International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Application Design of an Integrated Outdoor Air Quality Monitoring Device Based on Solar Power

V. V. Ravi kumar[1], N. Sai Nishanth[2], Pawan Gopal[3], P. Devi[4], B. Nagaraju[5], S. Dileep Kumar[6], T. Mohan[7], B. Yogesh[8], G. Karthick Varun[9],

[1]Assistant Professor, Department Mechanical, NSRIT, Affiliated to of JNTUK, AP, INDIA

[23456789]Students of Mechanical Engineering, Department Mechanical, NSRIT, Affiliated to of JNTUK, Visakhapatnam– 531173, Andhra Pradesh, India

sainishanthnalla@gmail.com, ravikumar.me@nsrit.edu.in

Abstract

Pollution has rocked the world with skyrocketing pollution levels. Though the long-term solution to the pollution problem lies in finding and minimizing pollution sources, we need to bring the current pollution levels under control by the time. The best way of controlling pollution is by using air purifiers. But regular indoor air purifiers are small low power devices that don't posses enough purifying capability needed for outdoor spaces. Along with this there is also an issue of power supply in outdoor machines.

So here we design a heavy-duty outdoor air purifier that is made for outdoor purification along and powered by solar panels so it is energy independent. 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.

Keywords: OUTDOOR SOLAR AIR PURIFIER, HEPA AIR FILTER, SOLAR PANEL.

1. Introduction

As we know that air pollution level in cities is very high. Most of pollution comes as by-product from vehicle and construction of buildings; these are in form of particulate matter which are like methane, carbon dioxide, dust particulate etc. These create a lot of health problems like respiratory illness, decreased lung functions, development of diseases like asthma etc. Larger dust particles are major particulate among these and if its air quality value is down to minimum then air has very improved quality in which all type of living things can breathe easily. Although there are many types of air purifier that are available in market but none of them are sufficient enough to deliver its working efficiency in public places like bus stand, near hospitals, traffic signals etc. Many institutes are also not able to afford these because of high cost and installation cost. Government organizations have very low budget for air purifier like extra expenditure. So, it is advisable to develop such air purifier which can cost less and are highly efficient. So, we are making solar powered air purifier, which runs on solar energy without use of filters and also works for longer duration than others. It uses component like solar panel, fan, converter, pump, etc.

The overall structure of integrated solar powered outdoor air quality monitoring device system is shown in Fig.1. Solar module and monitoring control cabinet composed of integrated design, and the LED display with removable independent modular design, which depending on the application to facilitate the needs of different occasions, different options in different ways to install. In the system module, a wireless communication unit can be optional, implementation and monitoring system, intelligent terminals and other wireless network, network monitoring.

Particulate pollution has important consequences for human health [1], and is an issue of global concern. In 2014, the World Health Organization (WHO) announced that air pollution exposure represents the single largest environmental health risk, causing one-eighth of total deaths in 2012. Ambient air pollution has become a cause for alarm in India in particular because recent data suggest that ambient pollution levels in Indian cities are some of the highest in the world [2]. In fact, globally, 13 of the 20 cities with the highest mean levels of PM2.5 ± which refers to particles with a diameter less than or equal to 2.5µm±are in India, and Delhi ranks as the worst. In light of the extremely high levels of air pollution encountered in Indian cities and the risks associated with exposure, we study the number of particles of diameter between 0.5µm and 2.5µm indoors while using an air purifier in the highly polluted city of Delhi. Air purifiers are marketed as a tool that can be used to mitigate exposure to high levels of particulate pollution. However, to our knowledge, no information is available on indoor air quality during realistic patterns of air purifier use in highly polluted environments such as those found in Indian cities. Documenting indoor air quality during air purifier use is important because of the health risks associated with particulate exposure. Exposure to PM2.5 has been linked to cardiopulmonary mortality [3] and morbidity [4] among adults, infant mortality [5], and deficits in lung function growth [6] and respiratory illness [7] among children. Because of the connection between PM2.5 and poor health outcomes, many countries in the world have prescribed limits for PM2.5 and regularly monitor its levels. However, in India, these limits are often not followed, and the health consequences are tremendous. An economic analysis of the implications India's pollution levels has on life expectancy estimates that the more than half of Indians living in areas that do not meet the annual Indian air quality standard of 40µg/m3 would live on average 3.2 years longer if air pollution in these areas were reduced to the standard [8].

A number of studies have examined the impact of air purifiers on the air quality in smokers' homes [9], on allergy and respiratory symptoms for adults and children [10], and on vascular health [11]. However, all of these studies have been conducted in cities and towns in Europe and the United States, in which pollution levels, even in the homes of smokers, are often much lower than those observed in Indian cities. A related body of literature addresses the effectiveness of air purifiers and introduces methods for determining particle removal rates attributable to air cleaning devices [12]. This study does not attempt to calculate improvements in air quality attributable to the air purifiers we test. Since exposure is what is most relevant for health impacts, we contribute to the literature by investigating overall indoor air quality during air purifier use, and how it responds to factors over which households or policy-makers may have some control. In addition to mass concentrations of particulate matter, number concentrations are an important marker of air quality [13-14]. Studies of number concentrations in urban India are scarce. Sharma and Patel [15] estimate the number distribution from the observed mass distribution in an industrial area in Mumbai. More recently, Monkkonen et al. [16] provide direct measurements of the number concentration of

particles larger than 10nm in diameter and the number size distribution of particles with diameter between 3nm and 800nm in Delhi.

1.2 Overview of Project:

This project provides a combination of process of sensing several gas levels in the air and also the ambient temperature and humidity, thus sensing the quality of the air. The levels of the gases and the temperature is displayed in a LCD display panel, which continuously shows the real time output values of the gas sensors, temperature and humidity sensor.

1.3 Objective:

- To measure and display temperature and humidity level of the environment.
- To combine advanced detection technologies to produce an air quality sensing system with advanced capabilities to provide low-cost comprehensive monitoring.
- To display the sensed data in user friendly format in LCD display panel.

BLOCK DIAGRAM:

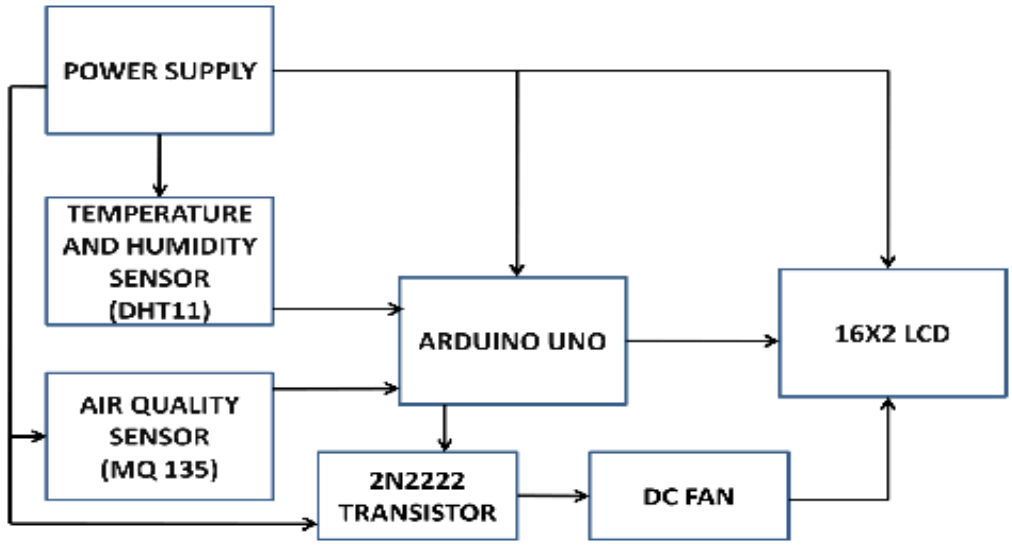

Fig:1. Block diagram of Air Quality Monitoring and Sensing

1.4 Methodology

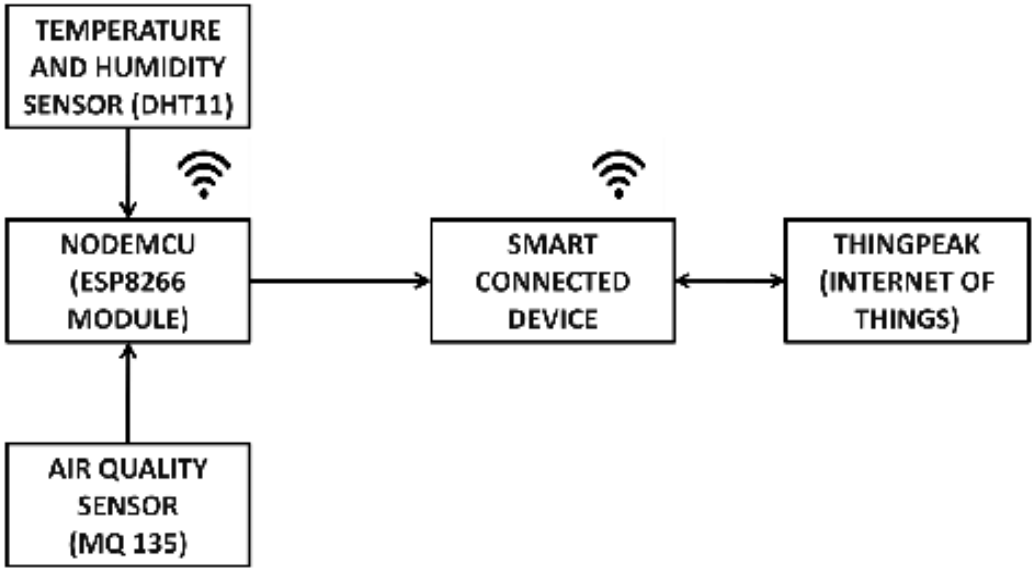

Fig.2 Block diagram of sending the data to THINKSPEAKER using NodeMCU

2. Experimental Procedure

Design and development of a heavy-duty outdoor air purifier that is made for outdoor purification along and powered by solar panels so it is energy independent. 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.

Now this suction fan is used to suck out air using high power centrifugal force and blowing out fresh air from the top. The system also includes an air quality sensor and display to display the current air quality. We now use a solar panel for the power supply. The panel is used to supply electricity to battery which in turn powers the motor to run the suction fan. The machine is mounted with 4 castor wheels and a handle for easy movement. This makes the air purifier portable so it can be easily moved to school play areas, parks, residential areas, public places for efficient and instant pollution control.

2.1 Components

High Torque Motor, Blower Propeller, Solar Panels, Battery, HEPA Filter, Active Carbon Filter, Castor Wheels, Inverter Setup, Electrical Setup, LCD Display, Keypad, Buttons and Switches, Supporting Frame, Mounts and Joints, Screws and Bolts

Fig. 3 Outdoor Air purifier Components

2.1 Working Principle

There is a chamber in which air is sucked in by the fan, while the air is entering it passed through strainer. The air passes through the HEPA filter here the HEPA filter absorbs the dust and carbon particles coming through the incoming air and cleans it. The exhaust fan connected to a propeller shaft of the motor, and runs at a high speed powered by a battery. A battery which is connected to the solar panel receives electrical energy from it and stores the electric current to provide for other electrical equipment. This way air is cleaned and is flown out from chamber by exhaust fan.

A prototype device system was design and development, Prototype and application shown in Fig 3 the prototype operation experiments were studied and tested by analysis of test results and the corresponding control experiments, indicating that the unit is stable and reliable, according to the design requirements can accurately monitor the various air quality parameters.

Fig. 4 Solar outdoor air purifier

Solar power supply unit for outdoor applications, use a separate solar power system can be unrestricted conventional mains supply, device installation flexibility, in addition, energy saving. Solar module power emitted via a dedicated charge controller to charge the battery, and then the DC / DC converter is converted into stable DC power supply for the entire system unit. Solar PV module capacity can use the daily generating capacity (Q) pv according to formula is calculated: Where: K stands for the comprehensive correction coefficient, which includes ramps attenuation correction and environmental components of other comprehensive correction coefficient; IM is the best PV module operation current; H is the average daily radiation; H is the overall efficiency of the system. The battery capacity according to the formula calculated as follows: Where: KA is comprehensive correction coefficient for the battery, including battery Utilization, the battery capacity and depth of discharge attenuation coefficient and other factors; Qal design means the total daily consumption; Nr is maximum rain (or no effective illumination) for several days.

The air quality monitoring data of air quality monitoring system including particulate matter (PM), combustible gases, toxic gases, ultraviolet radiation, atmospheric pressure and temperature and humidity and other common air quality qualitative parameters, the overall system are modular design. The sensors through corresponding interface to a master microcontroller.

LED display unit design. Bright LED display can display dynamic parameters information of air quality

The designed display uses two P5LED screen components. Display driven by a separate STC12C5A60S2 control chip, and the main control circuit unit can be used between the serial UART or wireless means to exchange information. The display part received from the master unit air quality multi-parameter acquisition and processing of information, then real-time scrolling display LED screen. The main screen displays real-time information and dynamic air quality information. The sources of Outdoor particle pollutants can be divided into Indoor pollution sources and outdoor pollution sources, and the concentrations and composition of outdoor particle pollutants are different with different pollution sources. In residential buildings, particles released by indoor pollution sources (e.g., cooking, smoking) were mostly fine particles and ultra-fine particles which were about 80% of the particles in terms of particle counts.

PM2.5 concentrations could be up to 3and 30 times higher than the ordinary levels during smoking and cooking, respectively.

Primary gaseous pollutants

Primary gaseous pollutants mainly include CO, CO2, SO2, NOX, O3, radon and VOCs. Chemical materials have widely been used outdoors recently. The chemical materials can release many kinds of chemical pollutants at room temperature, and VOCs are the main composition of these chemical pollutants. VOCs can cause many symptoms, such as headache; eye, nose, and throat irritations; dry cough; dizziness and nausea; tiredness. VOCs also have bad effects on respiration systems, blood vessel systems, and nerve systems.

Secondary gaseous pollutants

The mix of pollutants in outdoor environments can be transformed as a consequence of chemical reaction. Reaction Between ozone and some unsaturated hydrocarbons is an important source of indoor secondary pollutants which mainly include free radicals, aldehydes, ketones, alcohols, carboxylic acids, and fine particulate matter. Secondary pollutants may be more irritating than the original reactants. During the past few years, many investigations were conducted on indoor secondary pollution due to ozone reacting with limonene. Much significant research has occurred in three subtopics confirming the importance of hydroxyl radical in indoor transformations.

3. Result and Discussion

3.1 Automated Air Purification System for Outdoors (AAPSO) is a unique air purification system conceptualized on the modern air purification standards to meet the pollution demands of the busy industrial cities and the slow-moving rural areas as well. It has been designed with the ability to remove particulate matter and allergens and microbes from air and make the surrounding air cleaner to breathe and live. It is based on the modern methods like HEPA and ionizer which are the most energy efficient and favorable Indoor Air Purification systems and running on solar power also, this mechanism can help clean out outdoor air almost perfectly and efficiently. Moreover, the design has been conceptualized keeping in mind the dynamics of air flow and Bernoulli's principles. The concept has been derived from nature. Trees, as they form a basis of air purification in the ecosystem, give it inspiration and the mechanism used in it is very cheap and easily available without much strain. However, further modifications to this concept can take this to greater efficiency to tackle the modern Pollution problem that the world is facing today

3.2 General Methods of Air Purification studied the positive impact of mechanical air filters on indoor air pollution. Mechanical air filters refer to a meshed structure through which contaminated air is made to pass. The pore size of mesh is the most important factor for deciding the efficiency of mechanical filters. Contaminants having sizes greater than the mesh pore size are unable to pass and thus get separated leading to air purification. Such air filters are responsible for filtering out PM pollutants from indoor air. High Efficiency Particulate Air (HEPA) filters are the most used filtration media in today's air purifiers for filtering out PM. They have an efficiency of removing 99.97% of particulate matter of size less than 0.3 microns from contaminated air ensuring a flow rate anywhere between 150-400 cubic feet per minute

depending on the clogging of their pores. HEPA filters appear in the form of pleated paper which is actually a very dense network of glass fibers. HEPA filters work on the principle of Brownian motion pertaining to which, there are three different mechanisms of trapping dust particles viz., impact, interception and diffusion. It is customary to use a pre-filter with HEPA filters in order to increase their life between subsequent replacements. Pre-filters are essentially a fiber mesh of comparatively larger pore sizes. Pre-filters are essential to trap the relatively larger particulates present in air so that they do not unnecessarily clog the HEPA pores. Electronic filters are not filtering essentially. Instead, they create an electric field for ionizing the particles passing through it. Electrostatic Smoke Precipitators (ESP) are electronic air filters which work on the principle of corona discharge. It is to be noted that the working of ESP requires a supply of high input voltage. There are two oppositely charged terminals which may be in the form of plates, wires or bars. Contaminated air is made to pass through the negatively charged terminal. As a result, the pollutants present in air get negatively charged. The flow of air is made in such a way that it passes through the positively charged terminal after moving past its negatively charged counterpart. All the negatively charged contaminants get attracted to the positively charged plates. In this way, air purification is achieved. An important advantage of ESP is that any size of particulate matter may be removed from polluted air unlike mechanical (HEPA) filters that pose a restriction on the pore size of filtrable particles. All that matters in an ESP is the supply voltage. The higher the supply voltage, finer the size of filtrable contaminants. ESP is thus capable of filtering out PM 2.5 contaminants. Zukeran et al. [10] studied the role of ESP in filtering out smoke being emitted by incense sticks. The dependence of efficiency on supply voltage was plotted by varying the same from 9 to 30 Kilo Volts.

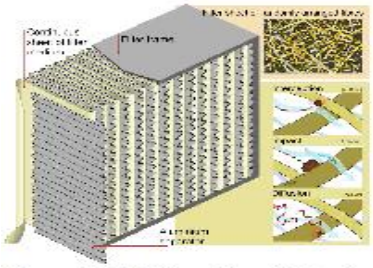

Figure HEPA air filter and its particle trapping mechanisms

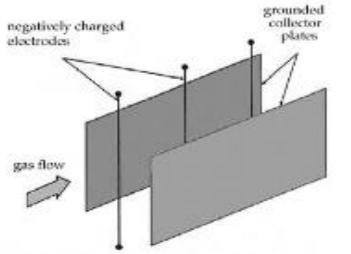

Figure . Schematic diagram of electrostatic smoke precipitator

Fig.5 HEPA Air filter

Filtrating the outdoor air to prevent outdoor pollutants from entering the room. Isolating the sites that may form pollution sources in order to avoid intercrossing infection, and using the enforced ventilation when necessary. making full use of pollution-free or low-pollution building Materials and decorating materials Preventing building products with high pollution from entering market by government Legislating and setting up industry standard. For the products in markets, government can label them with different grade. The building materials and decorating materials with high pollution can be eliminated by market mechanism.

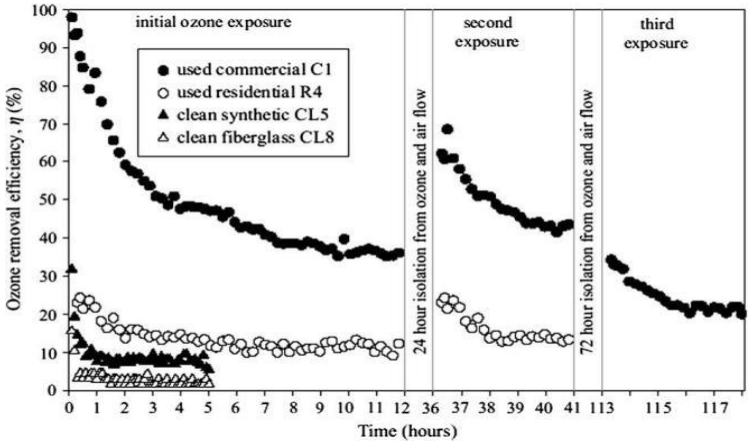

Fig. 6 Ozone exposure

Dust and liquid drops are the important medium for bacteria to spread. It is necessary to trebly clean the components that are easy to be infected in air-conditioning systems (e.g., filter, heat exchanger and muffler) and to replace them in time in order to avoid the aggradations of pollutants. Moreover, to prevent bacteria from propagating. In addition, occupants' behavior is also an important origin for outdoor pollutants, so we should form better customs such as no high strength activities, keeping better individual sanitation, no smoking in outside, and avoiding using pressurized spray and cosmetic. Researchers should keep on investigating chemical pollutants' releasing characteristics of materials used outdoors and exploiting new types of materials without release of pollutants.

3.3 Output of Solar Powered Air Purifier

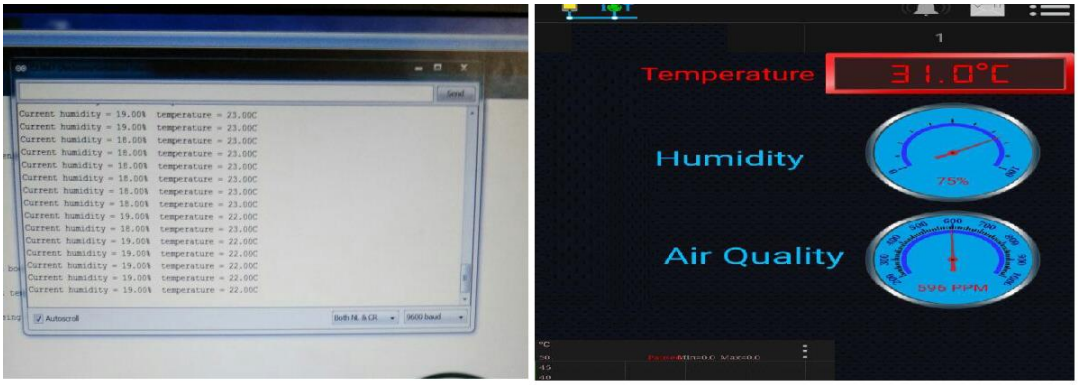

Fig.7 Experimental out put

A comfortable and healthy indoor air environment is favorable to occupants. In recent years, indoor thermal comfort has been improved greatly due to the development of air-conditioning systems. However, health problems related to poor IAQ appear more frequently, and it is the indoor pollutants that lead to poor IAQ. Many researchers have widely investigated the composition of indoor pollutants, sources, physical and chemical characteristics, and effects on human health. However, a given symptom usually has different causes, and a given pollutant may result in (or trigger) many different symptoms. The biological effects of different pollutants may differ by orders of magnitude. Moreover, the composition of indoor pollutants is quite complex and their concentrations are greatly different. The

chemical reactions among indoor pollutants may occur, which can produce more irritating secondary pollutants. Many secondary pollutants even cannot be measured for the moment. It is not clear that the effect mechanism of these pollutants to human body with exposure under low concentrations and short time levels. It is also uncertain that the impact of exposure amount and exposure time on human health. Only if these problems are resolved can indoor air environment be controlled accurately and reasonably.

4. Conclusions

Now we have seen that how efficient is SOLAR POWERED AIR PURIFIER than other type of device available in market.

- ❖ It also very economical and do not have to replace any component quickly.
- ❖ It reduces particulate level to satisfactory position where a person does not need to worry about pollution related problems.
- ❖ A pure and clean air is right of a human being and all other living creatures on this earth and this project is a small effort from our side to give the all their right.
- ❖ Also in future, modifications can be made to improve working efficiency without effecting setup.

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