Proceedings of 14th IOE Graduate Conference
Peer Reviewed
Year: 2023 Month: December Volume: 14
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Passive design strategies to improve Indoor air quality (IAQ) in primary school of Kathmandu valley.

Dibesh Man Malego [a], Shree Raj Shakya [b]

[a] *Department of Architecture, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[b] *Department of Mechanical Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[a] 078mseeb005.dibesh@pcampus.edu.np, [b] shreerajshakya@ioe.edu.np

Abstract

Indoor air quality (IAQ) is determined by factors such as temperature, humidity, presence of pollutants, lighting, ventilation, and sound. Poor indoor air quality can lead to low productivity, health issues, and reduced learning ability. Children are more vulnerable than adults as they breathe at a higher rate. Air pollution has become a big issue in Kathmandu Valley due to increased urbanization and industrialization. Students may be exposed to dangerous air pollutants in the school setting, where they spend over one-third of their regular day. This paper reflects upon the indoor air quality of primary schools based on the quantification of PM2.5 pollutants and a qualitative questionnaire survey conducted on seven naturally ventilated schools in Kathmandu Valley. This investigation reflects a comparison of existing IAQ with the WHO standard and the Kathmandu Valley Action Plan (KVQAMP) using LaserEgg2+ equipment for data collection. The study shows the perceptions of students in government, as well as private schools regarding indoor air quality. A passive design strategy appropriately uses the natural environment for sustainable development. This paper aims to shed light on the IAQ issue for students' health, well-being, and productivity, especially those from lower-income households, studying in government schools.

Keywords

Indoor air quality, PM2.5, Primary school, Kathmandu valley, Passive design strategy.

1. Introduction

IAQ stands for indoor air quality, which is essential for the health and comfort of building inhabitants both inside and outside of buildings and structures. IAQ issues have often been linked to older, poorly maintained construction projects, but it's becoming more common to find reports of ailments in newly built or recently renovated buildings that are linked to poor air quality. The interiors of our buildings were traditionally believed to offer shelter from the damaging effects of extreme weather and external air pollution may have higher levels of pollution than the ambient air in the area [1].

Since the beginning of architecture, one of its essential purposes has been to safeguard people from dangers. Currently, there is a lot of scientific research on COVID-19, particularly for public health interventions and engineering methods for enhancing IAQ without taking an architectural perspective [2]. Air pollution has grown to be a significant problem in the Kathmandu valley as a result of increased urbanization and industrialization. Nearly all low- and middle-income nations, including Nepal, breathe air that is worse than what is recommended by the World Health Organisation [3].

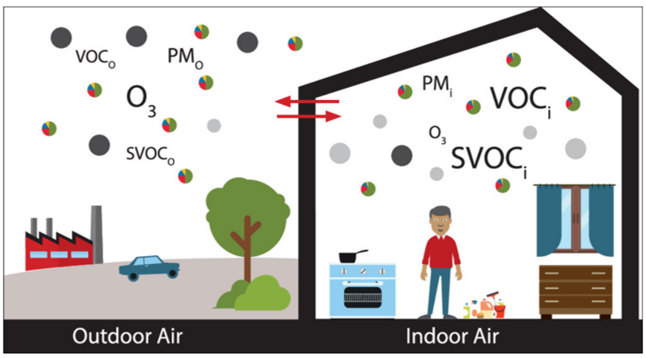

Figure 1: Impurities present in Indoor/Outdoor air (Source: NIEHS)

2. Material and Method

Laser Egg2+ equipment was used for quantitative data of indoor air pollutants present in classrooms of seven different schools located in the Valley. A qualitative questionnaire

Figure 2: Data collection in Patan Secondary School

survey was conducted to understand student's perceptions regarding IAQ and the classroom. The well-being questionnaire for PISA (Program for International Student Assessment) 2018 was used as a reference and edited to focus on IAQ, comfort, and student perception. The data collection began from 19 July 2023 to 27 July 2023.

3. Literature Review

3.1 Passive design strategy

A passive design strategy is making appropriate use of the natural environment. Passive design is a design that works with the local climate to maintain a comfortable temperature in the home. Depending on the region, good passive design should reduce or eliminate the need for supplemental heating or cooling, and it often relies on an active occupant to function correctly.

3.2 IAQ Measurement

IAQ is determined on the basis of desired Temperature, Humidity, Air movement, and presence of airborne impurities. The awareness regarding IAQ began from the early hygienic revolution. There is growth in research after understanding the significant impact of IAQ on health, well-being, and productivity.PM2.5 refers to the particulate matter smaller than 2.5 microns that can be inhaled during respiration. It is gravely dangerous to children when exposed to PM2.5 for a long duration causing respiratory problems like bronchitis and asthma. Schools are unique public buildings as they facilitate a larger number of people in dense areas than other public buildings. With the massive increase in time spent indoors and post-pandemic architecture, the IAQ investigation in school is more important now than ever before.

3.3 IAQ Standards

International standards for indoor air quality can vary from country to country, making it difficult to compare them. The WHO standard is widely accepted internationally, which gives PM2.5 exposure limit of 5µg/m3 annually and 15µg/m3 per day [4] . The exposure limit is 100 g/m3 per hour and 60 g/m3 per day according to the "National Indoor Air Quality Standard and Implementation Guideline 2009". The Kathmandu Valley Air Quality Management Action Plan (KVAQMAP) is a five-year plan proposed by the DoE and approved by the Cabinet of the Nepal Government in 2020. This action plan mentions an allowable PM2.5 exposure limit of 40 µg/m3 per day.

3.4 Site Context

The capital of Nepal, Kathmandu, is a "hotspot" of urban air pollution in South Asia. Its bowl-shaped structure (altitude 1300 m above sea level) with a floor area of 340 sq. km. surrounded by tall mountains provides a unique case study for analyzing pollution trapped by topography and local meteorology [4] .

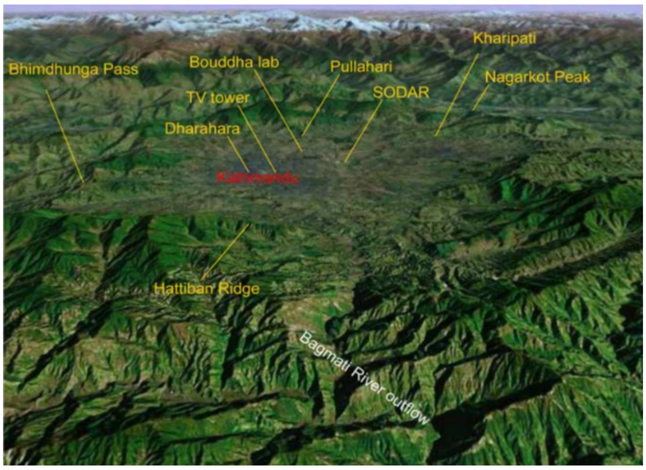

Figure 3: Kathmandu Valley viewed from south in Google Earth.

3.5 Review of research finding

Table 1: Review of research findings

Article	Findings
(Shrestha, S.L. 2012)	In 2004, 193 days passed with 24-hour average P.M. concentrations exceeding the standard. (120 µg/m3) with most of the days falling in winter days in the Valley.
(Mahapatraa, et.al, 2019)	Suggests an increase in pollution load by ~35% during the 1.5 decades of the present study of the valley.
(Ismail, I. F., et. al , 2020)	Total volatile organic compound is higher during winter due to insufficient ventilation. Use of air purifying system and glass surface partition can be helpful.
(Sahabuddin, M.,et.al, 2022)	In buildings with atriums ↑ and light-wells, ↓ there is a substantial difference in PM10 and PM2.5 concentrations.
(Marzouk, M., Atef, M., 2022)	Dominant causes of IAP are lack of indoor ventilation, outdoor environment, building materials, and occupants' behavior
(Y. Xu ,et.al, 2009)	Passive Displacement Ventilation (PDV) system cannot create a clean "microenvironment" as expected.

The majority of days passed with PM2.5 concentration far above the accepted level. [5, 6] suggests a huge increase in pollution levels in upcoming years. TVOC level is higher in winter due to insufficient ventilation and high occupant density [7].

4. Result and Discussion

24 students (14 male and 10 female) participated in the questionnaire survey. The result shows students' perception regarding IAQ, comfort and productivity

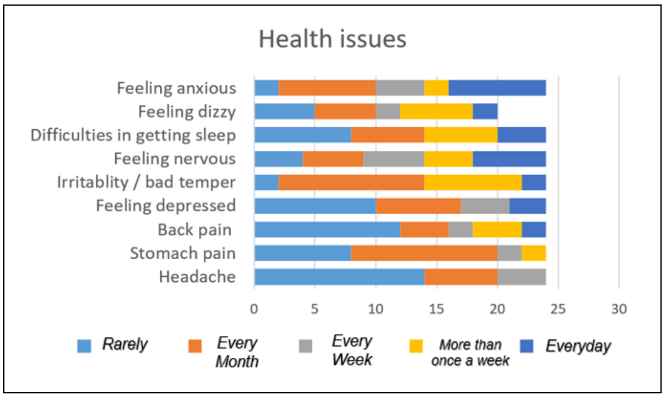

Figure 4: Health issue in last six months of students.

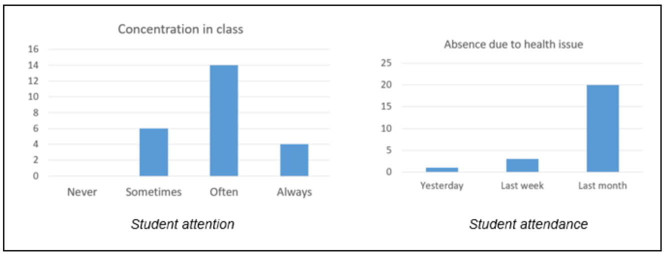

Figure 5: Students' perception using Likert scale

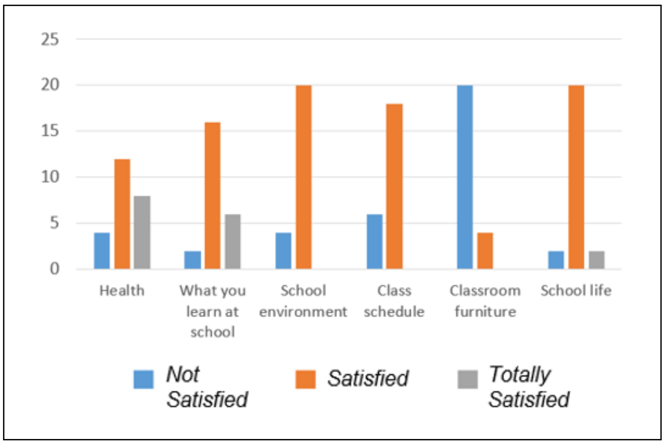

Figure 6: Satisfactory level of students

The graph shows the majority of students are satisfied with the school environment and school life with some complaints regarding classroom furniture. The average PM 2.5 value obtained is 21 ug/m3 per hour, which is more than the WHO standard (15 ug/m3), but lies below the maximum allowable level (40 ug/m3) suggested by KVAQMAP-2020 as shown in the figure below:

Table 2: Comparison of field data with standard guidelines

Parameter	Standard	Average Field data
Temperature	(24 – 28)'C in winter. (21 – 23)'C in summer.	27' C
R.H.	40% to 70 %	68.5%
AQI.US	Good: 51 to 100	65
Overall	Moderate: 51 to 100	59
PM2.5	15 ug/m3 or lower	21 ug/m3
TVOC	Good IAQ < 0.5ppm	0.56 ppm

As the table above shows different parameters of IAQ collected from different schools in Kathmandu Valley with the WHO standard. The time spent indoors is increasing day by day, and awareness regarding IAQ and its potential health damage is critical, especially regarding children from lower-income households studying in government schools.

5. Conclusion

Based on the papers reviewed, concern for the safety and health of students in educational facilities has become crucial as it is noted that they sensitive to pollutants than adults. Student health, performance, productivity, and cognitive processes are all affected by the IAQ of the educational facility. To reduce the effect of air pollution, an air purification system can be installed to achieve better air quality and increase indoor ventilation rates. Parameters, such as temperature and relative humidity, air quality index (AQI), PM2.5, and TVOC were measured. The existing condition of IAQ in the primary school of Kathmandu Valley is moderate condition with ample room for improvement. Different factors such as lighting and acoustic conditions are yet to be explored in the context of Nepal. The findings from such exploration can provide a reference for decision-makers and designers to move to achieve sustainable development with respect to energy, the economy, and the environment.

Acknowledgments

The authors are thankful to Center for Energy Studies (CES) for providing the equipment and all the colleagues who contributed to this research.

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