Effect of Sanitizing Treatments on Respirator Filtration Performance

Subjects: Public, Environmental & Occupational Health | Materials Science, Characterization & Testing | Instruments & Instrumentation
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Disposable respirator masks with an accepted performance rating are seriously compromised from an exposure to saturated alcoholic vapours, can tolerate a one-off spray treatment with an alcoholic solution and retain their attested protection under the influence of alcoholic vapours from the use of hand sanitizer or spray sanitizer.

Keywords: respirator masks ; COVID-19 ; sanitizing treatments

1. Introduction

The most common sanitizing treatments include alcoholic gel sanitizer for hand care and the spraying of alcoholic solutions onto table surfaces, door handles, keyboards, etc. to suppress the spread of viral loads via fomites, particularly where low ambient temperatures significantly slow the natural decay of coronaviruses [1][2]. Common products have a minimum of 60% alcohol content following recommendations by the Centre for Disease Control CDC [3] or even higher according to the World Health Organization WHO [4].

Another important tool in combatting the spread of disease is the use of face masks [5][6][7][8]. The COVID-19 pandemic has led, predictably, to significant face mask supply shortages due to high demand world-wide. Finding replacements for face mask materials is important and particularly difficult because common alternatives do not provide the necessary high-level protection and acceptable breathability at the same time [9].

Another way to overcome supply shortages, which is often practiced in areas of significant disease outbreaks, is the reuse of disposable face mask after subjecting them to specialized treatments that, in essence, maintain the performance of the PPE [10][11][12][13] while deactivating the virus captured on the masks [14].

Filter media that are either pleated or contain high levels of electrostatic charge achieve high protection levels from particles of all sizes. The reason for this is that at least one of these enhancement techniques is required to achieve an acceptable level of filtration performance under the typical constraints for face masks of size, weight and flow resistance. Disposable respirators, for instance, all work with electrostatic attraction to capture particles in a size range of approximately 0.05–2 µm, as shown in the example of **Figure 1**, which relates the particle concentration outside of the mask to the concentration that is breathed in (according to the definition of ‘protection factor’). These are the type of particles that are most difficult to capture because the normally predominant processes, which are based on fluid dynamics, are ineffective in this size range [15][16][17] (brown curve in **Figure 1**). It is the electrostatic field contained in these filter materials that captures aerosol particles almost exclusively in this sub-micrometre size range, rather than the physically visible filter material that acts as a screen. This is relevant because the actual size of coronaviruses is in the sub-micrometre size range, and simple activities such as breathing and talking alone already bear the potential to generate sub-micrometre aerosols from viral loads [18].

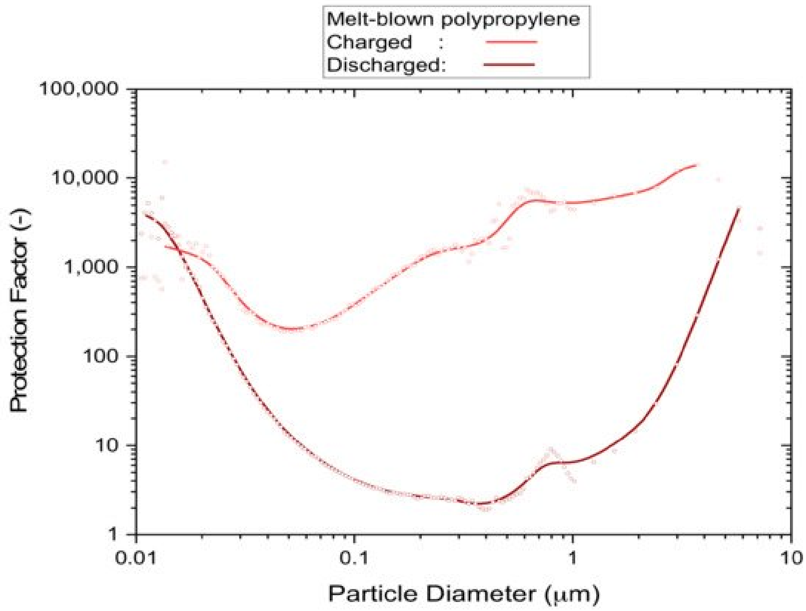
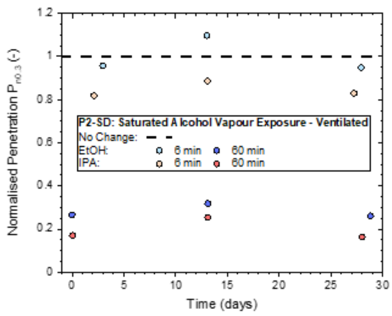


Figure 1. An example of the particle size dependence of the protection factor of uncharged and electrostatically charged filter media.

It is also known that saturated alcohol vapours can significantly erode the electrostatic charge that is contained in filter media for the capture of sub-micrometre particles [11][12]. For instance, the use of electrostatically enhanced filter media is actively discouraged for use in air-conditioning systems by international standards such as the ‘high-efficiency particulate air’ (HEPA) filter standard ISO 29463 [19]. Air-conditioning standards generally recommend removing electrostatic charge from filter panels and products by exposing them for up to 24 hours to saturated isopropanol vapours [20] or via immersion in isopropanol (IPA) before measurement [21]. This approach is adopted because uncharged air-conditioning media are resistant to chemical (and biological [22]) challenges and can achieve the required filtration performance by a technique known as ‘pleating’.

2. Exposure to Saturated Alcohol Vapor

The ‘worst-case’ screening test was designed to measure the loss of filtration performance from a static exposure to an atmosphere saturated with alcoholic vapour, as illustrated by the brown curve (discharged) of the example shown in **Figure 1**. It is a method that is commonly used by air-conditioning filter standards [20] to remove electrostatic charge from filter media prior to the actual performance test. When early test results (not shown) revealed severe deterioration in filtration performance after 24 h of exposure to saturated isopropanol vapour due to the depletion of electrostatic charge, a more detailed investigation at lower exposure times (5, 1 and 0.1 h) was undertaken. Changes in filtration performance are shown in **Figure 2** as 'normalized penetrations' $P_{n0.3}$, where a value of one indicates that the mask experienced no deterioration and a value of zero indicates that the mask has completely lost its capacity to protect from aerosols.



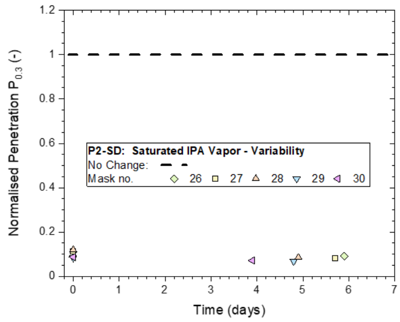


Figure 2. Normalized penetration $P_{n0.3}$ from filtration screening tests of a P2-rated mask (P2-SD: Shanghai Da Sheng) after exposure to saturated IPA vapor (**top**) for 2 or 4 h; (**bottom**) variability between 5 masks after exposure for 5 h. The exposure was followed by 30 min of ventilation in a fume hood and filtration performance was measured immediately after treatment and after storage in plastic bags for up to 6 days.

The filtration performance difference between exposed masks and unused masks is quite large and shows the detrimental effect of saturated alcohol fumes on disposable respirator masks. Since saturated alcohol vapours deplete electrostatic charge, these results also illustrate the important role that electrostatic enhancement plays in relation to melt-blown polypropylene filter media.

3. Exposure to Vapours from Hand Sanitization or Cleaning of Exposed Surfaces

Hand sanitizer dispensing stations are currently used in many places, ranging across shopping centres, restaurants, medical practices, aged care homes, hospitals and more. The common hygiene practice of spraying alcoholic solutions on table surfaces, door handles and controls of appliances is used to remove potential bacterial and viral fomites to curb the spread of infections.

No significant deterioration in filtration performance from non-destructive 'whole-mask screening' testing was detected, even for the highest treatment level that involved 4 h of continuous exposure, as shown by the normalized penetrations $P_{n0.3}$ of **Figure 3** from mask samples exposed to IPA vapours from table cleaning (spray sanitization).

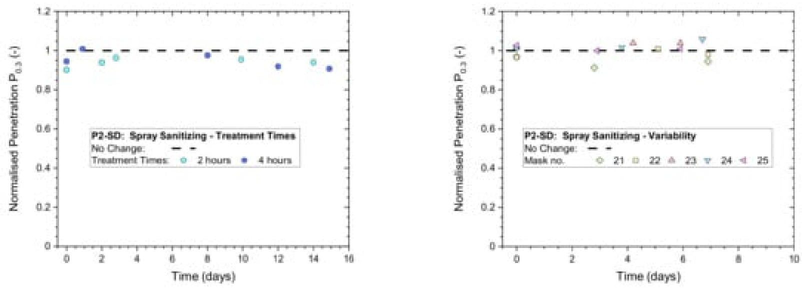


Figure 3. Normalized penetration $P_{n0.3}$ from whole-mask screening testing of a P2-rated mask (Shanghai Da Sheng) exposed to continuous spray sanitizing actions (**left**) for 2 or 4 h; (**right**) variability between 5 masks from the same batch and box exposed to 4 h of continuous spray sanitizing actions.

4. Exposure to Mask Sanitization

The 'mask sanitization' scenario was motivated by reports of disposable masks being reused after spraying the outer surface with an alcoholic solution to kill any germs accumulated during use or to make them more agreeable to wearing by spraying with perfume. Experiments devised to address these scenarios involved spraying a table cleaning solution with 70% IPA content directly onto the masks (three atomizer trigger actions from three different directions) and ventilating the masks for 1 h for drying.

The effect on filtration performance was assessed by 'whole-mask screening' tests, with two tests conducted before mask sanitization exposure, one test immediately after exposure and a follow-up test after two weeks. Normalized penetrations $P_{n0.3}$ from these tests are shown in **Figure 4**.

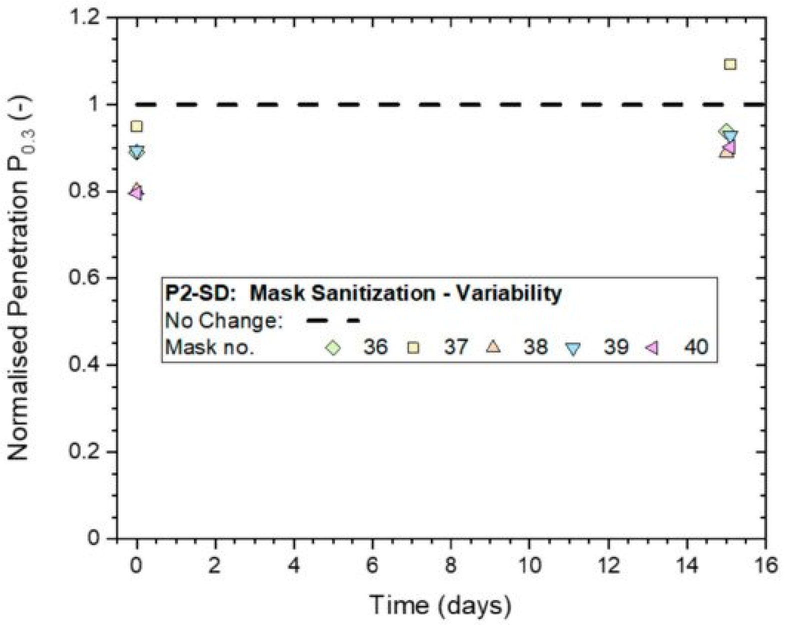


Figure 4. Variation in the Normalized penetration $P_{n0.3}$ from whole-mask screening tests between five masks (P2-SD: Shanghai Da Sheng) after exposure to mask sanitization application of 70% IPA solution and subsequent storage in plastic bags for up to two weeks.

Results support the conclusion that the filtration performance of some masks, at least, may have deteriorated as a result of the mask sanitization treatment.

5. Conclusions

The effects of alcoholic vapours (ethanol and isopropanol) released during use of hand sanitizers or alcoholic sprays on the protective properties of common disposable respirator masks has been investigated.

The most severe challenge involved exposing the masks to saturated alcoholic vapours, similar to the conditioning methods [33] typically used for the certification of air-conditioning products. Results revealed a large deterioration in particulate protection for exposures of 60 min or longer, with the deterioration easing to insignificant as the exposure period was reduced to 6 min.

The other three challenge types were designed to represent more real-world exposure scenarios, which people might experience when wearing respirator masks indoors in hospitals, office spaces, shopping centres and the like. The chosen experimental settings included 'worst-case' scenarios based on an 'experience' level that may be encountered during attempts to mitigate exposure to the SARS-CoV-2 virus:

1. The use of gel hand sanitizer, as commonly provided in many places by automatic or manual dispenser units, to maintain good personal hygiene;
2. The spraying of 70% isopropanol solution on table surfaces for general hygiene purposes and for the removal of fomites;
3. Sanitizing respirators by spraying small amounts of 70% isopropanol solution directly onto the face of the mask.

Results from heavy exposures showed respirator masks retained excellent protection performance in all three of these scenarios, while caution must be exercised with multiple applications of mask sanitization (scenario 3) as this may deteriorate mask performance and the reuse of disposable masks is not recommended by manufacturers.

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