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# Design and Development of Outdoor Air Purifier for Automotive Emission Powered by Solar and Wind Energy

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## Abstract

*People living in metropolitan cities have to make their way to anywhere through traffic every day. In traffic areas like signals, narrow roads, bazars etc., there is a very high concentration of air pollutants due to automobile emissions. The air pollution these days is a serious environmental concern. Faster escape solutions are required than permanent over the time changing solutions. In some cities like Delhi the air quality index has reached to an irrefutable level. To avoid such problems, we came through an idea of an Outdoor Air Purifier in heavy traffic areas which would efficiently decrease pollutants emitted by automobiles. The Air Purifier consists of layers of HEPA and Activated Carbon filter. In the present work, the propeller fans mounted in the suction chamber sucks the atmospheric air into the chamber. Then air sucked by the fans pass through the layers of filters where it absorbs the particulate matter as well as VAC and other gaseous chemicals like NOx and $SO_2$. Then the purified air is led to the atmosphere thereby decreasing the Air Quality Index. In addition, the alternate sources of energy like solar panel and wind turbine which are mounted on the unit, so that battery gets charged utilizing renewable energy such as solar and wind. The test results obtained were quite encouraging. There is a reduction of about 98% of CO and 95% HC emissions were revealed from the test results.*

## 1.0 Introduction

### 1.1 Air Pollution due to Automotive Emission

Due to rapid industrialization and ever-increasing traffic resulting in excessive amounts of hazardous gasses released to the atmosphere (Johnson *et al*., 2020). Health hazards resulting due to air pollution is leading to premature deaths and is growing year after year. There is around two million death per year is estimated. In addition, there is a huge economic loses for treatment is tremendous (Austin *et al*., 2021).

Increase in number of vehicles and pollution has almost doubled in the last decade. Rapid urbanization and growth of motor vehicles impose a serious effect on human life and the environment in recent years

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(Blanco, 2021). Contribution of motor vehicles on urban air pollution is significant and thus is also important contributors of anthropogenic $CO_2$ other greenhouse gases. Transport sector contributes a major sector, contributing 90% of total emissions. Air pollution leads to serious environmental health related issues ranging from nausea, breathing difficulties, eye ball rubbing, skin irritations, birth defects, immunosuppression and cancer. These are the indicators of air pollution becoming a major problem in Indian context and building a healthy environment is quite inevitable (Blanco *et al.*, 2021).

## 1.2 Need for Air Purification

Between, 1951 and 2011, the urban population has crossed 377.1 million, and its proportion has increased to 31.16%. This rapid increase in unplanned urban population has resulted in higher demand for transport, energy and other infrastructure, thereby putting a load on the pollution problem.

Through study reported in 2022. Three Indian cities find their place in the list of top 10 most polluted cities in the world. Their Air Quality Indices (AQI) are reported in (Table 1).

**Table 1.** Air quality index values in different cities (Hudda, *et al.*, 2018)

| | |
|---|---|
| No.1 | Delhi, India (AQI: 556) |
| No.2 | Kolkata, India (AQI: 177) |
| No.3 | Mumbai, India (AQI: 169) |

Fuel and its quality are one of the major issues with automotive vehicles has to be addressed. The majority pollutants released as a vehicle emissions are lead, NO, CO, unburnt HC and $SO_2$, Break dust, Tyre dust and suspended particulate matter emitted from tailpipes.

In India, the vehicle population is growing at the rate of over 5% per annum (Shirmohammadi *et al.*, 2017). Transport sector in India has a contribution of about 60% of total greenhouse gases. According to census done in 2011 there is around 72% of two wheelers (mainly driven by two-stroke engines) account for the total vehicle population (Habre *et al.*, 2018). Vehicle speed, age of vehicle and emission rate affect vehicular emissions.

## 1.3 Importance of Air Purifiers

One of the studies published in the British Journal of Psychiatry by conducting the survey of 13,000 participants in London, UK, and found that by reducing very low volume of particle pollution by even a few percentage points would make a huge difference to mental health and save tens of millions in sunk healthcare costs each year.

From the above studies it is concluded that for good health there is a need cleaner air and you can't always rely on the government and businesses to use cleaner vehicles or implement other clean air initiatives. But at your home, you can always use an air purifier.

## 1.4 Commercial Air Purifiers

Normally air purifiers or air cleaners are used to improve air quality which works by removing the contaminants in the air (Holm *et al.*, 2020). The air purifiers are beneficial to people with allergy issues and asthmatics. They also try reduce or eliminate second-hand tobacco smoke. The commercially graded air purifiers are manufactured as either small stand-alone units or larger units that can be affixed to an Air Handler Unit (AHU) or to an HVAC unit found in the medical, industrial, and commercial industries (Rim, *et al.*, 2010). The air purifiers also find their application in industries to purify air before their usage in industrial processes.

One of the well known commercial air purifiers are the HEPA (High-Efficiency Particulate Arrester) Filters**.** These filters (Figure 1) capture and filter out wide range of pollutants including pollen, dirt, dust and moisture. They also help in filtering out bacteria which range in sizes form

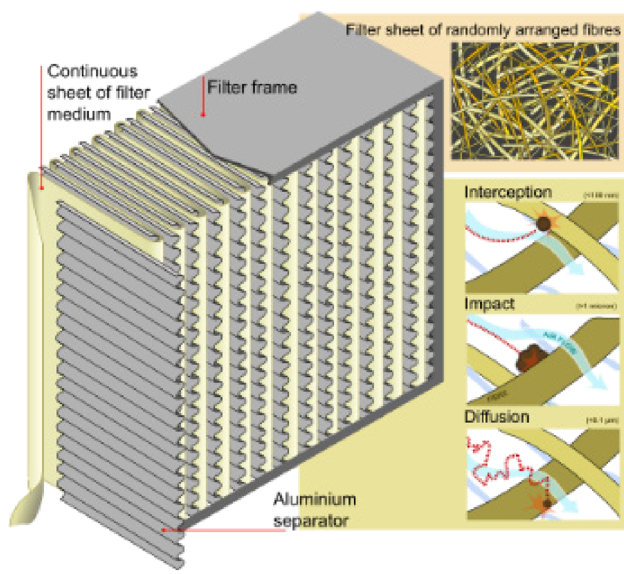



**Figure 1.** HEPA filter.

0.2-2.0 μm, virus whose size vary between 0.0 to 0.3 μm). Further they also filter submicron liquid aerosol whose sizes are between 0.02 to 0.5 μm.

HEPA filters also meet the standards required in terms of efficiency. ISO, European Standard Common standards require that a HEPA air filter must remove from the air that passes through it at least 99.95% of particles having diameter >= 0.3 μm. On similar lines ASME, U.S. DOE requires 99.97% of the same being removed. Further the filtration efficiency is expected to increase for particle diameters both less than and greater than 0.3 μm (Hudda & Fruin, 2016).

HEPA filters typically comprises a mat of randomly arranged fibers typically made of polypropylene or fiberglass with diameters between 0.5 and 2.0 μm. These filters are composed largely of tangled bundles of fine fibers (Hudda, *et al.*, 2016). In action, the air is passed through convoluted and narrow pathways. As the air is passed, the bundles of fibers block the particles from passing through. HEPA filters are designed to target a range of particle sizes. These particles are trapped (they stick to a fiber) through a combination of three mechanisms; viz., diffusion, interception and impaction. During Diffusion particles below 0.3 μm are captured, while mid size particles are captured during Interception. Finally, in impaction the larger particles which are unable to avoid fibers by following the curving contours of the air stream and are forced to embed in one of them directly (Masiol, *et al.*, 2017)

Some of the common disadvantages of these filters are: HEPA filters cannot trap other pollutants such as gases, fumes, chemicals and odors. Replacement of filters is also costly. Shape and compactness are the factors to be considered while designing the air purifier. Some filters might be washable others are not. There's no guarantee that this will conform to industry regulations.

## 2.0 Air Purifier with HEPA Filter

In the present work an attempt has made to design an outdoor Air Purifier with HEPA filter which would efficiently decrease pollutants emitted by automobiles in heavy traffic areas. The air purifier is designed to absorb the particulate matter, CO and Volatile Organic Compound (VOC) such as hydrocarbons. An attempt has also made to utilize renewable energy sources such as solar and wind energy for its operation. The current outdoor air purifier is a simple design which consists of a suction chamber and a specially designed air filter. The design of the same are discussed here.

### 2.1 Design of Air Purifier

Figure 2 shows the 3D model of suction chamber. The design of the suction chamber is done based on the size of the propeller fans. The suction chamber consists of the four serpentine ducts one in each of the four directions. The polluted air is sucked into the serpentine ducts by the propeller fans present in the inlet of the serpentine ducts. Then the serpentine ducts changes the flow direction of the sucked polluted air from horizontal in the inlet to the vertical as the polluted air reaches the common airway.

The common airway is designed exactly above the suction chamber so that the air coming from all four serpentine ducts flow in the same common path. Then the filter chamber is designed according to the requirements based on the dimensions of filters and number of filters to be installed in the filter chamber. The filter chamber is designed above the common airway where the air coming from the common airway passes through the filter layers present in the filter chamber to obtain clean and fresh air.

The proposed air purifier utilizes wind energy as the secondary source of power to run the battery we designed a wind turbine as per requirements. Then the outer stand is designed such as to hold the model and the solar-panel mounted on the top of it. The stand is designed in such a way that it has two compartments the upper and lower halves as shown in the Figure 3. The upper half is designed in a way to hold together the sub-assembly of the suction chamber, the common airway and the filter chamber. The lower half of the compartment accommodates the wind turbine installed in it with the use of ball bearing.

### 2.2 Design of Filters

In the present work the filters are chosen to decrease the amount of dust, Carbon Monoxide (CO), Carbon Dioxide ($CO_2$) and Volatile Organic Compounds (VOC's) such as hydrocarbons (HC) in the surrounding atmosphere. Based on requirement HEPA and two Activated Carbon filters are selected.

The HEPA filter is chosen for its purpose of removing dust particles, particulate matter and smoke. The selection of the Activated Carbon filter is to remove airborne chemicals, carbon monoxide (CO), and Volatile Organic

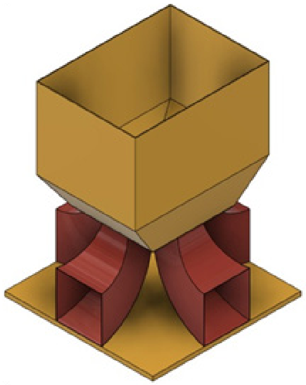


**Figure 2.** Suction chamber.

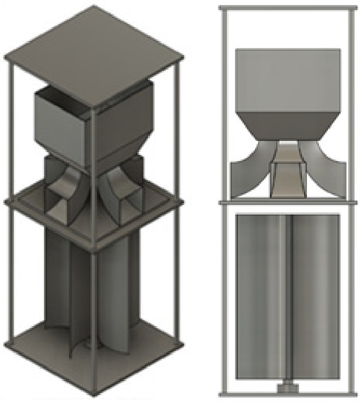


**Figure 3.** Typical views of proposed outdoor air filter.

**Figure 4.** Different filters used in the air purifier.

**Figure 5.** Construction of filter chamber.

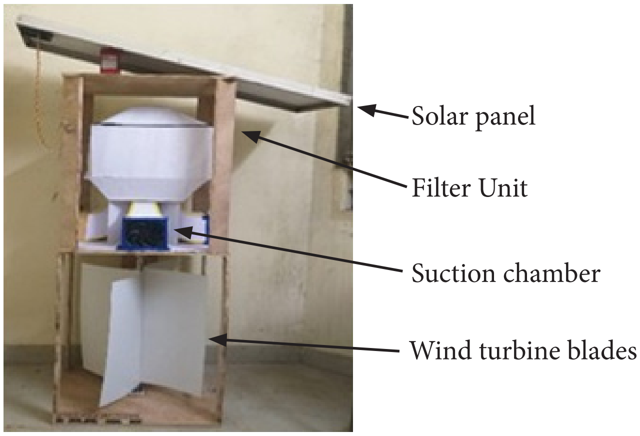



**Figure 6.** Final assembly.

**Figure 7.** Testing setup.

**Figure 8.** Testing at PUCTC.

Compounds (VOC's) such as Hydrocarbons (HC). Figure shows different filters used in the proposed model.

HEPA Filter Activated Carbon Filter Activated Carbon Filter 2

## 2.3 Fabrication of Air Purifier

The foam material is primarily used for the fabrication of the different parts and easier to build prototype and make any changes during testing. The suction chamber, the common airway and the filter chamber are all made of the foam material. Card-board is used for the fabrication of the wind turbine and pipe is used as the axis for the wind turbine. The outer stand is made of plywood material to withstand the model and the solar-panel. The stand is of two compartments namely upper and lower. The upper compartment is to accommodate the suction chamber, the common airway and the filter chamber and the wind turbine is installed in the lower compartment. The two compartments are held together by four columns each on either side. The solar panel is mounted at the top of the stand to get the sunlight required for its purpose. Figure 5 shows the construction of filter chamber and set up for carrying out the test. Solar panel is mounted on top of the stand so as to get the direct sunlight. Then the solar panel is connected to the battery via a micro controller to charge the battery continuously during the sunlight. The wind turbine is placed in the bottom half of the stand with the help of ball-bearing. The DC motor connected to the wind turbine is used to charge the battery as a secondary source of energy. The Filter chamber and final assembly is shown in the Figures 5 and 6.

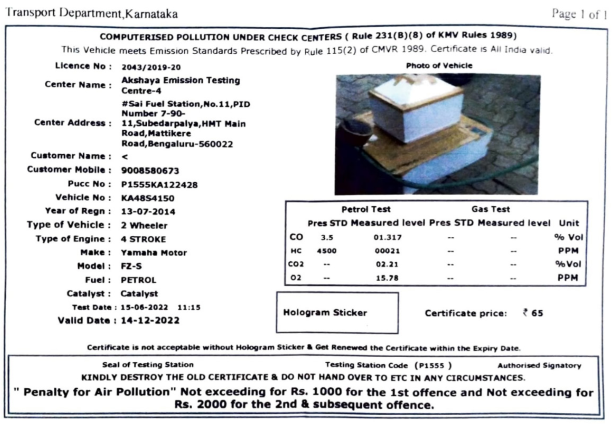
## 2.4 Testing of Air Filter

Purifier was tested in a public Pollution Under Control Testing Centre (PUCTC). Necessary construction was done to ensure that no leakage of the air from the system in between inlet and outlet. Test is conducted by accelerating the vehicle to ensure enough emission for the purifier and the unit was turned on for 10 minutes continuously. Testing Gun was inserted at the outlet of the purifier to check the quality of the air coming out of the purifier. Process is repeated four times to obtain accurate readings. Test results were noted and compared with vehicle emissions The test setup is shown in Figure 7. Figure 8 shows the testing in process.

# 3.0 Results

The tests were conducted using the current air purifier. Figure 9 shows a typical test report provided by the PUCTC.

It has been found that there is drastic increase in CO in the first two tests (Trial Nos. 1 and 2; Table 2). It is due to the erosion of filter installed inside the unit. To overcome this problem another Carbon filter is installed in the filter chamber to reduce the CO level. It is also provided with



Transport Department,Karnataka Page 1 of 1

COMPUTERISED POLLUTION UNDER CHECK CENTERS ( Rule 231(B)(8) of KMV Rules 1989)

This Vehicle meets Emission Standards Prescribed by Rule 115(2) of CMVR 1989. Certificate is All India valid.

Licence No : 2043/2019-20
Center Name : Akshaya Emission Testing Centre-4
Center Address : #Sai Fuel Station,No.11,PID Number 7-90-11,Subedarpalya,HMT Main Road,Mattikere Road,Bengaluru-560022
Customer Name : <
Customer Mobile : 9008580673
Pucc No : P1555KA122428
Vehicle No : KA48S4150
Year of Regn : 13-07-2014
Type of Vehicle : 2 Wheeler
Type of Engine : 4 STROKE
Make : Yamaha Motor
Model : FZ-S
Fuel : PETROL
Catalyst : Catalyst
Test Date : 15-06-2022 11:15
Valid Date : 14-12-2022

Photo of Vehicle

| | Petrol Test Pres STD | Petrol Test Measured level | Gas Test Pres STD | Gas Test Measured level | Unit |
|---|---|---|---|---|---|
| CO | 3.5 | 01.317 | -- | -- | % Vol |
| HC | 4500 | 00021 | -- | -- | PPM |
| CO2 | -- | 02.21 | -- | -- | %Vol |
| O2 | -- | 15.78 | -- | -- | PPM |

Hologram Sticker Certificate price: ₹ 65

Certificate is not acceptable without Hologram Sticker & Get Renewed the Certificate within the Expiry Date.

Seal of Testing Station Testing Station Code (P1555 ) Authorised Signatory

KINDLY DESTROY THE OLD CERTIFICATE & DO NOT HAND OVER TO ETC IN ANY CIRCUMSTANCES.

" Penalty for Air Pollution" Not exceeding for Rs. 1000 for the 1st offence and Not exceeding for Rs. 2000 for the 2nd & subsequent offence.

**Figure 9.** Typical test report.

**Table 2.** CO emissions' results

| Trial No | CO emissions from Vehicle (%Vol) | CO after adopting Air Purifier (%Vol) | %Reduction/ %Increase | Remarks |
|---|---|---|---|---|
| 1 | 0.114 | 1.459 | 11 % increase | Failure |
| 2 | 0.114 | 1.317 | 10 % increase | Failure |
| 3 | 0.365 | 0.008 | 97.80% decrease | Success |
| 4 | 0.365 | 0.006 | 98.35% decrease | Success |

**Table 3.** HC Emissions' results

| Trial No | HC emissions from vehicle (ppm) | HC after adopting Air Purifier (ppm) | %Reduction/ %Increase | Remarks |
|---|---|---|---|---|
| 1 | 88 | 15 | 82.95% decrease | Success |
| 2 | 88 | 21 | 76.13% decrease | Success |
| 3 | 590 | 35 | 94.06% decreased | Success |
| 4 | 590 | 32 | 94.57% decrease | Success |

better leak-proof isolation for the system and inlet air is driven by optimum acceleration of the vehicle. Later it was observed that there is significant reduction in the level of CO which is about 98%. The same result is obtained with the repetition of experiment. (Trials 3 and 4; Table 2). It was found that there is a maximum reduction of 98.35% CO emission

On similar lines, the results of HCs in the emissions were found to be 82.95 and 76.13% in the first two trials (Table 3). After addition of additional carbon filter, the HC emissions reduced by 94.06 and 94.57% in two trials (Trial Nos. 3 and 4; Table 3).

Reduction in the emission values is mainly due to the introduction of the HEPA and carbon filters. Use of alternate sources of energy is another added advantage of the proposed system.

## 4.0 Conclusions

This article seeks to provide some insight into design of innovative air purifier and its testing. The following conclusions can be drawn from the present work

1. The use of two Carbon filters and one HEPA filter was found to be more efficient than a single carbon filter and a HEPA filter at optimum conditions.
2. From the results obtained from the test it was found that there was an average decrease in the level of CO about 98% and level HC was about 86.8% respectively with respect to vehicle tailpipe emission. Which shows the Outdoor air purifier is effective and efficient in reducing the amount of CO and HC from the polluted environment.
3. Alternative sources of energy like solar and wind for charging the battery. Battery gets charged fully in 2-3 hours in optimum sunny conditions and in 4-5 hours in cloudy conditions and the battery can run up to 7 hours in full load conditions. From solar and battery specifications we conclude that the battery can run the whole day using solar energy.

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