Reviewer's report

Title: Mitigation of asthma triggers in indoor air: An inter-comparison of ventilation/filtration options for residences

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Reviewer: Otto Hänninen

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Environmental Health

Mitigation of asthma triggers in indoor air: An inter-comparison of ventilation/filtration options for residences

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Dear Editor,

The paper by Dr Myatt and colleagues on "Mitigation of asthma triggers in indoor air: An inter-comparison of ventilation/filtration options for residences" concerns an important and timely topic related to the reduction of health risks caused by contaminants in indoor air. They focus on asthma triggers, but the selected particulate matter pollutants considered are also well-known sources of other significant health impacts. Moreover, the modeled behavior of the pollutants concerns also other types of particles, especially particles of outdoor origin, that are known to be the most significant environmental cause of public health effects in the developed world.

The authors model indoor concentrations of four pollutants (cat allergen, ETS, contagious viral units (quanta) and fungal spores of outdoor origin) in a selected house type (2-storey detached house) for six different configurations of ventilation (natural ventilation and five combinations of mechanical ventilation and use of portable air cleaners). As such, the modeling very well captures the heterogeneous ventilation settings possible for dwellings and the results warrant publication.

There are a number of technical issues that the authors have to consider before publication of the manuscript.

When assessing the work, please consider the following points:

1. Is the question posed by the authors new and well defined?

The potential of ventilation systems and portable cleaners to reduce occupant exposure to pollutants in indoor air is well known. The authors provide a significant contribution to the field by systematically comparing the effects of six ventilation configurations on the most widely spread health concern, asthma.
2. Are the methods appropriate and well described, and are sufficient details provided to replicate the work?

The methods are adequate. However, several details of the modeling are not sufficiently described. These include
- model validation/evaluation (no numeric results nor sufficient citations are given)
- air circulation and mixing of air between compartments are not described. Related to this, the description of the ventilation system (location of air vents; adjustment of ventilation between rooms etc. has to be given)

Addition of these allows the reader to comprehend and interpret the reported results.

3. Are the data sound and well controlled?

The modeling work is based on input data from the literature and parallel experimental works by the same working group. The literature is sufficiently cited, but the description of the parallel experimental work that is planned to be published separately needs clarification (see detailed remarks). The model results are sufficiently compared with experimental data in the literature.

4. Does the manuscript adhere to the relevant standards for reporting and data deposition?

Yes.

5. Are the discussion and conclusions well balanced and adequately supported by the data?

The discussion covers well the experimental results from the literature. Several relevant topics are not discussed, however. These are:
- non-detached house types. The authors motivate the work by the relatively high prevalence of asthma in the US populations (adults and children), especially among the Hispanic ethnic groups. However, the modeling cases focus on detached houses, that represent the living conditions of high income households. The authors should give some data related to the prevalence of asthma among the populations occupying this type of houses, the fraction of population in question, and some guidance in interpreting the results for other types of buildings.
- non-inhalation based spread of contagious units. One very interesting source of health risk considered is the inhalation based spread of viral infections. It has been suggested that in general the viral infections spread via hand-mucous membrane contact and that therefore the inhalation spread would not be very significant in practical terms. The authors convincingly discuss that the model results match experiments where non-inhalation spread was prevented by the study setup, but this does not give any information on the relevant significance of inhalation spread in residential conditions modeled.
indoor sources of fungal spores. How should the model results for outdoor spores be interpreted in terms of more widely known problem of indoor generated spores? It should be made clear throughout the manuscript, that the calculations were performed only for outdoor spores, but nevertheless, in the discussion the authors should give some guidance to what extent the results can or cannot be used for spores of indoor origin (i.e., mould problem, for which e.g. WHO is currently developing Indoor Air Guidelines).

The second sentence of the Conclusions section is not appropriate. The work is only weakly related to the avoidance strategies cited. I would suggest to rewrite the conclusions to highlight the main findings, applicability, and limitations of the modeled cases.

6. Do the title and abstract accurately convey what has been found?

This reviewer finds the title and focus of the paper on asthma triggers slightly restrictive; as stated above, the many of the studied pollutants have other very significant health effects besides asthma, and the filtration systems modeled do affect also particles of other types. However, the title is technically speaking correct.

The abstract needs some clarifications. The methods section statement of the use of a "validated model" needs to be backed up by citations to the validation in the methods section of the manuscript. The section in the abstract should state that the emission rates are based on literature and hypothetical temporal patterns.

The last sentence of the Results section in the abstract is not appropriate; the conclusion that the avoidance strategies can be enhanced is correct, but the reference made to the specific recommendations is not in any substantive way related to the modeling conducted.

The statement about the conclusions in the abstract is weak and should be rewritten to highlight the main results as e.g. in the first sentence of the main conclusions section instead of merely stating that the findings are useful.

7. Is the writing acceptable?

The writing is excellent.

1 Major Compulsory Revisions

My remarks are discussed in more detail below; here is a bullet list to the revisions that I consider compulsory:

1.1 - demonstrate that the CONTAM model has been validated, give citations to peer reviewed works where this has been published, and add a paragraph in the methods to shortly describe the model evaluation results.

1.2 - the model assumptions/quantification of indoor air re-circulation and passive/active (pressure difference induced) mixing of air between the
compartments is a central factor affecting the results e.g. concerning emissions in a particular room. The authors have to add a paragraph to the Methods section explaining how the model handles the mixing.

2 Minor Essential Revisions, including Discretionary Revisions

Introduction

2.1 p 4, 1st para: figures given on asthma prevalence in the US (6.7 and 8.5%) are presented with artificial precision. Due to the difficulties in definition (e.g. temporal aspects) and diagnosis of asthma-related symptoms, any estimates of asthma prevalence in the population have less than one significant digit precision; therefore presenting the prevalence with two is not justified.

2.2 p5, last para of Introduction; the last sentence is evaluating the results, ie. presenting conclusions of the study (and as such, is formulated too weak to be useful); move to the conclusions and reformulate to mediate the value of the results

Methods

2.3 Validated CONTAM model. The authors refer to the CONTAM model the whole work is based on as being validated, yet the only citation given for this model is the User's Guide, not expected to be a source of scientific validation. The User's Guide itself cites 8 references, none of which is a scientific publication. While the model itself may be valid and validated, neither of these basic requirements for the current paper is demonstrated by explaining the type of validation, showing validation (or evaluation) results, or by citing material showing these. Addition of the needed references and short 1-paragraph summary of the conducted validation/evaluation tests of the model is crucial.

2.4 Besides the detached house templates in the additional materials, the floor area (m²) should be given in the text. As the modeling is considering detached houses only, it would be interesting to read what percentage of the US populations do live in such conditions. Moreover, it is possible, that the Hispanic population groups, suffering more from asthma symptoms may have different percentage of detached house residences than the other ethnic groups. As these details are brought up by the authors as a motivation for the work, it would be interesting to push the aspect few figures further. In the discussion section it will be interesting to consider how the modeling results would apply for non-detached housing types.

The ventilation model.

2.5 Currently the ventilation model details are started with meteorological inputs, which at least for this reviewer would be the least interesting in understanding the model setup; ie. I would move this paragraph together with the first para on p8, where the temperature-dependent probabilistic window and door opening schedules are explained. This also brings together the 1st and 3rd para on page 6, which both concern the housing templates.
2.6 Air re-circulation and mixing of air between the rooms should be explained in an additional paragraph.

Cat allergen

2.7 Page 8: Fel d 1 not explained. The cat allergen emissions were described using a constant and an intermittent source; former in all rooms except bedrooms, and latter once an hour during the waking hours in the living room only. These emission characteristics are hypothetical based on expert judgment. Nevertheless, the CONTAM assumptions related to the mixing of air between rooms becomes significant and should be explained in few sentences where the model is introduced. Here it is also significant to consider the use of doors between the rooms (e.g. concerning the recommendation of not allowing cats to the bedrooms requires to keep the bedrooms closed, lowering also air mixing between the bedroom and rest of the house)

Fungal spores:

2.8 report the mean and range (or variability) of the spore concentrations (not given in Table 2 with the other source data; add there or in the text). Spore size up to 50 µm must be mixing spores with fungal filaments.

Viruses

2.9 The second half of the main paragraph on page 11, starting "For the in-duct electrostatic…", referring to qPCR analysis, remains unclear. I would recommend to leave it out (or shorten substantially), and to clarify what the previous sentence, citing [22], actually means – ie. give numeric data on the test results.

2.10 Wess-Riley equation needs a reference [58]. The breathing rate of 0.48 m3/h corresponds to daily average ventilation volume including sleep/resting. Higher quanta emission rates being related to wake-up hours, higher ventilation rate for the exposure might be justified. Spending time in the adjacent room again highlights the need to describe how the model is estimating the room to room air mixing.

Results

2.11 Reported similarity of the results between the two housing templates guided the authors to present only the results for the newer two-storey house (DH28). This is in slight contrast with the population relevance; while people having the option to live in two storey detached house have also good resources to choose between alternative ventilation systems, it seems to this reviewer that such a setup concerns only the highest percentiles of household income, and therefore has limited significance to contribute to the alleviation of asthma symptoms as a public health problem.

ETS

2.12 Page 13 Comparing the HE and CP2 systems using the median seems a bit exaggerating. The hourly median of course concerns hours when smoking is not taking place (smoking in the living room modeled for the morning and evening
hours only), and therefore affected strongly by the overall ventilation rate as well as the filtration of the air. Using a linear dose-response model, the mean concentration (for the time of occupancy (different time-activities for e.g. a working adult/school child/pre-school child/house wife) would be most relevant parameter for the comparison.

2.13 The text citing Figure 3A,B states that Feb 1 is representative day; would it be more precise to state it is typical day?

2.14 Smoking event takes approximately 6.5 minutes; during this time the air exchange in all windows-closed scenarios should have a limited effect on the peak concentration. Is it correct that the difference between HE and C1 is 2-fold (40 vs 80 µg m-3)? This sounds unplausible for the living room; I would expect similar magnitude for the peaks with lower spread to the other rooms of course in the case of HE, as well faster decline. Is it possible that e.g. the C1 smoking event may take place during the non-operating phase of the AHU? (but still this would not explain 2-fold difference!)

Outdoor Fungi
2.15 Page 14 – the first sentence gives the spore ranges that belong (and were requested in my previous remark) to be presented in the methods. These are inputs to the current work, not a result.

2.16 The last sentence states that the lowest levels in "the bedroom", while in Table 4 the lowest figures in "Bedroom 2" are reported for HE (41 against 52-54).

Viruses
2.17 The text presents three time-activity scenarios (very good). Numerical results are split in Tables 5 & 6, with results for the second scenario missing. I would suggest to combine all results in the same table, adding the missing scenario.

Discussion
2.18 Please consider in the discussion
a- indoor sources of fungal spores; to what extent the results are the applicable?
b- non-detached house types; IAQ problems in detached houses; health problems of populations living in detached houses; applicability of the results to other types of buildings?
c- non-inhalation based spread of contagious units; this may have serious practical implications for the interpretation of the presented inhalation spread results

References
2.19 References 1, 2, 21, 23, 24, 25, 27, 30, (43), 54, 66 have to provide url-links.

Generally speaking, the manuscript cites relatively large number of reports and
other sources that are difficult to obtain and all of them have not passed a peer review process. The overall number of cited works is also relatively high (66).

Table 1

2.20 CP1, CP2 -> C+1P, C+2P (Conventional forced ventilation with 1 inch filter operated together with 1 or 2 protable HEPA filter devices (details in parentheses)
HE: Forced ventilation with high efficiency filter (details in parentheses)

Table 2

2.21 The emission rates are presented with ridiculous 0.1 ng/h precision (the authors are asked to consider also the relevant precision for the other variables, e.g. particle size and filtration efficiency with 3-digit precision?).

2.22 It is unclear if the particle sizes, deposition rates, and removal efficiencies are used as point values or as a probability distributions (in which case the parameters describing the spread are missing).

2.23 Unit of measure for the particle sizes and efficiency rates missing (μm, %?)

2.24 Replace "Mold" with "Outdoor fungal spores" to avoid confusion with indoor mold

Table 3

2.25 Column titles incomplete (e.g. "Template" is not readily comprehensible – add "House"; add column title for air exchange rate (the precision of 3 digits is exaggerated)

Are the percentiles for the time during the annual simulation? What explains the large variation of the forced ventilation rates? Times windows are kept open?

Table 4

2.26 Indicate units in the caption or header row, not in footnote (GM, GSD)
Ventilation codes cryptic – spell out
sp/m3 => 1/m3 or spores/m3

Clarify "Bedroom 2" (clear in the housing template, but is this the bedroom with the portable cleaner or not?)

Table 5

2.27 Three digit precision for infection risks is meaningless

Figure 3A,B

2.28 In the text expression "Living room" was used. The figures use "Family room"; may confuse some readers. The substantial difference between these two settings suggests to me that the model is assuming that all mixing of air between the rooms is assumed to take place via the air re-circulation. If this is the case,
passive mixing may be underestimated, producing unrealistically good results for all scenarios with indoor sources in a specific room.

**Level of interest:** An article of importance in its field

**Quality of written English:** Acceptable

**Statistical review:** No, the manuscript does not need to be seen by a statistician.

**Declaration of competing interests:**

I declare that I have no competing interests.