Quantitative analysis of indoor air quality under future climate scenarios: Projection till 2100's for a Belgian case-study

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SUMMARY
The variations of Indoor Air Quality (IAQ) levels under the impacts of climate change are linked to the alterations of air pollutant emissions, both indoor and outdoor, and of the occupant behaviour. On the other hand, the retrofit action plans being applied on buildings to tackle the increasing extreme weather events and corresponding energy demands, result in more air-tight buildings with reduced air exchange rates and new HVAC technologies. In the current research project, the future state of IAQ in a Belgian case-study is investigated quantitatively through the simulation process with CONTAM. The test house was a naturally ventilated studio flat (+2 exhaust fans) in the Wallonia region, south of Belgium. The new methodology developed allows for consistent results and can be used for IAQ predictions under the climate change.

KEYWORDS
IAQ, Climate Change, Modelling, CONTAM.

1 INTRODUCTION

The level of chemical and airborne contaminants in dwellings are mainly linked to infiltration rates of outdoor air and emissions of internal sources. Future scenarios correlated with indoor built environment include future climatological, and GHG (Green House Gas) emission scenarios, and buildings' adaptation and mitigation strategies. It is known that these scenarios will impact the contaminant concentrations in residential buildings (Spengler 2012, Nazaroff 2013, Zhong & Lee 2017, Fazli & Stephens 2021).

2 METHODS

To address the study objectives, a 3 phase process was carried out as follows. 1) A measurement campaign carried out by lab made devices with calibrated Low-Cost Sensors (LCS), between 20 June to 31 August 2021. The target pollutants (CO, NOx, PMs, VOC, and O_3), as well as the meteorological data (T, P, RH, and wind (outdoor only)), both indoors and outdoors were recorded. 2) An IAQ multi-zone model was developed in CONTAM. The IAQ model was validated (by ASTM-D5157) and calibrated with the measured data by LCS of the basis year of 2021. 3) Future input variables for the IAQ model were obtained (see Figure 1). The future ambient climate data was obtained from the climate model "MAR", with a spatial resolution of 5 km (Doutreloup & Fettweis, 2021). Three different future climate scenarios were considered based on Shared Socio-economic Pathways (SSPs) 2, 3, and 5. Future outdoor air pollution data was obtained by a developed deep learner artificial neural network (ANN), with a hybrid structure of CNN-BiLSTM. The input and output layers of the ANN consisted of weather data and outdoor air pollution data, respectively. The learning, validation, and the test processes of the ANN were carried out by the past 15 years hourly outdoor air pollution and climate data of 5 different regions in Belgium. The future indoor temperatures were obtained by the hourly measured indoor to outdoor air temperature ratios of the 2021 experiments. With the assumption of fixed occupants and ventilation behavior, the future outdoor air pollution, and indoor and outdoor climate data were fed to the case-study CONTAM model (basis-year 2021).

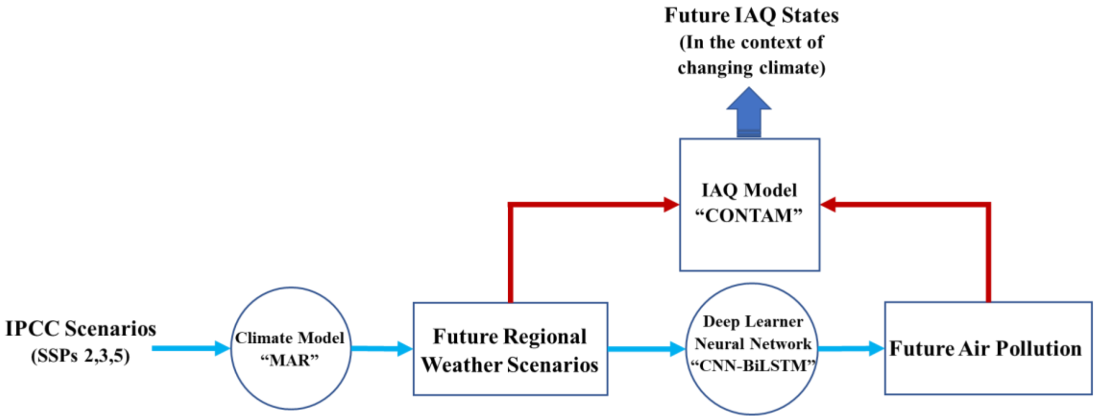

Figure 1. Conceptual framework of the "future state" inputs for the IAQ model.

3 RESULTS

The mean concentrations of LCS measurement and output of CONTAM (20 June to 31 August 2021), were similar at the 77% level of confidence for PMs, 83% for CO, and +90% for other contaminants. The deep-learner network (CNN-BILSTM) test performance for prediction of future outdoor O_3 levels based on temporal and spatial meteorological information showed correlation agreement of r=0.87. Estimating results of future IAQ levels by CONTAM for this case-study indicated increased levels of NO_2 (slightly), PM_{10}, and O_3, those with periodic indoor sources which are naturally ventilated with decreased outdoor concentrations; decreased levels of $PM_{2.5}$ and NO; those with dominant outdoor sources which impact indoor concentrations (by ventilation) with increased outdoor levels, and no variations in CO levels.

4 CONCLUSION

The new methodology developed allows for consistent results based on a deterministic approach and can be used for IAQ predictions under future climate scenarios. The overall methodology including 1) the application of calibrated LCSs for indoor & outdoor measurements, 2) using of CONATM as a free and advanced IAQ multizone modelling software, 3) employing a climate model with regional resolution of 5km for future weather data, and 4) utilizing the Artificial Intelligence (deep-learner black box model) for future ambient pollutant concentrations; provides a reasonably time and cost-efficient solution for the quantitative assessment of the climate change impacts on IAQ.

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