Retraction

Retraction: Review on indoor air quality in Indian buildings
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IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

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Review on indoor air quality in Indian buildings

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Abstract. World Health Organisation reports Chronic Obstructive Pulmonary Disease (COPD) and lung cancer has the second in top ten reasons of death worldwide accounting to 4.7 million deaths in 2016 next to Ischaemic heart disease and stroke. COPD and Lung cancer is a chronic disease which arises while (i) Inhaling a small amount of irritants over a long period of time (ii) Inhaling a large amount of irritants over a short period of time. Therefore Polluted air or contaminated air is the main reason behind the cause of COPD. Air Quality is classified into Ambient Air Quality (AAQ) and Indoor Air Quality (IAQ). IAQ has more influence on people than AAQ since 90% of time person spends indoor such as in home, office, industrial buildings worksite, etc,. Therefore proper maintaining proper indoor quality within the confined building can save people from diseases like COPD. Indoor Air Quality get poorer due to reasons like smoking, incomplete combustion of solid fuel, improper ventilation, etc., In India there is no proper standards for Indoor Air Quality Assessment like Ambient Air Quality Assessment. Also the characteristic influencing Indoor Air Quality slightly differs from characteristics of Ambient Air Quality. According to ASHREA standard Indoor Air Quality is characterized with the parameters such as radon, aerosol and bioaerosol, VOC ,etc., Poor Indoor Air Quality can cause Sick Building Syndrome and Building related Illness too . It also influences the human comfort to people inside the building. Indian Buildings both residential and Commercial are constructed without proper ventilation leading to human discomfort and unnoticed indoor air pollutants can cause serious health concerns.

Keywords: Indoor Air Quality, Indian Buildings, indoor Health, Review

1. Introduction
Indoor air pollution is very severe than the outdoor air pollution as we spend 90% of our time indoor. Indoor air quality depends on various factors such as concentration of particulate matter, cooking gases, VOC emitted from indoor furniture, floor mats, etc.,Improper indoor condition leads to many syndromes such as Sick Building Syndrome, Building Illness etc. [1] reports Sick Building Syndrome(SBS) is a condition where people in a congested building with no proper ventilation and space suffer from symptoms of illness or feel unwell for no apparent reason. SBS increases with the time people spend their maximum time in the such building influencing their efficiency decrease in work performance and personnel relationships, etc. People in office completely air conditioned, Ladies exposed to cooking gas for long duration, workers exposed to particulate matter in factories are the major group of people getting affected due to poor indoor air quality. In above conditions people are exposed to many toxic gases and particulate matters which will affect their respiratory functions and
leads to high risk diseases to Chronic Obstructive Pulmonary Disease (COPD). Indoor air pollution does not result in immediate health risk but long time exposure of small amount of indoor air pollutants leads to irreversible health risks. Proper ventilation and sufficient amount of sunlight makes the indoor a right place for healthy living. [2] Indoorenvironments is a mix of ambient pollutants and indoor pollutants. Ambient pollutants associated with Vehicular emission and industrial emissions, which can enter by infiltrations and/or through natural and mechanical ventilation systems. Indoor contaminants originate inside the building, from combustion sources, pollutant release from building materials and furnishings, HVAC systems, humidification devices, products for household cleaning, pets, and the behavior of building occupants.

Population in India is increasing in rapid mode day by day leading to space conjunctions and environment pollution. Construction sector is fast growing economy in India with high concentration in residential and commercial buildings. In earlier days buildings were highly ventilated and had good Floor Space Ratio (FSR) which has been increased in present days. Natural ventilations are obstructed with contiguous homes, giving a way for artificial ventilation with HVAC systems predominantly. The current percentage of HVAC systems is 3% but is expected to grow at the rate of 30% per annum over the next five years [3]. Room air-conditioner purchases in India are currently growing at 20% per year, with about half of these purchases contributed by the non-residential sector. Among the Indian buildings many studies were reported on Indian homes with solid fuel used for cooking as it results in Asthma issues in women and School buildings with poor indoor air quality has affected the academic performance and health of students.

2. Factors for Indoor AirPollution
   • Inadequate Ventilation- Inadequate ventilation can increase indoor pollutant levels as the air to dilute the indoor emission is bought less from outdoor and indoor pollutants remains indoor itself
   • High temperature and humidity levels- High humidity provides the perfect environment for the growth of mold Mold spores, dust mites and other. It also leads to high temperature leading to thermal discomfort.
   • Combustion Sources- Burning of fuel such as wood, LPG gas, Cooking, etc done indoor increases the concentration of indoor air pollutants
   • Household Products- Cleaning products, paints, insecticides, aromatic products, etc releases more of VOC which is most common indoor air pollutant.

3. Sources and Types of Indoor AirPollutants:
   Indoor has both common and unique pollutants when compared with ambient pollutant source. Sources of Indoor Air Pollution (IAP) are from indoor emissions and outdoor vehicular and industrial emissions. Based on nature of pollutant it can classified as physical, chemical, radiological and biological pollutants. Most of Indoor pollutants are chemical in nature, Particulate Matter falls under physical pollutant, Microorganisms such as mold spores, virus, bacteria, algae are grouped under biological pollutant and radon is classified under radiological pollutant as shown in figure 2.
3.1. **Building Materials**:

Building materials such as wood, cement, stones, asbestos used during construction and utility items placed inside building such as furniture, carpets, etc., releases indoor pollutions like Formaldehyde, Volatile Organic Carbon and Radon. It also cause the emission of gaseous pollutants of CO, CO$_2$, NO$_2$ and SO$_x$.

3.1.1. **Formaldehyde**: Formaldehyde is colorless chemicals used in manufacture of various building materials and household products. Products such as particleboard, plywood, fiberboard, glues and adhesives; permanent-press fabrics; paper product coatings has the composition of formaldehyde. Formaldehyde has its secondary formation during the oxidation process of VOC in air. These products emit formaldehyde in slow rate when exposed to increased humidity and temperature. Lab studies has reported continuous exposure to formaldehyde by humans results non-cancer effects like sensory irritation to the eyes and upper airways, lung effects (asthma and allergy), eczema and so if untreated ends in cancer too[4].

3.1.2. **Volatile Organic Carbon**: Many sources in Indian buildings contributes for VOC emission. Paints, aromatic sprays, furniture polish, acoustic ceiling tile, differ from wet materials such as wood stain caulking sealant and floor wax, etc. contributes for the accumulation of VOC concentration in indoor environment. Research reveals that new buildings releases the VOC in level of $0.5$ to $19$ mg/m$^3$ and old building’s emission vary from $0.2$ and $1.7$ mg/m$^3$. New Buildings rate of VOC as the building materials are fresh in state and begins to get exposed to nature [5]. As days prolong the concentration of VOC decreases in Building elements thereby the emission rate reduces. Adverse health effects are observed when exposure of volatile organic compounds raises above $3$ mg/m$^3$ in indoor environment.

3.1.3. **Radon**: Building materials containing stones, concrete, brick, natural stone, gypsum, or granite are most likely to emit low levels of radiation as they contain naturally-occurring radioactive elements like radium, uranium, and thorium. On exposure to natural environment these can break down or decay into the radioactive gas radon. The emission of radon depends on the type of material used and the nature of exposed condition. Radon is odorless gas but very toxic in nature. It entraps into indoor through the foundation stones, flooring stones. Studies reports that old buildings release more of radon gas by diffusion [6] Very less studies are made on radon as pollutant in indoor environment.

3.1.4. **Asbestos**: Asbestos is a natural occurring silicate mineral often used as fibrous material in manufacturing of roofing sheets, asbestos-cement corrugated sheet, asbestos clothing, etc. releasing low level of asbestos into the environment. It causes health issue as they are inhaled in slow rate. The concentration of asbestos in ambient air are in level below $0.1$ ng/m$^3$ of concentration. The source for asbestos in indoor phase is exchange of indoor and ambient air. The source for asbestos pollution are weathering on asbestos containing minerals. Usage of asbestos has banned in Indis but the concentration of it in environment exist because of the removal of asbestos building materials from older building [7].
3.2 Particulate Matter

The high concentration of particulate matter in indoor environments also leads to poor indoor air quality. Particulate matter is a natural element present in the atmosphere, where the solid matter or liquid molecules are suspended in the air. These suspended particles represent particulate matter or called Aerosol [8]. In air there are variety of aerosols produced naturally or by anthropogenic means. The size of particulate matter varies from millimetres to microns. Particles sized below 10 microns are considered as pollutant as it can be harmful to humans and can cause respiratory diseases. Concentration of particulate matters relies on factors such as ambient air concentrations, air exchange rates, penetration factors, as well as deposition and resuspension mechanisms. In indoor PM concentration accounts for total concentration of particulate matter present in indoor and it was reported the indoor particulate concentrations are often measured to be higher than those outdoors. All combustion activities, cooking, heating, cleaning and movement of inhabitants are the main source of Indoor particulate matter [9].

3.3 Gaseous Pollutants

Gaseous pollutants are one of common indoor pollutants enters and its sources are vehicular emission, combustion of cooking solids and fuels, emission of volatile gases from household materials, etc. Carbon Monoxide, Carbon dioxide, Volatile Organic Carbon, SOx, NOx, Ozone and Radon are the gases predominant in indoor environment fig2. Heating and cooking activities contribute for increase in concentration of CO, CO2 and it ranges from 0.5 to 30ppm based on the type of cooking and fuels used for cooking. Tobacco smoking also highly contributes for CO and CO2. CO is a toxic, odorless and colorless gas produced by incomplete combustion mostly at ambient and enters the indoor space. Its concentration varies between 0.7 to 1.4 ppm. CO2 in indoor environment reduces the heat exchange and thus makes the indoor very humid. Presence of NOx is possible from both indoor and outdoor sources and among the Nitrogen Oxides Nitrogen Dioxide (NO2) and Nitric oxide (NO) were reported in high concentration in buildings such as office and schools. Cooking increases the NO2 upto 10% when compared to normal indoor condition. Ozone occupy the indoor because of photochemical reaction between Nitrogen Dioxide and Volatile Organic Carbon. Electronic equipment such as computers, photocopiers and laser printers are the main source for the Ozone production. Therefore the concentration of Ozone is found to be maximum at office buildings than in residential homes.

3.4 Biological Pollutants

Air Borne Diseases are much common than water borne diseases. Ambient and indoor air provides the beat suiting condition for many microorganisms. As we accommodate more in indoor space, badly maintained indoor air quality leads to spread of many air borne disease including corona virus. The
biological pollutants commonly called as bioaerosol include pollen grains, viruses, bacteria, mold, skin flakes and hairs of pets and rodents, etc. All these are of micro sized which can easily inhaled and create more allergic conditions and diseases.

4. Indoor Air Quality in Indian Buildings

All Indian buildings are constructed in different forms and shapes based on the need of service by the building. Indoor Air Quality depends highly on Building type and surrounding environment in which it is built. In ancient days population was very mere and it keeps on increasing day-by-day. Tremendous changes are observed in construction pattern in India. Though we concentrate more on sustainability and green buildings, population growth and urbanization leads to people crowding both in rural and urban India. Per capita Floor Space (PCFS) has drastically reduced in both residential homes and commercial building space. Studies reports that PCFS only 26-50 Sq.Ft per person is found in residential homes and in office buildings PCFS has reduced from 225 Sq Ft Per Person to 125 Sq.Ft Per Person. Is it also predicted for further reduction too. Density increase in floor space give rise discomfort and health issues as there is no space for ventilation.

4.1 Residential Homes in Rural and Urban India

In urban and rural India has recent construction practices of buildings small homes for residential living. In urban location people have accommodation in apartments and street homes because of lack of space. In rural India homes are in small size due to lack of economic stability. Both these type of homes are no proper ventilation and people have congested living. Studies reports that poor indoor air quality in homes leads to respiratory disorders. Indoor air Quality becomes poorer with different reasons in both these types of homes.

4.1.1 Rural Indian Home

In rural homes indoor air is seriously affected because of the usage of fuels for cooking purpose. Manyinvestigation reported that solid cooking fuels like wood, crop residues and cow dung used in rural India creates health issues to women and children. Solid Fuel or biomass stove releases indoor pollutant such as particulate matter (PM10, PM2.5 and PM1) and gaseous pollutant (CO/CO2). PM2.5 was found in higher concentration upto 87ppm during the cooking period and prevails throughout the day in indoor with a small level of subsiding concentration. The analysis of PM collected in rural indoor environment has many toxic carcinogenic compounds.

4.1.2 Urban Indian Home

In urban India scenario, people live in an congested homes with no proper ventilation. The reasons for poor indoor air in urban homes include the pollutants like benzene, VOC, Formaldehyde, Toluene, etc released from the household products and activities along with pollutants emitted in cooking activities. The studies reports for maximum urban indoor pollution from the building materials and household products like furniture, paints, LPG, insane sticks, cleaning agents, etc. Among the indoor pollutants in urban homes along with CO/CO2 concentration, higher concentration is recorded for PM2.5 and for VOC [10].

4.2 Commercial Buildings in India

Office, school and hospital are the most common type of buildings chosen for indoor quality assessment in India. It has been reported that among the above commercial buildings offices have the poor indoor air quality when bench marking with ASHRAE standards. Ductless air-conditioning system couple with poor air-circulation and active air-filtration could be attributed to significantly higher concentration of PM2.5 and VOC. It was identified the environmental condition, nature of work and duration of working hours influence the results of assessment. Indoor air quality in schools were
influenced more by the ambient and traffic volume near the school campuses. In hospital more than pollutants, concentration of biological pollutant like bacteria, fungi and viruses were high.

5. Health Effect by Indoor Air Quality

WHO reports Chronic Obstructive Pulmonary Disorder (COPD) as the second common reason for increased death rate globally. COPD includes the respiratory and lung disorders. Poor Indoor Air is highly responsible for lung disorders. Studies reveals that Sick Building Syndrome (SBS) was diagnosed in many individuals residing and working in newly or remodeled buildings in recent times. Building occupants experiencing discomforts like throat irritation, dry cough, itching skin, dizziness, fatigue, nausea, etc and if the cause of the symptom cannot be identified is said to be affected by SBS. There is substantial evidence for premature death in children under due to household air pollution. Smoke from burning solid fuels with pollutants of PM2.5, VOC, Poly Aromatic Hydrocarbon (PAH), etc, deposits in alveoli in many women and children and ends in adverse health issues like lung cancer, COPD, pneumonia, cardiovascular attacks, etc.

6. Conclusion

In above review made, it is evident that the indoor air quality is poorly maintained in many Indian buildings because of various reasons. Poor ventilation, reduced per capita floor space, usage of solid fuels for cooking and household products releasing toxic gases and particulate matter are the more depending factors for indoor air pollution. Polluted ambient air is also responsible for indoor air pollution as there is high circulation of air between indoor and ambient air. Therefore maintaining good ambient condition with natural trees, maximum reduction in usage of indoor polluting household products can help in reducing the indoor pollution to the maximum.

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