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Low Cost Home Air Purifier Design to mitigate the risk of raising pollution levels in Indian Cities

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Abstract— In Indian cities, increased automotive emissions, construction, and industrial activities are producing significant air pollution. In many places, the Air Quality Index (AQI) index rises above 300 for several days of the year, posing a major health risk to humans. Fine-particle exposure Particulate matter $PM_{2.5}$ particles with diameters less than 2.5µM are causing severe respiratory and cardiovascular illnesses, resulting in premature deaths. Both outdoor and indoor pollution levels have a negative influence on low-income and impoverished households. While pricey and high-cost alternatives are available, they are out of reach for the majority of households. This study presents a low-cost Air Purifier Design for families. To decrease the health hazards associated with increasing indoor pollution levels, this unit can be quickly constructed and assembled by semi-skilled technicians using locally accessible materials. The prototype's detailed design and experimental results are presented.

Keywords— Indoor Pollution, AQI, $PM_{2.5}$, Low-cost Air Purifier, HEPA filter.

1 INTRODUCTION

Over the years, the population living in urban areas is rapidly growing. According to the Urban Affairs survey (Growth, 2022), as per 2011 census, 31.8% of Indian population lives in urban areas. And according to UN survey report (Wikipedia, 2022) by 2030 around 40.76% of Indian population will be living in urban areas.

It is a well known fact that rapid urbanization has resulted in unceasing construction work and automobile traffic. The effect of growing cities has brought in very high levels of outdoor and indoor pollution. Air Qualty Index (Index, 2021)AQI is above acceptable levels in the cities.. The effect of growing cities has brought in very high levels of outdoor and indoor pollution. . An analysis report on air quality (IQAir, 2022) shows that the Air Quality Index AQI is above acceptable levels in the cities.

In the World Health Organization WHO report (WHO, 2021) it is said that millions of premature deaths are caused every year due to increased air pollution. According to WHO report Particulates may pose many health hazards to human beings. As per studies on Particulates (Particulates, 2022), it is said that they are microscopic particles of solid or liquid matter suspended in the air. They are also known as atmospheric aerosol particles, atmospheric particulate matter, particulate matter (PM), or suspended particulate matter (SPM). Smaller-diameter particles ($PM_{2.5}$ or smaller) are generally more dangerous and according to (IQAir, 2022) $PM_{2.5}$ particles are the main contributor to the overall pollution.

Figure 1 IQAir report Delhi on 12.03.2022 (IQAir, 2022).

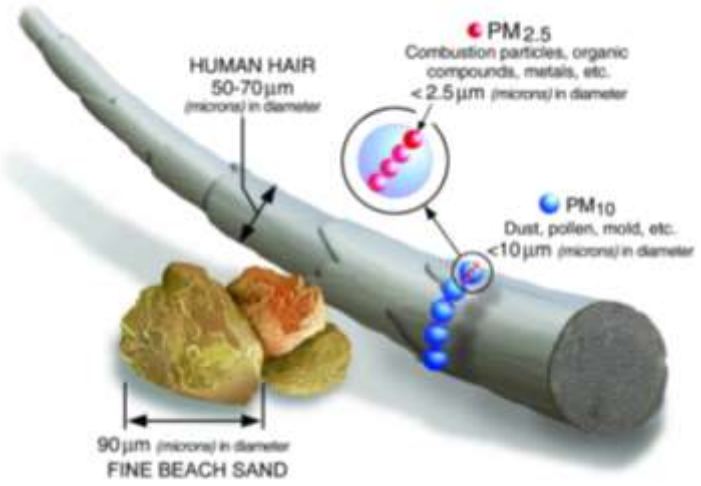


Figure 2 An Image Indicating the Graphic comparision of Human hair with $PM_{2.5}$ and PM_{10} Particulates (Particulates, 2022).

In Indian metropolitan cities like Delhi, it is a perinial problem with no solution in sight. Throughout the year, the air quality level is several multiples above the permissible limits defined by WHO. In cities like Bangalore, pollen and plant based pollutants also aggravate the situation causing severe health hazards to people. Macro level intervention and steps needed at infrastructure level to control the pollution are beyond the scope of this paper. However with a design proposed, individual households can build low cost Air Purifier and take care of their health. In rural Indian homes too, the use of firewood for cooking increases indoor pollution impacting children and sick adults.

It is critical to address this serious health concern as pollutants have the greatest impact on children and the elderly. Many commercially available clean air solutions are available. However, they are out of reach for low-income urban households. This paper suggests a low-cost room air purifier for small living rooms (100 square feet). The design is elegant and can be built by inexperienced carpenters and electricians using readily available commercial components. To make this device a viable option for low-income families, low-cost and semi-skilled labour are required. The device can significantly improve air quality while also protecting children, the elderly, and other vulnerable members of the household. A working prototype is created, and the results of the experiments are reported.

2 DESIGN OF LOW COST AIR PURIFIER

Low-cost air purifier is targeted to address the requirements of low-income households in urban India. According to research by Debarpita Roy and Meera ML (ML, 2020) Per capita carpet area in low income households is around 83 SFT. The design is made to cover a typical 100 sft living room which the target area for this project.
A detailed study of existing and popular room air purifiers was done based on actual user experience in terms of real time usage in polluted cities. An exercise is done to knock down the products to basic parts inside and an extensive search was done to locate the replacement parts which are available in the market.

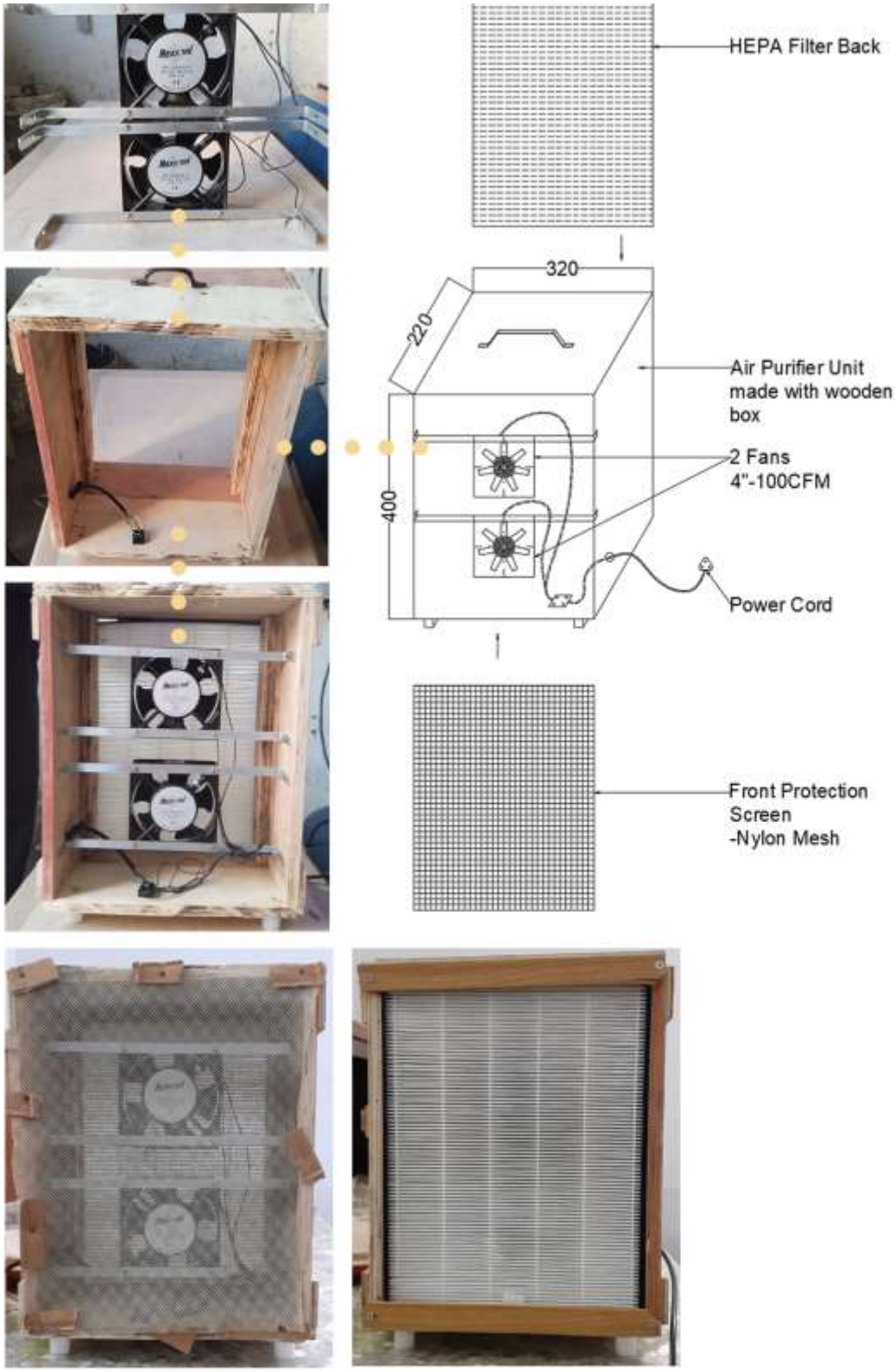
The design is based on a commercially available HEPA filter(High Efficiency Particulate Air Filter). It is said that a HEPA filter (HEPA, 2022), also known as a high-efficiency particulate absorbing filter or a high-efficiency particulate arrestance filter, is an air filter efficiency standard. According to numerous studies, HEPA-compliant filters must meet certain levels of efficiency. A HEPA air filter must remove at least 99.95 percent (ISO, European Standard) or 99.97 percent (ASME, U.S. DOE) of particles with diameters equal to 0.3 m from the air that passes through, with filtration efficiency increasing for particle diameters less than and greater than 0.3 µm.

HEPA filter is capable of capturing pollen, dirt, dust, moisture, bacteria (0.2-2.0 µm), virus (0.02-0.3 µm), and submicron liquid aerosol (0.02-0.5 µm). HEPA is also able to capture some viruses and bacteria which are ≤0.3 µm. HEPA is also able to capture floor dust which contains Bacteroidia, Clostridia, and Bacilli.

Standard 240V, two numbers 4 inch diameter 100 CFM (air flow-CFM stands for cubic feet per minute) ,commercial plywood and a nylon screen for protection. A typical room 10 feet by 10 feet and ceiling height of 10 feet, a 100CFM can achieve frequency of air exchange in 11 minutes. By using two 100 CFM fans, we can achieve 6 minutes as frequency of air exchange. However, as HEPA filter usage increases, with time air exchange time will increase and it requires replacement. The working prototype costed around Rs1800/ to build.

2. 1 Images of working Prototype

Figure 3 The following are the images of working prototype.



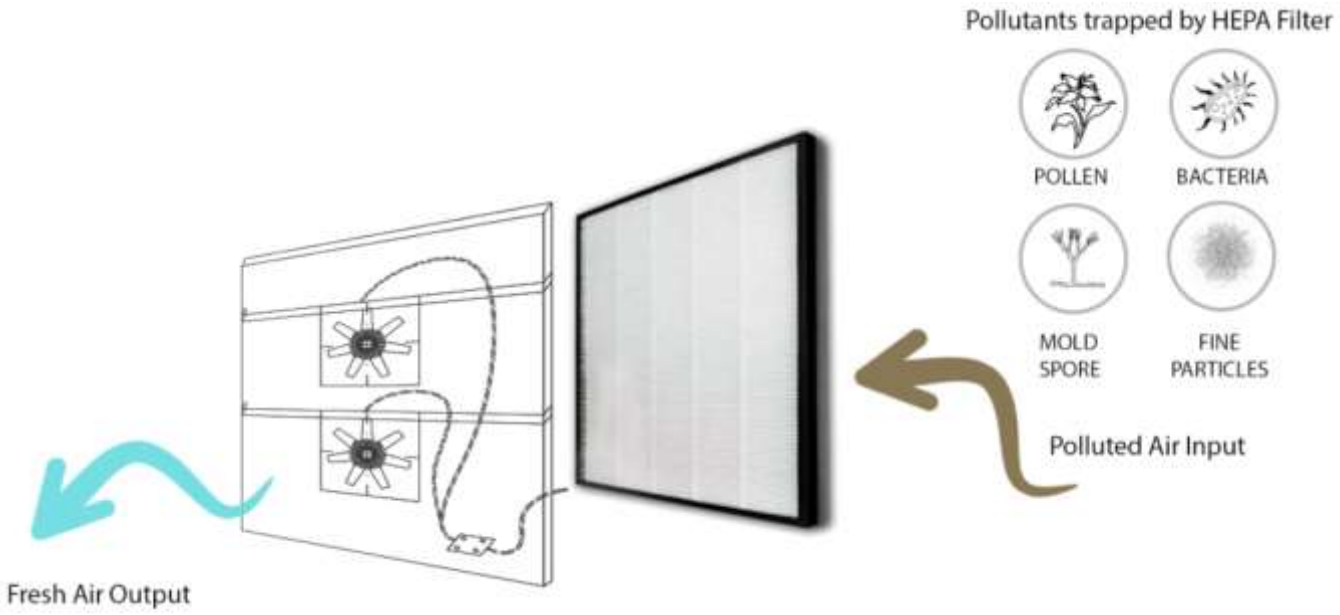


Figure 4 Illustration showing the concept of Air Purification using HEPA Filter.

3 EXPERIMENTAL RESULTS

Low cost air was installed indoors and monitored for $PM_{2.5}$ levels periodically using commercially available $PM_{2.5}$ monitor (Air Quality Monitor, 2022)

$PM_{2.5}$ detector measures and displays air quality in mass-density (µg/m3). The sensor inside has a LED (light-emitting diode) as source and Photo Diode- PD sensor. PD sensor detects scattered light which is correlated to $PM_{2.5}$ particulates in the air.

Common incidents like sweeping the floor, burning of food in the kitchen and vehicular/construction activities in the will lead to $PM_{2.5}$ levels above 900µgms/m 3 levels. The following table gives the $PM_{2.5}$ Monitor AQI levels.

PM 2.5	*AIR QUALITY LEVEL*
0-35µG/ m 3	Excellent
36-75µG/ m 3	Good
76-115µG/ m 3	Low Pollution
Above 115µG/ m 3	Mild Pollution

As seen in the figure, the readings indicate the change in levels of the impurities present in the air. It is 'RED' signal once the indicator crosses 115µG/ m 3 levels. The prototype was used in dusty rooms and after 15 minutes to 30 minutes usage, the dust levels got reduced to green levels.

Air Purifier was switched on when the $PM_{2.5}$ was around 174µG/ m 3 level and indicator was observed. The following table tabulates the results. In twenty six minutes room measuring 100 SFT, the air quality improved to green levels. In an adjacent room where air purifier is not operational, it took four hours to achieve green levels of below 0-35µG/ m 3 $PM_{2.5}$ levels.

Time in Hours	*PM 2.5 Reading µG/ m 3*
8.12 p.m	174
8.24 p.m	72
8.33 p.m	38
8.38 p.m	31

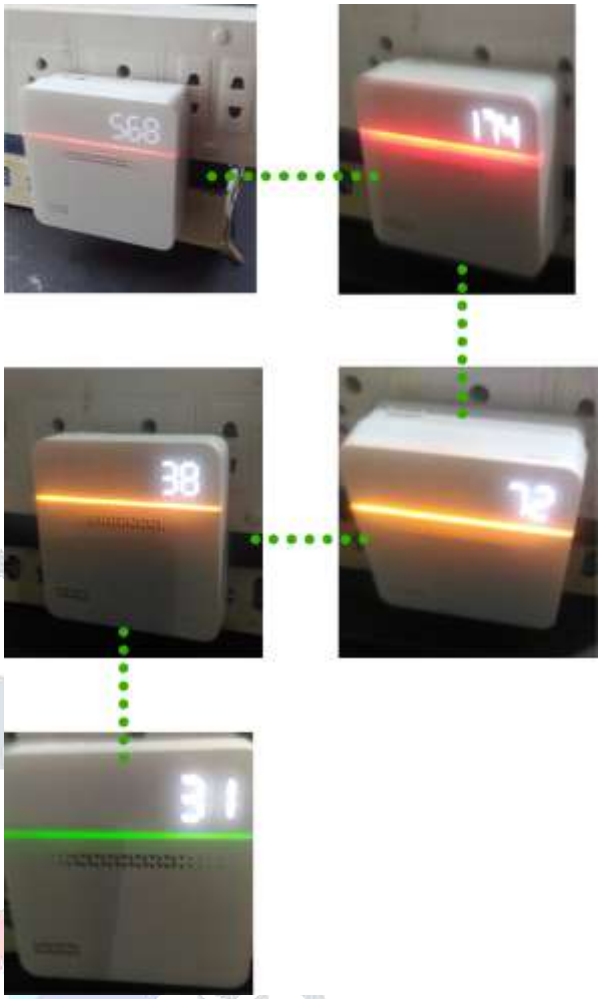


Figure 5 Comercially available Air Quality Monitor used to indicate results of the levels in Air quality.

4 CONCLUSION

As per the studies and experimental results, it can be concluded that a low-cost air purifier is very effective at removing pollutants from small rooms. In larger rooms, multiple units can be used to help improve the Air quality in the respective spaces. This sustainable design addresses the severe air pollution issues that urban India households face, allowing vulnerable people to breathe safely and avoid serious health risks, which can help reduce the effects of air pollution and particulate matter on cognitive performance.

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