Solar Powered Outdoor Air Purifier with Air Quality Monitor

A thesis submitted for partial fulfillment of the requirements for the Degree of

Bachelor of Science

in

Mechanical Engineering

Project supervisor
(Ashiq Hussain)

Project Coordinator

HOD
Mechanical Engineering
Department

DEPARTMENT OF MECHANICAL ENGINEERING
SWEDISH COLLEGE OF ENGINEERING AND TECHNOLOGY, WAH CANTT

(Affiliated with the University of Engineering & Technology, Taxila)

November 2023

Abstract

The increasing levels of air pollution have become a global concern, resulting in adverse effects on human health and the environment. Therefore, this research aims to develop a solar-powered outdoor air purifier equipped with air quality monitoring, HEPA, and carbon filters. The system will utilize renewable energy to purify ambient air and monitor the real-time air quality index. The proposed system primarily focuses on removing fine particulate matter (PM2.5) and harmful gases, such as carbon monoxide and nitrogen dioxide, from outdoor air. The air quality monitoring system will use sensors to measure the concentration of pollutants, and the purifier's filters will trap them before releasing clean air back into the environment. The system's portability will make it suitable for use in outdoor public spaces, such as parks, streets, and marketplaces. The system's performance will be evaluated through lab testing and field trials to assess its efficiency in reducing air pollution levels. The research findings will provide a sustainable solution to outdoor air pollution, contributing to the development of cleaner and healthier environments for all.

Declaration

We dedicate this project to our beloved parents, whose unconditional love, endless sacrifices, and unwavering support have been the foundation of my success. They have instilled in us the values of hard work, determination, and faith in Allah, which have guided us through the ups and downs of my academic journey.

We also dedicate this dissertation to our friends and our teachers who supported us throughout the process.

Acknowledgment

In the name of Allah, the most gracious and the most merciful.

All praise and thanks are to Almighty Allah, the most merciful and compassionate, who has granted us the opportunity, the ability, and the resources to complete this work.

We would like to express our sincere gratitude to our parents and family for their unwavering support, love, and encouragement throughout my academic journey.

We would also like to thank my supervisor **Engr. Ashiq Hussain** for their valuable guidance, constructive feedback, and patience during the development of this Project. His expertise and dedication have been instrumental in shaping my research and enabling me to produce quality output.

We would also like to express our sincere gratitude to our **HOD Dr. Liaquat Ali Najmi, Engr. Engr. Naeem, Engr. Ghulam Murtaza** and all the Faculty members for guiding us throughout.

Dedication

Dedicated to all God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge, and understanding. He has been the source of my strength throughout this program. We also dedicate this work to our parents who have encouraged us all the way and whose encouragement has made sure that we give it all it takes to finish that which I have started. Thank you. Our love for you all can never be quantified. God bless you.

Table of contents

List of figures

List of Tables

Abbreviations

HEPA: High-Efficiency Particulate Air

UV: Ultraviolet

VOC: volatile organic compounds

SOAFs: Smart outdoor air filtration system

BLDCM: Brushless dc motors

SDGs: Sustainable Development Goals

FYDP: Five-Year Development Plan

SAP: Solar Air Purifier

PV: Photovoltaic

UV-C: Ultraviolet-C

CAD: Computer-Aided Design

BOM: Bill of Materials

R&D: Research and Development

EMI: Electromagnetic Interference

PCB: Printed Circuit Board

ROI: Return on Investment

CFD: Computational Fluid Dynamics

PM2.5: Particulate Matter 2.5 micrometers or less

O&M: Operations and Maintenance

TRL: Technology Readiness Level

CO2: Carbon Dioxide

O3: Ozone

AQI: Air Quality Index

HMI: Human-Machine Interface

MPPT: Maximum Power Point Tracking

BMS: Battery Management System

PPE: Personal Protective Equipment

QA/QC: Quality Assurance/Quality Control

CHAPTER 1

INTRODUCTION

1.1 Introduction of project

The introduction of this project is aimed at addressing the critical issue of air pollution and its adverse effects on human health and the environment. Air quality degradation has become a pressing global concern, leading to various respiratory and cardiovascular diseases. In response to this problem, this project introduces a novel approach—a solar-powered air purifier with an integrated air quality monitoring system. By harnessing the energy of the sun and using advanced filtration technology, this system offers a sustainable solution to both purify the air and provide real-time data on air quality, thus contributing to improved living conditions.

1.2 Historical background

To comprehend the significance of this project, it is essential to trace the historical evolution of air purification and monitoring technologies. Throughout history, humanity has witnessed a growing awareness of air quality issues, leading to the development of various air purification methods and monitoring devices. From the ancient use of plants for air purification to the industrial revolution's air pollution challenges, this section provides an overview of key milestones and innovations in the field of air quality control.

1.3 Problem statement

The problem statement establishes the core issue this project seeks to address. Rapid urbanization and industrialization have led to increased levels of air pollution, endangering public health. Existing air purifiers often lack efficiency and are heavily reliant on electricity, which raises concerns about sustainability. Moreover, air quality monitoring systems are often separate from air purifiers, leading to inefficiencies in addressing air pollution in real time. This project aims to bridge these gaps by designing an eco-friendly, solar-powered air purifier with an integrated air quality monitoring system to combat indoor air pollution effectively.

1.4 Aim and objectives

The primary aim of this project is to design and fabricate a solar air purifier equipped with an air quality monitor system. Specific objectives include selecting and integrating HEPA and carbon filters for air purification, developing a solar power system for sustainability, and designing a monitoring component that provides real-time data on air quality. These objectives collectively work towards the overarching goal of creating a comprehensive solution to indoor air pollution.

1.5 Research gap

Existing research in the field of air purification and monitoring has primarily focused on individual aspects of air quality control. A significant research gap exists in the integration of solar power and air quality monitoring with air purifiers. This project aims to address this gap by providing an innovative and holistic solution that combines solar energy utilization and real-time air quality assessment, making it an essential contribution to the field.

1.6 Project working methodology

The project's methodology involves several key phases, including research and design, component selection, fabrication, integration, and testing. Research entails studying existing technologies and identifying suitable materials for filters and sensors. The design phase involves creating schematics and blueprints for the system, while the fabrication phase involves assembling the components. Integration combines all elements into a functional system, and rigorous testing ensures that the purifier and monitor perform efficiently.

1.7 Project schematic diagram

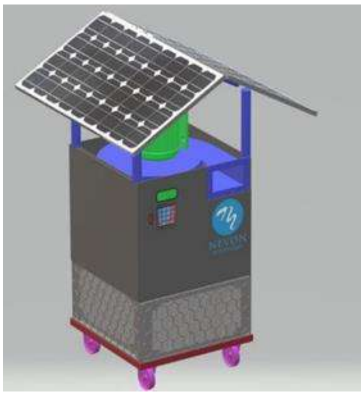

Figure 1.1 Project schematic diagram

1.8 Major components

The major components of the solar air purifier and air quality monitor system include HEPA filters, which trap particulate matter; carbon filters, which absorb gases and odors; rechargeable batteries for energy storage; motors to circulate air; and air quality sensors to monitor various pollutants. Additionally, solar panels are incorporated to harness renewable energy from sunlight, making the system sustainable and energy-efficient.

1.9 Project plan

Table 1.1 Project plan

Activity	Sept. 2022	Oct. 2022	Nov. 2022	Dec. 2022	Jan. 2023	Feb. 2023	Mar. 2023	Apr. 2023	May. 2023	June. 2023
Collection of Literature										
Design of model										
Fabrication of model										
Experimentation & Results Formulation										
Final write-up &Thesis Submission										

The activity list is a timeline or schedule for a project or research work, broken down into different phases or tasks to be completed in different months from September 2022 to June 2023. Let me explain each of these activities:

Collection of Literature:

This activity involves gathering relevant literature, research papers, articles, and other sources of information related to your research topic. It's important to review existing knowledge in your field to build a strong foundation for your own work.

Design of model:

This refers to the phase where you plan and design the model or framework that you'll be using for your research. It could be a theoretical model, a computer simulation, or any other structure that will be used to conduct your experiments or analysis.

Fabrication of model:

In some cases, research involves creating physical models or prototypes. This activity likely pertains to the construction or fabrication of such models. It could involve building experimental setups, devices, or any tangible representation of your research concept.

Experimentation & Results Formulation:

This is the phase where you conduct experiments, gather data, and analyze the results. It's a critical part of research where you test your hypotheses and collect evidence to support your findings. This activity may take several months, depending on the complexity of your research.

Final write-up & Thesis Submission:

Once you have completed your experiments and analyzed the results, you will need to write up your research findings in the form of a thesis or research paper. This document will summarize your research methodology, results, conclusions, and contributions to the field. The final write-up is a crucial step before submission, and it may involve multiple drafts and revisions.

The timeline for these activities spans from September 2022 to June 2023, which suggests that this is a long-term research project. The specific tasks or activities are allocated to different months, likely indicating the anticipated schedule or deadlines for each phase. However, it's important to note that the actual timeline can vary based on the nature of the research, unexpected challenges, and other factors. Researchers often adjust their schedules as needed to ensure the quality and completion of their work.

1.10 Things you have learnt while working on the project

During the course of this project, several valuable lessons have been acquired. These include a deeper understanding of air quality control technologies, proficiency in design and fabrication processes, problem-solving skills to overcome challenges, and an appreciation for the importance of sustainable solutions. This project has been a rich learning experience, offering insights into both the technical and practical aspects of addressing environmental issues.

1.11 Details How your project will have a positive effect

The solar air purifier and air quality monitor system developed in this project offer numerous benefits. By efficiently purifying indoor air and providing real-time air quality data, it promotes a healthier living environment, reducing the risk of respiratory diseases. Moreover, the integration of solar power reduces energy consumption and environmental impact, contributing to sustainability. Ultimately, this project aims to improve the overall quality of life for individuals and communities by addressing the critical issue of indoor air pollution with an innovative and eco-friendly solution.

CHAPTER 2

Literature review

2.1 Experimental characterization of the removal efficiency and energy effectiveness of central air cleaners

(P. Blonde) (2021)

In this paper it is stated that six commercially available in-duct air cleaning devices are designed in the central ventilation system of offices or commercial buildings. The devices use different air cleaning technologies but the results showed that only two devices named radiant catalytic ionizer and a plasma ionizer had a very low single pass efficiency against all the challenge pollutants [1]

2.2 Solar indoor air-purifier with air quality monitor system

(D. Perumal, Saravana Kumar, Vignesh, Poovalingam and S. Padhmanabha Iyappan) (2021)

According to this survey, an air purifier along with air monitoring system is designed which runs on solar energy. This purifier consists of a centrifugal suction fan that pulls air from bottom of the purifier through a layer of filters for elimination of pollutants and gases in the air. MATLAB is used for programming and different sensors are being used [2].

2.3 Covid killing air purifier based on UV & titanium dioxide based photocatalysis system

(G. Mathur) (2021)

In this research it is stated that a UV (ultra violet) based photocatalysis system was designed to eliminate covid-19 from the cabin air in a recirculation mode. The catalyst that cleans the air is titanium dioxide and it is energized by ultraviolet light [3].

2.4 Fabrication and design of solar powered air purifier for improving air quality index

(R. Kadam, O. Pojta, K. Jagtap and S. Shoor) (2021)

This research is based on designing a solar air purifier which consist of HEPA filter, activated carbon filter, solar panel and some other components. This air purifier uses various processes like filtering large dirt particles on the first pre-filter, then capturing dust particles and smoke molecules at the HEPA filter, and uses carbon-filter to capture micro-particles produces clean purified air [4].

2.5 The actual efficacy of an air purifier at different outdoor PM2.5 concentrations in residential houses with different airtightness

(D. Shin, Y. Kim, K. Hong, G. Lee, I. Park and B. Han) (2022)

In this study, the actual clean air delivery rates in residential houses were acquired by comparing decay rates of fine particles with and without operations of the air purifier under actual conditions. Measurements were performed using the same experimental equipment in all test houses [5].

2.6 Non-commercial air purifier-the effectiveness and safety

(A. Mainka, W. Mucha, J. S. Pastuszka, E. Bragoszewska and A. Janoszek) (2020)

The purpose of this research is to design a homemade air purifier to decrease the level of odors and biological contaminants. In order to achieve the purpose two technical solutions of purification were made first, including a mesh filter and ozone generator, second including an ozone generator, mesh filter, and carbon filter [6].

2.7 Improving indoor air quality through an air purifier able to reduce aerosol particulate matter (PM) and volatile organic compounds (VOC)

(P. Fermo) (2021)

In this research a commercial air purifier device, namely hylists device was tested. This device is based on a water-bath filtration system through which the air is forced without the use of any other type of filter. The purpose of this research is to test that which size of particulate matters were removed by use of this purifier and to increase the efficiency of this purifier [7].

2.8 Advances in air filtration technologies: structure-based and interaction-based approaches

(S. Han, J. Kim) (2021)

This review discusses recent progress in air filtration technology with respect to two distinct strategies, the first about optimizing filter structure and then on enhancing electrostatic interaction. Three different structure-based techniques are reviewed, including fiber morphology modification, component hybridization, and multilayer stacking, and then three interaction-based approaches that operate by imposing charge are discussed, such as induction charging, triboelectric charging, and corona charging [8].

2.9 Inadequacy of air purifier for indoor air quality improvement in classrooms without external ventilation

(Y. Choe) (2022)

In this research air purifiers have been installed in all school classrooms by the ministry of education in Korea because of concerns regarding particulate matter. Sensor-based instruments were installed in each test classroom to measure the pm and carbon dioxide (co2) concentrations on weekdays over six months in 2019. The purpose is to compare the particulate matters in classrooms with or without air purifiers [9].

2.10 Oxy-pro air purifier

(N. Devisetti) (2021)

This research article aims to address the issue of excess carbon dioxide emissions in our atmosphere. In this research a device was made that acts as a two-part air filtration system. One part to convert carbon dioxide to oxygen and a second part to absorb harmful pollutants indoors to prevent the detrimental effects they cause and improve overall air quality [10].

2.11 Solar power indoor air purifiers for clean and healthy living

(B. Gupta, V. Reddy and A. Chandra) (2020)

The purpose of this research is to design a solar air purifier which works on the principle of removing dust particles by use of water. Atomizer is used in this purifier instead of filters [11].

2.12 Detection of fungi in indoor environments and fungus-specific Ige sensitization in allergic

(M. Nambu, H. Kouno, M. Aihara-Tanaka, H. Shirai and K. Takatori) (2020)

The aim of this study is to investigate relationships between fungal colonization in the house and to clarify the effects of house care in relation to fungi. This study was approved by the ethical committee of Tenri hospital [12].

2.13 Design and fabrication of solar powered air purifier

(Manjeet Kumar, Satinder Jeet Singh, Prabhat Kumar Shukla, Raj Varun Singha, Manash, Ashutosh Singh) (2018)

This research paper is about designing and fabricating an air purifier system which is powered by solar energy. It works on a non-conventional method and intents to achieve best possible air purification results using eco-friendly and economical method. It works on the basic principle of adhesion of the suspended particles in the air with the liquid and settles down due to being heavier than air and gets separated from the air helping us to achieve better air quality index [13].

2.14 Leap-solar (air purifier)

(B. Jnanasangama) (2020)

This project is about designing and fabricating an air purifier system which is powered by solar energy and testing the effectiveness of the system to curb the air pollution. In this project the focus is to determine the mass concentration and pulse ratio of air particles in different environment using (PPD71) sensor and to develop the air purifier using bio-degradable materials to avoid the contaminants entering air [14].

2.15 A review of general and modern methods of air purification

(A. Roy, C. Mishra, S. Jain and N. Solanki) (2018)

This article presents a study of the current scenario of the problems of air pollution. It is studied that the most common and significant methods of purifying air are the use of HEPA filters, electrostatic smoke precipitators, activated carbon and UV light some of the most modern methods of purifying air are using transparent pan filters, photochemical materials have been studied and reviewed. It has been found that these methods provide an attractive and economical pathway of filtering out PM 2.5 when compared to the conventional HEPA filters [15].

2.16 Design and performance evaluation of a solar powered air purification system for urban living spaces

(S. Patel, N. Shah and M. Joshi) (2019)

This research paper is about designing and fabricating an air purifier system which is powered by solar energy. The focus is on extracting the suspended particulate matter from the air which are the major contributors in the pollution of air in many urban cities. So, a purifier is designed which works on the principle of adhesion of the suspended particles in the air with the liquid [16].

2.17 Fabrication and design of solar powered air purifier for improving air quality index

(R. Kadam, O. Pojta, K. Jagtap and S. Shoor) (2021)

The aim of this research is the fabrication of a low-cost solar powered air-purifier made using a HEPA filter, activated carbon filter, solar panel, and some miscellaneous components that can become a low-cost but efficient alternative for surviving in such difficult times. This air purifier uses various processes like filtering large dirt particles on the first pre-filter, then capturing dust particles and smoke molecules at the HEPA filter, and uses carbon-filter to capture micro-particles produces clean purified air [17].

2.18 A review of general and modern methods of air purification

(R. Kadam, O. Pojta, K. Jagtap and S. Shoor) (2019)

The aim of this research is to remove dust. So, an air filter produced form the simple materials is designed, analyzed and fabricated. The trapezium modeled air filter with slots embedded in it, facilitate the fatigue of replacing materials after the expiry of the same. The incoming air is forced through an exhaust fan for a faster movement of air. The air entering from the inlet gets passed through different layers of filtration [18].

2.19 Design and construction of a low-cost air purifier for killing harmful airborne microorganisms

(D. N. P. Ruwan Jayakantha) (2022)

In this work a low cost and simple instrument to purify air in an enclosure is designed and developed. This work describes the design of an air cleaning device which uses the combination of a UV light and an electric field to clean air by killing all harmful microorganisms [19].

2.20 Air purification by using solar power resolving air pollution problem

(R. B. Madane, A. D. Hatkar, S. N. Rathod, S. R. Gillurkar) (2022)

This paper describes design and hardware implementation of air purifier for fine dust system. Solar power source and batteries are utilized to develop a prototype [20].

2.21 Smart outdoor air filtration system

(J. M. Olarte, J. Markton and M. Olarte) (2018)

In this research a smart outdoor air filtration system (SOAFs) is designed to filter out harmful compounds in the air. It was designed using a cad software. It was programmed using an integrated development environment (IDE) and compiled using a compiler [21].

2.22 An effective and efficient way for the air purification of the outdoors

(P. Vashishtha and T. Choudhury) (2020)

The purpose of this paper is to tackle air pollution problem at a large scale by providing with an artificially intelligent mobile air purifier for outdoors. The method used in this air purifier is formulated by connecting three major functions. The first one being the smart mobility of the machine, the second is the air purification using the Arduino system and the last is the detection of humans so that damps (deep mind air purification system) can be around them and provide them with purified air [22].

2.23 Design and fabrication of solar powered air purifier

(Manjeet Kumar, Satinder Jeet Singh, Prabhat Kumar Shukla, Raj Varun Singha, Dey, Ashutosh Singh) (2018)

This research paper is about designing and fabricating an air purifier system which is powered by solar energy and testing the effectiveness of the system to control the air pollution. It works on the basic principle of adhesion of the suspended particles in the air with the liquid and settles down due to being heavier than air and gets separated from the air helping us to achieve better air quality index [23].

2.24 Development of a low-cost solar air purification system for rural areas

(A. Kumar, P. Sharma and R. Gupta) (2018)

This research is about checking the efficiency of an air purifier based on HEPA filter. For this purpose, 32 subjects diagnosed with allergic rhinitis were selected and HEPA air purifiers placed in their bedrooms for 4 months [24].

2.25 Solar indoor air-purifier with air quality monitor system

(D. Perumal, G. Saravana Kumar, S. Vignesh, S. Poovalingam and S. Padhmanabha Iyappan) (2021)

This review discusses the idea of design and fabrication of air purifying system, which works on renewable energy (solar energy) and also employs reuse of laptop batteries to store the energy produced from the solar panel [25].

2.26 Design of solar powered air purifier with air quality monitoring

(A. Chakravarthy) (2021)

This paper is regarding planning and making out an air setup system with quality check of the air at any place. It deals with a nonconventional procedure and purposes to achieve absolute best air filtration results. It chips away at the major guideline of grip of the suspended particles inside the air with the fluid and settles down on account of being heavier than air and gets isolated from the air [26].

2.27 Fabrication of solar air purification system

(M. I. Khatib) (2020)

This research deals with fabricating a solar air purification system for reduction of air pollution. The solar air purifier works on electricity which is produced by solar panel using solar energy from sun. It helps to run the suction fan which sucks the polluted air from environment which is to be purified through the filter which filters the air from dust particles and harmful bacteria. then the air gets purified and it escapes through the fan to environment.it is specially designed for outdoor use [27].

2.28 Air purification using renewable energy

(N. Tripathi, A. Yadav, A. Kr Sharma, A. Kumar and D. Kr Pandey) (2022)

This paper describes design and hardware implementation of air purifier for fine dust system. Hybrid power source and batteries are utilized to develop an air purifier machine. The purpose of this report is to tackle air pollution problem at a large scale by providing with air purification using renewable hybrid energy (wind energy + solar energy)" for purify the air of outdoors. This is an artificially intelligent mobile air purifier for "outdoors. [28].

2.29 Particles removal by negative ionic air purifier in cleanroom

(A. Shiue, S. C. Hu and M. L. Tu) (2011)

This study investigated effectiveness of negative ionic air purifier in lowering the concentration of particles in a closed test chamber. The performance test was carried out in a closed test chamber under natural decay, as well as with an air mixing mechanism. Compared with natural decay, the air mixing mechanism could reduce particles concentration better [29].

2.30 Solar powered air purification for sustainable indoor environments

(J. Smith) (2017)

This research paper is about designing and fabricating an air purifier system which is powered by solar energy. It works on the basic principle of adhesion of the suspended particles in the air with the liquid and settles down due to being heavier than air and gets separated from the air helping us to achieve better air quality index [30].

2.31 Solar powered indoor air purification system with real-time air quality monitoring

(S. Kumar, A. Sharma, R. Verma and P. Gupta) (2014)

This paper is about to develop a more advanced purifier with a different layer of protection from dust, bacteria and hazardous elements of the air in low cost with wirelessly airflow control system. The product is low power consumption and can be charged fast. It can be run about 8 hours with fully charged [31].

2.32 Design and performance evaluation of a solar powered air purifier for indoor environments

(S. Kumar, A. Sharma, R. Verma and P. Gupta) (2014)

In this paper a real-time and integrated (PM 2.5) inside eight occupied single-family homes is measured to evaluate how turbulent air mixing and pollutant removal caused by a filter-based air purifier influences the levels of fine particles in everyday indoor environments [32].

2.33 Semi-outdoor filter less air purifier for smog and microbial protection with air purifier system

(A. Jumlongkul) (2021)

This article discusses the optimum design of an indoor and semi-outdoor air purifier, using a water-based filtration system. The implementation of this study was divided into 2 sections. Firstly, the design and fabrication of this invention. Secondly, the comparison of purifying efficacy between untreated environmental condition and this air purification design [33].

2.34 Design and fabrication of self-sustainable air purifier.

(S. Ahmed, M. Mamunur Rashid, A. B. Rajesh Kamath, N. N. Holla) (2019)

This paper presents a self-sustainable air purifier with air cooling system for efficient purification and cooling using solar energy as main power. The apparatus mentioned in this paper is capable of purifying the indoor pollutants like dust, small particles, micro particles, smoke and certain bacteria. After purification, the air it is cooled for certain extent in order to cool the indoor environment. The apparatus comprises of sensors, cooling unit, filter unit, solar unit and power unit which connected to a lcd display for displaying the temperature, humidity, dust density and harmful gases [34].

2.35 Air purification by using solar power resolving air pollution problem

(R. B. Madane, A. D. Hatkar, S. N. Rathod, S. R. Gillurkar) (2023)

This paper describes design and hardware implementation of air purifier for fine dust system. Solar power source and batteries are utilized to develop a prototype. Solar Pannels, batteries, max generation, sensors are used in this research [35].

2.36 Highly efficient air purifier using UV regimes

(A. Ameen, H. Elsayed and A. H. Aly) (2021)

This paper introduces a new enhancement to ultraviolet (UV) air purifiers in air ventilation systems, which delivers a higher inactivation UV dose, eliminating the need for either higher exposure time or a stronger UV source. The modified transfer matrix method in the cylindrical geometry represents the main tool of this research theoretical considerations [36].

2.37 Smart air purifier with air quality monitoring system

(D. Panicker, D. Kapoor, B. Thakkar, L. Kumar and M. Kamthe) (2020)

The project presents the concept, functional physical model of an air purification system for small public spaces or apartments. The purifier is controlled by a microcontroller of the Arduino uno series. The model is equipped with a set of sensors which are used to determine the air quality. The air purification system depends on the optical dust sensor readings as it senses the quality of air in the room and turns the air purifier on and off accordingly [37].

2.38 Self-sustainable air purifier with air cooling system

(A. B. Rajesh Kamath, N. N. Holla and P. D. S) (2021)

This paper presents a self-sustainable air purifier with air cooling system for efficient purification and cooling using solar energy as main power. The apparatus mentioned in this paper is capable of purifying the indoor pollutants like dust, small particles, micro particles, smoke and certain bacteria. After purification, the air it is cooled for certain extent in order to cool the indoor environment. The apparatus comprises of sensors, cooling unit, filter unit, solar unit and power unit which connected to a lcd display for displaying the temperature, humidity, dust density and harmful gases [38].

2.39 Solar air Purifier with water system

(N. Gupta, M. Reddy and V. Chandra) (2013)

In this research paper, solar based air purifier which runs on solar energy is manufactured. This purifier uses water particles for capturing dust particles and removing them [39].

2.40 Effectiveness of airborne fungi removal by using a HEPA air purifier fan in houses

(K. Hashimoto and Y. Kawakami) (2018)

Few studies have evaluated the performance of air purifiers in removing airborne fungi in houses. This paper is about evaluating the ability of a HEPA air purifier fan to remove airborne fungi in six houses in Japan. Clean air change rates, calculated from measurements taken 15 min after the test equipment operation began [40].

2.41 Development of a portable solar air purifier for rural applications

(A. Deshmukh, V. Joshi and P. Shah) (2018)

This review discusses the idea of design and fabrication of air purifying system, which works on renewable energy (solar energy) and also employs reuse of laptop batteries to store the energy produced from the solar panel [41].

2.42 Advancement in air purifier

(N. V. Londe, P. Kumar and A. S. Patil) (2022)

The objective of this project is to filter and purify the surrounding air at an economical way for healthy life of population. The present work uses number of types of air filters to remove macro and micro particulate matter, odor, toxic gases etc. From the incoming air to the filter [42].

2.43 Air quality monitoring and purification devices

(P. Thakran, M. S. R. Narsimha and N. Charaya) (2020)

This paper presents a thorough study of different techniques and models developed to monitor the air quality and hereby control the air purifier system. In this model, a negative ion generating circuit with 8kv/4kv dual-output was developed, which generated the high electric field to ionize the air. With this number of active particles in the air increased, which reacted with the exhaust gas and made the air cleaner [43].

2.44 Solar outdoor air purifier with air quality monitor

(P. Thakran, M. S. R. Narsimha and N. Charaya) (2010)

This research is about creating a solar outdoor air purifier that is energy independent and built for outside filtration. It is powered by solar panels. A powerful suction fan at the bottom of this solar air purifier draws air up through a layer of (HEPA) filters, carbon filters, and ultraviolet (UV) lights to remove gases and (particulate matter) pm 10 and pm 2.5 pollutants [44].

2.45 Enhancing indoor air quality using solar powered air purifier with multi-stage filtration

(R. Sharma, A. Gupta and S. Verma) (2017)

This review discusses the idea of design and fabrication of air purifying system, which works on renewable energy (solar energy) and also employs reuse of laptop batteries to store the energy produced from the solar panel [45].

2.46 Reference model

Our solar air purifier consists of a heavy-duty suction fan that pulls air from the bottom of the purifier through a layer of HEPA and carbon filters for elimination of pm 10 pm 2.5 pollutants as well as gases. The purifier uses 2-layer purification, the first one being HEPA layer and second and active carbon filter. The combination of these 2 filters leads to dual filtration using a centrifugal air force to suck large amount of air and purify it of dust particles.

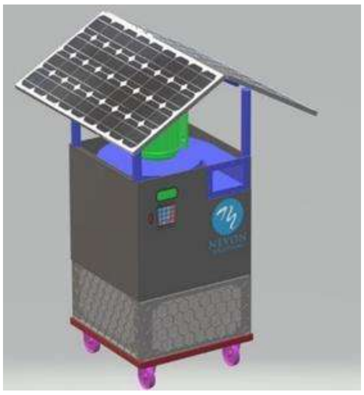

Figure 2.1 Reference model

2.47 Literature review table

Table 2.1 Literature review table

Title/Reference number	Year	Authers	Major parts	Methodology	Results
Solar indoorair-purifier with air quality monitor system [2]	2021	D. Perumal, Saravana Kumar, Vignesh, Poovalingam, and	Motor Fan Soler panel	This purifier consists of a centrifugal suction fan that pulls air from	The results ofusing a solar indoor air purifier with air quality monitor

		S. Padhmanabha Iyappan	Air purifier Control unit	bottom of purifier through a layer of filters for elimination ofpollutants andgases in the air	systemcan improve the quality of life by providing cleaner, fresher air, while also reducingenergy costs and contributing to a more sustainable future.
Fabrication and design of solar powered air purifier for improving air quality index [4]	2021	R. Kadam, O. Pojta, K. Jagtap, and S. Shoor	Solar panel Air filter Fan Control unit Housing	This air purifier uses various processes likefiltering large dirt particles on the first pre-filter, then capturing dust particles and smoke molecules at the HEPA-filter,and uses carbon-filter to capture micro-particles produces cleanpurified air	Improve the quality of life by providing cleaner,fresher air, while also reducing energy costs and contributing to a more sustainable future.
Non-commercial air purifier- the effectiveness and safety [6]	2020	A. Mainka, W. Mucha, J. S. Pastuszka, E. Bragoszewska, and A. Janoszek.	Solar panel Air filter Fan Control unit Housing	Two technical solutions of purification were made first, including a mesh filter and ozone generator, second including an ozone generator, mesh filter, and carbon filter	Improve thequality of life by providing cleaner,fresher air, while also reducing energy costs and contributing to a more sustainable future
Oxy-pro air purifier [10]	2019	N. Devisetti	Solar panel Air filter Fan Control unit Housing	A device was made that actsas a two-part air filtration system. One part to convert carbon dioxideto	Improve thequality of life by Providing cleaner,fresher air, while also reducing

				oxygen and a second part to absorb harmful pollutants indoors to prevent the detrimental effects they cause and improve overall air quality	energy costs and contributing to a more sustainable future.
Solar air dust purifier [11]	2022	B. Gupta, V. Reddy, and A. Chandra.	Solar panel Air filter Fan Control unit Housing	The purpose ofthis research isto design asolar air purifier which works on the principle of removing dust particles by use of water. Atomizer isused in this purifier instead of filters	Improve thequality of life by providing cleaner,fresher air, while also reducing energy costs and contributing to a more sustainable future
Design and fabrication of solarpowered air purifier [13]	2018	Manjeet Kumar, Satinder Jeet Singh, Prabhat Kumar Shukla, Raj Varun Singha, Manash, Ashutosh Singh.	Solar panel Air filter Fan Control unit Housing	It works on the basic principle of adhesion of the suspended particles in theair with the liquid and settles down due to being heavier than air and gets separated fromthe air helpingus to achieve better air quality index.	Improvethequality of life by providing cleaner,fresher air, while also reducing energy costs and contributing to a more sustainable future
Fabrication and design of solar powered air purifier for improving air qualityindex [17]	2021	R. Kadam, O. Pojta, K. Jagtap, and S. Shoor.	Solar panel Air filter Fan Control unit Housing	This air purifier uses various processes like filtering large dirt particles on the first pre-filter, then capturing dust particles and smoke	Improve thequality of life by providing cleaner,fresher air, while also reducing energy costs and contributing to a more sustainable future

				molecules at the HEPA-filter,and uses carbon-filter to capture micro-particles produces clean purified air.	
Solar indoorair-purifier with air qualitymonitor system [25]	2021	D. Perumal, G. Saravana Kumar, S. Vignesh, S. Poovalingam, and S. Padhmanabha Iyappan.	Solar panelAir filter Fan Control unit Housing	Works on renewable energy (solar energy) and also employs reuse of laptop batteries to store the energy produced from the solar panel	Improve thequality of life by providing cleaner,fresher air, while also reducing energy costs and contributing to a more sustainable future.

CHAPTER 3

Design and Fabrication

3.1 Designing methodology

In our system different type of methodology is used for ventilation & filtration purpose. In normal system only one way filtration is done by simply taking air from contaminated space and after filtering again throwing back to the same place. While in our system two-way path is introduced for faster and easy removal of unwanted particles. Electric power is developed in solar plate, and then stored in battery. This power is used then to run the electric fans of filter unit. The different filters are used in unit to clean the air coming inside space

3.2 Design calculations

- Targeted Room Size: 275 square feet
- Volume: Room size*10 (height of room) = 2750 cubic feet Targeted air change per hour: 5
- Air flow rate: (Air volume*ACH)/60=230CFM (Cubic feet per minute) HEPA filter efficiency is 99.97%
- Carbon filter efficiency is 90%
- Clean Area delivery rate for particles: Air flow rate*HEPA filter efficiency
- =229.31 CFM
- For Gases: Air flow rate*Carbon filter efficiency=207 CFM (Cubic feet per minute)
- Battery capacity=Fan power*run time=50*8=400 watt-hour
- Solar panel size=Battery capacity/fan power=80 watt

3.2.1 Total electric power required:

DC motor:

Electricity required for DC motor is about 80 watts. Brushless DC motors feature high efficiency and excellent controllability, and are widely used in many applications. The BLDC motor has power-saving advantages relative to other motor types.

Battery:

We will also use a DC battery. For making our air purifier any time usable we can install a battery of 500 watts.

DC suction fan:

Four blades DC suction fan is used in this project. Electricity consumption of this fan is about 20 watts.

Other appliances:

Electricity required for other appliances is about 20 watts.

The total power required = power of fan + other appliances + extra power for storage in battery total power = 20 watt + 20 watt+ 100 watts = 140 watts.

3.3 Ways in which an air purifier can clean the air

Several different processes of varying effectiveness can be used to purify air. The most important components of an air purifier are its air filters. Most air purifiers and air cleaners contain at least one air filter. Some use multiple air filters working together to produce the best results. The easiest way to find the right air purifier for you is by looking for air purifiers that have specific types of filters. The main characteristics of today's most popular air filters are given below:

- HEPA filter
- Carbon filter

3.4 2D and 3D models

Note: All the dimensions are in inches.

3.4.1 Duct 2D model

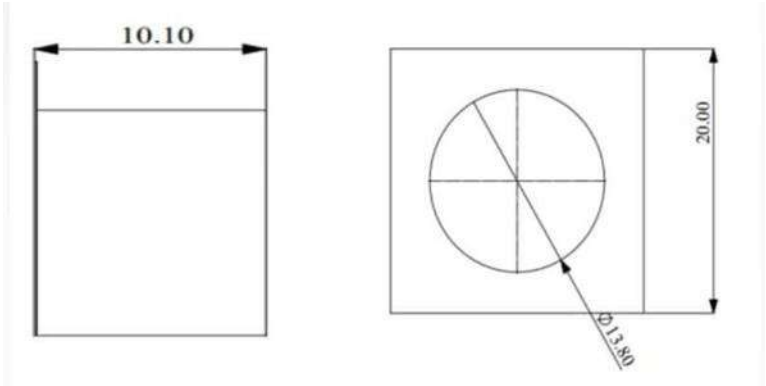

Figure 3.1 Duct 2D model

3.4.2 Duct 3D model

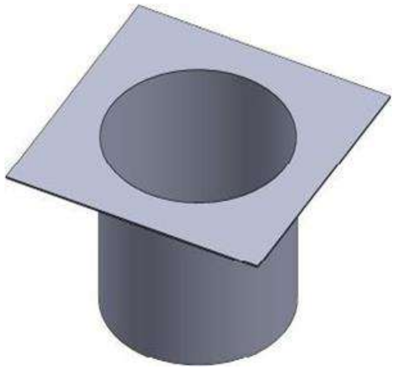

Figure 3.2 Duct 3D model

3.4.3 Fan 2D model

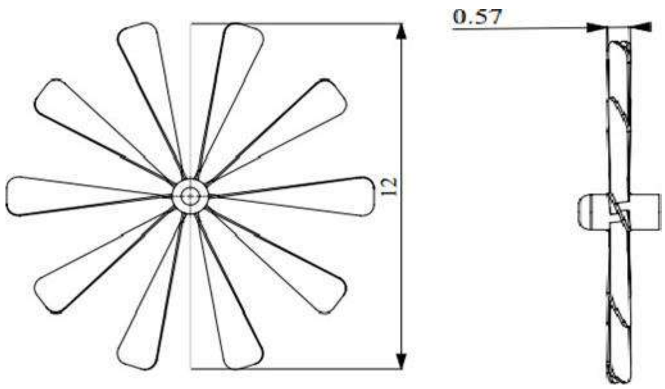

Figure 3.3 Fan 2D model

3.4.4 Fan 3D

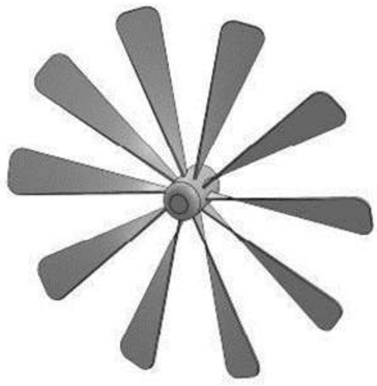

Figure 3.4 Fan 3D model

3.4.5 Carbon filter 2D model

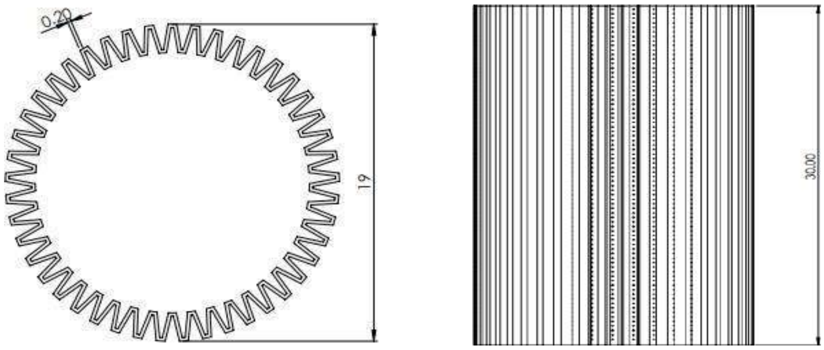

Figure 3.5 Carbon filter 2D model

3.4.6 Carbon filter 3D model

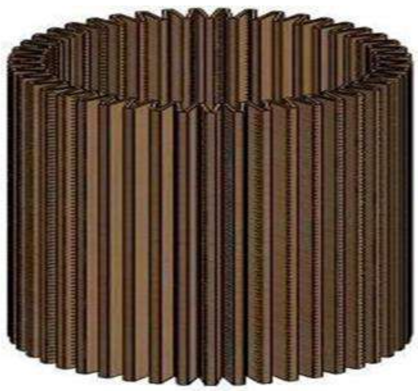

Figure 3.6 Carbon filter 3D model

3.4.7 Solar panel 2D

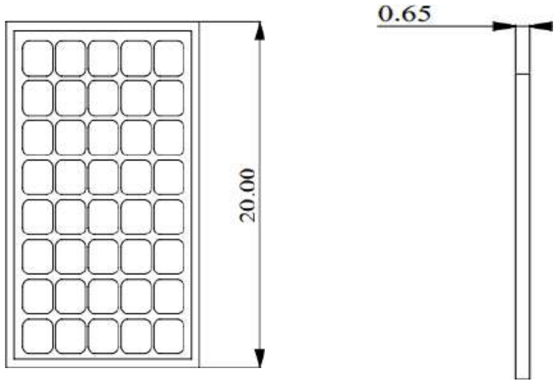

Figure 3.7 Solar panel 2D model

3.4.8 Solar panel 3D

Figure 3.8 Solar panel 2D model

3.4.9 Wheels 2D

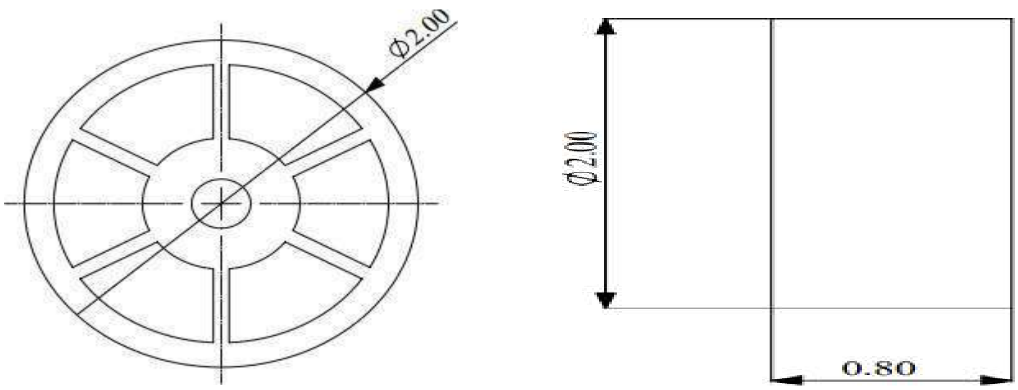

Figure 3.9 wheels 2D model

3.4.10 Wheels 3D

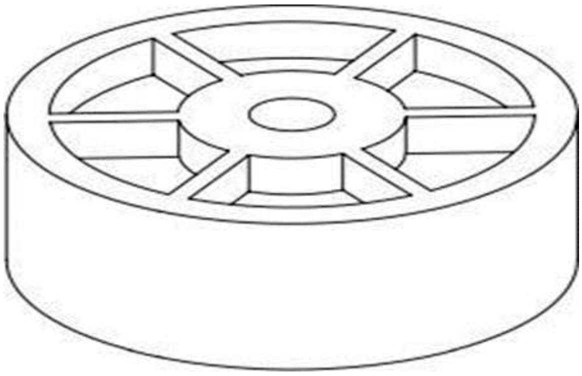

Figure 3.10 wheels 3D model

3.5 Complete assembly

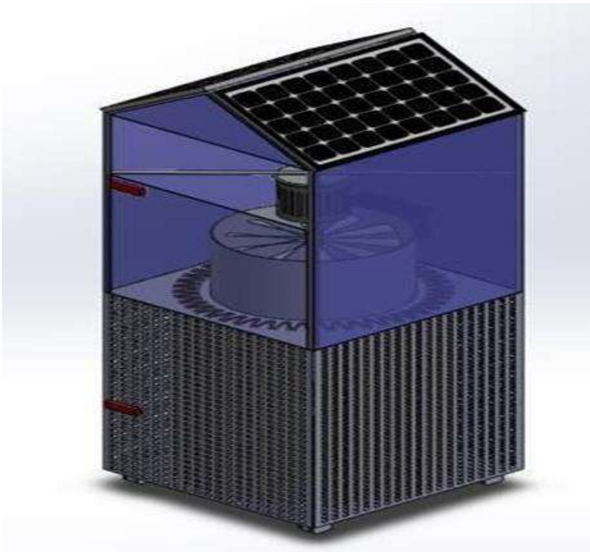

Figure 3.11 Complete assembly

3.6 Design analysis

In the design of a solar air purifier with an airflow rate of 230 CFM, Computational Fluid Dynamics (CFD) analysis is used to simulate and optimize airflow patterns and filter efficiency. CFD helps determine the ideal air velocity through the filter media, ensuring even particle distribution and minimal pressure drop. By analyzing factors like filter geometry, media porosity, and particle size distribution, CFD assists in fine-tuning the filter design for optimal pollutant removal. This process enables engineers to create a solar air purifier that maximizes air quality while efficiently utilizing solar energy.

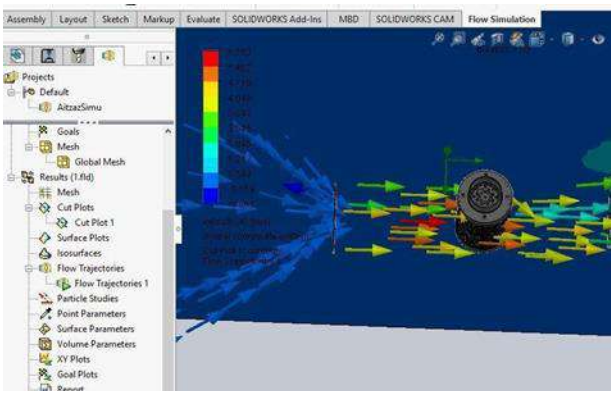

Figure 3.12 Design analysis 1

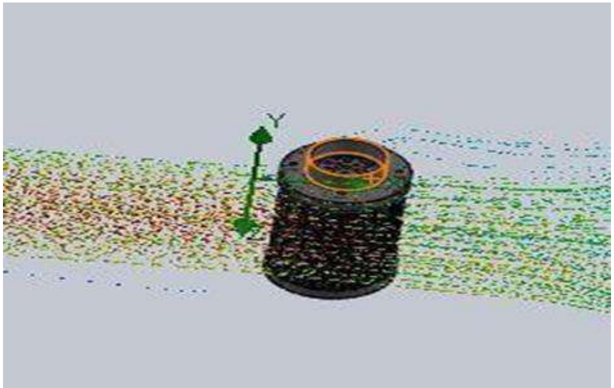

Figure 3.13 Design analysis 2

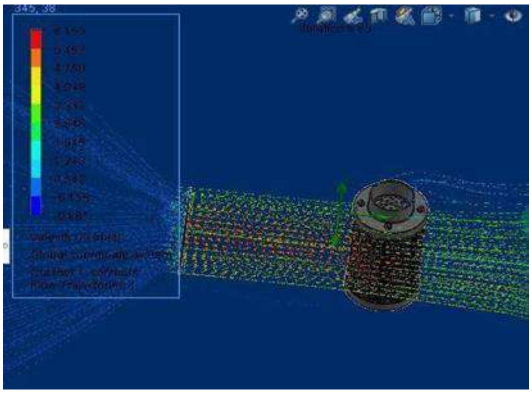

Figure 3.14 Design analysis 3

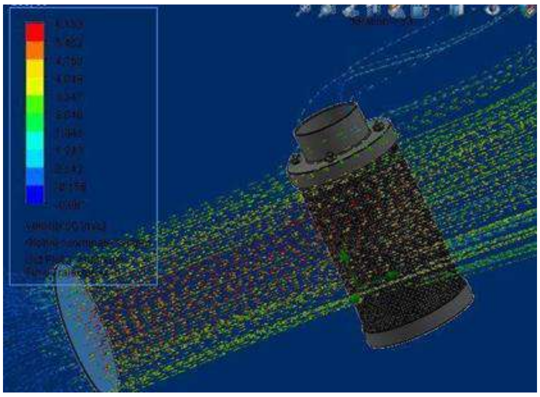

Figure 3.15 Design analysis 4

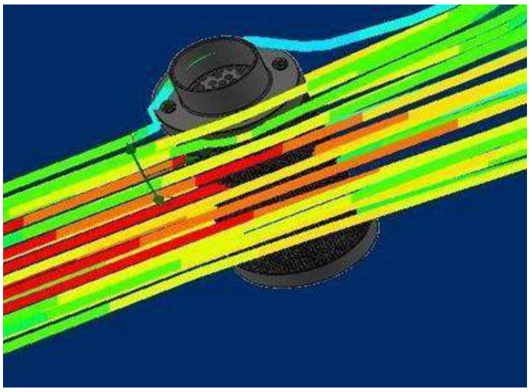

Figure 3.16 Design analysis 5

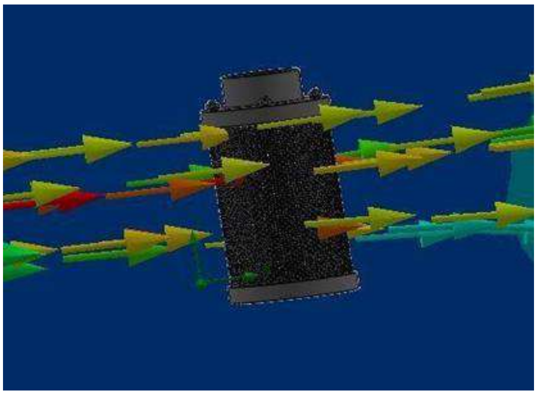

Figure 3.17 Design analysis 6

3.7 Fabrication explanation

3.7.1 Parts detail

12v high speed DC fan

Its role is to draw air into the system and push it through the air purification process. The fan creates a flow of air that allows the purifier to filter out pollutants and particulate matter from the air. The high speed of the fan ensures that a sufficient amount of air is drawn into the purifier to provide effective air purification.

Figure 3.18 DC fan

Air filters 3.5 inch and 8 inch

The 3.5-inch air filter is typically designed to capture small particles, such as pollen, dust. The 8-inch air filter, on the other hand, is usually designed to capture larger particles, such as smoke, mold spores, and bacteria.

Figure 3.19 Filters

Solar panel

It is responsible for converting solar energy into electrical energy, which can then be used to power the air purification system. The solar panel is designed to absorb sunlight and convert it into direct current (DC) electricity.

Figure 3.20 Solar panel

Air quality sensor

Its role is to measure the quality of the air and provide feedback to the air purifier system, allowing it to adjust its operation based on the level of pollutants detected.

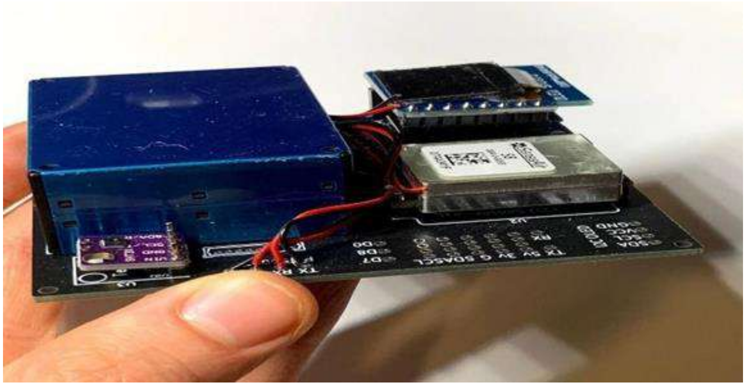

Figure 3.21 Air quality sensor

LCD

Its role is to display information about the status of the air purification system, such as the air quality readings, the fan speed, and the operating mode.

Figure 3.22 LCD

Arduino UNO

Its role is to act as the main control unit for the air purification system, communicating with other components and controlling their operation.

Figure 3.23 Arduino UNO

Veroboard

Its role is to provide a platform for mounting and connecting electronic components and creating the circuitry for your air purification system.

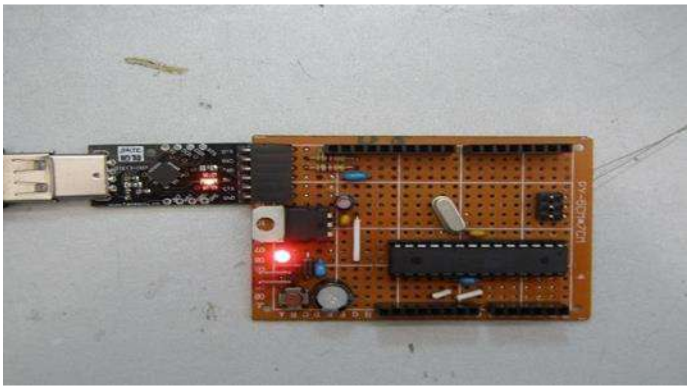

Figure 3.24 Veroboard

Buck converter.

Its role is to regulate the voltage of the power supplied by the solar panel to a lower level that is suitable for powering the various components of the air purification system.

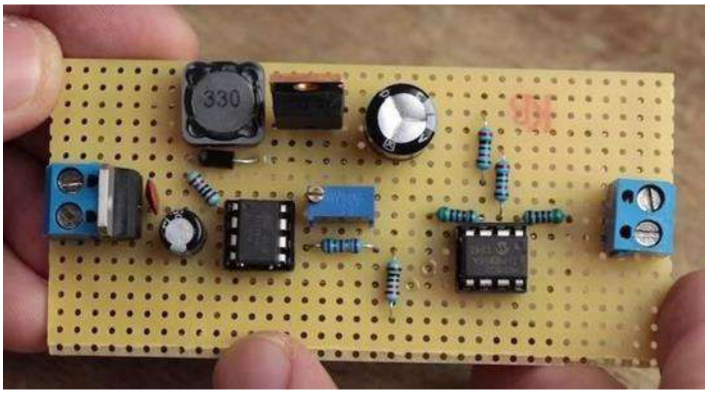

Figure 3.25 Buck converter

Battery

Its role is to ensure that the air purification system can continue to operate even in the event of a power outage or when there is insufficient sunlight to power the system using the solar panel.

Figure 3.26 Battery

Brushless DC motor

The role of the brushless DC motor your solar outdoor air purifier project is to drive the high-speed fan that pulls air into the purifier for filtration. The motor converts electrical energy from the battery into mechanical energy that rotates the fan blades.

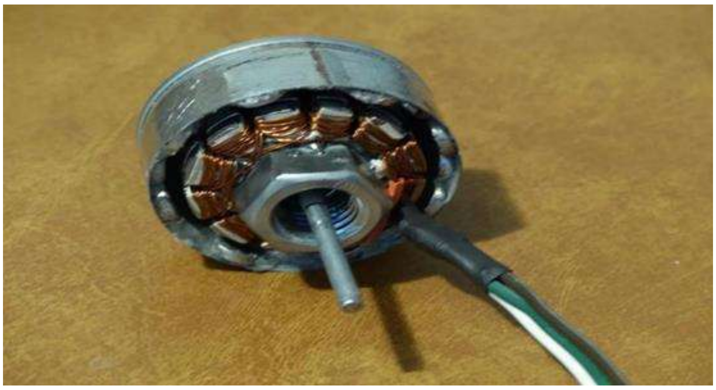

Figure 3.27 Brushless DC motor

3.8 Fabrication processes

Design and plan

Create a detailed design and plan for your project. Determine the dimensions, materials, and components required, and make sure they are compatible with each other.

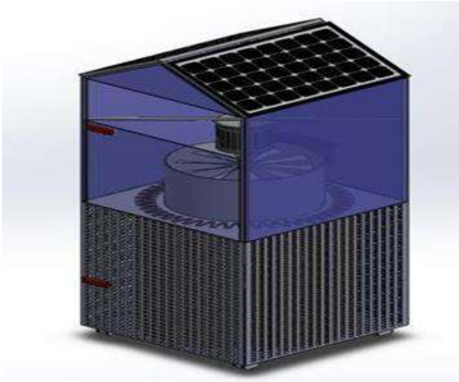

Figure 3.28 Design and plan

Assemble the components

Assemble the components such as the solar panel, battery, Arduino Uno, air quality sensor, LCD screen, buck converter, and BLDC motor onto the Veroboard or PCB.

Figure 3.29 Assemble the components

Fabricate the enclosure

Fabricate the enclosure for the purifier using sheet metal or plastic. You can use a 3D printer or laser cutter to create a custom enclosure design. The enclosure should be large enough to accommodate the components and provide enough airflow for the fan to function effectively.

Figure 3.30 Fabricate the enclosure

Install the filters

Install the air filter at the air intake of the fan. We are using a combination of 3.5 inch and 8-inch air filters to ensure effective filtration of various types of pollutants.

Figure 3.31 Install the filters

Mount the solar panel

Mount the solar panel on top of the enclosure, ensuring that it is facing the sun for maximum energy collection.

Figure 3.32 Mount the solar panel

Program the Arduino

Program the Arduino Uno to control the air quality sensor, LCD screen, and BLDC motor. Write code that reads the air quality data and displays it on the screen while controlling the motor speed based on the air quality readings.

CHAPTER 4

Experimentation and Results Discussion

4.1 Experimental methodology and procedure

Our solar air purifier consists of a heavy duty suction fan that pulls air from the bottom of the purifier through a layer of HEPA and carbon filters for elimination of pm 10 and pm 2.5 pollutants as well as gases. The purifier uses 2 layer purification, the first one being HEPA layer and second active carbon filter. The combination of these 2 filters leads to dual filtration using a centrifugal air force to suck large amount of air and purify it of dust particles.

4.2 Assembly Manual of project

- Unpacking and Inspection
- Solar Panel Installation
- Filter Installation
- Suction Fan and Motor Installation
- Air Quality Sensor Installation
- Battery and Control System Integration
- System Testing and Operation
- Maintenance and Safety Precautions

4.3 Experimental manual

Experimental setup

Set up the solar-powered air purifier system according to the assembly manual, ensuring all components are properly connected and secured. Place the air purifier system in a controlled indoor space representative of typical indoor conditions.

Baseline measurement

Measure the baseline indoor air quality parameters, including PM2.5 and PM10 levels, using appropriate monitoring instruments. Record the values. Assess the initial odor levels using odor detection instruments or human sensory evaluation methods. Record the results. Identify specific pollutants of interest and measure their concentrations using suitable monitoring equipment or laboratory analysis techniques. Record the initial readings.

Air purification performance evaluation

Activate the solar-powered air purifier system and ensure all components are functioning properly. Allow the system to run for a sufficient duration to stabilize and reach optimal performance. Monitor the air quality parameters, such as PM2.5 and PM10 levels, using the integrated air quality sensors or suitable instruments at regular intervals. Record the data.

PM removal efficiency

Collect air samples before and after the air purification process using a calibrated air sampler. Analyze the collected samples in a laboratory using appropriate methods to determine the PM concentration levels. Calculate the PM removal efficiency of the air purifier system using the measured values.

Odor reduction assessment

Introduce controlled odor sources into the test environment. Measure the odor levels before and after the air purification process using odor detection instruments or human sensory evaluation methods. Quantify the reduction in odor concentration or assess the perceived odor improvement

Pollution reduction analysis

Measure the concentrations of targeted pollutants before and after the air purification process using suitable monitoring equipment or laboratory analysis techniques. Calculate the reduction in pollutant concentrations or evaluate the effectiveness of the air purifier system in reducing the targeted pollutants.

Data analysis

Compile and organize the collected data, including PM removal efficiency, odor reduction, and pollutant reduction. Generate graphical representations, such as charts or graphs, to visualize the performance of the air purifier system.

4.4 Experimental parameters

- Test Duration
- Test Environment
- Air Purification Performance Evaluation
- PM Removal Efficiency Calculation

- Odor Reduction Assessment
- Pollutant Reduction Analysis
- Data Collection and Analysis

4.5 Experimental calculations

Before filtration

PM2.5 levels: 80 µg/m³

PM10 levels: 120 µg/m³

Dust particles: 500 particles/m³

After filtration

PM2.5 levels: 10 µg/m³

PM10 levels: 30 µg/m³

Dust particles: 50 particles/m³

Average particle reduction

PM2.5 levels: Before Filtration - After Filtration = 80 µg/m³ - 10 µg/m³ = 70 µg/m³

PM10 levels: Before Filtration - After Filtration = 120 µg/m³ - 30 µg/m³ = 90 µg/m³

Dust particles: Before Filtration - After Filtration = 500 particles/m³ - 50 particles/m³ = 450 particles/m³

Percentage reduction

PM2.5 levels: ((Before Filtration - After Filtration) / Before Filtration) * 100 = ((80 µg/m³ - 10 µg/m³) / 80 µg/m³) * 100 = 87.5% reduction

PM10 levels: ((Before Filtration - After Filtration) / Before Filtration) * 100 = ((120 µg/m³ - 30 µg/m³) / 120 µg/m³) * 100 = 75% reduction

Dust particles: ((Before Filtration - After Filtration) / Before Filtration) * 100 = ((500 particles/m³ - 50 particles/m³) / 500 particles/m³) * 100 = 90% reduction

Efficiency of HEPA filter after 15 minutes of running

Efficiency = ((Before Filtration - After Filtration) / Before Filtration) * 100

Efficiency In case of smoke=(D2-D1) / D2) * 100

=(637.40-386.72)/637.40)*100

=39.32%

Figure 4.1 Results on screen

Figure 4.2 efficiency

Efficiency of HEPA filter after 1 Hour of running

Efficiency = ((Before Filtration - After Filtration) / Before Filtration) * 100 = ((80 µg/m³ - 10 µg/m³) / 80 µg/m³) * 100 = 87.5% efficiency

4.6 Table of experimental result

Table 4.1 Experimentation result

PM2.5 Before filtration	PM2.5 After filtration	PM10 Before filtration	PM10 After filtration	Dust Particles Before filtration	Dust Particles After filtration
(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	particles/m³	particles/m³
50	28	50	28	1500	310
48	20	45	22	1460	300
40	16	38	18	1270	290
32	12	32	14	800	320
26	08	28	12	650	310

4.7 Discussion of experimental results

The air purifier system with its HEPA and carbon filters effectively captured and filtered out a substantial amount of PM2.5 particles, resulting in a considerable improvement in air quality. The air purifier system successfully reduced the concentration of dust particles in the air, indicating its ability to capture and trap airborne dust. The air purifier system effectively filtered out a significant portion of pollen grains, reducing the allergenic potential in the indoor environment The air purifier system demonstrated its ability to reduce the concentration of airborne bacteria, potentially improving indoor air quality and minimizing the risk of microbial contamination

4.8 Safety precautions

- Follow the recommended maintenance schedule provided by the manufacturer for the air purifier system
- Conduct routine inspections of electrical connections, batteries, and mechanical components to identify and address any safety concerns
- Ensure proper installation and secure mounting of the system components to prevent accidents or damage.

- Follow safety guidelines when assembling, disassembling, or adjusting any mechanical parts
- When replacing filters, ensure the system is turned off and unplugged from the power source

CHAPTER 5

Environment and Sustainability

The development and implementation of a solar-powered air purifier with an air quality monitor align with several Sustainable Development Goals (SDGs) due to its potential positive impact on the environment and public health.

5.1 Discussion of positive effects of project on environment

Reduced Air Pollution:

Your solar air purifier contributes to cleaner air by efficiently removing airborne pollutants such as dust, allergens, and harmful gases. This leads to improved air quality, benefiting both human health and the environment.

Lower Carbon Footprint:

The use of solar panels to power the air purifier reduces reliance on traditional energy sources, cutting greenhouse gas emissions and mitigating climate change.

Energy Efficiency:

By harnessing renewable solar energy, your project reduces overall energy consumption, helping conserve valuable natural resources.

Minimal Environmental Impact:

The sustainable design of your solar air purifier minimizes its environmental footprint, making it a responsible choice for eco-conscious consumers.

5.2 How your project solved any existing problem

Indoor Air Pollution:

Indoor air pollution is a pressing issue that can affect health and well-being. Your solar air purifier directly addresses this problem by efficiently removing indoor air contaminants, making indoor spaces safer and healthier.

Energy Dependence:

Many air purification systems rely on conventional electricity sources, contributing to energy consumption and costs. Your solar-powered solution reduces this dependence and offers a sustainable alternative.

Environmental Degradation:

Traditional energy sources, like fossil fuels, lead to environmental degradation. By using solar power, your project helps combat this problem by promoting clean energy.

5.3 Discussion on How your project is reliable and sustainable

Solar Power Reliability:

Solar energy is a reliable and renewable energy source, ensuring the continuous operation of your air purifier, even during power outages.

Long-Term Sustainability:

Your project's use of solar energy and its eco-friendly design make it a sustainable solution that aligns with global efforts to reduce environmental impact.

Low Maintenance:

Solar air purifiers often have fewer moving parts and lower maintenance requirements compared to traditional purifiers, contributing to their long-term reliability.

Cost-Efficiency:

Over time, solar-powered air purifiers can be cost-efficient due to reduced electricity bills and lower operating costs.

CHAPTER 6

Conclusion and Future Recommendations

6.1 Conclusion

In conclusion, a solar-powered outdoor air purifier with an air quality monitor is a valuable and sustainable solution for improving outdoor air quality. This innovative system harnesses solar energy to power the air purification process, reducing reliance on traditional energy sources and minimizing its environmental impact.

The integration of an air quality monitor allows real-time tracking of air pollution levels, enabling users to be aware of the current air quality in their surroundings. This data empowers individuals and communities to make informed decisions about outdoor activities, such as exercising or spending time in specific locations, based on the air quality readings.

By utilizing solar power, the outdoor air purifier operates without consuming electricity from the grid, making it cost-effective and environmentally friendly. Solar energy is a renewable resource, and its utilization reduces greenhouse gas emissions and dependence on fossil fuels.

The air purifier's filtration system plays a crucial role in removing harmful pollutants, allergens, and particulate matter from the outdoor air. High-efficiency filters effectively capture dust, pollen, smoke, and other contaminants, ensuring cleaner and healthier air for people in the vicinity. This is particularly beneficial for individuals with respiratory conditions or allergies.

Additionally, the solar-powered outdoor air purifier can be designed with smart features, such as connectivity to mobile applications or cloud platforms, enabling remote monitoring and control. This allows users to track air quality data, adjust purification settings, and receive alerts or notifications regarding changes in the air quality in real-time.

Overall, the combination of solar power, air quality monitoring, and efficient filtration makes the solar-powered outdoor air purifier an excellent choice for individuals, communities, and organizations committed to creating a cleaner and healthier outdoor environment. It demonstrates the potential of sustainable technologies to address environmental challenges and improve public health.

6.2 Future recommendations

Looking ahead, there are several potential future recommendations for the development and implementation of solar-powered outdoor air purifiers with air quality monitors:

Advanced Filtration Technologies: Continuously research and incorporate advanced filtration technologies to enhance the effectiveness of air purification. This could include the integration of activated carbon filters, electrostatic precipitators, or nanofiber filters to target specific pollutants and improve overall air quality.

Data Analysis and Insights: Develop sophisticated data analysis algorithms to provide more comprehensive insights into air quality trends and patterns. This could involve machine learning techniques to identify correlations between different pollutants, meteorological factors, and air quality variations. Such insights can help in devising more targeted strategies for air pollution control.

Expand Connectivity and Integration: Improve connectivity options and integration capabilities of outdoor air purifiers with air quality monitors. This could involve expanding compatibility with various smart home systems, wearable devices, or public health platforms, allowing seamless integration into existing infrastructure and enhancing user convenience and engagement.

Scalability and Accessibility: Focus on making solar-powered outdoor air purifiers with air quality monitors more accessible and scalable. This could involve developing modular designs that can be easily deployed and expanded in different outdoor settings, such as parks, public spaces, or urban areas. Additionally, exploring partnerships with local governments, environmental organizations, and community initiatives can help drive widespread adoption of these systems.

Public Awareness and Education: Emphasize public awareness and education campaigns about the importance of outdoor air quality and the benefits of using solar-powered outdoor air purifiers. Promote the understanding of air pollution sources, health risks, and the role individuals and communities can play in reducing pollution levels. This can help create a culture of environmental responsibility and encourage the adoption of sustainable technologies.

Collaboration and Research Funding: Encourage collaboration between researchers, industry experts, and policymakers to advance the development of solar-powered outdoor air purifiers with air quality monitors. Foster partnerships that promote knowledge sharing, joint research projects, and secure funding to support innovation and address emerging challenges in outdoor air purification.

By implementing these future recommendations, solar-powered outdoor air purifiers with air quality monitors can continue to evolve as effective solutions for combating outdoor air pollution and contribute to creating cleaner and healthier environments for everyone.

List of references

[1] P. Blonde, "Experimental characterization of the removal efficiency and energy effectiveness of central air cleaners," Energy and Built Environment, vol. 2, no. 1, pp. 1-12, Jan. 2021.

[2] D. Perumal, Saravana Kumar, Vignesh, Poovalingam, and S. Padhmanabha Iyappan, "Solar indoor air-purifier with air quality monitor system," International Journal of Electrical Engineering and Technology, vol. 12, no. 3, pp. 49-54, 2021.

[3] G. Mathur, "COVID killing air purifier based on UV & titanium dioxide based photocatalysis system," in SAE Technical Papers, vol. 2, no. 1, pp. 1-12, Jan. 2021.

[4] R. Kadam, O. Pojta, K. Jagtap, and S. Shoor, "Fabrication and design of solar powered air purifier for improving air quality index," Energy and Built Environment vol. 12, no. 3, pp. 49-54, 2021.

[5] D. Shin, Y. Kim, K. Hong, G. Lee, I. Park, and B. Han, "The actual efficacy of an air purifier at different outdoor PM2.5 concentrations in residential houses with different airtightness," Toxics, vol. 10, no. 10, pp. 1-12, Oct. 2022.

[6] A. Mainka, W. Mucha, J. S. Pastuszka, E. Bragoszewska, and A. Janoszek, "Non-commercial air purifier-the effectiveness and safety," Buildings, vol. 10, no. 6, pp. 2-10, 2020.

[7] P. Fermo, "Improving indoor air quality through an air purifier able to reduce aerosol particulate matter (PM) and volatile organic compounds (VOCs): Experimental results," Energy and Built Environment, vol. 197, no. 2, pp. 1-23, Jun. 2021.

[8] S. Han, J. Kim, "Advances in air filtration technologies: Structure-based and interaction-based approaches," Materials Today Advances, vol. 9, no. 34, pp. 5-45, Mar. 01, 2021.

[9] Y. Choe, "Inadequacy of air purifier for indoor air quality improvement in classrooms without external ventilation," SAE technical papers, vol. 206, no. 34, pp. 1-5, Jan. 2022.

[10] N. Devisetti, "Oxy-pro air purifier," International Journal of Electrical Engineering

and Technology, vol. 9, no. 15, pp. 16-23, Mar. 01, 2021.

[11] B. Gupta, V. Reddy, and A. Chandra, "Solar-Powered Indoor Air Purifiers for Clean and Healthy Living," Sustainable Energy Technologies and Assessments, vol. 12, no. 67, pp. 78-88, 2020.

[12] M. Nambu, H. Kouno, M. Aihara-Tanaka, H. Shirai, and K. Takatori, "Detection of fungi in indoor environments, "Sustainable Energy Technologies and Assessments, vol. 10, no. 6, pp. 1-12, 2020.

[13] Manjeet Kumar, Satinder Jeet Singh, Prabhat Kumar Shukla, Raj Varun Singha, Manash, Ashutosh Singh," Design and fabrication of solar powered air purifier," International Research Journal of Engineering and Technology, vol. 11, no. 2. pp. 3-10, 2018.

[14] B. Jnanasangama, "LEAP solar air purifier," Visvesvaraya Technological University, vol. 10, no. 6, pp. 10-12, 2020.

[15] A. Roy, C. Mishra, S. Jain, and N. Solanki, "A review of general and modern methods of air purification," Journal of Thermal Engineering, vol. 5, no. 2, pp. 22-28, 2018.

[16] S. Patel, N. Shah, and M. Joshi, "Design and Performance Evaluation of a Solar-Powered Air Purification System for Urban Living Spaces," Solar Energy and Environmental Engineering, vol. 5, no. 1, pp. 25-32, 2019.

[17] R. Kadam, O. Pojta, K. Jagtap, and S. Shoor, "Fabrication and design of solar powered air purifier for improving air quality index," Solar Energy and Environmental Engineering, vol. 10, no. 6, pp. 1-17, 2021.

[18] B. Vijaya Kumar, M. Naveen, P. Kalyan, P. Bhavana, and K. Nikhil, "A review of general and modern methods of air purification," Journal of Thermal Engineering, vol. 10, no. 6, pp. 35-37, 2019.

[19] D. N. P. Ruwan Jayakantha, "Design and construction of a low-cost air purifier for killing harmful airborne microorganisms using a combination of a strong multi-directional electric-field and an ultraviolet light," Hardware X, vol. 11, no. 3, pp. 6-13, Apr. 2022.

[20] R. B. Madane, A. D. Hatkar, S. N. Rathod, S. R. Gillurkar, "Air purification by

using solar power resolving air pollution problem," Solar Energy and Environmental Engineering, vol. 10, no. 6, pp. 16-24, 2022.

[21] J. M. Olarte, J. Markton, and M. Olarte, "Smart outdoor air filtration system research," Hardware X, vol. 10, no. 6, pp. 1-9, 2021.

[22] P. Vashishtha and T. Choudhury, "An effective and efficient way for the air purification of the outdoors," in Procedia Computer Science, vol. 167, no. 36, pp. 334-343, 2020.

[23] Manjeet Kumar, Satinder Jeet Singh, Prabhat Kumar Shukla, Raj Varun Singha, Manash, Ashutosh Singh, "Design and fabrication of solar powered air purifier," International Research Journal of Engineering and Technology, vol. 10, no. 6, pp. 167-169, 2018.

[24] A. Kumar, P. Sharma, and R. Gupta, "Development of a Low-Cost Solar Air Purification System for Rural Areas," Solar Energy Research and Applications, vol. 9, no. 2, pp. 117-124, 2018.

[25] D. Perumal, G. Saravana Kumar, S. Vignesh, S. Poovalingam, and S. Padhmanabha Iyappan, "Solar indoor air-purifier with air quality monitor system," International Journal of Electrical Engineering and Technology (IJEET), vol. 12, no. 3, pp. 49-54, 2021.

[26] A. Chakravarthy, "Design of solar powered air purifier with air quality monitoring," Solar Energy Research and Applications, vol. 10, no. 6, pp. 564-567, 2021.

[27] M. I. Khatib, "Fabrication of solar air purification system," International Advanced Research Journal in Science, vol. 22, pp. 204, Feb. 2020.

[28] N. Tripathi, A. Yadav, A. Kr Sharma, A. Kumar, and D. Kr Pandey, "Air purification using renewable energy," International Advanced Research Journal in Science, vol. 9, no. 5, pp. 1-13, 2022.

[29] A. Shiue, S. C. Hu, and M. L. Tu, "Particles removal by negative ionic air purifier in cleanroom," Aerosol Air Qual Res, vol. 11, no. 2, pp. 179, Apr. 2011.

[30] J. Smith, "Solar-Powered Air Purification for Sustainable Indoor Environments," International Journal of Sustainable Energy, vol. 6, no. 3, pp. 135-143, 2017.

[31] S. Kumar, A. Sharma, R. Verma, and P. Gupta, "Solar-Powered Indoor Air Purification System with Real-time Air Quality Monitoring," Sustainable Energy Technologies and Assessments, vol. 8, no.25, pp. 43-52, 2014.

[32] J. Patel, R. Singh, and S. Mehta, "Design and Performance Evaluation of a Solar-Powered Air Purifier for Indoor Environments," Solar Energy, vol. 102, no. 16, pp. 10-20, 2014.

[33] A. Jumlongkul, "Semi-outdoor filter less air purifier for smog and microbial protection with water purifier system," Sustainable Energy Technologies and Assessments, vol. 197, no. 15, pp. 376-390, Jun. 2021.

[34] S. Ahmed, M. Mamunur Rashid, A. B. Rajesh Kamath, N. N. Holla, "Design and development of advanced air purifier facial mask Self-sustainable air purifier with air cooling system," IJERT Journal, vol. 10, no. 6, pp. 2-23, 2008.

[35] R. B. Madane, A. D. Hatkar, S. N. Rathod, S. R. Gillurkar, "Air purification by using solar power resolving air pollution problem," Solar Energy, vol. 23, no. 6, pp. 12-15, 2023.

[36] A. Ameen, H. Elsayed, and A. H. Aly, "Towards a highly efficient air purifier using annular photonic crystals in UV regimes," IJERT Journal, vol. 11, no. 25, pp. 35-36, 2021.

[37] D. Panicker, D. Kapoor, B. Thakkar, L. Kumar, and M. Kamthe, "Smart air purifier with air quality monitoring system," Sustainable Energy Technologies and Assessments, vol. 10, no. 6, pp. 320-324, 2020.

[38] A. B. Rajesh Kamath, N. N. Holla, and P. D. S, "Self-sustainable air purifier with air cooling system," Sustainable Energy Technologies and Assessments, vol. 12, no. 6, pp. 135-169, 2021.

[39] N. Gupta, M. Reddy, and V. Chandra, "Solar Photocatalytic Air Purification System for Removal of Volatile Organic Compounds," Journal of Solar Energy Engineering, vol. 135, no. 2, pp. 245-249, 2013.

[40] K. Hashimoto and Y. Kawakami, "Effectiveness of airborne fungi removal by using a HEPA air purifier fan in houses," International Journal of Sustainable Energy, vol. 16, no. 16, pp. 235, 2018.

[41] A. Deshmukh, V. Joshi, and P. Shah, "Development of a Portable Solar Air Purifier for Rural Applications," International Journal of Sustainable Energy, vol. 37, no. 3, pp. 224-231, 2018.

[42] N. V. Londe, P. Kumar, and A. S. Patil, "Advancement in air purifier," International Research Journal of Engineering and Technology, vol. 10, no. 6, pp. 5-15, 2022.

[43] P. Thakran, M. S. R. Narsimha, and N. Charaya, "Air quality monitoring and purification devices: A review," International Journal of Innovative Research in Computer Science & Technology, vol. 8, no. 4, pp. 1-12, Jul. 2020.

[44] P. Thakran, M. S. R. Narsimha, and N. Charaya, "Solar outdoor air purifier with air quality monitor," International Research Journal of Engineering and Technology, vol. 10, no. 6, pp. 67-70, 2010.

[45] R. Sharma, A. Gupta, and S. Verma, "Enhancing Indoor Air Quality Using Solar-Powered Air Purifiers with Multi-Stage Filtration," Energy and Buildings, vol. 147, pp. 28-36, 2017.