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Impact of Air Purifiers on Indoor Air Quality in a Classroom of DTU

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Abstract*: In Delhi, the most polluted city in India, the outdoor air pollution is severely high and due to this indoor air quality has also got worse which is more significant especially in winters. One of the available solutions to tackle the poor indoor air quality is an Air Purifier, which is a device that removes contaminants from the air in a room to improve indoor air quality. But with so many kinds available, the need to choose the right air purifier is crucial in a polluted location like Delhi. This study puts an emphasis on the efficiency of some of the readily available Air Purifiers in India and compares them on the basis of their PM1 and PM2.5 particle reduction ability, and noise generated under similar conditions. In this study, different types of air purifiers were used, and the efficiency of each examined air purifier was calculated so that it could be concluded which air purifier is best for use in cities like Delhi. The concentration levels of the primary sources of pollution i.e. PM1 and PM2.5 were recorded in the absence of any air purifier. This process was again repeated for the same duration of time, but in the presence of different types of air purifiers in a classroom in DTU using an EPAM-5000. The noise generated by each purifier was recorded using a Sound Level Meter. The introduction of an air purifier in the study area resulted in the decline of concentration levels of PM1 and PM 2.5 gradually. However, the limitations of each of the purifiers are discussed in brief and the possible steps to overcome them are provided. The air purifiers used these days do not remove pollutants completely, due to which bacteria and viruses start to form their colonies on the filter which reduces the lifespan of the filter. It increases the maintenance cost of the product which makes it unaffordable. Therefore, the monopoly of filters should be changed to the new filter-less technology. One of the possible solutions is also provided which works on the principle of 'Trap and Kill' technology that is more effective in eliminating the Pollutants, Bacteria and viruses from indoor air.

Keywords*: Air Pollution; Indoor air; PM1; PM2.5; Air Purifiers; Efficiency.

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I. INTRODUCTION

Clean air is the fundamental source for us that keeps us alive in this world. However,

some say that clean air is not possible today due to continued deterioration and contamination. Living space are supposed to be kept clean and pure, as they can be packed with different types of pollutants that can harm our health and cause different types

of problems such as asthma, stroke, lung cancer, etc. You need to inhale fresh air. This could be one of all explanations that an air purifier is good-to reduce the concentration of pollutants. Air purifiers are the source from which we can get pure and clean air. It is especially useful for those who suffer from asthma or allergies and have been improved to eliminate secondhand smoke. Therefore, it can be said that the air purifier is needed if there's a smoker within the house. The air purifiers can be utilized in both commercial and residential environments. Air purifiers have HEPA filters that assist in cleaning and purifying the air that's circulated. HEPA stands for High-Efficiency Particulate Air and could be a kind of filter that purifies the air by trapping particles and then a vacuum would only recirculate into the air. If we look at the report which is published by consumer source experts test, there they mentioned that HEPA filter removes nearly 99.99% of dust particles and impurities from the air including pollen, mold and spores.

II. CONTEXT

Due to increasing levels of the outdoor as well as indoor air pollution in Delhi, mainly from October to January, it does impact the human health of those people who spend most of their time at home, mostly older citizens, women and children. It is also well-known fact, that indoor air pollution is more affecting than outdoor pollution. The increase in the burden of respiratory disease cases can be seen in the hospitals every year, especially during the winter season. To tackle this issue the air purifier manufacturing companies, manufacture the air purifiers which are suitable for humans but most of these products are not affordable for everyone to save their lives from indoor pollution and diseases. But many people who purchases these air purifiers do not know the actual efficiency of these products. Even though the manufacturer claims to provide higher efficiency rates, it is important for consumers to know the actual efficiency rates of the purifiers in the real-world scenarios.

The purifier companies market and advertises that their purifier removes the 99.9% contaminants from indoor surroundings but after the testing and analyzing the observation from some air purifiers, it's clearly visible that the actual efficiency of these purifiers for removing the pollutants from indoor surroundings is only ranging from 30% to 80%. In the year 2018, the market of air purifier stood at $49 million in India and it is predicated by major companies, that the air purifier market has the potential to expand itself at a compound annual growth rate of over 28% during 2019-2024 to reach up to $220 million in next coming years. The increase in the indoor air pollution levels led the companies to manufacture more purifiers and circulate them to the dealers and customers. 45% of the total air purifier is sold in the North India region because in this region the pollution is more than the other regions of India. The following Fig. 1. Depicts a pie chart showing the actual sales distribution of air purifier in India as of 2018.

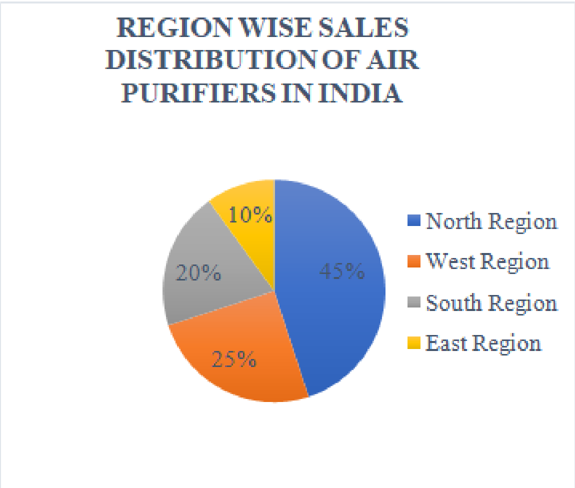

Fig. 1. Region wise Sales Distribution of Air Purifiers in India

In this study various experiments were conducted and the observations were recorded which indicates the concentration of PM2.5 and PM1 in the absence of air purifier. Firstly, a regular sized classroom was selected in DTU in which the concentration levels of the pollutants i.e. PM2.5 and PM1 was recorded, the room was closed during experiment. The concentration levels were recorded by using EPAM-5000 by Haz-dust in that classroom in the absence of air purifier and for observing the particulate pollutants of PM2.5 and PM1 the time interval was of 20 minutes for next 120 minutes.

From this case study, the aim is to find a perfect purifier that removes pollutants from indoor air more efficiently by using which humans can breathe fresh air in their homes.

A. PM2.5 and PM1 concentration in the absence of Air Purifier

The data so obtained in this study indicate the PM2.5 and PM1 concentration levels with respect to the time interval. This show the variations of particulate pollutants from 0 minute to 120 minutes i.e. 2 hours, the gradual increase is significant due to that time period of the experimentation. The concentration of particulate pollutants was more in the month of December and January.

Throughout this study, in the graphical representations, the dark blue line indicates the concentration of PM2.5 and PM1 in the absence of any type of air purifier, while the dashed line represents the actual linear concentration.

The maximum concentration level of PM2.5 was 0.199 mg/m^3 on the first day of experiment while the maximum PM1 concentration level was 0.200 mg/m^3 on the second day of experiment, the minimum concentration level of PM2.5 was 0.155 mg/m^3 on the first day of experiment while the minimum PM1 concentration level was 0.150 mg/m^3 on the second day of experiment.

On the next couple of days i.e. the third and fourth day, the maximum concentration levels of PM2.5 and PM1 was 0.233 mg/m^3 and 0.211 mg/m^3 respectively. The minimum concentration level of PM2.5 was 0.212 mg/m^3 on the third day of experiment while the minimum PM1 concentration level was 0.196 mg/m^3 on the fourth day of experiment. On the fifth and sixth day, the maximum concentration was 0.209 mg/m^3 and 0.224 mg/m^3 of PM2.5 and PM1 respectively. The minimum concentration level of PM2.5 was 0.175 mg/m^3 on the fifth day of experiment while the minimum PM1 concentration level was 0.156 mg/m^3 on the sixth day of experiment. These are the maximum and minimum concentration levels of the pollutants in the study area when none of the three air purifiers was on and the room was closed in which one of the door was only opened after every 20 minutes to replicate real world scenario.

III. METHODOLOGY AND PROCEDURES USED

A. Experimenting with Indoor Air Purifiers

We documented indoor particulate pollution, and also the factors related to it during realistic patterns of air purifier use in a socio-economic class neighborhood. The experiment was conducted with three of the foremost available and popular air purifiers containing high-efficiency particulate arresting (HEPA) filters, which claims to remove a minimum of 99% of particles as per their marketing sites. Purifier 'A' is an air purifier with HEPA filter with dimensions 350 L X 180 W X 482 H with an air flow speed of 180 cubic feet per hour. These materials cost approximately Rs 15,990 all at once. Purifier 'B', costing approximately Rs 54,900, is an air purifier containing a disciple with an air flow speed of 290 cubic feet per hour, and a HEPA filter with Base diameter 248mm, width 205mm, height 764mm. Purifier 'C', costing approximately Rs 9990, is an air purifier containing a disciple with an air flow speed of 150 cubic feet per hour, and a HEPA filter with dimensions 3.3 x 1.8 x 5.1 cm. the massive price differential between these three purifiers may be a reflection of the market: air purifiers with HEPA filters available in India cost between Rs 10,000 to Rs 80,000. Although these are the foremost affordable purifiers available, both filters are costly relative to average monthly expenditure in urban India; the price of Type 'A' Purifier is admired approximately one month of inflation-adjusted per capita expenditure for the common urban Indian, while the price of Type 'B' purifier is admired approximately five months and Type 'C' purifier is additionally available and reasonable in price.

It should be noted that throughout the study the nomenclature Purifier 'A' or Type 'A' Purifier denotes the same product which also stands true for both 'B' and 'C'. Tests were conducted in a 300 sq. ft. classroom in DTU (Delhi Technological University) located in Shahabad Daulatpur, Delhi, India. The three-story building in which the classroom is situated where the experiment was performed was not a replacement construction and was not nearby any construction site, and as is that the norm in such rooms, doors and windows were not sealed with weather strips. The space had a window unit for air conditioning (AC), four large windows, and two doors, one resulting in the corridor of the same floor(second floor) and the other to the corridor connecting to the staircase for

the third floor within the building. So as to scale back the quantity of air coming out of the doors entering the space, some large gaps were covered using plastic tape. Tape was only applied in two places: around the AC unit and over a hole within the glass of one of the four windows.The room within which tests were conducted was within the classroom on the second floor in DTU, with some attention paid to closing up large gaps through which outside air could penetrate. These were the gaps that might easily be closed without using special materials like weather strip, and without disrupting the flexibility to open and shut doors and windows. These efforts, however, by no means sealed the space completely; there have been still many gaps through which outside air could come in, as an example between doors or windows, and walls or the ground. The tests we conducted therefore represent what will be achieved if a little amount of effort, but no additional money, is invested in sealing the space. Although it's possible to keep the doors closed for an extended period of time while nobody goes outside the space, it's expected that room doors are going to be opened and closed as people move round the rooms. So, it's important to know the implications that opening and shutting doors have for air purification. Therefore, to tackle the issue of the incoming air through the opening doors, gaps and openings which will disrupt the concentration levels of the pollutants unevenly, the experiment was conducted in such a fashion so that the outside air flow does not affect the actual data, instead it was included in the experimentation by opening one of the two doors of the classroom after every 20 minutes during the whole span of the experiment. We recorded particulate pollution within the testing room by using EPAM-5000 by Haz-dust before using an air purifier. By using, EPAM-5000 we got the readings of the concentration levels PM2.5 and PM1 in mg/m3 on consecutive days in the very testing room with and without using an air purifier, which is employed finally to get the efficiency of an air purifier. Thus, there have been three test conditions combining different filter options–one Purifier 'A', Purifier 'B' and other is Purifier 'C'. Each test condition was conducted two-times. In all, we conducted six tests, with each test lasting for two hours. We undertook certain measures to confirm that the tests were representative of realistic usage, the AC unit was never switched on, the space wasn't cleaned while tests were happening. The testing room remained empty during the duration of the tests. We conducted tests over the span of 6 days between mornings to evening, the times within which pollution levels were reaching their highest levels. One test was conducted day by day, between 10:00AM and 2:00PM. Because it had been unimaginable to form multiple identical rooms, the tests were conducted consecutively in one room.

B. Measuring Particulate Matter and Noise Levels

We conducted experiments with and without using air purifiers measuring the concentration levels of PM2.5 and PM1 which is recorded by EPAM-5000 and background noise level is being monitored by a class II series cesva Sound Level meter. These equipment's are taken for the experiment thanks to their high accuracy.

EPAM-5000 provides real-time decision and data recording using PM10, PM2.5, and PM1.0 interchangeable size-selective impactors. You can also measure total suspended particles (TSP) without an impactor. EPAM-5000 is ideal for environmental, environmental, and indoor air quality and baseline surveys. Cesva Class II series, sound level meters are measuring instruments used to assess noise or sound level by measuring sound pressure. The noise is evaluated in the sound level meter, and the acoustic measurements are displayed on the noise planning surface.

For experiments, we took the reading of PM2.5 and PM1 with the use of EPAM-5000 with and without air purifiers on consecutive days. First two days of the experiment were assigned to Type 'A' purifier. The next couple of days (Day 3and Day4) were assigned to Type 'B' purifier and the last couple of days (Day 5 and Day6) were assigned to the type 'C' purifier. On Day 1 PM2.5 concentration levels were noted without the purifier for 2 hours then the Type 'A' purifier was turned on and the PM2.5 concentration levels were again recorded for the next 2 hours. This gave us the sufficient data to compare with each other and calculate the efficiency rate of type 'A' purifier while handling PM2.5 particles. On Day 2 the same experiment was repeated but this time concentration levels of PM1 was measured and compared and the efficiency rate of Type 'A' purifier while handling PM1 was calculated. Therefore, in simpler words the 6 days of experimentation can be described as on the days representing odd numbers i.e. first, third and fifth day PM2.5 was measured and compared and the efficiency rate of each of the purifier while handling PM2.5 was calculated. On the days representing even numbers i.e. second, fourth, and sixth PM1 was measured and compared and the efficiency rate of each of the purifier while handling PM1 was calculated. We repeated this experiment six times with and without air purifiers one by one. While experimenting we kept the air purifier and EPAM-5000 at a distance of nearly 5 meters. We also evaluated noise level with the use of sound level meter one by one of each air purifiers.

IV. RESULTS AND DISCUSSION

The central aim of this study is to understand the indoor air quality in the absence of an air purifier and how the introduction of an air purifier brings about the changes in the concentration of primary pollutants like PM2.5 and PM1 particles in the same duration of time.

We first discuss summary statistics of indoor air pollution level during the period in which the experiment was conducted. Then, we compare this data with the indoor air pollution levels with an air purifier. The PM 2.5 and PM1 particles were the primary pollutants in this study and the PM2.5 and PM1 levels in the study area as measured in the absence of any kind of air purifier or exhaust fans at the interval of 20 minutes for next 120 minutes is given.
With the PM2.5 level of ambient air noted for the sample size of 20 minutes interval, the same process was repeated for observing the concentration level of PM1 of ambient air under similar conditions for an interval of 20 min for the next 120 minutes. The recorded observations are provided below in the tabular format.

A. Indoor air quality during air purifier use is associated with study area

The PM2.5 and PM1 concentration levels along with the noise levels while using the Type 'A' purifier under similar conditions at the interval of 20 minutes is given below in table I.The PM2.5 and PM1 concentration levels along with the noise levels while using the Type 'B' purifier under imilar conditions at the interval of 20 minutes is given below in table II.
The PM2.5 and PM1 concentration levels along with the noise levels while using the Type 'C' purifier under similar conditions at the interval of 20 minutes is given below in table III.

Table I: Recorded observations of PM2.5, PM1 and Noise Level for Type 'A' Purifier

Time (min)	*PM 2.5 without purifier (mg/m3)*	*PM2.5 with purifier (mg/m3)*	*PM1 without purifier (mg/m3)*	*PM1 With purifier (mg/m3)*	*Max. Ambient Noise Level (dB)*	*Max. Noise Level With Purifier (dB)*
0	0.180	0.196	0.150	0.205	47.60	57.50
20	0.192	0.098	0.186	0.202		
40	0.199	0.074	0.190	0.189		
60	0.155	0.053	0.191	0.163		
80	0.176	0.056	0.190	0.121		
100	0.193	0.076	0.195	0.104		
120	0.198	0.080	0.200	0.084		

By studying the observations carefully, it was noted that the concentration level of PM2.5 and PM1 started decreasing gradually when the air purifier was turned on.

Table II: Recorded observations of PM2.5, PM1 and Noise Level for Type 'B' Purifie

Time (min)	*PM 2.5 without purifier (mg/m3)*	*PM2.5 with purifier (mg/m3)*	*PM1 without purifier (mg/m3)*	*PM1 With purifier (mg/m3)*	*Max. Ambient Noise Level (dB)*	*Max. Noise Level With Purifier (dB)*
0	0.214	0.207	0.199	0.198	55.80	60.40
20	0.212	0.165	0.202	0.173		
40	0.219	0.142	0.198	0.133		
60	0.223	0.121	0.197	0.101		
80	0.220	0.101	0.196	0.080		
100	0.229	0.092	0.205	0.061		
120	0.233	0.039	0.211	0.048		

Minimum concentration level of PM1 being 0.048 mg/m3 as opposed to 0.106 mg/m3 which was concentration level of PM1 particles when the air purifier was not turned on.

Table III: Recorded observations of PM2.5, PM1 and Noise Level for Type 'C' Purifier

Time (min)	*PM 2.5 without purifier (mg/m3)*	*PM2.5 with purifier (mg/m3)*	*PM1 without purifier (mg/m3)*	*PM1 With purifier (mg/m3)*	*Max. Ambient Noise Level (dB)*	*Max. Noise Level With Purifier (dB)*
0	0.186	0.207	0.194	0.210	53.7	65.1
20	0.175	0.195	0.192	0.180		
40	0.179	0.174	0.199	0.187		
60	0.185	0.152	0.156	0.162		
80	0.199	0.111	0.168	0.159		
100	0.202	0.132	0.193	0.143		
120	0.209	0.177	0.224	0.122		

However, the decline in the total concentration level of PM2.5 and PM1 particles is more significant in the case where the air purifier was on for 120 minutesMinimum concentration level of PM2.5 being 0.039 mg/m3 as opposed to 0.146 mg/m3 which was concentration level of PM2.5 particles when the air purifier was not turned on.

The changes in the concentration level of PM 2.5 with respect to the time is depicted graphically.Fig. 2. represents the variation of PM2.5 concentration in a room with and without using an air purifier.

PM2.5 concentration is monitored for nearly 4 hours (2hours without an air purifier and 2hours with an air purifier). On day 1, PM2.5 concentration has been monitored first without an air purifier which is shown by Blue line (as shown in graph) and it can be observed that PM2.5

concentration is deflecting because of changing environment condition which takes place in our environment. After monitoring PM2.5 concentration without any purifier, Type 'A' Air purifier is switched on and reading has been monitored for next 2 hours. PM2.5 concentration with an air purifier is shown by Orange line in graph. As shown in the graph, it can be observed that PM2.5 concentration has been reduced significantly after using an air purifier. It can be seen that during the first 2 hours, maximum concentration of PM2.5 when air purifier was not operating is 0.199 mg/m³ while the minimum concentration of PM2.5 during these 2 hours is 0.155 mg/m³ and after 2 hours when the purifier was running for 2 hours the maximum concentration reduced to 0.196 mg/m³ in between it also gets reduced to 0.053 mg/m³ being the minimum concentration, but it increases little bit due to changing atmospheric conditions. But, it is observed that PM2.5 concentration gets reduced after air purifier is running for 2 hours. Linear PM2.5 concentration with and without purifier is also drawn to show changing environment conditions in our atmosphere and it shows that PM2.5 concentration changes in our atmosphere rapidly and ambiguously.

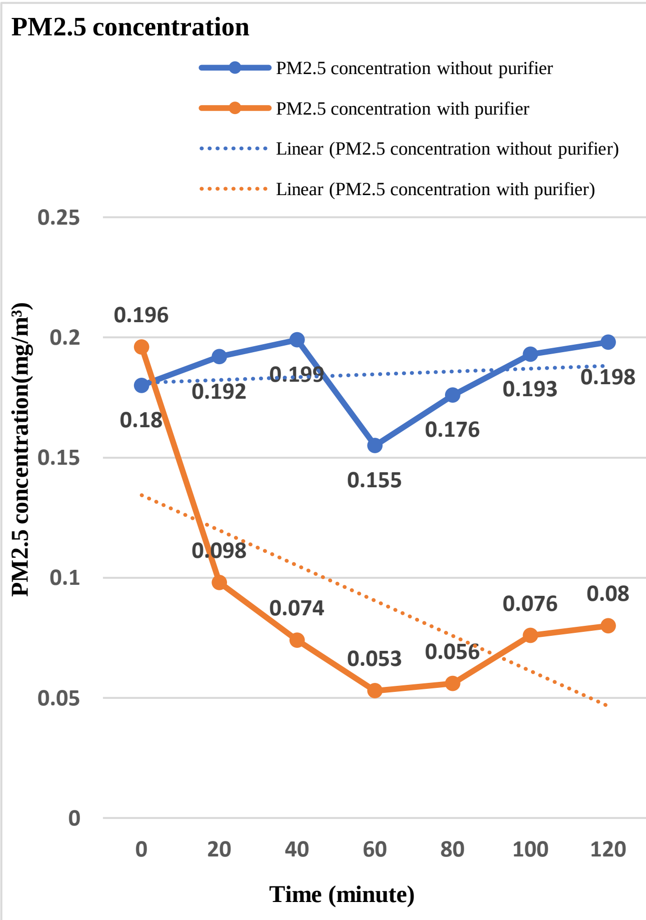

Fig. 2. PM2.5 concentration levels with and without using Type 'A' purifier on Day 1

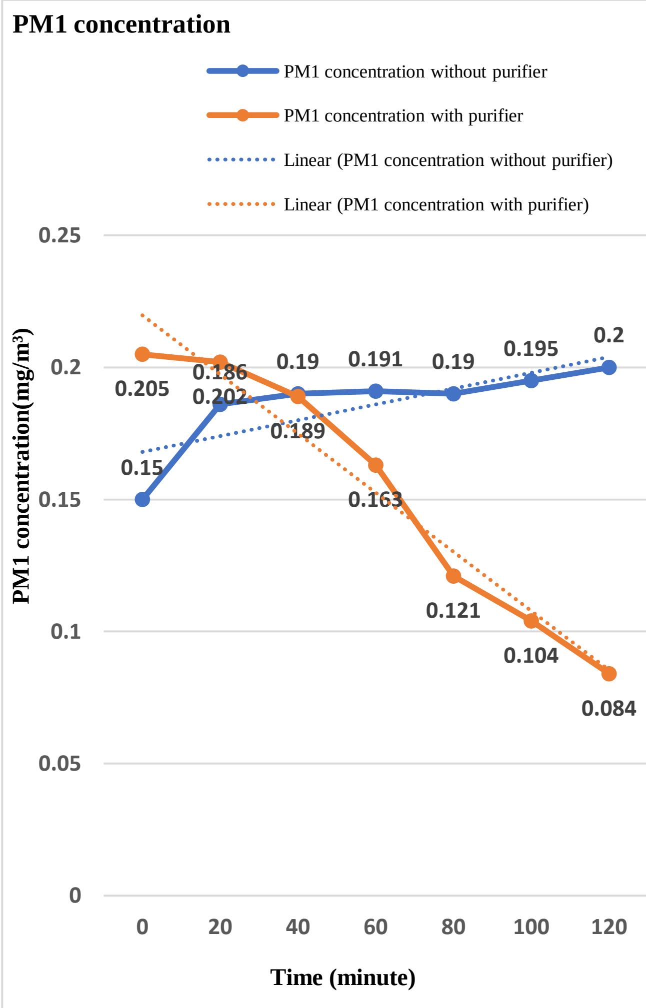

Fig. 3. PM1 concentration levels with and without using Type 'A' purifier on Day 2

Fig. 3. represents the variation of PM1 concentration in a room with and without using an air purifier. PM1 concentration is monitored for nearly 4 hours (2hours without an air purifier and 2hours with an air purifier). On day 2, PM1 concentration has been monitored first without an air purifier which is shown by Blue line (as shown in graph) and it can be observed that PM1 concentration is deflecting because of changing environment. After monitoring PM1 concentration without an air purifier, Type 'A' Air purifier is switched on and reading has been monitored for next 2 hours. PM1 concentration with an air purifier is shown by Orange line in graph. As shown in the graph, it can be observed that PM1 concentration has been reduced significantly after using an air purifier. It can be seen that during the first 2 hours, maximum concentration of PM1 when air purifier was not operating is 0.200 mg/m³ while the minimum concentration of PM1 during these 2 hours is 0.150 mg/m³ and after 2 hours when the purifier was running for 2 hours the maximum concentration reduced to 0.205 mg/m³ in between it also gets reduced to 0.084 mg/m³ being the minimum concentration, but it increases little bit due to changing atmospheric conditions. But, it is observed that PM1 concentration gets reduced after air purifier is running for 2 hours.

Linear PM1 concentration with and without purifier is also drawn to show changing environment conditions in our atmosphere and it shows that PM1 concentration changes in our atmosphere rapidly and ambiguously.Fig. 4. represents the variation of PM2.5 concentration in a room with and without using an air purifier. PM2.5 concentration is monitored for nearly 4 hours (2hours without an air purifier and 2hours with an air purifier). On day 3, PM2.5 concentration has been monitored first without an air purifier which is shown by Blue line (as shown in graph) and it can be observed that PM2.5 concentration is deflecting because of changing environment condition which takes place in our environment. After monitoring PM2.5 concentration without any purifier, Type 'B' Air purifier is switched on and reading has been monitored for next 2 hours. PM2.5 concentration with an air purifier is shown by Orange line in graph. As shown in the graph, it can be observed that PM2.5 concentration has been reduced significantly after using an air purifier. It can be seen that during the first 2 hours, maximum concentration of PM2.5 when air purifier was not operating is 0.233 mg/m³ while the minimum concentration of PM2.5 during these 2 hours is 0.212 mg/m³ and after 2 hours when the purifier was running for 2 hours the maximum concentration reduced to 0.207 mg/m³ in between it also gets reduced to 0.039 mg/m³ being the minimum concentration, but it increases little bit due to changing atmospheric conditions. But, it is observed that PM2.5 concentration gets reduced after air purifier is running for 2 hours. Linear PM2.5 concentration with and without purifier is also drawn to show changing environment conditions in our atmosphere and it shows that PM2.5 concentration changes in our atmosphere rapidly and ambiguously.

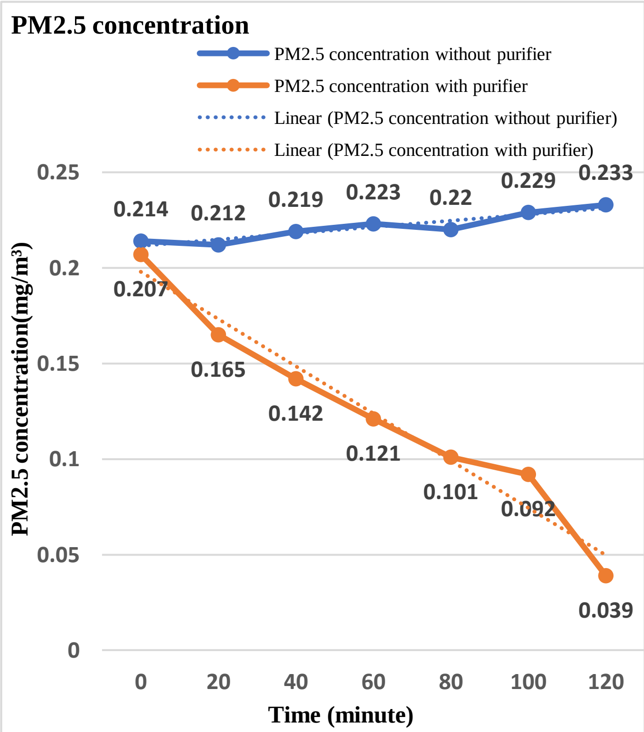

Fig. 4. PM2.5 concentration levels with and without using Type 'B' purifier on Day 3

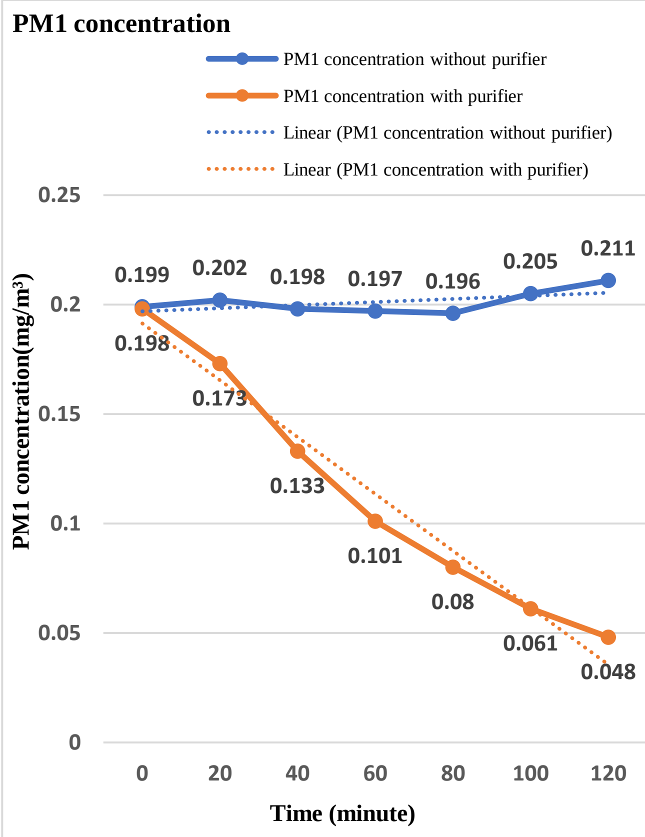

Fig. 5. PM1 concentration levels with and without using Type 'B' purifier on Day 4

Fig. 5. represents the variation of PM1 concentration in a room with and without using an air purifier. PM1 concentration is monitored for nearly 4 hours (2hours without an air purifier and 2hours with an air purifier). On day 4, PM1 concentration has been monitored first without an air purifier which is shown by Blue line (as shown in graph) and it can be observed that PM1 concentration is deflecting because of changing environment. After monitoring PM1 concentration without an air purifier, Type 'B' Air purifier is switched on and reading has been monitored for next 2 hours. PM1 concentration with an air purifier is shown by Orange line in graph. As shown in the graph, it can be observed that PM1 concentration has been reduced significantly after using an air purifier. It can be seen that during the first 2 hours, maximum concentration of PM1 when air purifier was not operating is 0.211 mg/m³ while the minimum concentration of PM1 during these 2 hours is 0.196 mg/m³ and after 2 hours when the purifier was running for 2 hours the maximum concentration reduced to 0.198 mg/m³ in between it also gets reduced to 0.048 mg/m³ being the minimum concentration, but it increases little bit due to changing atmospheric conditions. But, it is observed that PM1 concentration gets reduced after air purifier is running for 2 hours. Linear PM1 concentration with and without purifier is also drawn to show changing environment conditions in our atmosphere and it shows that PM1 concentration changes in our atmosphere rapidly and ambiguously.

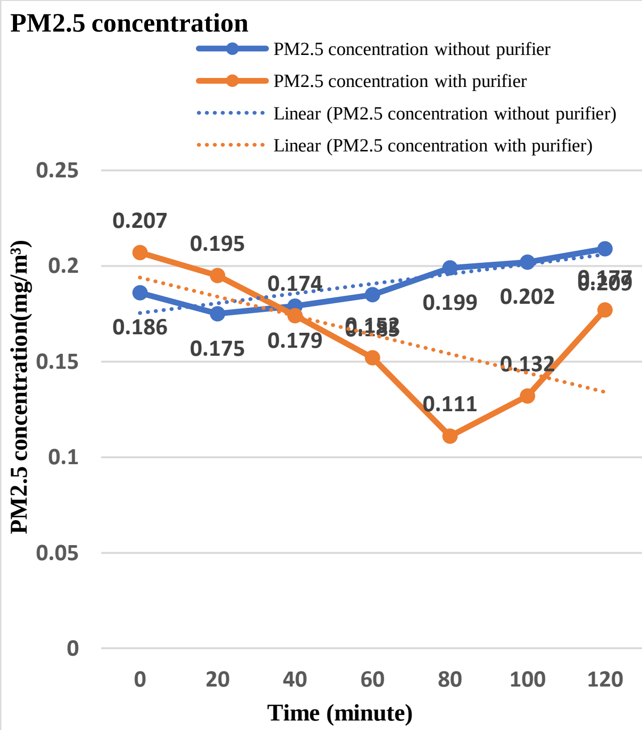

Fig. 6. PM2.5 concentration levels with and without using Type 'C' purifier on Day 5

Fig. 6. represents the variation of PM2.5 concentration in a room with and without using an air purifier. PM2.5 concentration is monitored for nearly 4 hours (2hours without an air purifier and 2hours with an air purifier). On day 5, PM2.5 concentration has been monitored first without an air purifier which is shown by Blue line (as shown in graph) and it can be observed that PM2.5 concentration is deflecting because of changing environment condition which takes place in our environment. After monitoring PM2.5 concentration without any purifier, Type 'C' Air purifier is switched on and reading has been monitored for next 2 hours. PM2.5 concentration with an air purifier is shown by Orange line in graph. As shown in the graph, it can be observed that PM2.5 concentration has been reduced significantly after using an air purifier. It can be seen that during the first 2 hours, maximum concentration of PM2.5 when air purifier was not operating is 0.209 mg/m³ while the minimum concentration of PM2.5 during these 2 hours is 0.175 mg/m³ and after 2 hours when the purifier was running for 2 hours the maximum concentration reduced to 0.207 mg/m³ in between it also gets reduced to 0.111 mg/m³ being the minimum concentration, but it increases little bit due to changing atmospheric conditions. But, it is observed that PM2.5 concentration gets reduced after air purifier is running for 2 hours. Linear PM2.5 concentration with and without purifier is also drawn to show changing environment conditions in our atmosphere and it shows that PM2.5 concentration changes in our atmosphere rapidly and ambiguously.Fig. 7. represents the variation of PM1 concentration in a room with and without using an air purifier. PM1 concentration is monitored for nearly 4 hours (2hours without an air purifier and 2hours with an air purifier). On day 6, PM1 concentration has been monitored first without an air purifier which is shown by Blue line (as shown in graph) and it can be observed that PM1 concentration is deflecting because of changing environment. After monitoring PM1 concentration without an air purifier, Type 'C' Air purifier is switched on and reading has been monitored for next 2 hours. PM1 concentration with an air purifier is shown by Orange line in graph. As shown in the graph, it can be observed that PM1 concentration has been reduced significantly after using an air purifier. It can be seen that during the first 2 hours, maximum concentration of PM1 when air purifier was not operating is 0.224 mg/m³ while the minimum concentration of PM1 during these 2 hours is 0.156 mg/m³ and after 2 hours when the purifier was running for 2 hours the maximum concentration reduced to 0.210 mg/m³ in between it also gets reduced to 0.122 mg/m³ being the minimum concentration, but it increases little bit due to changing atmospheric conditions. But, it is observed that PM1 concentration gets reduced after air purifier is running for 2 hours. Linear PM1 concentration with and without purifier is also drawn to show changing environment conditions in our atmosphere and it shows that PM1 concentration changes in our atmosphere rapidly and ambiguously.

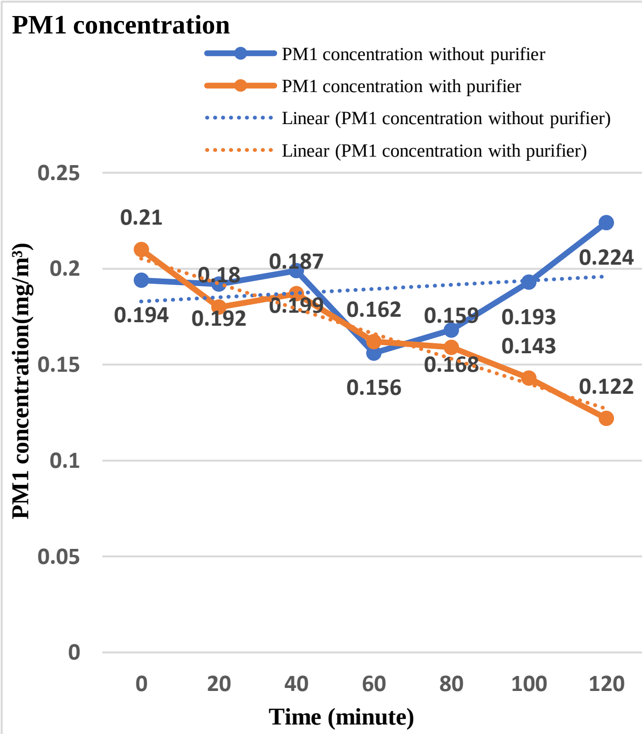

Fig. 7. PM1 concentration levels with and without using Type 'C' Purifier on Day 6

B. Efficiency rate of Type 'A' purifier

With the significant changes in the PM2.5 and PM1 concentration recorded it is important to calculate the efficiency rate at which the air purifier is operating in this particular case.

Therefore, For Type 'A' Purifier.

$$\eta A2.5 = \frac{PM2.5(min)\ without\ purifier - PM2.5(min)\ with\ purifier}{PM2.5(min)\ without\ purifier}$$

$$\eta A2.5 = \frac{0.180 - 0.053}{0.180} = 70.55\%$$

$$\eta A1=\frac{PM1\,(min)\ without\ purifier\text{-}PM1\,(min)\ with\ purifier}{PM1\,(min)\ without\ purifier}$$

$$\eta A1=\frac{0.150\text{-}0.084}{0.150}=44\%$$

C. Efficiency rate of the Type 'B' purifier

With the significant changes in the PM2.5 and PM1 concentration recorded it is important to calculate the efficiency rate at which the air purifier is operating in this particular case.

Therefore, For Type 'B' purifier

$$\eta B2.5=\frac{PM2.5\,(min)\ without\ purifier\text{-}PM2.5\,(min)\ with\ purifier}{PM2.5\,(min)\ without\ purifier}$$

$$\eta B2.5=\frac{0.212\text{-}0.039}{0.212}=81.60\%$$

$$\eta B1=\frac{PM1\,(min)\ without\ purifier\text{-}PM1\,(min)\ with\ purifier}{PM1\,(min)\ without\ purifier}$$

$$\eta B1=\frac{0.196\text{-}0.048}{0.196}=75.51\%$$

D. Efficiency rate of the Type 'C' purifier

With the significant changes in the PM2.5 and PM1 concentration recorded it is important to calculate the efficiency rate at which the air purifier is operating in this particular case.

Therefore, For Type 'C' purifier

$$\eta C2.5=\frac{PM2.5\,(min)\ without\ purifier\text{-}PM2.5\,(min)\ with\ purifier}{PM2.5\,(min)\ without\ purifier}$$

$$\eta C2.5=\frac{0.146\text{-}0.111}{0.146}=23.97\%$$

$$\eta C1=\frac{PM1\,(min)\ without\ purifier\text{-}PM1\,(min)\ with\ purifier}{PM1\,(min)\ without\ purifier}$$

$$\eta C1=\frac{0.106\text{-}0.065}{0.106}=38.67\%$$

With the information retrieved so far it can be seen that for the concentration levels of PM2.5 under similar conditions, the efficiency rates for the three air purifiers namely 'A', 'B' and 'C' under different test conditions, the following expression holds true which is:

$\eta B2.5 > \eta A2.5 > \eta C2.5$

The same is the case for PM1 concentration levels when purifier 'B' outperformed the other two purifiers by a large margin and the efficiency rates of the three air purifiers under different test condition follows a similar trend which is:

$\eta B1 > \eta A1 > \eta C1$

Hence it can be concluded that although the purifier 'A' and 'C' are also equipped to minimize the pollutants' concentrations under closed environment, their efficiency rate is comparatively low when compared to the purifier 'B' and hence Type 'B' purifier is more feasible in usage in location where indoor air quality is severely polluted. It was also observed that while operating purifier 'B' produces significantly less noise when compared to the other two purifiers which is also a relief for working environments and help in work productivity.

Where,

$\eta A1$ Denotes efficiency rate of Type 'A' Purifier against PM1 particles.

$\eta A2.5$ Denotes efficiency rate of Type 'A' Purifier against PM2.5 particles.

$\eta B1$ Denotes efficiency rate of Type 'B' Purifier against PM1 particles.

$\eta B2.5$ Denotes efficiency rate of Type 'B' Purifier against PM2.5 particles.

$\eta C1$ Denotes efficiency rate of Type 'C' Purifier against PM1 particles.

$\eta C2.5$ Denotes efficiency rate of Type 'C' Purifier against PM2.5 particles.

E. Noise level Before and After using an Air Purifier

With the Efficiency rates of each of the three purifiers known, it is fairly easy to assume which one of the three purifiers tested is better when it comes to removing the pollutants. However, one important aspect of any purifier which is supposed to run for a long duration of day and night, is the noise levels generated by it. It is evident that the purifiers with low noise levels should be preferred as with high noise levels in which it is very difficult to work with full concentration which subsequently reduces our productivity. Therefore, the noise levels with and without using an purifier was also measured using an class II Cesva Sound Level Meter. The instrument used was pre-calibrated to avoid any unforeseen errors.

The maximum noise level advertised by type 'A' purifier is <= 60 dB(A). However, the maximum noise level recorded while using type 'A' purifier during this study is 57.50 dB when compared to the maximum ambient noise level in absence of the purifier which was 47.60 dB.

The maximum noise level advertised by type 'B' purifier is <= 60 dB(A). However, the maximum noise level recorded while using type 'B' purifier during this study is 60.40 dB when compared to the maximum ambient noise level in absence of the purifier which was 55.80 dB

The maximum noise level advertised by type 'C' purifier is 55 to 60 dB(A). However, the maximum noise level recorded while using type 'C' purifier during this study is 65.10 dB when compared to the maximum ambient noise level in absence of the purifier which was 53.70 dB

If the Max(NoiseA/B/C) denotes the maximum noise level in the presence of the air purifier the following expression holds true.

Max (Noise 'C') > Max (Noise 'A') > Max (Noise 'B')

V. CONCLUSION

During the experimentation of 6 days , it was noted that even though the concentration levels of the pollutants i.e. PM2.5 and PM1 are significantly low during the run time of the purifiers, the efficiency of each of these purifiers will decrease with each working operation. Also, the purifiers do not eliminate these pollutants completely but inhaled them through its vacuum pump onto their filters.

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This can lead to mandatory frequent wash-ups and replacements of their
filters for them to work efficiently. This will ultimately increase the maintenance cost of these purifiers making them unaffordable for a majority of people. It was also noted that since these purifiers does not eliminate the pollutants and air-borne disease carrying particles, these purifiers might act as a accumulation point for these unwanted particles where they can form their colonies right on the surface of the filters and in-turn decreases the life expectancy and efficiency rate of these purifiers, and can aggravate the respiratory issues in humans especially for the lungs and asthmatic patients.

To ensure the fore mentioned issues are addressed in the air purifier industry, it is very important that a filter less approach is accepted for the portable air purifiers, where the technological process is close to HEPA class of particles filtration but with added advantage of System which should not only traps the micro particles but also kills the air borne germs. System should have long life with simple wash and supply without landfill, secondary pollution with very low pressure drop.

It should include Trap & Kill Technology and it must have Long Life with less power consumption.

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