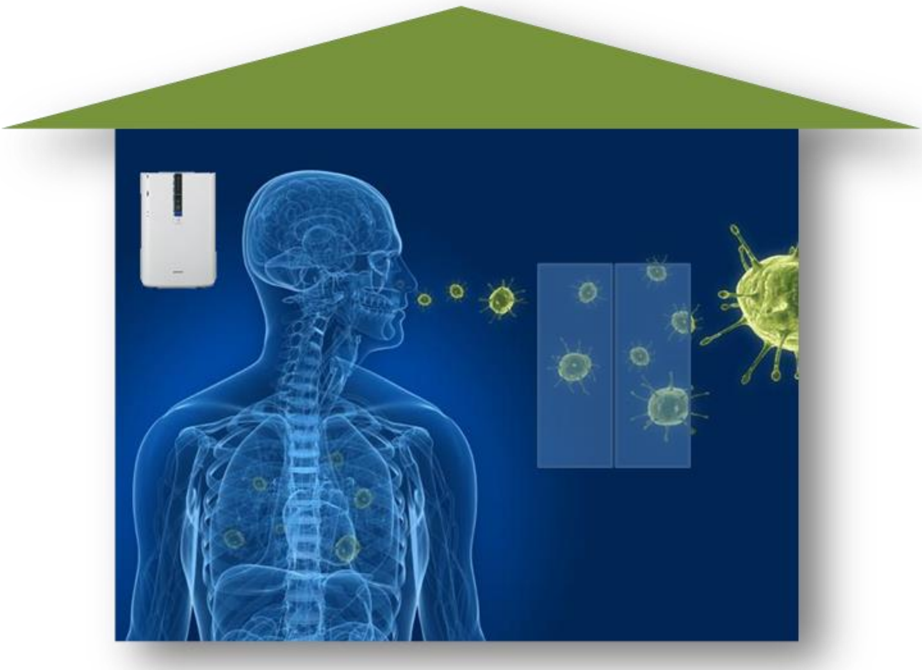
Final Report
Project Code 2016BG04

Studies on Air Purifier Investigation for improvement of IAQ

Prepared for
Sharp Business Systems (India) Pvt. Ltd.



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Suggested format for citation

T E R I. 2017
Studies on Air Purifier Investigation for improvement of IAQ
Bangalore: The Energy and Resources Institute. 15 pp.
[Project Report No.2016BG04]

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Studies on Air Purifier Investigation on Improvement of IAQ

1. Background

Indoor air quality is an area of increasing concern not only in rural households burning biomass fuel but also in urban buildings as it impacts the health, comfort, wellbeing, and productivity of building occupants. While most people are aware of the threat posed by outdoor air pollution, few realize that inside homes, schools and offices one can be exposed to two to five times as many pollutants as outdoors (U.S Environmental Protection Agency). These levels of indoor air pollutants may be of particular concern because most people spend about 90% of their time in indoors and many spend most of their working hours in an office environment.

Pollutants in our indoor environment can increase the risk of illness. Indoor air pollution has been ranked as one of the top five environmental risks to public health by the EPA and its Science Advisory Board. While most buildings do not have severe indoor air quality problems, even well-run buildings can sometimes experience episodes of poor indoor air quality. Windows that could not be opened became a common part of building design. In recent years, the increasing concern regarding IAQ has come primarily from the widespread use of mechanical ventilation and air-conditioning in modern buildings, with limited direct ventilation through open windows.

Because of inadequate ventilation to the outside, the air pollutants inside the buildings are neither diluted nor removed. The results can range from nose, eye and throat irritation and aggravation of asthma to an increased risk of lung cancer. With this growing concern on indoor air pollution, SHARP, a Japanese based electronics company developed plasma cluster health technology generating positive and negative ions similar to which occur in nature, in order to improve indoor air quality and health of occupants. The Positive & Negative Ions when released from the Sharp Air Purifier travels to each and every corners of the room and while they come in contact with the allergens and pathogens, combine together on the surface of the pathogens to create Hydroxyl (OH) momentarily which has a very high oxidizing abilities breaks the DNA of the pathogen thus pulling out the Hydrogen protein. This Hydrogen then combines with the Hydroxyl (OH) instantly and converts into Water Vapour (H2O).This technology suppresses the effects of Virus, mold and fungus in an Indoor environment. This methodology replicates Nature and has been proven through various laboratories across the world. It was tested also using global lab practices standards and has proven safe for skin and eye

Sharp Business Systems India Private Limited approached TERI to assess the performance of their Air Purifiers with Plasmacluster Ion Technology in three different types of locations located in two major tropical cities in India, namely Bangalore & Delhi. The Energy and Resources Institute (TERI) partnered to submit the proposal for undertaking this study for Sharp to see the impact of Air Purifiers in improving indoor air quality with special focus on Particulate Matter (PM) and Gaseous substances.

2. Objectives

The specific objective of the proposed study is to assess the efficacy of SHARP air purifiers with respect to their capacity to capture particulate matter of different size ranges (PM_{10}, $PM_{2.5}$ and PM_1), Carbon monoxide (CO), Carbon dioxide (CO_2), Ammonia (NH_3), Nitrogen dioxide (NO_2) and Formaldehyde (HCHO).

3. Materials and methods

Study area

Two major tropical cities in India namely Delhi and Bangalore having different climate characteristics were selected for the study. In each city, three different types of buildings were selected for impact assessments which are:

1. Centralized air conditioned office building
2. Naturally ventilated office building with individual AC's for conditioning of air
3. Air conditioned Residential building

In each building, locations were selected based on the size and representativeness of the rooms as suggested by SHARP. Monitoring was carried out during the period Feb-Mar 2017 and the indoor air quality assessments were carried out simultaneously in both Delhi and Bangalore. Measurements in all the locations were carried out in real world conditions and not in a controlled environment, with opening and closing of the doors of the rooms, as and when required. This means that no extra care has been given to maintain the air leakage in the rooms in order to achieve the maximum performance of air purifiers as specified by SHARP. However, we have taken good care on not to open the door unless and until it is that much required. Also the doors and windows in all the rooms, except that of the residential building, are made of glass.

Indoor air quality monitoring and assessment

Indoor air quality monitoring was carried out for the following parameters at all the selected locations with and without air purifier in both the cities

- Respirable suspended particulate matter less than 10µm (RSPM/PM_{10})
- Fine particulate matter less than 2.5 µm ($PM_{2.5}$)
- Fine particulate less than 1 µm (PM_1)
- CO (Carbon monoxide)
- CO_2 (Carbon dioxide)
- Ammonia (NH_3)
- Nitrogen dioxide (NO_2)
- Formaldehyde (HCHO)

GRIMM Aerosol Spectrometer was used for the measurement of PM_{10}, $PM_{2.5}$ andPM_1 in indoors.CO, CO_2, Temperature and Relative Humidity (RH) were measured simultaneously using a portable Q-track monitor (TSI make, USA). For gaseous pollutants like NH_3, NO_2 and HCHO, air is allowed to bubble through a suitable absorbing solution using a handy sampler which was further analysed by wet chemical methods. The summary of the sampling and monitoring techniques is given in Table 1.

Table 1: Summary of sampling and monitoring technique

Pollutant	Sampling and measurement Techniques
PM_{10},$PM_{2.5}$ and PM_1	GRIMM Aerosol Spectrometer
CO, CO_2, temperature and RH	Q-track, TSI instrument
HCHO, NO_2 and NH_3	Absorption and analysis by wet chemical methods

The methods followed were strictly in accordance with the guidelines laid down by Central Pollution Control Board (CPCB) and Bureau of Indian Standards (BIS) wherever applicable. Sharp Air Purifier model FP-F40E was used in this study for impact evaluation. The Plasmacluster Ion technology works by generating Positive and Negative Ions by breaking water vapour in the atmosphere which through the fan mechanism is pushed out of the Purifier and spreads into the room. The role of Sharp thus ends here and Nature takes over. These Ions then react with the pathogens to create Water vapour which combines with the indoor atmosphere. Indoor Air quality monitoring was carried for continuous 8 hours at each of the locations and after the installation of air purifiers, monitoring was carried out for five time periods namely, 15 minutes, 30 minutes, 45 minutes, 60 minutes and 90 minutes to assess the impact of air purifiers on indoor air quality over the period of time. Three samples each were collected from each of the selected locations in both the cities before and after the installation of air purifiers. This enabled us to average out the value of the monitored data. Throughout the study period, air purifier was operated at high speed fan mode as suggested by SHARP.

4. Results and discussions

a. Particulate Matter:

The data collected from both the cities were compiled and analysed. The data from same building type of both the locations were averaged out and plotted. The variation in PM10, PM2.5 and PM1 with air purifier monitored for different time periods namely, 15 minutes, 30 minutes, 45 minutes, 60 minutes and 90 minutes are plotted in figure 1, 2 and 3 respectively.

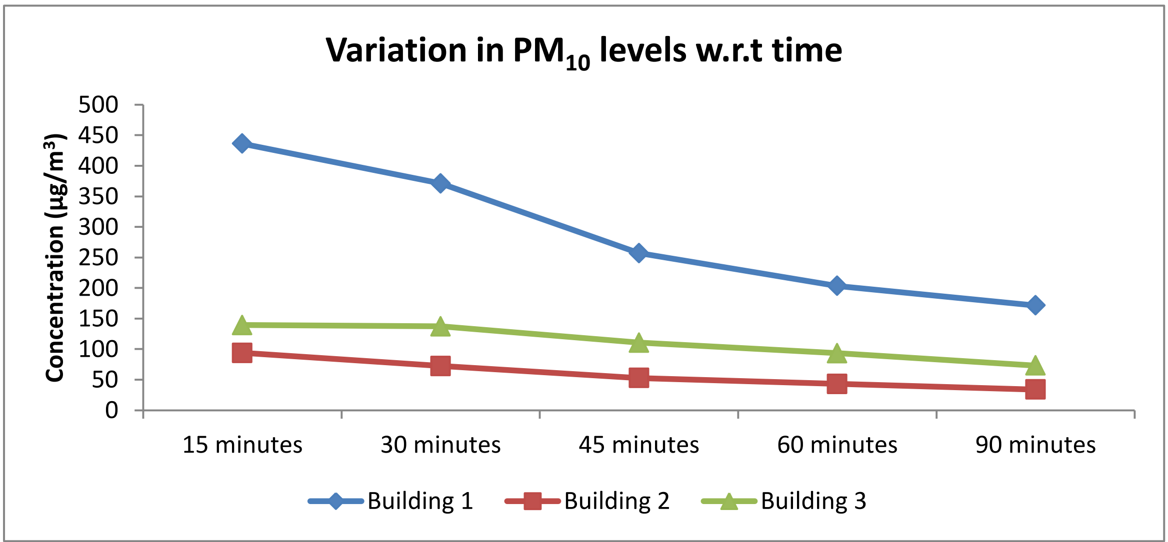

Figure 1: Variation in PM10 with different time intervals

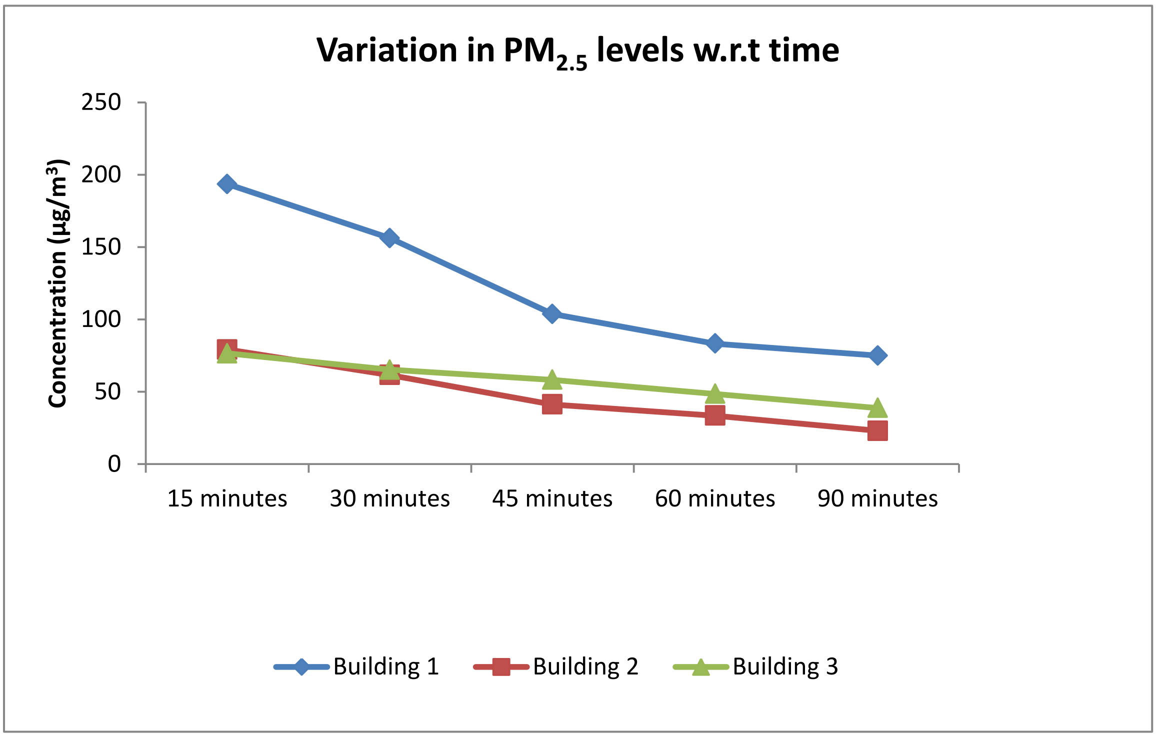

Figure 2: Variation in PM2.5 with different time intervals

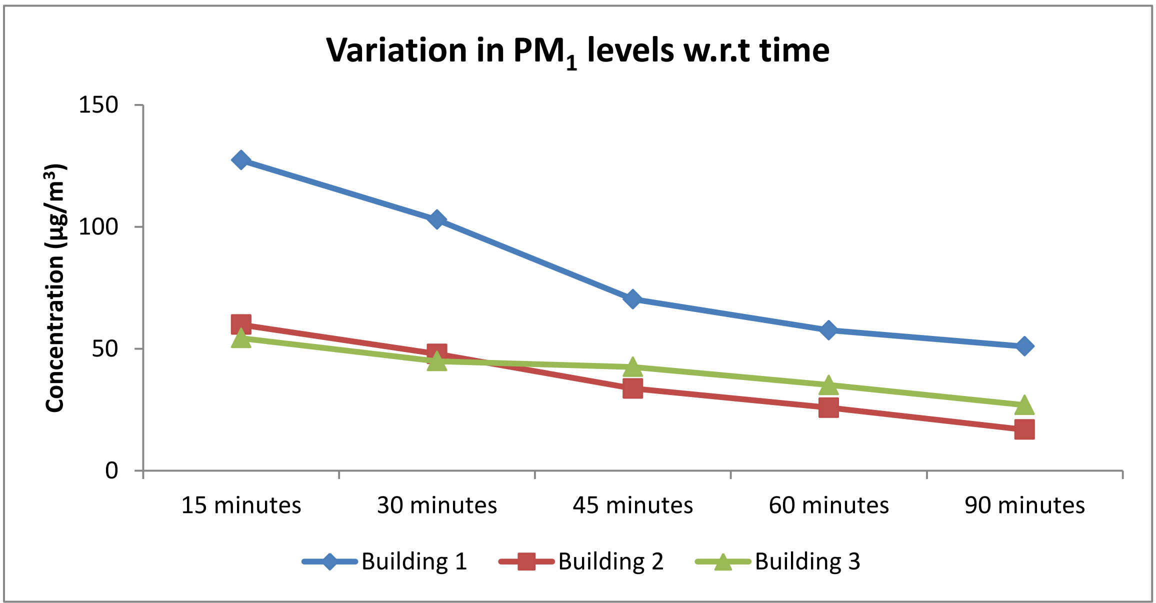

Figure 3: Variation in PM1 with different time intervals

It is evident from figure 1, 2 and 3 that the levels of PM_{10}, $PM_{2.5}$ and PM_1 at all the locations throughout the study period was found to be following a decreasing trend as time elapses which clearly indicates that irrespective of the building type, the performance of the air purifiers improves with time. The 15 minutes average concentration of PM in all the locations was found to be higher followed by 30 minutes, 45 minutes, 60 minutes and 90 minutes. The percentage reduction in PM_{10} (calculated from 15 minutes average and 90 minutes average levels) across the three locations (building 1, building 2 and building 3) varied between 41 and 64 while that of $PM_{2.5}$ ranged from 49-71 and for PM_1 the percentage reduction was found to be in the range 50-72. However more reduction can be achieved by ensuring minimum leakage and avoiding frequent opening of the doors.

The data collected with air purifier was then compared with the background levels (without air purifier) and are shown in figure 4, 5 and 6.

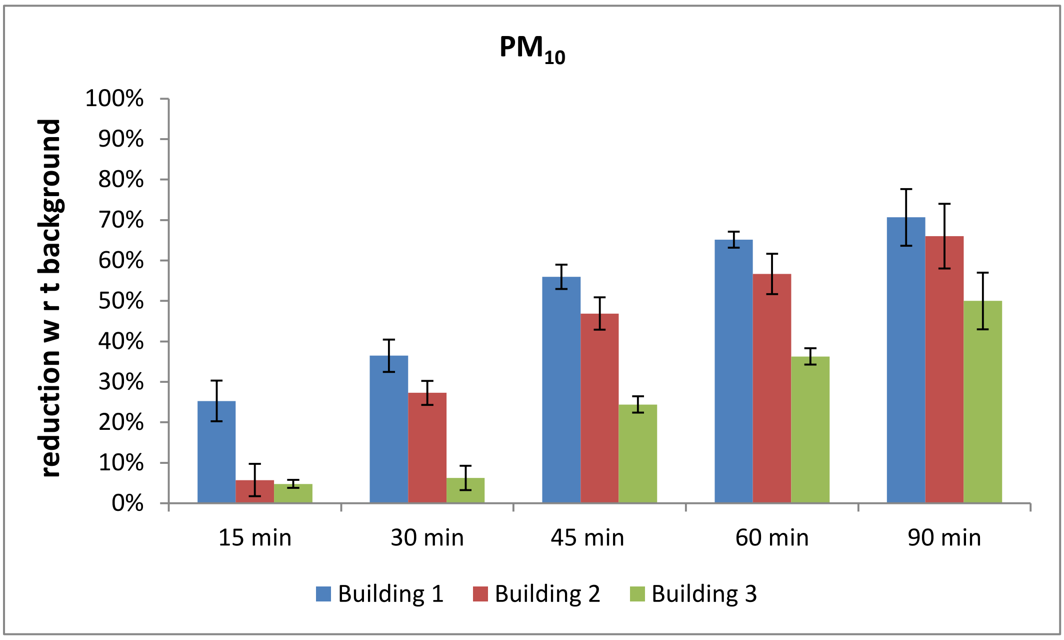

Figure 4: Reduction in PM10 using air purifier as against background levels

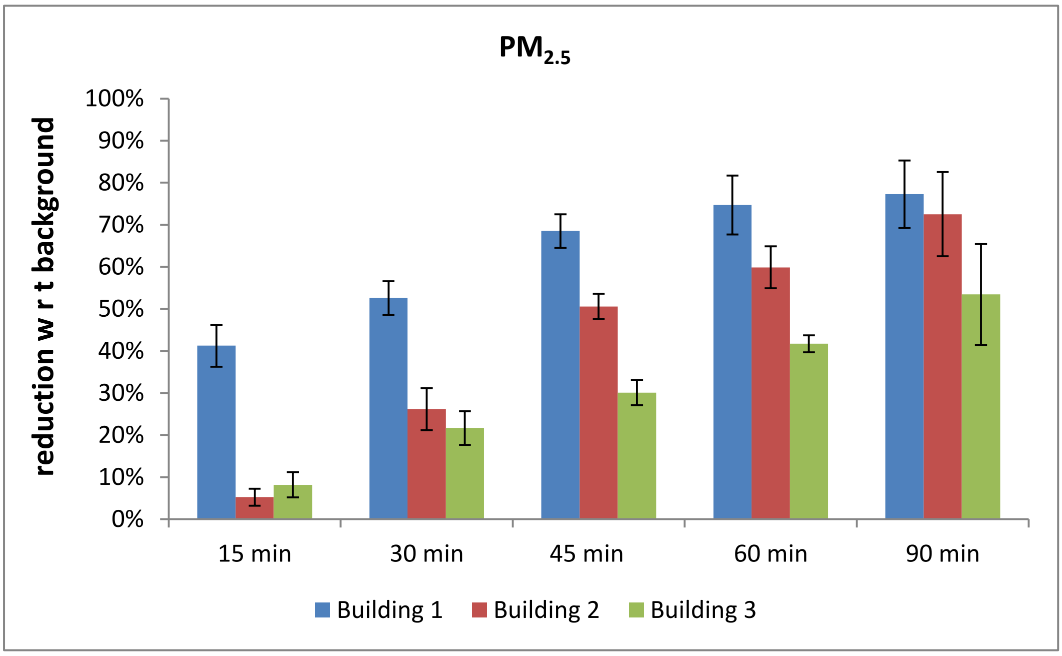

Figure 5: Reduction in PM2.5 using air purifier as against background levels

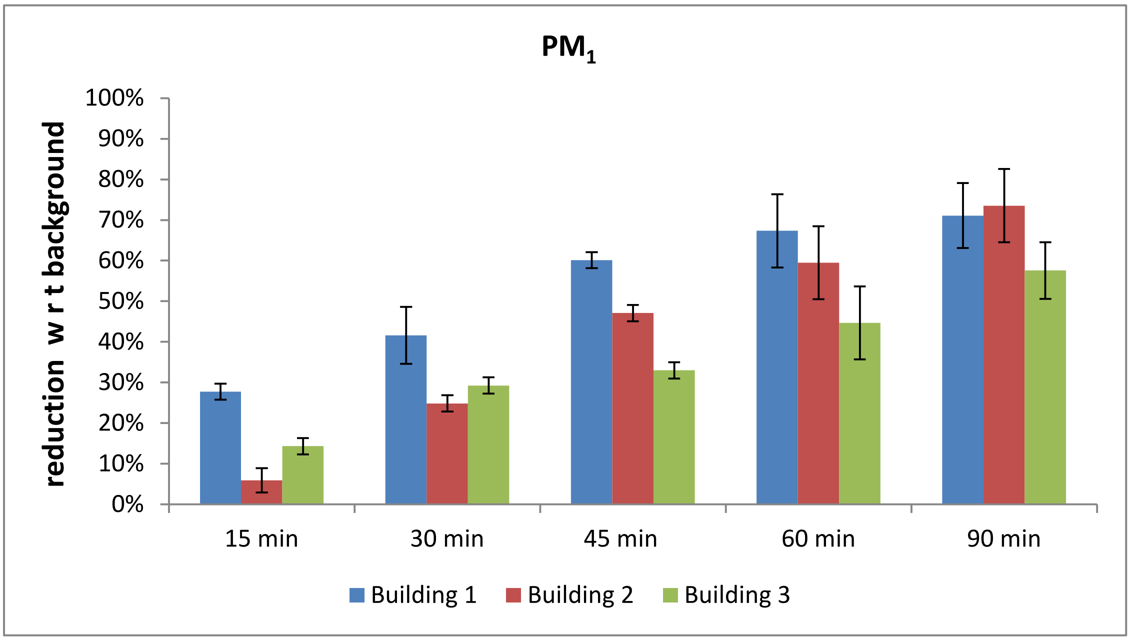

Figure 6: Reduction in PM1 using air purifier as against background levels

It is very much clear from figure 4, 5 and 6 that with the use of air purifiers, the levels of PM (PM_{10}, $PM_{2.5}$ and PM_1) were gradually reducing when compared with the background levels as time elapses and the maximum reduction in all the cases was observed when the air purifier run for 90 minutes. This clearly indicates, irrespective of the building type, the performance of air purifier was found to be improving over time. When the air purifier was run for 90 minutes, the reduction in PM across different locations was found to be in the range 50-71%, 53-77% and 58-74% for PM_{10}, $PM_{2.5}$ and PM_1 respectively. When compared with PM_{10}, finer particles ($PM_{2.5}$ and PM_1) show more reduction.

The overall reduction in PM_{10}, $PM_{2.5}$ and PM_1 with and without the use of air purifiers are plotted in Figure 7, 8 and 9

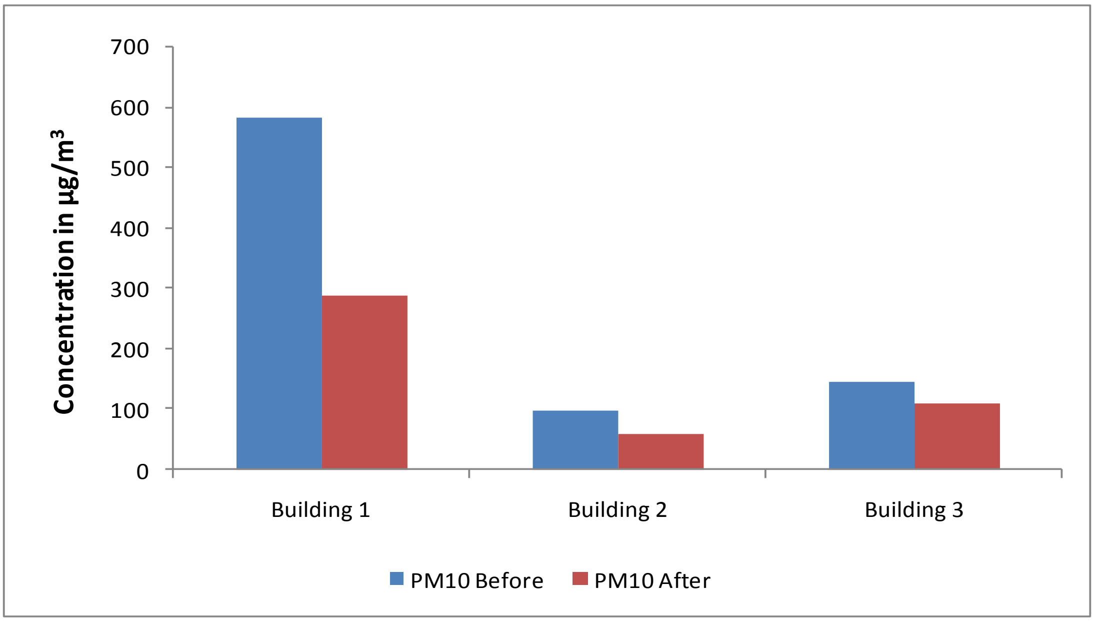

Figure 7: Comparison of PM10 with and without air purifier

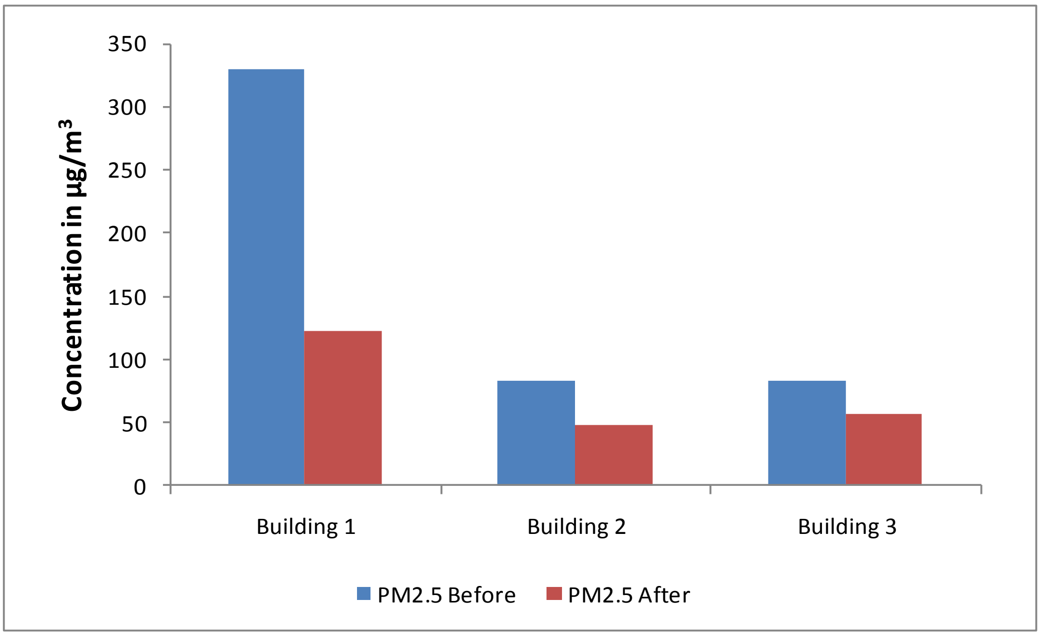

Figure 8: Comparison of PM2.5 with and without air purifier

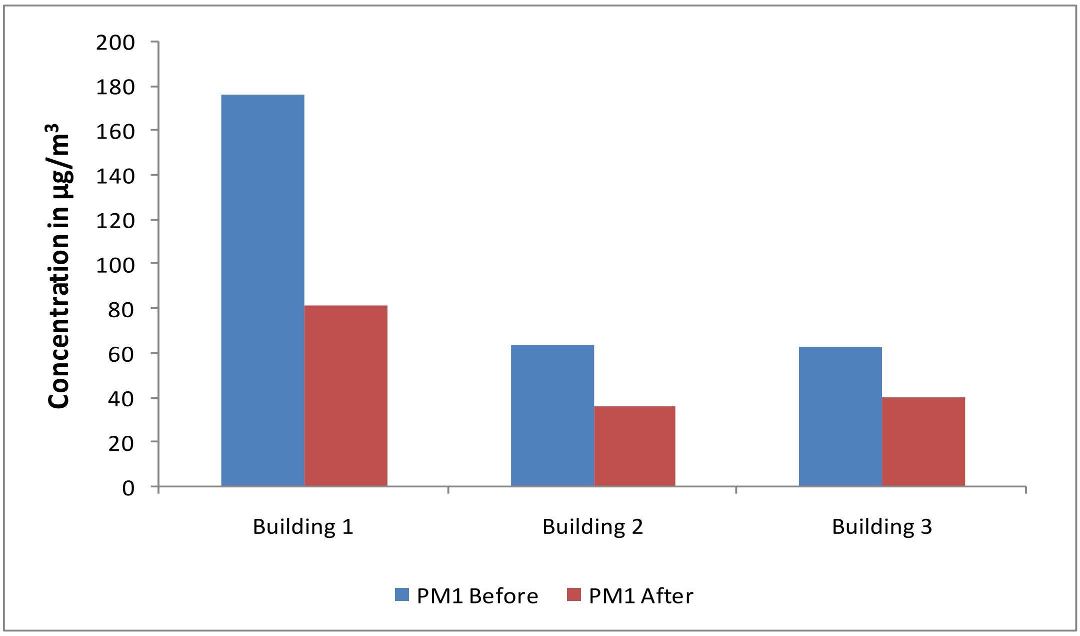

Figure 9: Comparison of PM_1 with and without air purifier

From figure 7, 8 and 9, it is clear that PM_{10}, $PM_{2.5}$ and PM_1 were found to be reduced with the use of air purifier when compared with the background levels. The reduction in PM across different building types varied between 24-51%, 31-63% and 36-54%for PM_{10}, $PM_{2.5}$ and PM_1 respectively. The overall reduction was also found be higher for finer particles namely $PM_{2.5}$ and PM_1.

b. Gaseous parameters:

Carbon monoxide:

Carbon monoxide (CO) is the product of any incomplete combustion. However, CO was not detected in two out of the three monitored locations throughout the study period. The minimum detection limit of the instrument used for measurement of CO was 0.1ppm. The variation in CO at Building 1 is shown in figure 10 and also in table 2.

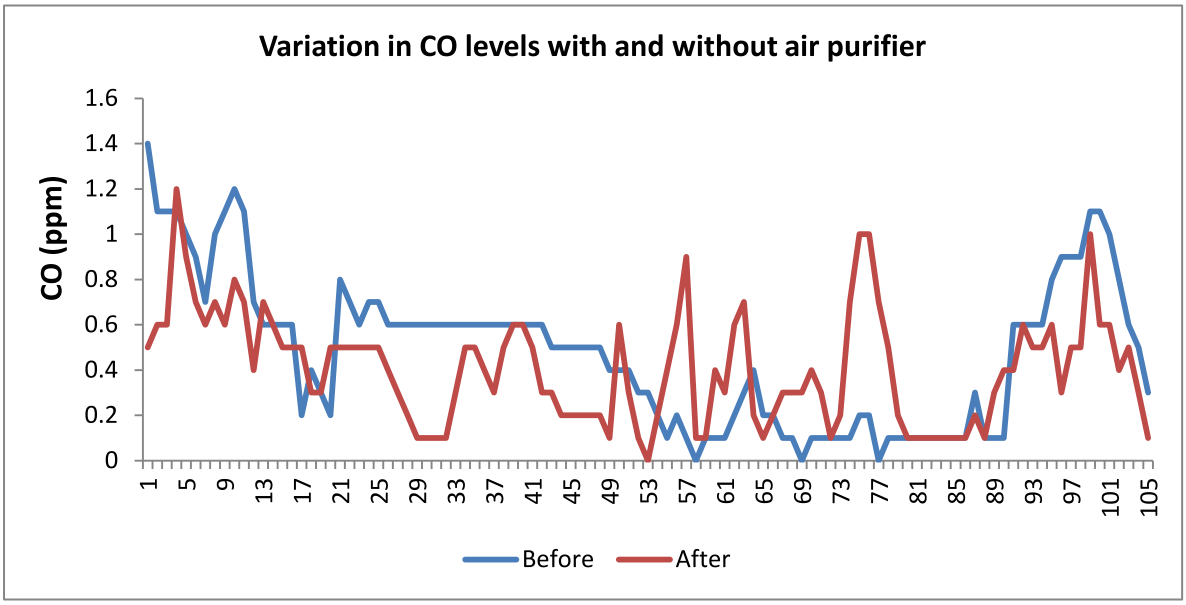

Figure 10: Variation in CO with and without air purifier at Building 1

Table 2: CO levels at different locations with and without air purifier

Location	CO (ppm)		% reduction
	Before	After	
Building 1	0-1.4 (0.48)	0-1.2 (0.41)	15
Building 2	< 0.1	< 0.1	--
Building 3	< 0.1	< 0.1	--

It is clear from table 2 that though building 1 shows a reduction of 15% in CO levels with the use of air purifier. Also, it is obvious from figure 10 that at most of the points there is a continuous reduction in CO with the use of air purifier. However, this needs to be studied further with simulation to confirm the findings because the levels of CO in indoor is already very low.

CO_2:

CO_2 detected at different locations with and without air purifier is shown in table 3

Table 3: CO2 levels at different locations with and without air purifier

Location	CO_2 (ppm)		% reduction
	Before	After	
Building 1	450-780 (646)	325-540 (419)	35

Location	CO_2 (ppm)		% reduction
Building 2	511-936 (645)	415-741 (495)	23
Building 3	521-888 (610)	445-698 (429)	30
ASHRAE Standard	1000		

Table 3 shows that the levels of CO_2 at different locations were reduced with the use of air purifiers and the percentage reduction in CO_2 across different building types varied between 23 and 35. However, in the absence of air purifier as well, the levels at all the measured locations were found to be well within the ASHRAE standard of 1000ppm.

NO_2 & HCHO

NO_2 and HCHCO levels across various locations with and without air purifier are shown in table 4 and 5 respectively.

Table 4: Levels of NO_2 at different locations

Location	NO_2 ($\mu g/m^3$)		% reduction
	Before	After	
Building 1	9-12 (11)	N D - 14 (9)	18
Building 2	6-13 (9)	N D - 14 (10)	--
Building 3	8-10 (10)	N D -14 (10)	--

ND – Not Detected

Though traces of NO_2 were found at all the locations throughout the study period, different buildings showed different trends for NO_2. However, at building 1 there is a reduction of about 18% in NO_2 level with the use of air purifier.

Table 5 shows that HCHO was detected at all the locations during the entire period of monitoring. The average HCHO levels without air purifier across different locations varied between 7-9 ppm whereas the corresponding levels across various monitored locations with air purifier ranged between 6-13 ppm.

Table 5: Levels of HCHO at various locations

Location	HCHO (ppm)		% reduction
	Before	After	
Building 1	4-9 (7)	N D-13 (7)	--
Building 2	8-10 (8)	7-15 (13)	--
Building 3	8-10 (9)	1-9 (6)	33

N D – Not Detected

There is no variation in HCHO levels with the use of air purifier in building 1 however building 3 showed a reduction of about 33% in the concentration of HCHO when compared with corresponding levels without air purifier.

NH_3:

Table 6: NH_3 levels at various locations

Location	NH_3 ($\mu g/m^3$)		% reduction
	Before	After	
Building 1	3-4 (3)	N D - 6 (4)	--
Building 2	1-4 (2)	N D - 3 (2)	--
Building 3	4-6 (6)	N D - 11 (6)	--

N D – Not Detected

Levels of NH_3 at various locations monitored with and without air purifier is shown in table 6. It is evident from table 6 that the levels are very low that one cannot arrive at a conclusion on the impact of air purifier on the NH_3 concentration.

5. Conclusions

The result of the impact evaluation of SHARP air purifier carried out at different locations in both the cities indicated that the particulate matter levels (irrespective of size range) were found to be reduced drastically with the use of SHARP air purifiers. However, more reduction can be achieved in a controlled environment by ensuring minimum leakage asleakages from the ambient air into the building have been identified as one of the sources of indoor air pollution. This may happen due to inadvertent structural defects and/or infiltration from open sources of outside air. Also the observations indicated that finer particles have more reduction with the use of air purifiers. It is a well-established fact that fine particulates can play a role in causing serious illness and death because they are small enough to be inhaled deep into the lungs. Therefore use of air purifiers in the long run may reduce the short term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose, shortness of breath, etc. **This may leads to improved lung function and medical conditions such as asthma and heart diseases.**

Gaseous pollutants in terms of the monitored parameters also showed an overall reduction of 15%, 23-35%, 18% and 33% for CO, CO_2, NO_2 and HCHO respectively with the use of air purifiers. Though studies showing the association of gaseous air pollutants on asthma are scarce in India and abroad, there are few studies which showed that exposure to NO_2 have significant and positive association with asthma hospitalization. Therefore use of air purifier in the long run may reduce the gaseous pollutants like NO_2 substantially which in turn may improve the respiratory health of the occupants. However, more scientific studies are required to validate the positive associations between CO, HCHO, O_3 and asthma hospitalization.

Sustainable Building Science

One of the prime areas of activity within the Energy Environment Technology division is adoption of efficient and environment-friendly technologies in new and existing buildings. The activities of this area focus primarily on energy and resource use optimization in existing buildings and design of energy efficient sustainable habitats.

The Centre for Research on Sustainable Building Science (CRSBS) comprising architects , planners, engineers , environmental specialists , specialised in urban and rural planning, low energy architecture and electro-mechanical systems, water and waste management and renewable energy systems has been offering environmental design solutions for habitat and buildings of various complexities and functions for nearly two decades. The group also undertakes LEED facilitation for buildings.

The Green Rating for Integrated Habitat Assessment (GRIHA) cell, also comprising professionals from the above-mentioned fields is actively involved in facilitation of green rating for buildings under the GRIHA framework. Inputs from CRSBS feed into the processes undertaken at GRIHA cell. The different services offered by the Sustainable Building Science (CRSBS and GRIHA) are as follows:

Environmental design consultancy

- Specialised environmental design consultancy and building performance analysis are conducted. A wide range of computations and simulation tools including DOE2, TRNSYS, ECOTECT, RADIANCE, FLOVENT, AGI32, LUMEN DESIGNER, BLAST, Phoenics, RETScreen are used to assess the environmental and cost impact of the design decisions.

LEED and GRIHA facilitation

- The team has experience in technically facilitating LEED accreditation [LEED India for New Construction (LEED India NC) and LEED India for Core and Shell (LEED India CS)] for buildings. The group also assists and administers GRIHA, an indigenous green building rating system for buildings, developed at TERI. GRIHA has now been now endorsed by the Ministry of New and Renewable Energy, Government of India, as the national building rating system for India.

Energy audits and energy management programs

- Energy conservation studies for a large number of buildings are conducted. There exists a vast experience in conducting energy audits and evaluating a whole range of building upgrade options including envelope retrofit and system retrofit or changes in operational patterns. In addition to establishing operating efficiency of electrical, HVAC, lighting and thermal systems, recommendations to improve upon the same by suitable retrofit measures or by refinement of operational practices are also offered. The group also has expertise in development of energy management programs for service industries like hotels and the corporate sector.

Capacity building

- Capacity building for architects, building developers and service engineers on issues such as energy efficiency in building envelopes and systems has been undertaken. Over 1000 architects, developers and engineers in the area of green buildings, energy efficiency and sustainability aspects of built environment have been trained through training programmes, refresher courses, seminars and workshops.

Policy inputs

- Several policy initiatives at central and state governments' level towards mainstreaming high performance buildings in India have been successfully completed. Senior members of the group are members of the Committee of experts for development of the Energy Conservation Building Code (ECBC) of India (2007). The manual for environmental clearance of large construction for the Ministry of Environment and Forests, Government of India has also been developed at CRSBS.

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