

## IAQ in Hospitals – Better Health through Indoor Air Quality Awareness

M. Ramaswamy  
PhD Technical Expert, Royal Court  
Affairs

Farooq Al-Jahwari  
College of Engineering, Sultan  
Qaboos University  
Sultanate of Oman

Saif M. Masoud Al-Rajhi  
Royal Flight Area Eng., Royal  
Estates, Royal Court Affairs

### Abstract

Quality air is fundamental to people's health and well-being. Indoor air quality is an important issue from both a social and economic point of view. Continual advances in medicine and technology necessitate constant reevaluation of the air-conditioning needs of hospital and medical facilities. The application of air conditioning to health facilities presents many problems not encountered in the usual comfort air conditioning design. Hospital air conditioning assumes a more important role than just the promotion of comfort. Studies show that patients in controlled environment generally have more rapid physical improvement than do those in uncontrolled environment. Air quality at hospitals needs special precautions during design and maintenance stage to prevent infections from spreading. 50% of all illnesses are either caused by, or aggravated by, polluted indoor air. The main objective of this paper is to critically review and summarize the available information about IAQ particularly in health care industries. Symptoms of poor IAQ in a building, contaminants causing poor IAQ, features of HVAC systems for a hospital for better IAQ are briefly discussed in this paper. Strategies to improve indoor air quality in hospitals and the current international research to improve indoor air quality are reported in this paper. Based on the extensive interactions with different stake holders of a hospital it is concluded that maintenance of proper indoor quality in a hospital needs meticulous team work among the various members of the hospital at various stages .

Key Words: - HVAC system, infection control, ventilation, clean room, hospital, AHU, Filters, pollutants,

### INTRODUCTION

Most of us spend major portion of our time indoors in homes, schools, the workplace, shopping malls or hospitals. The average person will use typically 15kg of air a day through breathing compared with 1kg of food and 2kg of water, yet there are no clear guidelines to ensure good air quality in buildings available.

The successful monitoring and control of the quality of room air is becoming increasingly important – particularly as the application of novel building techniques and materials coincide with improved awareness of their effects on comfort and health. Air quality within a building is influenced by many external and internal factors. The air we breathe can be degraded by a wide variety of contaminants, natural, synthetic, biological and inorganic. The major sources of contaminants in any building are occupants, office furnishings and equipments etc. Occupants generate odours, skin flakes, bacteria and other bio- effluents. Office furnishings release solvent vapours including volatile organic compounds, such as formaldehyde, as does office equipments such as copiers which also release ozone.

In recent years a large number of studies of health impact of suspended particulate air pollution have been under taken in developing countries (Air Quality Guidelines for Europe, 1997). These studies

show remarkable consistency in the relationship observed between changes in daily ambient suspended particulate levels and changes in mortality. In developing countries the problem of indoor air pollution far outweighs the ambient air pollution. In the minds of many people, air pollution is usually associated with the contamination of urban air from automobile exhausts and industrial effluents. But the fact of the matter is that indoor air quality creates serious problems if not understood properly. As we breathe, we use up available oxygen and replace it with carbon dioxide, which is a simple asphyxiant. A poorly ventilated room or a building, especially a crowded one, sometimes lacks enough proper fresh supply air to keep carbon dioxide concentrations at low levels. This sometimes results in drowsiness or discomfort.

The US Environmental Protection Agency (EPA) concedes that about 30% of new or renovated buildings have serious indoor air quality problems, and ranks IAQ as the most prominent environmental problem (Roodman, 1995). It is reported in the report titled "Causes of Indoor Air Quality Problems in Schools" (ASHRAE Journal, P16, 1999) that as many as 20% of U.S. Schools have indoor air quality problems. ASHRAE standard 62.2 P, Ventilation and Acceptable Indoor Air quality in Low – Rise Residential Buildings defines the roles of and minimum requirements for mechanical and natural

ventilation systems and building envelope intended to provide acceptable indoor air quality. It applies to spaces intended for human occupancy within single – family houses and low – rise multifamily structures. Max Sherman reviewed this draft standard in his article “Indoor Air Quality for Residential Buildings “(ASHRAE Journal, P26, 1999). He has recreated important question about this standard and its answer were also given in this paper. The demand on designers to provide comfortable buildings are increasingly balanced with the demands of low-carbon economy, greater environmental concern etc. Studies reporting perceived air quality (PAQ) and performance (Bako, 2004) have indicated a relationship between changes in PAQ and change in work performance (Figure 1). Researchers have suggested that when people feel good about the air they breathe, they are more productive and happier. Work collated by a team of researchers from the University of Technology, Finland, has shown that there is a likely link between the rate of ventilation and sickness in offices (Figure 2). (CIBSE,2006).Recent estimates place the direct health care costs of poor IAQ in the US at \$30 billion, with sick leave and productivity losses adding another almost \$100 billion annually (Fisk, 1997).

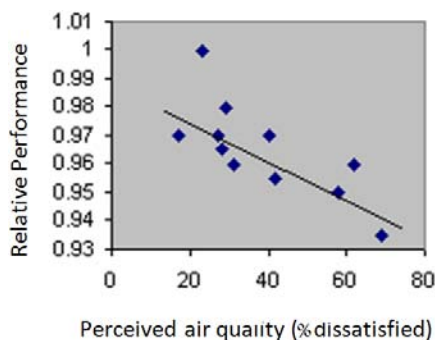


Figure1. Relative performance of typing depending on perceived air quality expressed as % of dissatisfied with air quality by non-adapted persons.

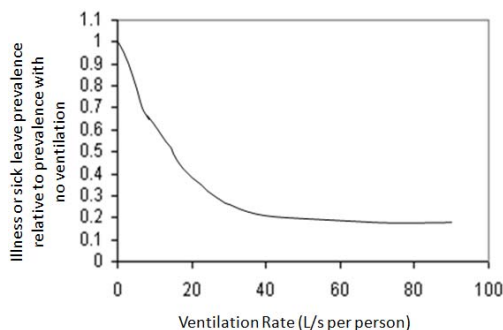


Figure 2. Relative short –term sick leave or illness Vs Ventilation rate

Air conditioning, as common man knows, is the control of temperature, humidity and quality of air simultaneously. IAQ is defined as the process of providing air which is comfortable in every way and does not cause negative health effects, disease or sickness in humans and is devoid of dust, smells, draughts and noise as much as possible. Air doesn't just get cleaned up by itself. We need special equipment to monitor and control the quality of air. The capital costs as well as running cost of the HVAC plants are the deciding factors to maintain the required quality of air for different applications. The more stringent requirement of quality of air the more capital cost & running cost. Indoor air quality is a prime factor, during the design stage and critical factor during the maintenance stage of HVAC systems. Governments across the world have begun to address IAQ problems through various measures. IAQ in hospital is more critical as the patients have less immunity. Hospital buildings involve complex installations. It is a known fact that in a typical hospital the level of airborne infectious contaminant increases proportionately with the increased population density of infected individuals. Therefore IAQ concept in hospital is emerging as a modern field of specialization among engineers and health care professionals. The importance of IAQ in hospitals is discussed with the theme better health through IAQ awareness in this paper.

## LITERATURE REVIEW ON IAQ WORKS IN HOSPITALS

Hospitals being the major segment of the total health care system, where most resources are allocated, are expected to function efficiently and effectively to achieve “Health for All” mission. Modern hospital is no more considered a place for the diagnostic and treatment of a patient’s disease. Broadly speaking, it is a place for the diagnostic and treatment of human sickness, where health education, training, research activities and many more activities are undertaken. It is functionally a complex organization having multi faceted developments in the society. Therefore healthcare facilities have to pay particular care to indoor air concerns. The basic difference between air conditioning for hospitals (and related health facilities) and that for other building types stem from

- The need to restrict air movement in and between the various departments;
- The specific requirements for ventilation and filtration to dilute and remove contamination in the form of odor, air-born microorganisms and viruses, and hazardous chemical and radioactive substances;

- The different temperature and humidity requirements for various areas ;
- The design sophistication needed to permit accurate control of environmental conditions.

Air quality at hospitals needs special precautions during design and maintenance stage to prevent infections from spreading. It is reported that 5% of all patients who go to hospitals for treatment will develop an infection while they are there (O'Neal C, 2000). The levels of some hazardous pollutants in indoor air at some places have been found to be up to 70 times greater than in outdoor air. Besides the complex hospital environment requires special attention to ensure healthful indoor air quality to protect patients and health care workers against nosocomial infections and occupational diseases. According to WHO, bad indoor air quality is a real health hazard and can have significant impact on the shortening of life expectancy. Children and the elderly are especially affected by polluted indoor air.

Researchers from Hong Kong university carried out a detail study about the role of ventilation in airborne transmission of infectious agent in health care units and concluded that there is a strong and sufficient evidence to demonstrate the association between ventilation, air movements in buildings and the transmission spread of infectious diseases such as measles, tuberculosis, chickenpox, influenza, and sars etc. (Ignatius T.S, 2004). Nordstrom and his team from Sweden investigated IAQ in hospitals in relation to building dampness and type of construction. They analyzed four hospital buildings of different age and design and concluded that building dampness in the floor construction may increase the sensation of air dryness and stuffy air (Nordstrom, 1998). An interesting study was carried out by researchers from Greece about the indoor air conditions in 20 numbers of hospital operating rooms in major hospitals in Greece and listed out the commonly encountered problems such as insufficient indoor air change, bad space ergonomics, poor maintenance etc. (Balaras, 2007). Studies show a direct relationship between certain concentrations of air pollutants with internal health problems, such as: allergies, asthma, bronchitis, pneumonia, lung cancer etc. [(Deloach, 2004), (Craig, 2003), (Health Canada Indoor air quality, 2005), (Hoskins, 2003)]. Modern methods for the management of indoor-air problems have been outlined in numerous publications, with some examples including the World Health Organization's air-quality guidelines, Health Canada's exposure guidelines for residential indoor-air quality, The American National Standard Institute's and the American Society of Heating, Refrigerating and Air-Conditioning Engineer's

standards 62.1 and 62.2 for ventilation and acceptable indoor-air quality, European standards 13779 and 15251 for building design and ventilation performance , the International Society of Indoor Air Quality and Climate's guidelines for biological indoor-air quality , the Finnish Society of Indoor Air Quality and Climate's classifications for indoor climate and the Federation for European Heating and Air-Conditioning Association's guidelines for ventilation and hygiene. These few cited literatures clearly indicate that in order to create a healthy environment for patient recovery and safe working environment for staffs IAQ is an important issue for the smooth functioning of a hospital.

### **SYMPTOMS CAUSES & CONSEQUENCES OF POOR IAQ**

Following are some of the symptoms of poor IAQ in a building;

- Limited fresh air.
- Temperature & humidity outside comfort zone.
- Eye, nose, throat irritation.
- Dry facial skin.
- Respiratory infections, asthma.
- Fatigue, Headaches.
- Increased allergic reactions.
- Sick building syndrome – SBS.

### **Potential Causes of Poor Air Quality**

- Reduced Ventilation.
- Building Materials and furnishings.
- Deferred Maintenance to Save Money.
- Pesticides, Housekeeping Supplies, Office Supplies, and Chemicals in Personal Care Products.

### **Consequences of Poor IAQ**

- Health Problems
- Reduced productivity
- Higher Costs to Fix
- Problems than to Prevent
- Poor Public Relations
- Liability Issues

### **FRESH AIR- VENTILATION ITS IMPORTANCE TO IAQ AND ENERGY COST OF THE HVAC PLANT**

Ambient air contains nearly constant amount of Nitrogen (78% by volume), Oxygen (21%) and Organ (0.9%) with varying amount of carbon dioxide (about 0.3%) and water vapour. Gases other than listed above are usually considered as contaminants. They have serious effect on occupant's health. To

delete/ remove the contaminants from the enclosed space fresh air is to be injected in to the area through the air conditioning system. This is known as ventilation. Assessment of indoor air quality relies on the experience of engineers, building managers and air quality consultants to determine whether satisfactory ventilation rates are maintained, occupancy levels are within guidelines and housekeeping practices are effective. To maintain proper air quality ASHRAE has created new standards. The new standards require more fresh air and exhaust large volumes of conditioned air which in turn raises energy cost. Engineers and owners of health care units are facing a major challenge to find solution without tripling the cost of building operation and maintenance system. Installation of suitable heat exchangers used to recycle the energy from the exhaust to the supply air stream, is one option to reduce the energy cost. During recent years Demand Controlled Ventilation (DCV) concept is being used in hospital HVAC system design. DCV is a strategy that attempts to reduce the energy used by ventilation systems while maintaining required levels of indoor air quality (IAQ). During the last few decades variable air volume (VAV) systems that were conceived to alter the volume flow rate to match thermal demand has become popular among air conditioning engineers. By regulating the flow rate of air through a properly designed system, significant energy savings could be achieved with the help of VAV systems. The concept has been developed and refined to produce the modern DCV systems that frequently not only control temperature (and humidity) but also optimize the supply of air volumes, and particularly outdoor air, so that appropriate levels of IAQ are maintained whilst minimizing energy costs.

#### **SICK BUILDING SYNDROME (SBS)**

The issue of improving air quality in buildings has previously been mainly related to SBS. It is a situation in which occupants of a building experience linked to time spent in the building with no specific illness. Symptoms of SBS are acute discomfort, headaches, dizziness, eye, nose, throat irritation, dry cough, itchy skin, nausea etc. Recently many researchers have worked on SBS issue and its effect on office workers and noticed that SBS is not linked to the type of ventilation or air conditioning system used but it is more likely to be a function of how well system are installed, managed and operated. Therefore Operation & Maintenance of HVAC systems in hospitals are more critical than other buildings.

#### **CONTAMINANTS CAUSING POOR IAQ IN HOSPITALS**

Contaminants causing poor IAQ can be broadly classified as outdoor and indoor contaminants. Later one plays a vital role in IAQ of hospitals. Indoor contaminants can be further classified as Chemical contaminants and Biological contaminants. Tobacco smoke, Volatile Organic Compounds (VOC), Radon, Inorganic gases, Carbon dioxide, and Nitrogen oxides are some sources of chemical contaminants. Chemical compounds that have a carbon basis and evaporate easily into the air are known as Volatile Organic Compounds .VOC cover a wide range of compounds having boiling points in the range of 50 – 260 °C and hence existing in vapour form at room temperature. ASHRAE Standard 62 (1999) suggests that complaints are unlikely to arise for total VOC concentrations below 3000 mg/m<sup>3</sup>, whereas above 3000 mg/m<sup>3</sup> complaints are likely. Radon is a colorless and odourless radioactive gas. It comes from radioactive decay of radium, which in turn comes from the decay of uranium. Radon is implicated in the cause of lung cancer. Respirable particles are those constituents of the air that are not in purely gaseous form. They can be ingested into the lungs while breathing and cause a wide range of health problems. The most potentially dangerous particulates are asbestos fibers but there are concerns about other 'man made mineral fibers' (MMMF), which are widely used for insulation with in buildings. Carbon monoxide (CO) is odourless and colourless gas. Its presence in air more than 1500ppm leads to death. Carbon dioxide (CO<sub>2</sub>) is also a colourless and odourless gas. It forms from burning carbon-based material and also from human respiration (200 ml/min). Its presence in air less than 5000ppm does not cause much problem but more than that creates metabolic stress and respiratory problems. Nitrogen oxide usually from combustion and vehicles, react with air to produce nitrates. It causes lung damage. Its presence more than 150ppm is lethal.

Air borne micro-organism may be sampled by drawing air across a growth medium followed by laboratory incubation and analysis to allow enumeration and species identification. Bacterial and fungi are always present in the indoor environment but, in most cases, not at levels to significantly detrimental to healthy adults .Biological contaminants such as bacteria, mold, and viruses can breed in stagnant water that has gradually accumulated in ducts, humidifiers and drain pans of the ventilation system; or water that has collected on ceiling tiles, carpeting, or insulation. Moulds reproduce by releasing tiny spores which when they land on a damp spot begin to grow. Above 60% RH

moulds grows rapidly. For example, certain respiratory care equipment produces a lot of mist, which can increase the humidity levels in a room. These rooms need to be cleaned regularly to prevent the growth of mold. Allergic reactions and asthma are few symptoms associated with mould. Fungi are another biological contaminant, which needs special attention. One researcher calculated that about 9% of reported hospital infections between 1986 and 1990 were caused by fungi. (Martone, 1992). Sarah et al reviewed the health effects of fungi and concluded that despite intense public interest in the subject science is not yet developed to answer many basic questions about the potential health threat posed by indoor fungi and no standards for exposure to molds have been promulgated (Sarah, 2002).

### **IMPORTANCE OF AIR FILTERS & DUCTS IN HVAC SYSTEMS**

It is very important that the air filters in the ventilation system be changed often. That is because filters are an ideal location for fungus to grow. Bacteria are microorganisms, which are less than 1 micron. They reproduce and develop to resist antibiotic. One out of six people who suffer from allergies do so because of the direct relationship to fungi and bacteria in air duct systems. All parts of the humidification and dehumidification systems must be kept clean and dry to prevent growth of bacteria. Viruses is an another infection mechanism found in almost every living organism, divided into 70 families over 4100 known types, 30-450nm, 95 times smaller than bacteria. Viruses do not reproduce but replicate by injecting their genetic information into a cell, which acts as a host. It damages or destroys host cell e.g. Cancer. Many diseases are the result of viral infection e.g. cold, flu, rubella, measles, chickenpox and shingles. Bacteria or viruses spread so easily through air. When someone sneezes, coughs, laughs or exhales air, respiratory droplets can become aerosolized and can stay airborne for hours. Tests show it takes 4.5 hours for an aerosolized droplet to reach the ground in a room with no air current. Complete removal of indoor contaminants is not easily possible due to the following reasons:

- Poor design and / or material selection of HVAC system and building materials.
- Air is recycled for energy efficiency.
- No / low efficiency internal filtration.
- Physical constraints--not easy to check or clean the filters regularly.
- Un-identified sources of pollutants, and no regular testing.

However with due care during the design and maintenance of HVAC systems in hospitals contaminants can be minimized as per the required standards. Proper maintenance of Air handling units and regular cleaning of ducts and its accessories is one of the important strategies to ensure a better IAQ in a hospital.

### **FEATURES OF HVAC SYSTEMS FOR A HOSPITAL FOR BETTER IAQ**

Various studies have shown that two out of three indoor air quality problems involve the HVAC system. Therefore it is very important to determine the ventilation strategy at an early stage of design to ensure that the systems are tailored to the requirements of each area of a hospital. In general, separate ventilation systems should be provided for each department or group of similar departments provided that they are closely grouped together. It is a general requirement for health care buildings that the building has an overall positive or neutral pressure and the extracted air replaced by treated make-up air supplied to, for example, internal areas, staff base, etc. in ward areas. Air handling plant for all medical areas should be of the 'blow-through' type with only the frost coil and pre-filter upstream of the fan to ensure that there is no inward leakage of air downstream of the coils and main filter. In general, outlets supplying air to ultra-clean areas such as operation theaters, ICUs should be located on the ceiling, and perimeter, or many exhaust outlets should be near the floor. This arrangement provides a downward movement of clean air through the breathing and working zones to the floor area for exhaust.

Surgery & Critical Care areas of a hospital such as obstetrical area, delivery rooms, recovery rooms etc need more careful control. The temperature set point should be adjustable by staff over a range of 17 to 27 °C. Relative humidity should be kept between 45 and 55%. Air pressure should be maintained positive with respect to adjoining rooms by supplying 15% excess air. Differential pressure indicating device should be installed to permit air pressure reading in the rooms. Thorough sealing of all wall, ceiling, and floor penetrations and tight-fitting doors is essential. Humidity indicator and thermometers should be located at the correct locations for easy observation. Filter efficiencies should be as per ASHRAE recommendation. Bad filtration does not control outdoor contaminants. Recycled air allows fine dust particles to accumulate in the air ducts. Figure 3 shows the condition of A.C duct in one of the hospitals in Oman.

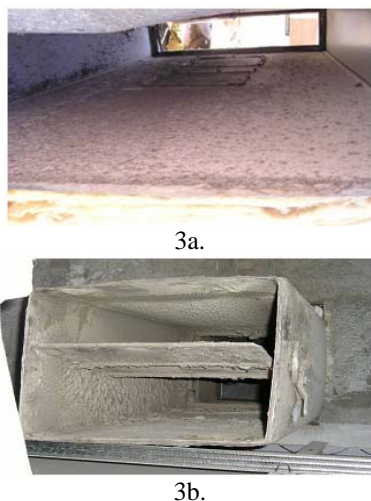


Figure 3. The condition of A.C duct in one of the hospitals in Oman.

In case of airborne infectious diseases like TB, patients are often kept in special isolation rooms that are under negative pressure so that contaminated air will not get out of the room. This type of isolation is called infectious isolation. Such rooms should have all air exhausted directly outdoors. Winter design temperature of 24C with 30% RH is recommended; 24C with 50% RH is recommended for summer. Each patient room should have individual temperature control.

Modern laboratories in a hospital require regulated temperature, humidity, relative static pressure, air motion, air cleanliness, sound and exhaust. In biological labs chemical fume hoods and biological safety cabinets are used. Operator protection may be provided by fume cupboards, microbiological safety cabinets or other local exhaust ventilation systems. Safety cabinets provide protection against dangerous pathogens. There are three classes of safety cabinets. Class 1 safety cabinets provide user protection. Class 2 safety cabinets protect the operator and the work by recirculating some of the air through a HEPA filter to provide a down-flow over the working area. Class 3 safety cabinets are totally enclosed units designed to provide a high degree of user protection.

As mentioned above filters are one of the critical parts of HVAC system to maintain the prescribed standards of IAQ. Air borne dust consists of dispersed solids of varying sizes and numbers. These can be graded as coarse, fine and very fine, according to their sizes. Air borne particles are measured in microns (1 micron = 0.001 mm). The human hair is 75 to 100 micron in diameter. Pre-filters are capable of filtering, particles of 15 to 20 microns in size with 90% efficiency. Pressure drop in these types of filters is 6mm WG. Fine filters can filter down to 5-micron

size with efficiency of 99.9%. Pressure drop is 15 mm of W.G. High Efficiency Particulate Air (HEPA) filters down to 0.3-micron size. Pressure drop in these type of filters is 50 mm of W.G. Use of appropriate filters and its regular maintenance is strongly recommended in all IAQ standards.

### STRATEGIES TO IMPROVE INDOOR AIR QUALITY IN HOSPITALS

Always follow guidelines such as ASHRAE/, WHO, NADCA etc during the design and maintenance stages. Regularly check and correct ventilation standards to dilute and remove impurities. Consider use of air purifiers or other methods to improve indoor air quality. Do regular inspection and testing for gases, particles, microbiological etc and take immediate actions to rectify the problems if any. Provide local hooding with exhaust for bathrooms and kitchen. Proper space planning, routine monitoring of various parameters of HVAC systems, proper maintenance of all parts of the system and regular inspection and cleaning of a.c ducts are some of the airborne infection control techniques. Apply techniques of elimination of contaminants at source itself. This is most effective and least expensive strategy. During the design stage use special care for space design for infection control. Segregation of sterile areas, separate path for dirty materials movement, provision of staff change / wash areas, sealed rooms are few important factors to be considered during the space design as a strategy for infection control. Examination of floor and wall surfaces for cleanability, regular "deep clean" after infectious patients left the site, measurement of air quality periodically and regular microbiological testing are some of routine monitoring strategies for infection control. Monitor controls, indoor conditions, and pressure devices, regular filter, coil & drain cleaning, regular water testing, regular component replacement are the recommended maintenance strategy for infection control in a healthcare unit. Another important strategy is that the infection control team is involved at all stages from pre-design through to opening and that adequate time for commissioning is built-in to the schedule, including an allowance of time for microbiological assessments particularly hospital operation theaters. Also operating theatres must be commissioned before being used, after being built or modified substantially. Commissioning is a task for both the Estates Department and the Infection Control Team, and co-operation and co-ordination between them is important. Pressure differentials between rooms in the theatre suite are given in Health Technical Memorandum 2025 (HTM 2025), volume b (Design considerations) and the same should be followed

strictly. The lights in various areas of the hospital should ideally be of a type that offers minimal interruption to the airflow pattern. The humidifier and cooling coil in air handling units be disinfected at least six-monthly. It is to be confirmed that drainage systems on the air-handling unit comply with HTM 2040.

Effective functioning of infection control committee in a hospital, in which pathologist, infection control officer, head of nursing affairs, representative from surgery department, hospital engineer are the members, is one of the most important strategy to be adopted to monitor the IAQ in a hospital. The infection control committee has to review the surveillance data routinely in order to identify/detect problems with regard to inherent potentials for unusual epidemics, clusters of infections, infections due to unusual pathogens or any occurrence of nosocomial infection that exceeds baseline levels and also to ensure strict compliance by all departments with the hospital's infection control policies and procedures. Create awareness among the staffs, and publics about the importance of IAQ and encourage them as not to do the following:

- Bringing non-sterile objects into the room – particularly in designated clean areas.
- Opening windows – Frequent opening of windows allows external pollutants in.
- Not changing prescribed clothes before entering into the clean areas and avoids washing hands after touching the infectious items.
- Allowing too many visitors around patients.

Primary methods of controlling air quality are:

- Elimination : removing potential contaminants from the workplace
- Substitution : replacing materials with alternatives that are less harmful
- Dilution: the reduction in concentration of harmful contaminants through the introduction of less contaminated or uncontaminated air.

#### **CURRENT INTERNATIONAL RESEARCH TO IMPROVE INDOOR AIR QUALITY**

Improvement of IAQ is a continuous process. It needs meticulous coordination and cooperation between the various departments of the health care unit. Researchers throughout the world are working hard to improve the IAQ in hospitals. W. Bread et al based on their review of three publications referencing successful application of the IAQ

Procedure have concluded that in order for the IAQ Procedure of ASHRAE 62.1 to be widely used, there needs to be a base contaminants of concern (CoC) set. They recommended that research is needed to establish a base CoC list for engineers using the IAQ Procedure of ASHRAE 62.1. (W.Bread, 2009). In recent years use of UVC emitters find interesting application in HVAC technology to improve the IAQ especially in hospitals. A seven and a half-year study conducted in the *in vitro* fertilization clean room laboratory of the Lehigh Valley Hospital and Health Network in the US found that the use of ultraviolet C or “UVC” lights installed in the HVAC system had a clinically significant impact on clinical pregnancy rates. The study found that UVC energy will destroy 90 – 99% of airborne microbial contaminants.

Some of the areas in which current research is focused are given below:

- Use of UV irradiation to kill bacteria.
- Physical re-modeling of theatre access.
- Air purifiers.
- Re-design of ducts systems and materials.
- Development of international standards.
- UV irradiation in ductwork.
- Air – Ceiling – unidirectional air distribution system.

#### **CONCLUSION**

A healthy solution should be able to be achieved if good standards of design, commissioning, operation and maintenance are followed. The most obvious steps in the prevention of indoor-air pollution are to ensure that (i) the design and the operation of the building is according to the state of the art in relation to building application and conducted activities, (ii) building performance is according to the specifications in relation to pollutant concentrations and operating parameters, and (iii) steps i and ii are routinely monitored. Even if the aforementioned preventive steps are taken, there is a potential for indoor-air problems to still occur, due to the various reasons outlined in this paper. In such cases, it is important for HVAC engineers, hospital facility managers and hospital infection control officers to be aware that there could be still problems, and not to ignore warnings or indications of problems, particularly if related to symptoms of human ill health, and be innovative and open to novel methods of investigation. Maintaining clean heating, ventilation and air-conditioning (HVAC) systems is an important part of sustaining acceptable indoor air quality (IAQ).

Based on the visual inspection of ducts at various sites it has been observed that very few HVAC systems are “spotlessly” clean. Therefore it is

suggested to make a statutory requirement to clean the ducts at constant interval as per the international standards in all health care units. Regular cleaning of cooling coils of the air handling units is strongly recommended to minimize the air pollution in a.c systems. In GCC countries health sector is one of the major areas which is growing exponentially. During recent years many private enterprises have started investing heavily on the infrastructure of health care units. Role of private sectors are different from government sectors. Profit is the main motive for the private enterprises although many corporate invest on this sector as a part of their social responsibility. Therefore a common strategy to maintain a proper IAQ in health care units in GCC countries is required urgently. The strategies it is ready can be enforced through local government regulations. The strategies should include various codes, practices, documents, procedures, commissioning formats, etc as described in the above paragraphs. Together identify report, rectify inferior conditions or potential problem areas and take necessary steps as not to re occur the same type of problem again elsewhere in the health care facility.

## REFERENCES

- Air Quality Guidelines for Europe. World Health Organization European, Regional Office for Europe, Copenhagen, Series No.23, 1997.
- ASHRAE Journal May 1999 P-16.
- ASHRAE Journal May 1999 P-26-30.
- Bako-Biro, Z. 2004. Human Perception, SBS symptoms and performance of office work during exposure to air polluted by building materials and personal computers. PhD Thesis. International Centre for Indoor Environment and Energy. Technical University of Denmark.
- Balaras C.A, Elena Dascalaki, Athina Gaglia,” HVAC and indoor thermal conditions in hospital operating rooms”, Energy and Buildings 39 (2007) 454-470 .
- CPD notes on IAQ (2006), CIBSE Building Services Journal (06/06) page -88.
- Craig, B.; et al. Air quality in interior environments. Ottawa: Canada Mortgage and Housing Corporation, 2003.
- Deloach, C. Healthcare is going green: saving dollars and making sense. Business Briefings: Hospital Engineering & Facilities Management: publication of the International Federation of Hospital Engineering, London, p 84-88, Jan. 2004.
- Fisk W. and Rosenfeld A., "Improved Productivity and Health from Better Indoor Environments", Center for Building Science Newsletter, Lawrence-Berkeley Labs, Summer, 1997.
- Health Canada Indoor air quality. Disponible en: <[http://www.hc-sc.gc.ca/ewhsemt/air/in/index\\_e.html](http://www.hc-sc.gc.ca/ewhsemt/air/in/index_e.html)>. Access in: 25 Oct. 2005.
- Hoskins, J. A. Health effects due to indoor air pollution. Indoor Built Environment. London, v. 12, n.6, p. 427-433, Dec. 2003.
- Ignatius T.S et al , “ Evidence of Airborne Transmission Syndrome Virus “ The New England Journal of Medicine, Vol 350:1731-1739 April 22,2004,Number 17.
- Martone WJ, Jarvis WR, Culver DH, Haley RW. Incidence and nature of endemic and epidemic nosocomial infections. In Hospital Infections, J.V. Bennett and P.S. Brachman, editors, Boston: Little, Brown, and Co. 1992:577-596 .
- Nordstrom et al, “Subjective Indoor Air Quality in Geriatric Hospitals” Department of Occupational and Environmental Medicine, Uppsala University hospital, Sweden.1998 Proc CIB World Building Congress ,Gaeve,Sweden.
- O'Neal C. Infection control; Keeping diseases at bay a full-time effort for healthcare professionals. The Fort Worth Star Telegram. September 24, 2000 .
- Roodman, D.M., and Lenssen, N., A. Building Revolution: How Ecology and Health Concerns are Transforming Construction. World Watch Institute, Washington, D.C., 1995.
- Sarah Armstrong, Jane Liaw,” The fundamentals of Fungi” ASHRAE journal November 2002 P18-24
- Ventilation for acceptable indoor air quality ASHRAE Standard 62-1999.
- W. Brad M. Stanley, Charlene W. Bayer, “Determining Contaminants of Concern When Implementing ASHRAE Standard 62.1 Indoor Air Quality Procedure” Proceedings of Healthy Buildings 2009, Paper No 721.
- [www.cleanroom-technology.co.uk](http://www.cleanroom-technology.co.uk)