TOILET (WC) and BATHROOM

ODOUR VENTILATION STUDY

Insert Project Address Here
TOILET (WC) and BATHROOM ODOUR VENTILATION STUDY

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Acknowledgements

This report was prepared by the Australian Passive House Association.
All modelling work was carried out Desanco (Engineering Consultants) on behalf of the Australian Passive House Association.

Disclaimer

The Australian Passive House Association (APHA) has exercised care in the commissioning of this report in terms of accuracy and broadness of application as defined above. Approval of a performance solution for specific projects ultimately rests with the designated project Certifier and as such APHA does not warrant that it will be accepted. APHA shall therefore not be held liable for any loss or damage resulting from assumed compliance with National Construction Code regulations, Acts, Australian Standards and other regulatory instruments nationally or State as they apply. It is the building’s Architect/Designer & project/building owner’s obligation and responsibility to seek clarification of acceptance with their Certifier.
ABOUT

The Australian Passive House Association is an independent, not-for-profit organisation that promotes superior indoor comfort and air quality while reducing energy use and carbon emissions through the use of Passive House principals.

Passive House (or Passivhaus) was developed in Germany and has since spread throughout Europe. The standard continues to evolve and is now finding popularity in diverse climatic regions including California, Japan and Indonesia. To date 40,000 houses, schools, offices, and other building types have been built to the Passive House standard around the world.

Our Vision:

Is for all Australians to live and work in healthy, comfortable, low energy, resilient buildings.

Our Mission

Lead change by educating, promoting, and supporting the delivery of Certified Passive House buildings in Australia, through:

To Promote the Passive House standard in Australia.

- Raise awareness
- Advocate
- Educate

To Support Passive House practitioners in Australia

- Networks
- Discussions
- Information sharing

To Research issues relating to the implementation of the Passive House standard in Australia

- Climate, climate change and sustainability
- Construction
- Regulation reform
PURPOSE

The Australian Passive House Association (APHA) commissioned a study into effective ventilation rates in bathrooms to assist members and the public in their pursuit of energy efficient and cost effective solutions for Passivhaus projects. This report and attached expert evidence outlines the compliance of Passivhaus-led design strategies for bathroom ventilation under the Performance pathway of the Australian National Construction Code (NCC).

This solution is intended to apply for Class 1 and 2 buildings, addressing the mechanical ventilation requirements of the relevant volume of the Building Code of Australia (BCA) of the NCC, though it can be used more widely as acceptable to the relevant certifier. This document is to be read in relation to being a performance solution as per clause A2.2 Assessment Methods, Vol 1 of the NCC 2019.

NATIONAL CONSTRUCTION CODE RELEVANCE

This study demonstrates compliance through the satisfying of the performance requirements relevant to:

- Class 2 buildings, NCC BCA Volume 1, Part F4.5, NSW F4.5(b)

  **F4.5 Ventilation of rooms**

  (b) a mechanical ventilation or air-conditioning system complying with AS 1668.2 and AS/NZS 3666.1.

- Class 1 buildings, NCC BCA Volume 2, Part P2.4.5

  The Objective is to safeguard occupants from illness or loss of amenity due to lack of air freshness.

  **P2.4.5 Ventilation**

  (a) A space within a building used by occupants must be provided with means of ventilation with outdoor air which will maintain adequate air quality.

  (b) A mechanical air-handling system installed in a building must control—

  (i) the circulation of objectionable odours; and

  (ii) the accumulation of harmful contamination by micro-organisms, pathogens and toxins.

(c) Contaminated air must be disposed of in a manner which does not unduly create a nuisance or hazard to people in the building or other property.

Noted that compliance with the NCC is achieved by satisfying the performance requirements as documented in Part A2 Compliance with the NCC. This is demonstrated through specialist consultant evidence which verifies the application of Passivhaus design methods.

**METHODOLOGY**

Demonstrating the application of the relevant performance requirements as per A2.2 the comparison of expectation of the current regulation documents requirements to Passivhaus standards is as follows:

The Deemed to Satisfy (DTS) route to compliance for bathroom and WC spaces without natural ventilation requires a minimum extract ventilation rate, nominally at 25L/s. The operation of this system is not stipulated, and thus introduces a wide range of expectations and user experiences.

A typical solution in a Passivhaus design is for much lower extract rates as part of an overall mechanical solution, being 12 L/s for durations of 9 minutes (WC incorporated into a bathroom) up to 16 minutes (WC is standalone). The critical difference lies in the operating strategy, with Passivhaus systems operating constantly (24/7) with boost capability; the DTS solution, having no minimum duration requirements, typically operates for the occupied time only (expected to be between 2-5 minutes).

**EVIDENCE**

Computation Fluid Modelling CFD report by Desanco (Appendix 1) demonstrates that the performance of the defined lower volume continuous ventilation solution exceeds the minimum requirements as set out in the DTS requirements of the NC. This is done by comparing the concentration of H2S during and after the use of amenities for both the continuous ventilation and prescribed DTS solution.

Full copy of report is attached in appendix 1. This evidence demonstrates the compliance with the performance requirements as stipulated in NCC BCA Vol 1 & 2 clauses FP4.3, FP4.4, FP4.5 and P2.4.5.

**EXPERTS & EVIDENCE**
CURRENT BUILDING STOCK

Current building stock typically relies on mechanical extraction of 25 l/s or more or an operable window to provide an acceptable natural ventilation solution.

Passivhaus strategy focuses on excellent air quality as a precondition for good building design as is evidenced with many thousands of successful projects worldwide and dozens in Australia. The typical ventilation solution delivers both supply air and extract, in a balanced system, to ensure this is maintained. We hope the provided CFD study, delivered with independent verification of performance, can assist with the delivery of many more cost-effective, simple and exemplar projects.

SUMMARY

Projects can submit the attached report directly to their Building Surveyor or Certifier for consideration.

The solution within demonstrates that the Passivhaus levels of ventilation successfully deliver better than the required air quality solution for a range of bathroom and WC spatial solutions.

CONTACT

TOILET (WC) and BATHROOM ODOUR VENTILATION STUDY

Australian Passive House Association is available to assist with queries that may arise in application of the information provided herein.

Contact admin@australianpassivehouseassociation.org
**TECHNICAL STATEMENT**

for

TOILET (WC) and BATHROOM ODOUR VENTILATION application using PASSIVHAUS standards

**PRODUCT DESCRIPTION:**
Effective ventilation rates in bathrooms to assist APHA members and the public in their pursuit of energy efficient and cost effective solutions for Passivhaus projects and ventilation of ancillary rooms, primarily wc’s and bathrooms.

**APPLICATION AND INTENDED USE:**
This solution is intended to apply for Class 1 and 2 buildings, addressing the mechanical ventilation requirements of the relevant volume of the Building Code of Australia (BCA) of the NCC, though it can be used more widely as acceptable to the relevant certifier.

**COMPLIANCE WITH THE NATIONAL CONSTRUCTION CODE:**
The Performance Requirements and/or Deemed-to-Satisfy Provisions (including the NCC edition) which the Product Technical Statement asserts compliance with are:

- Class 1 buildings, NC BCA Volume 1, Part F4.5(b), 2019
- Class 2 buildings, NC BCA Volume 2, Part P2.4.5, 2019

Computation Fluid Modelling CFD report by Desanco demonstrates that the performance of the defined lower volume continuous ventilation solution exceeds the minimum requirements as set out in the DTS requirements of the NC. This is done by comparing the concentration of H2S during and after the use of amenities for both the continuous ventilation and prescribed DTS solution.

Passivhaus levels of ventilation successfully deliver better than the required air quality solution for a range of bathroom and WC spatial solutions.

**LIMITATIONS OF USE:**
- Limited to Class1 and Class 2 buildings as defined by the NCC 2019

**CONDITIONS OF USE:**
Compliance with the voluntary passivhaus standard modelling through PHPP is required. Testing of same to verify the achievement of designed outcome is required during and post construction.

**INSTRUCTIONS FOR DESIGN, CONSTRUCTION OR INSTALLATION:**
Passive House is fundamentally about design. It is best approached as an integrated design process with the whole design team involved. As a fabric-first construction standard summarised by 5 design principles and performance criteria, it ensures a design delivers very high performance and comfort for the lifetime of the building, plugging the “Performance Gap” often experienced in building operations. It relies on building physics and carefully integrated, minimal building services and technology. By eliminating the need to bolt expensive additional technology onto a poorly performing building, it eliminates the risk of bolt-on green-bling compromising the architecture.

**MAINTENANCE INSTRUCTIONS:**
As per the manufacturers requirements for selected installed mechanical equipment.

**SUPPORT:**
https://passivehouseaustralia.org/about-us/  
admin@australianpassivehouseassociation.org
## WC Odour Ventilation

### CFD Assessment

<table>
<thead>
<tr>
<th>REV</th>
<th>DATE</th>
<th>DESCRIPTION</th>
<th>ORIG</th>
<th>APPR</th>
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</thead>
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<td>A</td>
<td>01-Nov-2017</td>
<td>Issued for use</td>
<td>AS</td>
<td>CP</td>
</tr>
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</table>

☒ Company Confidential

| Total Number of Pages (Including Cover Sheet) | 17 |

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EXECUTIVE SUMMARY

Desanco Pty Ltd has been commissioned by the Australian Passive House Association (APHA) to provide an odour ventilation assessment to determine the dissipation of hydrogen sulphide (H₂S) gas in a typical WC and bathroom. The aim of the assessment is to determine the ventilation effectiveness of the objectionable odours (in this case, H₂S) for two design scenarios (namely a passive house design, and an AS1668.2-compliant design).

The performance of the two designs has been assessed with computational fluid dynamics (CFD) modelling. The findings of this study can be summarized as follows:

- More H₂S/air mixing is observed for the WC due to the small size of the room;
- Lower H₂S concentrations are observed for the bathroom due to the large size of the room;
- Although the peak H₂S concentrations are similar for the standard and passive house designs, the H₂S concentrations decrease much more rapidly with time for the passive house design;
- The H₂S concentrations remain close to or above the odour threshold for the majority of time for the standard design, whereas for the passive design the H₂S concentrations decrease below the odour threshold in a matter of minutes;
- Better overall ventilation is observed for the passive house design.
### ACRONYMS & ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APHA</td>
<td>Australian Passive House Association</td>
</tr>
<tr>
<td>CFD</td>
<td>Computational Fluid Dynamics</td>
</tr>
<tr>
<td>ERV</td>
<td>Energy Recovery Ventilator</td>
</tr>
<tr>
<td>H₂S</td>
<td>Hydrogen Sulphide</td>
</tr>
<tr>
<td>NCC</td>
<td>National Construction Code</td>
</tr>
<tr>
<td>WC</td>
<td>Water Closet</td>
</tr>
</tbody>
</table>
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1 INTRODUCTION

1.1 Objective

Desanco Pty Ltd has been commissioned by APHA to provide an odour ventilation assessment for typical residential WCs/bathrooms. CFD is used to assess the extraction of unpleasant odours (in this case, H$_2$S) for two different designs, i.e. that corresponding to a NCC 2015 F4.5(b) design, compared to a generic passive house design as proposed by APHA.

The competing designs are assessed for two typical room sizes (i.e. smaller and larger rooms).

1.2 Design

The standard practice for the ventilation of residential rooms is to comply with Clause F4.5(b) of the NCC which requires a mechanical ventilation or air conditioning system complying with AS1668.2 and AS/NZS 3666.1. An alternative option as proposed by APHA is to replace the AS1668.2-compliant exhaust system with an energy recovery ventilator (ERV).

Whereas the AS1668.2-compliant exhaust system may be assumed to be in operation only when the WC is occupied (and switched off when unoccupied), the ERV system is proposed to operate continuously, irrespective of occupancy, in accordance with passive house design principles. To maintain energy efficiency, the continuous extraction rate is much lower compared to the requirements of AS1668.2.

The aim of the current modelling is to assess the ventilation performance of the ERV system compared to the standard mechanical exhaust system.

1.3 Performance Requirements

The performance requirements can be viewed in terms of the levels of H$_2$S in the modelled rooms; H$_2$S is a product of human bowel movements and is often described as a “rotten egg” smell. It is objectionable at low concentrations and deadly at high concentrations as summarized in Table 1 below.

<table>
<thead>
<tr>
<th>Concentration (ppm)</th>
<th>Symptoms/Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00011 – 0.00033</td>
<td>Typical background concentrations</td>
</tr>
<tr>
<td>0.01 – 1.5</td>
<td>Odour threshold (when rotten egg smell is first noticeable to some)</td>
</tr>
<tr>
<td>2 – 5</td>
<td>Prolonged exposure may cause nausea, tearing of the eyes, headaches</td>
</tr>
<tr>
<td>20</td>
<td>Possible fatigue, loss of appetite, headache, irritability, dizziness</td>
</tr>
<tr>
<td>50 – 100</td>
<td>Slight conjunctivitis and respiratory tract irritation after 1 hour</td>
</tr>
<tr>
<td>100 – 150</td>
<td>Loss of smell (olfactory fatigue or paralysis)</td>
</tr>
<tr>
<td>200 – 300</td>
<td>Marked conjunctivitis and respiratory tract irritation after 1 hour</td>
</tr>
<tr>
<td>500 – 700</td>
<td>Staggering, collapse in 5 minutes; serious damage to the eyes in 30 minutes, death after 30 – 60 minutes</td>
</tr>
<tr>
<td>700 – 1000</td>
<td>Rapid unconsciousness, breathing stops, death within minutes</td>
</tr>
<tr>
<td>1000 – 2000</td>
<td>Nearly instant death</td>
</tr>
</tbody>
</table>

Table 1. Effects of H$_2$S exposure (cf. [https://www.osha.gov/SLTC/hydrogensulfide/hazards.html](https://www.osha.gov/SLTC/hydrogensulfide/hazards.html)).
For the current study, the maximum H₂S concentrations are expected to be within the highlighted range in Table 1. Since the study is comparative, the ventilation performance of the two designs will be assessed in terms of H₂S concentrations with time.

1.4 Limitations

The findings and opinions expressed in this report are based on the conditions encountered and/or the information available at the date of issue of this document, and shall be applicable only to the circumstances presented herein. In addition:

- No liability is accepted for the use of the findings of this report outside of the simulated conditions;
- No liability is accepted for the accuracy of documents provided by any third party which form the basis of this analysis.

This document contains commercial, conceptual and engineering information which is proprietary to Desanco Pty Ltd. Inclusion of this information does not grant the Client any license to use the information or to divulge it to a third party without Desanco’s written permission.
2 METHODOLOGY

2.1 Input Data

The briefing information used to compile this report comprises the following items:
- Room dimensions;
- Operation of exhaust fans;
- H2S emissions volume and duration.

2.2 Design Scenarios

A generic WC and bathroom is considered in this study as shown in Figure 1. The geometries are representative of typical residential rooms, with room length (L), width (W) and height (H) as summarized in Table 2.

The scenarios simulated are described in Table 3. For each scenario, a hydrogen sulphide volume of 0.00037422 L is released within the toilet bowl for a duration of 2 minutes – this represents the approximate time that a person occupies the space.

Each room is provided with make-up air only from air infiltration underneath the door of the room; no other mechanical supply or natural ventilation source is provided. Each scenario is simulated for 60 minutes to allow for a statistically meaningful H2S transient profile to be obtained; this profile is plotted at a monitoring point located in the centre of the room at an elevation of 1.8m above floor level as shown in Figure 1.

<table>
<thead>
<tr>
<th>Room ID</th>
<th>Room Description</th>
<th>Dimensions (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Room 1</td>
<td>Typical WC with basin and toilet</td>
<td>2</td>
</tr>
<tr>
<td>Room 2</td>
<td>Typical bathroom with shower, bath, basin and toilet</td>
<td>4</td>
</tr>
</tbody>
</table>

*Table 2. Room dimensions.*

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Room</th>
<th>Description</th>
<th>Exhaust Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flowrate (L/s)</td>
</tr>
<tr>
<td>1</td>
<td>WC</td>
<td>Standard design</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Passive house design</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Bathroom</td>
<td>Standard design</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Passive house design</td>
<td>12</td>
</tr>
</tbody>
</table>

*Table 3. Simulation scenarios.*
2.3 Assumptions

The following assumptions are made in this study:

- A uniform air temperature of 20°C is simulated, which is representative of typical home conditions;
- The densities of both air and H₂S are calculated from the incompressible ideal gas law at the above-mentioned temperature;
- The exhaust fans are assumed to start and shut down instantaneously (i.e. no ramping).
3 COMPUTATIONAL MODEL

3.1 Software

The software used in this study is ANSYS Fluent, which is the world’s leading general-purpose CFD analysis software. Its reliability is well validated by academic researchers, independent organizations, technology partners and clients. Fluent is the tool of choice for many of the world’s largest and most innovative companies. Furthermore, ANSYS has a deep and longstanding commitment to quality, being the first organization to receive ISO 9001 certification for design analysis software.

3.2 CFD Model

The CFD model for both rooms was created based on generic WC and bathroom designs and is shown in Figure 1; the following items are highlighted:

- WC and bathroom fixtures – dark grey;
- Make-up air gap underneath the door – cyan;
- Exhaust fan – red.

The geometry was meshed using hexahedral elements. Mesh sizes were approximately 0.1 million cells and 0.3 million cells for the WC and bathroom respectively.

The realizable $k$-$\varepsilon$ turbulence model was used for its robustness and accuracy, and is known to be far superior to other $k$-$\varepsilon$ models because of its better performance for separated flows and situations with complex secondary flow features.

3.3 Boundary Conditions

The boundary conditions applied in this study are summarized in Table 4. The inlets to the fans were modeled with fan boundary conditions, which require pressure inputs to satisfy velocity (or flow rate) outputs.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Fan</td>
<td>Scenarios 1 &amp; 3</td>
<td>Velocity outlet</td>
<td>25 L/s</td>
</tr>
<tr>
<td></td>
<td>Scenarios 2 &amp; 4</td>
<td>Velocity outlet</td>
<td>12 L/s</td>
</tr>
<tr>
<td>Make-up air void</td>
<td>0.82 x 0.01 m gap beneath door</td>
<td>Pressure outlet</td>
<td>0 Pa</td>
</tr>
</tbody>
</table>

Table 4. Boundary conditions.
4 RESULTS

The H\textsubscript{2}S gas concentrations for all scenarios are shown at a vertical plane intersecting the toilet and exhaust fan in Figure 2 to Figure 5. The plots are shown at four different time intervals, namely at 2 minutes (when the gas emissions (and exhaust fan for Scenarios 1 and 3) cease), 16 minutes, 30 minutes and 60 minutes. The H\textsubscript{2}S concentrations at the monitoring point are shown in Figure 6 for all cases.

For all scenarios, fresh air is entrained into the room from the void underneath the door. For the WC room, the exhaust rate is high for the standard design (compliant with AS1668.2), such that the H\textsubscript{2}S mixes with the fresh air for the first 2 minutes; in contrast, the lower exhaust rate for the passive design induces less mixing and more direct extraction of the H\textsubscript{2}S. As time progresses, for the standard design the H\textsubscript{2}S begins to settle down whereas for the passive design the H\textsubscript{2}S is essentially completely removed.

For the bathroom, similar observations may be made although the magnitude of mixing is much less pronounced due to the size of the room.

Investigation of the H\textsubscript{2}S profiles at the monitoring location in Figure 6 shows that the H\textsubscript{2}S concentrations are above the odour threshold (i.e. 0.01 ppm) at various times; these are summarized in Table 5. For the standard design, for both the WC and bathroom the H\textsubscript{2}S remains above the odour threshold for most of the simulated timeframe; it should be noted, however, that the influence of the door opening (thereby introducing more fresh air and diluting the H\textsubscript{2}S concentrations) has not been considered. Nevertheless, for the passive house design the H\textsubscript{2}S concentrations decrease to below the odour threshold in a matter of minutes.

In summary, it is evident that the passive house design does a much better job of removing the objectionable odours from both the WC and bathroom models.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Room</th>
<th>Description</th>
<th>Time Above Odour Threshold (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time of Onset</td>
</tr>
<tr>
<td>1</td>
<td>WC</td>
<td>Standard design</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Passive house design</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>Bathroom</td>
<td>Standard design</td>
<td>2.9</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Passive house design</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Table 5. Time above odour threshold.
Scenario 1 – Standard design

**H₂S concentration at 2 mins**

Scenario 2 – Passive house design

**H₂S concentration at 16 mins**

---

**Figure 2.** Comparison of H₂S gas concentrations (in ppm) for Scenarios 1 & 2.
<table>
<thead>
<tr>
<th>Scenario 1 – Standard design</th>
<th>Scenario 2 – Passive house design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂S concentration at 30 mins</strong></td>
<td><strong>H₂S concentration at 30 mins</strong></td>
</tr>
<tr>
<td><img src="image1" alt="Scenario 1 H₂S concentration at 30 mins" /></td>
<td><img src="image2" alt="Scenario 2 H₂S concentration at 30 mins" /></td>
</tr>
<tr>
<td><strong>H₂S concentration at 60 mins</strong></td>
<td><strong>H₂S concentration at 60 mins</strong></td>
</tr>
<tr>
<td><img src="image3" alt="Scenario 1 H₂S concentration at 60 mins" /></td>
<td><img src="image4" alt="Scenario 2 H₂S concentration at 60 mins" /></td>
</tr>
</tbody>
</table>

**Figure 3.** Comparison of H₂S gas concentrations (in ppm) for Scenarios 1 & 2.
### Scenario 3 – Standard design

**H$_2$S concentration at 2 mins**

![Image of H$_2$S concentration at 2 mins for Scenario 3]

### Scenario 4 – Passive house design

**H$_2$S concentration at 16 mins**

![Image of H$_2$S concentration at 16 mins for Scenario 4]

**Figure 4.** Comparison of H$_2$S gas concentrations (in ppm) for Scenarios 3 & 4.
**Figure 5.** Comparison of H$_2$S gas concentrations (in ppm) for Scenarios 3 & 4.
<table>
<thead>
<tr>
<th>Scenario 1 – Standard design</th>
<th>Scenario 2 – Passive house design</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 3 – Standard design</th>
<th>Scenario 4 – Passive house design</th>
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</thead>
<tbody>
<tr>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
</tbody>
</table>

**Figure 6.** H₂S gas concentration vs time at the monitoring point.
5 CONCLUSIONS

An odour ventilation assessment has been performed for a generic WC and bathroom to determine the ventilation performance of a passive house design as opposed to an AS1668.2 compliant design. Using CFD analysis, the extraction of H₂S gas has been simulated and the designs compared.

The findings of this study can be summarized as follows:

- More H₂S/air mixing is observed for the WC due to the small size of the room;
- Lower H₂S concentrations are observed for the bathroom due to the large size of the room;
- Although the peak H₂S concentrations are similar for the standard and passive house designs, the H₂S concentrations decrease much more rapidly with time for the passive house design;
- The H₂S concentrations remain close to or above the odour threshold for the majority of time for the standard design, whereas for the passive design the H₂S concentrations decrease below the odour threshold in a matter of minutes;
- Better overall ventilation is observed for the passive house design.