



Solar Energy Based Air Quality Monitor And Purifier For Automotive Application

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Abstract: The article discusses the solar photo voltaic-based air purifier system for automotive application. In this system, impure air is drawn through layers of pre-filters consisting of HEPA and carbon filters. To kill the germs present in the cabin air it is passed through ultraviolet lights. The system successfully filters the particulate matter of size 2.5 micrometres to 10 micrometres. The system also reduces the pungent smell present in the impure air inside the cabin. The system uses solar energy to charge the batteries independently used for solar air purifier. The solar panels are placed on the roof top of the vehicle. This makes sure that the vehicle energy source does not have the additional load to power the air purifier system. The solar energy is used for charging the batteries. The energy from the charged batteries is used for powering suction and blower pumps. The proposed system is very successful in reducing particulate matter, germs, CO₂, NO_x, and pungent smell from the impure air in the vehicle cabin environment. The system is environmentally friendly since it uses solar energy as a power source.

Index Terms - DC Motors, ESP32, Sensors, Micro-controller, Bluetooth.

I. INTRODUCTION

Indoor air quality of passenger vehicles is utmost important and many of the studies has found that most of the working class spend at least 8% of the time in traveling. As per the World Health Organization (WHO) definition of health is given as "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Vehicle cabin bad air can result in discomfort and may cause serious illnesses. As per the WHO report [2] the major types of pollutants in the air are dust particles, methane (CH₄), carbon-di-oxide (CO₂), carbon mono-oxide (CO), oxides of nitrogen (NO_x), and oxides of Sulphur (SO_x). These airborne pollutants contribute to respiratory illnesses such lung cancer, acute lower respiratory infections, ischemic heart disease, and chronic obstructive pulmonary disease. Hence maintaining air quality is a big problem today that is faced by humanity.

Maintenance of good air quality inside the vehicle cabin is an important challenge for vehicle manufacturers. Especially if it is urban transport vehicles. The main challenge with these vehicles is the crowd inside the vehicles. The issues become more challenging during rainy days when the vehicle windows have to be kept closed. The results in lot of difficulties for fellow passengers. In this scenario maintaining air quality is a challenge.

Today, a variety of air purifiers are available in the market, to improve the air quality inside the vehicle. Some of this system are chemical in nature such as deodorants, activated carbon bags etc. They have hidden health hazards in long run. There are some systems which are mechanized in nature they are specifically designed to target the air around passengers travelling in the vehicle and they use vehicular power source to energize there sub systems. This results in additional load on the vehicle. This paper proposes as device that cleans the air vehicle cabin. The purifier absorbs the pollutants kills the germs and releases clean air to the

vehicle cabin. The proposed device uses solar energy as a source of power, cleans the surrounding air, and monitors the air quality inside the vehicle cabin.

II. RELATED WORK

To address the vehicular cabin air pollution researchers, academia and industry have done a significant amount of work in this area. Various types of materials and methods have been proposed to remove the contaminants from the cabin polluted air.

Textiles, athletic wear, automobiles, sunscreens, and coatings are just a few examples of the items that incorporate nanotechnology. Nano-fibers is one of the nanotechnology products that has been studied independently or in combination with other materials like fiberglass and textiles for air filtering purpose. The study shows that filtering efficiency is considerably improved. The use of nanofibers can filter volatile organic compounds, particulate matter, and bacterial contaminations [1].

"Photocatalysis is a term that defines a process in which a substance is activated or stimulated under the effect of light. Photocatalyst is the substance that induces this stimulation; it alters the rate of reaction without being involved itself in the chemical reaction" [2]. There are various types of photocatalysis available that are used for air filters. The commonly used is titanium dioxide (TiO₂) which costs less; availability is high and poisons less in nature. Other Photocatalysis considered is oxides of silver and zinc. The review proposes Photocatalysis as a useful technique to reduce air pollution by degrading air pollutants into harmless products and useful gases [3].

An investigation of various air filtration theories, materials, and standards is done for building ventilation. In this study, several air filtration systems are assessed in terms of their ability to enhance air quality, filtering effectiveness, energy and economic behaviour, thermal comfort, and auditory impact. The advantages, drawbacks, and difficulties of air filtration systems are also explored in the study, which also focuses on current research and development in this area. In the upcoming years, emerging filtration technologies including nanofibers, Trombe walls, and botanical bio-filter are projected to spread over the entire planet. [4].

The multiple indoor air purifiers are proposed for an educational institution. It comprises of a monitoring gadget for outdoor air quality and a PC-based administrative server application. To reduce the noise produced by the fans and blowers during class and during breaks, the indoor air purifiers feature additional modes. The gadget that monitors outside air quality that is installed on exterior windows measures outdoor air pollution and sends the results to a server application. The server application is then placed on a computer that the instructor is in charge of, and it is this computer that gets the measured data from the various inside air purifiers and the outside air quality monitoring equipment. If the external air quality is better than the inside air quality, the server software alerts the instructor that it is okay to open the windows for natural air circulation. In addition, the server program can control and turn the air purifiers on or off, and inform the teacher whether to open the window or not [5].

An air filtering system for subway stations, involving the use of dry aerosol that can provide high-performance antiviral ability to the filters is studied. It uses a dry aerosol coating process, along with a spark discharger and carbon-brush-type ionizer. Here, silver nanoparticles were produced using a spark-discharge generation system with an ion-injection system and were employed as antiviral agents for coating onto a medium-grade air filter. The proposed method is evaluated to determine if it was effective by using airborne viruses that mimic the real coronavirus. The results verified that the degraded antiviral performance regenerates without damaging other properties of the filter. The proposed method is highly practical as it can be applied to the filters without further complications [6].

A list of the most popular and important air purification techniques, including those using HEPA filters, electrostatic smoke precipitators, activated carbon, and UV light, has been shown. It has also been emphasized that these techniques are used in air purifiers made by OEMs. Studies and reviews have been done on some of the most cutting-edge techniques for air purification, including those that use transparent PAN filters, photochemical materials, soy proteins, and silk nano fibrils. When compared to traditional HEPA filters, it has been discovered that these techniques offer an appealing and affordable avenue for filtering out PM 2.5. [7].

The paper [8] focuses on the design and development of low-cost do-it-yourself (DIY) air purifiers, using a ventilating fan, air pump, water pump, and an ultrasonic generator that can be used during the haze pollution. There are six different types of home air purifiers available. At 0, 10, 20, 30, and 60 minutes (min), the levels of particulate matter (PM) and carbon dioxide (CO₂) were measured. This process was performed three times. The last air pollution measurement for each investigation would be taken after 10 minutes of the third trial. The results demonstrated that the electrostatic fiber and high-efficiency particulate air (HEPA) filter combination was the most effective method for lowering PM and CO₂ levels after 60 minutes. The air

pump technique produced the maximum PM reduction rate at 30 minutes (99.330 to 100%). All experiments' CO₂ levels have seen various fluctuations. All air purifier systems, with the exception of those with HEPA filters and electrostatic fibers, saw a drop in PM levels after 10 minutes of a closed machine. In conclusion, the HEPA filter and electrostatic fiber approach is the greatest option for lowering PM levels without increasing humidity and vapour generation, whereas the air pump technique is the best method for reducing particulate matter and cost without taking humidity into consideration.[13]

Proton-Transfer-Reaction Mass Spectrometry (PTR-MS), chromatographic methods (Gas Chromatography/Mass Spectrometry and High-Pressure Liquid Chromatography with UV detection), and sensory assessments of air quality performed by human subjects were used to measure the impact of an air purifier based on photo catalytic oxidation (PCO) on indoor air quality. The experiment was carried out in a mock workplace with 0.6, 2.5, and 6 hours of ventilation, along with other sources of pollution (carpet, chipboard, and linoleum). Additional measurements were taken at the lowest air change rate without any sources of pollution within the workplace. The photocatalytic air purifier was tested under each circumstance both on and off. The findings demonstrate that the air purifier's operation enhances indoor air quality in the presence of pollutants released by furnishings and building materials, as shown by sensory evaluations provided by human test participants. The PTR-MS method has shown that it also lowers the amounts of several chemical substances that are in the air. Results from chromatographic tests show a similar trend for the lowest ventilation, although several of the 50 chemicals that were intended for investigation were not found at all, regardless of whether the purifier was on or off. The outcomes weren't conclusive for the two greater ventilation situations. [9].

III. OBJECTIVES

Most of the work that has been carried out in the field of air purifiers has been related to the materials used for air purification or the ability to filter any one of the pollutants. The primary objective of the paper is to develop a solar energy-based outdoor air quality monitor and purifier. It should be able to sense different types of gases, and particulate matter and should be able to remove harmful germs in the impure air. The system should not depend on the utility energy source for powering its various components. The controller board used should be cost-effective and easy to implement. In this regard, it is proposed to use various types of sensors, and filters such as pre-filter, activated carbon filter, and HEPA filter. To remove the harmful germs it is proposed to use ultraviolet rays. To keep the system cost effective it is proposed to use an Arduino-based controller. To power the various components of the system it is proposed to use solar energy which will be stored in battery packs. The stored energy in the battery packs can be used during night-time.

IV. METHODOLOGY

Using information from sensors and a relay to turn on the Fans when necessary, the Arduino Uno is utilized to operate the complete system. The solar panel is used to collect energy from the sun, and the resulting electricity is then used as a power source to run the complete system. The system draws its necessary power from a 12v battery, which is also used to store the solar panel electricity that has been captured. Relays are employed in the system because they are programmable electrical switches that can be managed by Arduino and microcontrollers. It is used to turn on and off devices in accordance with a program that was created and makes use of high voltage and/or high current. Between Arduino and high-voltage devices, relay serves as a bridge.

Here, MQ series sensors are used to check the air quality. Sensors MQ135, MQ2, and MQ9 are employed. We employ two MQ135, two MQ9, and two MQ2 sensors. At the front of the model, MQ sensors monitor the environmental air's quality. First, the air quality is being measured at the front end by 1-MQ 135, 1-MQ 9 and 1-MQ 2 sensors. In the future, 1-MQ 135, 1-MQ 9, and 1-MQ 2 will be used to measure the air quality of the filtered air in the background. The two readings from the MQ series sensors, which were transformed from analog voltages to digital number values via the Analog to Digital Conversion process, are then compared.

V. DESIGN AND IMPLEMENTATION

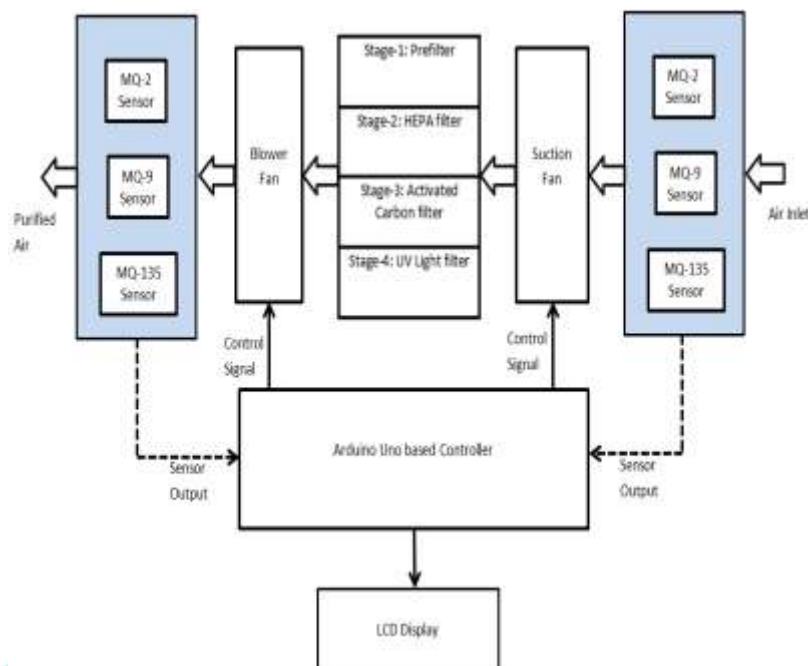


Figure 1: System Architecture of air quality monitor and purifier system for vehicles

Figure 1 shows the block diagram of the proposed system. Utilizing gas sensors from the 3-MQ series, the initial air quality of the ambient air is assessed. Specifically, MQ135, MQ2, and MQ9. The MQ135 sensor is used to detect toxic gases and smoke, such as benzene, ammonia, and Sulphur, from which the quality of the air is inferred. MQ2 operates on 5V DC and is used to detect liquid petroleum gas, methane, and carbon monoxide in the air. It also detects smoke and other airborne contaminants. There are analog and digital output pins on MQ series gas sensors. The digital pin goes high when the amount of gases in the air exceeds the threshold value. The on-board potentiometer allows you to change this threshold value. The analog output pin generates an analog signal that may be used to estimate the concentration of various gases in the atmosphere. They are also known as Chemiresistors since gas detection depends on a change in the sensing material's resistance when the gas comes into contact. Three distinct types of gas sensors are utilized to detect various sorts of gases. For reliable readings, MQ series sensors must be pre-heated for 30 to 60 seconds. [10]. The system architecture is shown in Figure 1.

Table 1: AQI comparison values according to the National Pollution board

AQI Category, Pollutants and Health Breakpoints								
AQI Category (Range)	PM ₁₀ 24-hr	PM _{2.5} 24-hr	NO ₂ 24-hr	O ₃ 8-hr	CO 8-hr (mg/m ³)	SO ₂ 24-hr	NH ₃ 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5-1.0
Moderately polluted (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-580	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	581-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-740	17-34	801-1600	1201-1600	3.1-3.5
Severe (401-500)	431-500	251-500	401-500	741-1600	34+	1601+	1601+	3.5+

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact.
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease.
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401–500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity.

As a result of the analog voltage varying in accordance with the gas concentration present in the air from MQ-series sensors, the sensors provide digital output values ranging from 0 to 1023. It is challenging to research the differences of these gas sensors since the six MQ-series sensors have distinct sensitivities and differ from one another. For around 45 to 50 seconds, the output from all of these sensors is compiled and standardized to the air quality index of the room without pollution. Therefore, by doing this, it is simple to analyze how the sensor outputs change when the gas concentration changes. Table 1 contains the National Pollution Board's comparative figures for the air quality index.

These sensors' output is delivered to the Arduino. These sensors' digital output values are shown below, which may be used to investigate how gases change over time. The AQI, which is used to gauge the air quality in the atmosphere, is thought of as the digital output values from the sensors. To determine the quality of atmospheric air, the output from three MQ series sensors—MQ135, MQ2, and MQ9—located on the model's front side is used. The National Government Pollution Board states that the air is deemed to be good if the air quality index varies from 0 to 50. The air quality is deemed moderate if the air quality index falls between 51 and 100. For sensitive populations, the air is deemed hazardous and maybe deadly if the air quality index falls between 101 and 150. If the AQI of the air is between 15 and 200, it is considered unhealthy and potentially harmful to human health. If the air quality index falls between 201-300, it is said to be extremely hazardous and harmful to breathe. The air is deemed dangerous and unhealthy to breathe if the air quality index is between 301 and 500. Therefore, if the air quality index exceeds 100, the air is considered to be unhealthy. [11].

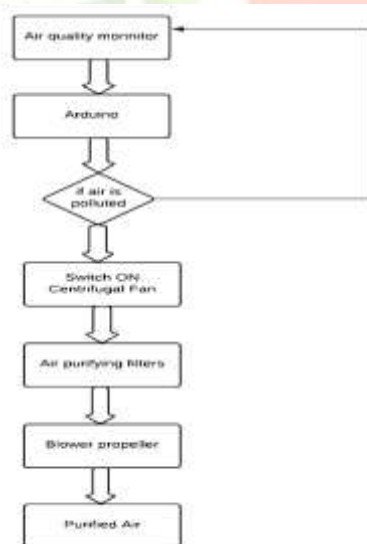


Figure 2: Flowchart of design

The limit has been set at 100. If the sensor's digital output is greater than 100, the air should be cleansed since it is deemed too filthy and harmful to breathe. In order to cleanse the contaminated air, turn on the centrifugal fan or blower that is located at the front of the model. Now the air is passed via a pre-filter where big particles such as sand, stones, dust, insects, pollen, and other fibers are filtered or eliminated before they reach the main filter. The air is then routed through a High-Efficiency Particulate Filter, which traps particles in a mesh of very small fibers, after being cleaned of big particles by the pre-filter. Dust, pollen, and other airborne pollutants may be eliminated from the air by using these fibers since they are so tiny that they can capture particles as small as 0.3 microns in diameter. Up to 99.97% of contaminants may be removed from dirty air

with HEPA filters. As a result of active carbon filters, which remove smells, gases, and volatile organic compounds from the air, it is now free of big particles and numerous contaminants. Now that infections, germs, and viruses are eliminated by UV radiation, the air is cleansed of big particles, pollutants, smells, gases, and volatile organic compounds. The blower located at the back of the model is now releasing air into the environment. Here, the MQ series sensors are used to verify the air quality of the filtered air using digital values derived from analog voltages and sent to an Arduino board. The MQ sensors are constantly monitoring the air quality. The centrifugal fan is turned on to draw in air to purify contaminated air if the Air Quality Index value is more than 100; otherwise, if the value is less than 100, the air quality is deemed satisfactory and there is no need to purify the air, thus the centrifugal fan is not turned on. [12]. Regarding pin connections, the MQ135 sensor—MQ135-1 to A0 of Arduino—is located at the front and is used to determine whether or not ambient air has to be filtered. MQ135-2 to A1 pin, which is located at the rear, is used to test the purity of the filtered air. MQ2-1 is attached to Arduino's pin A2 and is located at the front of the model used to determine whether or not ambient air has to be cleaned. MQ2, which is located at the rear and connected to the Arduino's A3 pin, is used to test the purity of the filtered air. MQ9 is linked to Arduino's A4 and is placed in front of the model used to determine whether or not ambient air has to be filtered. MQ9, which is located at the rear and connects to the Arduino's A5 pin, is used to test the purity of the filtered air. As our Arduino has a 10-bit analog-to-digital converter, the method involved in employing MQ series sensors is the analog voltage from these sensors is transformed to voltage values ranging from 0–1023. The procedure is done in a straightforward manner, as shown by the flowchart in Figure 2.

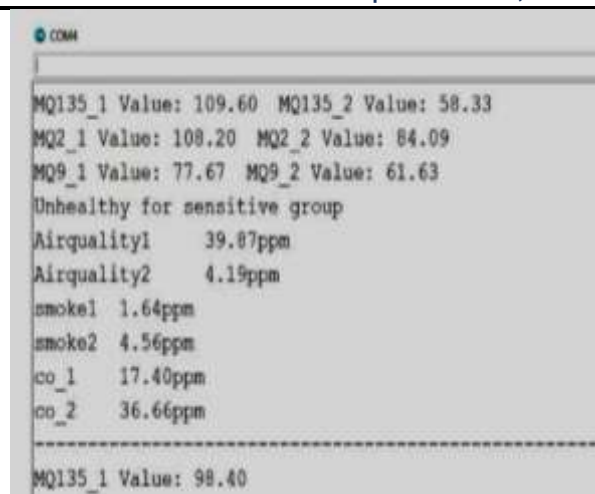
The system's flowchart is seen in Figure 2. If the Air Quality Index (AQI) is higher than the threshold value (100), it is monitored, and the centrifugal fan is turned on to draw the contaminated air in. The centrifugal fan is not turned ON if the AQI is less than 100. Figure 3 displays a model of a solar-powered outdoor air purifier with a device to measure air quality.



Figure 3: An implemented model of solar energy based air purifier with air quality monitor for vehicles

VI. RESULTS AND DISCUSSION

Utilizing gas sensors from the 3-MQ series, the initial air quality of the ambient air is assessed. Specifically, MQ135, MQ2, and MQ9. The centrifugal fan draws in air when the air quality index of the surrounding environment is more than 100, and the air is subsequently passed through filters. This allows us to breathe clean purified air. Figure 4 shows that the air quality of burning incense sticks before purifying was 110 and after purifying using our model, we are getting air quality of 58.33.



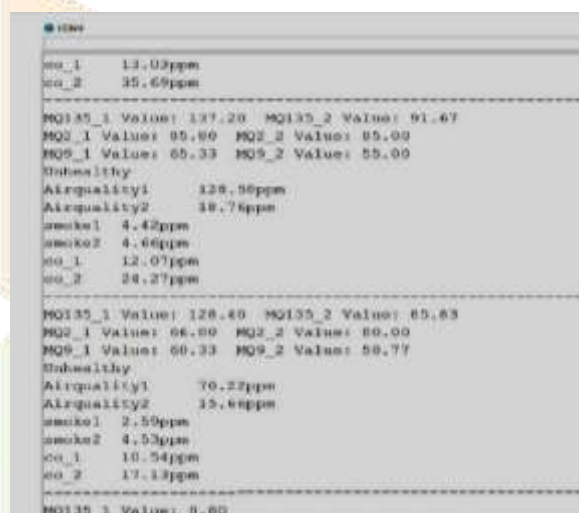
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COM1
MQ135_1 Value: 109.60 MQ135_2 Value: 58.33
MQ2_1 Value: 108.20 MQ2_2 Value: 84.09
MQ9_1 Value: 77.67 MQ9_2 Value: 61.63
Unhealthy for sensitive group
Airquality1 39.87ppm
Airquality2 4.19ppm
smoke1 1.64ppm
smoke2 4.56ppm
co_1 17.40ppm
co_2 36.66ppm
-----
MQ135_1 Value: 98.40

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Figure 4: Screenshot of filtered results of Air from Burning of Incense Stick

Figure 5 shows that the air quality of burning wood before purifying was 137.20 and after purifying using our model, we got an air quality of 91.67.



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COM1
co_1 13.03ppm
co_2 35.69ppm
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MQ135_1 Value: 137.20 MQ135_2 Value: 91.67
MQ2_1 Value: 85.00 MQ2_2 Value: 85.00
MQ9_1 Value: 65.33 MQ9_2 Value: 55.00
Unhealthy
Airquality1 128.98ppm
Airquality2 18.76ppm
smoke1 4.42ppm
smoke2 4.66ppm
co_1 12.07ppm
co_2 28.27ppm
-----
MQ135_1 Value: 128.40 MQ135_2 Value: 85.83
MQ2_1 Value: 86.00 MQ2_2 Value: 80.00
MQ9_1 Value: 60.33 MQ9_2 Value: 58.77
Unhealthy
Airquality1 70.22ppm
Airquality2 15.6ppm
smoke1 2.59ppm
smoke2 4.53ppm
co_1 10.54ppm
co_2 17.13ppm
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MQ135_1 Value: 8.60

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Figure 5: Screenshot of filtered results of Air from Burning of Wood

Table 2: Summary of the output obtained

Applied Smoke	(AQI Before)	(AQI After)	% Improvement in AQI
Burning a stick of incense	109	71	38
Burning a Dry grass	115	80	35
Burning a Wood piece	126	83	43

Table 2 gives the overall summary of the work carried out and percentage improvement of Air quality index value before and after filtering.

Figure 6 shows the air purifier placement inside the car. It is placed in storage of the car. Figure 7 shows the placement of solar panel on the roof of the car.



Figure 6: Solar energy based air purifier with air quality monitor placed inside the vehicles.



Figure 7: Placement of solar panel for solar energy based air purifier with air quality monitor for vehicles

CONCLUSION

Since it has continued for a long, the primary environmental problem, "Air pollution," is undeniably contributing to climate change, which is negatively affecting human health. All living species on this earth have a right to clean, unpolluted air, and it is the responsibility of all people to maintain this right. In this regard, solar outdoor air purifier is an initiative to keep the surrounding air clean. By employing MQ series sensors to measure an area's air quality index and then purifying the air using filters to provide safe air wherever feasible, the Solar Outdoor Air Purifier seeks to minimize pollution in a particular outdoor location. The developed solar outdoor air purifier can measure the pollutants in the air in real-time and record the same. The device is user-friendly, portable, and can monitor various pollutants in the air. The device uses solar energy to power its various equipment, and equipment used in this system consumes less power. Since the device is dependent on an environment-friendly solar energy source and the device itself is economical in the long run.

FUTURE WORK AND APPLICATIONS

- Using significantly more high-power centrifugal fans to cover a bigger area will help the project.
- The project may be improved by adding additional solar panels and by supplying extra electricity to outside sources.
- To use the Global System for Mobile (GSM) to monitor and regulate how the model in Android devices is operating.
- The device can be used near traffic junctions to address dust particles and vehicular emissions consisting of oxides of Nitrogen and Sulphur

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