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Can Masks Be Reused After Hot Water Decontamination During the COVID-19 Pandemic?

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ABSTRACT

Masks have become one of the most indispensable pieces of personal protective equipment and are important strategic products during the coronavirus disease 2019 (COVID-19) pandemic. Due to the huge mask demand–supply gap all over the world, the development of user-friendly technologies and methods is urgently needed to effectively extend the service time of masks. In this article, we report a very simple approach for the decontamination of masks for multiple reuse during the COVID-19 pandemic. Used masks were soaked in hot water at a temperature greater than 56 °C for 30 min, based on a recommended method to kill COVID-19 virus by the National Health Commission of the People's Republic of China. The masks were then dried using an ordinary household hair dryer to recharge the masks with electrostatic charge to recover their filtration function (the so-called "hot water decontamination + charge regeneration" method). Three kinds of typical masks (disposable medical masks, surgical masks, and KN95-grade masks) were treated and tested. The filtration efficiencies of the regenerated masks were almost maintained and met the requirements of the respective standards. These findings should have important implications for the reuse of polypropylene masks during the COVID-19 pandemic. The performance evolution of masks during human wear was further studied, and a company (Zhejiang Runtu Co., Ltd.) applied this method to enable their workers to extend the use of masks. Mask use at the company was reduced from one mask per day per person to one mask every three days per person, and 122 500 masks were saved during the period from 20 February to 30 March 2020. Furthermore, a new method for detection of faulty masks based on the penetrant inspection of fluorescent nanoparticles was established, which may provide scientific guidance and technical methods for the future development of reusable masks, structural optimization, and the formulation of comprehensive performance evaluation standards.

1. Introduction

During the coronavirus disease 2019 (COVID-19) pandemic in 2020, masks have become one of the most indispensable pieces of personal protective equipment. On 20 January 2020, Prof. Nan-Shan Zhong, the head of the high-level expert group appointed by the National Health Commission of the People's Republic of China to fight the novel coronavirus, emphasized the importance of wearing masks in an interview with China Central Television [1]. On 22 January 2020, the spokesperson of the National Health Commission in the State Council Information Office of the People's Republic of China advocated the "mask civilization" and pointed out that "wearing masks is not only for the protection of ourselves, but also for the protection of others" [2]. However, according to the data publicly reported by the Ministry of Industry and Information Technology of the People's Republic of China, the production of masks in China was only 8 million per day on 23 January 2020 and reached 10 million per day by 2 February 2020. Given China's population of over 1.4 billion people, the huge mask demand–supply gap is obvious. According to *Technical guidance on the selection and use of masks for different population to prevent novel coronavirus*, which was released by the National Health

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Commission of the People's Republic of China on 4 February 2020, people in supermarkets, shopping malls, airports, subways, indoor offices, and other low-risk places are recommended to wear disposable medical masks or surgical masks to prevent the spread of the COVID-19 virus [3]. As a result, medical masks, which were originally designed for use in clinics and hospitals, are now widely used and appear in stations, airports, markets, parks, and other public places. The technical guideline also indicated that during the COVID-19 pandemic, the use of masks may be appropriately extended (including the duration of single use and times of repeated use) if it is safe to do so. In particular, people in low-risk places are recommended to reuse masks. However, the existing national standards and local standards for masks mainly focus on the performance of disposable masks, and there are no specific requirements or instructions on mask performance for multiple uses, including the duration of a single use, disinfection methods, and the number of times a mask can safely be reused. How can masks be efficiently sanitized for multiple uses during the COVID-19 pandemic? Are masks damaged during decontamination treatment? How many times can masks be decontaminated by appropriate methods? In fact, there is no scientific theory or experi- mental data support to answer these questions. During the mask shortage, most people—including front-line medical staff—have been spontaneously reusing masks several times, which eases the tension between supply and demand to a certain extent; however, this practice might also increase these people's risk of exposure. Therefore, user-friendly technologies and methods are urgently needed to effectively extend the service time of masks.

Masks, including disposable medical masks, surgical masks, medical protective masks, and dust masks, are usually made of non-woven polypropylene fabric with electrostatic properties that enhance particle capture. The electrostatic charge keeps airborne particles out by drawing them onto the fiber surfaces, much like iron filings are drawn onto a magnet. The spaces between the fibers of the mask at the microscale are much larger than the sizes of bacterial viruses and respiratory aerosols/droplets, so masks are not able to block particles at the nanoscale by means of mechanical filtration. Therefore, the electrostatic charge on the fibers plays an important role in intercepting virus particles with diameters of 100 nm and aerosols/droplets containing bacterial viruses. In the process of using the mask, elimination of the electrostatic charge layer occurs along with the deposition of bacteria viruses and haze (water vapor) onto the electrostatic layers, which causes a decline in filtration efficiency and even invalidation of the protective performance of the mask. Therefore, during the COVID-19 pandemic, if people are driven by necessity to extend the use of masks that were originally designed and marketed as disposable masks, there are two points to consider: first, user-friendly decontamination to kill possible COVID-19 viruses on the used masks; and, second, efficiently controlled charge regeneration of masks to maintain mask performance for reuse. On 14 February 2020, the ScienceNet website reported a preliminary "regeneration treatment" approach toward the reuse of disposable masks developed by our group at Beijing University of Chemical Technology [4]. Advice was given to soak used medical masks in hot water at a temperature greater than 56 °C (typically 60–80 °C) for 30 min for decontamination. Ordinary household appliances such as a hair dryer, electric fan, or electronic igniter would then be used to dry the masks and recharge them with electrostatic charge. Successful regeneration of a mask could be confirmed by sprinkling the mask with small scraps of paper at home, without the need for special professional instruments [4]. According to official guidance from *Prevention and control program of COVID-19 (4th edition)* released by the National Health Commission of the People's Republic of China on 6 February 2020 [5], this temperature (> 56 °C) and time (30 min) are efficient for killing the COVID-19 virus. The charge-regeneration procedure aims to infuse the filter with electrostatic charge, which is the key contributor to a mask's high level of filtration.

In this article, we summarize our experimental results and evaluations on three kinds of typical masks (disposable medical masks, surgical masks, KN95-grade masks) treated by the so-called "hot water decontamination + charge regeneration" approach. The evolution of static electricity on the masks is revealed. The microstructures of the masks were studied by scanning electron microscope (SEM) and the waterproof properties were assessed by the hydrostatic pressure method. The filterability of the masks was tested according to respective national standards and local standards. The performance of the KN95-grade masks in 121 °C steam for 30 min, which is a well-accepted approach for killing almost all pathogens, was also investigated. Furthermore, a method based on fluorescent nanoparticle penetrant inspection was proposed for the detection of inner defects in used masks, in order to provide necessary data for the development of reusable masks, structural optimization, and evaluation standards.

2. Materials and methods

2.1. Samples

Three types of disposable masks were tested: disposable medical masks (CHTC Jiahua Non-woven Co., Ltd., China), disposable surgical masks (from three locations: ESound Medical Device Co., Ltd., Anbang Medical Supplies Co., Ltd., and Yubei Medical Supplies Co., Ltd., China), and KN95-grade masks (the 3M 9502 and KF94 masks from the Republic of Korea). These masks are referred to herein as "JH," "YX," "AB," "YB," "3M," and "KF," respectively.

2.2. Hot water decontamination and charge regeneration

Three kinds of containers, including a household aluminum basin, a polypropylene plastic lunch box, and a stainless steel thermos cup, were used in the experiments. In a typical procedure, boiling water was directly poured into the container at room temperature. The volume of water exceeded 80% of the total capacity of the container and the temperature was measured by a thermometer. The mask was immersed in the water by placing a heavier object on top of it, such as a spoon. The container was then closed and the mask was left to soak in the hot water for 30 min. After that, the container was opened and the mask was removed from the hot water. The liquid on the mask was slightly shaken off and the mask was placed on the surface of dry insulating material, such as wooden, plastic tables, and bed sheets. The mask was then dried with a standard hair dryer for 10 min.

2.3. Static electricity test

A hand-held electrostatic field meter (FMX-004; Simco, Japan) was used to test the electrostatic charge of mask. The mask to be tested was hung on an insulation component at least 5 m away from other instruments with static electricity in order to avoid interference from other static electricity fields. Before measurement, the researcher washed his or her hands with water to remove static electricity from the hands. The probe was gradually moved closer to the measurement position on the mask until the two laser dots from the electrostatic field meter coincided. The value of the instrument readings was recorded.

2.4. Waterproof test

Waterproof testing of the masks was performed by a Buchner funnel procedure. To summarize, the mask was placed at the