The Role of Cotton in Face Masks

ICAC

EXECUTIVE SUMMARY

The coronavirus disease COVID-19 pandemic warrants community protection through personal protective equipment (PPE) that commonly includes a face mask to prevent spread of infection. By early May 2020, wearing face masks for the general public was made mandatory in at least 75 countries that comprise about 88.0% of the global population.

In developing and least-developed countries, face masks are either in short supply, inaccessible or unaffordable for the poor who constitute the majority. Fabrics made of cotton, polyester and their blends are easily available to prepare home-made non-medical face masks that are also cost-effective, washable and reusable. Amongst the types of fabrics commonly available, cotton cloth appears to have specific filtration advantages over synthetic fabrics such as polyester because of its unique physical and chemical characteristics. The antimicrobial properties of cotton fabrics can be further strengthened with a nanoparticle-coating over the fibre surface.

FACE MASKS MINIMISE THE CONTAGION

Surgical masks and non-medical face masks were found to be effective in preventing transmission of SARS-CoV-2 in aerosols by more than 95%[2]. Wearing of a face mask outdoors in Beijing during 2003 SARS was associated with a 70% risk reduction compared to those not wearing a face mask[3]. Personal protective equipment (PPE) such as face masks could play a key role in minimising the contagion[4-5].

RATIONALE FOR RECOMMENDING COTTON

The main criteria for face masks are filtration efficiency, pathogen obstruction and physical comfort of the mask including breathability. Cotton fabric has been found to be superior to all other fabrics in all these respects. Research papers point out that due to their unique physical, chemical and iso-electric properties, cotton fibres were found to be superior to synthetic fibres such as polyester and nylon in filtration and in being detrimental to viruses[6-9,12-14], pathogenic bacteria[7,15] and fungi[25] as well as in comfort and breathability[9]. Mounting scientific evidence supports the recommendation of cotton being the preferred choice in face masks for protection against a wide range of harmful microbial pathogens including coronaviruses such as SARS-CoV-2. This note provides a mini review of scientific references that drive the recommendation of cotton being best suited in face masks to minimise infection and spread of COVID-19.

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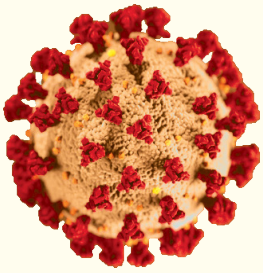


COVID-19 is a respiratory disease caused by a severe acute respiratory syndrome coronavirus named **SARS-CoV-2.** The virus is spread across humans through respiratory aerosol droplets released by infected persons. About half of the infections are believed to be transmitted by asymptomatic individuals[1].

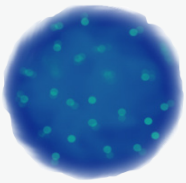
FACE MASKS MANDATORY IN 75+ COUNTRIES

By early May 2020, more than 75 countries comprising about 88% of the global population made it mandatory for the general public to wear face masks and 152 countries have recommended the use of face masks in public places either in some or all of the country, per Wikipedia.

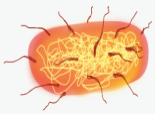
USA AND INDIA HAVE RECOMMENDED DIY COTTON MASKS FOR GENERAL PUBLIC

Because of the acute shortage in the availability of surgical masks, government agencies in India and USA have recommended using fabric of tightly woven cotton fibres, such as quilting fabric, cotton sheets or T-shirt fabric, for preparation of do-it-yourself (DIY) home-made non-medical masks[4,10-11].

THE SCIENCE BEHIND COTTON FACE MASKS

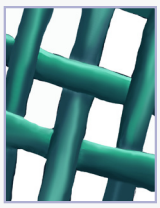


Fungal spore

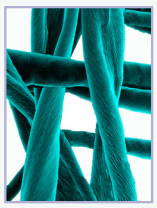


Bacterial cell

Virion



Polyester cloth

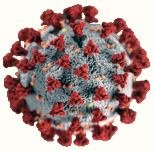


Cotton cloth

- **NANOPARTICLE:** The SARS-CoV-2 virus particle (virion) is a nanoparticle[16] with a diameter of 50 to 200 nanometers (nm).
- **MASKS FILTER >300nm:** By design, face masks effectively filter particles with a diameter of >300 nm.
- **COTTON HAS SPECIAL PROPERTIES:** At similar porosity, cotton can be superior to synthetic fibres such as polyester in filtering virions because of its special properties such as rough fibre surface, hydrophilicity (water absorbing) and higher iso-electric point. Synthetic fibres have a smooth surface.

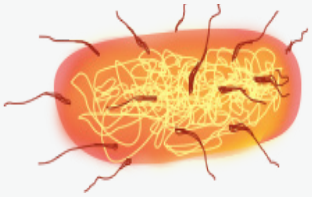
COMBATING VIRUSES

Scientific evidence shows that cotton masks are significantly superior to synthetic material such as polyester in blocking viruses.



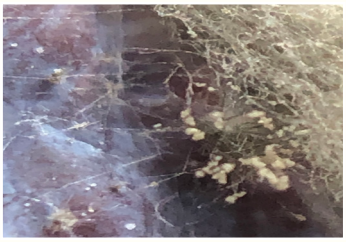
- **FILTRATION:** The median viral loads after coughs without a mask, with a surgical mask, and with a cotton mask were 2.56 log copies/mL, 2.42 log copies/mL, and 1.85 log copies/mL, respectively, thereby indicating that a cotton mask was better than a surgical mask in filtering the SARS-CoV-2 virions[17].
- Of the 15 different types of common fabrics tested for filtering aerosol nanoparticles, cotton cloth masks performed better than silk, chiffon, flannel, various synthetics and their blends[18].
- **VIRAL PERSISTENCE:** SARS-CoV survives longer in an infective form on synthetic-fibre-based disposable gowns than on cotton gowns[14].
- Recovery of human norovirus and feline calicivirus (FCV) was high at 5.59% on polyester but only 0.15% on cotton; murine norovirus (MNV) survival was 14.7% on polyester and 0.85% on cotton[8].
- Vaccinia and polio viruses (non-enveloped) were recovered from wool at up to 20 weeks whereas the viruses persisted for significantly far less time on cotton[13,19]. A combination of higher moisture absorbency and faster drying of cotton as compared to wool may have led to the lower persistence of the viruses on cotton fibres.
- The recovery efficiency (RE) of MS2 virus from polyester was 2.3% to 3.0%, significantly higher than 0.03% to 0.3% with cotton[7].
- **BLOCKING EFFICIENCY:** Of the 8 cloth materials tested, 100% cotton cloth had the highest virus-blocking efficiency compared to cotton blends and 100% ployester[20].
- **BREATHABILITY:** Cotton and cotton blends filtered 50.85% to 72.46% of the virions and 100% cotton T-shirt material was recommended as the most suitable household material for the preparation of non-medical face masks, also because of the ease in breathing compared to all other fabrics[9,21].

COMBATING BACTERIA



Tests conducted with 22 Gram-positive bacteria on five different hospital fabrics showed that 100% cotton was found to be significantly superior to cotton/polyester blends and 100% polyester in preventing the survival and spread of the pathogens[22-24].

COMBATING FUNGI



Five pathogenic fungi survived significantly longer (19.5 days) on 100% polyester, spandex, polyethylene and polyurethane but survived for less than 5 days on 100% cotton, cotton terry and blends[25].

WHY COTTON IS BETTER THAN SYNTHETICS

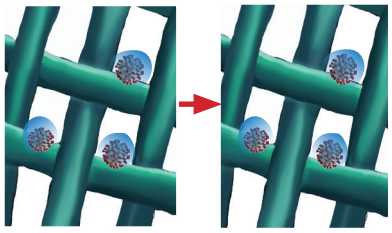
ABSORB, DEHYDRATE AND DEACTIVATE

The special properties of cotton cause a stronger attachment of virions to its fibres[26] followed by deactivation due to dehydration[6-8].

HYDROPHILICITY

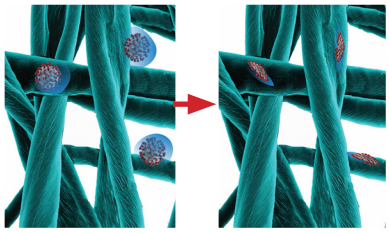
Cotton hydrophilicity is detrimental to virions. Cotton fibres are highly hydrophilic, which means higher water-absorbing capacity, whereas synthetic fibres like polyester are hydrophobic, so they repel water[27-28]. One gram of cotton fibre can hold 23.5g to 28.1g of water[29]. While non-enveloped viruses are less vulnerable to absorbent substrates, SARS-CoV-2 is an enveloped virus that needs moisture protection for it to be infective. Rapid absorption of water from the virus droplets of enveloped virions by cotton fibres hastens evaporation of the residual medium, removes moisture protection and renders virions vulnerable to dryness and desiccation. This contrasts with hydrophobic fibres of polyester in which water absorption is negligible and the virion remains intact due to longer moisture protection cover to the virus, which results in longer survival and continued infectivity. Therefore, the survival of pathogens and virions is higher on synthetic fibres compared to cotton[8] and as a result, a cotton-based face mask will outperform masks made out of synthetic fibres like polyester, particularly in the case of enveloped viruses like SARS-CoV-2.

POLYESTER FABRIC



Schematic diagram to show how virion-aerosol droplets remain on the hydrophobic fibres and survive.

COTTON FABRIC



Schematic diagram to show how virion-aerosol droplets are absorbed and the virions desiccate and dry.

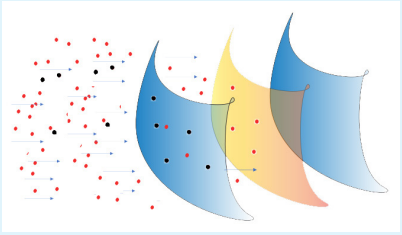
ROUGH SURFACE AND ADHESION HYSTERESIS

With a size ranging from 50 to 200 nanometer (nm), SARS-CoV-2 virions could behave like typical nano-particles which often exhibit Brownian motion[30]. Compared to the smooth texture of synthetic fibres, cotton fibres have a rough surface with numerous nano-sized pores[31] that may serve as anchors for adsorption and adherence of nano-sized virions. The adherence of virions on cotton fibres may be further intensified by the impact of a phenomenon called adhesion hysteresis, which is defined as the difference between the energy needed to separate two surfaces and that which originally brought them together. These properties may contribute to the superior performance of cotton in filtering out virions relative to synthetic fibres.

ISO-ELECTRIC POINT

Cotton fibre has a higher iso-electric point (IEP) of 3.0 compared to that of polyester (2.3) and glass (2.1)[27,32], because of which viruses with an IEP of 4.9 to 6.0 have a lower survival and lower recovery efficiency on cotton compared to polyester and glass[6,8,33].

SMART COTTON MASK



A three-layered cotton mask sandwiched with-nano-impregnated cloth may offer excellent protection.

ANTI-MICROBIAL SMART COTTON FABRIC

Cotton fibres are amenable for coating with nano-particles that make them anti-microbial. Cotton cloth has been coated with nano-metals such as nano-silver, nano-zinc, nano-copper, etc., resulting in smart fabric with antimicrobial properties.

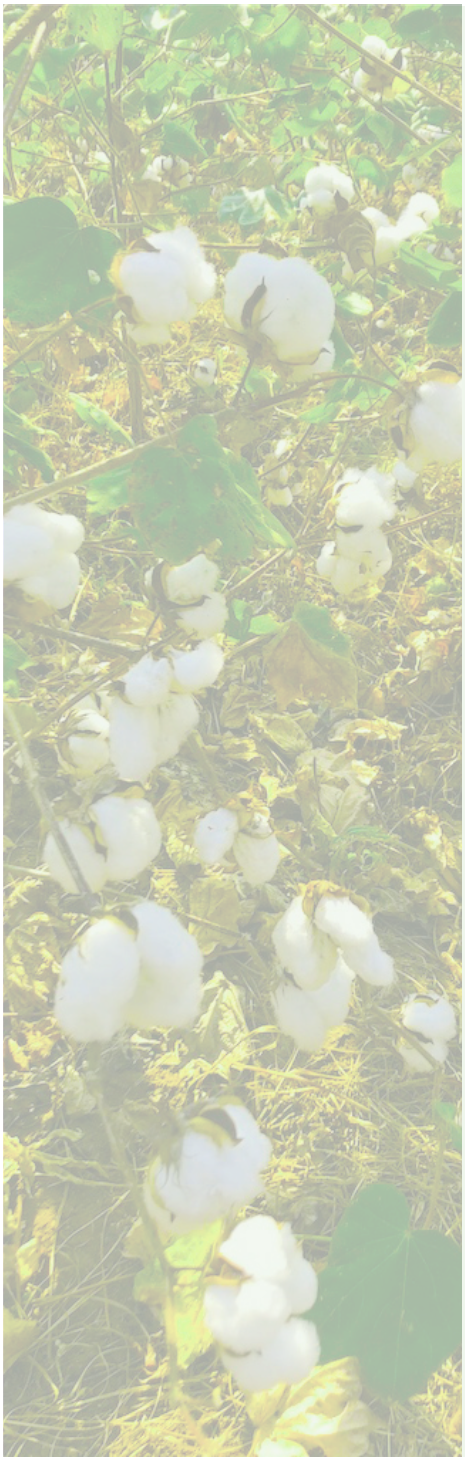
Nano-copper-coated cotton fibres showed broad-spectrum antimicrobial effect[34-36] including anti-influenza biocidal activity with clear breathability and no depletion in the antimicrobial activity after being washed[37-38].

Interestingly, highly cleaned and sterile unbleached cotton was found to have constituents that are beneficial to the hemostatic and inflammatory stages of wound healing. These properties were further strengthened by impregnation of nanometals[39-40].

BIODEGRADABLE

Being of natural origin, cotton fibres are biodegradable and can be the fibre of choice, especially for disposable items that can be safely discarded without causing environmental hazards.

Layout, design, illustrations and images:
Keshav Kranthi, ICAC
Coronavirus: Stock image modified.



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May 2020

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Citation: Keshav Kranthi, Joy Das, Rakesh Kumar, Mike McCue, Renuka Dhandapani, Kater Hake, Sandhya Kranthi, D. Blaise and Kai Hughes. 2020. The role of cotton in face masks. Brochure. ICAC, Washington, DC. May 2020.