Acta Mechanica Slovaca **27 (4): 6 -13 ,** December **2023**
https://doi.org/10.21496/ams.2023.036

Acta Mechanica Slovaca
ISSN 1335-2393
www.actamechanica.sk

Photocatalytic Efficiency Test Equipment

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Abstract: This article deals with a description of pathogens, ways to combat pathogens, and a brief overview of the devices we use to eliminate them. The aim of the article is to describe the photocatalytic efficiency, which will result in the application of the given technology to a newly developed device - an antimicrobial device, the efficiency of which we will be able to determine by means of a photocatalytic efficiency test device where we will examine the given technology with the help of a mass spectrometer.

The development in this area is due to the SARS-CoV-2 pandemic, which causes the Covid-19 disease, but also due to the involvement of the Faculty of Mechanical Engineering of the Technical University in Košice in the European project INTELTEX 313010AVF5 - Centre for the Development of Textile Intelligence and Antimicrobial Technologies, Operational Programme Transport.

Keywords: Viruses, photocatalysis, bacteria, efficiency, test equipment.

1. Introduction

The 21st century is also marked by the coronavirus pandemic, which has had a significant impact on the functioning of society as a whole. The deterioration in the health status of the population, the significant mortality rate due to the virulence and variable mutations of the Covid-19 virus and the way in which it spreads. This pandemic has left great damage to the population and the world economy. Since the very beginning of this pandemic, which struck the city of Wu-Chan in the province of Hubei in China, a total of 690 716 930 inhabitants have been infected with this viral respiratory disease in the world, and almost 7 000 000 inhabitants have succumbed to this viral respiratory disease; in Slovakia, 1 866 857 million inhabitants have been infected so far and, unfortunately, more than 21 000 inhabitants have succumbed to this viral respiratory disease. [1,2]

2. Characteristics of pathogens

Pathogens are microscopic organisms that can cause infections, diseases and illnesses in humans. Pathogens are diverse and have different characteristics depending on the type of pathogen. Understanding the differences between pathogens is important for effective prevention and treatment of infections. [3]

2.1 Characteristics of bacteria

The first type of pathogen is bacteria. Bacteria are unicellular organisms that are found almost everywhere on Earth. Some bacteria live harmlessly in our bodies, while others can cause serious infections. Bacterial cells have unique structures, such as cell walls, that distinguish them from other types of cells, such as human cells. Antibiotics are used to treat bacterial infections by killing or inhibiting the growth of bacteria. [4]

2.2 Characteristics of viruses

The second type of pathogen is viruses. Viruses are smaller than bacteria and cannot survive without a host cell because they lack the cellular machinery necessary for

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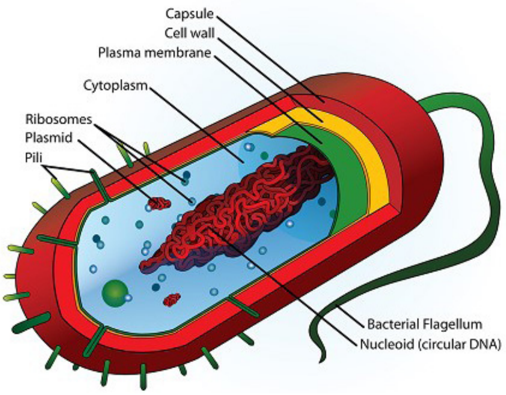

Figure 1: Schematic diagram of the bacteria. [12]

survival. Viruses range in severity from causing mild colds to life-threatening diseases such as HIV/AIDS or COVID-19. Antiviral drugs work by interfering with the processes of viral replication in host cells, thereby preventing the production of new viruses. [5]

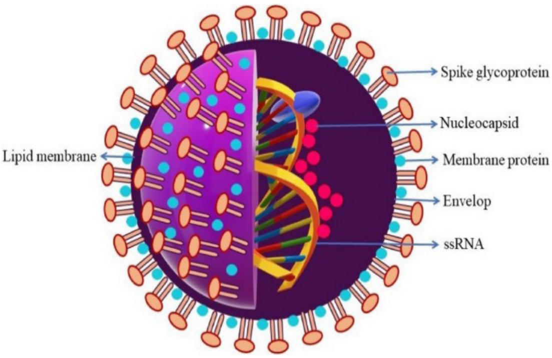

Figure 2: Schematic diagram of the viruses. [13]

2.3 Characteristics of mold

The third type of pathogen is molds. Fungi are eukaryotic organisms with cell walls made of chitin instead of cellulose, which is found in plant cell walls. Fungi can be harmless or cause fungal infections ranging from mild skin rashes to life-threatening systemic diseases. [5]

3.Anti-pathogen elimination method

The effectiveness of pathogen elimination technologies will depend on several factors, such as the type and concentration of pathogens, environmental conditions, contact time and dose of treatment, and potential side effects or associated risks. Therefore, it is difficult to say which technology is generally the most effective, as different

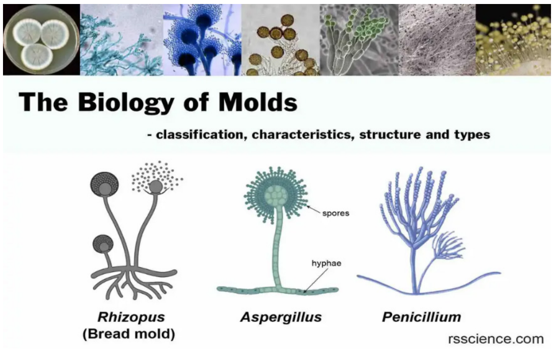

Figure 3: Schematic diagram of the molds. [14]

technologies may have different advantages and disadvantages for different applications.

Heat treatment can be effective for eliminating pathogens in water, food or clothing, but it can also damage the quality or functionality of treated materials or cause energy consumption and greenhouse gas emissions.

Electromagnetic waves can be effective in eliminating pathogens in the air, water or on surfaces, but can also pose health risks or environmental impacts if not properly controlled or regulated.

Pathogen filtration can be effective for eliminating pathogens in biopharmaceutical products or drinking water but may also require high pressure and frequent maintenance or replacement of membranes.

Pathogen inactivation can be effective for eliminating pathogens in blood products or vaccines but can also introduce toxic residues or alter the biological activity or immunogenicity of treated materials.

Cryotherapy can be effective for eliminating pathogens in plant tissues or organs but can also cause tissue damage or loss of viability if not performed carefully. [5,6]

4.Types of pathogen elimination devices

4.1 Chemical disinfection equipment

Chemical disinfection equipment uses various solutions such as chlorine, hydrogen peroxide, or quaternary ammonium compounds to destroy pathogens on surfaces. They are effective against a wide range of pathogens including bacteria, viruses, and moulds. Chemical disinfectants are versatile, easy to use and provide rapid disinfection, making them invaluable tools in preventing the spread of infectious diseases. [6]

Figure 4: Equipment for chemical disinfection. [15]

4.2 Plasma sterilizers

Plasma sterilizers use low-temperature plasma to remove pathogens. This technology generates reactive species such as hydrogen peroxide radicals, ozone, and UV radiation that effectively break down the genetic material of microorganisms. Their ability to penetrate complex spaces and eliminate a wide range of pathogens makes them important in healthcare facilities. [6,7]

Figure 5: Plasma sterilizers. [16]

4.3 Water purification systems

Waterborne pathogens can cause serious illness, so water purification facilities are crucial to maintaining public health. Systems such as ultraviolet (UV) disinfection units, reverse osmosis filters and activated carbon filters are used to remove bacteria, viruses, parasites, and chemical contaminants from water sources. These devices ensure the supply of safe drinking water and play an important role in the prevention of waterborne diseases, especially in regions with inadequate sanitation infrastructure. [6]

4.4 Germicide covers

Germicidal enclosures are specialized chambers that use a combination of UV light and controlled airflow to disinfect objects. These enclosures are

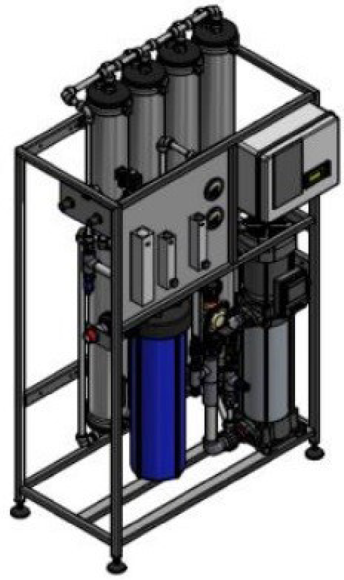

Figure 6: Water purifier. [17]

commonly used to disinfect personal protective equipment, electronic devices and small medical instruments. UV light effectively destroys pathogens present on the surface of these items, minimizing the risk of cross-contamination. [7]

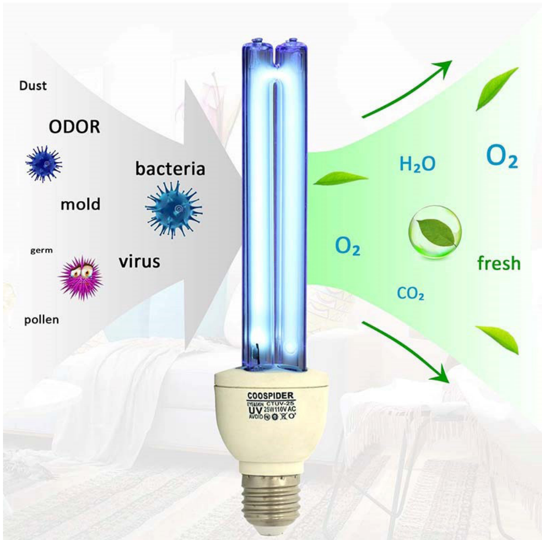

Figure 7: Germicidal bulb. [18]

4.5 Antimicrobial copper surface

Copper surfaces have intrinsic antimicrobial properties that can eliminate pathogens on contact. Copper and its alloys have been shown to be effective against a wide range of pathogens. The antimicrobial effect is attributed to the release

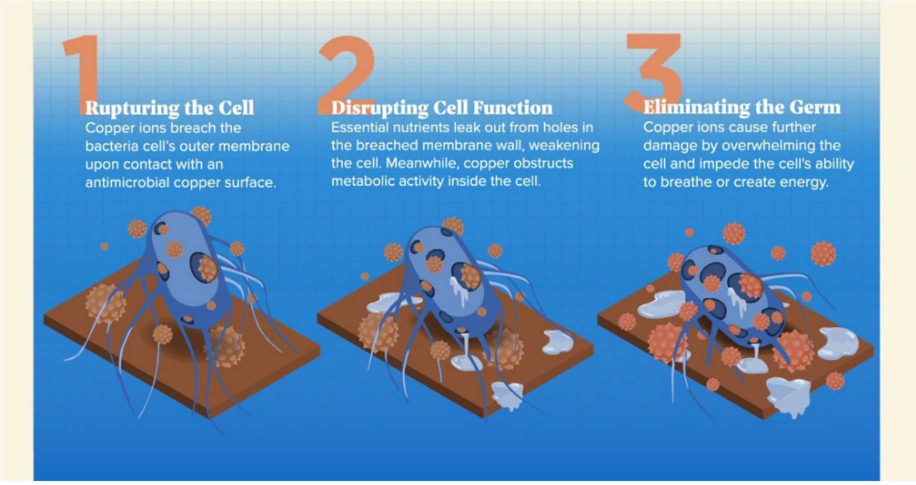

Figure 8: Antimicrobial Copper Surfaces. [19]

of copper ions, which disrupt the cellular processes of pathogens. Incorporating copper surfaces into areas that people frequently touch, such as door handles, railings and countertops, can significantly reduce the transmission of pathogens. [7]

Figure 9: Ultraviolet germicidal irradiation equipment. [20]

4.6 Ultraviolet germicidadl irradiation equipment

These devices use ultraviolet UV light to kill pathogens by damaging their genetic material and preventing them from reproducing. They have been shown to be effective against a variety of infectious diseases. [8]

4.7 Air purifiers with high efficiency particulate air (HEPA) filters

Air purifiers equipped with HEPA filters are designed to remove airborne pathogens from the indoor environment. By continuously circulating and filtering the air, these devices significantly reduce the concentration of pathogens, resulting in improved indoor air quality. [6,9]

4.8 Electrostatic Sprayers

Electrostatic sprayers use a positive charge to spray disinfectants in a fine mist. As the mist forms, charged particles are attracted to surfaces, creating

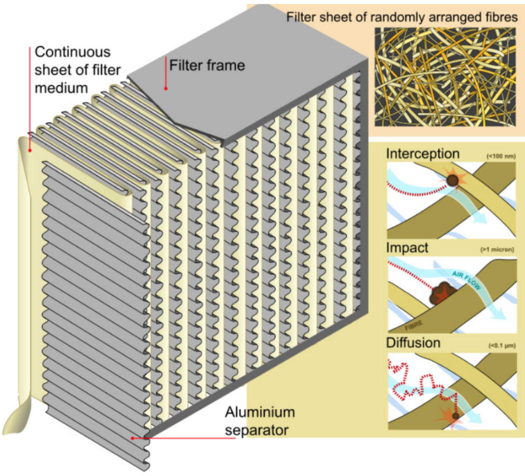

Figure 10: The principle of operation of a HEPA filter. [21]

a more uniform and effective coverage compared to conventional spraying methods. This technology enables large areas to be effectively disinfected in a relatively short time. Electrostatic sprayers can be used with a variety of disinfectants, including those specifically formulated to eliminate specific pathogens. [9,10]

Figure 11: Electrostatic Sprayer. [22]

4.9 Ozone generators

Ozone generators produce ozone, which is a powerful oxidizing agent capable of killing pathogens by disrupting their cellular structure. Ozone is particularly effective against viruses, bacteria, and spores. These devices can be used for air purification, water treatment and surface disinfection. However, it is important to note that ozone can be harmful to humans and should be used in the absence of people, following safety guidelines.[11]

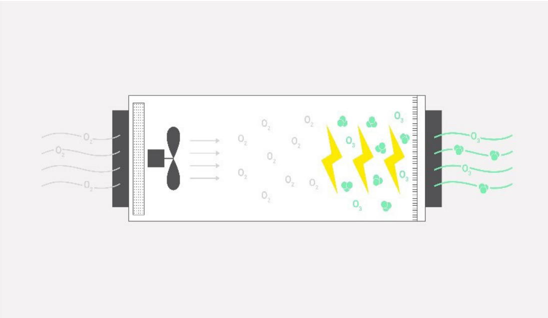

Figure 12: Ozone Generator. [23]

5.Photocatalytic efficiency test equipment

The photocatalytic efficiency device developed to verify the efficiency of the antimicrobial device, which is the output of my PhD thesis. The modeling and design of the photocatalytic efficiency test device was designed in SolidWorks.

The working principle of this test device is to exploit the effect of photocatalysis. During this process, photolysis, i.e. the natural decomposition of substances by the action of light, is accelerated by a photocatalyst, represented by an antimicrobial substance, on whose surface, after irradiation, the process of photocatalysis is produced.

Throughout the different parts of the test apparatus there are access points to the mass spectrometer probe for accurate quantification of the amount of test substance (toluene) evaporated.

5.1 Working principle of the photocatalytic efficiency test equipment

Measurement tests were carried out on the photocatalytic efficiency test rig. The device consists of a transparent polymer tube (1).

The test sample - evaporated test substance (toluene) is placed in a petri dish on a heating pad at the bottom of the device, which reaches faster evaporation when the temperature is raised.

The test substance is evaporated into the pre-

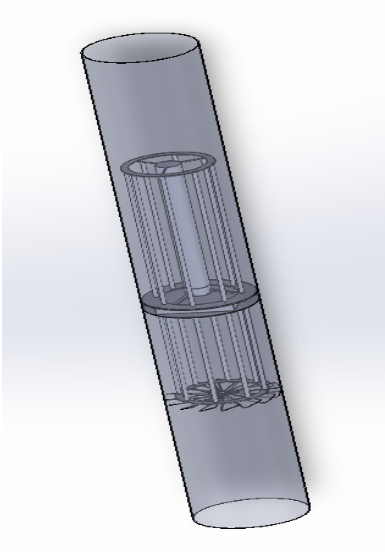

Figure 13a: Photocatalytic efficiency test equipment in SolidWorks.

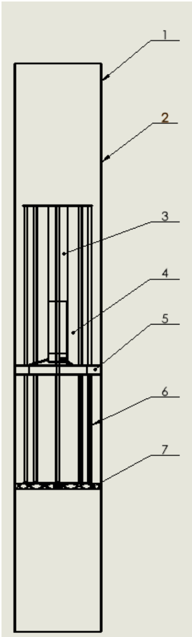

Figure 13b: Schematic of the photocatalytic efficiency test facility.

filter section (6) where the substance is further dispersed by means of a propeller-shaped mixing device (7). Subsequently, the evaporated substance is drawn by a fan (5), which pushes the test substance into the core of the antimicrobial filter section (4) formed by a knitted polymer fibre with metal oxides and a controllable light source located on the central tube (3).

After exiting the filtering activity, we measure the readings at the site (2) and detect the efficiency of the photocatalytic core.

5.2 Usability of the photocatalytic efficiency test equipment

The described embodiment is used to detect the effect of photocatalytic efficiency using an antimicrobial filter core comprising a filament and a light source at a controlled temperature.

In addition to the experimental function of the test device, which is of great importance in the testing of both organic and inorganic substances, we can also investigate the temperature, to carry out tests of the lifetime of the core of the antimicrobial filter part where a knitted polymer fibre with metal oxides is applied.

6.Mass spectrometer

This device is used to measure the concentration of a calibrated gas in each space. A mass spectrometer cannot measure the concentration of multiple gases.

Calibration of the device is required before each measurement. To determine the effectiveness of the antimicrobial under test in the photocatalytic efficacy test facility, the mass spectrometer will measure the concentration of the test gas before entering the filter section and after exiting the filter section. The output of the device is data in electronic form in the form of a graph.

This will prove whether the test substance contained in the test device meets the required parameters or the percentage of efficiency, which must exceed the 95% threshold.

If the test substance eliminates the test gas toluene to 95% or more, it is proven that the test substance will eliminate all pathogens that will be present in the area.

Figure 14: Mass spectrometer. [24]

Conclusion

The global pandemic caused by the rapid spread of the viral respiratory disease Covid-19 has shown the shortcomings of the antimicrobial technologies used so far in commonly available devices. Devices that claimed more than 99% air filtration efficiency failed to contain the virus and, in most cases, managed to ensure its spread. It is therefore a logical consequence that there is a need to develop equipment with new technologies that effectively destroy and trap viruses, bacteria and other pathogens.

Given that many countries do not have virological laboratories suitable for testing devices with real viruses, including Slovakia, it is necessary to verify the functionality of the devices in a different way that does not contaminate the environment of the laboratory in which they are tested, even after failure. Such a device is the above mentioned photocatalytic efficiency test facility, which can verify the functionality of the photocatalytic reaction of the core of the test devices on inorganic substances in safe conditions that do not endanger the health of the testers using a mass spectrometer.

Assuming the hypothesis that photocatalysis degrades the test substance toluene to a certain level within a defined time, it can be concluded that there is no virus, bacteria or other pathogens that could survive such a strong photocatalytic reaction. This facility has a huge safety benefit in testing newly developed and tested antimicrobial technologies that are not only highly effective, but also environmentally friendly and economically small.

Acknowledgments: The authors would like to thank the Slovak Grant Agency - project KEGA 054TUKE-4/2022.

This publication was created thanks to support under the Operational Programme Integrated Infrastructure for the project Center for the Development of Textile Intelligence and Antimicrobial Technologies co-financed by European Regional Development Fund. ITMS2014+ 313011AVF5 Center for the Development of Textile Intelligence and Antimicrobial Technologies.

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