Effectiveness of Constructed Indoor Air Purifier to Enhance Indoor Air Quality

Vinit J. Kedare, Smruti S. Kharat and Sonal Tawde

Abstract **— Air pollution is one of the most concerned issue worldwide as it affects the population at a time. Indoor air contamination can be due to different forms of allergens, smoke, mold, radon, and other pollutants all negatively impact the health of building occupants. These pollutants can have severe effects on health of individuals up to 10 times worse than the outdoor air pollution due to lack of ventilation. For purification of air an attempt has been made to construct a purifier using filters that can trap the indoor air pollutants. The prepared model is constructed considering the cost and working efficiency for maintaining a healthy indoor environment. The model is based on the filtration of air through compact filters (HEPA filters) that are more efficient than any other filters. To analyze the indoor air quality and the working efficiency of the purifier, certain quantitative analysis of the air micro-flora and the total mass concentration of the indoor dust were conducted at four locations in the premises of B. K. Birla College (Autonomous), Kalyan. Quality of the indoor air before using the Constructed Indoor Air purifier and during the use of purifier was checked. The resulted data showed a decrease in the microbial population as well as reduction in the concentration of dust particles, thus indicating the working efficiency of the constructed purifier.**

Index terms **— Air micro-flora, Dust particles, DustTrack Aerosol Monitor, HEPA filter, Indoor air pollution, Indoor air purifier**.

I. INTRODUCTION

Air pollution may be outlined as the presence of poisonous chemicals or compounds (including those of biological origin) within the air, at levels that may cause a health risk. In an exceedingly broader sense, pollution means the presence of chemicals or compounds within the air that are typically not found in air. These pollutants may lower the quality of the air or cause prejudicial changes to the standard of life. Indoor Air Quality (IAQ) refers to the air quality among and around buildings and structures, particularly because it relates to the health and luxury of building occupants. Majority of population within the developed world have about 90% of their time in indoor atmosphere and up to 60% of the manpower have their routine life in a workplace [1]. Reduced ventilation rates for energy conservation, along with exaggerated use of synthetic materials in buildings, have resulted in higher health complaints from building occupants [2]. The principal sources of indoor air pollution are: Combustion, building materials and bio-aerosols [3]. Whereas radon, asbestos, pesticides, heavy metals, volatile organic matter, environmental tobacco smoke and microorganisms are contributors of major indoor pollutants in developed countries, the combustive materials of biomass fuels contribute most to indoor pollution in developing nations. The pollutants arising from these sources are biological sources, carbon dioxide, carbon monoxide gas, asbestos, formaldehyde & acrolein, radon, environmental tobacco smoke, lead, Dust particles containing material of various particle sizes (i.e., PM1, PM2.5, PM10 & respirable particles with diameter less than 1 micron) etc. Fortunately, it is very rare that infections are caused by inhaling airborne mold, spores or bacteria present in the indoor air. These bacterial populations found in the indoor air environment can be from various sources like gases and air borne particulates, pets' dander, humans skin flakes and decomposed hair, dust mites, carpeting and furniture that produce enzymes and micrometer- sized fecal droppings, inhabitants emit methane, molds, and spores. Household plants or surrounding gardens or barren lands can produce pollen, dust, and molds. The presence of PM (Particulate Matter) poses a lot of danger to human health than that of ground-level ozone and/or different other common air pollutants (like carbon monoxide). It is detected that the chemical constituents of PM are diverse enough to incorporate nitrates; sulfates; elemental and organic carbon; organic compounds (e.g., polycyclic aromatic hydrocarbons); biological compounds (e.g., endotoxin, cell fragments); and metals (e.g., iron, copper, nickel, zinc, and vanadium) [4]. Exposure to PM has been known to cause various health effects as well as exaggerated hospital admissions, casualty room visits, respiratory symptoms, exacerbation of chronic pulmonary and vascular diseases, decreased respiratory organ functioning, and premature mortality [5]-[8]. Thus, PM becomes a very important polluting factor for examining the air quality. The impact of these air pollutants on humans depends on their toxicity, concentration, and exposure time, and can vary from person to person. Understanding and managing the common pollutants inside a room will facilitate to cut back the risk of indoor health considerations.

Health effects from indoor air pollutants can be witnessed shortly on exposure or, possibly, years later. This impact can be immediate effect (such as irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue, such effects are typically short-run and treatable) or long-lasting effect (including some pulmonary diseases, cardiological diseases and cancer, which may be severely harmful or fatal).

Published on December 16, 2020.
Vinit J. Kedare, Student, B.K. Birla College of Arts, Science & Commerce (Autonomous), Kalyan, India. Affiliated to University of Mumbai.
(e-mail: vkworld96@gmail.com)
Smruti S. Kharat, Student, B.K. Birla College of Arts, Science & Commerce (Autonomous), Kalyan, India. Affiliated to University of Mumbai.
(e-mail: smrutikharat93@gmail.com)
Dr. Sonal Tawde, Assistant Professor, B.K. Birla College of Arts, Science & Commerce (Autonomous), Kalyan, India. Affiliated to University of Mumbai.
(e-mail: sonal.tawde@bkbirlacollegekalyan.com)

However, some effects like Sick Building Syndrome (SBS) during which folks experience uncomfortable or acute health effects like irritation of nose, eyes and throat, skin ailments, allergies, and so on. The reason for this might be unidentified however, the syndrome may disappear when an affected person leaves the workplace or building. Indoor air quality may be improved and SBS may be reduced once the ventilation rate of the area is improved [9].

In India, out of 0.2 billion population utilize fuel for cooking; 49% use firewood; 8.9% cow dung cake; 1.5% coal, lignite, or charcoal; 2.9% kerosene; 28.6% Liquefied Crude Gas (LPG); 0.1% electricity; 0.4% biogas; and 0.5% the other means. Indoor pollution sources that release gases or particles into the air are the first explanation for indoor air quality issues. Inadequate ventilation will increase indoor pollutant levels by not transferring in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the area. High temperature and humidity levels may also increase concentrations of some pollutants. The indoor air quality should be maintained otherwise, it affects the performance of employees and staff in work environment [10].

We all are exposed to contaminated air; however, the impact depends on several factors like age, immunity, health etc. Nobody is aware about what proportion of contaminated air will they tolerate? The answer to the present downside may be best resolved by being well known or informed. Indoor air quality may be improved by 3 ways: dominant supply, planning ventilation systems to dilute pollutants and exhaust contaminated air, and cleansing air [11]. Thus, use of Indoor Air Purifiers becomes essential because it offers some necessary edges like cleans air, prevents the spreading of germs, removes all odors, safeguards from seasonal allergies slows down dust build up, lessens problems with pets and lessons burden on HVAC (Heating, Ventilation, and Air Conditioning). The constructed indoor air purifier is made utilizing High Efficiency Particulate Air (HEPA) filters as its main component is HEPA.

II. Study Area

The College is spread over 20 acres of land (including B. K. Birla Public School) in the prime location of Kalyan city, Maharashtra, India as described in Fig. 1 and developed as an eco-friendly campus.

TABLE 1: Study Area Description

Study Area	Site Description
Environmental Sciences Laboratory (L-1)	The laboratory is situated on the 4th floor of the IT building. It is occupied with all the lab essentials (Chemicals & Instruments) and is well ventilated.
Library (L-2)	Library is two floored building situated near the IT building. Sampling was performed on the ground floor that is contained with many books, book shelves and lacks ventilation.
Canteen (L-3)	Canteen is situated next to the NR building. It has a playground in its back yard. It is well ventilated but is a crowded place.
Environmental Sciences (EVS) Classroom (L-4)	Classroom is situated on the 4th floor of IT building in front of the EVS lab. It has many benches and bookshelves and is well ventilated

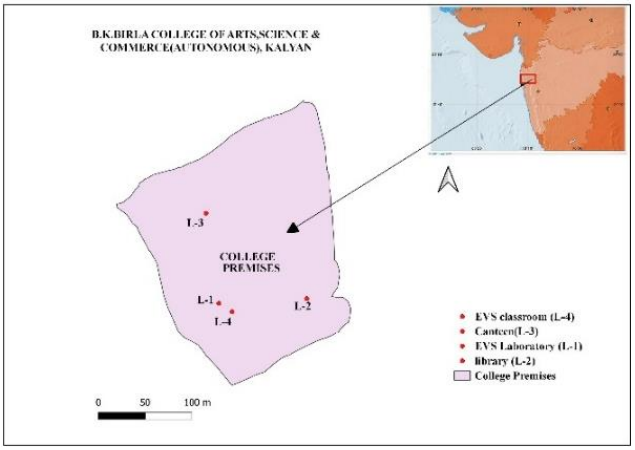


Fig. 1. Study area map.

III. Materials and Method

A. Construction of Indoor Air Purifier

1) Materials Used

a) Framing Material

Sandwich PUF (Polyurethane Foam) sheets and galvanized steel are used as the framing material for the construction of indoor air purifier. PUF sheets have many excellent properties like, It Can withstand wind velocity up to Maximum Level, these shelters are very light in weight, compact and have high structural strength thereby making it possible to create suitable size, does not allow air or water to penetrate through the panels of the shelter. PUF have a thermal conductivity of 0.018 kCal (Kilocalorie) prevents cross heat flow between room & outside ambiance, the galvanized steel does not corrode when exposed to water and also it provides outstanding resistance to mechanical damage with long life expectancy and lower cost than stainless steel.

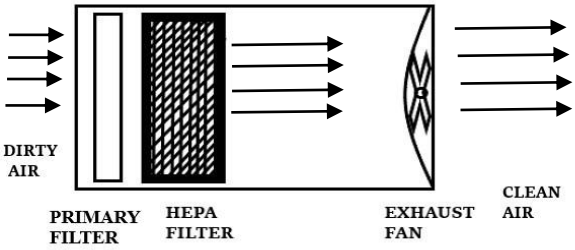


Fig. 2. Schematic diagram of constructed indoor air purifier.

b) Fan

The exhaust fan of 220 Volts power consumption has been used and requires a supply of AC (Alternate Current). This fan is responsible for the suction of air into the purifier.

c) Primary Filter

Primary filter consists of mesh used to extend the life of HEPA filter. Primary filter removes most of the larger dust particles, hair fibers, PM10 and pollen particles from the air.

d) HEPA Filter

The HEPA filter used in the air purifier model is composed of a mesh of randomly arranged fibers. These fibers are typically made of glass and possess diameters in the range of 0.2- 2µm. The air space between these fibers is typically of size that is less than 0.3µm. Thus, enabling the trapping of air microbes.

2) Principle and Working

The constructed air purifier works on the principle of purifying air by the use of high-quality filters. The purification of air occurs in two stages.

i) The first stage includes the filtration process in which the pre-filter, removes most of the larger dust particles, hair fibers, PM10 and pollen particles from the air.

ii) The second stage consists of high-quality HEPA filter which traps the finer particles. Thus, the particles escaped from the pre-filter further passes through & stuck inside the HEPA filter. At last, the pollutants free clean air is expelled through exhaust fan as illustrated in Fig. 2.

B. Estimating the Efficiency of the Constructed Indoor Air Purifier

1) Microbial Analysis and Particulate Matter Analysis

Standard Operating Procedures (SOP) were followed at the sampling sites to monitor the bacterial load by the settle plate method. Wherein, sterilized nutrition mediums agar plates (i.e., Nutrient agar, Potato dextrose agar, Blood agar) were used for sampling in the selected locations. Air was sampled both before purification using the constructed indoor air purifier and after purification in order to check the efficiency of the constructed indoor air purifier. The sampling height that is approximated to human breathing zone was considered 1 m above the floor and at the centre of the room. After sampling of air, the plates were incubated at 37 °C for 24 hrs. and 48 hrs. depending on the type of microbe i.e., fungi, bacteria, and pathogens.

TABLE 2: PARTICULATE MATTER STANDARDS BY ORGANIZATIONS

Particulate Matter (mg/m^3)	Organizations	Standards	References
Total Mass Concentration	OSHA	15 mg/m^3 (Over 8 hours duration)	ANSI/ASHRAE, 2004[21]
	ACGIH	3 mg/m^3 (Ceiling Level)	ANSI/ASHRAE, 2004[21]
	ASHRAE	65 $\mu g/m^3$ (Over 24 hours duration)	Air Dust Cleaners, 2013[21]
	US EPA	65 $\mu g/m^3$ (Over 24 hours duration)	Air Dust Cleaners, 2013[21]
PM2.5	OSHA	5 mg/m^3 (Over 8 hours duration)	ANSI/ASHRAE,2004[21]
	IGBC,2016	< 15 $\mu g/m^3$	IGBC Rating Guidelines' and 'Indoor Environment Quality Standard, ISHRAE Standard - 10001:2016' [20]
	WHO,2006	10 $\mu g/m^3$ (On average)	Bluyssen,2010; Salthammer,2011[21]
	ACGIH	3mg/m^3 (Ceiling Level)	ANSI/ASHRAE, 2004[21]
	US EPA,2004	150 $\mu g/m^3$ (Over 24 hours duration)	ANSI/ASHRAE, 2004[21]
PM10	WHO	50 $\mu g/m^3$ (On average of 24 hours)	Bluyssen, 2010; Salthammer, 2011[21]
	IGBC,2016	< 50 $\mu g/m^3$	IGBC Rating Guidelines' and 'Indoor Environment Quality Standard, ISHRAE Standard - 10001:2016' [20]

After incubation, the number of bacteria carrying particles settling over the area of the plate in a given period of time was recorded. The optimal duration of exposure gives a significant and readily countable number of well isolated colonies, for example about 30-100 colonies. This depends on the dustiness of sampled air.

DustTrak Aerosol Monitor (Model 8534) was used to quantify the particulate matter concentration. The sampling was done before and after purification using constructed indoor air purifier.

IV. RESULT AND DISCUSSION

A. Microbial Analysis

The indoor air microbial load was determined by taking 48 samples of bacteria, pathogens & fungi. The assessment was done by passive air sampling technique. Microbes, pathogens, and fungi were collected on the respective nutrient mediums. To obtain the appropriate surface density for and to determine the load with respect to time of exposure, the sampling times were set at 15 and 30 minutes. After exposure, the samples were incubated at 37 °C for 2 days for fungi and for 24 hrs for bacteria and pathogens.

The results indicated maximum microbial count for bacterial organisms grown on non-selective medium for both sampling periods i.e., before and after purification of air by the purifier. Considering the growth of microbes on selective medium that is the estimation of Colony Forming Unit Per Cubic Meter (CFU/m^3), maximum growth was observed for pathogenic organisms, i.e., (1887931CFU/m^3 for 15 minutes) specifically in location 4, followed by (969828 CFU/m^3, 15 minutes) in location 3. While during/ in post purification for the same sampling period, maximum growth was observed in location 3 (814655 CFU/m^3). A similar observation was made with pathogens being dominant in both pre and post purification (30 minutes), with maximum growth in location 4 (3879310 CFU/m^3) pre-purification followed by location 3(2353448 CFU/m^3). However, post purification the pathogenic growth was observed to be maximum in location 3 (1267241 CFU/m^3). Compared to pathogens, growth of fungi was observed to be less. While sampling for 15 minutes fungi were found to be dominating in location 3 both before (452586 CFU/m^3) and after (168103 CFU/m^3) the use of purifier. Maximum fungal growth was seen in location 4 (1448276 CFU/m^3) before the use of purifier and in location 3 (594828 CFU/m^3) after the use of purification (for 30 mins). All these data (Table 3) showed reduction in the number of microorganisms after the use of constructed indoor air purifier.

Bacteria showed higher growth as compared to slow growing fungi [13], as was also observed from the collected data. The use of air purifiers helps in reduction of microbial pollutants occurring in the indoor environment. Hence, focusing on the need to use an efficient air purifier in the indoor environment [14]. The use of constructed indoor air purifier also caused reduction in microbial enumeration in pre & post purification. The enumeration of the micro-organisms, fungal population was detected to be more than the stated limits [>500 CFU/m^3 as stated by WHO (World Health Organization) & Occupational Safety and Health Administration (OSHA) >1000 CFU/m^3] in all the locations before and after purification of air. Similarly, the bacteria

grown on nutrient medium were detected to be more than the standards in all locations throughout the analysis that is pre purification and post purification; these limits are stated by NIOSH (National Institute for Occupational Safety and Health) & ACGIH (American Conference of Governmental Industrial Hygienist) which is 1000 CFU/m^3 for airborne bacteria and 500 CFU/m^3 for the cultural count of total bacteria. However, it is not possible to present the exposure limits for pathogens as the response of the pathogens varies depending on other factors such as dose response relationship and epidemiological characteristics [14].

TABLE 3: MICROBIAL ANALYSIS

Sampling period		Before		After	
		(15min)	(30min)	(15min)	(30min)
		CFU/m^3	CFU/m^3	CFU/m^3	CFU/m^3
Location 1 (EVS Laboratory)	Bacteria	349138	1939655	38793	362069
	Fungi	90517	1163793	25862	232759
	Pathogens	517241	1112069	219828	6206890
Location 2 (Library)	Bacteria	530172	2974138	168103	646552
	Fungi	181034	1034483	25862	258621
	Pathogens	672414	2689655	155172	672414
Location 3(Canteen)	Bacteria	1448276	5870690	1112069	2482759
	Fungi	452586	1137931	168103	594828
	Pathogens	969828	2353448	814655	1267241
Location 4 (EVS Classroom)	Bacteria	775862	5818966	310345	1318966
	Fungi	284482	1448276	103448	258621
	Pathogens	1887931	3879310	232759	698276

B. Particulate Matter Analysis

The analysis of particulate matter along with its varying particle size was performed in the considered locations as described in Table 1. The total mass concentration of particulate matter was more in location 3 (Canteen) both before (0.981 mg/m^3) and after (0.716 mg/m^3) purification of air whereas minimum in location 1 (Environmental Sciences Laboratory) both pre (0.354 mg/m^3) and post (0.277 mg/m^3) purification. The dominance of PM10 concentration was observed in all the locations with a maximum concentration in location 3 before (0.579 mg/m^3) and after (0.477 mg/m^3) the use of purifier and was found to be minimum in location 1 before (0.216 mg/m^3) and after (0.218mg/m^3) purification. The concentration of PM10 was followed by Respirable particulate matter, PM2.5 and PM1 in all locations. Thus, indicating reduction in the concentration of particulate matter after the use of constructed indoor air purifier (Refer to Table 4).

The Total Mass Concentration for PM2.5 and PM10 were detected to be less than those found by [14] (80.0 µg/m^3 and 45.9 µg/m^3) and the standards given by USEPA (US-Environmental Protection Act), Korean standards and WHO. As per the standards mentioned in the Table 2, the observed values for Total Mass Concentration (TMC), PM2.5 and PM10 were less than the guided standards. However higher concentration of PM10 was detected to be dominant in all the considered locations which can be due to the occupancy of the location by students and their activities like walking, running or playing [16]. The increase in the concentration of particulate matter in Location-3 (Canteen) was evident of the effect of outdoor environment on the Indoor Air Quality (IAQ) [17] since Location-3 is in close proximity with the college playground.

C. Association Between Microbes and Particulate Matter

Pathogenic bacteria are more related to the particle size distribution [18]. Whereas PM10 is the best predictor of bacterial and fungal communities [19]. The data obtained from the study showed the concentration of PM10 to be dominant in the considered locations. Thus, PM10 was correlated with the pathogenic and fungal population, to determine the type of correlation between these pollutants. Also, further the association of microbial population with PM10 was checked (Refer to Fig. 3 & Fig. 4). The microbial species were negatively correlated with the PM10 in the data collected during pre-purification. While positive correlation was seen in post purification. The microbial populations have potential to associate with the dust particles and form aerosols with them. Thus, the microbial load viz., fungi and pathogens were proved to be dependent on PM10 forming linear correlations with PM10. These pollutants were further examined using Regression analysis in order to check the association with each other.

The pathogens were detected to be more relative with PM10 with R^2 value of 0.816, pre-purification and 0.124 post purification. This was found contradictory to the finding done by H. Liu et al.,2018 that stated low relative abundance of pathogens with PM2.5 and Total mass concentration (TSP).

D. Removal Efficiency

A trend of reducing concentration for particulate matter and microbial fauna post purification was witnessed by Hyeon-Ju OH et al., 2014 who further also calculated the removal rate that was 41-68% for PM2.5 and 49-86% for PM10. A similar conclusion was noted in the present study by comparing the pre and post purification data. The removal percentage for the pollutants after the purification of indoor air using constructed indoor purifier was determined the removal percentage for all the pollutants to be 84.80% for pathogens that were associated with PM10 while 80.45% for fungi that were associated with PM10. Hence, proving the constructed indoor purifier is efficient in removing the considered pollutants from the studied region

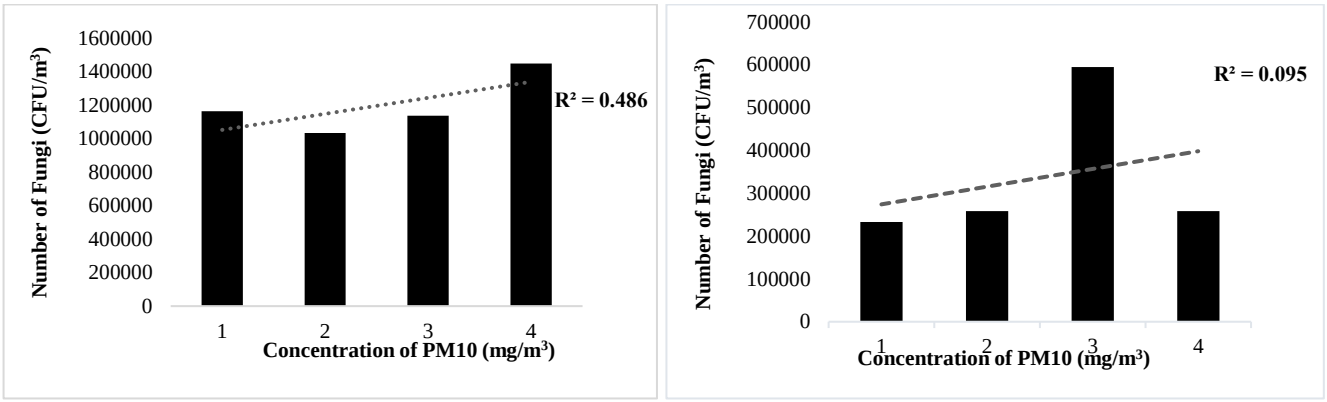
V. CONCLUSION

Construction of indoor air purifier was done successfully. Efficiency of constructed purifier was determined considering pollutants like pathogens, fungi, and particulate matter. The microbial analysis, pathogens were detected to be more then fungi in all the locations before the use of purifier and significantly reduced after the use of purifier. Same applies to particulate matter analysis, the dominance of PM10 in all the locations before the use of purifier was observed to be reduced after the use of purifier that can be due to the presence outdoor dust. The distribution of particulate matter with respect to size was PM10 > Respirable > PM2.5 > PM1. As pathogens and PM10 were determined to be dominant in all locations, correlation between them was checked to be linearly correlated.

Whereas Pathogens were found to be associated with the PM10. Considering the data obtained from the study, removal rate of the pollutants by the constructed indoor air purifier was determined to be 84.80% for pathogens that were associated with PM10 while 80.45% for fungi that were associated with PM10.

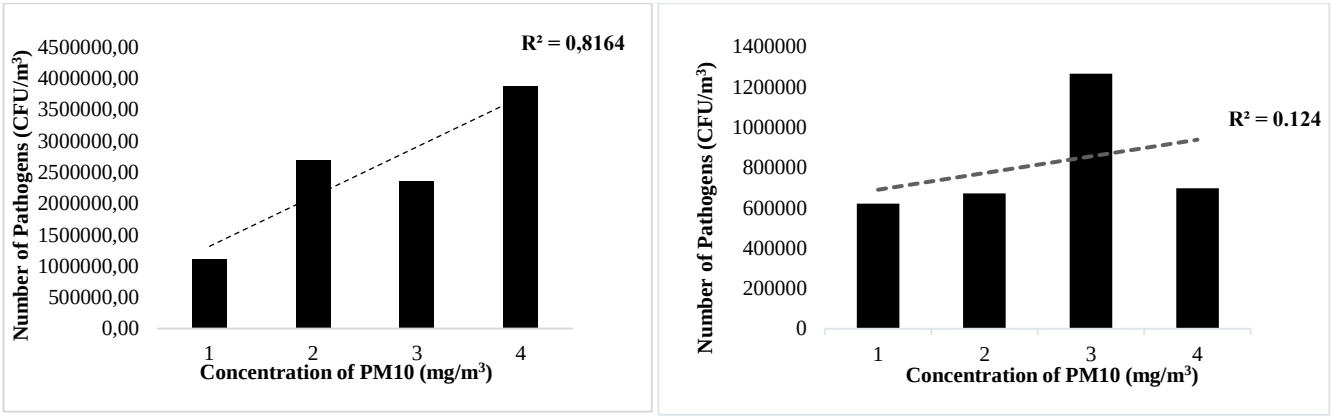
TABLE 4. PARTICULATE MATTER ANALYSIS

Sampling period	Location 1 EVS (Laboratory)		Location 2 (Library)		Location 3 (Canteen)		Location 4 (EVS Classroom)	
Before	PM1	0.216 mg/m^3	PM1	0.217 mg/m^3	PM1	0.23 mg/m^3	PM1	0.211 mg/m^3
	PM2.5	0.22 mg/m^3	PM2.5	0.228 mg/m^3	PM2.5	0.246 mg/m^3	PM2.5	0.218 mg/m^3
	Respirable	0.226 mg/m^3	Respirable	0.251 mg/m^3	Respirable	0.283 mg/m^3	Respirable	0.233 mg/m^3
	PM10	0.27 mg/m^3	PM10	0.4 mg/m^3	PM10	0.579 mg/m^3	PM10	0.33 mg/m^3
After	PM1	0.218 mg/m^3	PM1	0.213 mg/m^3	PM1	0.22 mg/m^3	PM1	0.212 mg/m^3
	PM2.5	0.221 mg/m^3	PM2.5	0.221 mg/m^3	PM2.5	0.233 mg/m^3	PM2.5	0.216 mg/m^3
	Respirable	0.227 mg/m^3	Respirable	0.237 mg/m^3	Respirable	0.268 mg/m^3	Respirable	0.223 mg/m^3
	PM10	0.258 mg/m^3	PM10	0.313 mg/m^3	PM10	0.477 mg/m^3	PM10	0.272 mg/m^3



(a) (b)

Fig. 3. Graphical representation of Fungi and PM10 (a) Before & (b) After.



(a) (b)

Fig. 4. Graphical representation of Pathogens and PM10. (a) Before & (b) After.

ACKNOWLEDGEMENT

The authors would like to thank the Director Dr. Naresh Chandra and Principal Dr. Avinash Patil of B. K. Birla College of Arts, Science & Commerce (Autonomous), Kalyan, Maharashtra, India for providing all required support. The authors would also like to thank Mr. Avick Sil, Regional Director of Enviro Policy Research India Pvt. Ltd. (EPRI), Mumbai, Maharashtra, India for providing DustTrak Aerosol Monitor (Model 8534) for analysis.

REFERENCES

[1] Tsakas, M. P., Siskos, A. P., & Siskos, P. A. (2011). Indoor air pollutants and the impact on human health. *Chemistry, Emission Control, Radioactive Pollution and Indoor Air Quality*, 447-484.

[2] Synnefa, A., Polichronaki, E., Papagiannopoulou, E., Santamouris, M., Mihalakakou, G., Doukas, P., ... & Delakou, A. (2003). An experimental investigation of the indoor air quality in fifteen school buildings in Athens, Greece. *International Journal of Ventilation*, *2*(3), 185-201.

[3] Saiyed, H. N., Patel, T. S., & Gokani, V. N. (2001). Indoor air pollution in India: a major environmental and public health concern. *ICMR Bull*, *31*, 61-69.

[4] World Health Organization. (2013). *Global tuberculosis report 2013*. World Health Organization.

[5] Guaita, R., Pichiule, M., Maté, T., Linares, C., & Díaz, J. (2011). Short-term impact of particulate matter (PM2. 5) on respiratory mortality in Madrid. *International journal of environmental health research*, *21*(4), 260-274.

[6] Halonen, J. I., Lanki, T., Yli-Tuomi, T., Tiittanen, P., Kulmala, M., & Pekkanen, J. (2009). Particulate air pollution and acute cardiorespiratory hospital admissions and mortality among the elderly. *Epidemiology*, 143-153.

[7] Perez, L., Tobías, A., Querol, X., Pey, J., Alastuey, A., Díaz, J., & Sunyer, J. (2012). Saharan dust, particulate matter and cause-specific mortality: a case–crossover study in Barcelona (Spain). *Environment international*, *48*, 150-155.

[8] Samoli, E., Peng, R., Ramsay, T., Pipikou, M., Touloumi, G., Dominici, F., ... & Katsouyanni, K. (2008). Acute effects of ambient particulate matter on mortality in Europe and North America: results from the

APHENA study. *Environmental health perspectives*, *116*(11), 1480-1486.
[9] Wargocki, P., Wyon, D. P., & Fanger, P. O. (2000). Productivity is affected by the air quality in offices. In *Proceedings of Healthy Buildings* (Vol. 1, No. 1, pp. 635-40).
[10] Wyon, D. P. (2004). The effects of indoor air quality on performance and productivity. *Indoor air*, *14*(1), 92-101.
[11] Guo, H., Murray, F., & Lee, S. C. (2003). The development of low volatile organic compound emission house—a case study. *Building and environment*, *38*(12), 1413-1422.
[12] Gupta, A. K. (2007). Modern trends in planning and designing of hospitals: Principles and practice. *Indian Journal of Medical Research*, *126*(2), 167.
[13] Yassin, M. F., & Almouqatea, S. (2010). Assessment of airborne bacteria and fungi in an indoor and outdoor environment. *International journal of environmental science & technology*, *7*(3), 535-544.
[14] Oh, H. J., Nam, I. S., Yun, H., Kim, J., Yang, J., & Sohn, J. R. (2014). Characterization of indoor air quality and efficiency of air purifier in childcare centers, Korea. *Building and environment*, *82*, 203-214.
[15] Goyal, R., Khare, M., & Kumar, P. (2012). Indoor air quality: current status, missing links and future road map for India. *Journal of Civil and Environmental Engineering*, *2*(4), 2-4.
[16] Yang, J., Nam, I., Yun, H., Kim, J., Oh, H. J., Lee, D., & Sohn, J. R. (2015). Characteristics of indoor air quality at urban elementary schools in Seoul, Korea: Assessment of effect of surrounding environments. *Atmospheric Pollution Research*, *6*(6), 1113-1122.
[17] Zhu, S., Cai, W., Yoshino, H., Yanagi, U., Hasegawa, K., Kagi, N., & Chen, M. (2015). Primary pollutants in schoolchildren's homes in Wuhan, China. *Building and Environment*, *93*, 41-53.
[18] Liu, H., Zhang, X., Zhang, H., Yao, X., Zhou, M., Wang, J., & Zheng, P. (2018). Effect of air pollution on the total bacteria and pathogenic bacteria in different sizes of particulate matter. *Environmental pollution*, *233*, 483-493.
[19] Liu, H., Hu, Z., Zhou, M., Hu, J., Yao, X., Zhang, H., & Li, C. (2019). The distribution variance of airborne microorganisms in urban and rural environments. *Environmental Pollution*, *247*, 898-906.
[20] https://igbc.in/igbc/html_pdfs/abridged/IGBC%20Green%20New%20Buildings%20Rating%20System%20(Version%203.0).pdf.
[21] Abdul-Wahab, S. A., En, S. C. F., Elkamel, A., Ahmadi, L., & Yetilmezsoy, K. (2015). A review of standards and guidelines set by international bodies for the parameters of indoor air quality. *Atmospheric Pollution Research*, *6*(5), 751-767.

Vinit Jaideo Kedare was born in Mumbai, India on 20th April 1996. He has completed his Masters in Environmental Sciences from B.K. Birla College of Arts, Science and Commerce, Kalyan, Maharashtra, India and Bachelors in Biotechnology from Elphinstone College, Mumbai, India. He had worked on subjects like plant and soil interactions with fertilizers, Microbial diversity in mangrove Sediments and Indoor Air quality. He had actively conducted various events in his academics. He had also participated in tree plantation program. He has also completed courses like Solid waste management, QGIS, Nanotechnology and Designing of ETP. He had worked on three research projects in his academics. He has participated in various competitions, seminars and national conferences. He had attended a seminar on zoonotic diseases held by Haffkine Institute for Training Research & Testing, Mumbai. He had won various competitions in academics and has also won an award in national conference for best oral presentation regarding his work in indoor air quality.

Smruti Sunil Kharat was born in Mumbai, India on 4th January 1996. She has completed her Masters in Environmental Science from B.K. Birla College of Arts, Science and Commerce (Autonomous), Kalyan, Maharashtra, India and Bachelors in Biotechnology from Elphinstone College, Mumbai, India. She had worked on subjects like plant and soil interactions with fertilizers, Oceanographic sediments, and Indoor Air quality. She had participated in various competitions and national conferences. She had also completed courses like Solid waste management, QGIS, Green Revolution action against climate change under the leadership of the Secretary-General, UN an initiative by International Centre for Culture and Education and Kalamora foundation, Basic course in Bioinformatics from Sciome Training & Research, Advance course in bioinformatics from Srujan Biotech. She has also participated actively in various workshops like Invitro Model System, Sciome training & Research, Bioinformatics (Drug interactions) held in St. Xavier's College, Research Methods in Molecular Biology from Elphinstone College, Mumbai and have attended seminar on zoonosis held in Haffkine Institute for Trainings Research & Testing. She had worked on three research projects in her academics. She has won award for best oral presentation in national conference.

Dr. Sonal Tawde was born in Mumbai, India on 18th October 1974. She has completed her PhD from Wilson College, Mumbai, University of Mumbai in 2014 and Masters in Environmental Science from Institute of Science, Mumbai. She has worked on Phytoremediation and Solid Waste. She also has a P. G. Diploma in Environmental Pollution Control Technology from University of Mumbai and cleared State Eligibility Test (SET) exam of Maharashtra State. She has also completed IEMA approved Advanced EMS Lead Auditor Course, for ISO 14001.
Currently she is an Assistant Professor at B. K. Birla College of Arts, Science and Commerce, Kalyan, Maharashtra, India. Her Field of interest is Solid Waste Management, Phytoremediation, Air Pollution and Environmental Management. She has published research papers in various aspects of Environmental Science in National and International Journals and presented oral /poster paper presentations in National and International Conferences. She has two minor research projects to her credit. She has mentored many students for their academic projects and dissertations on various topics of Environment.
Dr. Tawde is a life member of Indian Science Congress Association (ISCA), Kolkata. She is socially active and a life member of Society for Clean Environment (SOCLEEN), an Environmental NGO. She has won two awards for Best Oral Presentation at conferences.