Studying the indoor air quality (IAQ) of Educational Building, in Mumbai with focus on (CO2, Temperature & RH)

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Research Concern: Understanding the parameters affecting the Indoor air quality of educational building.

Abstract:

This research observes and studies the parameters affecting the Indoor air quality of educational building, (**Shivam vidya mandir high school, Deonar)**. The research begins with an introduction of deteriorating Air pollution of Mumbai and factors affecting the air quality i:e rise in humidity , increase in population, conventional construction practices, traffic dust, industry & power sector emissions, poor waste management in a broader perspective. Assessment of an educational building in , (**Shivam vidya mandir high school, Deonar Mumbai**) with focus on (IAQ), Understanding the IAQ Scenario in Deonar, Further will study an existing building with focus on (temperature, CO2 & RH readings).

Introduction (Ambient Air quality, Mumbai):

Air pollution is not just a regional issue but is a global issue. UNECE (United Nations Economic Commission) confirmed that air pollution is one of the world's largest environmental issue which results in nearly 7 million deaths every year. Air pollution causes asthma, cancer, pulmonary illnesses & heart disease. According to IARC (International agency for research on cancer) particulate matter is one of the major pollutant which is carcinogenic to humans.

This year in February 2023, Mumbai became the world's second most polluted city worldwide even beating Delhi which is infamous for its poor air quality. As per Swiss agency IQAir the AQI of Mumbai on Feb 13 2023 was 163 which was much above the WHO recommend levels.

Source:https://timesofindia.indiatimes.com/city/mumbai/mumbais-air-pollution-is-now-50-above-permissible-limits/articleshow/71159380.cms

Pollutants:

The primary pollutants found in Mumbai are PM 2.5, PM 10 & Nitrogen oxide (NO2). The pollutants found higher than national & international standards. In Mumbai, Concentration of PM 2.5 is much higher than the Delhi. As per the World Resources Institute India found that some areas of Mumbai like Deonar, Govandi, Mankhurd, and Trombay have consistently recorded the highest pollution levels in the city. Long-term exposure to PM2.5 causes reduction in average life-expectancy from 8.5 to 20 months and increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 mg m3 of PM2.5 (Krewski et al., 2009)

Climatic condition:

2017 Mumbai falls under warm & humid climatic zone. Its coastal nature and tropical season fluctuate throughout the year. The humidity levels fluctuates throughout the year and stays mostly high.

Rise in humidity & temperature makes air quality poor. Now the question is how does humidity affects air quality?

The presence of water vapour in the air is known as Humidity. Humidity reduces the air circulation which means the pollutants trapped in the air. Mold which releases spores into the air and reduces air quality. Also humidity increases the heat.

In densely populated & highly polluted urban area like Mumbai which shows relatively higher humidity level throughout the year leads to the increase in the concentration of pollutants in the air, as the pollutants trapped into the humid air which prevent them from dispersing into the atmosphere.

https://airly.org/en/how-does-humidity-affect-air-quality-all-you-need-to-know/

Population:

Rise in population makes air quality worse. One-standard deviation increase in population density Increase in air pollution by 3-12%. The rise in population in every year in Mumbai shows below which also leads to rise in CO2, PM 2.5 & NO2.

- The current metro area population of Mumbai in 2023 is **21,297,000**, a **1.6% increase** from 2022.
- The metro area population of Mumbai in 2022 was **20,961,000**, a **1.42% increase** from 2021.
- The metro area population of Mumbai in 2021 was **20,668,000**, a **1.26% increase** from 2020.
- The metro area population of Mumbai in 2020 was **20,411,000**, a **1.12% increase** from 2019

Source: Mumbai, India Metro Area Population 1950-2023

https://www.macrotrends.net/cities/21206/mumbai/population

Traffic Dust, Industry & power sector Emissions:

Vehicular emission in Mumbai have doubled in five years. Vehicular emissions contributed around 30.5% of all PM2.5 in Mumbai in the year 2022. The contribution of vehicular emissions in 2016-17 were just 16%. Industries and power sector contributed over 18% of the Mumbai's PM2.5 pollutant.

Introduction (Indoor Air quality):

Indoor air quality is associated with the nature of air inside any space of the building and it is linked with the health, comfort and well-being of the occupants. Indoor air is acceptable when all the pollutants are present at levels lower than the levels considered as harmful. People spend more than 90% of their daily life in indoor environments either inside buildings. When compared to an urban outdoor ambient environment with normal traffic, the concentration of contaminants in the inside environment is substantially higher (EPA inside air quality, 2013).

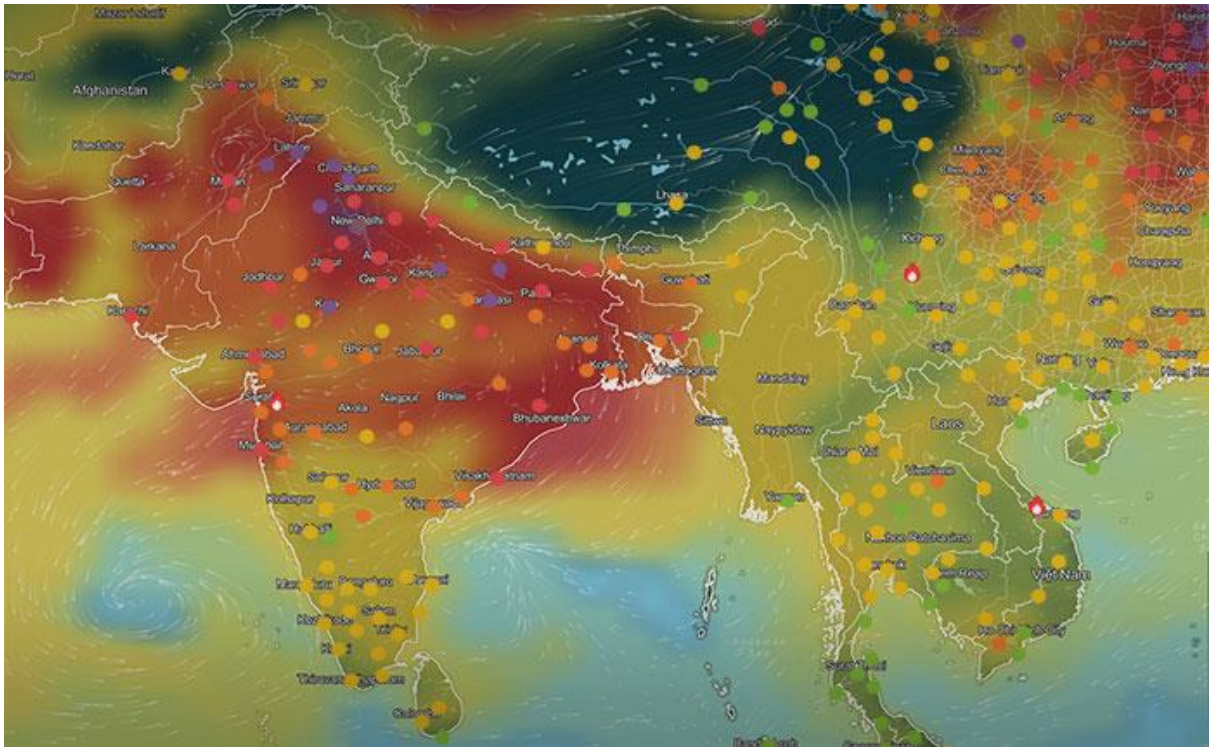
Poor indoor air quality can be particularly dangerous to vulnerable populations, including children, the elderly, people with cardiovascular and chronic respiratory conditions, such as asthma, and others. According to Krewski et al. (2009), long-term exposure to PM2.5 is linked to an average life expectancy reduction from 8.5 to 20 months and an increase in the long-term risk of cardiopulmonary mortality by 6-13% per 10 mg m3 of PM2.5.

In addition to having a significant impact on health, indoor air pollution lowers a building's occupants' comfort, productivity, and capacity for learning.

Approximately 3.8 million people around the world die every year as a result of indoor air pollution. Particulate matter is the cause of numerous respiratory ailments including asthma, respiratory

inflammation, decreased lung function, and cancer. Low-quality air reduces human productivity and our ability to process information.

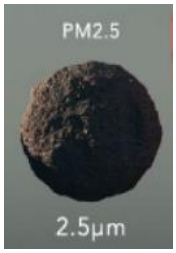
One of the TOP FIVE Environmental Risks to Public Health is Indoor Air Pollution.

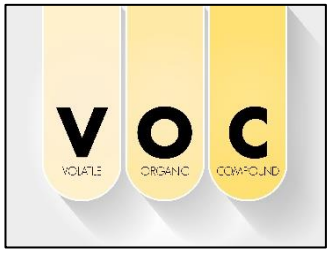


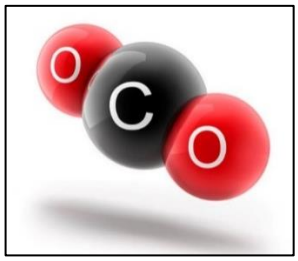
According to Swiss Firm IQAir report in March 2023, 39 among the world's 50 most polluted cities were in India.

Category of Pollutants Impact on indoor air quality:

- Volatile organic compounds (VOCs)
- Carbon monoxide (CO)
- Particulate matter (PM)
- Carbon dioxide (CO2)
- Radon
- Nitrogen dioxide
- Methane







Category of Pollutants Impact on indoor air quality in Educational Buildings

The environmental parameters that affect IAQ of educational buildings or the perceived air quality (PAQ) are:

- Ventilation rate (VR)
- Indoor relative humidity (RH)
- Air Temperature
- Concentration of gases such as CO2 and volatile organic compounds (VOCs)
- As per the studies the most important factor affecting IAQ is the VR (Ventilation rate)

Source : Seppanen et al., 1999

Indoor air temperature:

Compared to buildings with air conditioning, naturally ventilated structures have different comfort limitations for indoor temperature. According to studies (de Dear and Brager, 2002), the external temperatures have a substantial impact on the thermal comfort temperatures. The ASHRAE 55-2017 was created for naturally ventilated buildings to analyse the thermal comfort of the indoor spaces.

Ventilation rate (VR):

The educational facilities must provide outside fresh air to the classrooms to produce necessary ventilation and appropriate IAQ in order to maintain student health and have a favorable impact on student performance. This influences students' learning outcomes in an indirect manner (Chenari et al., 2016; Biler et al., 2018). the minimal VR required in a lecture as per ASHRAE Standard 62.1-2019 per person in the classroom is 4.3 L/s. According to Clements- Croome et al. (2008), "raising the air velocity to 10 L/s per person would result in a 14.5% increase in academic performance."

CO2 concentration as a VR and IAQ indicator:

CO2 emissions increase with the number of people in a space or building. It is necessary to purposefully introduce outside air into the building through a ventilation system to avoid CO2 levels from increasing too high, which could have a harmful effect on residents. High CO2 concentrations have been demonstrated to lower student productivity (Shandell et al., 2004; Bako-Biro et al., 2012; SM, 2018). In a classroom with high CO2 levels, Coley, Greeves, and Saxby (2007) found that students lose attention and focus, which has a negative effect on learning and educational achievement.

Relative humidity (RH):

RH below 25% is unacceptably bad for your eyes, skin, and mucous membranes, while RH above 65% may encourage the growth of pathogenic or allergic germs. To keep people comfortable, the humidity level must be managed. The RH has both indirect and direct effects on comfort and human health when the indoor temperature is outside of the ASHRAE 55 comfort zone. Direct impacts have an impact on physiological processes, whereas indirect effects have an impact on the growth of harmful organisms or substances. In

comparison to the direct impact on health, the indirect impacts are more complicated (Fang et al., 1998; Bornehag et al., 2001; Woloszyn et al., 2009).

Tools for measurement:

Sensors are gadgets that pick up input from the physical world, including light, motion, temperature, etc., and communicate it as a signal that can be measured and transferred electronically. In this scenario, a sensor for interior air quality would find the contaminant in question.

The following are the main categories for sensor measurements:

Carbon dioxide, particulate matter Humidity & Temperature

Sensor Positioning:

Sensors are commonly positioned in the common parts of buildings, away from induction heaters, floor fans, and personal heaters, and out of direct sunlight. It is ideal to mount on a wall because floors and ceilings might not accurately represent the scene.

Air quality of Deonar Site:

Deonar is a site with poor air quality that situated in the eastern suburbs of Mumbai. All waste, including hazardous material, is disposed in a vast open landfill in Deonar. 5,500 metric tonnes of rubbish, 600 metric tonnes of silt, and 25 tonnes of bio-medical waste are dumped daily at the 132-hectare site. Gaseous pollutants like ozone (O3) and nitrogen dioxide (NO2) are released into the air at this waste site, posing a major threat to human health. A recent test was performed to measure pollution levels on the roof of a residential community about 100 meters from the Deonar waste. It revealed that O3 concentrations were constantly above 200 ug/m3 for 12 hours each day and NO2 concentrations were regularly above 100 ug/m3 for for 18 hours in a day, over a four-day period.

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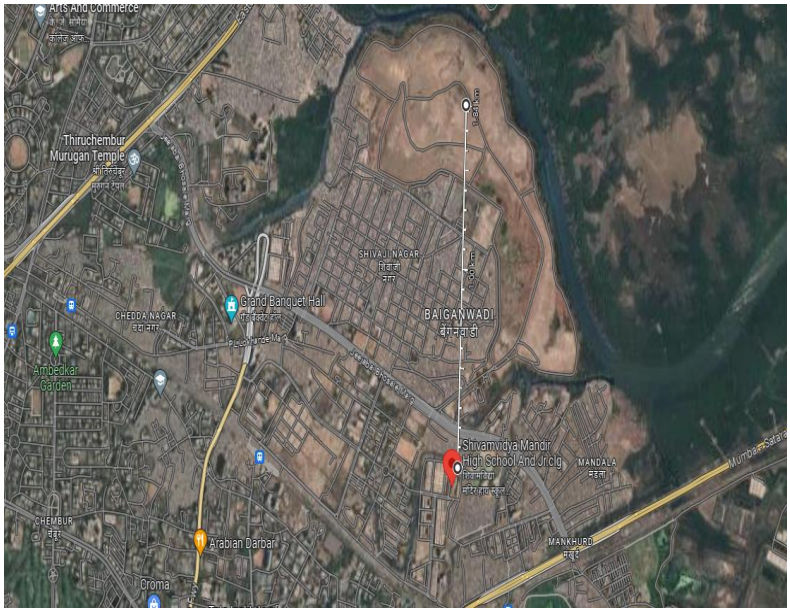
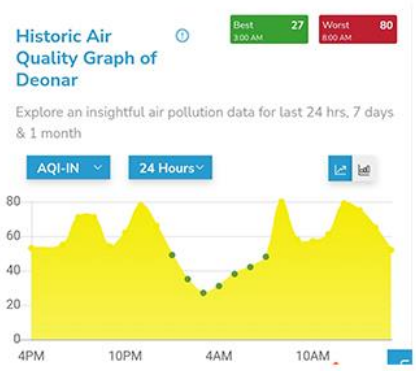
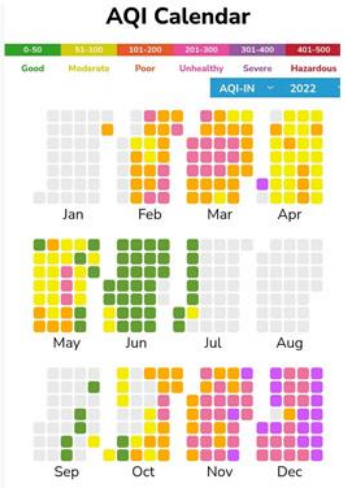
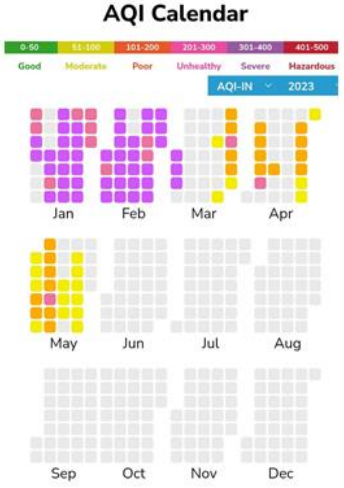


Deonar, in eastern Mumbai, is one of Mumba's most polluted neighbourhoods.

Most Polluted months as per AQI calendar 2022-23, Deonar):





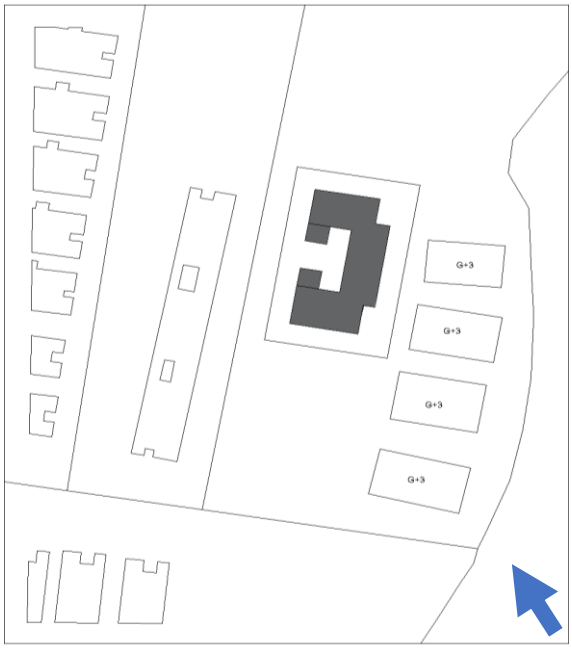


In late October, Deonar's air quality begins to deteriorate. In terms of air pollution, winter is the worst season.

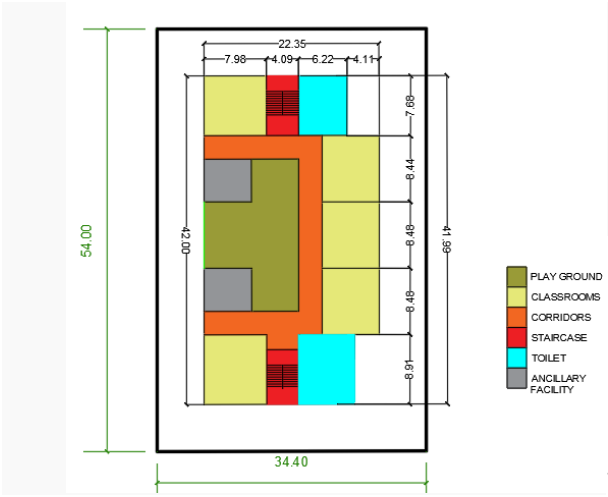
Site Context (Shivam vidya mandir, High school, Deonar):

Deonar's current air quality index is 124 (POOR). The current WHO 24-hour air quality standards value for PM2.5 concentration in Deonar is three times higher than the recommended level. The main contributors to outdoor air pollution include gases from burning fossil fuels and smouldering vegetation, as well as solid, liquid particles known as aerosols and gases from vehicle emissions. Hazardous gases from cooking fuels (such as wood, crop wastes, charcoal, coal, and dung), dampness, mould smoke, chemicals from cleaning supplies, etc. are the main causes of indoor air pollution.

Architectural drawings Plan highlighting (Shivam vidya mandir, High school, Deonar):



Site plan



Plan Front Elevation

Assessment of CO2, temperature & RH readings of classrooms (Shivam vidya mandir, High school, Deonar):

The assessment of Co2 was conducted across multiple classrooms which were located at different directions in the building. The measurement was carried out using a portable Co2 monitoring device. The findings were as follows.

Classroom 1 Classroom 2

Classroom Number	CO2 ppm	Temperature	Humidity
Classroom 1	654	30°C	76%
Classroom 2	584	31°C	75%
Classroom 3	2009	29°C	89%
Classroom 4	2159	29°C	85%
Classroom 5	2197	29°C	84%

Analysis:

As per the assessment classroom 1 & 2 have lesser Co2 level which is close to the safer levels of Co2 required. Yet, as per IGBC (Indian green Building Council) the Co2 levels must be less than 530 ppm and must have 10 cfm/person ventilation rates.

Whereas in classrooms 3, 4 & 5 the Co2 levels observed were very high compared to the baseline requirements and also the humidity levels were exceeding the 60% requirement.

Conclusion:

The indoor air quality is an important factor in maintaining good health. The indoor pollution contributes to a wide range of respiratory and cardiovascular health effects, from simple symptoms until the development of severe illnesses. In densely populated city like Mumbai close & compact built structure affects the wind circulation also humidity plays an equal role to decrease the air circulation inside the structure and the mold which releases spores into the air reduces air quality. Passive techniques like Cross & stack ventilation is an essential factors while designing or planning a structure. The appropriate preventive measures is regular indoor air quality monitoring this will help us to understanding the harmful effects induced by indoor air pollution and the Use of Low VOCs materials, green pro, green seal standard products will also help to reduce indoor air pollution.

References:

https://unece.org/air-pollution-and-health#:~:text=Air pollution is now considered, pulmonary illnesses and heart disease.

https://economictimes.indiatimes.com/news/india/mumbais-air-quality-continues-to-be-poor-doctors-suggest-mumbaikars-to-mask-up/videoshow/98568407.cms

https://timesofindia.indiatimes.com/city/mumbai/mumbais-air-pollution-is-now-50-above-permissible-limits/articleshow/71159380.cms

https://www.orfonline.org/expert-speak/taking-on-a-burning-problem-mumbais-air-pollution/

https://swachhindia.ndtv.com/air-pollution-national-health-issue-experts-speak-26854/

https://airly.org/en/how-does-humidity-affect-air-quality-all-you-need-to-know/

https://timesofindia.indiatimes.com/city/mumbai/lack-of-checks-at-construction-sites-kicks-up-dust-makes-mumbai-ill/articleshow/97410281.cms?from=mdr

Population density and Urban air quality. *Rainald Borck, Philipp Schrauth*

https://timesofindia.indiatimes.com/blogs/voices/easing-out-sustainable-and-green-buildings-is-key-to-reducing-global-carbon-emissions/

https://timesofindia.indiatimes.com/city/mumbai/power-usage-leads-to-71-of-greenhouse-gas-emissions-in-mumbai-city/articleshow/85914153.cms

https://indianexpress.com/article/cities/mumbai/mumbai-reels-under-construction-dust-devil-8534463/

https://www.aqi.in/in/dashboard/india/maharashtra/mumbai/deonar

Fang et al., 1998; Bornehag et al., 2001; Woloszyn et al., 2009.

Shandell et al., 2004; Bako-Biro et al., 2012; SM, 2018.

Krewski et al., 2009,

Seppanen et al., 1999.

Coley, Greeves, and Saxby (2007)

Chenari et al., 2016; Biler et al., 2018.

Croome et al. (2008)

EPA Indoor air quality, 2013

https://www.macrotrends.net/cities/21206/mumbai/population