COMPARATIVE STUDY ON HIGH-EFFICIENCY PARTICULATE AIR (HEPA) FILTERS FOR ENHANCING HOSPITAL INDOOR AIR QUALITY

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"COMPARATIVE STUDY ON HIGH-EFFICIENCY PARTICULATE AIR (HEPA) FILTERS FOR ENHANCING HOSPITAL INDOOR AIR QUALITY"

MASTER OF SURGERY

IN

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LIST OF ABBREVIATIONS

HEPA- High efficiency particulate airfilter

WHO- World health organisation

PM- Particulate matter

AED- Aerodynamic equivalent diameter

HVAC- Heating, ventilation, air-conditioning

UV- Ultraviolet

PCO- Photocatalytic oxidation

HAI- Hospital acquired infection

NVHAP- Non-ventilator hospital acquired pneumonia

IPC- Infection, prevention, control

HAP- Hospital acquired pneumonia

CXR- Chest X-Ray

IAQ- Indoor air quality

PRAC- Portable room air cleaners

ABSTRACT

Introduction:

Recently, infectious diseases caused by airborne bacteria and viruses have been of primary global concern for social and economic reasons. HEPA is an acronym for high-efficiency particulate absorption filters. The preventable proportion of healthcare-associated infections (HAIs) may decrease over time as standards of care improve. Most hospitals do not effectively track, report, or prevent non-ventilator-associated hospital-acquired pneumonia (NVHAP), despite it being one of the most prevalent and morbid healthcare-associated illnesses. We assessed the use of portable HEPA filters in open settings, i.e., in general wards, to improve hospital indoor air quality in given hospital-acquired pulmonary infections.

Aims and Objectives:

To measure the efficacy of HEPA filters used in an open setting in preventing/reducing HAIs & improving indoor hospital air quality by the incidence of hospital-acquired respiratory/pulmonary infections and air culture studies.

Materials and Methods:

Portable HEPA filters were placed in the test room, i.e., for patients with various diagnoses. The rate of respiratory infections was compared with the control group, i.e., the ward without the filter. Periodical air cultures were done in respective wards during this study period.

Results:

There were 250 patients in the study, with 125 each in the test and control groups. There were no significant differences in the incidence of respiratory infections between the groups, i.e., pneumonia changes in chest radiographs (CXRs). Air culture studies have shown similar microbes in both groups, with no significant differences.

Conclusion:

Despite installing HEPA filters, it didn't pronounce any protective effect against pulmonary infections in the open setting over improvement in indoor hospital air quality.

Keywords: Air filters, air pollution, HEPA filter, infection, pneumonia, indoor air quality, air culture studies

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INTRODUCTION

Each day 10,000 litres of air enter the lungs to extract the 420 litres of oxygen required for life and proper functioning. Our air quality affects how well our lungs and other organs function. Access to clean air is a fundamental requirement for human health and well-being. But air pollution still poses a major threat to everyone's health[1]. The World Health Organization (WHO) reports that air pollution caused seven million deaths in 2012, demonstrating that it is currently the top environmental health hazard in the world[2].

Exposure to air pollution leads to a variety of short- and long-term effect

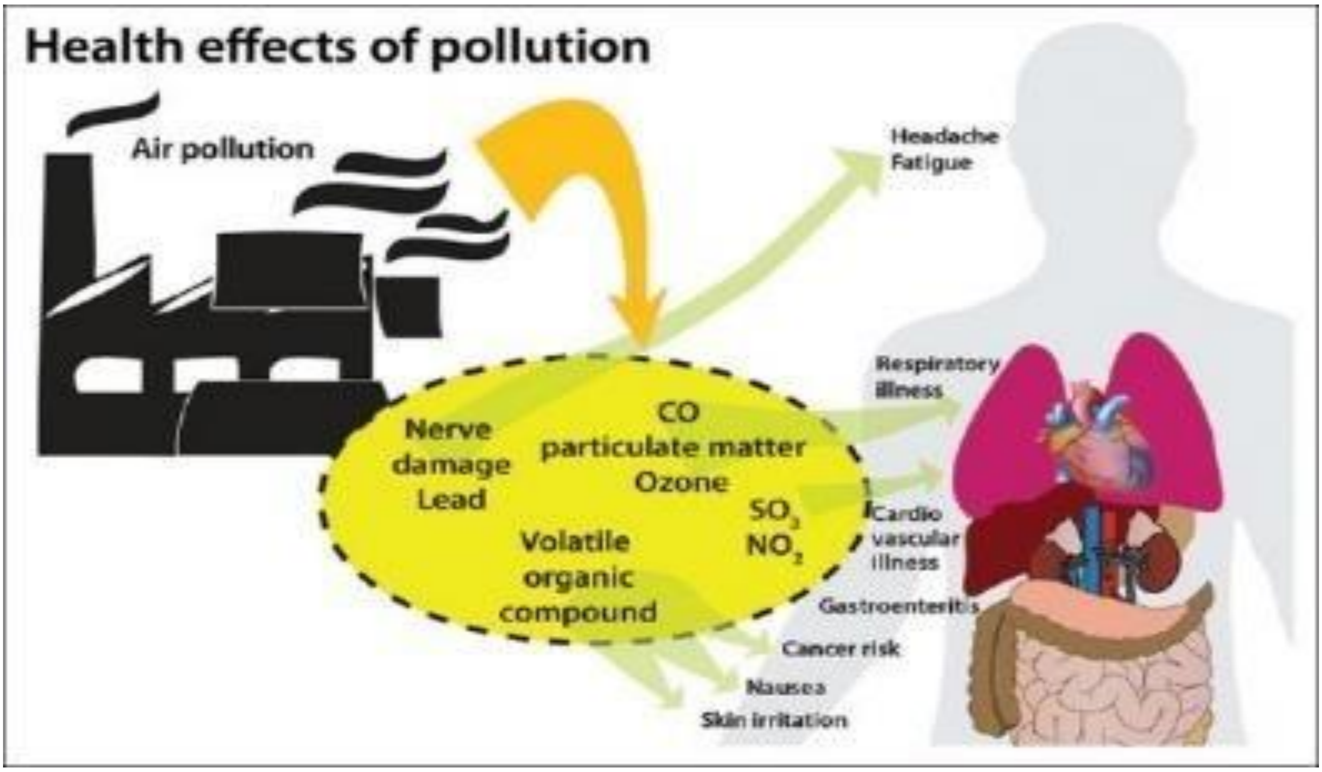

Figure 1: Health effects of pollution

Discomfort, such as nose, throat, eyes, or skin irritation, as well as headaches, dizziness, and nausea, are temporary/ short-term effects[3].

Long-term effects of air pollution include heart disease, lung cancer, and respiratory diseases like bronchitis, bronchiectasis, pneumonia, and asthma. Over several decades, mounting evidence has been that air pollution can exacerbate occult pulmonary pathologies. Because of today's advanced industry, the atmosphere is filled with many toxins and impurities. Most have a detrimental impact on practically all bodily systems and human health in general.

People spend 90% of their lives indoors, breathing indoor air. As a result, both indoor and outdoor air pollution expose people to risk. Air should be pre-cleansed or cleaned on-site to avoid this detrimental effect. Due to oxidative harm caused by particulate matter (PM) in air pollution, the airways become remodelled, inflamed, and more susceptible to sensitisation. On the other hand, the strength of the evidence differs even though various pollutants have been linked to air contamination[4].

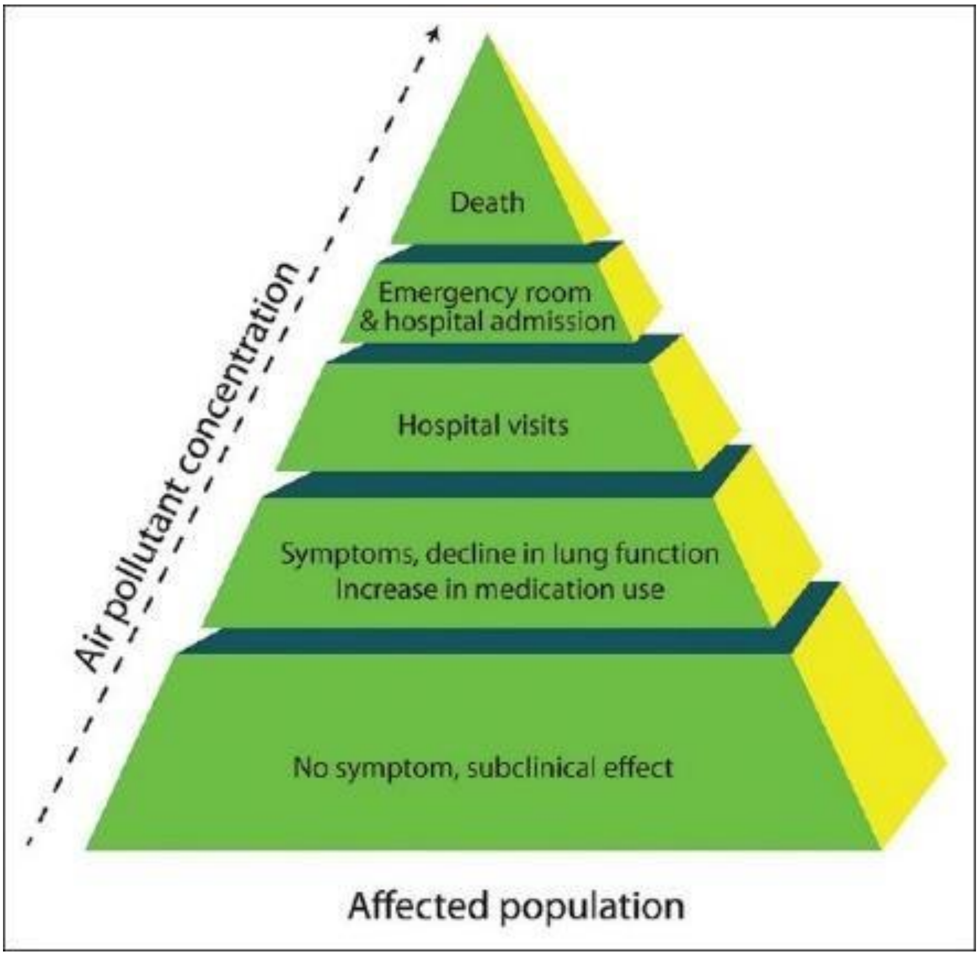

Figure 2: Impact of air pollution

CONTAMINANTS OF INDOOR AIR:

Indoor air pollution is a complicated mixture of pollutants produced indoors and contaminants that move into the indoor environment[5].

The term “aerodynamic equivalent diameter” (AED)characterises pollutants, essentially particulate matter. The settling velocity of particles with the same AED is frequently the same. Particulate matter is divided into AED fractions, such as PM10, PM2.5, and PM0.1, according to how the particles are formed and where they land in human airways[6].

The nose and upper airway filter out most particles larger than 10micrometers[6].Particles with a diameter between 2.5 and 10 micrometres (PM2.5-10) are categorised as “coarse,”“fine,” and “ultrafine”, respectively[6]. These particles can penetrate the respiratory system and reach the alveoli, causing inflammation and infection[5].

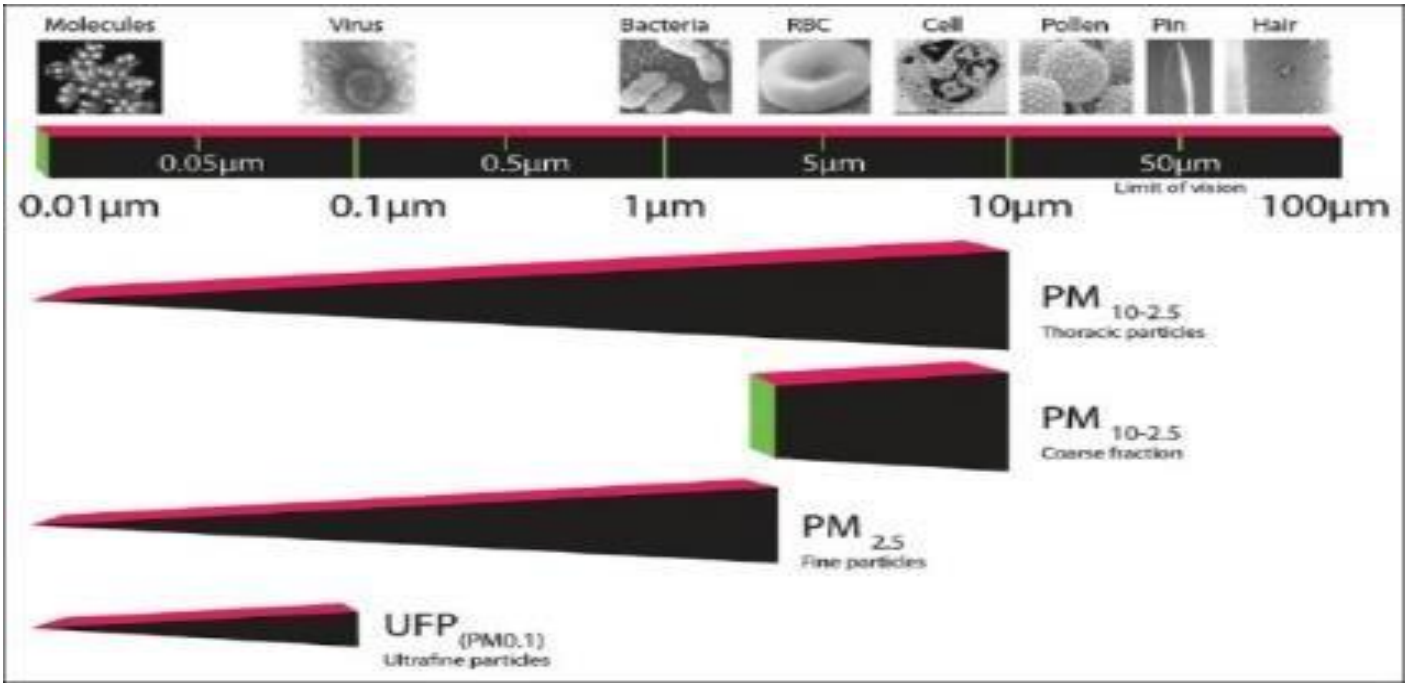

Figure 3: Pollutants size- Classification

In the above picture [figure 3], the size of pollutants was classified. PM 10-2.5, size of 10micrometers to 0.001micrometers includes all thoracic particles, further divided into

Coarse PM10-2.5, size of 10micrometers to 2.5micrometers, Fine PM2.5, size of less than 2.5micrometres and Ultrafine particles (UFP), size of less than 0.1micrometers.

When ultrafine particles or nanoparticles enter the bloodstream after inhalation, they willshow a systemic impact on the blood, vasculature, and organs, including the heart andthe brain[7,8].

Infectious organisms, such as fungi, bacteria, and viruses, can be dispersed into the air due to coughing or sneezing. Due to their small size, droplet nuclei—tiny moisture droplets with a diameter of 1 to 5 micrometres containing infectious microorganisms—remain suspended for several hours and are disseminated over vast distances by air currents. They are tiny enough to get through the respiratory tract's defences when breathed and settle in the lung, where they will spread infection[9].

WAYS TO IMPROVE HEALTH – FILTRATION OF INDOOR AIR

Air filtration is frequently suggested as a component of environmental management strategies. Indoor air filtration solutions include portable room air cleaners, whole-house filtration through the home's heating, ventilation, and air-conditioning system (HVAC), or combined[10,11].

Any air filter is a balance of the following three features[11]:

- To ensure proper ventilation, use airflow.
- Effectiveness in removing a variety of small particle sizes, and
- Ability to accommodate realistic, cost-effective maintenance schedules without negatively compromising airflow and efficiency.

The main characteristics of air cleaners:

The needed air quality affects how well filters clean the air. It depends on the issues you're seeking to resolve. The issue is more significant when allergic reactions occur and cleaner air is required. When using an air cleaner with a certain sort of filtration, people without allergies or milder cases of allergy may feel comfortable, but for someone with a more severe case of allergy, such an air cleaning system may appear extremely ineffective[12].

The best air cleaners are those that feature a photocatalytic filter or a HEPA filter. Asthmatics and allergy patients are advised to use these air purifiers. A key consideration when choosing an air cleaner is the air flow rate and the size of the space. Choosing an air cleaner with an airflow rate high enough for the air cleaner to pass through the room's whole air volume three times an hour is advised.

Sound level: While the individual is in the room, the air purifier must run nonstop. Noise from air cleaners becomes one of the key elements determining model selection, particularly at night. The filter area and fan operation influence utilisation noise. Device noise decreases with increasing filter area.

Nowadays, the following filters are used in air cleaners: -

Mechanical filters –

Electrostatic (ionising) filters –

Coal (adsorption) filters –

HEPA filters (filters for better mechanical cleaning) –

Photocatalytic filter

Mechanical filters:

The majority of filters used in air cleaners are of this sort. Mechanical filters stop large dust, fabric, and animal dander particles. They are made up of the typical fine grid that serves as a pre-filter. These filters are installed in practically all machinery and shield not only people but also the interior of machinery from dust. This grid is traversed by particles, who then settle there. However, the drawback of these filters is that they might contribute to air pollution. Filters should therefore be cleaned as needed. The dust had to be removed, or washing was required[12].

Electrostatic filters:

This filter stops significantly smaller particles (until 0.01 microns) than mechanical filters. A chamber for ionisation is used to process the air. Particles become positively charged in this chamber. After that, the air is passed across two negatively charged plates to deposit positively charged particles. However, gas molecules cannot be stopped by electrostatic filters. On the other side, using this filter can result in the production of ozone and nitrogen oxides. The application of several thousand volts in the ionisation chamber causes ozone to be produced. These filters are unable to remove dust particles from the air completely[12].

Coal filters:

Adsorption of gas molecules is the primary function of coal filters. Coal filters are effective at removing organic substances. This sort of filter eliminates odours and hazardous gas pollutants such as phenol, formaldehyde, and esters, as well as cigarette smoke, carbon monoxide, nitrogen oxides, and sulphur (which we feel like unpleasant odours). The basis for operation is activated carbon absorption. One of the key factors affecting efficiency is the amount of filter media. The longer the filter can function and the more gas and odour it can arrest, the more micropores it has. Mechanical filters ought to be included with the coal filters. According to pollution, carbon filters should be replaced with fresh ones. This filter's ability to effectively catch dust and practically all hazardous impurities with molecular weights greater than 40ng is a plus. However, if filters are not replaced on schedule, air cleaners can become a source of dangerous substances[12].

HEPA filters:

Many air cleaners use these filters as their primary filtering component. The HEPA filter works on a straightforward principle: air passes through the filter element and is cleared of dust particles. The unique porous substance used to create these filters is based on glass fibre. They collect odours and dust. Innovative HEPA technology filters capture more than 99 per cent of all pollutants smaller than 0.3 microns. People with allergies or respiratory diseases should use these filters because most allergens (pollen, fungal spores, animal dander, and dust mite allergens) are larger than 1 micron. However, these filters' drawbacks include their high price and lack of regeneration[12].

Photocatalytic filters:

These filters are among the best and are currently new in air purification. In contrast to other filters, this filter does not stop pollution. A photocatalytic filter eliminates them. Air purification involves oxidation and breakdown of harmful pollutants under UV light. Particles are smaller than 0.001 microns in size. Since these filters are clean, they cannot pollute the air like other filters. With these filters, the air is almost pristine. If you do not have asthma or allergies, it is not necessary[12].

The gas masks worn by World War II combatants served as the inspiration for the HEPA filter. A scrap of paper discovered inside a German gas mask has remarkably high chemical smoke capture efficiency. This was replicated, and the British Army Chemical Corps started producing significant amounts of their service gas masks. As Individual gas masks were not viable in operational headquarters; thus, they sought another option to use HEPA filters[13].

The Army Chemical Corps created a mechanical blower and air purifier unit using spacers in between the deeply pleated cellulose-asbestos paper shape. It was known as an "absolute" air filter and helped pave the way for more investigation into the HEPA filter's development.

The Manhattan Project used the next generation of the HEPA filter, developed in the 1940s, to stop the spread of airborne radioactive pollutants. The National Defense Research Committee and US Army Chemical Corps were tasked with creating a filter to remove radioactive elements from the air.

The Nobel Prize winner Irving Langmuir was asked by the Army Chemical Corps to suggest filter test procedures and other general recommendations for developing the material to filter out these radioactive particles. According to him, the hardest and most worrisome particles are 0.3 microns in size[14].

The word was popularised in the 1950s, at which point it was registered as a trademark and afterwards used as a generic term for extremely effective filters[15].

Filters that adhere to the HEPA standard must perform at a specified level of effectiveness. According to accepted standards, a HEPA air filter must remove at least 99.95% (ISO, European Standard) or 99.97% (ASME, U.S. DOE) of particles with a diameter of 0.3μm from the air that passes through[15].

A mat of fibres organised in a random pattern makes up HEPA filters. The fibres typically have sizes between 0.5 and 2.0 micrometres and are made of polypropylene or fibreglass. These filters often consist of tangled bundles of tiny fibres. Air travels along a tiny, intricate channel created by these fibres. The fibre bundles act like a household sieve when the larger particles try to pass through this channel, physically preventing the particles from passing through.

However, smaller particles cannot keep up and crash into the fibres when they move through the air with it as it twists and rotates. The tiny particles constantly move around the air molecules as if these molecules are assaulting them because they have very little inertia. They eventually crash against the fibres due to their movement[14].

Fibre diameter, face velocity, and filter thickness are important variables that impact how well it performs. Unlike sieves or membrane filters, which allow particles smaller than apertures or pores to pass through, HEPA filters target a range of particle sizes. These particles are captured/stuck to a fibre through a combination of the three techniques outlined below[15]:

1. ***Diffusion***: In a HEPA filter, diffusion is used to catch particles smaller than 0.3μm. The tiniest particles, notably those with diameters under 0.1μm, collide with gas molecules, leading to the development of this process. The tiny particles are blasted or bounced around and strike the fibres of the filter medium. This behaviour resembles Brownian motion and increases the likelihood that a particle will be stopped by impaction or interception; this mechanism becomes dominant with lower airflow.
2. ***Interception***: Particles travelling along a flow line in the air stream approach a fibre within one radius and stick to it. Mid-sized particles are captured by this method.
3. ***Impaction***: Larger particles must directly embed in a fibre instead of avoiding them by following the curves of the air stream. This impact worsens as airflow velocity and fibre spacing decrease.

The photocatalytic oxidation (PCO) technique is becoming increasingly well-liked for the disinfection of airborne microorganisms. A photon from the light excites a catalyst, causing an electron in the valence band to hop to the conduction band and leave a hole behind when a photocatalyst, primarily TiO2, is exposed to UV light. While the electron in the conduction band combines with oxygen to form a superoxide radical anion, that hole can also react with the surrounding water to produce a hydroxyl radical (-OH) (-O2). These radicals can damage the cell membranes of microorganisms, releasing K+, RNA, proteins, and other vital elements that finally lead to cell death[12]

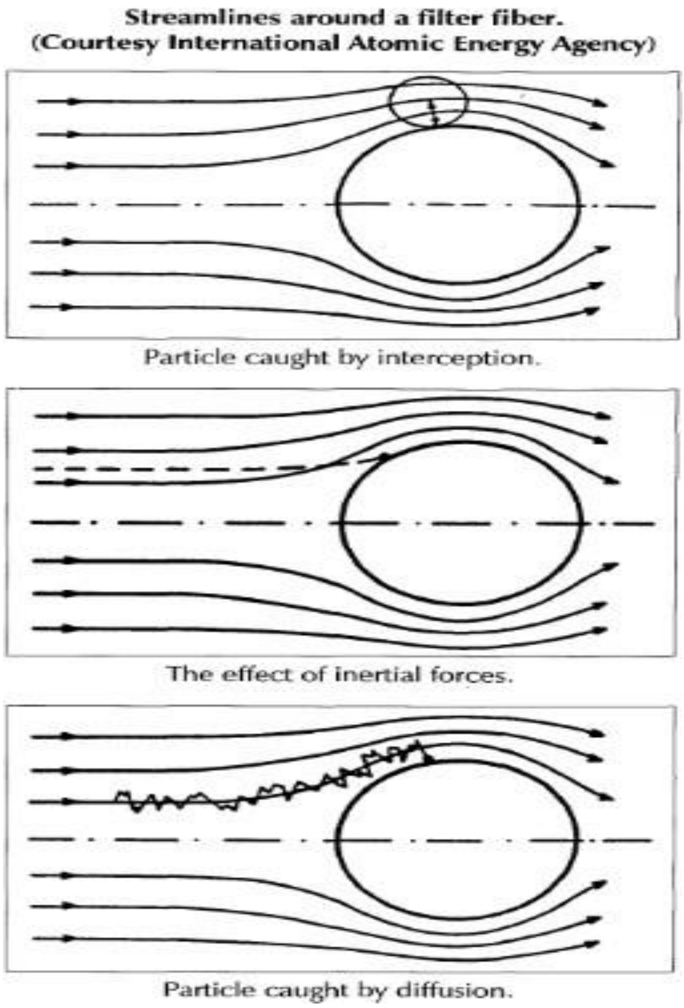

Figure 4: Streamlines around air filter

Filters have developed over the years to meet the ever-increasing requirements for air quality in various high-tech industries, including aerospace, the pharmaceutical industry, hospitals, health care, nuclear fuels, and integrated circuit fabrication.

There is a resurgence of interest in the usage of air filters in the COVID-19 era for several reasons, including the decrease of aerosol contamination, the reduction of particulate matter, and the reduction of HAIs. Although the advantages in high-density service areas like ICUs, ORs, etc., are well known, their contribution to reducing air contamination in common wards is not well understood. Even though few studies have demonstrated advantages, the numerous elements and proper scientific confirmation are crucial. To reduce particulate matter, organisms circulating in the air, and HAIs, this study aims to evaluate the contribution of air filters in open environments.

While filtration is essential to preserving the standard of hospital air, filters can occasionally serve as a haven for living organisms and thus promote their growth. As a result, the gadget itself could end up being contaminated.

The primary drawbacks of HEPA filters include their high maintenance costs and electrical requirements due to their high-pressure drop, which increases fan energy consumption[16].

This thesis focuses mainly on-air purification by portable air filters with HEPA in an open setting.

AIM OF THE STUDY:

- To observe the efficiency of HEPA filter portable air purifiers in enhancing the hospital indoor air quality in reducing the hospital-acquired pulmonary infections.

OBJECTIVES OF THE STUDY:

- To measure the efficacy of HEPA filters in preventing/reducing hospital-acquired infection & improving indoor hospital air quality in terms of
    - Incidence of Respiratory infection (pneumonia)
    - Quality of indoor air in open setting-air culture study.

NEED FOR STUDY

Maintaining excellent indoor air quality is an important non-pharmacological technique for reducing HAIs and cross-contamination. The quantity of breathing infectious microorganisms in indoor air has some bearing on the airborne transmission of infectious diseases[17].

HAIs are nosocomial (originating or occurring in a healthcare facility) acquired infections that can happen up to 30 days after surgery, up to 3 days after discharge from the hospital, up to 48 hours after hospital admission, or in a healthcare facility when someone is admitted for a reason unrelated to the infection[18].

Most hospitals do not effectively track, report, or prevent non-ventilator-associated hospital-acquired pneumonia (NVHAP), despite it being one of the most prevalent and morbid healthcare-associated illnesses. Through the air, an infection can spread from one person to another epidemically[19].

Few studies have calculated how many illnesses would be prevented or lives saved if hospitals used the most effective infection prevention and control methods (IPC). The study predicted the efficacy of the Nosocomial Infection Control (SENIC) initiative of the Centers for Disease Control and Prevention more than 30 years ago. White, Culver, and Haley, the authors concluded that with efficient surveillance and control strategies, 30 to 35 percent of the majority of healthcare-associated infections (HAIs) might be avoided[19]. Since then, a great deal of research has looked at strategies to lower the most prevalent HAIs, including central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), ventilator-associated pneumonia (VAP), and surgical site infections (SSI)[20].

There is still a lot of opportunity for development. Implementing evidence-based methods can still result in a 30 to 50 percent reduction in HAI, which suggests that current recommendations have not been followed to their full potential. Importantly, the effectiveness of infection control efforts cannot be determined just by a nation's economic standing[18].

In 0.5 to 2.0% of patients, pneumonia complicates hospitalisation and is linked to high morbidity and mortality. Mechanical breathing for more than 48 hours, ICU residency, length of ICU or hospital stay, the severity of underlying illness, and comorbidities are risk factors for hospital-acquired pneumonia (HAP).

The most frequent causes of HAP are Pseudomonas aeruginosa, Staphylococcus aureus, and Enterobacter. The majority of HAP cases involve polymicrobial flora.

Hospital-acquired pneumonia (HAP) affects 0.5 to 2.0% of hospitalised patients and makes up 15% of all nosocomial infections. HAP has a mortality rate of more than 30%; however, attributable mortality is lower. In various studies, the etiologic factors causing HAP have been clarified. Gram-negative bacteria, including Pseudomonas aeruginosa, Enterobacter, Acinetobacter, and enteric Gram-negative rods, cause 55 to 85% of HAP cases; Gram-positive cocci, including Staphylococcus aureus, cause 20% to 30%; and 40 to 60% of cases are multi-microbial. The intensity and severity of the disease, the length of hospitalisation, and prior antibiotic exposure are important variables influencing the probability of infections[20].

One in every 100 hospitalised patients develops non-ventilator-associated hospital-acquired pneumonia (NVHAP), which increases antibiotic use, lengthens hospital stays by up to 15 days, necessitates ICU admission in up to 46% of non-ICU cases, and is associated with readmission within 30 days in up to 20% of survivors. Despite the high morbidity, mortality, and expense associated with this condition, hospitals lack norms or standards to monitor or prevent NVHAP consequences[19].

Over the past 20 years, healthcare institutions and policymakers have committed significant resources to reduce additional healthcare-associated illnesses. Many device-associated infections, particularly ventilator-associated pneumonia, have dramatically decreased due to these steps, while NVHAP rates have remained chronically high. The development of microbiome diagnostic techniques has made it easier for us to understand that the lung is not a sterile organ but a complex ecosystem of bacteria interacting with their host and one another. One of the top causes of death in children and the elderly worldwide is pneumonia. Pneumonia is an infection brought on by a virus, bacteria, or other germs; it causes lung inflammation and, if not treated promptly, can be fatal[20].

Furthermore, pneumonia is risky, especially in underdeveloped countries where millions of people lack access to healthcare and live in poverty. The World Health Organization (WHO) estimates that air pollution-related pneumonia and other infections result in more than four million fatalities annually[21].

Escherichia coli (20.1%), Staphylococcus aureus (17.8%), Pseudomonas species. (11.5%), Enterobacteriaceae (10.6%), Candida spp. (11.5%), Enterococci (6.5%), Acinetobacter species. (5.7%), and coagulase-negative staphylococci (5.3%) were the pathogens that caused HAI most frequently worldwide in 2011, according to WHO[22].

Infectious agents with endogenous or exogenous origins are responsible for the pathogenesis of hospital-acquired infections (HAIs)[23].

Endogenous sources are areas of the patient's body typically colonised by the local microbial flora, such as the skin, nose, mouth, gastrointestinal system, etc. These bacteria have the potential to spread infection when given the right circumstances[23].

Exogenous sources are not internal to the patient, but from staff members, guests, equipment used in healthcare, or the surrounding environment. Due to the use of antibiotics and colonisation by new environmental bacteria in hospitalised patients, the natural flora alters. The use of antibiotics exerts selective pressure on the normal flora, killing off susceptible bacteria while allowing antibiotic-resistant ones to live, grow, and predominate[23].

Hospitalised patient attendees will also come into contact with the hospital environment, picking up local bacteria that are frequently antibiotic-resistant because they can survive in a setting where antibiotics are frequently administered. Additionally, antibiotics can kill out the typical, susceptible flora at these locations, leaving them vulnerable to colonisation by resistant flora from the environment[23].

Finally, the use of invasive devices that are made of synthetic materials allows bacteria that have evolved to survive on those materials to proliferate and take over, while bacteria that have evolved to survive on human tissue are disadvantaged and go extinct (for example, the plastic of an endotracheal tube or central venous catheter). These variables help to explain why bacteria linked to hospital-acquired infections are frequently antibiotic-resistant and belong to distinct species from those frequently found in community-acquired infections[24].

Because of the sterilised air, healthy humans' immunity may be reduced[24].

Chest radiography is an efficient, convenient, affordable, and widely used diagnostic method to find disorders affecting the chest. The global standard for diagnosing pneumonia is the chest X-ray (CXR)[25].

Pulmonary opacities, areas of increased attenuation visualized within the lung fields on chest imaging, are commonly used as criteria to support a diagnosis of pneumonia. Despite CXR being used as the primary radiographic test to evaluate for pneumonia, the test characteristics of CXR for detecting pneumonia are not well understood. Computed tomography (CT) is a more precise technique for imaging the chest, but has not supplanted CXR as the primary imaging test for pneumonia due to increased time, cost, and radiation exposure associated with CT[26].

Therefore, this study aims to evaluate how well HEPA filters reduce pulmonary/respiratory HAIs in an open setting.

REVIEW OF LITERATURE

Florence Nightingale wrote in *Notes on Nursing*: *"the very first canon of nursing [...] is [...] to keep the air he breathes as pure as the external air, without chilling him [the patient]*[19]*."*
Healthcare facilities, which are intricately constructed, ought to promote health and happiness[22]. The indoor air quality (IAQ) issues should be regarded as one of the most crucial things to be evaluated and managed in healing spaces[24]. IAQ requires close attention to ensure healthy indoor air and safeguard users—patients and staff—against occupational diseases and hospital-acquired infections (HAIs)[25,26].

According to research from the scientific community, indoor air quality is a complicated and dynamic issue that can impact users' health due to physical factors, biological contaminants, and chemical pollutants produced in indoor and outdoor environments[27].

In reality, most patients spend most of their time in bed, while the medical personnel in a ward depends on the daily tasks they must complete.

The layout of inpatient wards is based on standard units with 24-28 beds that are furnished with all essential amenities. A nurse station, the head nurse's office, a kitchen, clean and filthy storages, material storage, public and staff restrooms, ambulatories, and doctor offices are just a few of the support facilities found in each hospital ward.

Indoor air factors in inpatient room[27].

Criterion	Field of interest	Influence	Focus
Design factors	They refer to all the components characterising the inpatient room (room dimensions, furniture, finishing, etc.)	Their emissions are constant, although, concerning their life, the emissions may decrease over the time	(i) Dimensional aspects, room configuration, and door motion (ii) Finishing materials and furniture
Management and cleaning activities	They refer to the management and maintenance activities, ventilation systems, cleaning and disinfectant activities, etc., carried out in the room and the functional units	They can highly affect the indoor air, but their emissions can be controlled through the applications of strategies, and at the same time, they can be changed if their actions are dangerous for users	(i) Cleaning and maintenance activities (ii) Ventilation systems (iii) Maintenance and operational strategies
Human presence and activities	They refer to the presence of users, their health status, and the medical activities carried out in the inpatient room	Their presence and application can vary, and therefore they can affect the indoor air in different modes. In general, this component does not affect indoor air performance highly	(i) Human behaviour (ii) Medical activities (iii) Medical equipment
Outdoor and microclimatic factors	They refer to the outdoor air, solar exposure, and microclimatic parameters	Although these factors can vary, they have a great influence on the indoor air and the performances of materials in the room	(i) Outdoor issues and site localisation (ii) Microclimatic parameters

Table 1: Indoor air factors in inpatient room

An outbreak of pulmonary TB that affected 140 out of 308 crew members on a military ship and 6 staff members in the emergency room was due to inadequate filtration systems[28].

Rutala and et al., did study over HEPA filter unit and concluded that both as a stand-alone device and as an addition to the current ventilation system, portable HEPA units efficiently removed aerosols from space and the location of the unit was not considered crucial[28].

According to recent recommendations from the CDC, airflow rates should whenever possible, be 12 or more air changes per hour, with the room being circulated through a fixed, monitored high-efficiency particulate air (HEPA) filtering system or portable air cleaners[28].

A study done by Miller-Leiden et al. compared portable filters with ceiling-mounted filters concluded that portable units were more practical at more ventilation rates i.e., more air cycles per minute, minimum 6cycles per second[28].

A study by Boswell that used portable HEPA units to lower the number of MRSA CFU on agar plates concluded that HEPA filters substantially impact air quality control[28].

According to a study by Qian et al., employing portable units requires at least 6 air changes per hour to ensure adequate air quality[28].

In a retrospective study by Abdul Salam et al., the incidence rate of invasive aspergillus was reduced twice in patients at the hospital where the study was conducted following the adoption of portable HEPA filters[28].

In a study conducted by Rao et al. in 2020, it was shown that employing air purifiers considerably decreased the amount of inpatient hospitalisation duration and the need for non-invasive breathing techniques[28].

Francis et al. investigated the clinical results of interior HEPA air purifiers in 30 adult asthmatics who were sensitive to but lived with, an indoor cat or dog during a year-long, randomised, parallel-group trial. The treatment group outperformed the controls regarding the primary endpoints in the combined asthma outcomes (bronchial reactivity and treatment needs)[29].

Sulser et al. compare sham versus HEPA portable room air cleaners (PRACs) in 36 asthmatic children with cat or dog sensitivities[29]; in the HEPA filter group, nocturnal symptoms, such as stuffy noses, significantly decreased. Additionally, there was a tendency for bronchial hyperresponsiveness to improve, as evidenced by a decline in delta FEV1 (the difference between FEV1 before and after a cold air challenge) as compared to an increase in the sham group.

Streifel and colleagues (1995) found that HEPA filters are exceptionally effective at catching submicron particles[28], which is a finding that bears repeating. It has been determined that the SARS-CoV-2 virus has a diameter of less than 1 m. A recent assessment on the likely airborne pathway of the SARS-CoV-2 transmission in hospitals[30] observed that this further supports that HEPA filters will be useful instruments to reduce hospital spread.

Studies showed that air cleaners apply technologies such as HEPA (High-Efficiency Particulate Air) filters to effectively remove particles without generating ozone or other harmful by-products (Shaughnessy and Sextro, 2006; Waring et al., 2008)[31].

From the Study of Xu et al. (2010), fine particle (PM2.5, aerodynamic diameter<2.5µm) concentrations decreased by an average of 72% with HEPA filters[32]

Noh and Yook (2006) concluded that the room air cleaner was more cost-effective than the ventilation system for reducing indoor particle concentration[33].

One of the advantages of using an air purifier is that the performance of air cleaners can be compared with Clean Air Delivery Rate (CADR), which is the metric that accounts for particle removal efficiency and flow rate (Noh and Yook, 2016[33]; Shaughnessy et al., 1994[34]; Offermann et al. [35]., 1985; Zhang et al., 2011)[36].

Another advantage of air cleaners is portability, which can be placed at desired locations where air cleaning is needed (Novoselac and Siegel, 2009)[37].

Because air purifier performance is usually examined in a controlled laboratory setting (e.g. chamber study of portable air cleaners) or classrooms for general public activities, the results may not best reflect real-life

.

METHODOLOGY

A detailed history was taken and patients were examined. Required investigations like complete blood picture, blood urea, serum creatine, blood sugar, urine analysis was done and noted. Initial CXR was done at the time of admission which was used as baseline for comparison with the next CXR done after a week. Pulmonary opacities, areas of increased attenuation, cavitations/ infiltrations, consolidations within lung fields, were noted as CXR changes.

HEPA FILTER

The air filter used in this study is Eureka Forbes 4S with a HEPA filter. It is a portable air filter. This HEPA filter has effective filtration efficiency for PM 2.5-99.97% with 6 stages of filtration as follows according to product specifications,

1. Pre-filter

2.Swiss HEPA filter (H-13 grade)

3. Activated Carbon filter

4. NANOPURE™ with 360^0 UV C Germicidal technology

5. Photocatalyst TiO2 technology6. Patented Duotron technology (Ionizer)

Figure 5: Portable HEPA filter

Product specifications:

Product:

Aeroguard 4S Air Purifier

Brand:

Eureka Forbes

Coverage Area:

46 m.Sq

Air Flow Control:

297 m3/h

Power Consumption:

17-85 W

Rated Voltage:

200 -240V AC/ 50/ 60 Hz

Dimensions:

53x45x23 cm

Weight:

9.20 Kgs

AIRBORNE MICRO FLORA SAMPLING PROTOCOL:

An air sampler is used for air sampling. Air was aspirated at a fixed rate of 180 l/min through a sterilized perforated metal plate cover onto the surface of a 50mm contact plate containing a selected agar,i.e., blood and nutrient agar plate. Aspirated plates from the air sampler were incubated at 25^{o}c for 7days or until visible growth appeared, after which results were noted.

Figure 6: Air sampler

STUDY AREA:

The indoor air quality survey was carried out in a surgical ward with an average of 200 m3 with a 4-window area of 20m^2. Accommodation of an average of 20 people with a variable range of 5 people (involving nursing staff and patients' attendees) is maintained.

Written informed consent was obtained from all patients, along with a detailed explanation of the procedure, as well as risks and complications involved, as well the benefits and drawbacks of the same, and the patient was given the choice of participation. The primary outcome was changes noted in CXRs taken after a week.

STUDY DESIGN

- A prospective comparative study
- Study period: July 2020 –October 2022

With the Anticipated Proportion of hospital-acquired infections (clinically documented infections) between the study and control 23.3 **%** and 9.4%, a study conducted by Mhemet ozen et.al. A quasi-experimental study is taken as a reference[38].

- The study required a sample size of 125 per group. (i.e., a total sample size of 250 assuming equal group sizes), to achieve a power of 95% for detecting a difference in proportions between two groups at a two-sided p-value of 0.05.

Formula used

- $$n = \frac{(z_\alpha + z_\beta)^2 \, 2\, p*q}{MD^2}$$

Where Z = Z statistic at a level of significance

MD = Anticipated difference between two proportions

p = Common Proportion

q = 100-p

Statistical Analysis

- The data obtained was entered into a Microsoft Excel sheet, and statistical analysis was performed using a statistical package for the social sciences (Version 20).
- Results were presented as Mean ± SD, counts and percentages, and diagrams.

The normally distributed continuous variables between two groups were compared using an independent t-test; the Mann-Whitney U test was used for those not normally distributed. Categorical variables between the two groups was compared using the Chi-square test/Fisher`s Exact test.

INCLUSION CRITERIA:

- Inpatients with more than 5 days of hospital stay
- Patients with normal respiratory function
- Age more than 18 years

EXCLUSION CRITERIA:

- Inpatients with less than 48 hours of hospital stay
- Patients with a history of lower respiratory tract infections needed treatment within one year or present.
- Patients with immunocompromised status

RESULTS

In total, 250 patients enrolled in the study who were admitted in male surgical ward.

TEST GROUP: This group included 125 patients admitted to male surgery ward1 with HEPA portable filter.

CONTROL GROUP: This group included 125 patients admitted to male surgery ward2 with no air filter.

Under predetermined objectives, all patients included in the study were evaluated in terms of history, physical findings, and chest x-ray findings. Periodical air cultures were taken in both wards, and reports were noted. Periodical data values of the HEPA filter arranged in the test group were noted. The observations made during the study were as follows.

Age	**Test Group**		**Control group**	
	No. of patients	**Percentage**	**No. of patients**	**Percentage**
< 20	5	4.0	1	.8
20 - 29	7	5.6	10	8.0
30 - 39	23	18.4	23	18.4
40 - 49	25	20.0	11	8.8
50 - 59	21	16.8	30	24.0
60 - 69	31	24.8	31	24.8
70 - 79	9	7.2	11	8.8
80-90	4	3.2	8	6.4
Total	125	100.0	125	100.0

Table 2: Distribution of case and control groups according to age

Age ranged between 20 to 90 years among patients undergone survey. With the mean age of presentation between test and control group is 47.9 and 46.34 years respectively. P value is 0.70. There is **no significant difference** in the age in both the groups.

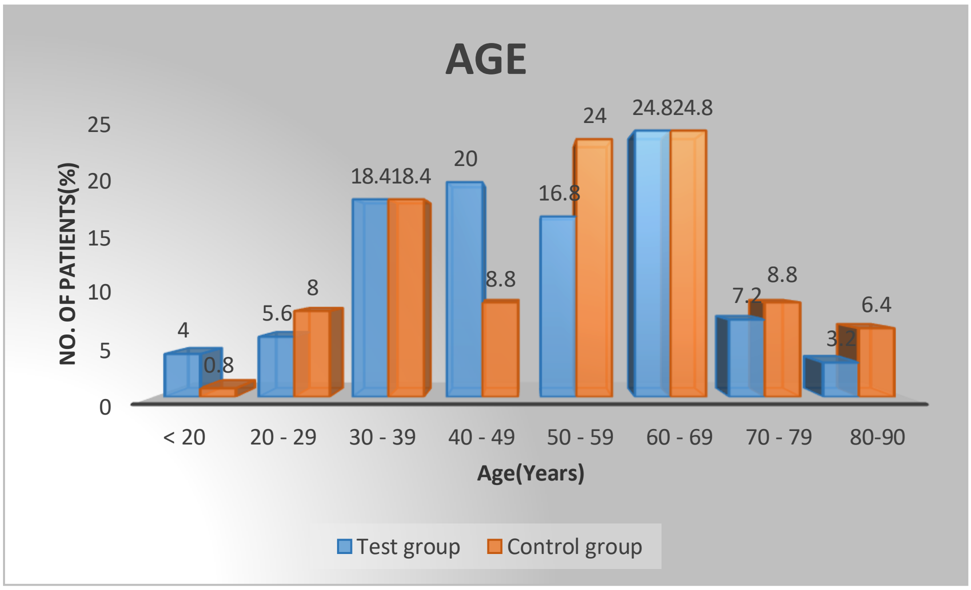

Figure 7: Distribution of cases and controls according to age

Pneumonia Changes in CXR	Test Group		Control group		Chi-square test	P value
	No. of patients	Percentage	No. of patients	Percentage		
NO CHANGES	98	78.4	101	80.8	0.2212	0.6378
PRESENT	27	21.6	24	19.2		
TOTAL	125	100.0	125	100.0		
Statistically insignificant						

Table 3: Pneumonia changes in CXR in test and control groups

The present study showed that 27 patients out of 125 showed notable pneumonia changes in CXR in test group i.e., with HEPA filter, and 24 patients showed pneumonia changes in CXR in control group.

With chi-square test value of 0.2212 and p-value of 0.6378, which is statistically **not significant.**

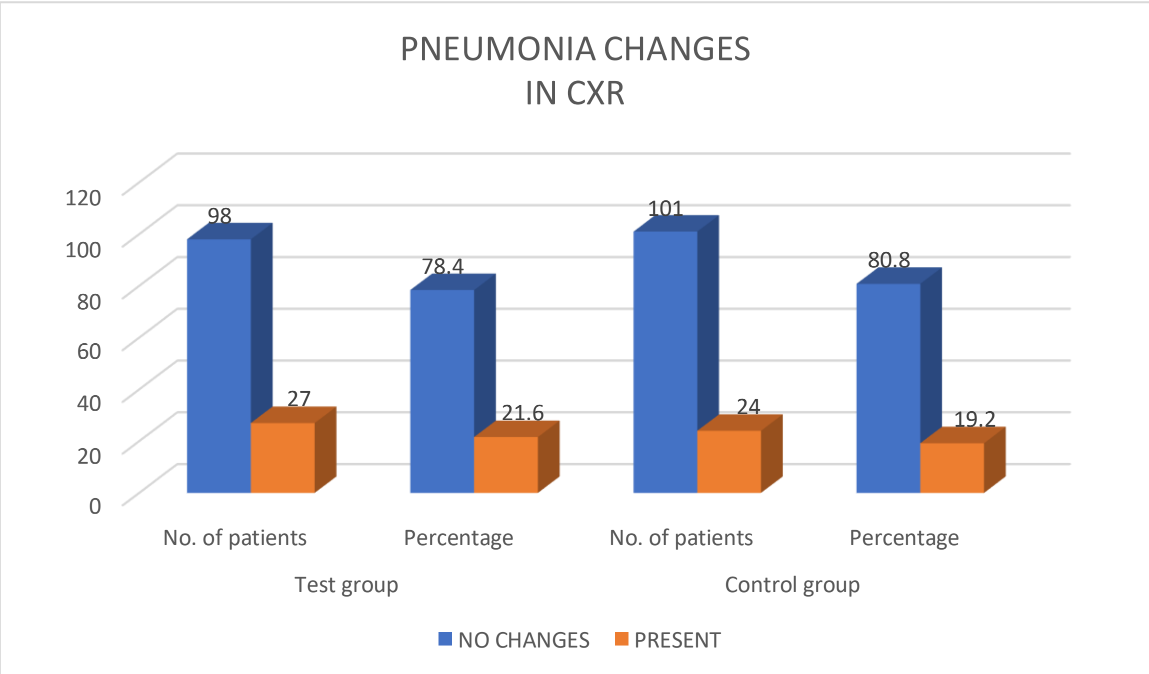

Figure 8: Pneumonic changes in chest x-ray in test and control groups

TEST WARD (212)	Frequency	Percent
CITROBACTER FREUNDII	3	10
ESCHERICHIA COLI	12	40
KLEBSIELLA PNEUMONIA	13	43.4
PSEUDOMONAS AERUGINOSA	2	6.6
TOTAL	30	100

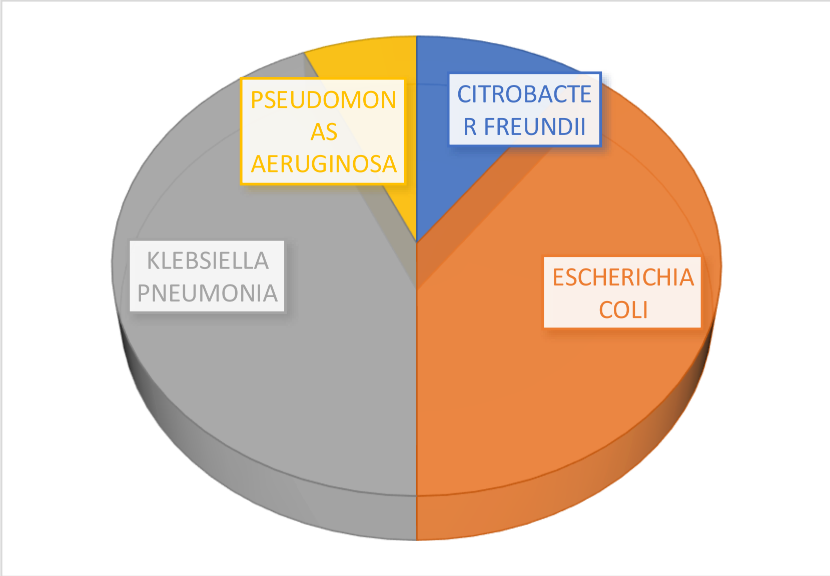

Table 4: Air culture study in test ward **Figure 9:** Air culture study in test ward

CONTROL	Frequency	Percent
CITROBACTER FREUNDII	6	20
ESCHERICHIA COLI	14	46.7
KLEBSIELLA PNEUMONIA	7	23.3
PSEUDOMONAS AERUGINOSA	3	10
Total	30	100.0

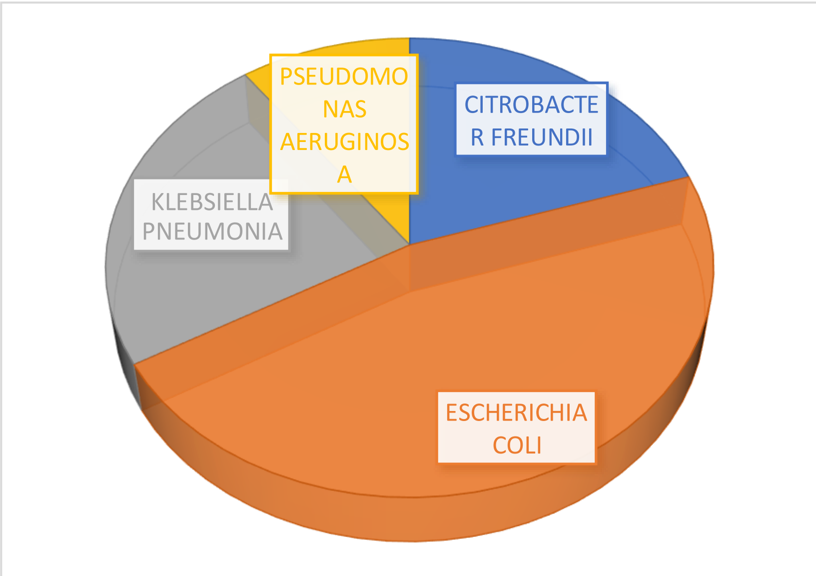

Table 5: Air culture study in control ward **Figure 10:** Air culture study in control ward

In the study total of 30 air cultures were taken respectively at same time from both test and control wards, giving **no significant difference in results** with same cultures in both wards. Total of 13- E.Coli, 12- K.Pneumonia, 3- C.Freundii, 2- P.Aeruginosa.

HEPA FILTER DATA		FAN SPEED	TEMPERATURE	HUMIDITY (%)	CLOUD (STICK)
Mean		3.53	27.06	70.86	3.44
Median		4.00	27.00	71.00	3.00
Std. Deviation		.502	.818	2.145	.499
Percentiles	25	3.00	26.00	69.00	3.00
	50	4.00	27.00	71.00	3.00
	75	4.00	28.00	73.00	4.00

Table 6: HEPA filter data

DISCUSSION

Pneumonia is a known complication causing morbidity and mortality in hospitalized patients. In the past, majority studies done mainly concentrated on areas like operation theatres, ICUs etc., to assess the efficacy of air filters. In our study, we looked into the filter's effect in an open setting, i.e., general wards. To our knowledge, this is the first prospective study that compares the outcome of HEPA filter in open setting enhancing hospital indoor air quality by assessing HAI (pneumonia using CXR)

In a study done by wolfgang Rosenberger on Effect of charcoal equipped HEPA filters on cabin air quality in aircraft, he concluded that HEPA filters improve air quality by reducing the concentration of air pollutants in order of 30%[44].

A Randomized trial of asthmatic children receiving a HEPA filter intervention combined with integrated pest management concluded that there were significant improvements to indoor air quality, with a 45% reduction in indoor PM2.5 in HEPA-treated classrooms as compared to untreated classrooms[45].

A randomized crossover study of HEPA filtration, without a washout period, in 23 homes of low-income Puerto Ricans in Boston and Chelsea, MA, concluded that a portable HEPA filter intervention resulted in significant improvement of indoor air quality, by showing filtration rate of 50 to 85% when compared to no filtration homes, but there was no observed benefit in terms of reduced inflammation in alveoli[46].

In a multicenter study of Hospital Acquired Pneumonia(HAP) in non- ICU patients by Nieves, Neunos study group, showed S. pneumoniae, L. pneumophila, Aspergillus sp, Pseudomonas aeruginosa and Enterobacteriaceae sp were most frequent etiologies and pneumonia attributed to 13.9% cause-specific mortality concluding Non-ICU HAP is an important cause of hospital mortality and morbidity[47].

In a HEPA filter intervention study among healthy elderly couples in Denmark, Bräuner et al found an improvement of 8.1% In Reactive Hyperaemia Index (RHI) with filtration, which reduced PM2.5 from 12.6 to 4.7 mg/m3[48].

The effect of portable HEPA filter air cleaner use during pregnancy on fetal growth: The UGAAR randomized controlled trial by Prabjit Barna, Enkhjargal Gombojav et al, shows the use of HEPA filters was associated with a 40% reduction in PM2.5 concentrations causing greater birth weight only among babies born at term[49].

In a study done by Battsetseg Ulziikhuu, Enkhjargal Gombojav, et al over portable HEPA air filter indicated that reducing PM air pollution during pregnancy improve cognitive performance in childhood as Portable HEPA air filters will help to reduce the neurodevelopmental impacts of air pollution[50].

Reduction in MRSA environmental contamination with a portable HEPA-filtration unit-study done by T.C. Boswell, P.C. Fox concluded that portable HEPA-filtration unit can significantly reduce MRSA environmental contamination within patient isolation rooms[51].

By these studies, we can conclude that HAP is a notable cause for longer hospital stay causing morbidity and morbidity to patient. And HEPA filter is efficient in filtering PM and shown good outcomes over health improvement. We conducted the study, Use of portable HEPA air filter in general wards to enhance the indoor hospital air quality by reducing HAP.

CONCLUSION

The present study comparing intervention of HEPA filters in inpatient health and hospital indoor air quality concludes:

1. The HEPA filter in a portable air filter in an open setting, i.e., an uncontrolled environment, may not improve hospital indoor air quality as inpatients in wards with HEPA filters showed pulmonary infections the same as without filters.
2. In terms of particulate matter filtration, the filter shown poor result, i.e., showing continuous positive air cultures as in areas without the filter.
3. Due to limitations of the setting this study needs to be repeated in various settings to strengthen the observations.

Further research is indicated to investigate and supplement strategies to use HEPA filter in open setting

SUMMARY

The present study compared the HEPA filter intervention to enhance the hospital's indoor air quality, namely in the view of pulmonary infections in inpatients and air culture studies.

The present was done between July 2020 – October 2022. A total of 250 patients were included in the study, with 125 in the test group, i.e., with HEPA filter and 125 in the control group. The results were inferred, and it was found that portable HEPA filter intervention showed poor result in enhancing the hospital indoor air quality in an open setting.

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ETHICAL CLEARANCE CERTIFICATE

IEC/NO-9/2021
Date- 22/01/2021

B.L.D.E. (DEEMED TO BE UNIVERSITY)

(Declared vide notification No. F.9-37/2007-U.3 (A) Dated. 29-2-2008 of the MHRD, Government of India under Section 3 of the UGC Act, 1956)

The Constituent College

SHRI. B. M. PATIL MEDICAL COLLEGE, HOSPITAL AND RESEARCH CENTRE

INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The Institutional ethical committee of this college met on 11-01-2021 at 11-00 am to scrutinize the synopsis of Postgraduate students of this college from Ethical Clearance point of view. After scrutiny the following original/corrected and revised version synopsis of the Thesis has been accorded Ethical Clearance

Title: A comparative study on high efficiency particulate AIR (HEPA) filters for enhancing hospital indoor air quality

Name of PG student: Dr Bommu Divya Teja, Department of Surgery

Name of Guide/Co-investigator: Dr Tejaswini Vallabha, Professor
Department of Surgery

DR .S.V.PATIL
CHAIRMAN, IEC
Institutional Ethical Committee
B L D E (Deemed to be University)
Shri B.M. Patil Medical College,
VIJAYAPUR-586103 (Karnataka)

Following documents were placed before Ethical Committee for Scrutinization:

1. Copy of Synopsis / Research project
2. Copy of informed consent form
3. Any other relevant documents.

6

INFORMED CONSENT FORM

B.L.D.E.(Deemed to be University)'s,

SHRI B.M. PATIL MEDICAL COLLEGE HOSPITAL AND RESEARCH CENTRE, BIJAPUR – 586103, KARNATAKA

TITLE OF THE PROJECT: A COMPARATIVE STUDY FOR HIGH-EFFICIENCY PARTICULATE AIR (HEPA) FILTER IN AIR PURIFIERS FOR ENHANCING HOSPITAL INDOOR AIR QUALITY

PRINCIPAL INVESTIGATOR: DR. BOMMU DIVYATEJA

DEPARTMENT OF GENERAL SURGERY.

PG GUIDE: DR. TEJASWINI VALLABHA

M.S. (GENERAL SURGERY)

PROFESSOR

DEPARTMENT OF SURGERY

ALTERNATIVES:

Even if patient declines to participate, they got routine line of management.

CONFIDENTIALITY:

I understand that medical information produced by this study will become a part of this hospital records and will be subjected to the confidentiality and privacy regulation of this hospital. Information of a sensitive, personal nature will not be a part of the medical records but will be stored in the investigator's research file and identified only by a code number. The code key connecting the name to numbers will be kept in a separate secure location.

If the data are used for publication in the medical literature or teaching purposes, no names will be used, and other identifiers such as photographs and audio or videotapes will be used only with my special written permission. I understand that I may see the photograph and videotapes and hear audiotapes before giving this permission.

REQUEST FOR MORE INFORMATION:

I understand that I may ask more questions about the study at any time. DR. BOMMU DIVYATEJA is available to answer my questions or concerns. I understand that I will be informed of any significant new findings discovered during the course of this study, which might influence my continued participation.

If, during this study, or later, I wish to discuss my participation in or concerns regarding this study with a person not directly involved, I am aware that the social worker of the hospital is available to talk with me.

And that a copy of this consent form will be given to me to keep and for careful reading.

REFUSAL OR WITHDRAWAL OF PARTICIPATION:

I understand that my participation is voluntary, and I may refuse to participate or may withdraw consent and discontinue participation in the study at any time without prejudice to my present or future care at this hospital.

I also understand that Dr. BOMMU DIVYATEJA will terminate my participation in this study at any time after he has explained the reasons for doing so and has helped arrange for my continued care by my own physician or therapist if this is appropriate.

INJURY STATEMENT:

I understand that in the unlikely event of injury to me/my ward, resulting directly to my participation in this study, if such injury were reported promptly, then medical treatment would be available to me, but no further compensation will be provided.

I understand that by my agreement to participate in this study, I am not waiving any of my legal rights.

I have explained to____the purpose of this research, the procedures required and the possible risks and benefits, to the best of my ability in patient's own language.

Date:

DR. TEJASWINI VALLABHA (Guide)

DR. BOMMU DIVYATEJA (Investigator)

STUDY SUBJECT CONSENT STATEMENT:

I confirm that DR. BOMMU DIVYATEJA has explained to me the purpose of this research, the study procedure that I will undergo, and the possible discomforts and benefits that I may experience in my own language.

I have been explained all the above in detail in my own language, and I understand the same. Therefore, I agree to give my consent to participate as a subject in this research project.

________________________________ __________________

(Participant) Date

________________________________ __________________

(Witness to above signature) Date

PROFORMA

B.L.D.E. (Deemed to be University)

SHRI B. M. PATIL MEDICAL COLLEGE HOSPITAL AND RESEARCH CENTRE,

VIJAYAPURA.

DEPARTMENT OF DERMATOLOGY, VENEREOLOGY, AND LEPROSY

SCHEME OF CASE TAKING

“A COMPARATIVE STUDY FOR HIGH-EFFICIENCY PARTICULATE AIR (HEPA) FILTER IN AIR PURIFIERS FOR ENHANCING HOSPITAL INDOOR AIR QUALITY”

SL NO

NAME

AGE	IP NO
SEX	UNIT
RELIGION	DOA
OCCUPATION	WARD
ADDRESS	DOD

SOCIO-ECONOMIC STATUS

Complaints:

HISTORY OF PRESENT ILLNESS

SYSTEMIC SYMPTOMS

PAST HISTORY:

PERSONAL HISTORY:

<u>GENERAL PHYSICAL EXAMINATION</u>

BUILT: WELL/MODERATE/POOR

NOURISHMENT: WELL/MODERATE/POOR [BMI=]

PALLOR

ICTERUS

CYANOSIS

CLUBBING

PEDAL EDEMA

GENERAL LYMPHADENOPATHY

<u>VITAL DATA</u>:

TEMPERATURE:

PULSE

RESPIRATORY RATE

BLOOD PRESSURE:

SYSTEMIC EXAMINATION

PER ABDOMEN:

RESPIRATORY SYSTEM

CARDIOVASCULAR SYSTEM

CENTRAL NERVOUS SYSTEM

CLINICAL DIAGNOSIS:

LABORATORY TESTS

HB%

TOTAL COUNT

DIFFERENTIAL COUNT

N/L/E/B/M

HIV

HBsAg

HCV

CHEST X-RAY PA VIEW

KEY TO MASTERCHART

MASTERCHART

DATE	TIME	FAN SPEED	TEMPERATURE	HUMIDITY(%)	CLOUD (STICK)	DATE	AIR CULTURE ORGANISM	
							212	213
13-02-2021	8.00 AM	3	28	74	4	23-08-2021	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
	1.00 PM	4	27	72	4	07-09-2021	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
	5.00 PM	3	28	72	4	22-09-2021	CITROBACTER FREUNDII	CITROBACTER FREUNDII
						07-10-2021	ESCHERICHIA COLI	ESCHERICHIA COLI
14-02-2021	8.00 AM	4	28	68	3	22-10-2021	ESCHERICHIA COLI	ESCHERICHIA COLI
	1.00 PM	3	27	72	3	06-11-2021	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
	5.00 PM	4	27	74	4	21-11-2021	PSEUDOMONAS AERUGINOSA	PSEUDOMONAS AERUGINOSA
						06-12-2021	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
15-02-2021	8.00 AM	3	28	68	4	21-12-2021	ESCHERICHIA COLI	ESCHERICHIA COLI
	1.00 PM	4	27	69	3	05-01-2022	CITROBACTER FREUNDII	CITROBACTER FREUNDII
	5.00 PM	4	26	71	3	20-01-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
						04-02-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
16-02-2021	8.00 AM	3	26	72	4	19-02-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
	1.00 PM	4	26	74	3	06-03-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
	5.00 PM	3	28	69	4	21-03-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
						05-04-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
17-02-2021	8.00 AM	3	28	72	3	20-04-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
	1.00 PM	3	28	74	3	05-05-2022	CITROBACTER FREUNDII	CITROBACTER FREUNDII
	5.00 PM	3	27	68	4	20-05-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
						04-06-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
18-02-2021	8.00 AM	3	27	68	3	19-06-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
	1.00 PM	4	28	68	3	04-07-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
	5.00 PM	4	27	73	4	19-07-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA

						03-08-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
19-02-2021	8.00 AM	4	26	69	4	18-08-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
	1.00 PM	4	28	71	4	02-09-2022	PSEUDOMONAS AERUGINOSA	PSEUDOMONAS AERUGINOSA
	5.00 PM	3	28	69	3	17-09-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
						01-10-2022	KLEBSIELLA PNEUMONIA	KLEBSIELLA PNEUMONIA
20-02-2021	8.00 AM	4	26	69	3	15-10-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
	1.00 PM	4	26	70	3	30-10-2022	ESCHERICHIA COLI	ESCHERICHIA COLI
	5.00 PM	3	26	72	3			
21-02-2021	8.00 AM	4	28	69	4			
	1.00 PM	3	27	70	3			
	5.00 PM	4	26	68	3			
22-02-2021	8.00 AM	3	27	73	3			
	1.00 PM	3	28	71	4			
	5.00 PM	3	27	74	4			
23-02-2021	8.00 AM	3	27	73	4			
	1.00 PM	3	28	69	3			
	5.00 PM	3	28	68	3			
24-02-2021	8.00 AM	4	28	73	4			
	1.00 PM	4	26	73	3			
	5.00 PM	4	28	70	3			
25-02-2021	8.00 AM	3	28	70	4			
	1.00 PM	4	28	73	4			

	5.00 PM	4	27	72	3			
26-02-2021	8.00 AM	3	27	69	4			
	1.00 PM	3	26	68	3			
	5.00 PM	3	27	68	4			
27-02-2021	8.00 AM	3	26	71	3			
	1.00 PM	3	26	74	4			
	5.00 PM	4	27	70	3			
28-02-2021	8.00 AM	4	26	74	3			
	1.00 PM	4	28	70	3			
	5.00 PM	4	26	72	3			
01-03-2021	8.00 AM	4	27	69	4			
	1.00 PM	4	26	68	4			
	5.00 PM	4	27	71	3			
02-03-2021	8.00 AM	4	26	70	4			
	1.00 PM	3	27	69	3			
	5.00 PM	3	27	70	3			
03-03-2021	8.00 AM	3	27	73	3			
	1.00 PM	3	26	71	3			
	5.00 PM	4	27	74	4			
04-03-2021	8.00 AM	3	28	72	4			

	1.00 PM	3	28	74	4			
	5.00 PM	4	27	71	3			
05-03-2021	8.00 AM	4	28	70	4			
	1.00 PM	3	27	68	3			
	5.00 PM	4	28	74	4			
06-03-2021	8.00 AM	4	27	74	3			
	1.00 PM	4	28	68	4			
	5.00 PM	4	27	73	3			
07-03-2021	8.00 AM	3	26	72	3			
	1.00 PM	4	28	68	4			
	5.00 PM	4	26	69	4			
08-03-2021	8.00 AM	4	27	68	3			
	1.00 PM	3	28	70	3			
	5.00 PM	3	27	72	3			
09-03-2021	8.00 AM	3	26	73	3			
	1.00 PM	4	28	74	4			
	5.00 PM	4	28	68	3			
10-03-2021	8.00 AM	4	26	72	4			
	1.00 PM	3	28	71	3			
	5.00 PM	3	26	68	3			

11-03-2021	8.00 AM	4	27	70	3			
	1.00 PM	4	28	72	3			
	5.00 PM	3	26	72	4			
12-03-2021	8.00 AM	4	26	68	4			
	1.00 PM	3	28	68	4			
	5.00 PM	4	28	69	4			
13-03-2021	8.00 AM	4	27	74	3			
	1.00 PM	3	27	68	4			
	5.00 PM	4	26	70	4			
14-03-2021	8.00 AM	3	26	73	3			
	1.00 PM	4	27	70	3			
	5.00 PM	3	26	71	3			
15-03-2021	8.00 AM	4	28	74	3			
	1.00 PM	4	26	74	4			
	5.00 PM	3	28	73	3			
16-03-2021	8.00 AM	3	28	73	3			
	1.00 PM	4	28	72	3			
	5.00 PM	3	26	73	4			
17-03-2021	8.00 AM	3	26	73	3			
	1.00 PM	4	28	69	4			
	5.00 PM	3	28	68	3			

18-03-2021	8.00 AM	4	26	73	4			
	1.00 PM	4	26	68	3			
	5.00 PM	3	26	71	4			
19-03-2021	8.00 AM	3	27	69	3			
	1.00 PM	4	28	74	4			
	5.00 PM	4	27	73	4			
20-03-2021	8.00 AM	3	26	69	3			
	1.00 PM	3	27	73	4			
	5.00 PM	3	27	74	3			
21-03-2021	8.00 AM	3	28	74	4			
	1.00 PM	4	27	70	3			
	5.00 PM	3	28	68	3			
22-03-2021	8.00 AM	4	27	73	3			
	1.00 PM	4	27	69	4			
	5.00 PM	4	28	68	4			
23-03-2021	8.00 AM	3	27	74	3			
	1.00 PM	4	27	71	3			
	5.00 PM	3	28	69	3			
24-03-2021	8.00 AM	4	27	74	4			
	1.00 PM	4	27	68	4			
	5.00 PM	4	26	69	4			

25-03-2021	8.00 AM	4	28	70	4			
	1.00 PM	3	26	69	4			
	5.00 PM	4	27	70	4			
26-03-2021	8.00 AM	4	27	73	3			
	1.00 PM	3	27	68	4			
	5.00 PM	4	26	74	3			
27-03-2021	8.00 AM	3	26	72	4			
	1.00 PM	3	26	71	3			
	5.00 PM	4	28	71	4			
28-03-2021	8.00 AM	3	26	74	3			
	1.00 PM	4	26	70	3			
	5.00 PM	3	26	72	4			
29-03-2021	8.00 AM	4	26	74	4			
	1.00 PM	3	27	74	4			
	5.00 PM	3	26	73	3			
30-03-2021	8.00 AM	3	27	69	4			
	1.00 PM	3	27	69	4			
	5.00 PM	3	28	70	4			
31-03-2021	8.00 AM	3	26	69	4			
	1.00 PM	4	26	73	4			

	5.00 PM	3	26	72	4			
01-04-2021	8.00 AM	3	27	72	4			
	1.00 PM	3	27	68	4			
	5.00 PM	3	27	74	3			
02-04-2021	8.00 AM	3	27	73	3			
	1.00 PM	3	27	74	3			
	5.00 PM	3	26	70	3			
03-04-2021	8.00 AM	4	26	69	3			
	1.00 PM	4	28	74	4			
	5.00 PM	4	27	74	3			
04-04-2021	8.00 AM	3	27	70	4			
	1.00 PM	4	27	74	4			
	5.00 PM	3	28	69	4			
05-04-2021	8.00 AM	3	26	71	3			
	1.00 PM	3	26	72	3			
	5.00 PM	4	28	73	3			
06-04-2021	8.00 AM	3	28	70	4			
	1.00 PM	3	27	70	3			
	5.00 PM	4	28	70	4			
07-04-2021	8.00 AM	4	28	69	3			

	1.00 PM	3	28	71	4			
	5.00 PM	3	27	73	3			
08-04-2021	8.00 AM	3	28	74	3			
	1.00 PM	3	26	72	4			
	5.00 PM	4	27	71	4			
09-04-2021	8.00 AM	4	28	72	4			
	1.00 PM	3	26	71	4			
	5.00 PM	4	26	72	3			
10-04-2021	8.00 AM	4	27	73	4			
	1.00 PM	4	27	69	3			
	5.00 PM	3	26	68	4			
11-04-2021	8.00 AM	3	26	72	3			
	1.00 PM	4	26	70	3			
	5.00 PM	3	27	69	3			
12-04-2021	8.00 AM	3	28	74	4			
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	5.00 PM	4	28	73	4			
13-04-2021	8.00 AM	3	27	73	4			
	1.00 PM	4	28	73	4			
	5.00 PM	3	27	74	4			

14-04-2021	8.00 AM	4	28	74	3			
	1.00 PM	4	26	73	3			
	5.00 PM	3	26	70	4			
15-04-2021	8.00 AM	3	28	69	4			
	1.00 PM	4	26	68	4			
	5.00 PM	3	27	74	3			
16-04-2021	8.00 AM	4	28	72	3			
	1.00 PM	3	27	69	4			
	5.00 PM	4	26	72	4			
17-04-2021	8.00 AM	3	26	68	3			
	1.00 PM	3	26	74	4			
	5.00 PM	3	26	70	4			
18-04-2021	8.00 AM	4	26	71	3			
	1.00 PM	3	28	70	3			
	5.00 PM	4	28	70	3			
19-04-2021	8.00 AM	3	28	74	4			
	1.00 PM	4	28	71	3			
	5.00 PM	4	27	68	4			
20-04-2021	8.00 AM	3	26	74	3			
	1.00 PM	3	26	71	3			
	5.00 PM	3	28	68	3			
21-04-2021	8.00 AM	4	27	71	4			

	1.00 PM	3	27	69	4			
	5.00 PM	4	27	71	3			
22-04-2021	8.00 AM	4	26	74	3			
	1.00 PM	3	28	68	4			
	5.00 PM	4	26	70	3			
23-04-2021	8.00 AM	4	28	72	4			
	1.00 PM	3	27	69	4			
	5.00 PM	3	27	73	4			
24-04-2021	8.00 AM	4	28	71	4			
	1.00 PM	3	28	74	4			
	5.00 PM	4	28	70	4			
25-04-2021	8.00 AM	3	28	72	4			
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	5.00 PM	4	28	68	4			
26-04-2021	8.00 AM	4	26	72	4			
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27-04-2021	8.00 AM	4	26	71	3			
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	5.00 PM	3	26	68	4			
28-04-2021	8.00 AM	4	26	73	3			
	1.00 PM	4	28	70	4			
	5.00 PM	3	26	70	4			

29-04-2021	8.00 AM	4	28	71	4			
	1.00 PM	4	28	70	3			
	5.00 PM	4	28	72	4			
30-04-2021	8.00 AM	3	27	74	3			
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	5.00 PM	3	27	69	3			
01-05-2021	8.00 AM	4	26	73	4			
	1.00 PM	3	26	70	4			
	5.00 PM	3	28	72	3			
02-05-2021	8.00 AM	4	26	73	3			
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	5.00 PM	3	27	73	4			
03-05-2021	8.00 AM	3	28	72	4			
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04-05-2021	8.00 AM	4	28	71	4			
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05-05-2021	8.00 AM	3	26	70	4			
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	5.00 PM	3	27	70	3			
06-05-2021	8.00 AM	4	28	73	4			

	1.00 PM	4	26	68	4			
	5.00 PM	4	28	68	3			
07-05-2021	8.00 AM	3	28	73	4			
	1.00 PM	4	26	68	4			
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08-05-2021	8.00 AM	3	27	70	3			
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09-05-2021	8.00 AM	3	26	73	3			
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10-05-2021	8.00 AM	4	26	73	3			
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	5.00 PM	3	28	68	4			
11-05-2021	8.00 AM	3	28	73	4			
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12-05-2021	8.00 AM	3	28	68	4			
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	5.00 PM	3	27	74	3			
13-05-2021	8.00 AM	4	27	74	4			
	1.00 PM	4	28	74	3			
	5.00 PM	3	27	70	3			

14-05-2021	8.00 AM	4	27	71	3			
	1.00 PM	4	26	70	4			
	5.00 PM	4	28	74	3			
15-05-2021	8.00 AM	3	27	72	4			
	1.00 PM	4	27	71	4			
	5.00 PM	3	26	72	4			
16-05-2021	8.00 AM	4	28	69	3			
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	5.00 PM	4	28	72	3			
17-05-2021	8.00 AM	4	28	69	3			
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	5.00 PM	4	28	71	3			
18-05-2021	8.00 AM	4	27	74	3			
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	5.00 PM	3	27	68	3			
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20-05-2021	8.00 AM	4	27	74	3			
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21-05-2021	8.00 AM	3	28	72	3			

	1.00 PM	3	28	71	4			
	5.00 PM	4	28	73	4			
22-05-2021	8.00 AM	4	26	74	3			
	1.00 PM	4	28	70	4			
	5.00 PM	3	27	72	4			
23-05-2021	8.00 AM	4	26	72	4			
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24-05-2021	8.00 AM	3	28	71	3			
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	5.00 PM	4	28	69	3			
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26-05-2021	8.00 AM	4	27	68	4			
	1.00 PM	3	27	74	4			
	5.00 PM	4	27	70	4			
27-05-2021	8.00 AM	3	26	69	4			
	1.00 PM	3	27	73	4			
	5.00 PM	3	28	71	3			
28-05-2021	8.00 AM	3	27	69	3			
	1.00 PM	3	26	72	4			
	5.00 PM	4	26	72	3			

29-05-2021	8.00 AM	3	27	72	4			
	1.00 PM	4	27	71	3			
	5.00 PM	3	27	68	4			
30-05-2021	8.00 AM	4	27	68	3			
	1.00 PM	3	27	68	4			
	5.00 PM	4	27	69	3			
31-05-2021	8.00 AM	4	27	72	3			
	1.00 PM	4	26	74	3			
	5.00 PM	3	28	68	3			
01-06-2021	8.00 AM	3	28	69	3			
	1.00 PM	3	27	74	4			
	5.00 PM	4	26	74	3			
02-06-2021	8.00 AM	4	27	71	3			
	1.00 PM	4	27	69	4			
	5.00 PM	4	27	68	4			
03-06-2021	8.00 AM	3	26	74	4			
	1.00 PM	4	27	71	4			
	5.00 PM	3	26	74	4			
04-06-2021	8.00 AM	3	27	71	3			
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	5.00 PM	3	28	69	3			
05-06-2021	8.00 AM	3	27	74	4			

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06-06-2021	8.00 AM	3	27	71	3			
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	5.00 PM	4	27	74	4			
07-06-2021	8.00 AM	4	26	70	3			
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09-06-2021	8.00 AM	4	28	69	4			
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	5.00 PM	4	28	69	3			
12-06-2021	8.00 AM	4	28	72	3			
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13-06-2021	8.00 AM	3	26	70	4				
	1.00 PM	3	26	69	3				
	5.00 PM	4	26	68	3				
14-06-2021	8.00 AM	4	26	70	4				
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	5.00 PM	3	27	74	3				
15-06-2021	8.00 AM	4	27	71	4				
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	5.00 PM	3	27	72	3				
16-06-2021	8.00 AM	3	26	69	4				
	1.00 PM	4	27	71	3				
	5.00 PM	4	26	71	4				
17-06-2021	8.00 AM	3	28	68	3				
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	5.00 PM	4	26	70	4				
18-06-2021	8.00 AM	3	27	71	4				
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19-06-2021	8.00 AM	3	28	73	4				
	1.00 PM	4	26	74	3				
	5.00 PM	3	27	72	4				
20-06-2021	8.00 AM	3	26	73	3				

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	5.00 PM	3	28	70	4			
21-06-2021	8.00 AM	3	27	74	4			
	1.00 PM	3	27	68	3			
	5.00 PM	3	27	73	3			
22-06-2021	8.00 AM	4	27	70	3			
	1.00 PM	3	27	72	4			
	5.00 PM	3	28	74	3			
23-06-2021	8.00 AM	4	27	74	4			
	1.00 PM	3	26	68	3			
	5.00 PM	4	27	74	4			
24-06-2021	8.00 AM	4	28	72	4			
	1.00 PM	4	26	70	3			
	5.00 PM	4	28	72	3			
25-06-2021	8.00 AM	3	28	69	4			
	1.00 PM	3	26	68	3			
	5.00 PM	3	27	70	4			
26-06-2021	8.00 AM	4	27	72	4			
	1.00 PM	4	26	72	4			
	5.00 PM	4	28	69	3			
27-06-2021	8.00 AM	4	28	69	4			
	1.00 PM	3	26	74	3			
	5.00 PM	4	28	68	4			

28-06-2021	8.00 AM	3	27	72	4			
	1.00 PM	4	28	74	3			
	5.00 PM	4	28	71	3			
29-06-2021	8.00 AM	3	26	74	3			
	1.00 PM	3	28	69	3			
	5.00 PM	3	27	69	4			
30-06-2021	8.00 AM	3	28	69	4			
	1.00 PM	3	28	69	3			
	5.00 PM	4	26	68	3			
01-07-2021	8.00 AM	4	27	68	4			
	1.00 PM	3	28	70	3			
	5.00 PM	4	26	70	3			
02-07-2021	8.00 AM	4	28	72	4			
	1.00 PM	3	28	71	4			
	5.00 PM	4	26	74	3			
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	1.00 PM	3	26	74	4			
	5.00 PM	4	26	73	3			
29-09-2022	8.00 AM	4	27	72	4			
	1.00 PM	3	26	70	4			
	5.00 PM	3	28	68	4			
30-09-2022	8.00 AM	4	27	71	3			
	1.00 PM	3	26	74	4			
	5.00 PM	4	26	68	3			
01-10-2022	8.00 AM	4	26	69	4			
	1.00 PM	3	27	74	4			
	5.00 PM	4	27	73	4			
02-10-2022	8.00 AM	4	26	71	4			
	1.00 PM	3	27	69	4			
	5.00 PM	3	26	68	3			
03-10-2022	8.00 AM	3	28	73	3			
	1.00 PM	3	26	69	4			
	5.00 PM	3	26	71	4			
04-10-2022	8.00 AM	4	27	73	4			
	1.00 PM	4	28	74	3			
	5.00 PM	3	26	72	3			
05-10-2022	8.00 AM	4	28	72	4			
	1.00 PM	3	28	69	3			
	5.00 PM	3	27	69	3			

06-10-2022	8.00 AM	4	28	72	4			
	1.00 PM	3	28	73	4			
	5.00 PM	3	27	74	3			
07-10-2022	8.00 AM	4	26	74	3			
	1.00 PM	3	27	71	4			
	5.00 PM	3	26	68	3			
08-10-2022	8.00 AM	4	28	69	4			
	1.00 PM	4	28	70	3			
	5.00 PM	4	27	69	3			
09-10-2022	8.00 AM	4	27	68	3			
	1.00 PM	4	27	69	3			
	5.00 PM	4	26	74	3			
10-10-2022	8.00 AM	4	27	73	4			
	1.00 PM	3	26	70	4			
	5.00 PM	3	27	71	3			
11-10-2022	8.00 AM	4	28	71	3			
	1.00 PM	3	28	69	4			
	5.00 PM	3	27	72	4			
12-10-2022	8.00 AM	4	26	74	3			
	1.00 PM	3	27	72	3			
	5.00 PM	4	27	74	4			
13-10-2022	8.00 AM	3	26	68	4			

	1.00 PM	3	28	68	4			
	5.00 PM	3	28	68	3			
14-10-2022	8.00 AM	4	28	72	3			
	1.00 PM	3	27	70	4			
	5.00 PM	4	26	70	3			
15-10-2022	8.00 AM	3	26	71	3			
	1.00 PM	3	26	68	4			
	5.00 PM	4	26	71	4			
16-10-2022	8.00 AM	3	27	69	4			
	1.00 PM	3	27	73	4			
	5.00 PM	3	27	68	3			
17-10-2022	8.00 AM	4	26	72	4			
	1.00 PM	4	27	68	3			
	5.00 PM	3	27	73	3			
18-10-2022	8.00 AM	4	26	70	3			
	1.00 PM	3	26	68	3			
	5.00 PM	4	28	72	4			
19-10-2022	8.00 AM	3	27	74	4			
	1.00 PM	4	26	69	4			
	5.00 PM	3	26	73	3			
20-10-2022	8.00 AM	4	26	69	3			
	1.00 PM	4	26	72	3			
	5.00 PM	4	27	74	3			

21-10-2022	8.00 AM	4	26	74	3				
	1.00 PM	3	26	74	3				
	5.00 PM	4	27	74	4				
22-10-2022	8.00 AM	3	27	73	3				
	1.00 PM	4	28	68	3				
	5.00 PM	3	28	69	4				
23-10-2022	8.00 AM	3	26	71	4				
	1.00 PM	3	26	70	3				
	5.00 PM	3	26	73	3				
24-10-2022	8.00 AM	3	27	73	3				
	1.00 PM	3	28	70	3				
	5.00 PM	3	27	73	3				
25-10-2022	8.00 AM	3	28	74	4				
	1.00 PM	4	26	68	4				
	5.00 PM	4	28	72	3				
26-10-2022	8.00 AM	3	27	68	4				
	1.00 PM	3	27	70	4				
	5.00 PM	4	28	73	4				
27-10-2022	8.00 AM	4	28	73	4				
	1.00 PM	3	26	70	3				
	5.00 PM	3	28	74	4				
28-10-2022	8.00 AM	3	26	74	4				

	1.00 PM	4	28	68	4			
	5.00 PM	4	28	72	3			
29-10-2022	8.00 AM	3	27	72	4			
	1.00 PM	3	27	70	3			
	5.00 PM	4	28	71	3			
30-10-2022	8.00 AM	3	26	73	4			
	1.00 PM	3	27	74	3			
	5.00 PM	4	26	68	3			
31-10-2022	8.00 AM	4	26	73	3			
	1.00 PM	3	26	69	3			
	5.00 PM	4	28	70	3			