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Medical Oxygen Mandate and Blazes Inhibition in Emerging Hospital ICUs, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims and Objective: Pure Oxygen proved palliative care or considered a lifesaving drug causing innumerable deaths due to its inaccessibility against SARS-COVID-19. Medical oxygen (MOX) availability in COVID Care Hospitals (CCHs) in India was scanty during the peak period of the pandemic. The fatalities, trauma, and fire incidences in CCHs had increased multifold.
Methodology: The major fires in hospitals from March 2020 were collected from media and past literature and analyzed considering causalities, time, sectors, pre-pandemic, *etc*. The world faced MOX shortages and infrastructural lags with wildfire hazards in CCHs have forced the research. The fire incidents in major hospitals, globally, and 150 hospitals in India are analyzed from the 20th century onwards.
Focused Area: The SARS-2 virus has been undergoing many mutations and remediation to date. MOX supply chain was observed distorted from the manufacturer, to end users during its 2nd

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phase. The existing architecture of COVID beds, space, MOX demand, resource management, and heating Ventilating & air conditioning (HVAC) bottlenecks needs rebuilding.
Results and Future Research: The blazes in the early 20th century were mainly due to curtains, kitchens, chimneys, *etc.* whereas electrical short circuits cause the 21st-century hospital blazes from HVAC systems and surges in oxygen levels in ICUs. The higher oxygen level and poor maintenance of electrical gadgets are the attributes. The blazing timing causes were from 6 PM to 8 AM, mostly in Government hospitals. This study can prioritize and stimulate curative measures in hospital fire safety and epidemiology of MOX generation, storing, transportation, and carriage in case of future biological disasters.

Keywords: COVID-19; hospital fire; blaze substances; fire safety; government hospitals; oxygen level; HVAC.

ACRONYMS

AN: Afternoon; COPD: Chronic obstructive pulmonary disease; ARDS: Acute respiratory distress syndrome); WHO: World Health Organization; GOI: Government of India; COPD: chronic obstructive pulmonary disease; FiO2, the fraction of inspired oxygen; NRB: non-rebreather; mask ICU: intensive care unit; O2, oxygen; paO2, arterial partial pressure of Oxygen; p/F, a ratio of partial pressure arterial oxygen and a fraction of inspired oxygen; NIV: non-invasive ventilation; SaO2, arterial oxygen saturation; SpO2, pulse-oximetry oxygen saturation; LOX: Liquid Oxygen; PAHO: Pan American Health Organization; HCUs: health care units; CCH: COVID Care Hospital; PVT; Private; Ckt: Circuit; Hos: Hospital; Morn: Morning; WB: West Bengal; NICU: neonatal intensive care unit; GF: Ground floor; No: Number; Std: Standard; VOC: variants of concern, VOIs: variants of interest; PSA: Pressure Swing Adsorption.

1. INTRODUCTION

Fire exists from the origin of the earth that had burned everything from those days. The holistic approach to analyzing fire science is “Pyro geography”, [1]. Fire (transformation and digestion) is the Agni God in India as an element of Pancha Bhutas (Earth, ether, fire, water, and space). Atharva-Veda, tells it is the Agni. It transmits to the soul of the dead during antyesti on the pyre to take rebirth. Fire is the form of energy that burns but all living beings have thirteen forms of Agni as Krodha_Agni, (the Fire of anger), Jathara_agni, (the Fire of digestion), and the Kama_ Agni,(the lust), the Krodha_agni (the anger), Mand_agni (nondigestive), Bhut_agni,(the fire element), etc., [2]. The Pyre as per Veda is ‘Agni’which is strong and luminous. Hominids tamed fire meanwhile and used from great ancient times in human use. The troglodytes live in caves and used fire since about 40000 years before the present (BP). Ancient Indian history depicted Oxygen in the air as the “pran-vayu” by Susruta (3000 BP) and Aristotle mentioned as the essential element for life, Mishra SP. [3], Jindal et al. [4]

Spates and wildfires were large in numbers in India but also around the world that threatened human living, ecosystems, and biodiversity, and disseminating the impact of climate change in the 21st century [5]. Climate Change is the anthropogenic and innovative research on biodiversity that has resulted in the generation of new viruses, microbes, and bacteria from time to time. One among them is the severe acute respiratory syndrome coronavirus (SARS-CoV-2). COVID-19 proliferated fast as an apocalyptic pandemic that propagated in about 223 nations taking 1.016mil lives and 80.808mil active cases globally by Oct 2022, [46].

The SARS-2-COVID emerged from Wuhan City, China, on 31st December 2019. The SARS-2 variant exploded and spread globally declared a pandemic, in March 2020, reported by WHO. India declared a lockdown nationwide from March 24, 2020. The transmissible infectious virus has more than 80.8 million cases and is still active. The SARS-CoV-2 virus is constantly under mutation and few transforming as prominent variants, including Alpha, Beta, Omicron (BA.5 and BA.4), Delta, and the Greek letters, *etc.* The emerging variants of SARS-CoV-2 into variants of concern (VOCs) and variants of interest(VOIs) and the viruses can have various mutations or transmutation by mutation, recombinant, lineage, and variant [7-9].

Oxygen can be crowned as a drug for SARS diseases. It is benign but it helps combustion. The atmospheric percentage is about 21 %. When O_2 conc. level surpasses 23 %, may create

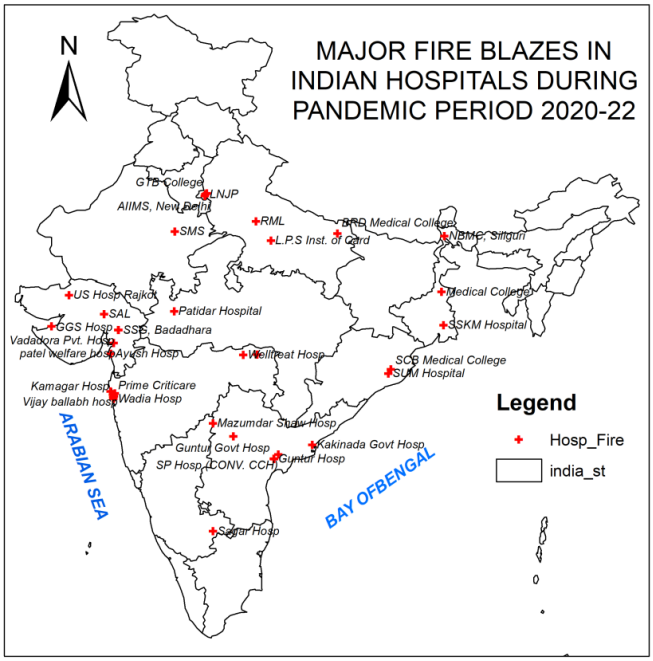

Fig. 1. Major fire blazes in indian hospitals during the ensuing pandemic

fire hazard being ignited by sparks, oil, and lubricants that causes fires, and may explode under high pressures [10]. During April, and May 2021 there was an acute shortage of oxygen for SARS-2 patients, about 20 patients in Jaipur Golden Hospital CC units, in NW-Delhi died as per Saxena, and Sinha, TOI, on 25th April 2021. Covid-19 cannot only be linked to Anthropocene activities but also to the living beings in the Geo-bio and hydrosphere on earth that may aggravate the ongoing 6th extinction [11]. Several fire blazes occurred in various hospitals in India during the present pandemic [12]. (Fig. 1).

2. REVIEW OF LITERATURE

Since the early 20th century, fires especially wild ones have been regularly observed, Rachel et al. [13], Mishra et al. [3], Juli et al. [14]. Burning of forests and vegetation under climate changes, anthropogenic activities, and enhanced lightning flashes have become faster spatiotemporal occurrences, Broton et al. [15], Gao et al. [16]. The common wildfire activities in (South Asia) are in China's tropical/subtropical forests and are significantly driven by El-Nino southerly Oscillation (ENSO). Climate change (CC), not only changed the frequency and intensity of precipitation, and lightning but also the fire incidences, geographic wildfire regime, and distribution, affecting the global vegetation index, climate change dynamics, and conservation planning Moritz et al. [17], Krawchuk et al. [18], Juli et al. [14]. The viruses, microbes, and their proliferation have surged up during the golden spike period of the Anthropocene, causing epidemics and even pandemics [19].

Oxygen (O2) upgrading of room air is predominantly liable for record of fire incidences in Hospitals, particularly in ICUs (intensive care units) [20], Dhaliwal et al. [21], Wood et al. [9], Mishra S P. [22], Kumar et al. [23]. The liquid and cryogenic oxygen used in Industries were used in HCUs during urgencies of COVID-19 Wood et al. [9]. On 31st Jan 2009, the newspaper Economic Times reported that five infants burnt alive as an incubator caught fire. Disaster, its risk, and reliability should be analyzed against fire hazards and safer life in Hospital buildings and healthcare units, Kumar K et al. [24]. Liquid Oxygen (LOX), is the first drug of choice during the pandemic. The primary source for storage and transportation is the LOX. Generally, hospitals in India use compressed gas cylinders, of the E (679 L of O2), and larger H sizes. Ministry of Transport contemplates MOX ear marked hazardous substantial, and the truck drivers conveying need distinctive training Wood et al. [9], Suran [25].

The *objectives of the present study* are to find the causes of hospital fires from the early 20th century to till date and the abrupt surged demand

for MOX during COVID-19. The present work examine discusses the demand and uninterrupted MOX supply, augment production, and even conversion from Industrial Oxygen exigencies and well-distributed within the entire country, identifying the role of central and state govt. under medical Oxygen crisis. It is pertinent to calculate the number of beds and specify the quantity of MOX and provisions for supply in a Hospital.

3. METHODOLOGY

Fire service, the most emergent response to blaze incidents in India, comes under the 12th schedule of the constitution dealing with Municipal functions or under the Home department. In health care units (HCUs), the imperfections of the arrangements are ordinarily displayed precisely during fire incidents. Attending the traumatized but also shifting the co-patients as per the WHO/PAHO (the Pan American Health Organization) Hospital Fire Prevention and Evacuation Guide followed (Fig. 2).

Information from dependable websites (like the world health Organization (WHO), Government portal, etc.), hospitals, medical kit/gadget suppliers, MOX distributors, government personnel, regulatory bodies, multi-media, and research from various journals are collected and properly referred for analysis. However, a fire hazard in a hospital is complex and fatal but the sources of fire may be technological (electrical or fuel driven). The organizations, WHO and PAHO have promised to keep their hospitals safe from fire. It is pertinent to study the causes, risks, precautions, and regulations to be made by the concerned authorities like Municipalities, Hospitals. The optimization in the concentration of oxygen level based on beds in the Hospital and ICUs are to be studied and reported.

3.1 Role of Medical Oxygen (MOX)

In atmospheric air, the Oxygen level is about 21%. Oxygen supports combustion but does not burn itself. Medical Oxygen (MOX) should be pure (up to 98%) and act as a life-saving drug for patients and should be at par with normal blood oxygen levels. In blood, the RBC (red blood cells) captures tissues and organs and gets oxygen to support the energy making in the body.

3.2 Production of MOX in Plants

Oxygen is separated from the air by a plant called the Air Separation Unit (ASU) and used in the petroleum, steel, medical, and chemical industries, *etc.* Hospitals get a share of it. It was felt under a pandemic crisis of MOX; the industrial Oxygen (of low conc. of Oxygen) can be further processed to bring it to the level MOX and logistically started. Oxygen can also be available in concentration form as liquid Oxygen (LOX) or Cryogenic Oxygen (COX) at low temperatures at higher concentration (up to 99.8%) purity and compressed. An *oxygen generator* device that can concentrate O_2 from atmospheric air by eliminating nitrogen using various aperture sieves like Ion Transport membranes, or zeolite to generate 90–95% pure oxygen.

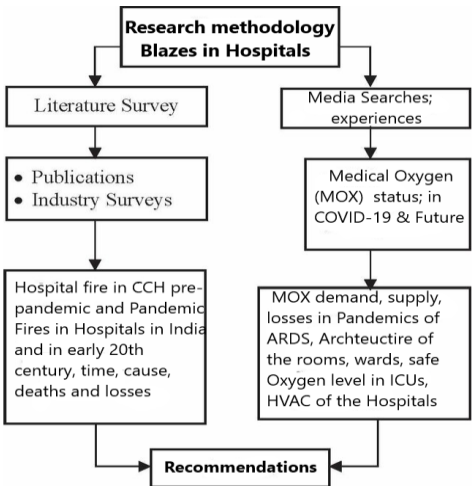

Fig. 2. The methodology adopted in the study of oxygen demand and blazes

Fig. 3. A Pressure swing adsorption (PSA) Unit in a Hospital

Nowadays PSA (Pressure Swing Adsorption), Deployable Oxygen Concentration System (DOCS), and Vacuum Pressure Swing Adsorption (VPSA) plants using zeolite (hydrated aluminum silicates of alkaline earth metals) are used to separate the nitrogen. VPSA generates a small volume of MOX (1 m3 = 1000 liters of oxygen) only. The VPSA is expensive but used in industrial oxygen production units that can produce a much higher volume of industrial Oxygen purified by the adsorbent bed, moisture and CO_2 are captured but NO is adsorbed under pressure. DOC's methodology employs portable units for oxygen-making by molecular sieve technology. The DOCS increase the Oxygen flow rate from 30 to 500 liters/minute delivering 90-96% of MOX.

Self-sustaining concentrators PSA with multiple molecular sieves can supply oxygen at higher flow, (Fig 3). The system is connected through a centralized distribution arrangement for multi-bedded COVID hospitals. This system must have the backup from a 10 × 10 cylinders MOX-bank. That can deliver 93% pure (acceptable) oxygen needs of patients with hypoxemic conditions, (Madan et al. 2021).

3.3 Classification of HCU Fire

The national fire protection Association (NFPA) has 5 classes of fire (Class A, B, C, D, K). The stages of fire in your Hospital can be incipient, growing, fully developed, decay, and doused, Fig. 4. The fire hazard locations are classified as light (low), ordinary (moderate), or extra (high) as per National Fire Protection Association [25]. The fire extinguishers are a logical fragment for any fire safety unit. The guidelines for their use, location, and addresses should abide by the National Fire Protection Association (NFPA) norms.

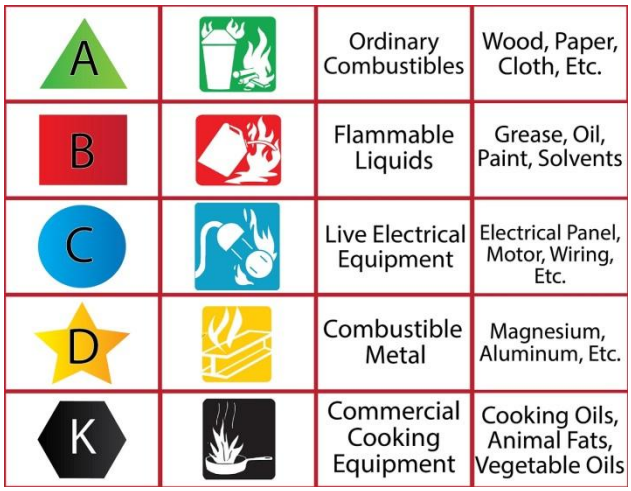

Fig. 4. The classes of Hospitals fire

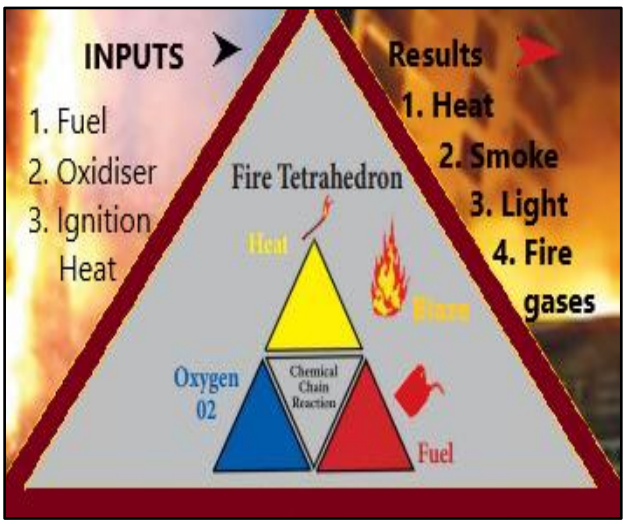

Fig. 5. Chemical Chain reaction in Hospital

Table 1. The agents, originators, Risk, and intervening agents in fire tetrahedron

The agent	The originators	The Risk	The intervening agent
Oxygen	Helps to burn	High level of air	Closed rooms like ICUs, and OTs.
The Fuel	Burns when fired	Wastes, tags, Drapes, gowns, sponges, gauze disposables, Masks, nasal cannulas, tents,	Leaks, high MOX level rooms and surgical fluids, stand-on electrical gadgets, laser/ fiber optics contact, Polythene disposables, preps; *etc.*
Ignition	That initiate fire	Electrosurgical like Laser, Fiber optic lights, High-speed drills, defibrillators, etc.	Tunneling/flapping drapes, Xiphoid stand on laser OT fiber optic lights or contact with fuel, warn before use of electrical/ electronic devices, Irrigate the saws & drills in operation, etc.
The Oxidizer (Oxygen and nitrous Oxide)	That exacerbates fire (via *open* or *closed* sources)	The Oxygen conc. level maximum >30%, Avoid NO in presence of O_2, OT, and ICU above Xiphoid	Communication gap, negligence, no tunneling in drapes, Reducing oxygen level if very high by ventilation, Using open draping, using an Endotracheal tube (ETT) when needed like airway surgery or using laser reinforced ETT with methylene blue in cutoff

However, the Oxygen, heat, and fuel constitute a fire triangle or fire cube but when added to the involved chemical reaction, form a fire tetrahedron. Fig. 5 [26] Table 1.

3.4 Calculation of Beds/Space and Amount of O_2 for Indian COVID Hospitals

The population size depends upon, geography, Topography, demographics based on the type of burden of diseases, distribution in private (Pvt.) hospitals, District head quarter hospitals, travel time allowed, and hospitals run by other Govt. setups that decide the number of beds. In India contests, prominent cities and DHH have 500K to 1000K beds. Say, the COVID-19 patient takes admission 1 per 100 with a baseline stay in a COVID hospital of 10 days, the number of beds required for a population of 10000K in India (IPHS guideline, 2012 and 2022).

The total number of admissions per year	= 1000000 × 1/100 = 10000
Bed days per year	= 10000 × 10 = 100000
Total number of beds required when 100% occupancy	= 100000/365 = 274 beds
Optimized No of beds with 75% occupancy	= 274 x 0.75 = 205.5 beds (Say 205beds)

3.5 Amount of O_2 Needed for a District COVID Hospital

The amount of Oxygen in the gaseous, liquid, or cryogenic form required for a 210 bedded Hospital (designed by the WHO), in liters/ minute (l/min) is given by the formulae:

Total MOX in l/min = (No. of general beds × 0.75 lit/min) + (No. of OT beds × 7 lit/min) + (No. of beds in ICU × 30 l/min).

Let for a 100-patient CCH having 25% ICU beds (n_1 = 25), and with 5 numbers OT (n_2 = 5), the MOX demand shall be:

Overall MOX (lit/min) = [{100-(25 + 5)} × 0.75] + (5 × 7) + (25 × 30) = 841.25 lit/min.

For a CCH 210 beds shall demand = 841.25 x (205/100) = 1725 lit/min (say **1750 lit/min)**

When HFNC (High flow nasal cannula) is used, the oxygen demand shall go up to 120 l/min. The COVID care units demand variable flow rates. In such cases from Covid-19, oxygen demand in acute conditions (even if with no ICU support) is at a 10 l/min rate of flow, and in life-threatening states in ICU needs at 30 lit/min, changes the entire CCH flow rate.

The consumption of O2 in acutely infested COVID patients needs a regular E-size O2 gas cylinder, which lasts roughly 1.5 hrs. if the 10 l/min flow rate is asper (Table 2).

3.6 Minimum air Changes and Ventilation in CCH

The intake (to suck in air) and exhaust fans (to suck out) is essential to reduce the concentration of Oxygen and heat and maintain ambient temp and air and airborne infection. The ventilator direction should be such that the optimum use of fans can be done near a window and must not be pointed toward crowded areas. Wind-driven ventilation flow rate is calculated as (https://www.who.int/water_sanitation_health/publications/natural_ventilation.pdf)

Assuming the room has minimum opposite openings (e.g. a window or door):

ACH = minimum openings (m^2) x (0.65 × wind speed (m/s) x (3600 sec/hour)/ vol in cum.

Ventilation rate (lit/sec) = 0.65 x smallest opening (m2) x wind speed (m/s) x 1000 lit/cum

The air Changes and ventilation and rate of ventilation due to the 1 m/s wind speed only,

Presumptuous of a ward having floor area 7 m (length) × 6 m (width) × 3 m (ht), with size (1.5 m× 2 m) and door size (1 m × 2.2 m^2 (the smallest opening) should have

Table 2. Minimum air changes /Hour (ACH) during COVID-19 Hospitals in India

Type of Medical setup in CCH For ward setting in isolation **a. Old single rooms: Ventilation >6ACH** **b. Newly formed negative pressure Airborne Infection Isolation (All) Room: >12ACH**	**Minimum ACH**	**Av. Minimum Hourly ventilation rates (liter/ sec/patient)**
Registration Areas (For a 4mx2mx3m=24m^3 space)	>6ACH	40lit/sec/patient
OPD and their waiting places	>6ACH	40lit/sec/patient
Indoor patients	>6ACH	40lit/sec/patient
High-risk areas, waiting for places, ART, and among COVID Patients (For minimum space 4mx2mx3m=24m^3 space ventilation is minimum 80lit/sec	>12ACH	80 – 160 lit/sec/Patient

Source: Lisa Gilbert, 2020; Parikh et al, 2022

Table 3. (ACH) and ventilation rate (7 m x 6 m x 3 m) of a ward

#	Opening	ACH (Air change/hour)	Ventilation rate Lit/Sec
1	Window (Open 100%) + door (100%)	37 (AC/Hour)	1300lit/sec
2	window (Open 50%) + door (100%)	28 (AC/Hour)	975lit/sec
3	window (100%) + door closed (0%)	4.2 (AC/Hour)	150lit/sec

(Source: Lisa Gilbert, 2020)

Table 4. The causes of blazes in domestic and Hospital buildings in India

Sl No	Type of fault	Fire initial locations	Pertinent action
1	Faulty appliances and leads	Fault/old electrical wiring, short-ckts, electrical tools	Regular Inspection and rectification
2	A leak or faulty fuel supplied	Leak in gas or fuel supply lines	The arson act firing to goods and properties
3	Equipment/appliances misuse	Kitchens, buffets, cafeterias, transformers, or waste pit fire	Fixed fire safety audit,& safety training for all.
4	Anthropogenic actions/slip /arson	Smoking, charge/ heating of electrical tools illiteracy of incendiary materials, use.	Prohibition of all arson actions, High-density urban areas to avoid.
5	Natural & climatic causes	Natural threats i.e. lightning, more heat with low humidity, blazes, and other fires	Make a special ward & remain alert for immediate care
6	ICU Fires	During COVID-19 the level of Oxygen in ICU units is the threshold to catch the slightest spark from AC/ Refrigerators/ electrical sparks	Electrical maintenance regular; Management Hospital must fix (< 30%) optimum Oxygen level for their premises.

3.7 Causes of Hospital Fire

The reasons that contribute to Hospital fires until the 19th century were clothes, fireplaces, wood furniture, human negligence, lamps, strong wind, and hospital oil use. But from the 20th century, the strategy has altered i.e. due to poor hospital maintenance or medical gadgets and the Oxygen level. The causes of fire incidences in the hospital arena of India are mainly reported as:

3.8 Oxygen Considered Lifesaving or Palliative Care

In long-term oxygen therapy (LTOT) in chronic obstructive pulmonary diseases (COPD), and chronic hypoxemia, each breath is vital, and safe ventilation is the prerequisite. ICUs cannot run without oxygen (Jindal et al. 2022). The demand is high in acute respiratory Syndromes. It keeps the air sacs open for Oxygen. Many a time patients suffering from Covid-19 may need low-flow O_2 by nasal cannula to a non-rebreather (NRB) mask. MOX as the prescription is given to the poor in worsening conditions. It is powered ventilation, including non-invasive ventilation (NIV) administered via masks, [27,28,(Kane et al. 2013, Ismail et al. 2022) [27,28].

Medical oxygen concentrators (MOCs):

Medical oxygen concentrators (MOCs) have brought a revolution that can absorb oxygen from the air. Among all medical supplies, oxygen is a dire consumable resource. The supply of Oxygen is carried by portable oxygen tanks from the oxygen station, including the oxygen generator. Premeditated management of MOX supplies in disasters demands priority. In the Indian scenario, hospitals have huge supplies of LOX and a supply of compressed LOX cylinders runs for several days. Blackman et al. [29], Wood et al. [9],

3.9 Supply of MOX

Leakage in O2 in a limited space with less circulation, the concentration (Conc.) increases to a dangerous level. Though O2 does not burn it supports combustion taking anything as fuel. The hospital uses disposables that catch fire easily. The beds and curtains increase the rate of the blaze. The ignition is received from electrical, short circuits, incubators, or ventilators. Continuous use of large numbers of ventilators, and HVAC setup during Covid-19 has heated the electrical wires that initiate a fire. The oxygen storage and supply systems in some hospitals have stress on old delivery systems, leading to handling and storage errors, etc Jain et al. [29].

Oxygen storage in MOX: In the Indian context, the supply and distribution of Oxygen among COVID Patients were the major responsibilities of the administration. Commonly the Oxygen is supplied by Oxygen cylinders, Oxygen concentrators (Portable or Bedside), and a Liquid tank & Oxygen generator as a central source. The supply may be primary (O_2- Generator or Jumbo type Cylinder), secondary (permanent

pipeline), or reserve systems (compressed gas cylinders or LOX). Storing of LOX in large volumes in insulated, double-walled tanks is manufactured of the inner wall from austenitic steel/carbon steel and the outer wall with anticorrosive steel as per IS7285 -2004.

Distribution of MOX: MOX can be stored in gaseous or liquid form, more compressed in volume as cryogenic liquid form. The primary plant is used to produce oxygen but is stored in secondary plants in larger volumes. According to the demand and use the oxygen is supplied either as LOX or vaporized LOX to convert as gases for use in Hospitals.

During COVID-19, some government hospitals even built up their oxygen plants, but not functional due to poor repairs. It is necessary to create captive oxygen plants and augment the production of more volume of pure Oxygen. Around 3500+ units of PSA (Pressure Swing Adsorption) and oxygen generators are procured in India. About 1222 of them are through the PM Cares fund with AMCs (annual maintenance contracts). To satisfy the shortage of skilled operators and maintenance staff, freshers to be trained to enhance their skills in this domain.

Table 5. Top Ten fires incidences in crowded areas around the globe with fatalities in past

#	Name of Hospital	date	Fatalities/loss	Ref
1	Griffin Memorial Hospital; Norman USA	13th Apr 1918 (Night)	40dead; linen closet caught fire (Ward's)	Blaze Claims 40 At Norman Asylum 'Firetraps' Spurred Safety Steps; The Oklahoman, 18th Apr 1999
2	Manhattan State Hospital; Ward's Island; New York	February 18, 1923 (more)	24 patients + three escorts	The Manhattan State Hospital fire of 1923, NY, Angelo Verzoni; NFPA Journal®2019January February 2019
1	Cleveland Clinic, Ohio, USA	May/1929(midnight)	125 death incl one burnt	Flamed nitrocellulose X-ray film ignites; Wikipedia,124 choked dead.
2	Anthony Hospital, Effingham; Illinois, USA	April/1949 (Midnight)	74 deaths +one newborn	Choking of escapes & fire exits; Significant Illinois Fires St. Anthony Hospital Fire, K T Dunn, location
3	Mercy Hospital; Davenport, Iowa, USA	7th January 1950	41deaths	Choking of escapes & fire exits; https://worldhistoryproject.org/1950/1/7/mercy-hospital-fire
4	Doctor's Memorial (Eitel) Minneapolis	23rd Dec, 1950,3a.m.	8deaths	https://hclib.tumblr.com/post/38650257032/doctors-memorial-eitel-hospital-fire-december Minneapolis.
5	Guatemala Mental Hospital Fire	July 14, 1960	225killed	July 15, 1960-inmates-200.html
6	Coldharbour Hos. Sherborne, England	5th July 1972	30killed, curtain fire	Coldharbour hospital (fire),13 Dec. 1972, 848, 80441-8441, 3.33 p.m.
7	GG mental hosp. fire, Poland	1st Nov 1980	55died, 26 were injured	https://nieznalska.com/en/fire-in-a-psychiatric-hospital/
8	Saavedra Psy. Hos., Buenos Aires, Argentina	28th Apr. 1985, night	79 and injured 247	Fire in clinic kills 79 in Buenos Aires, Lydia Chavez, Special the New York TimesApr.28, 1985
9	Erwadi fire, Kerala India; (Govt)	6th Aug 2001 (Morn)	28burnt mental Asylums	Wikipedia, Twenty years after gruesome Erwadi tragedy, Singh S., Updated: August 10, 2021, 8:28:
10	Miryang hospital fire, South Korea	26 Jan.2018 7.35 am	41 dead and injured 153	Fire from the emergency room; Wikipedia Miryang hospital fire;

Major hospital fires worldwide are (i) NS Convalescent Hos. Hartford, Connecticut, 21dead Dec 24, 1945, Moscow psych. Hosp. fire 2013 (38 died) and many others

3.10 The Major Fire Blazes

Until the 19th century, the curative medical concept of technology was meager. Various major fires in municipalities and Hospitals have been collected from literature and media sources for the period from 23rd December to date giving importance to hospital wildfires. The distribution, causes, causalities, timing, etc are collected and analyzed (Table 5, Table 6 Table 7, Table 8, and Table 9).

The major cause of Hospital fires in different medical units in the 19th century was unknown due to safety deficiencies (like St. Anthony's Hospital, Cleveland Clinic, Ohio, etc). The hostile fire was due to a blend of combustions of building materials, open corridors, stairwells, vertical shafts, etc. There was a lack of fire sprinklers, detectors, and alarms essential in the hospitals as soon as the fire began.

The frequencies of Hospital fires during the COVID-19, Pandemic period (2020 and 2021) in CCH globally are: In the year 2020, fire incidents recorded are *Piatra Neamț hospital*, Romania, causing 10 deaths, *Socola hospital,* Iași, Romania, 1 death, *Kharkiv* nursing home fire, Ukraine,(15dead, and injured 11, *Balș Hospital,* Bucharest, Romania, (17 deaths), Ibn al-Khatib hospital fire in Baghdad, Iraq (dead). In the year 2021, fire blazes throughout the world are in the Tetovo hospital fire in Tetovo, North Macedonia, 14 died, and in the Constanta hospital fire, in Romania, 7 died.

3.11 Fire Statistics in India

Various major fires in municipalities and Hospitals in India have been collected from literature and media sources for the period from 23rd December to date giving importance to hospital wildfires. The distribution, causes, causalities, timing, etc are collected and analyzed (Table 6).

The main causes of wildfire from short ckt, negligence, violation of Government instructions or crackers, or gas cylinders. The numbers of wildfire cases were less in number (13 only) but were fierce and accompanied by more fatalities and causalities (Table 4).

3.12 Pre-pandemic Hospital Fires in India

The major Hospital fires for the period Feb 2010 to 2022 in the 21st century have been gathered from media and literary sources and the location, time, date, causalities, and causes were reported in Table 7.

The wildfire in hospitals for the period Feb 2010 to 27th Jan 2019 was referred and analyzed for 34 cases causing 175 deaths during the Pre-COVID period. It is found that the start of the fire in the morning (04 AM to 12noon), Evening (1200noon to 0800PM), and rest in the night was 15, 11, and 8 respectively in numbers of CCH. Out of 34, the Government and private Hospitals were 25 and 9 respectively. The causes of the fire blazes are 25 are of electrical origin (Short CKT) and the rest were others. 30% of the fires were of ICU origin. The causes of the fire were poor electrical maintenance in Government Hospitals.

3.13 Pandemic Hospital blazes in India

After our breaking of SARS-2 (COVID-19), on 27th Jan 2020, (Andrews et al, 2020), 27 incidences of fire hazards are reported and declared a Pandemic. SARS-2 is a respiratory disease (ARDS), and with COPD, the first drug of choice was oxygenation from the mild stage. The MOX demand during the period escalated so high that availability was scarce. Many COVID care Hospitals were set up temporarily. They should be designed properly as per norms and guidelines to maintain a safe distance.

The hospital blazes considered for the pandemic period from Feb 2020 to Aug 2022 were referred and analyzed for 32 cases causing 180 deaths during the Pre-COVID period. It is found that the start of the fire in the morning (04 AM to 12noon), Evening (1200noon to 0800PM), and rest in the night was 15, 11, and 8 respectively in numbers of CCH. Out of 34, the Government and private Hospitals were 25 and 9 respectively. The causes of the fire blazes are 25 are of electrical origin (Short CKT) and the rest were others. 30% of the fires were of ICU origin. The causes of the fire were poor electrical maintenance and heat generation mainly in Government Hospitals.

3.14 Fuel Sources under Fire Risks

All flammables are potential Fires when it occurs in OTs/ICUs are shattering. The cause and gravity of the fire depend upon the oxidizer, ignition, chemical reaction, fuel type, and time of cognizance. The fuel sources may be patient-dependent or non–patient-dependent or both. The patient-dependent sources may be hair, bears, soft tissues, or methane gas. Those can

Table 6. Some major fires incidents in India with fatalities and losses amalgamated

Place of fire	Year	Impact	Cause	Source
Dabwali fire accident	23rd Dec 1995	442 deaths/ 150 burns	Short circuit/ stampede	Dabwali fire victims to get Rs 3.42 cr more/The tribune; Feb 21, 2018,
Uphar Cinema fire, New Delhi	13th June 1997	59 deaths /100injured	Short ckt/ smoke choked	Uphaar Tragedy: The 23-year-old legal battle ends, leaving families heartbroken; Somya Lakhani; February 24, 2020, 11:22:56
Baripada religious gathering	24th Feb. l997	206dead (thatched camp)	electric spark	Mass deaths at a religious congregation in Orissa highlight Nag Choudhry, S., India today April 25, 2013, 17:46
Shree-Jee Shoe fac-tory Agra	24th May 2002	42 +1 people died	Violation occupational safety	42 die in Agra shoe factory fire | Lucknow News - Times of India; May 25, 2002, 00:41
Shri Kalu bai Jatra, Wai, M- Rashtra	25th Feb; 2005	>300 people died	Stampede & fire Mandhar Devi temple	Kalubhai temple mishap: More than 300 devotees killed; Joshi P., May 2, 2012, 10:20
Amuri Hosp. DhakuriaCal, WB.	9th Dec., 2011,2:30 am	About 73 deaths	Electrically short-circuited	Fire in Kolkata's AMRI hospital: 73 killed, several injured; Times of India; TNN / Dec 9, 2011, 14:05
Sivakasi Factory fire, TN.	5th Sept. 2012, 12:15 pm	54dead/ >40 injured	Failing safety STDs; Chemical for fireworks caught fire	54 killed in Sivakasi fire | Deccan Herald; Decan Herald ; Sivakasi(TN) Sept 5, 2012,
Surya Sen St. fire, Kolkata	27th Feb 2013	20dead/ 12injured	short-circuit blazed by 56 gas cylinders	20 killed in Surya Sen Market complex inferno in Kolkata; The Economic Times; Published on Feb 28, 2013, 04:03 AM IST
Puttingal DeviTempFire, Kerala	10th Apr. 2016; 0300am	111dead/ ≈ 400 injured	high decibel cracker brust.	Kerala tragedy; India Today; Published on Apr 10, 2016, 18:44 IST
Karolbag fire; New Delhi	12th Feb 2019; 8:54:	17dead	A fire from Hotel Arpit Palace; laxity	Karol Bagh Hotel Arpit Palace fire highlights - The Indian Express; Feb 12, 2019
Sarthana; Takshashilacenter, Surat	24th May 2019	22died/ ≈ 35 injured burning	Short cut. A/c; 4th floor, High rise structure	Surat fire: 22 killed in the coaching center, kids falling off burning building; May 26, 2019, 23:04
Jamia Nagar, SE Delhi	Apr 14, 2022, 06:23 PM	13 persons injured	cylinder exploded Punjabi Bag restaurant-cum-bar,	13 injured in cylinder blast in Delhi's Jamia Nagar; The Hindustan Times; Published on Apr 14, 2022, 06:23 PM

Abbreviation:: PVT; Private; Ckt: Circuit; Hos: Hospital; Morn: Morning; ICU: Intensive care Unit; AN: Afternoon; WB: West Bengal; ICU, Intensive care Unit, NICU: neonatal intensive care unit; GF: Ground floor;

Table 7. Some major fires incidences in crowded areas of India with Causalities (Feb 2010 – Nov 2019)

Place of fire	Date	Source/ Losses	Cause	Source
Park SS Hospital (PVT), HYD.	2nd Feb 2010 (morn)	43injured; property loss	Short Ckt	M.Srinivas, 43 injured in city hospital fire; The Hindu, Pub. on Feb 02, 2010, at 13:02
AMRI Hos. Calcutta, WB (PVT)	9th Dec 2011 (Night)	92 deaths &property losses	Flammable Materials Basement	The Fire at AMRI Need for Legislation on Corporate Culpability; Economic & Politica weekly Vol. 52 (34), 26 Aug 2017
Medi Point Hos. Pune, (PVT)	26th May 2012 (FN)	36inclusive 4 from ICU shifted	Short Ckt	Fire guts Aundh hospital's storeroom on the terrace in; Times of India; Published on May 27, 2012,
PBM Govt Hos; Bikanir	13thJan. 2013(Morn)	ICU; 3injured	Short Ckt	LK Chhajer, Close shave for 100k ids in Bikaner hospital fire; Times of India, Published on 14 Jan 2013
SS Hospital, Chembur, Mumbai	19th Sept. 2015 (AN)	Non-injured; property loss	AC Short Ckt in ICU	Sumitra Debroy, Patients evacuated after smoke engulfs ICU of a Chembur hospital, Times of India, Published on Sep 20 2015 22:52 IST
Acharya HH Govt. hosp. CTK, Odisha	16th Oct 2015 (Even)	One boy died in the evacuation	AC Short Ckt	Fire in a cancer hospital, a patient dies during the evacuation, Times of India, Published on Oct 17, 2015,
Govt, Sishu Bhawan, Cuttack (SVPPGIP)	29th Nov 2015 (Even)	No injuries or casualties (SNCU)	ICU (short ckt.) (Spcl. Newborn Care Unit)	17 escape unhurt as 'short ckt' sparks fire at Sishu Bhawan ICU, TOI, Mar 14, 2021, 12:57 IST
Murshidabad Govt., Med. College, WB.	27th Aug. 2016 (Morn))	3killed and 50injured	Stampede to death of two nurses	Two staff killed in Murshidabad hospital fire, The Hindu, Published on AUG 27, 2016 15:32 IST
Govt SCB Med college, CTK, Odisha,	31St May 2016 (AN)	No injuries or casualties	Short cut, X-former [AC] cardiology dept.	Fire Breaks Out On Premises Of SCB Medical In Cuttack, Odisha Bytes, Published on 5 March 2022
Govt; Safdarjung Hospital, New Delhi	21st Sept. 2016, (AN)	60 patients were shifted	Short Circuit at ICU meter Box	Himanshu Mishra, Fire breaks out at ICU of Safdarjung Hospital in Delhi, 60 patients evacuated; India Today, Published on: Mar 31, 2021, 10:38
SUM Hos, PVT BBSR, Odisha	17th Oct 2016 (AN)	23dead, 120 injured	Short Ckt 1st floor spread to ICU	BBSR's SUM Hospital fire, The New Indian Express, Published: 17th October 2016
KGMU. Govt. Medical UP Lucknow,	16th July 2017 (AN)	No injuries or casualties	Short Ckt, Patients shifted safely	Lucknow: Major fire in KGMU, Trauma Centre hit; The Times of India, published on: Jul 16, 2017,
Kakinada Govt Hos	20thFeb 2018(Morn)	One Died shortage of Ventilator	Fire CPAP m/c. neonatal ICU	Panic in Andhra Pradesh's Kakinada government hospital after CPAP machine gets burn
Safdarjung Hos. Govt. ND	3rd Sept 2018, Morn	Three injured	Short ckt eye OT Spirit, 4th floor	Fire breaks out at Delhi's Safdarjung hospital; Hindustan Times, Published on: May 27, 2022

Place of fire	Date	Source/ Losses	Cause	Source
Apollo Hosp., Pvt., Hyd., Telangana	14thSept.2018(Morn)	no casualties reported	Electric short circuit.	Minor fire accident at Apollo Hospital in Hyderabad; The Times of India, Published on Sep 14, 2018,
Calcutta Govt Med. College &Hos, Cal, WB	14th Sep 2018 (Morn)	Nil trauma, 250 patients shifted	AC Short circuit; Pharmacy ground floor	Fire at Calcutta Medical College brought under control; India Today, Published on 14 Sep 2018 11:20 IST
School of Trop. Med. Cal, B (Govt)	12thNov 2018 (Morn)	7 patients shifted	AC Short Circuit	Major fire at Calcutta Medical College, no casualties so far; The Hindu, Published on 03 Oct 2018
Govt C.R. National Cancer Inst; Calcutta	20th Nov 2018 (AN)	Nil Casualty,	AC Short Ckt, patients shifted to safe	Sumanta Ray Chaudhuri, Fire breaks out in cancer hospital in Kolkata; The Hindustan Times, Published on Nov 20, 2018,
ESIC Kamgar Hos., Mumbai, Govt, Hos	20th Dec 2018 (AN)	9 dead 175 injured incl. a firefighter	Short Ckt from AC, firefighter (welders)	Vijay V Singh & Richa Pinto, Major fire breaks out at Mumbai's ESIC Kamgar hospital; 6 dead, 143 injured; The Times of India, Published on 17 Dec 2018
Cal. Govt. Med. College and Hospital (WB)	31st Dec 2018, (Midnight)	Nil Causality, patients shifted to safe wards	Short circuit in a refrigerator in hematology dept.	Sujit Nath, Fire Grips Kolkata's Calcutta Medical College, and Hospital; Second incident in 3 months; News18, Published on DEC 31, 2018, 13:21 IST
General Govt. Hos., Alwar, Rajasthan	31st Dec 2019, (night)	A baby died & rest shifted to safe wards	Fire at NICU	Fire at Rajasthan hospital's neonatal ward, 15-day-old girl sustains burns; Times of India, Updated on Dec 31, 2019, 18:22 IST
ESIC hospital, NOIDA, UP,(Govt.)	9th Jan 2020 (Morn))	No Casualty	A Short circuit	Fire breaks out at ESI hospital in Noida; The TOI, Published on 9 Jan 2020 17:06 IST
(CMIS) Bilaspur (Govt), MP	23rd Jan 2019(Morn)	Fainted 3 firemen, 40 shifted	Short ckt in TB ward	Chhattisgarh hospital fire: due to suffocation; Indian Express, on Jan 23, 2019, 11:54:57 am
Apolo His. (Pvt) BBSR, Odisha(Pvt)	2nd Feb 2019 (Morning)	Safe; 26 patients shifted to safe wards	Short ckt 5th-floor battery room [ICU]	HEMANTA PRADHAN, Fire in Bhubaneswar's Apollo Hospital creates panic; The Times of India, Published on Feb 2 2019 20:04 IST
Pvt Metro Hos. and Heart Inst, NCR, ND	7th Feb 2019 (Morning)	Nil death; 40 patients shifted safe	Short ckt, 2nd floor ICU, [water heater inside]	Massive fire at Metro hospital in Noida, people try to jump out of windows, India Today, Published on 7 Feb 2018 14:26 IST
Govt.SCB Med. Col., CTK, Odisha	14th Feb 2019(night)	Nil, Trauma, patients shifted safe	Short circuit, Main OT of ICU neuro-surgery dept.	Odisha: Fire Breaks Out At SCB Hospital; Sambad English Bureau, Published On: Feb 14, 2019, at 12:11 PM
Govt; AIIMS; Trauma Centre, ND.	24th Mar. 2019 AN	No trauma, 50 shifted safely	Short circuit (leak MOX supply pipe	Fire breaks out at AIIMS trauma center; The Hindu, Published on: MARCH 24, 2019 19:43 IST

Place of fire	Date	Source/ Losses	Cause	Source
Govt. SCB Med. College, Odisha	8th Mar2019 (Night)	No Causality,	AC Short ckt Pathology Dept,	Sharmili Mallick, Fire breaks out at SCB Hospital in Cuttack, property worth crores gutted; Odisha TV, Pub: Friday, 08 Mar. 2019
LNJP. Narayan Hos, ND, Govt	10th Apr 2019 Night	No Causality reported	First-floor plastic surgery ward	Fire breaks out in plastic surgery ward of Lok Nayak Jai Prakash Narayan Hospital; Business Std., Published on Apr.10, 2019,
SMS Govt. Hospital, Jaipur (Govt)	10th May 2019 Night	125moved safely No Trauma	Short circuit in Med. Shop GF	Fire breaks out in SMS Hospital; The Times of India, Published on May 10, 2019, 14:06 IST
AIIMS GF. Govt, New Delhi. (Govt)	17th Aug 2019, (AN)	No Casualty	Fire Occurred on the ground floor	Himani Bhandari, Fire breaks out at AIIMS hospital in Delhi, under control now; The Hindu, Published on August 17, 2019, 17:37 IST
North Bengal Med. Col. & Hos(Govt)	27thSept -19 (Morn)	one lady died	Short CKt coronary care unit (CCU),	Patient dies in fire at North Bengal Medical College and Hospital; The New Indian Express, Published: 27th Sept. 2019 11:52 AM
Shine Children's Hospital (Pvt)	17th Oct 2019 (Morn)	1 dead, 4 injured	Short Ckt patients shifted to safe wards	B. Kartheek, Four-month-old child dies in fire at Hyderabad's Shine Children's Hospital; The New Indian Express, Pub: 21st Oct. 2019
KEM Hospital, Mumbai; Govt	8th Nov 2019 (Night)	1 injured	Short ckt Pediatric ward,	Jyoti Shelar, KEM Hospital fire: BMC initiates inquiry, baby battles for life, The Hindu; Pub: Nov 09, 2019

Table 8. Some cases of hospital fires, and related deaths in India between 2020 to Aug-2022

Name of the Hospital fire	Date	Causality	Source
Vadodara Pvt hosp., (Pvt), Gujarat	12th Apr 2022 (Mng)	No death, All rescued, short ckt	Guj_ Fire in Vadodara hospital; 23 patients rescued, none hurt; 17th March 2021 11:54 pm, Siasat,
Wadia Hospital, Mumbai; Govt	5th Aug 2022(Even)	No death all shifted safely	Fire in Paediatric OT (UPS; Short Ckt)http://timesofindia.indiatimes.com/articleshow/93382738.cms?utm
Mazumdar Shaw Hos., Pvt, Bengaluru (CCH)	May 1, 2021,(Even)	no death, short ckt	Bangalore Mirror Bureau / Updated: May 1, 2021, 22:19 IST
SVVS Hos, Mandvi, Pvt Hos, Vadodara, Gujarat	17th Mar 2021 (Evening)	23 (incl.17 CCH)patients rescued	23 patients rescued from a fire at Covid-19 hospital in Gujarat, Ghanghar G.M, 18th Mar -2021

Name of the Hospital fire	Date	Causality	Source
Prime Critic Care Hospital, Pvt, Thane	April 28, 2021 (even)	4 deaths (short Ckt in meters)	Mumbai Mirror Online / Updated: Apr 28, 2021, 08:20 IST
Ayush Hospital, Pvt Surat	April 26, 2021 (Morn)	4 deaths+16 rescued, ICU short Ckt	4-covid-patients-die-after-fire-breaks-out-at-surats-Ayush-hospital: NDTV: Apr 26, 2021, 4:41 pm IST
Vijay Vallabh Hospital, Pvt, Virar Gujarat (ICU)	April 29, 2021 (early morn)	14 deaths, 27 shifted, Short ckt	Vijay Vallabh covid care hospital - The Economic Times; 28 Aug. 2021, 09:22 AM IST | PTI
Well Treat hospital, Wadi, Nagpur (Govt)	April 9, 2021 Night	8 deaths (CCH)	Police probe reveals 8 patients died due to Wadi hospital fire. Nov 21st, 2021, TOI, Anparthi A./ TNN
Dahisar jumbo centre, Mumbai (Pvt)	April 4, 2021 (Noon)	no death (CCH) elec short ckt	Mumbai Mirror Online / Updated: Apr 4, 2021, 18:12 IST
Sunrise Hospital, Mumbai; CCH Pvt	Mar 26, 2021 Night	11 persons dead; fire swept from a mall	At least nine COVID-19 patients killed in Mumbai hospital fire; Alok DeshpandeMUMBAIMARCH 26, 2021 08:05 IST
Patidar Hospital, Pvt, Ujjain	April 4, 2021 (Morning)	no death (ICU)	COVID patients, rescued from burning hospital in MP's Ujjain; New Ind. expresses; 04, Apr. 2021
Safdarjung Hospital, Govt Delhi	March 31, 2021 (Morn)	no death; the inverter caught fire	Delhi: Fire breaks out at ICU ward of Safdarjung Hospital, 50 patients evacuated; India TV news; Parashar A., March 31, 2021, 13:02 IST
LPS Institute of Cardiology, Kanpur (Govt)	March 28, 2021 (morning)	no death (ICU) Short Ckt	A fire erupts close to the emergency unit of the LPS Institute of Cardiology in Kanpur; Dragtrex; 28th Mar 2021
Civil General Hospital, Bhandara (Govt)	Jan 09, 2021 (Night)	10 deaths in the Neonatal care unit (ICU)	Bhandara District General Hospital fire: 10 infants killed in a massive blaze; Business Today; Jan 09, 2021, 9:51 AM
Patel Welfare Hos. (Pvt) Bharuch	1st May 2021 (midnight)	19 died (ICU)	Fire in hospital's intensive care kills 18 in India's Gujarat; Reuters; 1-5-2021
Government General Hospital, Guntur	Jan 06, 2021 (Night)	no death; Short ckt, ICU	Andhra Pradesh: Minor fire breaks out in Guntur Government General Hospital, all patients safe; Samdani / TNN / Jan 6, 2021, 23:22 IST
(a)Bhandar Hosp ICU; (b)SRe Hosp. Mumbai; (c)VV Hos. Virar; (d) VV Hosp., (Maharastra)	20th Jan,20 26th Mar-20 23rd Apr.-20 28th Apr.-20	10 Children 11 died; 15 died 4died; (T:40died)	The perilous state of fire safety in Maharashtra's hospitals | India Today Insight; Kiran Tare; Mumbai May 3, 2021, 21:18 IST
Chhatrapati Pramila Raje Hos.al,	Sep 28, 2020	no death	Fire rages at Kolhapur's Covid hospital TNN / Sep 29, 2020,

Name of the Hospital fire	Date	Causality	Source
Kolhapur			
Uday Sivananda Hospital, Rajkot	Nov 27, 2020	13 deaths	Rajkot Hospital Fire: Seventh Tragedy in Gujarat Covid-19; News 18; Mar.04, 2021,
Sadguru Hospital, (Pvt) Cuttack	Sep 21, 2020; 05:45 PM	no death	Over 100 Covid-19 patients rescued as fire breaks out at Odisha hospital; Hindustan time; Sep 21, 2020
SSG Municipal Hospital, (Govt), Vadodara	Sep 08, 2020	no death	Gujarat: Fire at a government hospital in Vadodara, nobody injured; Sep 08, 2020, 09:05 PM
GGS; Hospital, Govt, Jamnagar	Aug. 25, 2020	no death	The Hindu; Aug 10th, 2020; 09:14 IST
Swarna Palace Hotel (CCH), Vijayawada Govt. (PVT)	Aug 09, 2020 Morn)	10 deaths; 20 injured,	Vijayawada: Massive fire at Covid-19 care facility; BBC News, 9 Aug. 2020, (from the dis-infected spray)
Bhandup Hospital Mumbai (ICU)	Mar 26th, 2021	11died	Alok Deshpande, The Hindu; TNN / Updated: Jul 8, 2021, 08:47 IST
Tank leak; near Nashik Hospital (on-road)	Apr 21, 2021	22dead Oxygen	https://www.dnaindia.com/india/report-oxygen-tank-leaks-at-nashik-hospital-22-dead-2887294
AIIMS New Delhi (Two blazes) (Govt)	16th & 20th June 2021	No casualty	The Hindustan Times, Updated on Jun 28, 2021, 07:24 AM IST
Ahmednagar Hospital Fire (ICU) (Govt)	Nov 6, 2021	11deaths 7th Nov	The Newyork Times, Nov. 6, 2021 Updated May 14, 2022

be reduced by hair clipping or removal and Indian nurses use inflammable gels. Bowel gases, preoperative can be a fuel. The non-patient reliant case of causing fire are antiseptics, Alcohol-based preparations, Airway devices including Endotracheal tube (ETT) and supra-glottis radiology, surgical sponges, gauge and gowns/drapes (when dry), anesthetic gases like old OTS like cyclopropane, ethylene chloride, were combustible, Jones et al. [30].

3.15 Management Hospital Fire

Apocalyptic fires in Hospitals can be extinguished fast under timely identification and appropriate management by following risk assessment and follow up of the checklist, cognitive supports. On doubt of a fire occurrence, the instantaneous action plan is to shift the co-patients to safe wards/ other hospitals by seizing all activities. On identification of a fire, break the flow of all air tracks of gases and disconnect the breathing circuits, remove ETTs, all burning of flammables, and patient care sustained by room air. If possible use fire extinguishers to douse.

4. RESULTS AND DISCUSSIONS

The medical oxygen demand (MOD) during pre-COVID-19 was about 700MT/day. The 1st wave of the pandemic was 800MT- 4000MT, further was scaled up to about 8000MT during 2nd wave. Production of this higher value is achievable, but maintaining the supply chain and logistics to HCUs (Health care units) is a herculean task. Medical Oxygen is evolved at -183^{0}C and stored in distinct cryogenic transportation containers. A huge number of safe cryogenic transportation containers and networks, Oxygen concentrators, and PSA (Pressure swing adsorption) in oxygen-producing plants are required. Also, nobody can give a guarantee of no other waves in the future, https://pib.gov.in/PressReleseDetailm.aspx?PRID=1717459, Mohammad A, [31-35].

India has a capacity of about 7200MT unevenly spread seventy numbers of plants, producing 80% of the total production. The plants are clustered in Maharashtra, Odisha, Tamil Nadu, Jharkhand, Karnataka, Kerala, and West Bengal states, but nearer to the industries and meet industrial Oxygen demand. Only 11700 such containers are available in India, out of which only 15% of them meet the MOD produced in India [36].

4.1 Pandemic Demand and Supply of Oxygen

The consumption of medical oxygen has been multifold in the largely populated states during COVID-19 in government CCHs and designated COVID Care Centers. The lion's share of allotment of the Government funds has been diverted during CCHs in different states, such as Delhi, Maharashtra, Gujrat Uttar Pradesh, WB, Bihar, and many states, Bikkina et al. [37].

The demand peaked in India (about 9000MT) during 2nd wave whereas the peak demand during 1st wave was 3095 MT (Loksabha was informed on 23 July 2021). The daily liquid medical oxygen (LOX) production, was ≈5700 MT in one day in August 2020. That has increased to about 9690MT on May 13, 2021. On 28th May 2021, the GOI allocated 10250MT to all the states of India. On the rising mandate of COVID active cases, 1385MT of LOX was

Table 9. Surge in O_2, LOX, and COX status in India in the first phase period (source: GOI)

Item	Period: COVID-19	August 2020	May 2021
Oxygen/ LOX and COX	2020-2021	MT/day	MT/day
Oxygen production	Aug'20 - May'21	5700	9551
Production Capacity	Aug'20 - May'21	6817	7419
Capacity utilization	Aug'20 - May'21	84%	129%
LOX yield steel plants	4th May 2021	3680.30 MT	
LOX Supply per day	15th Apr to 25th Apr	1600MT	3132 MT
LOX sale	25th Apr to 4th May	3132MT	4076.65MT
No. of tankers	Mar 2020- May 2021	1040	1681
Capacity of transport	Mar 2020- May 2021	12480MT	23056 MT
Cryogenic MOX Cylinder	Mar 2020 to May 21	4.35 Lakhs	11.19 Lakh

LOX sale in India was augmented from ≈1,300 MT/day from Mar 21 to 6th May was 8,920 MT/day. From March 2020, the pandemic's first wave, the optimum sale of 3095 MT/day of LOX was on 29th Sept. 2020. The trade of LOX grew about five-fold (from 1559 MT/day on March 31st, 2021 to about 8000 MT by 3rd May 2021, GOI data

imported from countries like Kuwait, Singapore, Qatar, Bahrain, UAE, and many others. Monaghesh, E., Hajizadeh, A. MOX Express services of Indian railways (IR) delivered 35500 MT of LOX as on June 21. Air Force, India conducted sorties 1630 domestic and 229 international to lift MOX airlift tankers to satisfy the demand. Besides 1222 MT, Pressure Swing Adsorption (PSAs) having a capacity of O_2 generation plants with a capacity of 1771.76 MT were sanctioned. https/pib.gov.in/PressReleseDetailm.aspx?PRID =1717459.

4.2 MOX Crisis during 2nd Wave in India

India encountered a staid crunch of MOX during the 2nd wave. This redundant catastrophe took on the profusion of COVID patients requiring an instant huge volume of MOX. Media made headlines of the horror stories of oxygen cylinders' unavailability. The crisis invited stockpiling, and black marketeering. The government (both state and central) seriously took cognizance of the supply of liquid oxygen and even the conversion of COX (cryogenic) to MOX. Hospitals were permitted to institute oxygen plants and extra beds, (Table 10).

4.3 Hurtling WEB GIS, digital stage, and Tracking System

The number of active cases, the Web and App-based Oxygen Digital Tracking System (ODTS) can propel the real-time tracking of MOX demand in India. The judicious allocations of the plants are ordered against real-time tracking of MOX movement. The GSTN database, E-waybill, tracing of MOX tankers through GPS, SIM (via Driver Mobile No.), FAS Tag, and Automatic alerts, to track route deviations, inadvertent, slowdowns, deferrals, etc. during transport by roads, rails, or air, Bharadwaj et al. [38].

Table 10. Status of oxygen-added beds in India during pandemics; India

Type of beds	As on April 2020	As on Jan 2021	% of increase
Oxygen aided beds	62458	157344	151.92%
ICU beds	27360	36008	31.61%
Ventilators	13158	23619	79.50%

During the pandemic, the oxygen-aided beds, ICU beds, and Ventilators increased by 151.92%, 31.61%, and 79.5% respectively. India had a potential manufacturing volume of 7127 MT of MOX/day on 12th April 2021, but demand from the hospital sector was 3842MT (54%) of production,hhtp//nhm.gov.in/New_Update-2021-22/PIP/ECRP-I/Guidance_Note_on_LMO, Baheti, et al. [39]

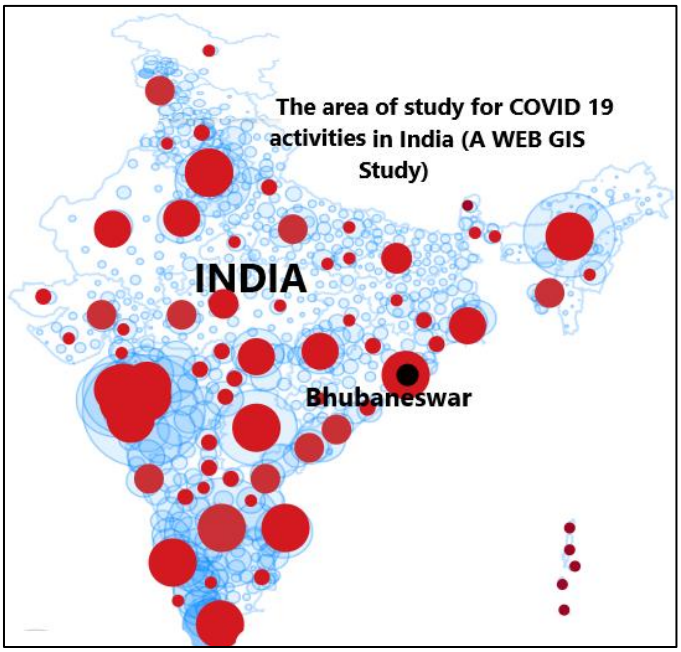

Fig. 6. The WEB GIS map showing the COVID hotspot areas in India

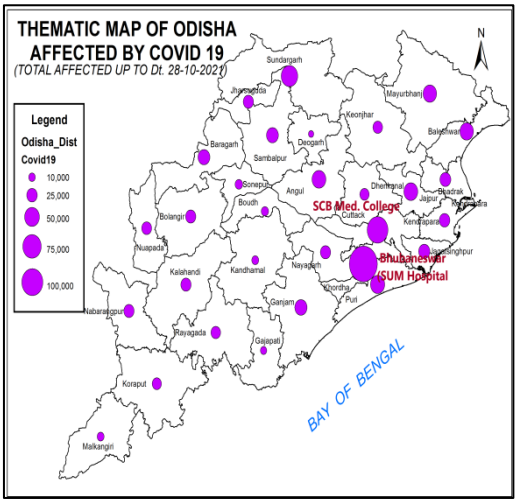

Fig. 7. The WEB GIS map showing the COVID hotspot areas in Odisha

The digital policy push is the National Health Policy (NHP-17). NITI Ayog has published NDHB (National Digital Health Blueprint) considering the wide application of the VEB GIS, (Use of mobile and internet), Telehealth services, under a cloud platform reaching the remote areas of India for digital tracking of fire and diseases, Monaghesh et al. 2020. The below (Figs. 6 & 7) shows the WEB GIS map showing the COVID hotspot areas in India and Odisha state.

4.4 Training Drivers of Oxygen Tankers and Cryogenic Tanks

Considering properly licensed tanker drivers and MOX users, the National Skill Development Corporation (NSDC) and Logistics Sector Skill Council (LSSC), India have trained additional 2,500 drivers to add to the safe oxygen tankers drive. The existing 609 cryogenic tanks have been enhanced to 901 by Mar 2020 to satisfy the demand for Medical Oxygen (MOX). Additional 127000 cylinders are ordered on 21.04.21. On a war footing basis, 1000000 NRM valves were manufactured to decrease the wastage in the use of MOX by DRDO (Hindustan Times, on Jun 03, 2021).

4.5 Oxygen Conservation Practices

COVID-19 has taught us to conserve Oxygen not only for CCHs but also because its conservation is prioritized by the Government. Not only the hospital authorities were vigilant on oxygen plants but also government officials conducted regular checks of leakages in plants, storage unit pipes, and in the final delivery systems. The health care staff should have to check oxygen balance, and masks with open oxygen circuits. Portable oxygen concentrators were encouraged and leakages were to be well guarded. Proper use of nasal cannulas, the MOX delivery system developed by DRDO (Defense Research and Development Organization) based on patient's SPO_2 levels constitutes a highly conserving system with MOX level targeted at 92% rather than 95% Jha et al. [40].

Inadequate MOX production: The essential drug, Oxygen has few vendors in India. The poor production and focus on deficient manufacturers have stemmed in cost intensifications, hoarding, and black-marketing and resulted in an irrational supply of MOX. To achieve a rational market, encouragement from the State Governments is desired.

Acute shortage MOX: The second wave in Delhi caused fatalities to about 20 numbers of COVID-19 patients against the scarcity of MOX. Globally Pneumonia alone causes 800K fatalities/per annum and is projected that about 20–40% higher were ignored due to oxygen non-availability. With the expertise of oxygen manufacturers and efficient sustenance, the supply chain can fill a huge stop-gap, so that MOX suppliers could yield safe and timely supply performances.

MOX Supply system: Lack of central and piped MOX distribution systems faced acute short supply during heavy consumption, in many CCHs, district headquarters hospitals (DHH), and even hospital complexes in large cities and cosmopolis. They used solo cylinders. To satisfy uniform and uninterrupted MOX supply, central

and piped was felt bare necessity. It was felt necessary to have an assessment of five years gap or at a fixed interval and decided GOI to address the demand and cope with the technology changes.

Establishing MOX demand-supply examination: Each DHH should have an innovative system for assessing along with forecasting the MOX demand. That should contain regular or seasonal variations. MOX suppliers' performance needs to be reviewed. The DHH should utilize the gathered information and finalize the procurement of MOX, Jha M et al. [40].

MOX monitoring system: Most of the district hospitals are not well equipped to monitor incessant MOX supply coping with the exigencies in the CCHs. An active alarm network based on monitoring is indispensable to oversee the MOX supply in various CCHs and Health care units, to address MOX supply shortages.

MOX in future epidemics: The provision of more cryogenic containers, tankers, and liquid storage tanks is indispensable. The Oxygen producing plants are to be technologically redeveloped to augment their capacity to meet the emergency demand with simultaneous production and storing of Nitrogen. For judicious distribution, more numbers of oxygen cylinders are necessary for wise use. More oxygen concentrators are to be manufactured, along with initializing action plan to have more PSPs in the Hospital complex [41]. Save Oxygen both in liquid and gaseous form with an action plan as follows:

1. Oxygen is a lifesaving drug in SARS-2 cases (WHO)
2. Target spO_2 levels in optimum in CCHs
3. However, always choose the use of the right Fire Extinguisher (Centrally or isolated)
4. All Hospital staff must undergo regular fire training.
5. Allow trained CCH staff to handle oxygen but not relatives and attendants
6. Identify and maintain regularly the Oxygen supply leakages or pilferages
7. Prescribe Oxygen only when it's conc. is <94% (depending on necessity)
8. Use an accurate size face mask to avoid leakage
9. Appoint staff to handle MOX; dedicated
10. More CCTV cameras and fire extinguishers for surveillance in important places are to prevent vandalism.
11. Once a fire breaks shift the patients to other safe wards with appropriate gadgets.
12. Display important contacts like higher medical centers, blood banks, fire departments, police, and ambulance services available in the nearby area.
13. The Florescent Fire Exit plan shall be displayed on each floor.

Hospital fires are less common on holidays of the week. Indian hospitals are more susceptible to fire (TIMESOFINDIA.COM / Aug 2, 2022, 10:47 IST) [42]. The peak period was 9:00 a.m. to noon. They were least common between midnight and 6:00 a.m. It is an incident when the Hospital is either lonely or crowded. Consumption of Medical Oxygen in overcrowded cities like Mumbai, Calcutta, Hyderabad, Delhi, etc. Even some crowded townships warrant equal care like Cuttack, Bhubaneswar, Ahmednagar, *etc.*

5. CONCLUSIONS

Disaster invites people to tragedies where pandemics to cataclysms. The current picture of the pandemic SARS-02 (COVID-19) is a replica of the pandemic in the year 1919. The current pandemic in 2019, has witnessed patients' isolation from their relatives, society, children, and family and societal humiliation. There are suffering from loss of livelihood, and unavailability of basic items, transportation, emergency needs, medicines, and even oxygen. Patients are under the clutches of healthcare staff, police, and administration, and agonized in the containment area. Closing of industries and livelihood means forcing the slum dwellers, and jobholders to migrate to their mother place.

The MOX, the palliative care, and considered lifesaving drugs were beyond reach in the hours of crisis to the economically backward class though amply available to the rich. In the government Hospital, electrical gadgets like fans, ACs, and electric distribution are not under proper maintenance. They catch fire and become wild in a dry environment. Stockpiling and black marketing of MOX aggravated the strategies. Rather than condoning the crisis, it is high time to join and work together to build CCHs and maintain them safe and fire-free, MOX

abundance for COPD patients. Regular repairs with scheduled checks and reports of oxygen levels within vulnerable zones of a hospital, warrant making the CCHs fire-free risk zone. Similar leakproof CCH Oxygen supply services should be made to HCUs, particularly in Government Hospitals.

The epidemiological data of COVID-19 is based on the number of new cases, deaths, targeted tests, persons vaccinated, and research on the virus survival on various ages, gender, comorbidity, settings, and temperatures. India has remained dormant about further 5T investigations. Nobody can tell about further remediation, aggravation, or proliferation of SARS-CoV-2, as the virus has not deserted the homosapiens, but shall remain as our cohabitate.

HIGHLIGHTS

i. Fireplaces, chimneys, initiated past blazes in Hospitals and fuels are wood, linen curtain, bed sheets, etc. Now electrical short circuits or HVAC systems, Intensive care units, are replaced them.
ii. The numbers of fire blazes are higher in Government Hospitals than in Private Hospitals.
iii. During the Pandemic COVID-19, fire blazes are more in COVID wards and ICUs
iv. The major attributing cause of fire in COVID care Hospitals is electrical short circuits and over capacity.
v. In future pandemics, Hospitals need to prioritize their architecture, air conditioning, heating, and ventilation. The Oxygen levels in the air inside hospitals need maintaining within 30%.
vi. The periodical testing of the firefighting network, production storage, carriage proper use along with web GIS, and digital oxygen monitoring must be prioritized with recording for inspection and future study.
vii. Storage of flammables, the central gas supply points, and faulty electrical Ckts should be far away from CCH and crowded areas. Hospitals should adhere to proper Planning.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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