How a harm budget can be used to regulate Indoor Air Quality in Dwellings

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ABSTRACT

This work quantifies the chronic harm caused by long-term exposure to common indoor air contaminants in dwellings located in the global north. Two methods are used to compute DALYs. The first uses incidence data and the second considers toxicological evidence. They are synthesised to produce Harm Intensities, the number of DALYs per person per unit of annual-average concentration the person is exposed to. Then, uncertainty in annual mean concentrations for 45 contaminants commonly found in dwellings in the global north is determined from a systematic literature review.

$PM_{2.5}$, $PM_{10\text{-}2.5}$, NO_2, O_3, and HCHO are estimated to be the most harmful contaminants by an order of magnitude. Together they account for >99% of the estimated harm from typical indoor exposures and should be designated *contaminants of concern* in dwellings in the global north. A harm budget approach is used to show that complying with ASHRAE standard 62.2 could see the total population harm drop by ~70%.

KEYWORDS

DALY, dwelling, harm intensity, harm budget, ranking, *acceptable* indoor air quality

1 INTRODUCTION

Common metrics for assessing air quality in buildings are based on guidelines and standards that regulate concentrations by stating threshold concentrations that should not be exceeded over a period of time. There is disagreement on the magnitude of these thresholds, perhaps because methods for determining them do not relate the magnitude of any exceedance to specific health outcomes. Accordingly, there is a need to develop health-centred IAQ metrics that can quantify the burden of disease using current epidemiological and toxicological evidence of population morbidity and mortality. The Disability Adjusted Life Year (DALY) is used as an air quality metric because it can be used to quantify and rank the burden of household air contaminants.

2 METHODS

Two methods are used to compute DALYs. The first uses incidence data and the second considers toxicological evidence. They are synthesised to produce Harm Intensities, the number of DALYs per person per unit of annual-average concentration the person is exposed to. Then, uncertainty in annual mean concentrations for 45 contaminants commonly found in dwellings in the global north is determined from a systematic literature review.

Uncertainty in the median DALYs for the 45 contaminants is estimated by combining the harm intensities and concentrations for the epidemiological and toxicological models and pooling results. The contaminants are then ranked by the magnitudes of predicted harm.

Preliminary results are contained in Morantes et al. (2023). Finally, an acceptable limit of population harm is set using a *harm budget* where any combination of exposures is permissible as long the total harm stays below a limit. This limit is determined using a *reference scenario*, a sample of 70 houses that all comply with the California energy code, and thus ASHRAE Standard 62.2, for mechanical ventilation. HIs and measurements of some CoCs ($PM_{2.5}$, HCHO, NO_2) and guideline values (Rn, O_3) are used to set the budget.

3 RESULTS

Coarse and fine particulate matter, NO_2, O_3, and formaldehyde are estimated to be the most harmful contaminants by an order of magnitude. Accordingly, these should be designated contaminants of concern in dwellings, prioritised for removal, and regulated. The total median harm from these contaminants is 2,200 DALYs/10^5 people /year. The total median harm for the 70 houses of the reference scenario is 610 DALYs/10^5 people /year, showing a reduction of around 70%.

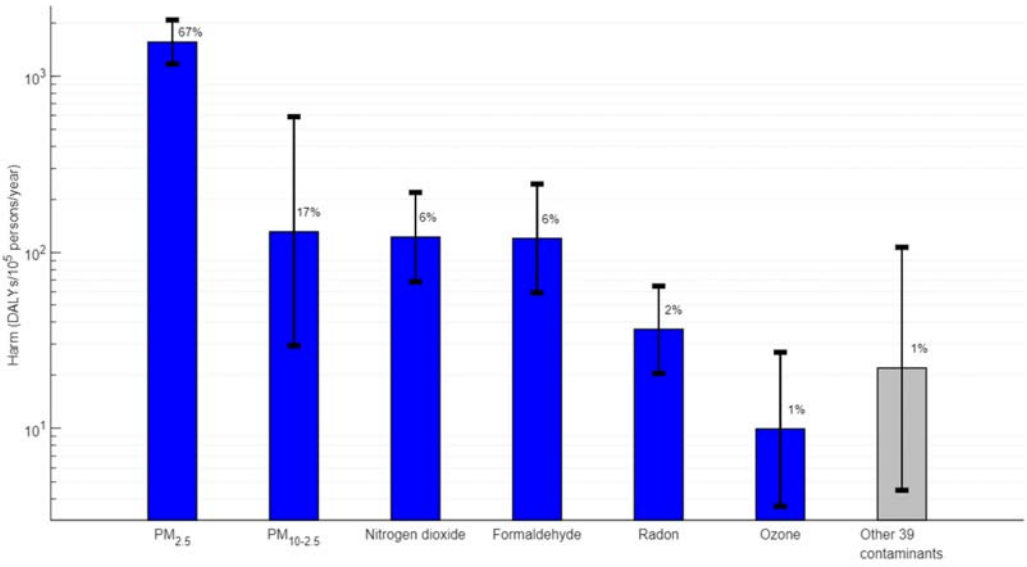

Figure 1: Harm caused by contaminants of concern. Median (bar) & GSD (error bar). Percentage contribution for total harm.

4 DISCUSSION

A new method is required to regulate contaminants and a harm budget is proposed as a way to quantitatively determine *acceptable* IAQ in dwellings. It sets a maximum acceptable limit of population harm and them permits any combination of exposures to CoC so long as the harm stays below the limit. The methods we propose can be used to re-evaluate the harm the contaminants cause, or to consider other contaminants, as new evidence emerges. Harm is shown to be a way of prioritising the contaminants that cause the greatest chronic harm to populations of people, and the harm budget is used to quantifiably set *acceptable* IAQ based on exposure to airborne contaminants in buildings. Generalizing to dwellings is not possible, but the approach used here is a starting point for harm budget evaluation rather than a definitive solution. Changes in the budget's magnitude will occur when comparing the magnitude against other non-IAQ hazards and when considering additional houses.

5 CONCLUSIONS

The most harmful contaminants in dwellings are $PM_{2.5}$, $PM_{10–2.5}$, NO_2, formaldehyde, radon, and O_3, accounting for over 99% of total median harm of 2,200 DALYs/10^5 person/year. The

chronic harm caused by all airborne contaminants in dwellings accounts for 7% of the total global burden from all diseases.
An acceptable harm budget of 610 DALYs/10^5 person/year is set using a reference scenario, and is as a way to quantitatively determine acceptable IAQ based on exposure to airborne contaminants in buildings.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

Morantes G, Jones B, Sherman M, Molina C. A preliminary assessment of the health impacts of indoor air contaminants determined using the DALY metric. International Journal of Ventilation. 2023:1-10.