Fire and Life Safety Approaches in Hospitals

Mehboob Shaikh[1] Nisha Kushwaha[2]
[1]Research Scholar [2]Head of Department
[1,2]Department of Industrial Safety Engineering
[1,2]SKSITS College Indore, India

Abstract— A significant increase in fire incidents was observed in the past few decades for intraoperative fires in Indian hospitals. This is primarily due to Oxygen (O2) enrichment of air and unsafe practices of storing flammable and combustible liquids in basements furthermore unprotected areas of hospitals without any compartmentation or protective measures. In Oxygen Enriched atmosphere (OEA), it becomes easier for a material to get ignited with the small source of ignitions. The central air conditioner and most split air conditioners are pretty vulnerable to fire due to the presence of various parts that support combustion. In addition to poor maintenance of this system, particularly clogged, dirty air filters make it easier to produce more smoke, leading to poor visibility and difficulty in evacuation, especially when the hospitals have critical occupants at risk who are partially or entirely incapable of self-preservation. In accordance with the prescriptive and performance-based requirements of NFPA codes and standards, Indian hospitals must make several changes to the organization of their equipment and procedures for handling Oxygen, as well as raise awareness among hospital staff, physicians, and administrators.

Keywords: Fire, Hospitals, Buildings, Fire Codes, NFPA, Air Conditioning

I. INTRODUCTION

Globally, fire in hospital buildings poses a significant threat to patients and other users. World Health Organization statistics claim that more than 300,000 deaths are caused yearly by fire-induced burns [1]. Qien et al. (2011) averred that building fire is one of the significant threats to the safety of building occupants, including hospital buildings. Chow et al. (2015) identified four fire code systems available to determine building fire safety provisions: a fire engineering approach, prescriptive code, engineering performance-based fire code, and performance-based design [2]. This paper focuses management of fire safety in public healthcare facilities in India. Fire safety administrations in healthcare buildings have not been given adequate priority because of the multiple functions associated with the facilities[3]. The interfaced with patients, staff, equipment, services, and information within the healthcare facilities make it a complex environment. Hospital buildings are becoming bigger across India. State and local building codes regulate the hospital buildings and physical features (Parston, 1983) [4].Fire safety provisions in buildings, including hospitals, were determined by the building prescriptive & some time by performance-based codes such as the National Building Code, India (NBC-2016) and various national and international NFPA Codes and Standards [5]. Some of these preventive and protective approaches in this prescriptive concluded provision of adequate means of egress and fire protection systems such as sprinkler systems, standpipe systems, fire pumps, etc. Water-based fire suppression systems are commonly used to improve fire safety in spaces where the early suppression by people is not guaranteed to occur. Water sprinklers protect patient rooms, common areas, and auxiliary spaces in health care units [6]. The primary response to a fire in a patient room is to evacuate the people from the room of fire origin, but it is often questioned if the health care personnel can perform the task without proper training and equipment. It may be possible that the fire service eventually evacuates the room, and the effectiveness of sprinklers in protecting the patients inside the room becomes then in question. The fire protection performance of water-based fire protection systems has been widely investigated, and they are effective in cooling the room of fire origin and restricting the fire spread. It is commonly understood that the primary threat to occupants is caused by hazardous gases and lack of visibility. The effects of different asphyxiant and irritating gases have been studied extensively [3] .

II. MATERIAL AND METHODS:

This section presents the material and methods employed in this paper. This includes study design, eligibility criteria, information sources and search strategies, systematic review process and data abstraction and analysis.

A. Study design

This study Evaluates the following questions

- What are the factors influencing fire outbreak in healthcare facilities worldwide in general and in India specific?
- What are the preventive measures to mitigate fire-related occurrence in healthcare facilities?

B. Systematic Review Process

Criteria	Eligibility	Exclusion
Type of Literature	Journal articles Previous projects FLS strategy reports	None
Time & language	Between 2001 & 2020, English	<2001, non-English

III. FIRE AND LIFE SAFETY ANALYSIS

A. Factors that influence fire in Health Care facilities

This section concentrates on the factors that influence fire in hospital buildings. A total of 22 out of 30 articles focused on fire safety management in hospital buildings [3]. Fire safety management plan implementation in hospital buildings is generally low. Findings from the reviewed literature perceived disregard for safety rules, use of combustible and flammable materials, electricity, lack of fire safety installation, violation of building codes, negligence of staffers, among others, as the major factors [2]. The authors recognized that fire safety management should encompass events that affect the safety of healthcare environment and address those measures that would enhance prevention for

fire-related occurrence. The identified factors are categorized into three groups: technical, management and legislation factors [7]. The technical factors are low standard of contractors' work, use of combustible and flammable materials and electricity. These factors are associated with the hospital buildings "technical know-how". Previous studies, for example, Ong and Suleiman (2015) have shown that combustible materials and electricity are the two main root causes of fire in healthcare facilities [2]. Thus, major electrical faults that climax to fire outbreak are due to known or unknown technical issues that arise from the healthcare facilities. Regarding the management factors, these factors are associated with direct attitudes of employees. There are issues of management staff not setting example for the followers to follow. Examples of management factors are negligence of staffers and disregard for safety rules/carelessness [8]. This is probably evidence in healthcare facilities where there is fire safety management plan lax and inadequate fire safety education. There is a need for further studies with empirical evidence to support this submission. The legislation factors are associated with bylaws and legislation. Examples are violation of building codes and a lack of fire safety installation. The National building code, 2016 in India provides basic guidance to achieve compliance for fire safety in buildings, healthcare facilities inclusive.

In India, data from various new papers and articles suggests there were approximately 34 incidents occurred across various states of India. Findings agree with Pal and Ghosh (2014) and reported that in the opinion of the Director of the Fire Department, the conversion of the hospital basement to storing empty and filled-up LPG cylinders may have contributed to the spread of the fire and possibly due to electrical hazard presents in the basement [9]. The air-conditioning duct enhanced the spread of the fire to other floors. This is one of the outcomes of disregard for safety rules, negligence of staffers, violation of building codes, among others, in healthcare facilities [10]. Many other practices in Indian hospitals are unacceptable from a fire hazard point of view. The National Fire Protection Association USA publications, NFPA 53 [17] and NFPA 99 [18], list recommendations, which are not followed in Indian hospitals. In fact, very few numbers of hospitals are aware of international guidelines for fire and safety in India and oxygen safety. (3)

1) Role of Air conditioning systems

There are typically three types of air conditioners: window, split, and central. The smallest of the three is the window AC. It comes in capacities ranging from 0.5-TR to 3-TR (1-TR, or tonnes of refrigeration, equals 3.5 kW of refrigeration). It is separated into two components: the evaporator side, which projects into the area to be cooled; and the condenser and compressor side, which hangs outside the room. Both sides are put together in a single casing. In order to evacuate heat, the condenser component of this type of AC needs to be installed in a window. The evaporator side houses the filter, cooling coil, fan, centrifugal blower, and electrical control panel. Inside the air conditioner, the refrigerant runs in a closed cycle. The indoor and outdoor pieces make up the split air conditioner. The space between these components, which are put in separate casings, can range from 5 to 10 metres or even more. Evaporator coil, evaporator blower with motor, capillary tube, air filter, electric control, and other components make up the interior unit.

The term "indoor unit" refers to the location of this unit inside the room. It draws air from the surroundings, cools it, and then pumps it back into the room to cool it. It might be suspended from the ceiling or mounted on a wall. The compressor, condenser coil, and condenser fan with its motor make up the outside unit. Two lengthy pipes—a high-pressure liquid line from the condenser and a low-pressure vapour suction line to the refrigeration compressor—join these two components. Depending on the load, one outdoor unit can supply up to three interior units. A split air conditioner is quieter than a window air conditioner because the compressor is outside the room.

One can see that the split AC's indoor unit is situated directly over the patient's bed. O2 may seep out when it is supplied to the patient, making the area close to the administration site O2-rich.

Numerous plastic components included in air conditioners are flammable in normal air and even more so in an O2-rich atmosphere. Although using metal is safer, it is more expensive, heavier, and requires more power when used in an AC than when using non-metals like plastic. The capital cost of ACs as well as the power consumption of fans and blowers (AC models are rated as 3-star, 4-star, or 5-star based on their power consumptions) have been significantly decreased by expanding the use of plastics. However, there has been a significant increase in the combustibility of plastics

Electrical control panels for both split and window air conditioners are available to the cold environment of a room. With the aid of electronic chips, transformers, and relays, a control panel aids in controlling the operation of an AC system. Sparks are frequently produced by these electrical devices, which is typical of how they work. The materials in normal air are not ignited by the sparks because these devices are made to function in that environment. These sparks may start fires if there is too much oxygen present.

The indoor AC unit's blower motor is also prone to catching fire. The resistive portion of the winding will heat up and eventually catch fire if the motor bearing becomes jammed and continues to draw current.

Solders are frequently used to connect electrical lines because of their low melting temperature. These connections are frequently made loose by the ACs' vibrations, which might ignite the joints.

When compared to window or split AC units, central air conditioners, which range in capacity from 20 TR to 2000 TR, can manage far higher refrigeration loads. In such a system, the air handling unit's heat exchanger coils are filled with chilled water from the refrigeration plant, which is used to cool the air leaving the air-conditioned room (eg, ICU). The air-handling unit, chilled water plant, and air-conditioned room make up the system's three components. Compressor, condenser, chilled water-air heat exchanger, and pumps make up the chilled water plant, which is often installed outside or on the roof.

Aside from the air entering from the cold room, which may already be enhanced with oxygen, the blower in the air handling unit also takes some fresh air from the surroundings. Enriched oxygen is exposed to the motor

powering the blower and the bearing (which contains lubricating lubricant). The lubricating oil in the bearing and the motor windings, which are frequently hot from the electric current drawn and friction, respectively, both have the potential to catch fire. When there are higher O2 concentrations in the air, the lubricating oil's auto-ignition temperature may drop and it becomes more flammable.

Hospital management includes ventilation as a critical component. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has produced comprehensive guidelines about hospital ventilation requirements and how to meet them [10–12]. Window and split air conditioners cannot stop the buildup of O2 concentration within the ward because of their restricted ventilation capacity (split air conditioners can not suck fresh air). If hospitals lack active ventilation equipment, oxygen levels will occasionally be enriched and other times depleted. Ventilation nearly stops at night as the number of door openings declines.

Date	City	Location of Fire	Injuries and Deaths	References
13-Mar-08	Ahmedabad	Incubator	One baby death	[1]
13-Mar-08	New Delhi	Incubator	One baby death	[1]
16-Nov-08	Meerut, UP	Incubator	One baby death	[1, 11]
29-Jun-09	Punjab	Incubator	Five babies Burned	[1]
2-Feb-10	Hyderabad	Diesel Generator/ Short Circuit	One death/ 38 injured	[1, 12]
Feb-10	Kolkata	Short Circuit in the meter box	No injuries	[1]
15-Apr-10	AP	Incubator	One baby death	[1]
19-Apr-10	MP	Air Conditioner	8 Babies Evacuated	[1]
14-May-10	Maharashtra	Electric Short Circuit in ICU	One death	[1]
14-Jun-10	West Bengal	Air Conditioner	No injuries	[1]
9-Mar-11	Maharastra	Incubarator	Two Baby death	[1]
28-Jun-11	Chandigarh	Ventilator	One Person Injured	[1]
24-Jul-11	Chennai	Air Conditioner	Two Person death	[1]
Dec 09,2011	Kolkata	Flammable Materials	90 dealths	[1]
Jan 08,2012	Hisar, Haryana	Electric stabilizer	No injuries	[1]
Mar 20, 2012	Jorhat, Assam	Radial warmer	26 babies rescued	[1]
Mar 21,2012	Kolkata	Air conditioner	No injuries	[1]
Mar 22, 20122	Medinipur, WB	Air conditioner	No injuries	[1]
April 06, 2012	Allahabad	Air conditioner	No injuries	[1]
April 21,2012	Guwahati, Assam	Air conditioner	No injuries	[1]
May 31,2012	Delhi	O2 line	40 pts saved	[1]
July 02,2012	Delhi	Air conditioner	No injuries	[1]
Aug 17,2012	Cuttack, Orissa	Air conditioner	No injuries	[1]
Aug 23,2012	Mumbai	Air conditioner	No injuries	[1, 12]
Aug 29,2012	Delhi	Electrical box	No injuries	[1]
Sep 05,2012	Jaipur, Rajasthan	Air conditioner	No injuries	[1]
Sep 06,2012	Madurai	Air conditioner	No injuries	[1, 12]
Oct 02,2012	Kolkata	Air conditioner	No injuries	[1]
Nov 24,2012	Kolkata	Air conditioner	No injuries	[1]
Jan 05,2013	Mangalore, Karnataka	Air conditioner	No injuries	[1]
Jan 09,2013	Mangalore	Air conditioner	No injuries	[1]
Jan 13,2013	Bikaner, Rajasthan	AC and heater	4 infants injured	[1]
Feb 23,2013	Kolkata	Air conditioner	No injuries	[1]
April 21,2013	Allahabad	Air conditioner	No injuries	[1]
May 29,2013	New Delhi	Air conditioner	No injuries	[1]
June 17,2013	New Delhi	Electrical short circuit	No injuries	[1]
June 18,2013	Pune	X-ray unit	No injuries	[1]
Aug 25,2013	New Delhi	X-ray unit	No injuries	[1]
Aug 05,2013	Cuttack, Orissa	AC machine	No injuries	[1]
July 05,2013	Sheikhupura, Punjab	Electrical fire	One injury	[1]

B. Preventive Measures and Mitigation Strategies

Findings from this study reveal that among the major preventive measures for fire-related occurrence in hospital buildings across the Asian region, authors include [1] to develop a fire safety management plan. This is one of the highest-ranked preventive measures across the reviewed papers. This implies that a fire safety plan is germane to hospital buildings' fire-free success. The fire safety management plan will mitigate factors that influence fire across the technical, management and legislation identified [2] . (2) To improve on safety technology. The globe is technology-driven, so, fire safety in hospital buildings should not be left behind. Safety technology will mitigate the

factors associated with technical and legislation. (3) To increase fire safety education and preparedness. This is very important because one cannot apply what he does not know. Basic safety knowledge is vital, such as regular evacuation drills. This will make the stakeholders know the level of preparedness for any unforeseen circumstances. Fire safety education and preparedness preventive measure will tackle across the three groups identified. If successfully implemented by hospital management, fire outbreak in healthcare facilities will drastically reduce. (4) Stakeholders' cooperation to enforce fire safety rules. Safety is the responsibility of all, including the policymakers, hospital management, hospital staff and patients. Enforcement and implementation should be the responsibility of healthcare facilities management. Thus, this preventive measure focusses on mitigating factors associated with management. (5) Safer architectural design via fire safety design (1). (6) Safe handling of Air conditioning and Ventilation Systems (7) All Sources of ignition shall be isolated and removed from O2 enriched areas. (8) All kinds of rusts, dust particles, and powders are potential sources of fire. Periodic maintenance of electrical units should include cleaning of potential heating spots (or points that are likely to spark) from dusts. This cleaning should be done specifically to prevent fire as fine dusts are generally considered to be the biggest culprit in initiating fires (due to the availability of large surface area per unit mass and low bulk thermal conductivity) [7].

IV. Result and Conclusion

The major fire accident which occurred in AMRI Hospital in the year 2010 was a watershed moment in fire safety among hospitals. It has since become infamous for having the single largest number of causalities (n=94) reported from any hospital fire in India. In the year 2020-2021 India witnessed spike in covid cases as well as number of fires across the country overstressing hospitals especially electrical wiring system, ventilators, air conditioners etc. which resulted into death of 93 people, most of them Covid-19 patients, died in 24 incidents of fire in hospitals in India. Lack of Fire Sprinkler systems, smoke control system made fire rescue and firefighting work more difficult and challenging. The details of fire incidents were compiled and tabulated as in Table 1. A total of 33 fire incidents were reported online by mainstream media sources. A total of 131 fatalities were occurred in 8 of these incidents. 25 incidents were reported to have occurred in government owned establishments, 7 in private hospitals and 1 in a trust hospital. In 19 incidents occurred in hospitals which reported having functional firefighting measures. 7 fire incidents each were reported from states of West Bengal, Orissa and National Capital Region (NCR). West Bengal reported the highest number of hospital fire related deaths in the past decade (n=117); most of these were due to the AMRI hospital incident. The most common cause of fire was reported as due to electrical short circuit 78%. Air conditioners were the most common source of origin for short circuit. Fire safety management of public hospital buildings in line with international best practices will boost medical tourism in the continent. Medical tourism has become the central narrative in tourism practices across the globe. Many countries in Asian continent do not want to be left out in this economic boaster avenue. Therefore, these healthcare facilities should be resilient to disasters including fire outbreak. On the average, resilient and fire safety management efficiency in healthcare facilities is presently missing from the findings across the continent. This paper recommends that government intervention to upgrade the safety technology equipment in healthcare facilities should be, as a matter of urgency, be nipped in the bud. This will mitigate issues concerning technical and legislation factors. The consequences may be disastrous if not acted upon. Therefore, top hospital management support is needed for the successful development of the fire safety management plan Hospital fires are disruptive in terms of threat to life, damage to property and interruption of services. People losing their lives at a place which is supposed to be a beacon of health is a tragic phenomenon. The consequences are economically and socially disastrous.

The other factors that further increases the risks to fire outbreaks are:

- Response time
- Enforcement of building byelaws, planning and zoning norms
- Apathy and information
- Individual load management
- Lack of infrastructure
- Enforcement of building byelaws, planning and zoning norms
- This study showed that electrical short circuit is the most common cause for fire.

V. Recommendations:

- Simple measures such as judicious placement of electrical devices (particularly air conditioners) and monitoring equipment in oxygen rich areas is the need of the hour.
- Safety audits should be conducted on periodical basis to check the functioning of firefighting equipment
- Training programs and dissemination of fire preparedness policy among staff members should be given priority.
- Internal fire control systems need to be strengthened and buffer capacity is to be ensured. Flammable materials should be stored away from the patient care areas, never in the basement and always in conjunction with robust fire detection and control systems.
- Hospitals, especially in the government sector, should strictly adhere to their planned capacity both in terms of physical space as well as energy needs.
- It is the responsibility of every healthcare establishment to ensure that fire safety standards and regulations are followed to prevent fire accidents and the consequent human suffering.

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