INDOOR AIR QUALITY (IAQ) INSIDE A HOSPITAL THEATRE

Miss. Sanduni Gunaratne,
Undergraduate Research Student, Department of Civil Engineering University of Moratuwa
email: gunaratne.sanduni@gmail.com
Miss. Dhanushika Gunatilake,
Undergraduate Research Student, Department of Civil Engineering University of Moratuwa
email: dhanuvida@yahoo.com
Mr. Rumesh Madushanka
Undergraduate Research Student, Department of Civil Engineering University of Moratuwa
email: hkrumesh@gmail.com
Miss. Manori Perera
Postgraduate Research Student, Department of Civil Engineering, University of Moratuwa
email: manori2007@gmail.com
Prof.(Mrs) Chintha Jayasinghe
Professor, Department of Civil Engineering, University of Moratuwa
email: chintha@civil.mrt.ac.lk
Prof. Anul Perera
Professor, Department of Chemical and Process Engineering, University of Moratuwa
email: anul@cheng.mrt.ac.lk
Dr. Samadhi Rajapaksa
Medical Professional, National Cancer Institute of Sri Lanka
email: samadhirajapaksa@yahoo.com

Abstract: In this research study, the effect of the activities associated with a hospital theatre, on its IAQ has been studied since the theatre staff experience some discomfort while being inside the theatre. In order to evaluate this, variation of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOC) and Particulate Matter less than 2.5 microns ($PM_{2.5}$) concentrations inside the theatre were measured and analyzed.
Significant variations were observed in the concentrations of CO_2, TVOC and CO inside the operation theatre. CO_2 concentration inside the room increased at the beginning and end of the surgeries due to high occupant density and also during *Laparoscopic surgeries*. TVOC concentration was affected by the usage of different chemicals during the surgery. Major effect to the CO concentration was by *Diathermy*.

Key words: Indoor Air Quality (IAQ), Hospital theatre, Sick Building Syndrome (SBS)

1. Introduction

Indoor Air Quality inside a building mainly depends on the activities associated with the building and its design features. Based on the indoor activities taking place, it is essential to consider different building planning aspects at the design stage to create a healthy building. The designs should be implemented such that, they minimise the adverse effects on indoor air, generated by the indoor activities. Along with the proper ventilation practices adopted at the design stage, appropriate building operational practices would result in improved IAQ.

Recently the scientific community has become increasingly interested in the air quality of indoor areas of hospitals and healthcare facilities. Operation theatres, laboratories, hospital wards and private practices have been examined, as the locations where there is a higher possibility for both patients and hospital staff to get exposed to infectious agents, which can be harmful to their health. [1]

When a hospital theatre is considered, various chemicals are used depending on the type of surgery. Since the theatre is an enclosed area, emissions due to the chemicals are stagnated inside. Thus, the doctors and other hospital staff have a greater impact from the polluted air than the patients as they are exposed to this environment for long hours.

In order to understand the indoor air pollution, it is essential to identify causative agents and the sources of them. Sulphur Dioxide (SO_2),Nitrogen Dioxide (NO_2),Carbon Monoxide (CO) ,Volatile Organic Compounds (VOC),Carbon Dioxide (CO_2),Particulate Matter (PM) can be identified as common types of causative agents. Since the chemical reactions are active at higher temperatures, thermal measurements are also useful in the study. Different types of surgical equipment and chemical solutions used during surgeries, release various causative gases. Depending on the chemicals present, the impact on indoor comfort and occupant health can vary.

2. Objectives

The main objective of this research study is to determine the concentrations of causative agents due to the various chemicals used during surgeries in a hospital theatre and the effects on the occupants due to the long term exposure. In addition, the adequacy of the existing ventilation system was assessed for its suitability for dilutional dispersion of pollutants.

3. Methodology

3.1.Test Chamber

The study took place at an operation theatre of one of the leading hospitals in Sri Lanka. This theatre consisted of two compartments, surgery area and doctor's changing room, attached to each other by a door (size 2.0m x 0.9m) which was kept open throughout. The dimensions of the openings of the test chamber are shown in Figure 1.

Both compartments of this room were ventilated by a central air conditioning system, of which the corresponding outlet was located directly above the theatre bed as indicated in Figure 1. Both the compartments were under sterilization throughout. The state of the art equipment and technology is used in this hospital with old infrastructure which in turn results poor air quality.

The occupant density of the room was not the same during the course of the experiment. At the initial stage of a surgery the occupant density of the room has reached its maximum value. But gradually it decreased during the surgery and came to an average value of 10 people. At the end of the surgery also the occupant density increased to about 15 people. This was the major factor for higher CO_2 concentration inside the room.

3.2.Pollutants under consideration and the equipment used

The study was to measure the variations occurred in the concentrations of indoor air pollutants such as Carbon Monoxide (CO), Volatile Organic Compounds (VOC), Carbon Dioxide (CO_2), Particulate Matter ($PM_{2.5}$) under the influence of the chemicals used during various types of surgeries. Apart from those, the variation of room temperature and Relative Humidity were also recorded.

The pieces of equipment used in this study were Indoor Air Quality Monitor (IQM60 Environmental Monitor V5.0) and Haz-Dust Particulate Air Monitoring Equipment.

Indoor Air Quality Monitor (IQM60 Environmental Monitor V5.0) was used to measure the concentrations of CO, Total VOC, CO_2, room temperature and relative humidity. Haz-Dust Particulate Air Monitoring Equipment was used to measure the concentrations of $PM_{2.5}$ throughout the study.

3.3. Experimental programme

Instruments were placed at a height of 0.9m from the ground and at 2m distance from the theatre bed. Both the instruments were plugged in for warming up for one hour before the surgeries were started. Test was conducted in an air conditioned and sterilized environment. Measurements were taken for several days, during different surgeries in order to obtain average results with a representative sample. The theatre was allowed to function under its usual condition,

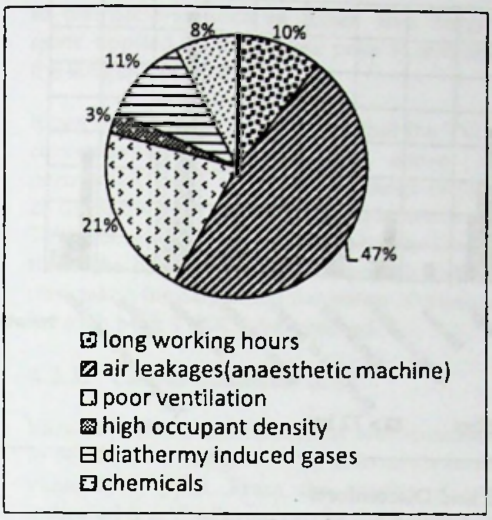

Figure 3: Suspected Causes

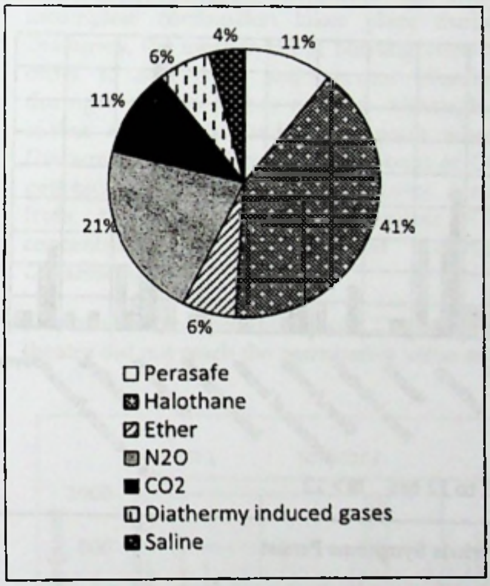

Figure 4: Suspected Causative Agents

4.1.3. Discomforts felt at different time periods of the day

It can be seen from Figure 5 that the discomfort is more severe (54%) after coming out of the theatre. While inside the theatre, during a surgery also there is the substantial effect. When the Figure 6 is considered, it is apparent that the higher numbers of complaints are from the occupants who are exposed to the poor indoor air for a comparatively lower time period (i.e.: less than 24 hours per week). The main reason for this could be the occupants who are working long hours have been adapted to this indoor environment so that they feel less discomfort and thus the actual effect is not felt by them (acclimatization). People who are exposed to this environment for lower time periods have complained more on the uneasiness compared to the ones who are exposed for long hours, which in turn shows the effect of acclimatization. When the Figure 7 is considered it is noticeable that the effect lasts for about 3 hours for the majority of occupants. A fewer number of people suffer from discomfort more than 12 hours. Sleepiness, Lethargy and headache are the symptoms which last for a longer period. Therefore it is apparent that the majority of the occupants suffer from SBS.

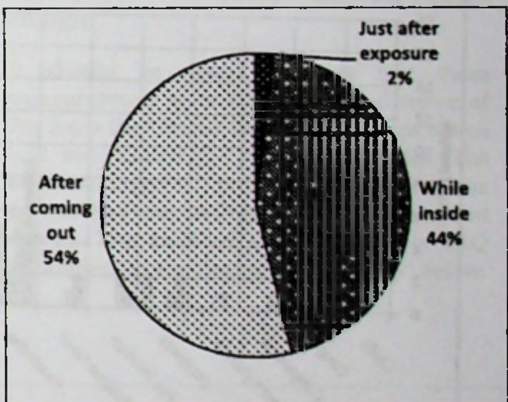

Figure 5: Discomforts felt at different times of the day

4.2. Concentrations of The Causative Agents

Due to the usage of different chemicals and also the differences in the number of occupants inside the theatre, significant variation in the concentrations of measured parameters was witnessed. The concentrations of causative agents in three days showed different variation patterns depending on the types of surgery.

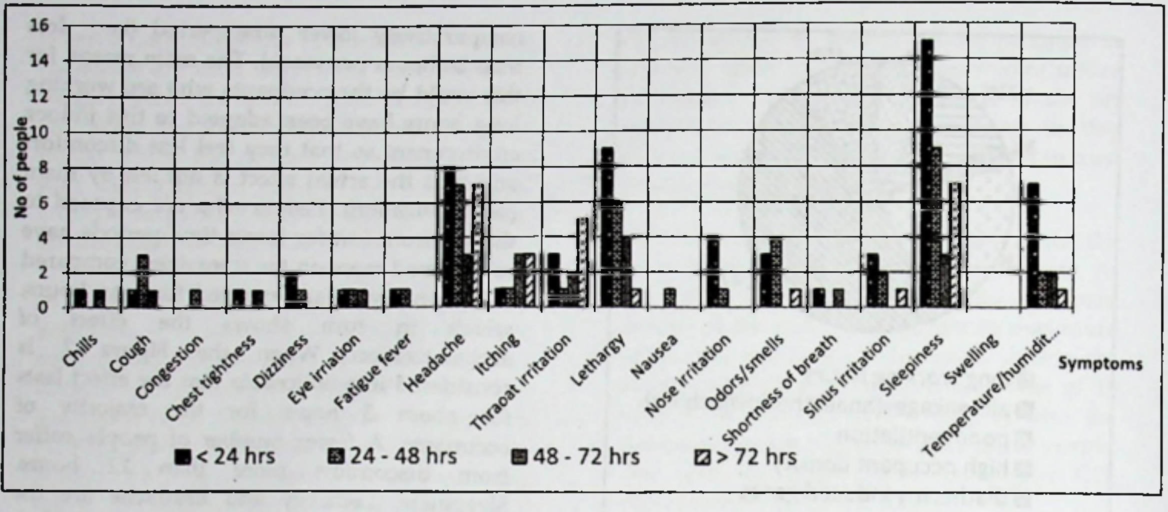

Figure 6: Exposure Levels and Discomforts

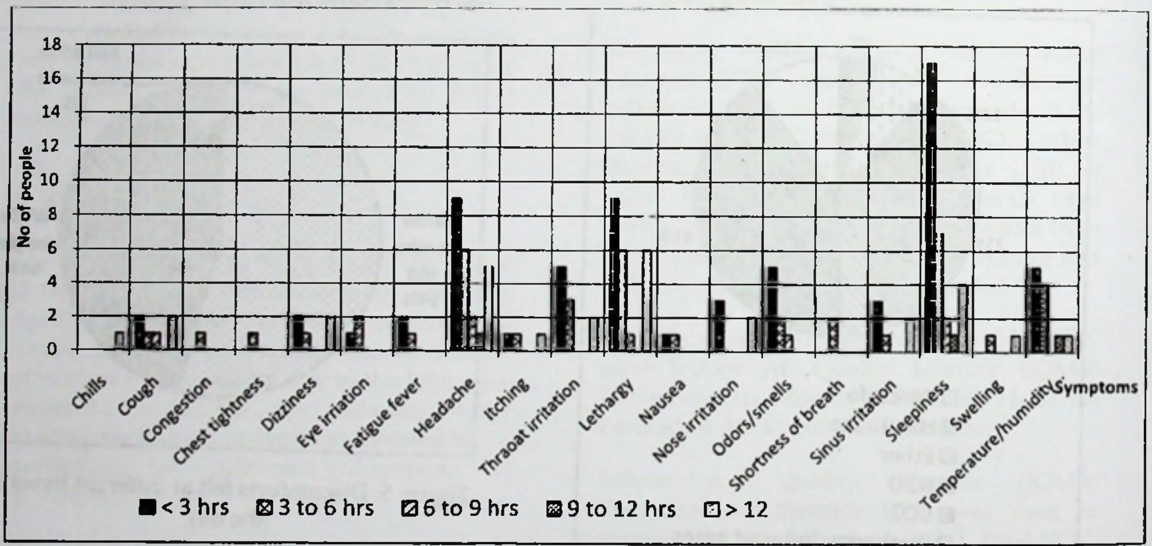

Figure 7: Time Periods Symptoms Persist

4.2.1. Carbon Dioxide (CO_2)

Since occupant density is a major concern with respect to the CO_2 concentration inside a room, the variation of the number of occupants inside the operation theatre was also recorded. CO_2 concentrations were high at the commencement of a surgery and also at the end of the surgery as the occupant densities inside the theatre were generally high during those instances. (*Figure 8*)

Further to that, *'laparoscopic surgeries'* also have shown an increase in the indoor CO_2 concentration. That is because of the release of CO_2 blown into the body of the patient during these surgeries to get a much clear image of the area under the surgery on the screen.

Although CO_2 level did not exceed the ASHRAE (American Society of Heating Refrigerating and Air conditioning Engineers)[2] recommended value, it was higher than usual indoor CO_2 concentration.

4.2.2. Total Volatile Organic Compounds (TVOCs)

The TVOC concentration inside the theatre has shown a variation with high peaks at the start and at the end of surgeries. This is mainly due to disinfectants such as *'Ether'* and *'Surgical spirit'* applied on the patient prior to and after the surgery. (*Figure 9*)

It can be observed in the graph that the TVOC concentrations increase well above the permissible level, mostly in the range of 10 to 25 times the permissible level. Maximum value TVOC concentration has reached more than 55 times the permissible. It is noticeable that the time taken for dispersion lies above 30 minutes for each peak TVOC level reached.

4.2.3. Carbon Monoxide (CO)

Variation of CO concentration was examined to be within a range of 2 ppm from its initial value of 0 ppm. From the graphs, it was indicated that *Diathermy* can be the main cause of emitting CO to the indoor air. Since incomplete combustion takes place during *Diathermy*, the mechanism of burning veins in order to seal them and prevent bleeding during a surgery CO is emitted. Although a sucker machine is used at the point where *Diathermy* is carried out, some amount of CO gets escaped to the indoor environment. Apart from that, an increase in indoor CO concentration was observed during Laparoscopic surgeries as well.

Nevertheless, concentrations of CO inside the theatre did not reach the permissible value and was in the range of 0-22% of the permissible value (*Figure 10*).

4.2.4. Particulate Matter ($PM_{2.5}$)

Particulate matter concentration for the particles of size less than 2.5µm was measured inside the theatre. Even in the normal condition, the concentration was lying half way closer to the permissible value. It was observed that the $PM_{2.5}$ goes beyond the permissible value of 0.025mg/m^3 during the period of surgery (*Figure 11*)

4.2.5. Temperature and Humidity

Temperature inside the room did not show any significant variation from its average value of 24°C, which was varying between few degrees. Relative humidity was also varying between 65-75% without showing abrupt changes

It should be noted the fact that these measurements were taken from a distance of 2m from the theatre bed, at a distance which will not disturb the ongoing surgeries. The concentrations of pollutants closer to the theatre bed can be higher than the recorded values. The most critical variations of IAQ parameters in the theatre are presented below.

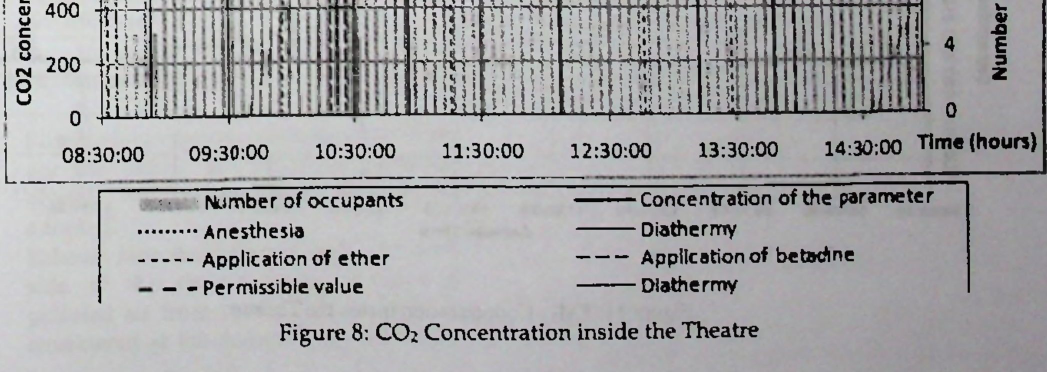

Figure 8: CO_2 Concentration inside the Theatre

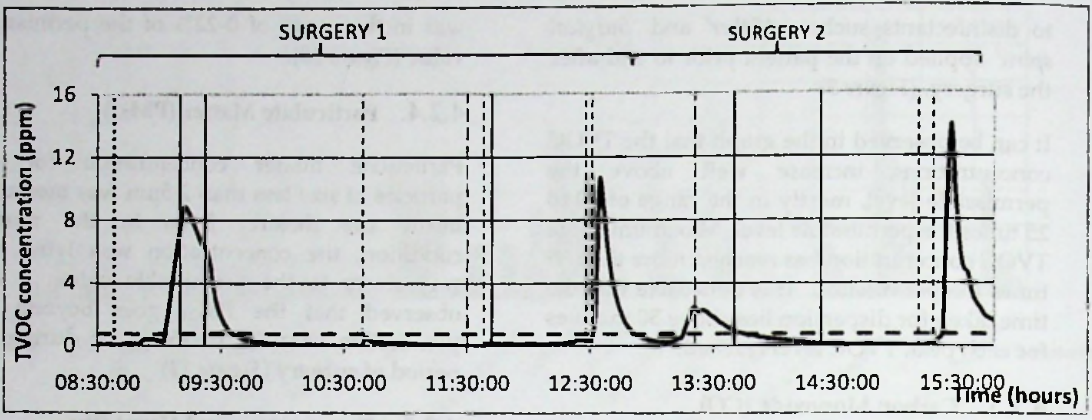

Figure 9: TVOC Concentration inside the Theatre

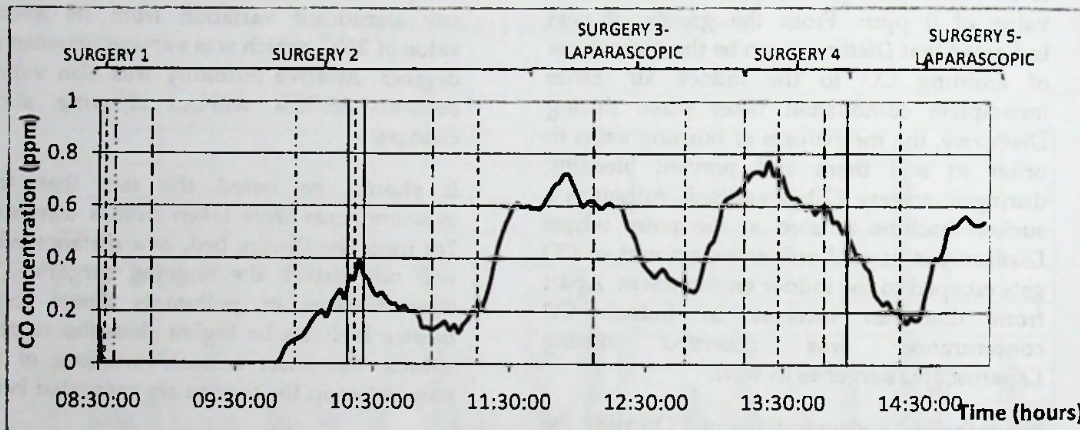

Figure 10: CO Concentration inside the Theatre

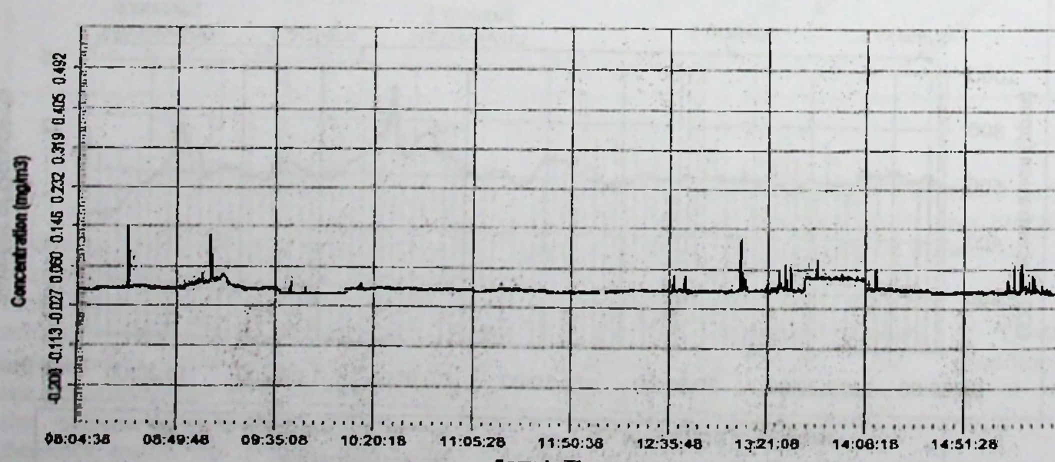

Figure 11: $PM_{2.5}$ Concentration inside the Theatre

5. Conclusions

The IAQ of an operation theatre in a leading hospital in Sri Lanka was studied during surgeries, to study the effects of different chemicals and methods used, on the concentrations of CO, TVOC, CO_2 and $PM_{2.5}$.

- Although researchers experienced a breathing difficulty during the periods of Ether application, surgical staff did not feel the discomfort TVOC s create on their respiratory systems due to acclimatization.
- Due to the current air circulation system of the theatre released gases are stagnated inside. Following system (Figure 12[5]) will enhance the IAQ of the theatre by flushing out indoor air pollutants generate around the theatre bed.

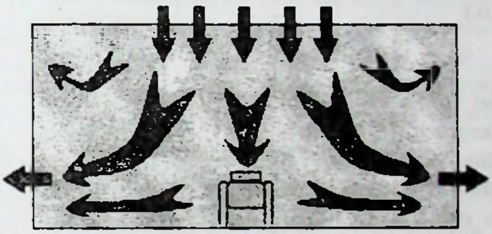

Figure 12: Recommended air circulation system for the Operation Theatre.

- Recorded variations of the concentrations of CO, TVOC, CO_2 and $PM_{2.5}$ are lower than the actual variations of concentrations near the surgical area. (recorded at 2m distance)
- As the surgical staff around the theatre bed is exposed to the more severe conditions than the measured values, it is important to design the building and equipment to minimize the release of causative agents.

6. Recommendations

- Proper air circulation methods those flush out the indoor air pollutants generate around the theatre bed should be adopted.
- Exhaust fans should be installed on each side of the theatre room to remove polluted air from room. This could be a considered at the design stage as well as can be used to improve an existing system.
- Installation of an air suction system to collect anesthetic gas or evaporated medication emanating from surgical area.
- Natural or mechanical ventilation during on- working hours is recommended. Sterilization of the area can be done afterwards. [6]

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