ethylhexyl salicylate | a | ab | b | b |
| Butyl acetate | a | b | a | b |
| 2-Ethylhexanol | a | a | b | b |
| Limonene | a | ab | b | b |
| Pinene | bc | c | b | a |
| Terpinene | c | ab | b | a |
| Tetrachloroethylene | a | a | a | b |
| 1,4-Dichlorobenzene | a | ab | c | b |

Different letters for the same VOC indicate significant difference among the schools ($p < 0.05$)

Table S4. Spearman rank correlation coefficients for aromatic hydrocarbons

Correlation matrix (Spearman):

| Variables | 123TMB | 124TMB | 135TMB | Benzene | BuB | Cumene | DEtB | EtB | EtT | NAP | MPXY | OXY | Styrene | Toluene |
|-----------|---------------|---------------|---------------|---------------|---------------|--------------|---------------|--------------|---------------|--------------|--------------|--------------|----------|----------|
| 123TMB | 1 | | | | | | | | | | | | | |
| 124TMB | 0.845 | 1 | | | | | | | | | | | | |
| 135TMB | 0.797 | 0.798 | 1 | | | | | | | | | | | |
| Benzene | 0.705 | 0.605 | 0.444 | 1 | | | | | | | | | | |
| BuB | -0.797 | -0.817 | -0.759 | -0.568 | 1 | | | | | | | | | |
| Cumene | 0.122 | 0.171 | 0.303 | -0.206 | -0.048 | 1 | | | | | | | | |
| DEtB | 0.818 | 0.782 | 0.814 | 0.497 | -0.708 | 0.366 | 1 | | | | | | | |
| EtB | 0.026 | 0.131 | 0.303 | -0.452 | -0.184 | 0.458 | 0.277 | 1 | | | | | | |
| EtT | 0.748 | 0.739 | 0.843 | 0.396 | -0.789 | 0.211 | 0.779 | 0.301 | 1 | | | | | |
| NAP | -0.218 | -0.269 | -0.246 | 0.009 | 0.438 | 0.191 | -0.070 | -0.109 | -0.296 | 1 | | | | |
| MPXY | 0.002 | -0.010 | 0.203 | -0.484 | -0.082 | 0.474 | 0.163 | 0.620 | 0.184 | -0.071 | 1 | | | |
| OXY | 0.092 | 0.155 | 0.267 | -0.308 | -0.142 | 0.574 | 0.316 | 0.575 | 0.205 | -0.052 | 0.683 | 1 | | |
| Styrene | -0.559 | -0.604 | -0.427 | -0.702 | 0.678 | 0.354 | -0.350 | 0.293 | -0.433 | 0.469 | 0.383 | 0.303 | 1 | |
| Toluene | 0.828 | 0.732 | 0.795 | 0.449 | -0.659 | 0.477 | 0.879 | 0.303 | 0.721 | 0.016 | 0.269 | 0.280 | -0.216 | 1 |

Values in bold are different from 0 with a significance level $p = 0.05$

Table S5. Spearman rank correlation coefficients for alkanes

Correlation matrix (Spearman):

| Variables | Nonane | Decane | UnD | DoD | TriD | TetraD | HexaD |
|-----------|---------------|---------------|---------------|---------------|---------------|---------------|----------|
| Nonane | 1 | | | | | | |
| Decane | -0.382 | 1 | | | | | |
| UnD | -0.392 | 0.871 | 1 | | | | |
| DoD | -0.389 | 0.841 | 0.896 | 1 | | | |
| TriD | -0.446 | 0.729 | 0.745 | 0.703 | 1 | | |
| TetraD | -0.081 | 0.629 | 0.597 | 0.589 | 0.495 | 1 | |
| HexaD | 0.616 | -0.554 | -0.521 | -0.457 | -0.535 | -0.343 | 1 |

Values in bold are different from 0 with a significance level $p = 0.05$

Table S6. Spearman rank correlation coefficients for aldehydes, esters and terpenes

Correlation matrix (Spearman):

| Variables | Hexanal | Heptanal | Octanal | Nonanal | Decanal | BZALD | HMS | EtHexS | BuAc | EtHexanol | Limonene | Pinene | Terpinene |
|-----------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------|-----------|
| Hexanal | 1 | | | | | | | | | | | | |
| Heptanal | 0.594 | 1 | | | | | | | | | | | |
| Octanal | 0.267 | 0.465 | 1 | | | | | | | | | | |
| Nonanal | 0.557 | 0.616 | 0.686 | 1 | | | | | | | | | |
| Decanal | -0.117 | 0.213 | 0.378 | 0.338 | 1 | | | | | | | | |
| BZALD | 0.244 | 0.545 | 0.791 | 0.547 | 0.321 | 1 | | | | | | | |
| HMS | -0.660 | -0.285 | 0.188 | -0.293 | 0.281 | 0.174 | 1 | | | | | | |
| EtHexS | -0.607 | -0.231 | 0.130 | -0.352 | 0.235 | 0.169 | 0.839 | 1 | | | | | |
| BuAc | 0.635 | 0.597 | 0.258 | 0.228 | -0.068 | 0.396 | -0.276 | -0.139 | 1 | | | | |
| EtHexanol | -0.556 | -0.154 | 0.353 | -0.126 | 0.103 | 0.302 | 0.719 | 0.604 | -0.258 | 1 | | | |
| Limonene | -0.008 | 0.227 | 0.533 | 0.133 | 0.022 | 0.514 | 0.453 | 0.253 | 0.263 | 0.556 | 1 | | |
| Pinene | -0.141 | -0.462 | -0.735 | -0.503 | -0.279 | -0.736 | -0.226 | -0.249 | -0.268 | -0.422 | -0.448 | 1 | |
| Terpinene | -0.337 | -0.608 | -0.560 | -0.308 | -0.177 | -0.700 | -0.140 | -0.260 | -0.777 | -0.180 | -0.474 | 0.697 | 1 |

Values in bold are different from 0 with a significance level $p = 0.05$

Evaluation of non-cancer and cancer risks via the inhalation pathway:

The Exposure Concentration (EC) ($\mu\text{g}/\text{m}^3$) for non-cancer and cancer risks was calculated using the following equation:

$$EC = \frac{CA \times ET \times EF \times ED}{AT} \quad (\text{Equation S7})$$

where CA is the VOC concentration in indoor air ($\mu\text{g}/\text{m}^3$), ET is exposure time (hours/day), EF is exposure frequency (days/year), ED is exposure duration (years), and AT is averaging time (period over which the exposure is averaged, hours).

For the evaluation of non-cancer risk, Hazard Quotient (HQ) for the inhalation pathway was calculated as follows:

$$HQ = \frac{EC}{\text{Toxicity Value} \times 1000} \quad (\text{Equation S8})$$

where HQ is dimensionless, and Toxicity Value (mg/m^3) for chronic exposure is the inhalation Reference Concentration (RfC) that is available in the EPA's online IRIS system (EPA, 2009). An HQ higher than 1 represents a possible adverse non-cancer effect, and an HQ less than or equal to 1 indicates that adverse non-cancer effects are not likely to occur.

The cancer risk for children exposed via the inhalation pathway was estimated using the linear low-dose represented by the following relationship:

$$\text{Cancer risk} = \text{IUR} \times EC \quad (\text{Equation S9})$$

where IUR is Inhalation Unit Risk (probability of cancer for a 70-year exposure to $1 \mu\text{g}/\text{m}^3$) ($\mu\text{g}/\text{m}^3$)⁻¹. IUR values were obtained from the IRIS system. A value higher than 1×10^{-6} denotes a possible carcinogenic effect, and a value less than or equal to 1×10^{-6} represents no carcinogenic effects occur as a result of exposure. It is suggested that exposure to carcinogenic VOCs in early-life may result in higher lifetime cancer risks than comparable exposure durations later in life. Therefore, 3-fold adjustments were made for exposures with respect to the age group of 2 to 11 years of age, respectively (EPA, 2009).

Table S10. Exposure parameter values

| Parameters | | Unit | S1 | S2 | S3 | S4 |
|-----------------|----------------------------------|-----------|-------|-------|-------|-------|
| ET | Exposure time | hrs/day | 9.75 | 9.75 | 9.75 | 9.75 |
| EF | Exposure frequency | days/year | 240 | 240 | 240 | 240 |
| ED | Exposure duration (Age 3 – 5) | years | 5 | 5 | 5 | 5 |
| AT (non-cancer) | Average time | days | 43800 | 43800 | 43800 | 43800 |
| AT (cancer) | | | 25550 | 25550 | 25550 | 25550 |

Table S11. Toxicity values

| Compounds | RfC, mg/m ³ | IUR $\times 10^{-6}$, ($\mu\text{g}/\text{m}^3$) ⁻¹ | References |
|-------------------------------|------------------------|---|--------------|
| 1,2,3-Trimethylbenzene | 0.06 | | EPA |
| 1,2,4-Trimethylbenzene | 0.06 | | EPA |
| 1,3,5-Trimethylbenzene | 0.06 | | EPA |
| Benzene | 0.03 | 29 | EPA, OEHHA |
| Butylbenzene | 0.4 | | EPA |
| Cumene | 0.4 | | EPA |
| Ethylbenzene | 1 | 2.5 | EPA, OEHHA |
| Xylenes | 0.1 | | EPA |
| Naphthalene | 0.003 | 34 | EPA, OEHHA |
| Styrene | 1 | | EPA |
| Toluene | 5 | | EPA |
| 1,4-Dichlorobenzene | 0.8 | 11 | EPA, OEHHA |
| Tetrachloroethylene (PERC) | 0.04 | 6.1 | EPA, OEHHA |
| Butyl acetate | 0.4 | | Michigan DEQ |

References

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