AIR QUALITY IN HARMONY WITH INFECTION CONTROL

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Infection control in healthcare facilities is dependent on indoor air quality – past outbreaks of hospital acquired infections have been shown to be caused or spread by air handling systems. How can hospitals stretch their limited maintenance and engineering budgets to ensure adequate air quality performance? This whitepaper showcases a risk management schema developed by QED to assist hospitals to prioritise maintenance spend according to infection control risk and observed air quality outcomes.

QED has for many years carried out a comprehensive air quality monitoring and management inspection function for commercial buildings, such as high rise multiple occupancy office blocks. QED is the only NATA accredited company carrying out this kind of audit of indoor air quality in Australia. This annual inspection and testing aids compliance with the Australian Standards AS1668.2 (2012) The use of ventilation and air-conditioning in buildings, Australian Standards AS 3666 (2012) Air handling and water systems of buildings, Australian Standard SAA/SNZ HB 32 Control of microbial growth in air-handling and water systems in buildings and other relevant legislation and standards. Similar programmes are also in place in several commercial buildings as tenants require the knowledge that the air in the building is of a high standard, as this can impact upon productivity and profitability. Inspection of the air handling units, along with testing for various air quality parameters in the occupied areas gives a good indication of the overall quality of the system in place, and any rectification works that are required to improve the air quality in the building.

Hospitals are however, much more complex that commercial buildings. A commercial building usually has a healthy population, with no extremes of age present, and the presence of very few pre-existing health conditions. The use of space in the building is mostly confined to office use, with usually only the server room having specialist heating and cooling needs. The building usually has fit outs that are all of a similar age, and a few, large air handling units are present.

In comparison, hospitals have a much more diverse population of users of all states of health and ages, areas of use that vary from offices to laundries, operating theatres, commercial sized kitchens, sterile areas, imaging and radiation bunkers. Additional to this, hospitals usually are sites that have developed and evolved over many years, with many stages of construction and development, and reuse of often very old buildings. Air handling units are also of vastly differing ages, manufacturer and type, depending on the needs of the area. Specialist ventilation and heating requirements are also present with HEPA (High Efficiency Particle Arrestance) filtration for isolation rooms, theatres and cleanrooms, along with positive and negative pressure isolation rooms.

Provision of safe air within a hospital environment is of vital importance. Hospital acquired infection is a major cost burden for hospitals, and also a significant burden on the patients affected. Mortality of the patients is increased, and increased length of stay in hospital of between 7-10 days on average are noted. At a cost in WA of a hospital stay of nearly $2200 average per day per patient in 2013-14[1], the costs associated with this are significant. Outbreaks have previously been associated with the air handling systems within hospitals – examples include an MRSA outbreaks associated with dirty supply registers and ducting[2]; an outbreak of fungal infections in cardiac surgery patients[3], and an outbreak associated with old air conditioning systems that were poorly maintained which resulted in 6 deaths from 6 infections[4]. There can also be a problem with ‘pseudo-outbreaks’. This is where the laboratory air supply is contaminated, and the air supply introduces contaminants into specimens[5]. This means that infection can be found in the samples when none is present in the patient – situation which can lead to unnecessary surgery and treatment with antibiotics.

NHMRC Australian Guidelines for the Prevention and Control of Infections in Healthcare[6] highlight the role of the air handling systems within a hospital of reducing airborne transmission of pathogens, and in contributing to the health of the population within the hospital. The NHMRC guidelines state that many studies indicate that infection rates are lower when there is very good air and water quality. In addition to this, the Australasian Health Facilities Guidelines[7] and the WA Health Facilities Guidelines[8] state that ventilation should "Provide breathing air free from contamination harmful to building occupants or processes undertaken in and around the building".

With the importance of providing good quality air into the hospital environment being of paramount importance, QED undertook to develop a programme specifically for hospitals, that took into account not only the physical condition of the air handling units, but the quality of the air at the point of supply, and the individual risks present in the areas that the air is supplied to. Taking into account the three critical areas of:

RISK OF THE POPULATION SUPPLIED WITH AIR

CONDITION OF THE AIR HANDLING UNITS

QUALITY OF THE AIR SUPPLY IN A PARTICULAR AREA

A risk matrix was developed that, if any rectifications to systems were required, could risk assess each individual problem present and rank this according to the impact it could potentially have on patients and other users within the building.

Examination of both the air handling units and the air quality in unison with each other is vital. Problems beginning in the air handling units may not yet have had an impact upon the air quality within the area supplied, and also, there may be other problems within the hospital, for example moisture ingress or use of chemicals that can impact upon the air quality, without necessarily being related to the air handling unit.

MEASUREMENT OF INDOOR AIR QUALITY

A number of parameters are measured to determine the quality of the air inside the hospital.

Carbon Dioxide

Carbon Dioxide (CO2) is a gas that occurs naturally in the earth's atmosphere, and is generally accepted as a surrogate indicator of ventilation within buildings and occupied premises. At normal concentration levels carbon dioxide exerts an important regulatory effect in the body; it can however become an asphyxiant at high concentrations. Historically, the most common complaint expressed about indoor air quality is that of "stale air".

Typically, complainants claim symptoms of headache, stuffiness, upper respiratory tract irritation, drowsiness, lethargy and fatigue etc.

Research has shown that these symptoms tend to worsen during the course of the day, often peaking in the mid to late afternoon, but abate after vacating the premises in question.

Moderately raised levels of carbon dioxide have also been shown to reduce productivity, decision making performance, basic activity levels, information levels and crisis response - all essential for staff within a hospital[9], who make life and death decisions every day.

Particulate matter

The National Environmental Protection Council (NEPC)[10] stipulates a standard for ambient particulate matter of <10 microns in size (PM_{10}) of 50 µg/m3 (0.05 mg/m3) measured over a 24 hour period, with five allowable exceedances per year. QED has adopted the guideline level of 50 µg/m3 for indoor air.

Raised levels of particulate matter, especially the PM_{10}, $PM_{2.5}$ and PM_{1} fractions have clear associations with increasing respiratory distress and hospital admissions, and also with worsening cardiac function and cardiac events at raised levels. Mortality in cardiac, cancer and respiratory patients is also increased when levels of airborne particulates are high[11]. Particulates should be controlled to prevent the worsening of these conditions within the hospital.

Carbon Monoxide

In high concentrations, carbon monoxide can be fatal. At lower concentrations, headache, dizziness and other symptoms can be present. It is usually found when combustion products enter the airstream, for example from plant exhausts or vehicle fumes. Carbon monoxide is an odourless gas, and can only be detected using a specialist monitor. Any detection of carbon monoxide must be investigated.

Temperature

Air temperature is one of the parameters that are known to influence the thermal balance of the human body as a whole, which in turns affects the perceived comfort of the individual. This can often be a contentious area in a hospital, as there are so many different levels of activity, from the busy staff to the bed bound patient. Even within well maintained office spaces, temperature is one of the factors that building managers have the most complaints about.

Humidity

A level of RH (Relative Humidity) below 35% exacerbates and sensitizes an individuals' response to airborne pollutants, and the following problems have been known to occur;

- Dryness and irritation of eyes, nose, throat
- Increased allergic response by asthmatics
- Increased static electricity shocks
- Increase rates of ozone generation

High humidity can also provide conditions favourable to the growth of micro-organisms such as fungi or mould and bacteria. Elevated levels of these micro-organisms may then have negative health effects, and also cause damage to property and assets.

Volatile organic compounds

Volatile organic compounds (VOCs) are measured as a total for the air quality monitoring programme, and act as an indicator that a problem may be present. In an office environment sources of VOCs are usually from furniture, paints, and new building products. Within a hospital, there are many more sources of VOCs, from alcohol hand rub to more toxic chemicals used for disinfection and cleaning. High levels of VOCs usually indicate the need for more targeted investigation, and for measurement of Occupational Exposure[12] to the chemicals in use in the area. VOCs are a wide group of compounds, some of which can have quite serious health effects at low concentrations, and some of which are relatively harmless at the concentrations usually found in a hospital day to day[12].

Microbial Air quality

The levels of microbial contamination within the air of the hospital area sampled using an active sampler. No specific guidelines exist for the levels of microbes within the air that are acceptable within a building, except for those within Operating Theatres[13]. It is however very useful to build up a picture of the usual levels for the different areas of the hospital over time and then deviations from this can be investigated. Comparison of the levels within the building with those in the outside air are also extremely useful. Levels of microorgansms should usually be lower inside a building than outside a building, and be of a similar species mix. Higher levels of microbes inside that outside, or inside air readings that show a predominance of a problem species of fungus for example is a cause for concern and would require investigation. Results should always be interpreted by a person experienced in interpreting microbial air testing results.

INSPECTION OF AIR HANDLING UNITS.

Air handling units are inspected by experienced staff to ensure that they are clean, functional and that no problems are present that may impact upon the air quality supplied. A condition report detailing the condition of the unit, corrosion, condition and cleanliness of the coils, condition, specification and change dates of the filters, along with the condition of the plant rooms and any external factors that may impact upon air quality.

Inspection of the maintenance records is also carried out if required to ensure that the monthly inspections required under AS3666[14] have been carried out.

Microbial culture of the heat exchange coils is also possible at inspection, using a method devised by QED in association with a NATA accredited laboratory to give an early indication of if there may be a problem with microbial contamination.

RISK GRADING OF AREAS AND AHUS FOR FUNCTIONAL AREA SENSITIVITY STATUS

Each area and the AHU it serves are graded according to a risk assessment tool developed by QED. This is based upon guidelines from Queensland, Western Australia, New South Wales and the Northern Territory[15], with additional knowledge from QED consultants. The term ‘Functional Area Sensitivity Status’ is used instead of a term that is more focussed on patients, as sometimes, for example in the case of Pathology laboratories, the Cyclotron or pharmaceutical preparation areas, the persons present in the area are of good health, but the use of the area requires a higher grade risk classification.

AHUs and areas that are grouped in Groups three and four for functional area sensitivity status are examined and air quality testing carried out on a six monthly basis, to ensure that problems are dealt with in a timely manner and do not reach the levels where patients are put at risk. The areas grouped into Groups one and two are inspected and tested on an annual basis. This is then used to produce a risk rating for each AHU.

Functional area sensitivity status

Group Four Highest risk	All Intensive Care Units and High Dependency Units All Operating Rooms Day Surgery Labour & Delivery Operating Rooms Anaesthesia areas Oncology and Haematology units and outpatient clinics for patients with cancer Transplant units and outpatient clinics for patients who have received bone marrow or solid organ transplants Wards and outpatient clinics for patients with AIDS or other immunodeficiency Infectious Diseases wards. ENT Wards (especially Head and Neck surgery)	Burns Units Respiratory Wards (Chronic) Dialysis Units Tertiary care nurseries Transport routes of patients from any of the above categories All Cardiac Catheterisation & Angiography areas Cardiovascular/cardiology patients All Endoscopy areas Pharmacy admixture rooms Pharmacy Cleanrooms Sterile processing rooms Computer centre Central inventory department Cyclotron
Group Three High risk	All patient care areas unless stated in Group 3 or 4 including but not limited to: General medical & surgical wards other than those listed in Group 4 Paediatrics Geriatrics Long-term care Normal newborn nurseries Emergency rooms Radiology/MRI Post anaesthesia care units Mortuary	Transport routes of patients from any of the above categories Labour and Delivery (non-operating room) Nuclear medicine Physiotherapy respiratory function areas Echocardiography Medical laboratories (specimens) Dental clinics Pathology Specimen Collection Kitchens
Group Two Medium risk	Unoccupied wards, Outpatient clinics (except for oncology & surgery), Admission/discharge units, Research laboratories, Psychology	Allied Health areas including but not limited to: Physiotherapy, Occupational therapy, Social work, Dietetic / Nutrition and Prosthetics / Orthotics. Pharmacy
Group One Lowest risk	Office areas Public areas	Workshops and Plantrooms (subject to risk assessment)

Specific AHU risk groupings, XXX Building

AHU risk groupings			
Asset Number/ AHU Identification	Population Served	Functional Area Sensitivity Status	Audit frequency
AHU 1	Oncology	4	Biannual
AHU 2	Respiratory Wards	4	Biannual
AHU 3	Emergency Dept.	3	Biannual
AHU 4	Physiotherapy	2	Annual
AHU 5	Offices	1	Annual

RISK ASSESSMENT OF THE AHU OR INDOOR AIR QUALITY PARAMETERS

Each noted exceedance from the expected air quality guidelines, or each rectification that is required for an AHU is graded by our consultants as to the potential impact to the area that is served using the following table.

AHU hygiene assessment

QED Hygiene Assessment of AHU.	
Low Risk	Manage as part of current maintenance procedures.
Moderate Risk	Remedial actions required.
High Risk	Expedite remedial actions.
Very High Risk	Immediate remedial action required.

These two pieces of data are then used to calculate a Maintenance priority rating, using the following matrix.

Maintenance priority rankings

QED Action Priority Ranking				
	Functional Area Sensitivity Status			
Hygiene risk	Group 1	Group 2	Group 3	Group 4
Low	1	1	1	2
Moderate	2	2	3	4
High	2	3	4	5
Very High	4	4	5	6

1: Routine maintenance issue
2: Moderate priority
3: High Priority
4: Very High Priority
5: Extremely High Priority
6: Requires Urgent and Immediate Attention

The maintenance priority ranking is then used to produce a list of maintenance and other rectifications and investigations that are required to improve the system and ensure that it is up to standard and providing safe and clean air to the hospital.

This provides both the Engineering and Infection Control and Prevention Departments with a targeted list of actions, in the order that they need to be done, to ensure maximum patient safety within the hospital with regard to the supply of air.

A full report is produced, along with a searchable and sortable excel spreadsheet of recommendations. This ensures that maintenance can then either target a particular air handling unit, or sort by the most important rectifications first.

With only limited budgets for maintenance and repairs, and limited staff to carry out works this ensures that all of the available resources are directed in the most effective, efficient and safest manner.

CRITICAL ISSUES AND RECOMMENDATIONS

Location / Item	Asset #	Hygiene/ Impact Assessment	Area status	Maintenance Priority	Issue / Recommendations	EMPAC Ref#	Date Complete	XXX hospital Sign-off
Critical Issues								
Plant room	AHU 2	Very High	4 Highest Risk	6 Immediate	Microbial growth is present on the heat exchange coils and there is also some corrosion, the coils should be cleaned immediately with an appropriate biocide and the corroded areas sealed. The unit should be shut down for cleaning. As the area served houses particularly sick patients, the Infection Control team should be consulted prior to cleaning taking place.			
Plant Room	AHU 1	Very High	4 Highest Risk	6 Immediate	Microbial growth is present on the supply air dampers. This should be removed as a matter of urgency. A suitable biocide should be used, and the unit isolated for cleaning. The unit should be shut down for cleaning. As the area served houses particularly sick patients, the Infection Control team should be consulted prior to cleaning taking place.			

Location / Item	Asset #	Hygiene/ Impact Assessment	Area status	Maintenance Priority	Issue / Recommendations	EMPAC Ref#	Date Complete	XXX hospital Sign-off
Oncology Ward		High	4 Highest Risk	5 Extremely High	High levels of Volatile Organic compounds have been detected in this area. Alcohol hand gel and isopropyl alcohol wipes were noted to be in use. If these are the only volatile organic substances in use in this area, then exposure levels are likely to be below the Occupational Health and Safety Exposure Standard. If other compounds are in use, further monitoring may be required to ensure that OH&S limits are not exceeded. The MSDS file for the area should be consulted to determine which compounds are in use.			
Plant room	AHU 4	Very High	2 Medium Risk	4 Very High	Bird faeces present on the top of the unit, and these have been washed into the unit by water leaks. The outside and inside of the unit should be cleaned and decontaminated immediately with a suitable biocide. The unit should be turned off and isolated while cleaning takes place.			

Location / Item	Asset #	Hygiene/ Impact Assessment	Area status	Maintenance Priority	Issue / Recommendations	EMPAC Ref#	Date Complete	XXX hospital Sign-off
Recommendations								
Physio-therapy		High	2 Medium Risk	3 High	High levels of fungi and bacteria were detected in the air in the unused physiotherapy department store. This was adjacent to an area of water damage with visible mould present. The source of the water should be investigated and rectified, and the damaged areas removed and made good.			
Plant room	AHU 2	Low	4 Highest Risk	2 Moderate	Filters do not have change dates displayed, but appeared clean and new. Change dates and specifications should be displayed at the next filter change date.			
Offices	AHU 5	Moderate	1 Lowest Risk	1 Routine	Levels of CO2 higher than the Guideline upper limits were detected. This may affect concentration and alertness. The provision of outside air to this area should be increased to improve occupant comfort.			

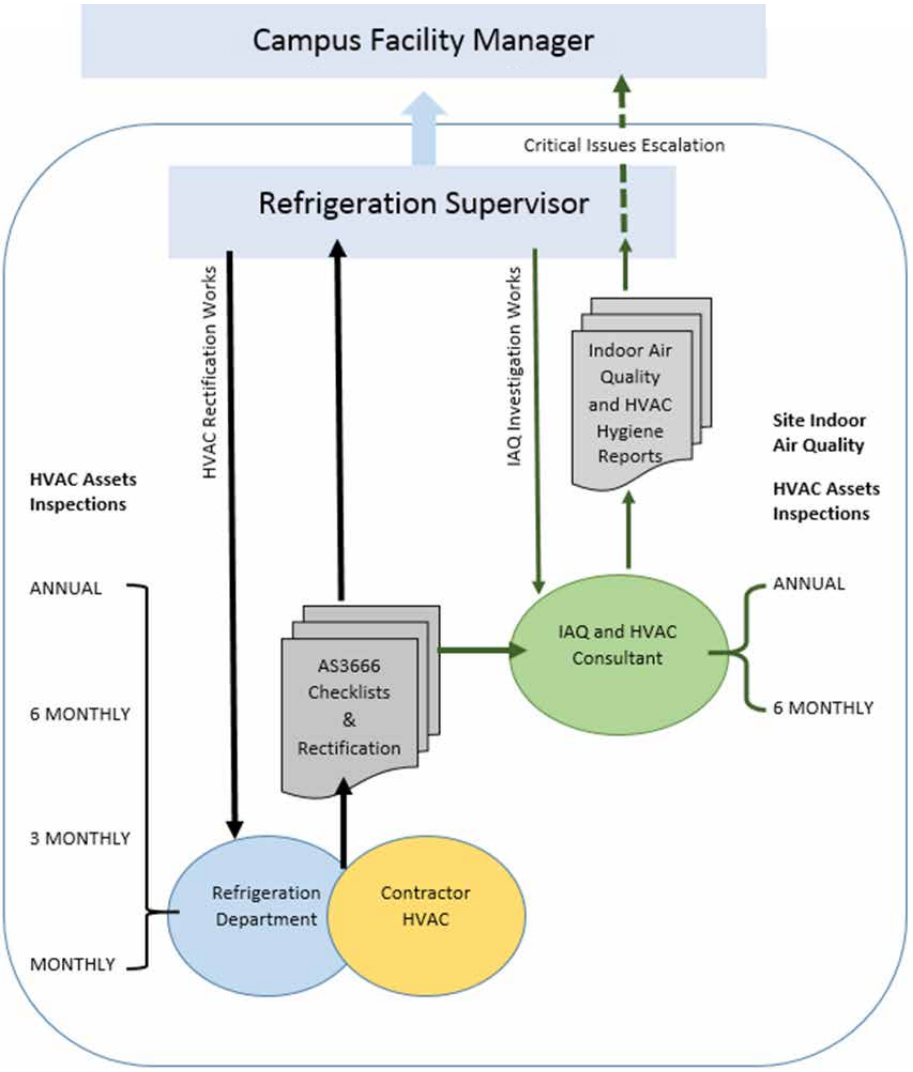
EXAMPLES OF ISSUES UNCOVERED IN AHUs,

QED carries out this audit scheme for many hospital and commercial buildings, and the following are examples of problems that have been discovered with the air quality testing:

- Formaldehyde and VOC exposures
- Dampness and mould issues
- Fungal growth within critical AHUs
- Bird faeces contaminating outside air intakes
- Negative pressure room vents adjacent to outside air intakes
- Decomposing air handling units

FOLLOW UP PROCEDURES AND REPORTING PROTOCOLS

QED produces a comprehensive report of all of the issues, graded as to their importance to patient/staff health and safety. Once these issues have been investigated or rectified, QED can also provide a reinspection service to ensure that rectifications have been carried out and are to standard.


Campus Facility Manager
Critical Issues Escalation
Refrigeration Supervisor
HVAC Rectification Works
IAQ Investigation Works
Indoor Air Quality and HVAC Hygiene Reports
Site Indoor Air Quality
HVAC Assets Inspections
HVAC Assets Inspections
ANNUAL
6 MONTHLY
3 MONTHLY
MONTHLY
AS3666 Checklists & Rectification
IAQ and HVAC Consultant
ANNUAL
6 MONTHLY
Refrigeration Department
Contractor HVAC

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