Indoor Air Quality Improvement in a School Building in Delhi

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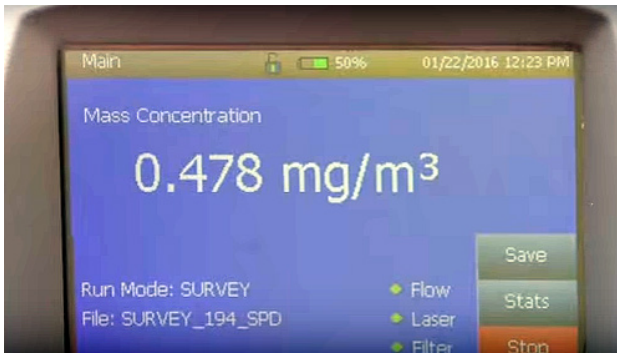
Mrs. Maija Virta is the Founder and Director of Santrupti. She has 30 years of experience in construction and HVAC-industry and she has been in India for the last 5 years. Her key areas of expertise are IEQ, energy efficiency of buildings as well as sustainable building policies and technology. Prior to moving to India, Maija was the CEO of the Green Building Council Finland. Among her various contribution to this field, she has authored many books and publications on sustainable buildings and technology. She has lectured on innumerable topics for ISHRAE, REHVA and ASHRAE. She is the member of ISHRAE IEQ task force preparing the IEQ standard for India as well as the member of IGBC task force that is developing local wellbeing standard.

After the indoor air quality measurements, occupant satisfaction surveys and system performance analysis in March 2014, the target was set to reduce indoor air particulate matter PM2.5 (2.5 µg/m³ and smaller) level to be 70% below ambient air level, to remove traffic emissions (gases) from supply air and improve the cooling in classrooms. Before carrying out this project, the indoor air was as bad as outdoor air or in some cases worse. After finishing the project, the indoor air quality was measured and compared with ambient air measurements. During the first measurement period, ambient air PM2.5 level was 142 µg/m³ and the air in the classrooms 95% less i.e. 7 µg/m³. To monitor this improvement continuously, the school has installed in 2016 the continuous Indoor Air Quality monitors in each classroom, and they now demonstrate continuously the very low particulate matter levels (95–98% reduction of the ambient levels).



Simultaneous indoor and outdoor air PM2.5 measurement result one year after the refurbishment.

Introduction

Millions of people die each year due to air pollution and indoor air pollution is the second highest killer in India. Respirable Suspended Particulate Matter (RSPM) is the main ambient and indoor air pollutant in India[1]. Between 2005 and 2010, the death rate rose by 4% worldwide and by 12% in India. Cost of air pollution to society in 2010 was estimated at US$ 0.5 trillion in India according to a study by the Organization for Economic Co-Operation and Development (OECD)[2]. According Central Pollution Control Board's (CPCB) database[3] that includes RSPM data of 124 Indian

1 UNEP Year Book, 2014. Air Pollution: World's Worst Environmental Health Risk.

2 OECD Report, 2014. The Cost of Air Pollution: Health impacts of road transport.

3 CPCB, Environmental Data Bank, Central Pollution Control Board, Government of India.

cities, 123 cities have the PM2.5 annual average level above WHO Air Quality Guideline level (10 µg/m³)[4]. Delhi annual average PM2.5 value was 122 µg/m³. The International Agency for Research on Cancer (IARC) and WHO concluded in 2013 that ultra-fine particulate matter is carcinogenic to humans[5].

In this project, we focused on the indoor air quality improvement in a one of the largest international school campuses in Delhi.

The school campus consists of 10 school buildings and 3 residential buildings. Each building has a mechanical ventilation system with cooling. The typical system consists of an air handling unit (AHU) located inside an air handling unit room. The air handling unit is supplying the cooled air into the classrooms or apartments via ducts. The return air path is a ceiling void and corridors. Fresh air intake is via a duct from the façade into the air handling unit room. Outdoor air volume is controlled by a damper at the end of the duct. Some of the classrooms and apartments have e additional fan coil units for local cooling. All air handling units had either EU2 or EU4 filters.

School campus in Delhi.

The school wanted to address increased concerns with indoor air quality (IAQ) as it is related to staff and student health. But it was not clear for the school what all need to be done to ensure good air quality inside the buildings. Room air purifiers had been tested but the air quality results were not good and, also, the high maintenance was an issue. Lots of plants had already been located in school premises to purify air, but mechanical ventilation system had not been addressed.

4 WHO, 2005, Air Quality Guidelines.

5 IARC and WHO, 2013. Outdoor air pollution a leading environmental cause of cancer deaths, press release no. 221.

User satisfaction results before refurbishment.

Indoor Air Quality was studied thoroughly in School Campus

To improve indoor air quality (IAQ) in school campus, we first had to understand the current performance of ventilation systems in each building, the current maintenance practices and the current IAQ & user satisfaction. In the second phase the recommended solution was designed and piloted in one of the buildings and then later the same concept with some improvements were executed in all buildings at the campus.

During the 'Indoor Air Quality and Ventilation System Performance Study' we reviewed all buildings in the school campus. We studied the maintenance practices, we conducted the user satisfaction survey, we measured the indoor air quality (IAQ) parameters in various locations in each building and we studied the ventilation system operation.

The User Satisfaction Survey consisted on three major elements: perceived indoor environmental quality (based on the CBE Berkeley questionnaire), users' awareness of air quality problems in Delhi and user's Building Related Health Symptoms (based on the Orebro MM40 questionnaire). We covered the following areas: Thermal comfort, Indoor air quality, Lighting and daylight, Acoustic conditions and Cleanliness. Survey results shows that the Indoor Air Quality (60% dissatisfied) and Thermal Comfort (40% dissatisfied) are the two major areas creating dissatisfaction among the users.

The only symptom that stands out is coughing which may be due to the high level of particulates and irritants in the respiratory system.

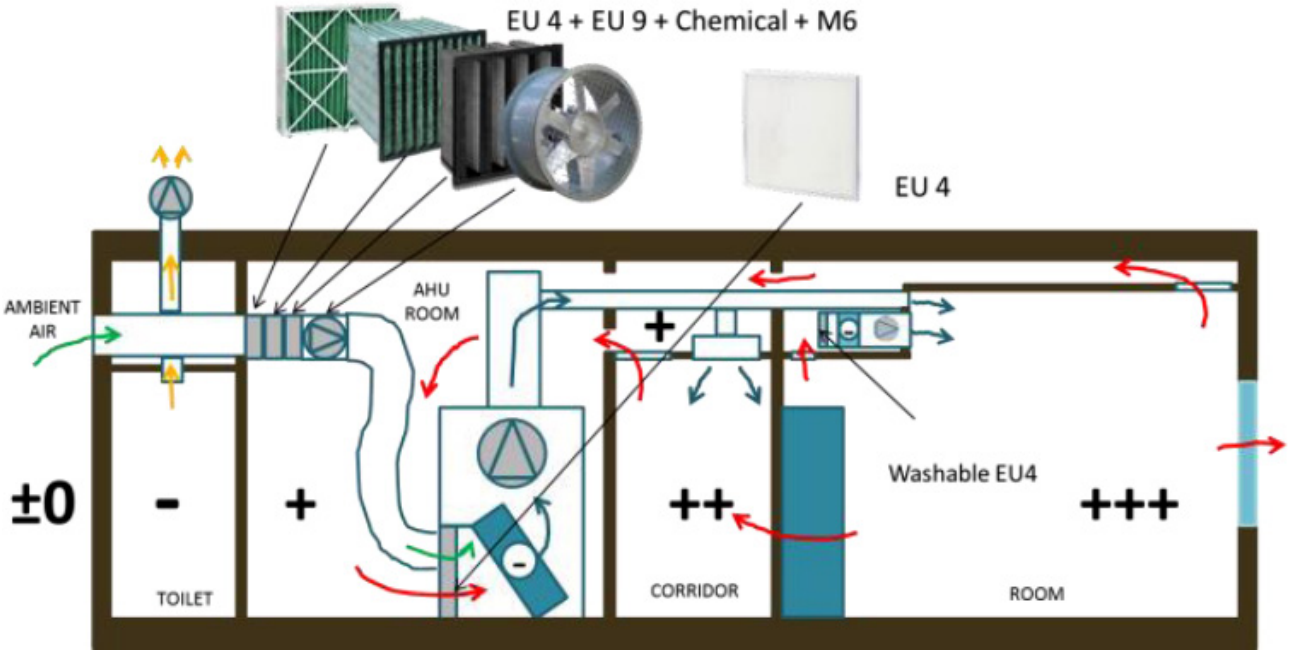
We measured temperature, relative humidity, CO_2 and particulate matter in several locations in each building. Temperature was mainly comfortable in all those spaces, where either fan coil units were operating or ventilation was properly functioning. High temperature and CO_2 were problems in the rooms where there was no sufficient ventilation. Relative humidity was mainly below 65%, however during the measurements the outdoor air was very dry. The biggest IAQ problem were the high ultra-fine particulate matter (PM2.5) levels. They were very high everywhere, sometimes even higher than in the outdoor air, especially near the doors and in the spaces with several printers and copy machines. The PM5 levels were between 100 and 200 µg/m³ during the measurement both in indoor air and outdoor air.

Ventilation System Performance Audit

During the ventilation system performance review, we measured air flow rates in each air handling unit and pressure loss across each component (filters, cooling coil and fan). Air flow rates in all air handling units were below design value. The current filtration G3+G4 was not sufficient to remove RSPM. The pressure loss across the filter section was very low, about 40–100 Pa only, indicating the poor quality of current G4 filters. This was confirmed with visual inspection – there were lots of damaged filters and due to the regular washing, the filter media had worn out.

Recommendations to improve IAQ

To improve air quality, ambient air and AHU filtration needs to be improved, buildings needs to be properly over-pressurized to avoid ambient air from entering indoors via windows and doors and each room to have the sufficient amount of supply air. Maintenance and operation of ventilation system needs to be improved. HVAC-system components (including AHU rooms) need to be maintained at a high standard. Operation and maintenance personnel need additional training



Proposed Ambient Air Purifier solution to clean the outdoor air before it is supplied to the AHU room.

to better manage the operation of ventilation and air conditioning system in each building. Regular 3rd party inspection of indoor air quality and HVAC-system operation is required.

Ambient Air Purifier is the core of the IAQ solution

The main target was to reduce indoor air particulate matter PM2.5 level to be 70% below ambient air level. Simultaneously, traffic emissions (NO_2, SO_2, O_3) shall be removed from the supply air and cooling capacity needs to be improved in classrooms by ensuring correct ventilation rates and balancing the ductwork properly.

The selected solution consists of retrofitting an ambient air purifier into each AHU room, repairing and cleaning the ventilation system, balancing the ductwork and improving the system maintenance. Ambient Air Purifier (AAP) is a fan-filter unit that cleans the outdoor air before it is supplied into the AHU room. The fresh air supply of each unit was designed at 1.5 l/s,m² (which equals 15% of the total air handling unit air volume), which gives the air exchange efficiency of 2 air changes per hour. Each unit has a place for five filters: washable G4 filter, M5 coarse filter, F9 fine filter, chemical filter and M6 post-chemical filter. This unit shall give the filtration efficiency that is more than 99% for PM2.5, 100% for PM10 and remove gases from outdoor air.

The ventilation system required lots of small repairs and maintenance activities. All air handling unit rooms were cleaned and sealed properly. New G4 filters were installed to all air handling units. Some ductwork modifications were done. All loose mineral wool surfaces were covered inside the air handling units and ducts. Ducts and diffusers were cleaned. After installing the Ambient Air Purifier units, some new balancing dampers were installed and all ductworks were balanced in order to have sufficient ventilation and to maintain positive pressure in all classrooms against outdoor air and other spaces.

Independent third-party validation proved the results

After the pilot project the indoor air quality was measured and compared with ambient air quality as the target was set relative to that. During the measurement period, the ambient air PM2.5 level was 142 µg/m³ and in the classrooms 7 µg/m³. This is 95% less than ambient air level. Also, SO_2, NOx and O_3 levels were below detectable limit.

This case study shows that indoor air quality can be improved a lot even in the most polluted cities in the world by designing and maintaining the ventilation system properly and that standalone, high maintenance requiring room air purifiers are not necessary. In this case, the ambient air purifiers were installed, but the same result in terms of IAQ could have been achieved by retrofitting existing air handling units with similar set of filters and new EC fans. However, this would have meant higher filtration and energy cost, as the improved filtration would have been needed for the total air volume. Now the higher-pressure loss impacts only 15% of the air and also the number of filters to be changed annually is less. This case study proves, that as long as the main pollution source is the outdoor air, good IAQ can be achieved by just properly cleaning the outdoor air before supplying it into a building. ■