Air Purification System

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Abstract— The air purifier industry has seen a growth in terms of demand and sales lately. All credit goes to massive industrialization in developing countries such as India and China. As a result, a lot of research has been focused into the various methods of purifying air. The most harmful of the pollutants are PM 2.5 particulates, NOx emissions and Bacterial viruses. The aim has been to bring down the costs without compromising on efficiency as efficient air purification is an expensive deal. This paper presents one solution to all types of contamination problems of air pollution. A compilation of the most common and significant methods of purifying air such as those employing the use of HEPA filters, activated carbon and UV light has been presented and their use in air purifiers. We will provide new air purification system which consists of combination of Hepa filer, UV light and Carbon filter.

Keywords: Air Purifier, PM 2.5, NOx Emissions, HEPA filters, activated carbon and UV light

I. INTRODUCTION

This paper presents a compilation of some of the most recent methods of purifying air which are cost effective and efficient at the same time.

A. General Background

Air pollution has become one of the most significant and deadliest causes of deaths today. The World Health Organization (WHO) stated that around 6.5 million deaths were caused by air pollution in the year 2012 translating to 11.6% of total global deaths. WHO states that air pollution is the cause of one-third of deaths caused due to stroke, lung cancer, and chronic respiratory diseases. Approximately, 92% of the world's population is exposed to air pollution levels that are beyond the permissible limits prescribed by WHO. There are three basic strategies to tackle indoor air pollution. The first is Source Control where in, the source of pollutants is considered, and steps are taken to eliminate or decrease pollutants right from the source. If feasible enough and practically possible, this is the most effective method of reducing air pollutants. Ventilation is another method of reducing indoor air pollution. The fundamental for attaining a good ventilation system is very simple. An efficient system of exchange of air between inside and outside of a closed space needs to be ensured. Infiltration refers to the induction of outside air into a closed space through openings, joints or cracks in walls. Infiltration falls under natural ventilation which on a broader spectrum refers to the inclusion of outside air into a room or building without the aid of any external promoter. The third method of reducing indoor air pollution is usage of air purification systems also known as air purifiers. Air purifiers have been in trend lately because of their high efficiency of purifying polluted air. There are various OEMs that manufacture air purifiers with different technologies and mechanisms of air purification. It can be stated here that an air purifier is not self-sufficient to tackle indoor air pollution but requires a good ventilation system in conjunction. The job of an air purifier is twofold reduction of pollutants, they being particulate matter (PM) and gaseous pollutants. The most common air purification media are being discussed here.

Fig. 1.1: Deaths form Air pollution

Household air pollution is one of the areas that need immediate attention. There are different sources of indoor air pollution like tobacco smoking, fuel used for cooking, use of pesticides and chemical which causes disabilities among people. Household air pollution affects mostly the respiratory system and further leads to cancer. Apte and Salvi helped in identifying different household air pollutants and their health implications and strategies to curb household air pollution. Indoor air quality (IAQ) is one of the major factors for the building owners and facility manager. IAQ has to be assessed properly before building any structure. Advanced techniques like moisture control pressurization strategies were developed to better manage IAQ. Shriman dilkar provided an analysis of relationships between IAQ technologies and construction practices. Recommendations are made for monitoring moisture in buildings during construction. There is a serious concern over the pollution emitted from burning of various fuels like cow dung, wood etc. for cooking purposes. IAQ was tested to estimate the emissions of particulate matter and Volatile Organic Compounds (VOCs). The results revealed that cow dung is most polluting fuel with maximum emissions of PM and VOCs. The solution to this is LPG fuels which is a healthier option as compared to the conventional fuels. Gautam et al. claimed that the level of pollution can also be decreased by providing proper ventilation systems, replacing traditional stoves with improved efficient stoves.

Bolashikov and Melikov illustrated different methods and technologies for indoor air purification and disinfection from microorganisms and viruses for HVAC systems and their applications. Different air purification methods like Dilution, Filtration, Photocatalytic oxidation

etc. were studied and their characteristics were compared with the air purification techniques used today. Some oils can be used as antimicrobial and anti-fungal agents for reducing the number of pathogens and thus helping in disinfection of air. Carbon dioxide is one of the vital resources one needs but on the other hand if its indoor volume increases, it can pose some threats. Hu et al. illustrated the use of sorption type air filters along with coconut based granular activated carbon to prevent Carbon Dioxide. The adsorption of Carbon Dioxide can be increased by using Magnesium Oxide and Calcium Oxide. This paper also explains the surface area analysis and calculation of initial efficiency, breakthrough curves and pressure drop to validate the results.

B. Classifications of Air Contamination

1) Solid Contamination

PM stands for particulate matter (also called solid air contamination): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope. These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles. PM10: inhalable particles, with diameters that are generally 10 micrometers and smaller; and PM2.5: fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller. How small is 2.5 micrometers? Think about a single hair from your head. The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.

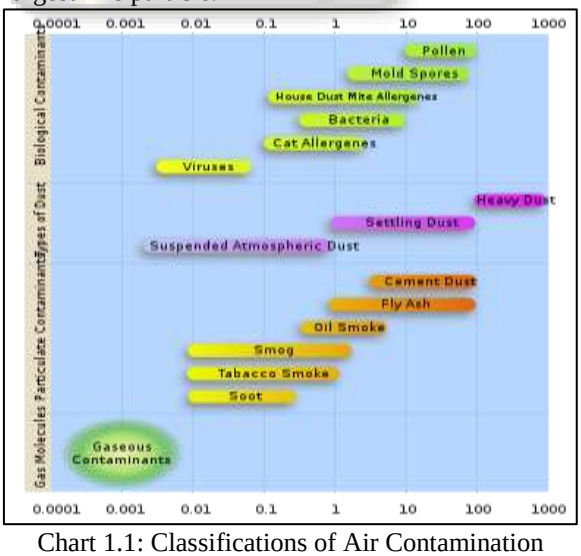


Chart 1.1: Classifications of Air Contamination

2) Biological Contamination

Biological contaminants include bacteria, molds, mildew, viruses, animal dander and cat saliva, house dust, mites, cockroaches, and pollen. There are many sources of these pollutants. Pollens originate from plants; viruses are transmitted by people and animals; bacteria are carried by people, animals, and soil and plant debris; and household pets are sources of saliva and animal dander. The protein in urine from rats and mice is a potent allergen. When it dries, it can become airborne. Contaminated central air handling systems can become breeding grounds for mold, mildew, and other sources of biological contaminants and can then distribute these contaminants through the home. By controlling the relative humidity level in a home, the growth of some sources of biological can be minimized. A relative humidity of 30-50 percent is generally recommended for homes. Standing water, water-damaged materials, or wet surfaces also serve as a breeding ground for molds, mildews, bacteria, and insects. House dust mites, the source of one of the most powerful biological allergens, grow in damp, warm environments.

3) Chemical Contamination

The gaseous criteria air pollutants of primary concern in urban settings include sulfur dioxide, nitrogen dioxide, and carbon monoxide; these are emitted directly into the air from fossil fuels such as fuel oil, gasoline, and natural gas that are burned in power plants, automobiles, and other combustion sources. Ozone (a key component of smog) is also a gaseous pollutant; it forms in the atmosphere via complex chemical reactions occurring between nitrogen dioxide and various volatile organic compounds (e.g., gasoline vapours). Carbon monoxide is an odourless, invisible gas formed as a result of incomplete combustion. It is the most abundant of the criteria pollutants. Gasoline-powered highway vehicles are the primary source, although residential heating systems and certain industrial processes also emit significant amounts of this gas. Power plants emit relatively little carbon monoxide because they are carefully designed and operated to maximize combustion efficiency. Exposure to carbon monoxide can be acutely harmful since it readily displaces oxygen in the bloodstream, leading to asphyxiation at high enough concentrations and exposure times.

C. General Methods of Air Purification

1) High Efficiency Particulate Air (HEPA) filters

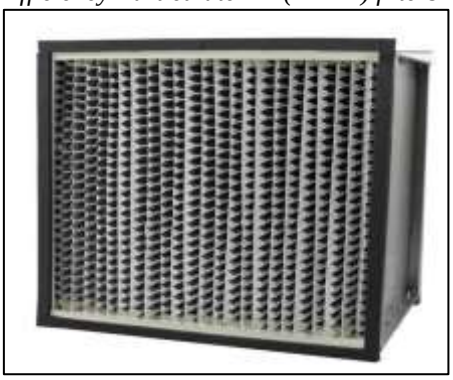


Fig. 1.2: HEPA Filter

HEPA stands for High Efficiency Particulate Arresting. It refers to a type of filter that has been manufactured, tested, certified to remove 99.7% of all particles greater than 0.3 microns (or millionth of a meter). To give some scale, a human blood cell is 5 microns wide – so 0.3 microns would be less than 1/15th of that size. Understandably, these filters are top of the line for air filtration. When air is forced through a HEPA filter, airborne particles get trapped in dense, randomly arranged fibrous mat. HEPA-like filters are commonly used in vacuums to remove

dust and allergens from carpets and other types of flooring. However, the HEPA filtration products that are installed in HVAC systems are stringent enough to remove not only dust but many of those unhealthy microbes that float around in the air during cold and flu season.

A HEPA filtration system will reduce the allergens and other airborne respiratory triggers that circulate throughout your home. Certified HEPA filters are efficient enough to capture:

- Dust
- Pollen
- Mold spores
- Pet dander
- Bacteria
- Viruses
- Odors
- Chemicals from cleaners

2) Ultra Violet (UV) light

Fig. 1.3: UV Light

UVGI is a proven method for removing volatile organic compounds (VOCs) and for killing or deactivating bacteria, viruses, mould spores, and other pathogenic microorganisms that may be present in room air. UV systems destroy high levels of airborne and surface bio-contaminants. Infections Acquired in Hospitals (HAI) can be a significant cost for the healthcare industry and is considered a preventable injury. Ultra IAQ systems are the ideal tool to help reduce nosocomial infections. UV-C Air and Surface Disinfection models contain one or more germicidal ultraviolet lamps that produce ultraviolet wavelengths lethal to microorganisms. As the air passes through the UV-C purification device or the surface is exposed to germicidal UV light, the genetic material of microorganisms is deactivated, preventing them from reproducing and rendering them harmless. This helps to maintain a clean evaporator coil, thus saving time and resources on coil cleaning. Using MERV filters in conjunction with in-duct UV systems can reduce the need of HEPA Greatly improves Indoor Air Quality (IAQ) and cures "Sick Building Syndrome" by destroying harmful airborne contaminants such as bacteria, viruses, mould. Germicidal Ultraviolet rays cause harmful irritation to skin and eyes. Always wear protective clothing, gloves and eye shield (goggles, glasses, etc.) when working with direct ultraviolet radiation.

3) Activated carbon filters

Fig. 1.4: Activated carbon filter

Carbon air filters are the filters most commonly used to remove gases. They are designed to filter gases through a bed of activated carbon (also called activated charcoal) and are usually used to combat volatile organic compounds (VOCs) released from common household products. They are also often used to remove odors from the air, such as the smell of tobacco smoke. They cannot remove fine particles like mold, dust, or pollen from the air. Carbon air filters remove pollutants from the air with a process known as adsorption. Note that this is different from absorption. In absorption, the substance you want to remove (let's say water) is absorbed into the structure of the absorbent (like a sponge), but it doesn't become a part of the absorbent on a molecular level. Therefore, when you absorb water with a sponge, the water does not become chemically bonded to the sponge. It just fills in the spaces inside it. Carbon filters on the other hand use ad-sorption, not ab-sorption. The key difference here is that during adsorption the pollutants stick to the outside of the carbon. Whereas with absorption, the pollutants are absorbed inside the structure itself–as with the sponge. Carbon is a lattice of carbon atoms connected to each other. The activation process is so important because the increase in surface area gives gases a greater area to stick to. When a molecule of some gaseous substance comes through the carbon, it can stick to the surface of the bed, provided there is an open adsorption site.

II. Literature Review

This section of report presents the study of literature for the topic, Hepa Filter, UV light, SARS-CoV- 2, Activated carbon Filter and its Effect. All these topics are covered below.

A. Impact of High Efficiency Particulate Air(HEPA)filters

Vijayan et al.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.

B. Effect of Ultra Violet (UV) light

Kujundzic et al. studied the mechanism and effects of air purification using UV light in great detail. A setup combining HEPA filter and UV light filter mounted on the ceiling was used for analysis. The purpose of the study was to analyze the effectiveness of UV air filters when used in conjunction with HEPA filters. The setup reduced the total bacteria in the target space by 12% and 76% over a span of two years respectively. The process of air purification using Ultra Violet (UV) light as a filtration medium is very simplistic in nature. A source of UV radiations is selected appropriately which emits UV radiations in the surrounding medium. Polluted air is made to pass through this medium as a result of which, the bacteria and pathogens present in air get filtered out. UV filters are responsible for removing only microbes and pathogens from air and do not contribute in PM filtration.

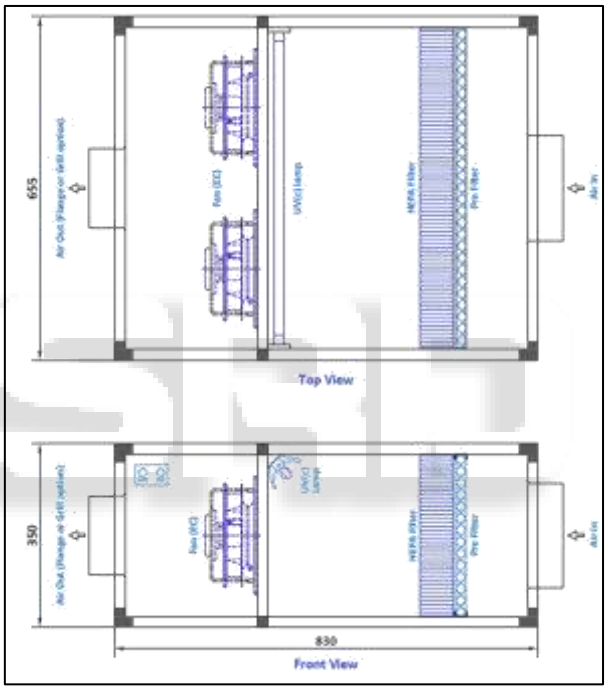
C. Effect of Activated carbon filters

Chambre studied the effects of an activated carbon layer in the path of impure air. Activated carbon is used for filtering out the gaseous pollutants present in air. There may be two forms of activated carbon viz., granular and bonded as studied by Chambre. It exhibits a high degree of porosity and a large surface area for interaction with pollutants. This enables it to attain very good adsorption characteristics. the principal governing the operation of activated carbon is based upon the concept of adsorption. There are two main types of adsorption that take place viz., physical adsorption and chemisorption. The preliminary process is physical adsorption wherein, Brownian motion of molecules is the dominating factor. Van der Waals' forces promote adsorption in which case, the gas molecules interact with the pores and get trapped as shown in Figure 3. Chemisorption follows the process of physical adsorption. The remaining gas pollutants react with chemical media of the activated carbon layer to form a compound which get trapped in the filter material. Results showed that granular activated carbon filter performed better than bonded activated carbon in terms of retention of mass of isopropanol at a given run time before reaching 1% of threshold limit value.

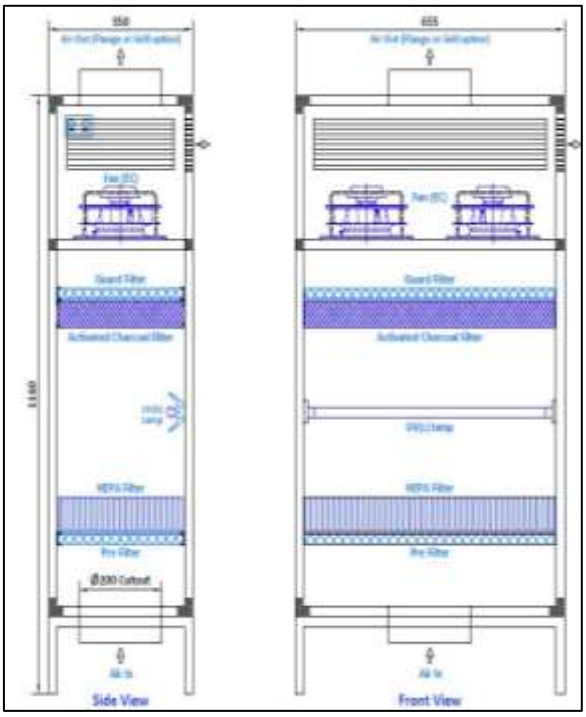
D. Influence of SARS-CoV- 2

Bin Zhao studied the current outbreak of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV- 2), continues with astonishing speed. Although the transmission of COVID-19 occurs mainly via droplets during close contact or contaminated surfaces, a recent study showed that SARS-CoV-2 remains viable in aerosols for multiple hours, and the World Health Organization (WHO) is considering "airborne precautions" for medical staff. China even issued the airborne precaution in the "Chinese Government's New Coronavirus Pneumonia Diagnosis and Treatment Plan".

We have seen extensive literature survey about the Uv light, Hepa Filter, Activated carbon Filter and Sars Cov-19. The literature survey is mainly available for the Uv light, Hepa Filter, Activated carbon Filter Air Purification. Uv Light is used for removing Biological contamination. Hepa Filter is used for removing Solid Contamination and Activated carbon Filter used for removing Chemical Contamination. So by combining them we will provide new air purification system which will effective against Corona Virus.



Horizontal Air Purification System



Vertical Air Purification System

III. CONCLUSION

Air pollution has become one of the largest sources of all reported deaths in the past few years and it would not be wrong to say that mankind has been shaken by its very existence. Air pollutants can be subdivided into categories but the most harmful of them all are particulate matters of sizes less than 2.5 microns and NOx emissions. Human body is equipped suitably to trap the particulate matter entering while we exhale but the problem occurs in dealing with PM 2.5 as their size becomes so minute that it is not technically possible for our body to trap them. In an effort to find a solution to this problem, HEPA filters were designed which are a multi layered structure of glass fibers in order to trap the PM 2.5 particles. They do promise a very high efficiency of 99.97% but all of this comes at a cost owing to the expensive and intensive process of production. UV light proves to be a suitable method to fight the bacterial pollutants that may be present provided the wavelength of light being used is not harmful for humans. Activated carbon is one of the conventional methods of purification with little to no disadvantages. This paper presents a compilation of some of the most recent methods of purifying air which are cost effective and efficient at the same time. we will provide new air purification system which consists of combination of Hepa filer , UV light and Carbon filter will effective against Corona Virus.

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