The impacts of COVID-19 pandemic on the hygrothermal environment of our homes

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Abstract. In 2020 the residential sector witnessed a complete transformation of the way people live and occupy the spaces. Indeed, different Countries introduced total lockdowns as a measure to contain and prevent the spread of COVID-19, forcing people to stay at home. These measures impact the indoor hygrothermal environment: higher internal thermal loads and moisture generation rate may create the perfect situation to support mould growth. This project aims to understand the impacts of increased work-from-home practices on the hygrothermal performance of residential buildings. The assessment uses a two-step methodology: firstly, whole building transient simulations (software trnsys) are used to generate the indoor temperature and humidity profiles, secondly hygrothermal transient simulations (software WUFI) are used to quantify the risk of mould growth. This research reveals the inadequacy of current design and construction practices to support flexible occupation patterns.

1. Introduction
The global pandemic of 2020 exposed the residential sector to new challenges, lifting the institutional barriers to remote work. Globally, the pandemic pushed the boundaries of the way we live and occupy the space with some countries enforcing rigid lockdowns, with people not allowed to leave their homes. In New South Wales (NSW), the Government and Ministry of Health encouraged work from home (WFH) form early 2020, resulting in 46% of the NSW workforce working remotely [1].

It is estimated that 63% of NSW workers had the potential to WFH pre-pandemic, but only 25% took this advantage for 1 or 2 days per week [1]. After 2020, between 67% and 76% expects to regularly WFH [2], with the majority aiming for 3 or more days in remote [1]. With increasing time spent indoors, the ability of the buildings to provide healthy indoors become critical.

However, Australian houses are known for their poor thermal performance [3], as well as hygrothermal behavior [4]. Almost one on three Australia homes suffer from excessive damp and mould proliferation, with significant economic [5] and health impacts [6]. Mould favorable conditions for growth include warm temperature and high humidity environment, yet a relative humidity of 70% may be enough for mould to germinate and initiate the growing process [6].

Higher occupancy rates resulting from WFH arrangements, as well as moisture-intense activities that rigid lockdowns forced to be performed at home, lead to increased levels of indoor humidity. This, in turn, may support faster mould growth and lead to unhealthy and hazardous indoor environments.

This paper investigates the effects of WFH arrangements and cyclical lockdowns on the indoor environment, specifically looking at mould occurrence in Sydney, Australia homes. The scope of the
research is to provide quantitative evidence about the effects of different WFH arrangements in the residential sector.

2. Methods and tools
The transient hygrothermal calculations are performed in WUFI Pro and assessed following the VTT mould growth model [7], which is based on the mould index (MI). For indoor surfaces MI should always be lower than 1, meaning that mould should never occur, neither at the microscopic scale. MI between 1 and 2 indicates the need for further assessment, while MI above 2 is deemed unacceptable for the building occupants’ health.

2.1. Wall assemblies
This study targets typical construction technologies to identify how standard buildings can cope with different occupancy scenarios. Hence, the selected wall assemblies reflect the most diffused construction typologies across Australia, as indicated by the National Construction Code NCC [11].

Three different assemblies with three different structural materials have been selected:
- Steel/timber frame: plasterboard (26mm), steel or timber frame with glass wool 11kg/m³ (50mm) between the vertical studs, plasterboard (26mm), rainscreen
- Concrete: plasterboard (13mm), concrete (75mm), glass wool 11kg/m³ (75mm), rainscreen
- Masonry: interior plasterboard (13mm), clay bricks (110 mm), air gap (20mm), mineral wool 11/m³ (50mm), rainscreen.

2.2. Indoor climate scenarios
The indoor climate, meant as combination of hourly temperature and indoor humidity, has been generated through transient thermal simulations (trnsys). The selected architectural model is a two-bedroom apartment, designed according to the NSW Apartment Design Guide [9], designed to accommodate four occupants. A description of the model can be found in [9].

2.2.1. Occupancy patterns. Five different occupancy patterns have been considered. Starting from the internal sensible and latent heat gains standardized by the Energy Rating Scheme (NatHERS) guidelines [10], the occupancy density and moisture generation rate has been modified based on emerging WFH trends [1]. The following scenarios have been considered:
- Scenario 1: standard occupancy as per NatHERS [10];
- Scenario 2 and Scenario 3: future WFH trends, 1 day/week WFH, 2 day/week WFH;
- Scenario 4: lockdown scenario, full occupancy;
- Scenario 5: cyclical lockdown, mixed WFH and full occupancy.

The same reference is used to assume all other parameters necessary to perform the calculation, such as ventilation air rate [10].

3. Results and discussion
Results show that increased indoor hygrothermal loads lead to an increased risk of mould growth. Albeit characterized by different materials and construction technologies, all wall assemblies show similar behaviours and trends as shown in Figure 1.
Figure 1. Mould Growth Index for the different scenarios assessed on the internal surface of a north facing wall.

When occupants work remotely 1 or 2 days per week, the associated risk of mould growth is higher, but still within the acceptable risk thresholds. On the contrary, full lock-down scenarios result in an unacceptable risk of mould growth, highlighting how the wall assemblies are very likely to be affected by mould growth due to the increasing hygrothermal loads. Despite it is highly unlikely that full lockdown measures will be taken for prolonged period of time, this scenario may be representative of increasing voluntary WFH situations. As suggested by scenario 5, also mixed WFH arrangements or cyclical lockdowns throughout the year are likely to result in mould occurrences. Indeed, the MI increases over time with a rate that would lead to unacceptable mould growth risk in less than 6 years.

4. Conclusions
This paper investigates the effects of novel work-from-home arrangements and it demonstrates that typical Australian homes are not equipped to cope with increasing indoor hygrothermal loads. Current construction practices already perform poorly under standard conditions [3][4][5], and this analysis reveals that future trends may aggravate this issue even further. The findings reveal the need for an update of the current design and construction practices, including a re-assessment of the occupancy schedules currently prescribed by the relevant certification standards, to ensure that present and future buildings will be capable to adapt to changing occupancy patterns and offer healthy indoor environments.

Albeit this study refers to Sydney as case study and it is contextualized to the Australian construction market, the findings call for a common international effort aimed at assessing and quantifying the hygrothermal risks derived from national WFH trends. Indeed, if possible, international cases where the temperature difference between indoor and outdoor is higher, or where the air change rate due to higher energy efficiency requirements is lower, are likely to show even higher mould growth risks, posing a serious threat to the health of the building occupants.

Future research will build upon an indoor environmental monitoring campaign undertaken on several case studies to provide robust occupancy patterns and reduce the simulation uncertainties.

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