Nature driven designs for the new generation of self-cleaning face masks

Abstract

Since the dawn of humanity, health has been considered on top of priorities in human life. However, pathogens are found to constitute a severe threat to human health. Although significant advancements have been made in the medical system, the best method for maintaining health is still preventing the infections. While it looks good on paper, this approach is very demanding, especially with airborne microbes. Although face masks are deemed an effective method for preventing these pathogens from spreading in society, they suffer from certain deficiencies. For example, if not appropriately worn or have damaged fabric, face masks lose their usefulness. Besides, the conventional masks hold the pathogens on their fabric; they get damped quickly and need to be changed regularly.

In this research, we aim to employ wettability-altering nanoparticles based on a nature-driven design to create self-cleaning face masks. The nanoparticles will attract the aerosols, nuclei, dust, ETC that carry pathogens. Furthermore, they absorb water droplets and direct the microbes with water to the straps. Then a combination of moisture absorbers and disinfectants tend to damage the pathogens' structures and destroy them. In conclusion, the new masks are designed to be much more efficient and sustainable than traditional face masks.

problem description

As far as history goes, health maintenance by improving the medical system and curing ill people has been one of the most critical issues. However, it was since the 19 century that the semi-modern concept of epidemiology and prevention of infection was introduced [1,2]. Unfortunately, this process is rather challenging when it comes to airborne microbes since they can travel very long distances swiftly. One of the best methods for personal protection against these pathogens is wearing face masks [3,4]. However, the inherent problems of these masks can render them underwhelming. These problems are as follows:

1- The masks tend to absorb the water droplets form air and the respiratory system while breathing; thus, they get damp, malodorous, and needing regular change [2,5].

2- They are designed to physically filter the pathogens using small mesh sizes. In other words, they are intended to trap the organisms on the cloth, making the surface of the masks highly contaminated. Not to mention that changing the face mask without proper protocols can potentially lead the infections to spread to hands [2,3].

3- The masks do not usually fit the face well enough to prevent leakage, and as a result, the microbes can effortlessly get into the respiratory system [2,4].

The mentioned deficiencies of conventional face mask result in poor performance of them in many cases. This research aims to solve these issues and improve the general performance of the masks.

proposed solution

Intellectual novelty

The standard masks in the market are usually designed to trap the microbes inside their fabric as the air moves through them. However, this proposal is aiming at designing masks that not only attract the microbes from the breathing air but also remove it from the surface of the mask, making the mask's surface microbe-free. Furthermore, unlike the typical masks that get damp and smelly in a very short time, the proposed design will not absorb the water to its fabric, which will prevent the mentioned issues.

The new designs for the face masks are inspired by the Namib Desert beetle and the grand canyons. To explain more, the Namib Desert beetle harvests water from thin air by letting droplets of fog accumulate and drip down its wing case into its mouth. This method is the core idea behind the functionality of the new face masks. The new masks are aiming at attracting and removing the particles that tend to carry airborne pathogens [5,6], and it will comprise three parts: a water collector, a dust collector, and dehumidifying/ antibacterial/antiviral straps.

Functionality

The most outer surfaces of the mask will have patterns of hydrophilic nanoparticles (silica[7]) and hydrophobic nanoparticles (Pyrophyllite[8]). These patterns will attract water droplets and aerosols from the breathing air near the surface of the mask from both sides. As water droplets and microbes accumulate and get significant on the mask; the impact of gravity will induce them to move downward. As a result, the combination of nanoparticle patterns (inspired by the grand canyon) will lead the water droplets to the mask's outer boundaries (replaceable straps). Consequently, the bacterias and the viruses will also move with these small droplets, creating a microbe-free surface for the mask. The next step is to deal with the highly dangerous water droplets at the replaceable straps.

The replaceable straps, especially the lower strap, is saturated with dehumidifying crystals (potassium polyacrylate powder) combined with water-wet and oil-wet nanoparticles and other disinfectants. The crystals will absorb the water, and at the same time, since these droplets are full of bacterias and viruses, their contact with extreme oil-wet and extreme water-wet nanoparticles combined with disinfectant material will damage the cell membrane in bacteria and the envelope and capsid in viruses. As a result, not only the straps will kill the microbes, but also they will not get damp in the process.

The next challenge is to remove the dust from the breathing air. Although some dust particles will be removed through the outer layer, the middle layer is designed to maximize this process's efficiency. This layer is composed of air-wet nanoparticles (Pyrophyllite) conducting the air through the fabric. In other words, these nanoparticles will lead the air inside the fabric. As a consequence, the air will take a longer path inside the textile resulting in much efficient performance. To explain more, this process will lower the chance of the particles and the microbes to get to the respiratory system.

To summarize, the mask will not only tend to attract and direct the pathogens but also will destroy them, resulting in a self-cleaning mask. Furthermore, considering different situations, various disinfectants and water absorbers can also be employed instead of the mentioned materials for the annihilation of the infectious microbes and absorbing the water. As a result, these replaceable straps are customizable based on the circumstances. Consequently, instead of changing the entire masks in different countries and circumstances, only the replaceable straps need to be changed.

Practicality

Different industries have used various nanoparticles for enhancement of their standards; to elaborate more, for many years, nanoparticles have been used to develop desired textile characteristics, especially in the healthcare industry. Affaf Khamis Aloufy and Magdi Abdel-Moneim[9] investigated Nano-silver embedded face masks for infection control. They concluded that Ag nanoparticles have great antibacterial responses that make them a distinguished candidate for face mask application. Furthermore, Hiragond et al.[10] used colloidal silver nanoparticles for enhancement of face mask's Performace against Staphylococcus aureus and Escherichia coli bacteria. As a result, while the proposed face mask in this proposal is novel (in terms of the way it employs nanoparticles in a face mask), it is definitely practical. However, different investigations should be conducted for optimizing the performance of its elements.

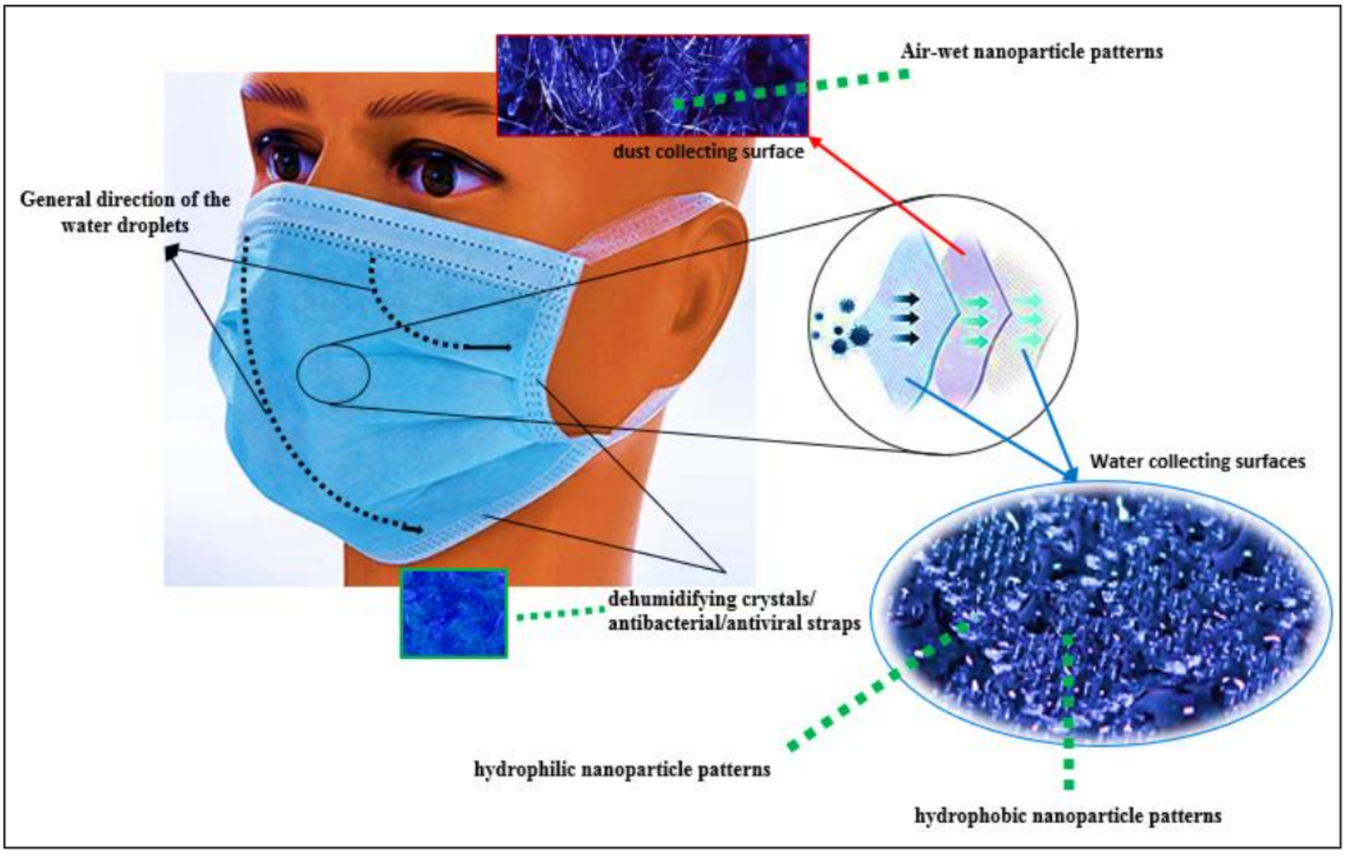

Figure 1 a schematic view of the new face masks

Costs[1]

The usual face mask's price tag in the market varies significantly from 0.17 pounds per mask for simple surgical masks up to 3 pounds per mask for N95 masks. Based on the assessments (Appendix 1), the newly designed self-cleaning mask will cost from 1 to 2.9 pounds per mask. These variations depend on the climate and different customizations (amount of nanoparticles and disinfectants used). It should be mentioned that the new designs will perform better and last longer since they do not absorb water into their fabric and do not get foul-smelling. Moreover, instead of a need to change the entire mask, only the removable straps need to be replaced, which costs about 0.5 pounds per strap. Consequently, the newly designed masks can be used two to four times longer than the typical masks, and as a result, they are far more economical and eco-friendly in comparison to others.

possible defects and alternative plans

When it comes to novel research, though considered unfortunate, no one is immune from failure, and this study is not an exception either. There are some uncertainties in the new face mask's designs, including the most efficient patters for nanoparticles, the number of required layers, and the replaceable straps. As an explanation, although the base patterns for the hydrophilic and hydrophobic nanoparticles are based on the grand canyons, there is a possibility that these patterns do not work efficiently. Consequently, plenty of studies need to be conducted to optimize the face masks' nanoparticle patterns.

Furthermore, the new face masks have at least three layers; however, they might not be enough in some cases. As a result, more studies are needed to discover the most influential parameters on the layers' performance and adjust the number of them.

Moreover, although the idea of having replaceable straps is fascinating, it can be very challenging. Since the mechanism of attaching straps to the masks is somewhat complicated. The initial idea is using double-sided fabric tape for attaching the straps to the mask. However, there is a chance that they fail to perform as planned, which might Result in altogether leaving the idea behind and use fixed straps. While this decision does not impact the mask's performance, it might make the face masks not as long-lasting as initially planned.

Expected results and achievements

The new face mask is specifically designed to solve some of the most common issues among the masks. One of the main issues associated with traditional masks is that in case of leakage, they lose their usefulness entirely. However, the newly designed masks can still clean the breathing air even if it tends to leak from the masks' sides. To elaborate more, the hydrophilic nanoparticles attract the water droplets and nucleus when the air moves near them, as a result even in case of leakage, the nanoparticles located at the inner side of the mask will absorb the nucleus and microbes making the air that gets to the respiratory system clean. In other words, the new masks do not depend on the fact that air should flow through their fabric for traping the pathogens, but they can attract the microbes even if the air flows near the surface.

As mentioned, one of the typical problems with current masks is that they get damp by traping the water droplets off the air into their fabric and as a consequence, they get stinking. However, the newly designed face masks do not absorb water to their fabric but accumulate and lead the water droplets to the straps. These straps solve the second problem associated with the masks. As an explanation, typical face masks tend to collect the microorganisms; thus, they are extremely dangerous and capable of transmitting the microbes when changing them; and unfortunately, the traditional masks need to be changed frequently. However, Since the new masks can remove the water and pathogens from their surface, they do not need to be regularly changed. Besides, since their surface does not gather microbes, touching them is not as dangerous as the typical masks.

Moreover, one of the different aspects of the new designs is that they have replaceable straps. The water droplets and the pathogens are lead to these straps while the surface of the mask is dry and microbe-free. Consequently, instead of changing the entire mask, only the removable straps can be replaced. Furthermore, the replaceable straps are saturated with dehumidifying crystals, antibacterial and antiviral substances, which makes changing them not dangerous since the microbes have been killed. Thus, the new masks are much more safe and sustainable.

Another outstanding aspect of this new face mask is its customizability. In other words, depending on the person who uses masks (i.e., patient, doctor or regular people), the climate that the mask is utilized, and the purpose of the use, the newly designed masks can be customized in order to make them as efficient and cost-benefit as possible. To explain more, since Cough-generated aerosols are one of the primary sources of microbe spreading, the mask used by patients can have several water-absorbing layers on the inner surface while the masks used by doctors can have more water-absorbing layers on the outer surface. Besides, since these masks are specifically designed to attract and conduct the particles that hold microbes, there is no need to make the fabric's mesh size minimal, which makes breathing easier through these masks.

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[1] All the prices mentioned in this section are based on the online wholesale stores.

APENDIX 1[2]

	cost	Aproximate amount used in a mask	Fianl cost
silica (Hydrophilic nanoparticle)	11 pound/kg	Up to 10 grams	0.11 pound/mask
Pyrophyllite (hydrophobic nanoparticle)	150 pound/ton	Up to 20 grams	0.003 pound/mask
disinfectant	75 to 230 pound/kg	Up to 10 grams	0.3 to 2.3 pound/mask
potassium polyacrylate powder (water absorber)	190 pound/ton	Up to 20 grams	0.004 pound/mask
surgical mask	0.5 pound/mask	1	0.5 pound/mask

[2] All the prices mentioned in this section are based on the online wholesale stores.

Refernces

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