Mold Growth Risk in a Newly Built Hospital Building in Malaysia – Problems and Solutions

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Post Construction Assessment (PCA) provides critical feedback for project stakeholders to be able to evaluate and design construction processes as well as building maintainability. This paper aims to evaluate the problems caused by indoor environmental quality (IEQ) contaminants, particularly mold growth during PCA in a newly built hospital and to identify the potential solutions. Mold growth risk analysis which is a part of IEQ monitoring during PCA has not been widely emphasized, and thus leads to the creation of uncertainties in many new public hospitals in Malaysia. IEQ exercises were not prioritized during PCA not until when new mold growth occurred and were alleviated. Questionnaires were distributed to hospital projects' stakeholders to identify the criteria of PCA with regards to mold growth in the new hospital's indoor air. Results showed that post construction defects coupled with building design and construction quality as well as building operational issues was significant criteria that should be evaluated during the PCA of a newly built hospital. Stakeholders' firm viewpoint on the key criteria is to be applied as a valuable input for identifying possible solutions as significant inputs in PCA for a newly built hospital.

Keywords: *Post Construction Assessment, Indoor Environment Quality, Hospital Maintenance, Mold Growth*

1. INTRODUCTION

Leakage, poor air circulation and temperature control, health and safety problems and accumulation of dirt are among the problems in building performance (Hadjri & Crozier, 2009). Post Construction Assessment (PCA) may not be able to tackle all issues as the process may take a period of few days to a month (Jabatan Kerja Raya Malaysia, 2007). The best time to carry out the whole building diagnostics should be in the period of post occupancy evaluation (POE) throughout building lifecycle (Razak & Jaafar, 2012).

Preiser (2006) described PCA which is known as pre-handing over inspection in building works, as a process of auditing design performance, construction quality and building maintainability. This process had been widely practiced as part of the building inspection and audit prior to the issuance of the acceptance certificate by relevant authority. Jabatan Kerja Raya Malaysia, (2013a) stressed that this process will ensure that the new building is fit for occupation.

PCA is a platform used for respective authorities, engineers, project managers, building users and facility management personnel's to evaluate the building systems prior to building handover. Throughout the process, building performance is tested, commissioned, fine-tuned, litigated and documented. Recommendation will be issued to whether the building is ready for occupancy or not recommended for occupancy. This method seems to have similarity to that of POE and Facilities Management (FM) (Hadjri & Crozier, 2009). While POE and FM may incur separate cost out of the building construction cost which may not be favorable to the building owner (Bee Won et al., 2013), PCA is seen to be part of the building contract cost.

Indoor Environmental Quality (IEQ) audit, a part of PCA is not largely performed in building projects in Malaysia especially for healthcare facilities projects, with comparison among other factors as well as unavailability of specific IEQ regulations in building contracts or by-laws. According to the Public Works Department of Malaysia (JKR), condition appraisal gives a report of over nine public hospital projects performance during Defects Liability Period (DLP), only two of these projects performed at a minimum IEQ audit i.e. temperature and relative humidity monitoring (Jabatan Kerja Raya Malaysia, 2007). Furthermore, guidelines with reference to prevention on mold growth in buildings were then published by JKR to provide sufficient information and measures to be taken in preventing mold formulation in buildings (Jabatan Kerja Raya Malaysia, 2009). In 2011, new public hospital projects had to incorporate IEQ in their building contracts as part of precautionary measures. Again, it was not seriously implemented during PCA. The only report on implementation of IEQ during PCA was revealed in 2013 for a newly built cancer hospital (Jabatan Kerja Raya Malaysia, 2013a).

Experience from Malaysian public hospital projects showed that mold issues were common. Razak & Jaafar (2012) stated that faulty design in hospital buildings in Malaysia among others, had to deal with environmental and biological considerations such as fungal growth. Kumar & Wc (2007) found that *Penicillium sp., Aspergillus sp. and Cladosporium sp.* which colonized a two-month old hospital were initially detected during the construction period and manageably got eliminated through the use of reactive-silane antimicrobial. From the perspectives of a global scenario, mold in hospital is not unusual and thus, preventive and curative action is largely applied. Chang et al., (2008) underlined outbreak management for fungal growth during hospital building works. This is due to high risk patients' sensitivity towards invasive aspergillosis even towards concentration of *Aspergillus* spp. less than 1cfu/m^3. Emmerich et al., (2013) introduced multi-zone airflow to reduce the risk associated with airborne infectious agents such as mold in hospital. Nevertheless, Yau, Chandrasegaran, & Badarudin (2011) acknowledged ventilation studies for non-air conditioned spaces of a hospital in tropic climate to improve IEQ. All of these studies focused on improving IEQ of a hospital to alleviate indoor air pollutants such as mold which is prone to live in the hospital indoor environment.

The objective of this study is to identify factors related to potential mold growth in hospital buildings during PCA from the perspective of healthcare facilities stakeholders and the potential solutions to mitigate the issues as a whole.

2. RESEARCH METHODOLOGY

Quantitative method based on designed questions (Appendices A) was employed by the study. Respondents comprised of engineers, architects, contractors, building owners and facilities managers who were selected based on their experience in projects, particularly in healthcare facilities project phases which comprises of planning, design, procurement, construction, operation and maintenance. Assessable population were from Public Works Department of Malaysia (JKR), Ministry of Health Malaysia (KKM), project consultants, contractors and hospital facilities concessionaires. The study population was based on stakeholders who were involved in the planning, design, construction and maintenance of public hospitals in Malaysia.

Questionnaires were developed based on relevant studies on mold risk and their issues in building. Measures for factors of mold risk were adopted from Vereecken *et. al.* (2012) and Philomena (2009). Issues pertaining to post construction of newly built hospitals were gathered from Yau *et. al.* (2011) and Jabatan Kerja Raya (2007, 2009, 2013b). The survey questionnaire was based on a Likert scale format ranging from Scale 1 which represented strongly disagree to Scale 5 which represented strongly agree. The Statistical Package for Social Sciences version 19 (SPSS) was used for descriptive analysis of the retrieved data.

The Cronbach's alpha coefficient obtained for reliability analysis were above acceptance significant level (see Table 1). The survey was administered via a combination of both online and manual face-to-face approach.

Table 1: Analysis of reliability

Variable	No. of item	Cronbach's Alpha
Parameters of mold growth	10	.822
Building defects	5	.823
Construction quality	4	.820
Mechanical ventilation design	4	.832
Architectural and structural design	4	.666
Building operational	5	.848
Total	**32**	**.739**

3. RESULTS AND DISCUSSIONS

Out of the total 300 questionnaires distributed, 152 of the questionnaires were returned and analyzed (50.7% response rate). In summary, 98.7% of respondents knew what mold or fungus meant. They also agreed that mold can grow in buildings and 93.4% respondents knew that it is dangerous to live in a building with mold.

3.1. Demographic detail of the study population

3.1.1. Results

Respondents comprised of professionals in healthcare facilities, project management, building construction or building management. From 152 respondents, the mean age of the study population was between 31 to 40 years old. There were 140 respondents in the technical and engineering profession (92.1%) and the remaining 12 respondents were purely medical staff. The nature of works varied, ranging from project managers (25%), designers (22.4%), policy makers and consultants (11.8% each), contractors (10.5%), hospital support services (7.9%), building owners (6.6%) and facility managers (3.9%). From this survey, 86.8% of respondents had relevant working experience in healthcare facilities management, planning, design or operations with the mean years of experience from 1 to 5 years (Table 2).

3.1.2. Discussion

Even though the response rate was below 70% as targeted, the results obtained, significantly represented the concerns of this study. 92.1% of the respondents were from engineering and technical background which technically represents the consistency of this study. The findings were based on eloquence which therefore made the responses to be undisputable. Post construction phase brings about a new episode of a building lifecycle as most elements of building design, planning and construction are being assessed and used in this phase by these technical masters. The nature of works of the respondents has tremendous implications as to the success or failure of a new hospital design, planning and construction. This can only be seen and experienced by building owners and operators. Thus, PCA is vital to be implemented by building stakeholders in order to mitigate the risk of faulty, malfunction or defects of such buildings in a systematic way.

Table 2: Demographic characteristics (Population, N=152)

Features		Frequency (n)	Percentage (%)
Age group	Below 30 years	10	6.6
	31-40 years	92	60.5
	41-50 years	30	19.7
	51 years and above	20	13.2
Profession	Architect	30	19.7
	Civil & Structural Engineer	50	32.9
	Mechanical Engineer	24	15.8
	Electrical Engineer	20	13.2
	Quantity Surveyor	12	7.9
	Medical Officer	2	1.3
	Healthcare Provider	10	6.6
	Bio-Medical Engineer	4	2.6
Nature of work	Project Manager	38	25.0
	Consultant	18	11.8
	Contractor	16	10.5
	Designer	34	22.4
	Building Owner/User	10	6.6
	Facility Manager	6	3.9
	Policy Maker	18	11.8
	Hospital Support Service	12	7.9
Experience in hospital project or management or maintenance	No experience	20	13.2
	1-5 years	84	55.3

	6-10 years	22	14.5
	11-15 years	14	9.2
	16-20 years	6	3.9
	21 years and above	6	3.9

3.2 Factors of mold risk in a hospital during post occupancy period

3.2.1. Results

Respondents were assessed on the factors that contributes to mold growth and its risk. As illustrated in Figure 1, 61.8% strongly agreed that humidity is the major factor and 36.8% agreed to it. The second most agreeable factor was temperature with a total score of 96% for agree and strongly agree selections. Third factor was spore availability with total respondents' agreement of 82.9%. Forth factor was exposure time with 26.3% respondents who strongly agreed and 53.9% of them agreed. Substrate did not seem to be known by all respondents as only 19% strongly agreed to this factor. Other factors recorded a high percentage of neutral answer which indicated that the respondents may not be familiar to or had no knowledge about the subject.

The pattern of answer for agree (orange bar) shows significant consistency in most of the parameters. To create more meaningful categories, "agree" and "strongly agree" answers combination would generate a significant percentage of agreement. In this case, the factor of humidity, temperature, substrate, exposure time and spore availability produce a very significant percentage of agreement with 98.6%, 96%, 76.3%, 80.2% and 82.9% respectively.

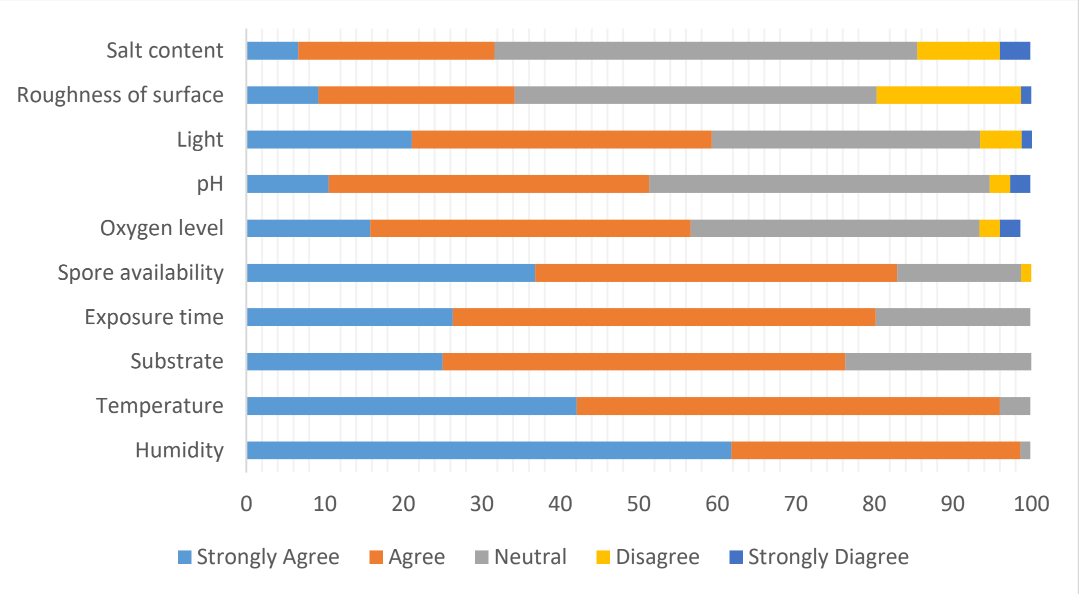

Figure 1: Understanding of mold risk factor

3.2.2. Discussion

This study confirms that the factor of humidity, temperature, substrate, exposure time, and spore availability are the five most prominent factors of mold growth that were exceptionally recognized by the respondents. As 92% of the respondents consisted of technical persons, this finding is in agreement with previous study by Johansson *et. al.* (2013), WHO Regional Office for Europe (2009) and Crook & Burton (2010). Johansson *et. al.* (2013) concluded that the factor of temperature and relative humidity in construction are highly predict mold growth risk. However, information on moisture level and calculated mold growth limit were important factors in the selection of construction material for the minimum risk of mold growth. WHO Regional Office for Europe (2009) declared that temperature and relative humidity are the main factors that must be looked into for mold risk besides the type of substrates and spore count. Crook & Burton (2010) concluded that health symptom associated with mold exposure in a Sick Building Syndrome may not occur individually, but might be related to building materials, stagnant air and ideal temperature.

Whilst factors of oxygen level, pH and light were averagely agreeable, the factor of surface roughness and salt content were found to be outlandish or uncommon to many respondents. This was due to the lack of information that would be highlighted as prominent factors of mold growth risk in Malaysia.

3.3. Issues pertaining to building defects in post construction assessment of newly built hospitals

3.3.1. Results

Respondents were assessed on several major issues during post construction assessment due to building defects that may have significant impact of mold risk in hospitals. Five elements were asked based on issues pertaining to the presence of water and dampness as shown in Table 3.

Analysis of mean was used to measure the tendency of the respondents towards the issue. The highest mean value was recorded for the prolonged water leakage either from mechanical piping system or infiltration of rainwater with a mean score of 4.39. Then, fluctuations of temperature and relative humidity due to air-conditioning system instability upon commissioning had a mean score of 4.33. The third was element of wall cracks that may cause water seepage and penetration, with a total mean score of 4.28. Forth element was unattended defects that prone to surface dampness for certain period of time, which had a mean score of 4.14. Finally, recurrence of defects that relate to surface dampness due to unidentified root cause of the problem, had a mean score of 4.11.

3.3.2. Discussion

Defects on building in post construction phase especially in hospital are inevitable. It may record as low as 300 defects up to a value as high as 20,000 defects (Jabatan Kerja Raya Malaysia, 2007). Out of this number, defects that have significant impact of mold risk can be summarized into 5 major elements which was tabled in the questionnaires.

Cook & Hinks (1992) described building defects as a building which has been performing badly in the structural and hydrothermal sense. In a newly built hospital in Malaysia, penetration of water and prompt action from the building contractors and end users were the main challenges for defects appraisal (Jabatan Kerja Raya Malaysia, 2007). The symptoms therefore should be identified and cured in a timely manner so as not to affect hospital building operations and procedures.

Table 3: Mean value for major building defects that contribute to mold growth

	Mean value	**Standard Deviation**
Prolonged water leakage either from mechanical piping system or infiltration of rainwater.	4.39	.655
Fluctuations of temperature and relative humidity due to air-conditioning system instability upon commissioning.	4.34	.601
Wall cracks that may cause water seepage and penetration.	4.28	.665
Unattended defects that are prone to surface dampness for certain period of time.	4.14	.725
Recurrence of defects that relate to surface dampness due to unidentified root cause of the problem.	4.11	.793

Scale: 1.49 and less = strongly disagree; 1.5-2.49 = Disagree; 2.5-3.49 = either agree or disagree; 3.5-4.49 = Agree and 4.5-5.0 = strongly agree

3.4. Post construction issues due to major architectural design that may lead to mold growth in hospitals

3.4.1. Results

Table 4: Mean value for architectural design that may lead to mold growth in hospital

	Mean value	**Standard Deviation**
Building elements were not fully covered (i.e. wall, roof, etc.)	3.95	.878

and water tight before commencing with final finishes works, installation of sensitive materials and equipment etc.		
The use of drying equipment (i.e. dehumidifiers, blowers etc.) may lessen the risk of mold growth during construction and operation.	3.91	.969
Availability of water features and landscape gardens inside/nearby the building that may introduce microbiological and particulate matter (i.e. spores, moisture, etc.) into the building.	3.45	.972
New design that contribute to the risk of mold growth i.e. energy efficient design, Green Building, IBS etc.	2.95	1.031

Scale: 1.49 and less = strongly disagree; 1.5-2.49 = Disagree; 2.5-3.49 = either agree or disagree; 3.5-4.49 = Agree and 4.5-5.0 = strongly agree.

3.4.2. Discussion

Distinguished architectural elements such as natural lighting, indoor vegetation, air-well etc. has been introduced in healthcare building design. This study had shown clear evidence that these elements had unintentionally created mold-friendly environment. Microbiological and particulate matters (i.e. spores, moisture, etc.) were prone to be generated via indoor courtyard that involved water and vegetation (Johansson *et. al.*, 2010). Creation of air-well that was originally designed for better view, ventilated air and natural lighting, had ended up with building dampness and air stagnation. Thus, creating pleasant environment for mold growth.

3.5. Construction quality issues that contribute largely to mold growth in newly built hospitals

3.5.1. Results

Table 5: Mean value for construction quality issues that lead to mold growth in hospital

	Mean value	Standard Deviation
Mechanical ducting and piping insulation	4.37	.690
Waterproofing	4.26	.772
Sanitary and piping system installation	4.21	.771
Untreated wood / mineral-based furniture	3.99	.856

Scale: 1.49 and less = strongly disagree; 1.5-2.49 = Disagree; 2.5-3.49 = either agree or disagree; 3.5-4.49 = Agree and 4.5-5.0 = strongly agree.

3.5.2. Discussion

There was a clear relationship between the quality of construction and its impact on indoor environmental quality. Poor construction quality that leads to water permeability such as structural crack, roof leakages, and drip water via air-condition ductworks etc. are among the prominent factors that leads to dampness and mold risk (Chang *et. al.*, 2008). PCA observation in newly built hospitals reported that the most common type of building defects were water stain on ceiling board (Jabatan Kerja Raya Malaysia, 2007). This shows clear sign of water seepage whether from roof leakages or water drip from mechanical pipework and ducting.

Several other construction quality issues that relates building moisture and dampness with mold risk are waterproofing and damp proof membrane, sanitary systems and the use of untreated wood or mineral-based furniture. The problems with waterproofing and damp proof membrane were poor workmanship during installation, insufficient design or under-design and inappropriate selection of waterproofing (either cementitious, membrane type or integral system). In many cases of water seepage found during PCA, the waterproofing were teared off (membrane) or cracked (cementitious), and installation was not in line with the manufacturer’s specification and material weathering (Jabatan Kerja Raya Malaysia, 2009). For sanitary systems, the issues of poor installation (untightened joints, insufficient pipe support etc.), false material were often found during PCA which usually cause leaking from droplet to a very seldom pipe burst. While for wooden or mineral-based furniture, treatment for the raw materials used in making the furniture base was inappropriate (Nielsen *et. al.*, 2004). There were also cases of contaminated wooden and mineral-based furniture been transported to the hospital and hence jeopardized the quality of the indoor environment (Jabatan Kerja Raya Malaysia, 2007).

Water tightness of a constructed building is an important element in controlling dampness that has always been neglected during construction. Sufficient air-ventilation system is demonstrated to help alleviate dampness in buildings under construction. The use of drying equipment such as dehumidifiers and air blower for reverse air flow had proven to be significant in decreasing the risk of mold growth during construction and would be favorable during operation (Galvin, 2010).

3.6. Mechanical ventilation and air-conditioning design that contribute to mold growth in building

3.6.1. Results

Table 6: Mean value for mechanical ventilation and air-conditioning design that lead to mold growth in hospital

	Mean value	**Standard Deviation**
Imbalance air-change that cause stagnant air	4.26	.681
Insufficient duct insulation	4.21	.754
Improper fresh air intake	4.16	.749
24H / 8H air-conditioned room design	4.11	.793

Scale: 1.49 and less = strongly disagree; 1.5-2.49 = Disagree; 2.5-3.49 = either agree or disagree; 3.5-4.49 = Agree and 4.5-5.0 = strongly agree.

3.6.2. Discussion

Mechanical ventilation design is the most crucial element in mechanical systems for a hospital building. More than 90% of hospital spaces are designed with air-conditioning system. Thus, issues pertaining to mechanical ventilation and air-conditioning has to be predominantly reviewed and inspected during PCA. Issues of imbalance air-change that causes stagnant air was found to be prominent in many hospitals during PCA (Jabatan Kerja Raya Malaysia, 2013a). Process of enquiring the optimum air balancing and ambient relative humidity (RH) has always been a great challenge for mechanical engineers in any new hospital building (Yau *et. al.*, 2011). It may be prolonged to an unreasonable time to achieve its designed value and thus, it may cause building perspiration and high RH. This situation then increases the risk of mold growth if the situation is not properly sorted out.

Accurate air-condition duct insulation design and installation was found as an important element obtained from the survey. Insulation plays an important role on duct surface to eliminate condensation due to air-cooled transportation. Design, material selection and specification of insulation may differ according to duct sizes, length, pathways etc. Poor workmanship during construction and lack of quality control were commonly noted during PCA (Jabatan Kerja Raya Malaysia, 2007). These were among the reasons why insulation creates condensation, dampness and later initiates mold growth on affected surface such as ceiling boards, walls, medical equipment and furniture.

Hospital design requires stringent intake for fresh air circulation. The ratio of fresh air intakes as compared to the returned air for general hospital spaces are usually set at 80:20 (Jabatan Kerja Raya Malaysia, 2010). In certain areas such as operations theatres, clean rooms and laboratories, 100% fresh air is required for infection control purpose. The fresh air will be filtered gradually to screen micro-organisms and dirt away before entering the Air Handling Unit (AHU). The highest percentage of fresh air means more effective filtration process is needed. In many cases of mold growth found in hospitals during PCA, filtration membrane was not part of their working condition (Razak & Jaafar, 2012). Besides, selection of the fresh air intake point locations were erroneous due to the last minute decision and were never allocated specifically in the design. Wrong decision in locating fresh air intake adjacent to cooling tower areas, damp environment etc. may introduce prevalent mold spores to enter the air-conditioning system (Jabatan Kerja Raya Malaysia, 2009). Findings from this study shows that fresh air intake are significant factors to support the above statement.

Hospital operations may differ departmentally as some department may be in operation 24 hours a day such as wards, pharmacy, emergency, etc., while the others might be running 8 hours a day such as administration offices, specialist clinics etc. Obviously, there were differences in the air-conditioning usage and thus, special treatment to the wall and ceiling soffit are undeniably needed to avoid condensation (Jabatan Kerja Raya Malaysia, 2009). Design on cavity wall and polyurethane spray on soffit slab are commonly used nowadays to overcome the problem and have been found to be the best solution at the moment during PCA. However, traditional treatment on walls and slab soffit such as the use of anti-fungus spray paint alone are still been widely practiced and has been found to be inadequate.

3.7 Building operational factors that contribute to mold germination in indoor environment of a hospital

3.7.1. Results

Table 7: Mean value for building operational factors that lead to mold growth in hospital

	Mean value	Standard Deviation
Unused space/room for a certain period of time	4.11	.776
Irregular air-conditioning system maintenance	4.08	.762
Inexperienced building maintenance team in handling the new building system	3.99	.808
Insufficient building occupancy rate as per the building design which resulted in imbalance heat exchange	3.97	.765
Inadequate support service personnel for building maintenance	3.84	.895

Scale: 1.49 and less = strongly disagree; 1.5-2.49 = Disagree; 2.5-3.49 = either agree or disagree; 3.5-4.49 = Agree and 4.5-5.0 = strongly agree.

3.7.2. Discussion

Whilst typical construction period of a hospital building project in Malaysia usually takes about 36 to 72 months to get completed, hospital operators' readiness has always become an issue (Jabatan Kerja Raya Malaysia, 2013a). This is because the hospital support service cannot be established until the new building is ready. The hospital operators requires few months after the project handover prior to the establishment of the dedicated hospital maintenance team. The idling time had created uncertainties to the hospital indoor environment. Unused spaces for a long period of time plus the existence of the mold growth factors may increase the mold risk. This was seen to be the most agreeable finding from this study.

As temperature been the most critical factor for mold risk, air-condition systems is the most to be periodically maintained so as to avoid temperature fluctuations (Jabatan Kerja Raya Malaysia, 2007). Daily monitoring on the air-condition system through Building Control System (BCS), regular cleaning on all air filters, monitoring of the quality of chilled and condenser water and monitoring of the interlocking between the air-condition system with BCS are among the most practical air-condition system maintenance program.

Experienced and competent maintenance team personnel are the key elements during maintenance and operational stage (Bee Won *et. al.*, 2013). Their participation during PCA is somehow needed before the project handover and sufficient numbers of support service personnel is obligatory during project handover. Therefore, the personnel must be well trained and adaptive to the building systems and must be able to immediately react to any systems malfunction that may cause inconvenience to the indoor environment. Attention should also be given to the understanding of the system which may directly involve moisture and water intrusions.

Other building operational factors that may contribute to possible mold growth is insufficient building occupancy rate as per building design which ends up resulting in imbalance heat exchange. In many new buildings, the occupancy rate is always less than the design criteria due to many reasons (Preiser, 2006). This will leave the space empty and heat generated from equipment and human activity will be unable to balance the design temperature. Low room temperature will cause low surface temperature which contributes to condensation (Galvin, 2010).

4. CONCLUSION

PCA on potential mold growth in newly built hospital building seems to be marginalized. This was due to the inexistence of specific clauses in the government's building contract that requires all hospital projects to witness mold risk. This study showed that hospital stakeholders agreed to a major point that mold can grow on newly built hospitals.

PCA investigated building physics prior to project handover and came out with list of defects. Specific defects that may have significant impact on mold risk in hospital building were identified. Issues on water intrusions via structural and non-structural crack, pipe leakages and rainwater infiltration; instability in temperature and relative humidity; non-attendance to moisture-based defects; and defect recurrence, dominates the hospital stakeholders' understanding on mold risk factors.

There are three most important elements in PCA for mold risk assessment of a newly built hospital; building design, construction quality and building operational factors. Architectural features and mechanical systems were categorized under building design critical factors. In summary, it is recommended that hospital design should be more delicate towards new architectural features that may cause indirect contribution to dampness and mold growth risk environment. Process of PCA could focus more on architectural design functionality versus the impact on indoor environmental quality. Whereas mechanical design plays a very significant role in ensuring hospital buildings are condensation-free. This study confirmed that among the major elements that requires special attention, accurate air balancing and air-change for air-conditioning system, precise fresh air intake, good insulation design and workmanship and sufficient design between the 8 hours air-conditioned spaces versus 24 hours air-conditioned spaces were identified. This major elements should be measured and treated as emerging risk for mold growth.

Quality of construction always depend on good supervision. However, that does not guarantee that the building is 100% watertight even with excellent testing and commissioning tools. This study has established that the factors in major construction quality issues that leads to mold growth in hospital building were waterproofing, leaked pipes and mechanical ducts, and untreated wood and mineral-based furniture. Besides, sufficient air-ventilation using reverse air flow and heating element were needed during the entire construction stages to keep the building dry.

Building operational factors are additional relevant factors of mold risk. Unused space with or without ventilation for some period of time may invite mold growth. Irregular air-conditioning systems maintenance also affects building cooling performance. This is followed by incompetence and inexperience maintenance, personnel and insufficient numbers of support service staff that may not be able to attend to moisture immediately. Low building occupancy rate in the early operation of a hospital is unavoidable and thus creates imbalance heat exchange that may result in condensation and overcooled surfaces.

In short, thorough investigation on mold risk factors is crucial in hospital early operations. Data obtained from PCA helps in formulating actions plans for corrective action and subsequently implementing corrective measures.

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