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Journal of Infectious Diseases & Preventive Medicine

Research Article

Application of Rotation Channels for Decontamination of Pathogens in Metamaterials Penetrated by UVC Radiation

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ABSTRACT

The main idea of new decontamination equipment proposed in this paper is connected with the rotation of contaminated fluid by screw channels for pathogens moving between the elements of quarts metamaterial penetrated by ultraviolet C radiation. In order to improve the decontamination rate, the space between two quarts tubes was filled up with fibers having a helical wounded on the first cylinder. The efficiency of the decontamination rate as a function of the applied velocity of the fluid was demonstrated. The similar screw channels were observed when the contaminated fluid flows between the spherical elements of metamaterials. The rotation radius has the order of quartz bubbles used in experiment.

Keywords: UV-C radiation; Rotation channels; Decontamination; Contaminated fluid

INTRODUCTION

Pathogens (viruses and bacteria) can reach the organism not only through transmission, but also by traditional mechanisms like direct contact with other persons. However, the last time we observed a positive correlation between virus spread and fluids (water or air) pollution, also where ultraviolet rays inhibit the immune system in a variety of ways. It suppresses antigen presentation, triggers the ejection of immunosuppressive cytokines, and promotes the development of regulatory cells [1]. UV-induced DNA damage is the primary biochemical target for UV-induced immunodeficiency. The most susceptible bacteria examined were *Sphaeroides* and *E. coli*. UV-induced immunomodulation also appears to be harmful. *Micrococcus luteus* and *Micrococcus radiophilus* are two bacterial species disclosed to be UV radiation resistant. Where this metamaterials are materials that have been intentionally structured and are used to regulate and alter light, sound, and a variety of other physical events. Microorganisms are inactivated by ultraviolet radiation by creating dimers of pyrimidines in RNA and DNA, which may cause problems with transcription and replication. UV light causes photooxidative degradation, which results in the breaking of polymer chains, the production of radicals, and the reduction of molecular weight, resulting in decline of mechanical characteristics and the formation of useless materials after an undetermined period. The UV region covers the wavelength range 100-400 nm and is divided into three bands: UVA (315-400 nm) UVB (280-315 nm) UVC (100-280 nm). Experimental animal studies have revealed that UV exposure can impair the resistance to many infectious agents, such as bacteria, parasites, viruses, and fungi. COVID-19 could have an air/water transmission through particulate matter could create a suitable environment for transporting the virus at greater distances than those considered for close contact. SARS-CoV-2 is an enveloped virus 0.1 μm in diameter. Viruses are often transmitted through respiratory droplets produced by coughing and sneezing. Respiratory droplets are usually divided into two size bins, large droplets (>5 μm in diameter) that fall rapidly to the ground and are thus transmitted only over short distances, and small droplets (<5 μm in diameter). Small droplets can evaporate into "droplet nuclei", remain suspended in air for significant periods of time and could be inhaled [2]. As a usual they are not transparent in UVC decontamination diapason (200-280 nm) and needs a more near action of such radiation obtained from traditional sources from all direction to such droplets in order to achieve a good effect.

MATERIALS AND METHODS

In this investigation, we are focused on the applying of various geometry methods to packing elements which create the screw channels for pathogen acceleration through the elements of this metamaterial. The principal idea in this paper is connected with the rotation of contaminated liquids and gases by screw channels of this meta-materials, prepared from UVC fiber optics in the torsion configuration represented in the Figures 1 and 2. The contamination liquids are rotated along the flow direction.

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Received: 10-Feb-2023, Manuscript No. JADPR-23-21773; **Editor assigned:** 13-Feb-2023, Pre QC No. JADPR-23-21773 (PQ); **Reviewed:** 01-Mar-2023, QC No. JADPR-23-21773; **Revised:**10-Mar-2023, Manuscript No. JADPR-23-21773 (R); **Published:** 20-Mar-2023, DOI: 10.35841/2329-8731.23.11.296

Citation: Enaki NA, Munteanu I, Ţurcan M, Bazgan S, Paslari T, Starodub E (2023) Application of Rotation Channels for Decontamination of Pathogens in Metamaterials Penetrated by UVC Radiation. Infect Dis Preve Med. 11:296.

Considering that the density of virus and bacteria droplets are larger than the density of liquids, the adherence of the pathogens to the "external surface" of the rotation channels increases as a function of the torsion degree of channels [3, 4]. As the number of such rotation canals in the proposed meta-material is large, the total surface consists of the sum of the surfaces of each flow canal between the fibers. This UVC decontamination effect depends on the inertial centrifugal force, which appear on the droplets infected by pathogens during its rotation. The large density of pathogens gives us the possibility to find the connection between its flow velocity and spinning radius of rotation channel [5]. The centrifugal force must pull the pathogen droplets to the fibers/sphere surface penetrated by evanescent UVC radiation in the flow channel during the spinning effect (from figures 1 and 2). This UVC decontamination effect depends on the inertial centrifugal force, which appears on the pathogens during its rotation flow along the channel [Figures 1-3].

Considering that the density of the pathogens, ρp is larger than the density of fluids ρf. The centrifugal force, $F=(\rho p-\rho f)\omega^2 r$ which acts on the pathogen along the rotatory radius, r, with frequency ω in the rotational acceleration represented in the figure 2, must be compensated by resistance force opposed by the fluid, $-\beta dr/dt$, when the rotation radius increases. Taking this into consideration the projection of the second Newton law on the radius direction may be approximated by the expression $(\rho p-\rho f)\omega^2 r-\frac{\beta dr}{dt}=0$, or in this dt description radius increases as the function of time in the $r(t)=r_0\exp\left[(\rho p-\rho f)\omega^2 r/\beta\right]$. From which follows the pathogens deflects from the flow's lines achieved the UVC evanescent zone of the elements of metamaterial represented in figure 1. This estimation demonstrates why the quick decontamination effect may be achieved with higher efficiency in the dynamic situation in comparison with static representation. The decontamination efficiency substantially increases in the moving pathogens together with liquids (or infected aerosols in flow gazes) between the elements of metamaterials in comparison with quasi- stationary decontamination regime.

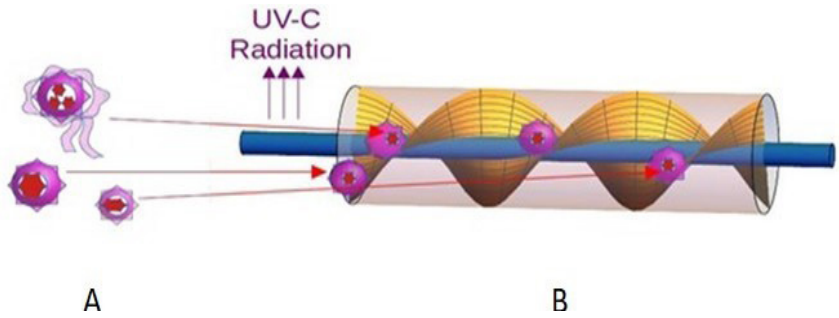

Figure 1: The pathogen droplets. (A) with dimensions about 10-100 nm can be pumped and imposed under rotation acceleration between free space of helical ensemble of the scrolled fibers and (B) Achieving the evanescent zone of UVC radiation of each fiber the pathogens can be effectively inactivated.

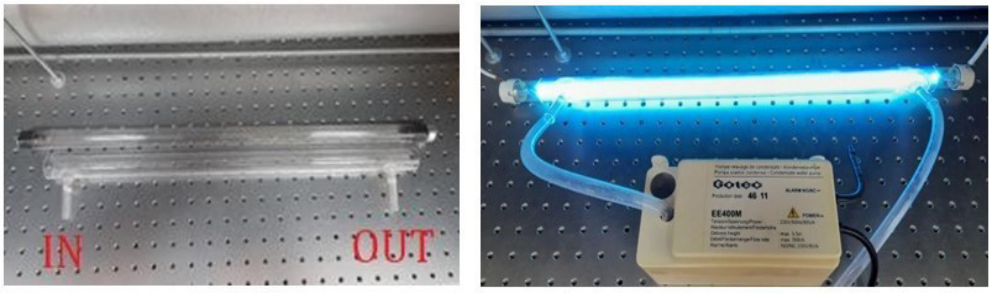

Figure 2: (A) The decontamination device consists of the lamp (UV) and the quartz tube with 2 holes that serve as input- output (IN-OUT) decontamination solution and (B) the decontamination device connected to a pump source.

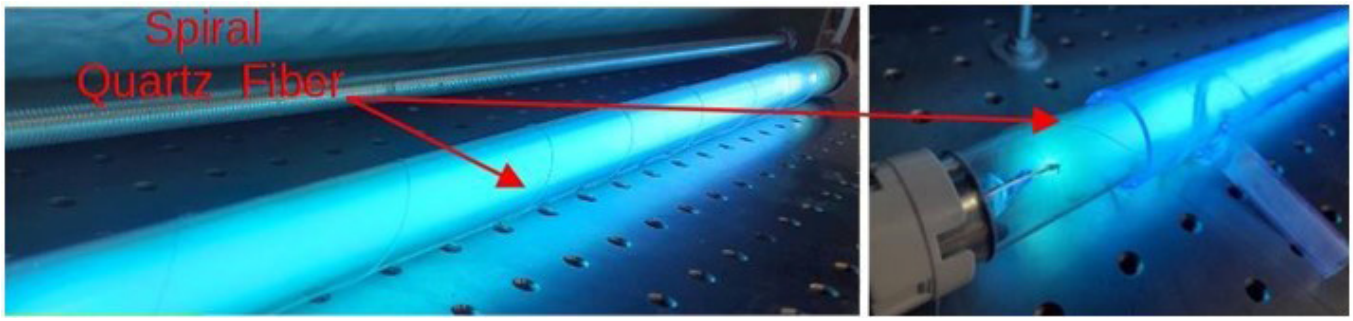

Figure 3: Here is shown the quartz fiber spiral located between the UV lamp and the tube which serves for the rotation effect of molecules, bacteria and pathogens when the contaminated liquid flows through the tube.

RESULTS AND DISCUSSION

It is not possible to use pathogens in the decontamination procedures in the physics laboratory because there are several measurements to be taken to protect, since the area is covered with viruses. But taking into consideration that the big number of pathogens are sensible to UVC radiation than eukaryotic cellular structures, we have to substitute these contaminated fluids with yeast solution, which has larger resistance to UVC radiation in comparison with many viruses or bacteria [6,7]. In this approach, the improving of the inactivation rate of the yeast colony using this method of decontamination with rotation channels penetrated UVC radiation by metamaterial will mean that this efficient method will work successfully well in the case of prokaryotic cells specific for many bacteria.

In this experiment, we will compare the inactivation of pathogens with the help of two devices, one will work in dynamic mode which was described in this paper and the other in static mode [3]. Static mode device has the next construction; the core is covered by 6 mercurial lamps, with a maximum radiation of 250-260 nm. To improve the efficiency of UVC radiation, the system is placed in the aluminum cylinder with the diameter about 20 cm so that the intensity of the radiation in the center of the big cylinder increase significantly due to the reflection proprieties of the aluminum. For obtaining good an experimental result was taken 1.5 ltrs of water in which was dissolved in 40 grams of yeast and added 40 grams of sugar. In Figure 4 a microscopic view of yeast fungi until decontamination is shown. After few minutes of decontamination, the static regime (from figure 4) and dynamical (from figure 5) experiments began [Figures 4 and 5].

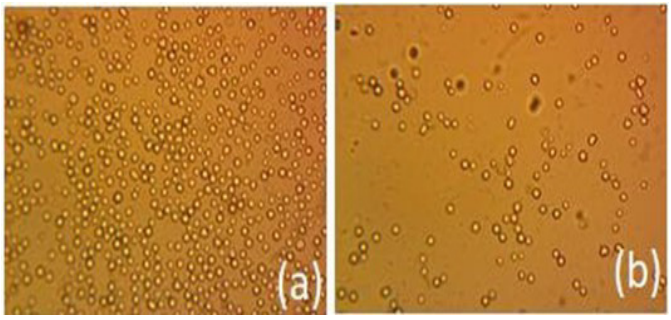

Figure 4: (a) Microscopic view of yeast fungi until decontamination and (b) After 3 Min of decontamination, the static regime.

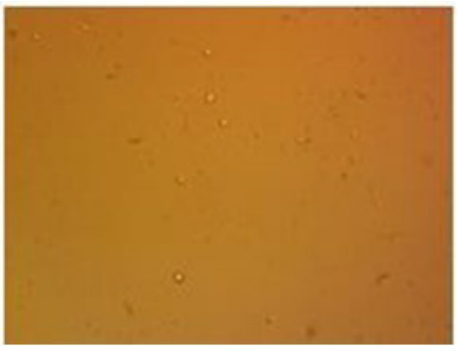

Figure 5: After 5 Min of decontamination, the dynamic regime

The decontamination efficiency is connected with the rotation of contaminated liquids and gases by screw channels of meta-materials, prepared from UVC fiber optics (or closely packed spherical elements of metamaterial) in the torsion configuration. The contamination liquids are rotated along the flow direction. Considering that the density of viruses and bacteria (or droplets, aerosols contained they) are larger than the density of liquids, the adherence of the pathogens on the rotation channels increases as a function of the torsion degree of the channels [8]. As the number of such relative canals in the proposed meta-material is large, the total surface consists of the sum of the surface of each flow canal between the fibers.

CONCLUSION

We estimated that for inactivation of 1.5 ltrs of fungus solution, we need about 5 min of UVC radiation in the cyclical rotation of the fluid through our decontamination equipment. In the static regime for decontamination of 0.15 ltrs of fungus solution, we need 3 min UVC radiation. This comparison means that for decontamination of 1.5 ltrs of fungus solutions in the static regime, we need 10 times more of the decontamination time. For example, in the dynamic regime we used about 3 min for 1.5 ltrs instead of 30 min in the static one for the same quantity of contaminated solution. This estimation demonstrates that the dynamical regime with the mean velocity of fluid through the decontamination were equal to 30-60 cm/sec, to give us the 10 times increase in the decontamination rate. We consider that in the turbulent flow, the rate may increase drastically on the decontamination efficiency.

ACKNOWLEDGEMENT

This paper is supported by the projects: No. 20.80009.5007.01 and NATO EAP SFPP 984890.

CONFLICT OF INTEREST

There is no conflict of interest.

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