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Managing condensation and mould in Malaysia

Dr Muhammad Syukri Imran Abdullah, registered professional engineer with BEM Malaysia, and Dr Khairul Azmy Kamaluddin, president of Biomedical Engineering Association of Malaysia (BEAM), look at the strategies Ministry of Health Malaysia is using to manage condensation-related mould issues in healthcare facilities, showcasing how they prioritise health and safety while navigating moisture control complexities.

The Ministry of Health Malaysia (MOH) has been dedicated to providing healthcare services to the nation's citizens while maintaining high standards in its facilities. However, the challenge of condensation and mould growth persists due to Malaysia's humid climate. MOH has taken proactive steps to address this issue, given the health and structural risks it poses. Over the years, as Malaysia has urbanised and built more healthcare facilities, some constructions did not fully consider the climate's challenges. Notably, classic cases like the Sultan Ismail Hospital (SAMY, 2004) and Air Keroh Healthcare Clinic (YEEN, 2008) mould outbreaks highlighted this issue, leading to temporary closures. In MOH facilities, managing mould growth due to condensation is a significant concern. This challenge arises from moisture accumulation, the tropical climate, and building design.

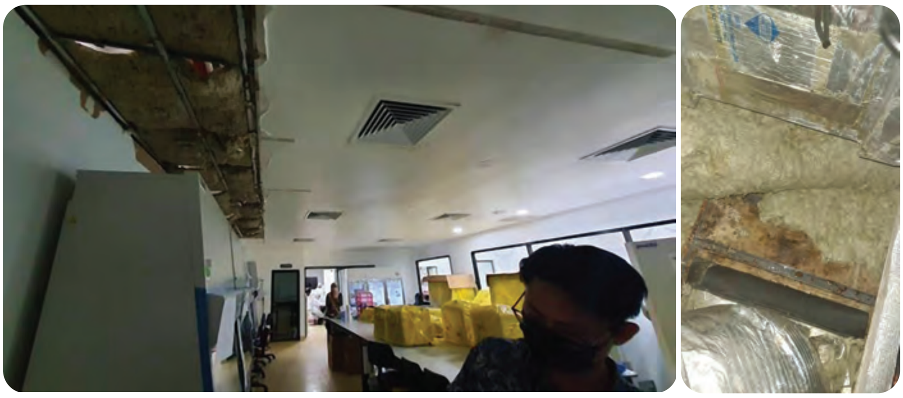

Figure 1. Condensation on ceiling and metal supports.

Local experience and lessons learned

Issues of condensation in healthcare facilities in Malaysia can be primarily attributed to two major factors: building design and ventilation systems. High humidity levels pose unique challenges in maintaining indoor environments that are free from excessive moisture. The design of healthcare facilities plays a crucial role in determining how effectively moisture is managed within the buildings. Real world incidents underscore the tangible consequences of inadequate moisture management as shown in Figure 1, which shows condensation on ceiling and metal supports which led to ceiling collapse in a general hospital.

The building design in many older healthcare facilities, and even occasionally in new facilities, did not sufficiently consider the impact of the local climate on indoor air quality. Insufficient insulation and inadequate air and vapour barriers allowed warm, moist air to come into contact with cooler surfaces, leading to condensation. Additionally, older building materials might not have been adequately moisture-resistant, further contributing to

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the problem of condensation. Moreover, ventilation systems play a critical role in maintaining indoor air quality and controlling moisture levels. In some healthcare facilities in Malaysia, the ventilation systems might have been outdated or inadequately designed to cope with the humid climate. Additionally, poorly maintained ventilation systems may accumulate dust and debris, which can lead to the growth of mould and other allergens, exacerbating indoor air quality issues. Another instance, as portrayed in Figure 2 (in which dark patches of mould growth are visible on the surfaces, indicating areas where moisture has accumulated over time due to elevated humidity levels originating from the air conditioning system as well as unintentional building envelope openings), further highlights the adverse effects of moisture-related challenges related to ventilation systems and building envelope.

Figure 2. Dark patches of mould growth are visible on the surfaces.

The following provides some overview of condensation-related challenges in healthcare facilities derived from a range of case studies, each yielding valuable lessons. Ultimately, understanding these cases and their lessons emphasises the need for comprehensive strategies to combat condensation risks.

- AHUs and chiller sync issue: AHUs in some clinics operate out of sync with the chiller system, causing them to run without chill water. This leads to outdoor humid air being drawn in without dehumidification, resulting in condensation as warm air meets cold surfaces.
- Fan Coil Unit (FCU) duct defect: a day-care centre experienced unexpected condensation due to a defect in shared fresh air ducts among fan coil units. Elevated room humidity occurred after working hours, causing condensation due to differential vapour pressure conditions.
- Intentional air conditioning (AC) operation: leaving ACs intentionally running after office hours, led to surface wall condensation in rooms not designed for 24-hour air conditioning.

Figure 3. Wet and saturated PU foam.

- Cooling equipment sizing issues: insufficient cooling capacity caused ACs to struggle in maintaining desired temperature, leading to high indoor humidity. Oversized ACs resulted in frequent compressor cutting out, pulling in humid air and causing surface condensation.
- Door ajar issue: leaving air-conditioned patient room doors ajar introduced humid, warm air from adjacent areas, leading to condensation on cooler surfaces.
- Change in space use impact: transitioning from open ward to ICU ward introduced condensation issues due to MVAC modifications, temperature differentials, and inadequate insulation.
- Wet and saturated PU foam: insufficient thickness of PU foam insulation led to wet and saturated conditions, reducing thermal performance, and potentially causing moisture-related issues (Fig 3).
- Condensation on soffit of reinforced concrete (RC) slab: a classic case at Sultan Ismail Hospital observed condensation on the soffit of an RC slab. This occurrence is attributed to the cold and uninsulated surface exposed to high humidity levels prevalent in the area (Fig 4).

An in-depth understanding of the various factors contributing to condensation is crucial for effective moisture management within healthcare facilities. To shed light on these causes and their implications, we present the following tables that categorise and detail the sources of condensation-related challenges in healthcare environments. Table 1 outlines the causes of condensation associated with building envelope conditions, Table 2 highlights the causes stemming from defects in mechanical cooling and ventilation systems, and Table 3 covers

Figure 4. Condensation on the soffit of a RC slab.

Table 1. Causes of condensation related to building envelope or design condition.

Causes	Effects	Proposed mitigations
Cold surfaces meeting warm air	Condensation forming on surfaces	Improve insulation; seal air leaks
Inadequate sealing of windows and doors	Moisture entering indoors	Improve weather stripping; seal gaps
Building envelope air leaks	Air leaks, moisture intrusion	Seal cracks and gaps
Cracks and unintentional openings	Moisture intrusion, mould growth	Seal cracks, identify and address intentional openings
Non-vapour barrier materials with thermal barrier properties – condensation absorption	Trapping moisture and promoting mould growth	Use vapour barrier coatings; Improve ventilation

additional factors that contribute to condensation. By examining these tables, we gain valuable insights into the complexities of moisture-related issues in healthcare settings, helping us develop targeted strategies for prevention and mitigation.

Proactive approach

MOH implements a comprehensive approach and multifaceted strategy to tackle condensation and mould issues within its healthcare facilities for the health and safety of patients, staff, and visitors. Firstly, MOH engineers and facility managers (FM) adopt internationally recognised guidelines and standards that provide clear instructions on designing, constructing, and maintaining healthcare environments to prevent condensation and mould growth. These guidelines encompass aspects like proper ventilation, moisture control, insulation, and building materials. Prominent guidelines, standards, and a local case study in Table 4 provide insights for managing condensation and mould.

FMs conduct regular inspections and proactive monitoring enabling early identification and swift mitigation to detect condensation and mould-prone areas. Infection control practices, including maintaining indoor air quality, hygiene protocols, and building upkeep, are emphasised. This is explicitly outlined in the facility management contract for government hospitals, which also mandates indoor air quality assessments. Trained professionals conduct comprehensive air quality tests, analysing humidity, temperature, ventilation, airborne particles, organic compounds, and mould spore counts. Detailed reports with results and recommendations guide follow-up actions, where facility management reviews, prioritises, assigns responsibilities, and implements remedies. Continuous monitoring ensures ongoing air quality improvement to protect building occupants' health.

Engineers incorporate design elements to minimise moisture accumulation, including drainage systems, moisture-resistant materials, and efficient mechanical, ventilation and air conditioning (MVAC) systems. This proactive approach is exemplified in Figure 5, which shows a retrofit project involving the installation of a new Air Handling Unit (AHU) equipped with an Outdoor Air (OA) dehumidification or preheating system – in the image, the AHU is seen integrated into the existing MVAC infrastructure; this innovative addition aims to address high humidity concerns by effectively drying the incoming outdoor air before the cooling process. Figure 6 showcases a new building project using PU panel insulative

Table 2. Causes of condensation related to defects related to mechanical cooling and ventilation of building.

Causes	Effects	Proposed mitigations
Leaky air ducts	Creates suction that draws moist outdoor air from leaky building envelope	Seal air duct leaks
Inadequate & inefficient dehumidification	High or uneven indoor humidity levels	Upgrade or adjust dehumidification system; monitor humidity levels
Incorrect thermostat settings	Temperature fluctuations	Calibrate thermostat settings; maintain consistent temperature
Chiller and blower miss synchronise	Effects of mis-synchronised chiller and blower	Mitigations for mis-synchronised chiller and blower
Inconsistent cooling	Variable temperature distribution	Synchronise chiller and blower operations; maintain systems
Multiple FCUs operating at different schedules sharing the same outdoor air intake ducting	Moisture migration from outdoor air duct into room	Separate fresh air ducts for units with varying schedules
Frequent compressor cycling and continuous air circulation with outdoor air supply	Gradually increase indoor humidity levels and promote condensation on cold surfaces	Optimising compressor control and implementing demand-based ventilation strategies
Inadequate or poor ventilation leading to stagnant, moisture-laden air	Can lead to condensation on surfaces, indoor air quality issues and discomfort for occupants	Install exhaust fans, optimise ventilation system settings, clean air filters

Table 3. Other causes of condensation.

Causes	Effects	Proposed mitigations
High indoor humidity levels due to indoor processes	Mould growth on surfaces	Maintain indoor humidity below 60 per cent; use dehumidifiers
Lack of proper maintenance	Mould growth due to unresolved issues	Establish regular maintenance schedule; promptly address issues
Changes in room or space function	Condensation due to altered usage patterns	Assess and adjust MVAC and ventilation systems; enhance insulation
Vapour pressure difference across envelope	Moisture intrusion and condensation	Use vapour barriers; ensure proper ventilation and insulation
Air pressure difference across envelope due to gusting wind or stack effect	Moisture buildup and condensation	Enhance building envelope integrity; consider pressure equalisation measures
Occupant behaviour in response to thermal comfort like heavy layers of clothing	Unnecessary overcooling of space	Educate occupants on proper indoor thermal comfort control and management
Indoor plants and trees release moisture through a process called transpiration	Can increase indoor humidity level and create a conducive environment for mould to grow on surfaces	Proper ventilation, moisture control, and regular maintenance

walls to address heat gain, air leakage, and condensation. These panels provide thermal resistance, prevent excessive heat, and minimise air leakage for energy efficiency. Their strategic use also curbs condensation risks by maintaining balanced temperatures and reducing moisture accumulation on surfaces. Additionally, MoH invests in staff training to raise awareness of condensation and mould risks, empowering them to promptly report potential issues.

MOH Engineers are also testing an innovative early warning system in selected hospitals to detect condensation risks. Specialised sensors gather temperature, humidity, and dew point data, triggering alerts when condensation risk thresholds are reached. This proactive approach leverages technology to prevent moisture-related issues and ensure a healthy indoor environment in healthcare facilities.

Apart from that, MOH have been collaborating with global experts to investigate and address condensation and mould issues. Expert's assessments cover air quality, ventilation, and moisture sources, generating comprehensive reports with recommendations. These reports guide MOH engineers in managing condensation and mould effectively, reflecting their commitment to high-quality healthcare infrastructure.

Figure 5. A retrofit project involving the installation of a new Air Handling Unit (AHU).

The highlighted strategies so far have set a precedent for healthcare facility design and operation, emphasising proper envelope design, airtight building structures, as well as meticulous ducted ventilation systems. Insulation materials like PU foam and EPS foam, along with water and vapour barriers, enhance moisture control. Predictive software was also used with building information modelling to anticipate and prevent condensation risks. Figure 7 shows the use of building modelling software which includes a built-in module for condensation risk analysis. This powerful tool allows engineers and designers to simulate and evaluate building performance in terms of condensation risks. Additionally, the software's inclusion of Computational Fluid Dynamics (CFD) wind pressure analysis provides insights into how air movement and pressure differentials could influence moisture distribution within the building. This approach empowers engineers to proactively identify and address condensation risks during the design phase, ensuring that building envelopes are well-prepared to manage moisture-related challenges effectively.

Conclusion

In the context of MOH facilities in Malaysia, effectively managing condensation and mould is pivotal for maintaining a safe and conducive environment for patients, staff, and visitors. Through a collaborative

Table 4. Highlights of prominent guidelines and standards.

	Reference	Highlights
1	ASHRAE, 2013	ASHRAE's position document on limiting indoor mould and dampness in buildings.
2	Australian Building Codes Board, 2014	Handbook on condensation in buildings, offering guidance for addressing moisture-related issues in Australian codes.
3	BSI, 2021	BS 5250-Management of moisture in buildings – Code of Practice.
4	EPA, 2008	Mould remediation guidance for schools and commercial buildings.
5	EPA, 2013	Moisture control guidance for building design, construction, and maintenance.
6	Harriman, 2017	The guidance for fungus avoidance in MOH healthcare facilities, report prepared for The Ministry of Health Malaysia
7	Harriman *et al.*, 2001	Design guides for humidity control in commercial and institutional buildings, especially in hot and humid climates.
8	Heseltine & Rosen, 2009	WHO guidelines for indoor air quality, focusing on dampness and mould issues.
9	IICRC, 2015	Reference guide for professional mould remediation.
10	Public Works Department, 2009	Guidelines on the prevention of mould growth in buildings prepared by Malaysian Public Works Department.
11	Rose, 2005	Architect's guide to moisture and mould, covering water-related challenges and prevention.
12	Sanders, 1999	CIBSE Guide A Chapter 7: Moisture transfer and condensation, addressing moisture movement and prevention.
13	Harriman, 1990	Specialised guidance for dehumidification and hot and humid climates
14	Harriman & Lstiburek, 2009	ASHRAE guide for buildings in hot and humid climates. Specialised guidance for managing moisture and mould prevention.
15	Abdullah *et al.*, 2023	In-situ measurement and remediation of condensation issues in a hospital lab during COVID-19.

approach involving international experts, adhering to comprehensive guidelines, codes, and standards, as well as learning from past experiences, MOH engineers and stakeholders have harnessed a wealth of knowledge to address complex challenges posed by humid tropical climates.

The strategy adopted encompasses a multi-faceted approach, including meticulous building design, advanced MVAC systems, specialised insulation, and predictive software for moisture control. The integration of these measures not only prevents condensation and mould growth but also boosts indoor air quality, enhancing the overall well-being of occupants. Notably, the use of predictive technology and early warning system should empower engineers to proactively manage moisture risks, setting a new precedent for healthcare facility management in the country. Through partnerships with international experts and careful implementation of best practices, MOH is in a better position in term of mould and condensation management of its healthcare facilities. IFHE

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Figure 6. PU panel insulative walls.

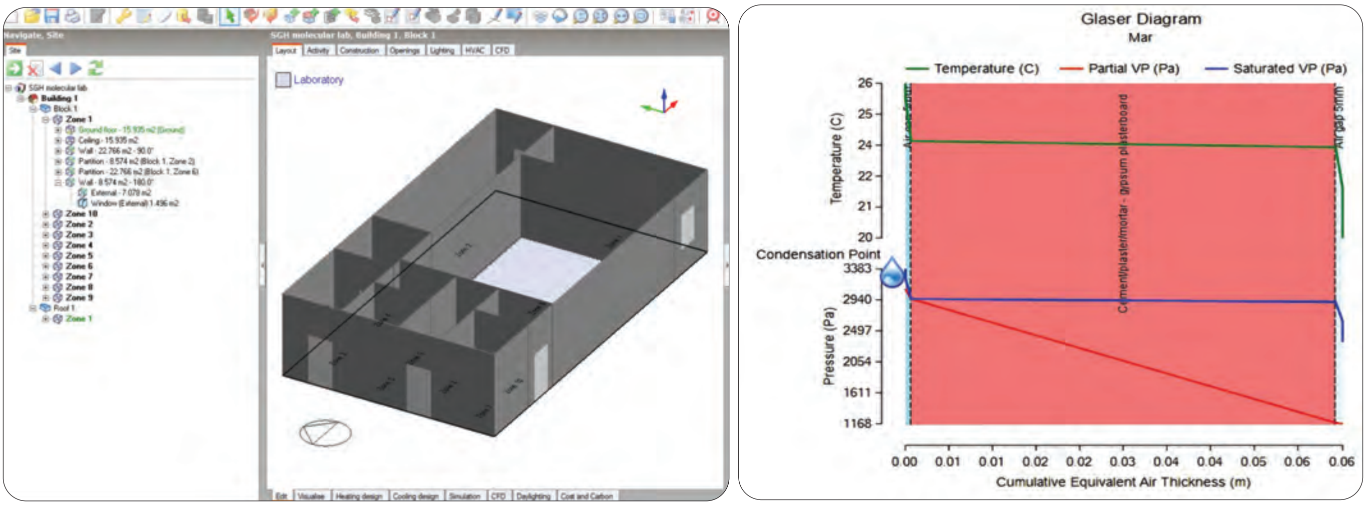

Figure 7. Condensation risk analysis.

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