AIR POLLUTION, CLIMATE CHANGE AND THE HEALTH SECTOR: LINKAGES AND SOLUTIONS

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Introduction

Prolonged exposure to air pollution can result in numerous health hazards such as cardiovascular diseases, respiratory diseases, hypertension, stroke, cancer and premature births. In the past three decades, non-communicable diseases (NCDs) have emerged as a major cause of death in India, with air pollution as one of the major risk factors. The share of NCDs has increased (31% to 55%) while communicable diseases have decreased (61% to 33%) from 1990 to 2016 (Dandona *et al.*, 2017).

Lungs take the greatest stress from air pollution, from increased inflammation, predisposition to infections of upper and lower airways, and impairment of lung development. A recent study outlined the role of air pollution in triggering asthma as well as changing the genetic pattern in asthma initiation (Paramesh, 2018). Air pollutants can also affect the central nervous system, resulting in dementia, Alzheimer's disease, cognitive impairment, and other neurological problems. Children present "windows of susceptibility" to air pollution threats, where the effects may be cumulative and intergenerational, and its effects evident either early in life, in adulthood, or in the next generation (Paramesh, 2020).

Apart from the health burden, there are significant economic and social costs involved with air pollution, which include burgeoning healthcare and welfare costs, and the subsequent loss of productivity. Air pollution is closely related to climate change since they share common sources; hence, significant co-benefits can be expected from the mitigation of either of these two issues. Air pollution can also increase vulnerability to other diseases, burdening the already overloaded health system. Paradoxically, the health system can itself contribute to emissions, thus resulting in an additional burden of diseases. This chapter examines:

- The role of the health sector in contributing to air pollution.
- The issue of indoor air quality in hospitals and health facilities, and how to ensure safe indoor air quality for patients and healthcare workers.

- The role of the health sector in combating air pollution and its ill effects on human health.

Air pollution and the health sector

Studies have estimated the contribution of the health sector to increased greenhouse gas (GHG) emissions along with other air pollutants (particulate matter, ozone, etc.). The emissions could be from direct activities associated with hospitals such as physician services, or indirect activities related to procurement and waste management. There is an urgent need to identify and mitigate emissions associated with healthcare. The various sources of air pollutants related to healthcare facilities are listed in Table 7.1 and discussed below:

- The incineration of medical wastes can emit toxic pollutants such as dioxins, furans, and other criteria air pollutants. It is reported that the burning of medical devices containing polyvinyl chloride (PVC) is a major source of dioxins, and metals in the waste act as a catalyst for its production (Datta *et al.*, 2018). The particulates are released into the atmosphere in the form of fly ash. A major emission from incineration includes heavy metals such as mercury (Hg), lead (Pb), and cadmium (Cd) which are re-distributed in the fly ash and released with exhaust gases. The nitrogen content in the waste can trigger the formation and release of nitrogen oxides.
- The operation of boilers and generators can result in the release of gaseous pollutants such as NO_x and SO_x, along with other pollutants such as PM and CO. Other sources include sterilisation units that use volatile organic compounds (VOC) such as ethylene oxide and anaesthetic gas emission.

Table 7.1 Sources of pollutants in the health sector

<i>Sources</i>	<i>Pollutants</i>
Waste Incinerator	Particulate Matter (PM), Carbon Monoxide (CO), Hydrogen Chloride (HCl), Sulphur Dioxide, Nitrogen Oxides, various metals, dioxins/furans, Volatile Organic Compounds (VOCs), heavy metals such as Hg, Cd, Pb, etc.
Boiler	PM, SO _x , NO _x , Hazardous air pollutants (HAPs)
Generator	PM, SO _x , NO _x , Hazardous air pollutants (HAPs)
Sterilisation units	VOCs especially ethylene oxide
Refrigeration	CFCs
Laboratory fume hood	HAPs
Anaesthesia	Nitrous Oxide and Waste Anaesthetic Gases (halogenated anaesthetic agents)

- Laboratory operations that handle toxic chemicals can result in the emission of hazardous air pollutants into the atmosphere.
- Transport-related activities for hospital services and procurement can result in vehicular emissions. It is estimated that significant carbon dioxide emissions are contributed by ambulance services. Most ambulances run on diesel engines which produce more emissions as compared to petrol engines.

As per Central Pollution Control Board (CPCB) norms, all biomedical waste incineration facilities should attach a stack to the incinerator with a stack monitoring facility (as per the guidelines) for the regular monitoring of emissions. Air pollution control devices (filters, scrubbers, precipitators, etc.) should also be attached (CPBP Guidelines, 2016). For example, PM, HCl, and SO₂ can be controlled using filters, electrostatic precipitators, scrubbers, etc., and nitrogen oxides by process modification. Dioxins and heavy metals such as mercury can be controlled by passing the flue gas through suitable sorbent beds or activated carbon. An advanced technology (rarely practiced in India) is plasma pyrolysis and chemical treatment that contributes to lower emissions. More sustainable options such as electric ambulances or greening the ambulance fleet service will decrease the health facility's vehicular impact on the environment.

Human exposure

The workers and people living near the incineration facility/healthcare facility are more vulnerable due to direct exposure (inhalation of pollutants through the air) and indirect exposure (through the consumption of water or food contaminated by toxic particles deposited from air to water, soil or vegetation). Pollutants such as heavy metals stay longer in the environment and can be carried to other places. Even though emissions from one facility contributes only to a fraction of total emissions, the cumulative effect of emissions from multiple facilities within an area could be significant. This is important in highly polluted cities such as Delhi. Some studies have indicated that incinerator workers are exposed to higher concentrations of toxic metals, dioxins, and furans (Kumagai *et al.*, 2002). Most of these metals are carcinogenic, causing irreparable damage to the human immune systems. Dioxins can accumulate in fatty tissues and also pass through the food chain. Studies have reported that exposure to dioxins released from incinerators can affect child development and result in cancer (Lundqvist *et al.*, 2006). However, studies on the health impacts of such facilities are limited in India.

Indoor air quality in hospitals

Indoor air quality (IAQ) within hospitals is compromised due to the number of patients carrying infectious diseases entering the space, as well as

infiltration of polluted outdoor air into the building. Various factors influence indoor air quality, such as building design and management, ventilation, airflow, and the presence of sources that release particles or toxic gases inside the building. Depending on these factors, the build-up of air pollutants could take place in enclosed spaces such as hospitals, affecting health and facilitating the easy spread of infectious diseases through airborne particle transmission. As a place for healing, hospital buildings/healthcare facilities pose the highest risk due to deterioration in indoor air quality. Patients thus become more vulnerable due to their already compromised immune system.

Indoor air quality (IAQ) is affected by many factors, of which outdoor air quality is a major one. The hospital should be located away from major air pollution sources such as busy roads, major traffic intersections, industries, waste-dumping sites, etc. Most hospitals in cities are located very close to busy roads, which can result in the entry of harmful vehicular emissions into buildings, where it takes a long time to dissipate. Apart from that, the microclimate (temperature, humidity, airflow, pressure, etc.) inside the buildings can also affect IAQ as it has a significant role in the dispersion and transport of pollutants, and can affect the thermal comfort of patients. The microclimate inside the buildings is maintained by air conditioning systems, which itself could be another source of pollutants if not properly managed and maintained. The ventilation and HVAC systems should be adequately designed to facilitate good air distribution inside the building (six air changes per hour).

Chemical compounds (especially VOCs) from substances used for cleaning, disinfecting, and sterilisation can also pollute the indoor air. Excess moisture content in the walls can foster fungal/mould growth and can spread as bio-aerosols. Renovation activities or construction in the hospital could introduce dust and toxic substances such as asbestos into the hospitals. Another major IAQ issue in hospitals is airborne infectious diseases which can easily spread due to poor indoor conditions.

The activities within hospital buildings also have a greater role in determining the IAQ. The patients and hospital staff can act as vectors, carrying air pollutants, especially toxin-laden particles, and aid in spreading them through occupant movement, which can re-suspend the settled particles, or by shedding particles from clothing and bodies (Takahashi *et al.*, 2008). Medical activities such as nebulisation therapy, sterilisation, and use of anaesthetic gases can be a source of harmful pollutants such as VOCs and PAHs. Large microbial concentrations were found to be associated with the nebulisation treatments in the hospitals (Roberts *et al.*, 2006). Studies have shown that pharmacy and medical equipment (blood bags, plastic film, injectors, infusion bags, etc.) can be a source of pollutants, especially phthalates (which are used to make polyvinyl chloride or vinyl more flexible and pliant) (Wang *et al.*, 2015).

Vulnerable populations in the hospitals

The groups that are particularly vulnerable to indoor air pollution are the patients (especially infants and the elderly) who spend a considerable amount of time in hospitals, and those with weak immune systems. This may subject them to new infections or aggravate their existing medical conditions. Other major groups potentially at risk are the hospital staff and doctors who are in close contact with the sources. The prolonged exposure to toxic chemicals and pollutants can affect their health. People who visit the facilities are also at risk (although not as much as the aforementioned groups) which include technical staff, inpatient/outpatient users, visitors, etc., depending on their health condition and age.

Hence, unlike other occupational exposure, indoor air pollution in healthcare facilities not only affect the workers, but also the patients and other visitors. Since most of these facilities are enclosed spaces with artificial air conditioning systems in place, this can result in a group of diseases called Sick Hospital Syndrome, which is associated with symptoms such as eye irritation, respiratory problems along with headache, dizziness, fatigue, and nausea (Brandt-Rauf *et al.*, 1991). The presence of endocrine-disrupting chemicals (EDCs) in the indoor air of hospitals can affect the reproductive system, with serious effects on pregnant women and babies in hospitals (Wang *et al.*, 2015).

Hospital-acquired infections (HAI) through airborne transmission

Microorganisms can be transmitted via three major routes – direct contact, droplet transmission, and airborne transmission. Microorganisms carried by air can be transmitted to longer distances, affecting a higher number of people. The enclosed hospital spaces and healthcare facilities can lead to the spreading of infectious diseases through airborne particle transmission. It is estimated that hospital-acquired infections (HAI) result in costs of \$96–146 billion (direct and indirect costs) in US acute care hospitals (Marchetti and Rossiter, 2013). Some microorganisms such as *Aspergillus* or *Legionella* species and fungal spores are aerosolised and can be transmitted via air. If HVAC systems and cooling towers are not properly maintained, they can become breeding grounds for microbes such as *Legionella*, which is transmitted through the air, causing a respiratory infection called Legionellosis (D'Alessandro *et al.*, 2015).

Studies have also shown that some of these microbes can attach to particulate matter and infect the people who inhale these particles. This is important in highly polluted environments as the particles in the air aid in the transfer of diseases. The activities of staff, patients, and visitors such as coughing,

sneezing, making of beds (skin scales shed by the infected patient), absence of proper behavioural rules, etc., can all aid in transfer. Coughing and sneezing can form droplet nuclei (of microbes), which can settle on to the particles in the 0.5–12 μm range and become re-suspended in the air (Cole and Cook, 1998). The main routes of transmission of respiratory droplets are by talking (100), coughing (1000), and by sneezing (over 1 lakh). Hence, the recommendation is to keep three feet away from the patient.

The environmental factors contributing to airborne pathogens are design, construction, operation and maintenance of hospital buildings which can lead to an environment that is favourable to the growth of microbes. The burden of disease due to HAI can be reduced if proper care is taken during the design and operation of healthcare facilities, taking into consideration the various environmental transmission routes. Studies have indicated the possibility of several respiratory viruses (SARS-CoV, MERS-CoV, Respiratory Syncytial virus, etc.) of being transmitted via both long-range and short-range airborne transmission.

Ensuring safe indoor air quality

- Airflow and filtration techniques: Healthcare facilities use heating, ventilation, and air conditioning (HVAC) systems to maintain better indoor air quality and thermal conditions for the safety and comfort of personnel and patients. A critical part of HVAC systems is the filter used to control the airborne contaminants and dust. The use of High-Efficiency Particulate Air (HEPA) filters are generally recommended and internationally recognised; they can filter particles of size up to 0.3 microns with an efficiency as high as 99.99%. Proper ventilation and filtration are crucial to provide a healthy healing environment inside hospitals; proper design and maintenance of HVAC systems can have a positive impact on the health of staff and patients inside the building.
- Use of ultraviolet germicidal irradiation (UVGI) for disinfection: Another common technique used in hospitals to inactivate airborne infectious agents on hospital room surfaces is ultraviolet germicidal irradiation (UVGI). In this method, UV light of wavelength 253.7 nm is used; this can inactivate airborne bacteria, viruses, fungi and mycoplasma. This system has been in use for a long time and is found to be effective against most airborne pathogens.

Air pollution and COVID-19

The World Health Organization (WHO) declared the coronavirus disease 2019 (COVID-19) as a global pandemic on 11 March 2020 following its rapid spread across the world. Contact, droplet and airborne transmission are the widely accepted routes for its transfer. WHO acknowledged the possible role of airborne transmission in the spread of COVID-19, especially in

indoor facilities and crowded areas. It is also hypothesised that particulate matter could carry the virus, triggering the spread of disease in highly polluted areas. A 2020 study has identified airborne transmission as a possible route based on global trend analysis (Zhang *et al.*, 2020). The study reported that the initial outbreak in Wuhan occurred when the ambient PM_{2.5} levels were also higher. However, authors have mentioned that the effect of PM_{2.5} on transmission could be highly variable in different urban environments and needs to be studied further. A study in the US reported higher COVID-19 death rates in regions with higher PM_{2.5} concentrations (Wu *et al.*, 2020). The aerosols bearing the virus can undergo coagulation or grow by attaching to the surface of ambient PM within a few hours. This could also enhance the lifetime of the virus and it may remain active for a much longer time, as indicated in a study from Italy (Setti *et al.*, 2020). The possibility of such spread is higher in highly polluted environments and many Indian cities may fall in this category. However, in enclosed spaces such as hospital environments, aerosol transmission possibility is much higher, and this could result in hospital-acquired COVID-19 infections, affecting healthcare workers, patients and visitors. Healthcare workers worldwide have been affected by the virus. In India, some hospitals had to shut down due to a surge in COVID-19 cases among hospital staff.

The role of the health sector

As India is struggling to meet the emission standards, the need of the hour is a collaborative effort at a multi-sectoral level, which is required to tackle air pollution-related issues (Box 7.1). Consequently, the health sector's contribution to air pollution cannot be ignored, and appropriate measures should be taken to reduce the emissions from the sector.

Advocacy as Physicians: Physicians can advise patients suffering from diseases related to air pollution to adopt preventive measures when they are exposed to pollutants or during periods of higher pollution. They can provide necessary counselling on how to deal with the pollution problem in their day-to-day life. The doctors can put air pollution into the rational and larger context of a patient's life. Apart from that, all stakeholders, including those in the health sector, should work to reduce air pollution at source, eliminate existing pollutants, protect the health of the affected population and improve the quality of life.

Community Advocacy: Healthcare professionals can bring their expertise with an increased focus on public health to the centre of policy-making and can act as advocates in generating awareness about the ill effects of air pollution.

Research: Health professionals need to be actively involved in health research associated with air pollution in order to generate evidence. They can study the causes, mechanisms, and effects of air pollution

Box 7.1 Case study

Role of health professionals in combating the health effects of air pollution

Healthcare professionals could be the leaders in promoting changes through the active involvement and coordination of all community stakeholders. Concerted actions have already been undertaken in a few cities in India (such as Bengaluru) under the leadership of doctors, such as banning tobacco smoke, banning leaded petrol, improving the health of traffic police by reducing their exposure to air pollution, and restricting the use of firecrackers. Studies for over three decades on airway diseases in the city of Bengaluru indicated that asthma prevalence in children has increased over the years; the results from these studies helped the Bhurelal Committee to formulate guidelines and issue a circular in 2004 to reduce air pollution in Indian megacities and improve the air quality of school environments. When research showed the influence of heavy school bags in adding to the burden of obstructive airway disease from air pollution, the Department of Education, Government of India, passed an order in November 2018 that a student's school bag should not weigh more than 10% of the bodyweight of the child.

exposure on human beings, focusing on vulnerable groups. Research also needs to be conducted on the quantification of health care emissions and to design strategies to mitigate the quantum of pollution. They should explore traditional systems which are accessible, available and sustainable.

Reducing emissions from the health sector: The health sector should plan and work towards mitigating air pollution and reducing emissions from the sector. Through proper waste segregation strategies, the volume of waste going to incineration facilities can be reduced, thus reducing toxic emissions. Policies should be implemented to reduce the use of dioxin precursors such as PVC, thus achieving reductions in dioxin emission. Proper management and maintenance of sterilisation units, labs, and pharmacies, and promoting the use of solar water heaters, can also reduce emissions. Studies have shown that a good ventilated ward should have six air changes per hour which reduces to 1.5 air changes per hour with windows closed, which can lead to infections four times higher in hospitalised patients (Gilkeson *et al.*, 2013). “Vaastu,” the science of structure and design of environments based on Vedic mathematics, recommends good cross-ventilation, natural light and greenery.

Ensuring safe indoor air: Healthcare facilities should be places for healing and recovery, but this can be compromised with poor indoor air quality. The infiltration of polluted outdoor air can be reduced by strategically planning the design of the building and the area around the building. Green belt development around the building can reduce the pollutant concentration to some extent. Air filtration units and HVAC systems should be maintained properly to ensure proper air ventilation and filtration. The use of VOC emitting disinfectants and use of chemicals should be discouraged. A safer indoor environment would be conducive for the faster recovery and improved well-being of patients and workers.

Key takeaways

- Air pollution is a public health issue of paramount importance requiring a multi-sectoral collaborative effort, in which the health sector has a great role to play.
- The role of the health sector is crucial in dealing with the increased burden of disease due to air pollution.
- As abodes of healing, healthcare facilities should provide a safe environment for patients, visitors, and healthcare workers. The indoor air quality in hospitals is of utmost importance as the presence of air pollutants can facilitate the spread of infections.
- The health sector should work towards reducing their emissions while ensuring healthy air quality inside their facilities.
- Health voices in air quality-related policy-making are vital, and as thought leaders in a community, health professionals can promote advocacy for policy changes.
- To deal with air pollution and associated health effects one needs to think locally, act locally and propagate the results globally.

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