Washing Of Protective Masks For Reuse

Observing the effects of laundering FFP2 and FFP3 facial masks with Nikwax products to extend their service life.

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Aim

To investigate the design and construction of FFP2 and FFP3 facial masks, and determine whether it is possible to prepare and enhance the masks for re-use by washing them with Nikwax products.

Material and Products Used for Testing

- Deltaplus FFP2 and FFP3 facial masks
- Nikwax Cleaning Product A
- Nikwax Product B
- Hoover WDXOA4106HC/5-80 Washer-Dryer (20°C Wool and Delicates Cycle, 400RPM spin).
- 40°C Drying Cabinet

Method

Assessment of construction

Initially masks were assessed for their construction, and method of function. This was done through disassembly of the masks, to understand the functioning layers (ply), and how air was inducted and exhausted from the mask.

Benchmarking and measurement

The individual layers (ply) of the mask were assessed for water repellency and absorbency. Layers were then taken, and air permeability was measured across the ply to identify the layers responsible for filtration, and to benchmark the airflow permitted through the material. Samples of the identified filtration material were also assessed under the microscope for size.

Wash Durability

Initially, masks were washed once in Nikwax Cleaning Product A and Nikwax Product B. Due to the poor results with Product B discussed later, further work was only carried out with Nikwax Cleaning Product A.

The masks were laundered five times in Cleaning Product A. This was chosen as it has a very high soap content, and some zirconium acetate content, both of which are known to destroy coronavirus particles (virions). After each wash cycle, masks were visually subjectively assessed for physical changes against an unwashed control, and for water repellency.

After all five washes, the masks were disassembled, constituent layers were tested for air permeability, and the filtration material was examined under the microscope.

Sterilisation

Due to the degradation of filter material at high temperatures observed during the course of the experiment, it became clear that temperature sterilisation of masks would not be possible.

Chemical sterilisation is another potential solution for removing micro-biological contamination that may not be removed by soap alone. To this end a proprietary 2-part Chlorine Dioxide solution was trialled. The citric acid component was added to the washing machine along with a Deltaplus FFP3 mask, and then when the main wash cycle began the second sachet of sodium chlorite was added via the detergent draw. The cycle was allowed to finish, and then another cycle was run with Cleaning Product A.

Results

Fig 1. - Smoke being exhausted from an FFP2 mask to examine airflow.

Observe leakage around the nose, and significant spread from the valve.

Fig. 2 - The three ply of an FFP2 mask.

Top of image is the inner layer, then the middle filtration layer, followed by the outer. All ply (layers) appear to be polypropylene, with the filtration material an electro-spun nanofiber of polypropylene. FFP3 masks have a very similar structure, except the filtration layer is significantly thicker.

Table 1 – Water repellency data for masks, before and after washing

Key: Y = Hydrophobic (water-repellent), N = Hydrophilic (no water repellency) Filter = Middle layer.

Mask type	Before washing (control)	One wash cycle in Cleaning Product A
Deltaplus FFP3 (UK-sourced)	Inner: N Filter: Y Outer: Y	Inner: N Filter: Y Outer: Y
Deltaplus FFP2 (UK-sourced)	Inner: N Filter: Y Outer: Y	Inner: N Filter: Y Outer: Y
FFP2 (China-sourced)	Outer: Y Filter: Y Inner 1: Y Inner 2: Y	N/A (not tested)

Table 2 – Air permeability of untreated FFP2 mask, showing air permeability of different layers.

Deltaplus FFP2 Mask layer	Air permeability, CFM/F^2			Average
Inner	262.5	262.5	262.5	262.5
Filter	15.5	15.5	15.5	15.5
Outer	Infinite	Infinite	Infinite	Infinite

Table 3 – Air permeability of FFP3 mask when washed once in Cleaning Product A, Product B and a control.

Deltaplus FFP3 Mask	Air permeability, CFM/F^2			Average
Control	12.5	13.8	13.5	13.3
Cleaning Product A	13.0	13.5	13.5	13.3
Product B	18.5	13.5	16.3	16.1
Pre-treated 'rinse' in Chlorine Dioxide then Cleaning Product A	13.25	14.5	13.5	13.75

Table 4 – Observations after washing FFP3 Mask once

Deltaplus FFP3 Mask	Observations
Cleaning Product A	No noticeable difference in terms of structure. Mask remained rigid, and seal appeared intact.
Product B	Mask appeared softened, and 'puffy'. Build-up of product on nose-piece seal.

Fig. 3 – Microscope images of standard fibre, FFP2 and FFP3 filter material

Comparing standard 1.1 decitex microfibre polyester (left) to FFP3 (middle), and FFP2 filter material. Based on pixel count, the filter material is 10 – 12x finer than that standard fibre (280-360 pix, vs 28-38 pix).

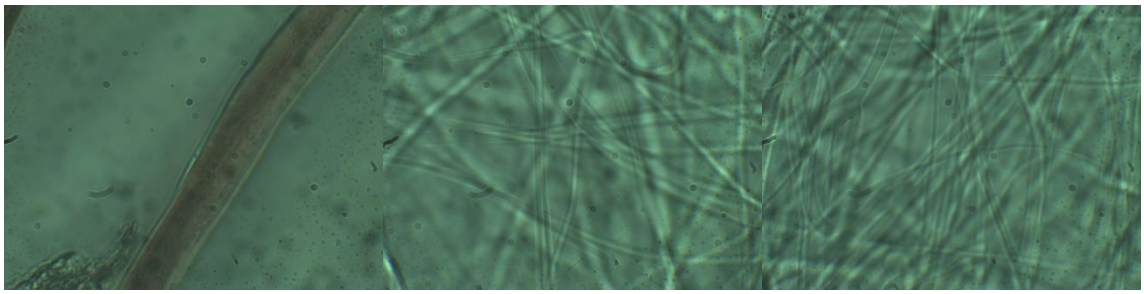


Fig.4 – Microscope images of FFP3 filter material washed once in Cleaning Product A, and Product B.

Cleaning Product A on the left, and Product B on the right. No visible changes after one wash.

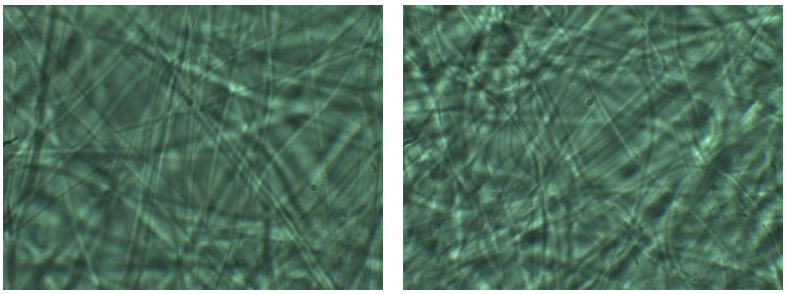


Table 5 – Observations and water repellency of FFP3 mask after 5x Cleaning Product A cycles

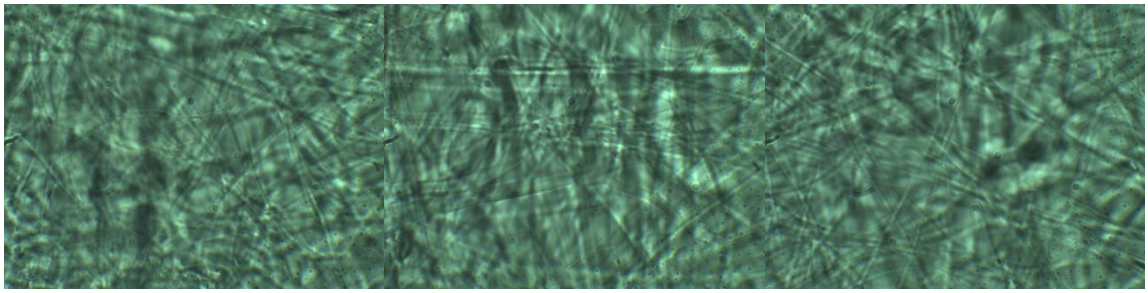
Deltaplus FFP3 Mask	Observations
Cleaning Product A x5	Slight reduction in strength of compression. When valve was pushed down, structure was significantly less stiff than unwashed mask. After washing, all mask components had significant levels of DWR, including the previously hydrophilic inner layer.

Table 6 – Air permeability of FFP3 mask after 5x Cleaning Product A cycles

Deltaplus FFP3 Mask	Air permeability, CFM/F^2			Average
Cleaning Product A	13.5	13.5	14.5	13.8

Fig.5 – Microscope images of FFP3 filter material washed five times in Cleaning Product A.

Cleaning Product A washed filter material, in three different areas of the mask. No visible change in fibres.



Discussion and analysis of results

Mask structure and design

The Deltaplus FFP2 and FFP3 masks tested contained valves. While these function to allow air to escape, it is clearly less than ideal, as it allows unfiltered air from the wearer into the atmosphere. These masks are clearly only for personal protection, as can be seen in Fig. 1.

The Deltaplus FFP2 and FFP3 masks were composed of three layers, apparently heat-formed together. The outer layer appeared to be a light polypropylene mesh, with an electro-spun filter material and a thicker heat-formed polypropylene inner to give structure (see Fig. 2). The filter material is the middle layer in the masks. It appeared to be layers of nanofibres, electro-spun together. The fibres were approximately 0.1 decitex, based on the microscopy images (Fig. 3).

Air Permeability and Filtration

A difference was observed in the amount of filtration provided by FFP2 compared to FFP3 masks. FFP3 filters are rated for removing 99% of all particulate matter from the environment, whereas FFP2s are rated at 95% removal.

A 16.9% difference in air permeability between the filters was measurable, with the FFP3 significantly reducing air permeability compared to the FFP2. It is therefore suggested that air permeability can be used to infer the effect of a treatment on the filter's efficacy.

Wash Resistance

Single-Wash Cycles

The masks performed differently, depending on what they were treated with. The FFP3 mask treated with Product B experienced some delamination and mis-shaping. There was also some build-up of product on the face-seal of the mask. Notably, there was an increase in the air permeability of the filter material as well, indicating that the filtration material had been compromised.

The FFP3 mask treated with Cleaning Product A, on the other hand, did not mis-shape, and did not experience delamination. The air permeability of the filter remained unchanged, and therefore the filter efficacy was not reduced.

Temperature had an effect on the delamination of these masks. Cold washes reduced the risk of damage occurring to the mask. A 20°C wool cycle with a low spin speed caused the least mechanical damage to the mask.

Microscopy carried out on both types of mask treatments (Product B and Cleaning Product A) did not reveal any damage to the individual fibres.

Five Washes in Cleaning Product A

As Cleaning Product A did not appear to have impacted the masks' performance after a single cycle, another FFP3 mask was washed 5x in Cleaning Product A, to establish whether repeated re-use would be possible from a mechanical perspective.

Over five washes, there was a slight decrease in the level of observed stiffness of the mask. There was no sign of delamination, and the masks' seals remained intact, and had not stretched. It was observed that there was a significant build-up of water repellency on all components of the mask, including the previously hydrophilic inner section of the mask.

With regard to air permeability, there was a 3.6% increase in the air permeability of the filter. This would suggest a negligible effect on the filtration efficacy of the mask – by contrast, an FFP2 mask demonstrates a 16.9% increase in air permeability, over an FFP3.

Sterilisation

The effect of chemical sterilisation on the mask, using the Chlorine Dioxide solution, was not positive. The air permeability increased a significant amount over one cycle, and the water repellency on all layers of the mask was slightly reduced. The mask also appeared to lose some structural integrity.

Other solutions, such as WHO suggested 1% bleach (4-5% sodium hypochlorite) will be tested by Nikwax to establish whether other disinfectants have a similarly negative impact upon masks.It may not be necessary for masks to be made sterile, as they are not sterile items. Masks are not sterile upon leaving the factory.

Conclusion

From a wash durability and filter maintenance perspective, Nikwax recommends the use of Cleaning Product A in conjunction with cold, short, gentle wash cycles to clean and maintain FFP2 and FFP3 masks.
Washing with Cleaning Product A maintains the efficacy of the filter material, and, with the correct wash cycle, will not have a detrimental effect upon the masks' structural properties.

Face fit testing has been started, to evaluate the effect of Nikwax Cleaning Product A on the structural integrity of FFP3 masks.

Further work is required to demonstrate the potential of Nikwax products to remove or destroy particles of coronavirus, and a suitable surfactant-free disinfectant solution may be required in the interim.