INTRODUCTION

Several nosocomial infections may be caused by atmospheric fungi, and among these, Aspergillus infections remain the most widely threatening. In the last years, reports of Aspergillus infections acquired during surgical or transplant interventions, which were often followed by patient death, became increasingly more frequent ***(Lutz et al., 2003; Munoz et al., 2004).***

Other medically important fungi include Penicillium spp., which are occasional causes of infection especially in immunosuppressed hosts. Penicillium has been isolated from patients with keratitis ***(Deshpande et al., 1999)***, endophtalmitis, otomycosis, necrotizing esophagitis, pneumonia, endocarditis, peritonitis, and urinary tract infections. In addition to its infectious potential, Penicillium verrucosum produces a mycotoxin, ochratoxin A, which is nephrotoxic and carcinogenic ***(Pitt, 2000).***

In addition, high concentration of airborne fungi is considered to represent a risk factor for respiratory symptoms in childhood ***(Garrett et al., 1998)***, it is therefore important to assess, regularly, the indoor air quality in order to better control fungal respiratory diseases in hospitals.

The levels of airborne fungi are dependent on environmental factors such as relative humidity, temperature, and wind ***(Horner et al., 1995).*** Several studies showed that water from showers might be responsible for the high fungal levels found in the air of clinical wards ***(Anaissie et al., 2002).***

In hospitals, preventive measures should be established in high infection risk units, particularly by the use of high-efficiency particulate air (HEPA) filtration, with high ventilation rates, in addition to special access conditions to hospital units, like the limited access of personnel and the routine use of protective clothes. These preventive measures limit drastically the access of outdoor fungi to such environments, reducing their concentrations, resulting in a concomitant decrease in the incidence of fungal infections in critical patients ***(Leenders et al., 1999; Alberti et al., 2001; Oren et al., 2001; Munoz et al., 2004; Araujo et al., 2008).***

One study found a direct proportionality between levels of penicillia and aspergilli so that the determination of penicillia can lead to an estimate of aspergilli. Penicillia levels were much higher than aspergilli, and therefore technically much easier to determine. In addition, penicillia are easy to identify in an agar culture medium. So, based on these findings, Penicillium can be used as a general indicator of hospital indoor fungal levels ***(Araujo et al., 2008).***

AIM OF THE WORK

The first aim of this study is to compare the levels of different fungi, especially Aspergilli and Penicillia in various hospital environments. This may help identify a fungal indicator of air quality, technically easy to assess, in order to simplify regular evaluation in hospital indoor environments.

This work also aims at evaluating the effect of infection control measures (such as HEPA filters wih high ventilation rates as well as the special access conditions like the use of protective clothes and the existence of an anteroom) on limiting the access of outdoor fungi into the hospital rooms, reducing their concentration.

Additionally, this study tries to find out if the air fungal concentration is affected by aerosolized contaminated tap water.

CHAPTER I

INDOOR AIR QUALITY

Acceptable indoor air quality was defined by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) as: "Air in an occupied space toward which a substantial majority of occupants express no dissatisfaction and in which there are not likely to be known contaminants at concentrations leading to exposures that pose a significant health risk" ***(Glantz and Schick, 2004).***

Health problems related to IAQ:

Indoor air quality (IAQ) is of great importance to health. According to the U.S. Environmental Protection Agency (EPA), many people spend >90% of their time indoors breathing air that has significantly declined in quality. The American Lung Association reports that up to 50% of illnesses over the past decade are either caused or aggravated by indoors airborne contaminant ***(Brummet, 2003).***

According to the Public Employees Occupational Safety and Health Program (PEOSH), most IAQ health problems can be categorized either as sick building syndrome or building-related illnesses.

Sick building syndrome is associated with the situation where a large number of building occupants experience health and comfort problems that cannot be attributed to any particular illness or sources, and that seem to disappear upon leaving the building. Sick building syndrome symptoms include headaches; eye, nose, or throat irritation; itchy skin; and loss of concentration.

Building-related illnesses are associated with the situation where a relatively small number of building occupants experience health problems or symptoms that are not necessarily alleviated by leaving the building. This condition generally is caused by allergic reactions to microbial contamination and/or specific chemical or biological exposure to substances such as carbon monoxide, formaldehyde, pesticides, bacterial endotoxins, or mycotoxins. Illnesses and symptoms may include asthma; Legionnaires' disease; eye, nose, or throat irritation; skin irritation or rashes; chills; congestion; muscle aches; and pneumonia.

(Ofungwu, 2005)

Indoor air contaminants:

A) Biological contaminants:

They include bioaerosols, which are airborne materials that are or were living, such as bacteria, molds, viruses, animal dander and cat saliva, house dust, mites, cockroaches, and pollen. Molds and other biological agents can multiply in the increasing proportion of Cairo's buildings that are closed and climate-controlled.

B) Chemical pollutants:

1. Environmental Tobacco Smoke (ETS) or "second-hand smoke".
2. Pollutants from stoves (CO, NOx, particulates); buildings equipped with gas- or kerosene-fueled appliances often have indoor concentrations of nitrogen oxides and carbon monoxide exceeding outdoors ambient standards. In particular, burning kerosene indoors put inhabitants at high-risk.
3. Toxic consumer products and building materials (e.g., solvents, paints, pesticides, asbestos, urea-formaldehyde insulation).
4. Radon, which is a cancer-causing, radioactive odorless gas that is found in soils. It can become

concentrated at dangerous levels in any building. Radon seeps into homes through cracks and other holes in the floor. Radon-resistant construction can control radon in buildings by reducing moisture levels and all the associated problems with increased moisture in buildings.

(Farghali, 2003)

Factors affecting IAQ:

Indoor air pollutant levels are increased under some circumstances; factors that increase indoor pollutant levels can be summarized as:

A) Inadequate ventilation by not bringing in enough outdoor air to dilute emissions from indoor sources and by not discharging indoor air pollutants out of the building.

B) High temperature and humidity levels.

C) How old the source is and whether it is properly maintained. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

D) How long the source emits pollutants? Some sources, such as building materials, furnishings, and household products, release pollutants more or less continuously. Other sources, related to activities carried out in the building, release pollutants intermittently.

(NSCEP, 2003)

Assessment of IAQ:

During a detailed assessment of an indoor environment, air quality indicators and pollutant sources are investigated and measured and the heating, ventilating, and air-conditioning (HVAC) system is checked. Tools include checklists and calibrated measuring equipment. Some measurements may require the use of complex instruments and laboratory analysis. Specialists may be required at certain stages of the diagnostic process, and a team approach is advisable *(Health Canada, 1993).*

Potential Air Quality Indicators of Interest:

A) ***Carbon Dioxide (CO2):***

Carbon dioxide is a colourless, odourless gas. Its concentration in indoor air can, under certain conditions, provide a good indication of the ventilation rate. It is generated indoors primarily through human metabolism.

Standards or Guidelines:

ASHRAE standards for indoor CO_2 are 800 PPM to 1000 PPM when outdoor level is 300 PPM.

B) Sulphur Dioxide (SO_2):

Sulphur dioxide is an acidic gas which can be used as an indicator of pollution from the combustion of coal. The principal source of this gas is power stations burning fossil fuels (coal) which contain sulphur. Major SO_2 problems now only tend to occur in cities in which coal is still widely used for domestic heating and in power stations.

Health Effects:

Even moderate concentrations may result in a fall in lung function in asthmatics. Tightness in the chest and coughing occur at high levels, and lung function of asthmatics may be impaired to the extent that medical help is required. Sulphur dioxide pollution is considered more harmful when particulate and other pollution concentrations are high.

Standards or Guidelines:

No standards for SO_2 have been agreed upon for indoor air. The U.S. National Ambient Air Quality

Standards for outdoor air are 0.14ppm (365μg/m^3) for 24hrs.

C) Respirable particulate matter (PM10):

Respirable particulate matter can be used as an indicator of smoke and dust from the cooking and heating appliances. Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM10 particles (the fraction of particulates with diameters less than 10μm are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks.

Health Effects:

Fine particles can be carried deep into the lungs where they can cause inflammation and the worsening of the condition of people with heart and lung diseases. In addition, they may carry surface-absorbed carcinogenic compounds into the lungs.

Standards or Guidelines:

No standards for PM10 have been agreed upon for indoor air. The U.S. National Ambient Air Quality Standards for outdoor air are 150μg/m^3 for 24hrs.

D) Carbon Monoxide (CO):

Carbon monoxide is a toxic gas which can be used as an indicator of incomplete combustion of fuel and inefficient waste gas exhaust. It survives in the atmosphere for a period of approximately one month but is eventually oxidized to carbon dioxide (CO_2).

Health Effects:

This gas prevents the normal transport of oxygen by the blood. This can lead to a significant reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease.

Standards or Guidelines:

No standards for CO have been agreed upon for indoor air. The U.S. National Ambient Air Quality Standards for outdoor air are 9ppm (40,000μg/m^3) for 8 hours, and 35ppm for 1hr.

E) Nitrogen Dioxide (NO2):

Nitrogen dioxide is a toxic and corrosive gas that can be used as an indicator of pollution from Kerosene heaters, gas stoves and heaters and environmental tobacco smoke. Nitrogen oxides (nitric oxide (NO) and nitrogen dioxide (NO_2) collectively known as Nox) are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel.

Health Effects:

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. Continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children.

Standards or Guidelines:

No standards have been agreed upon for nitrogen oxides in indoor air. ASHRAE and the US. EPA National Ambient Air Quality Standards list 0.053ppm as the average 24-hour limit for NO_2 in outdoor air.

(WHO, 2004)

F) Penicillium:

Penicillium was proposed as a biological indicator of indoor airborne fungal contamination. Pencillium fungi are versatile and opportunistic. In additition to their harmful effects, the clinical significance of Penicillium species comes from their relation to Aspergillus species. Many studies found that they were both the most commonly isolated airborne fungi in hospitals ***(Al-Falih, 2001; Su et al., 2005, 2006; Araujo et al., 2008).***

Araujo and his coworkers have found a direct proportionality between levels of Aspergillus and Penicillium in the studied hospital atmosphere, so that the determination of penicillium level can lead to an estimate of aspergillus level, the main fungus of concern in hospital indoor environment. The use of this indicator has important advantages as Penicillium levels are usually much higher than aspergillus, and therefore are technically much easier to determine. In addition, penicillia are easy to identify in an agar culture medium ***(Araujo et al., 2008).***

Health Effects:

Penicillium species are occasional causes of infection in humans mostly in immunosuppressed hosts. Penicillium has been isolated from patients with keratitis, endo-phtalmitis, otomycosis, necrotizing esophagitis, pneumonia, endocarditis, peritonitis, and urinary tract infections ***(Deshpande and Koppikar, 1999).*** Penicillium marneffei is a pathogenic fungus and specifically infects patients with AIDS who live at or visit Southeast Asia where the fungus is endemic ***(Deng et al., 1988; Supparatpinyuo et al., 1992; Singh et al., 1995).*** Penicillium marneffei infections have also been reported in non-AIDS patients with hematological malignancies and those receiving immunosuppressive therapy ***(Wong et al., 2001).***

In addition to its infectious potential, Penicillium verrucosum produces a mycotoxin, ochratoxin A, which is nephrotoxic and carcinogenic ***(Pitt, 2000).*** In addition, Penicillium is a common allergy inducing mould that seems to be chiefly involved in the genesis of asthma and allergic alveolitis ***(Perdelli et al., 2006).***

Standards or Guidelines:

No exposure standards have been established that relate health effects to specific levels of indoor molds ***(Rao et al., 2007).*** However, there is a current set of available guidelines for indoor fungal levels provided by some organizations, e.g.: American Conference of Governmental Industrial Hygienists (ACGIH), 1989, and US Public Health Service, 2003, have reported that 200 colony forming units per cubic meter (CFU/m^3) is recommended as a guideline for fungal bioaerosols ***(Giardino, 2004).***