Università degli studi di Roma "Foro Italico"

Photocatalytic treatments for Personal Protective Equipment: experimental data and perspectives for the enhancement of antimicrobial activity also in the prevention of COVID-19

Lory Marika Margarucci, Gianluca Gianfranceschi, Federica Valeriani, Vincenzo Romano Spica

Premio 2021

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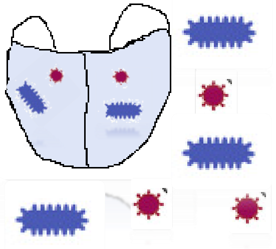
PRESENTATION OF THE ISSUE

The World Health Organization (WHO) recommends the use of **face masks** as part of a comprehensive package of prevention and **control measures** to limit the spread **of SARS-CoV-2**

Mask demand **increased** all over the world. With several **consequences**:

A potential source of **microplastics** for the environment

Produce an increase in non-recyclable waste with a consequent **environmental impact**



Compromises the filtration efficiency and promotes bacterial proliferation, creating **hygiene problems and health risks**.

Source: World Health Organization. (2020). Mask use in the context of COVID-19: interim guidance, 1 December 2020.

A possible strategy to reduce these negative aspects is the development of <u>decontamination methods</u>

Governments, manufacturers, scientists or experts in the field are working towards finding the most effective method for disinfection of personal protective equipment (PPE)


04/11/21, 21:27 COVID-19 Decontamination and Reuse of Filtering Facepiece Respirators | CDC

CDC Centers for Disease Control and Prevention

COVID-19

Implementing Filtering Facepiece Respirator (FFR) Reuse, Including Reuse after Decontamination, When There Are Known Shortages of N95 Respirators

Updated Oct. 19, 2020 Print

Disposable masks: Disinfection and sterilization for reuse, and non-certified manufacturing, in the face of shortages during the COVID-19 pandemic

Juan Carlos Rubio-Romero, María del Carmen Pardo-Ferreira, Juan Antonio Torrecilla-García, Santiago Calero-Castro

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Dry heat and microwave-generated steam protocols for the rapid decontamination of respiratory personal protective equipment in response to COVID-19-related shortages

M.J. Pascoe[a], A. Robertson[a], A. Cray... R. Wesgate[a], S.L. Evans[b], A. Porch[b]

Received: 14 April 2020 | Accepted: 20 April 2020

DOI: 10.1002/jmv.25921

RESEARCH ARTICLE

JOURNAL OF MEDICAL VIROLOGY WILEY

Decontamination of face masks with steam for mask reuse in fighting the pandemic COVID-19: Experimental supports

Qing-Xia Ma | Hu Shan | Chuan-Mei Zhang | Hong-Liang Zhang | Gui-Mei Li | Rui-Mei Yang | Ji-Ming Chen

Evaluation of decontamination methods for commercial and alternative respirator and mask materials – view from filtration aspect

Qisheng Ou[a,1], Chenxing Pei[a,1], Seong Chan Kim[a], Elizabeth Abell[a], David Y. H. Pui[a,b,*]

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CHEMICAL METHODS

hydrogen peroxide

ethylene oxide

alcohol

chlorine

bleach

ozone decontamination

soap solutions

PHYSICAL METHODS

Heat with steam or with dry air

γ irradiation

microwave

UV rays

LIMITS

- Reduction of durability of PPE
- Expensive costs
- May present risks for workers' safety and health
- Reduction in filtration capabilities
- Some treatments could affect the electrostatic properties of the fibers or even deform the mask structure

OUR PROPOSAL RESPONDS TO:

The introduction of environmentally friendly materials within the fibers of the mask could be an alternative to overcome these limits.

The proposed solution confers antimicrobial action at masks and allows them to implement their protective capability, avoiding the addition of disinfectant chemical compounds or the disruption of the fibers of the face mask, and/or their inhalation. Furthermore, the antimicrobial property limits the risk that the same masks used for an extended time become vehicles for different respiratory pathogens, including **SARS-COV-2**.

THE AIM OF OUR PROPOSAL

Evaluate the efficacy of a photocatalytic compound, **Titanium dioxide (TiO_2)** as an exemplificative possible strategy for the decontamination of face masks.

NOTES ON TITANIUM DIOXIDE (TiO_2)

TiO_2 is a white pigment and due to its brightness and very **high refractive index** it is the most used to confer **shining** in different product (Gázquez et al. 2021)

TiO_2 **absorbs UV radiation** effectively, especially when the pigment particles are small. A coating containing TiO_2 in form of small particles is **transparent** because the particles **weakly scattering visible light** (Stengl et al. 2008)

TiO_2 in presence of **specifics wavelengths**, upon excitation with photons presenting energy higher than the band gap energy, promote **redox reactions** (Etacheri et al. 2015)

TiO_2-based photocatalysis is a versatile and effective process that has already proved effective for the disinfection of **air, water, surfaces, fabrics** (Foster et al. 2011)

TiO_2 triggers redox reactions responsible for the **photodecomposition of organic compounds and deactivation of microorganism.** Water and oxygen play an important role in the generation of **Reactive oxygen species** (Bono et al. 2021)

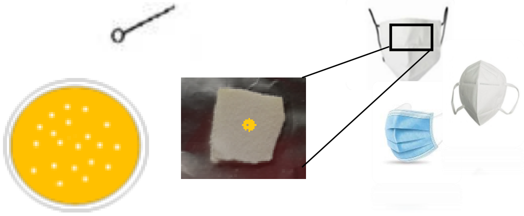
TiO_2 is the most used **semiconductor** for photocatalysis. In nature is present in five different crystalline forms: **rutile, anatase, brookite** (Hu et al. 2020)

METHOD

Three different kinds of masks were selected for this study: a **cloth face mask** (80 % polyamide and 20 % elastane); **surgical masks** (comply with EN 14683); and **FFP2** masks (CE 2233).

TiO_2 (1–4 µm and 1.2 ± 0.1 % w/w of concentration - rutilium) was micronized in distilled water solution

Creation of coating on the face mask (pieces of about 7 × 5 cm) with TiO_2 wetted only one side



The face masks coated have been contaminated with bacteria *E.coli* and *S.aureus*. Simulating external contamination by droplets.

Exposures at different time points (1′, 5′, 15′) were performed using a dedicated LED-based display system encompassing a UV source and light sources also **in the visible spectrum**.

Incubation after the exposition of each sample on agar plates at 37° C for 24 hours. The number of bacterial concentrations were determined counting bacterial colonies present in the agar plates

RESULTS

A reduction of the microbial load (over 90%, $p < 0.01$) was observed using both Gram negative (*E. coli*) and Gram positive (*S. aureus*) bacteria already after 15 minutes of irradiation

International Journal of *Environmental Research and Public Health*

MDPI

Article

Photocatalytic Treatments for Personal Protective Equipment: Experimental Microbiological Investigations and Perspectives for the Enhancement of Antimicrobial Activity by Micrometric TiO_2

Lory Marika Margarucci [1], Gianluca Gianfranceschi [1], Vincenzo Romano Spica [1,*], Giuseppe D'Ermo [2], Cristiano Refi [3], Maurizio Podico [4], Matteo Vitali [5], Ferdinando Romano [5] and Federica Valeriani [1]

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Citation: Margarucci, L.M.; Gianfranceschi, G.; Romano Spica, V.; D'Ermo, G.; Refi, C.; Podico, M.; Vitali, M.; Romano, F.; Valeriani, F. Photocatalytic Treatments for Personal Protective Equipment: Experimental Microbiological Investigations and Perspectives for the Enhancement of Antimicrobial Activity by Micrometric TiO_2. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8662. https://doi.org/10.3390/ijerph18168662

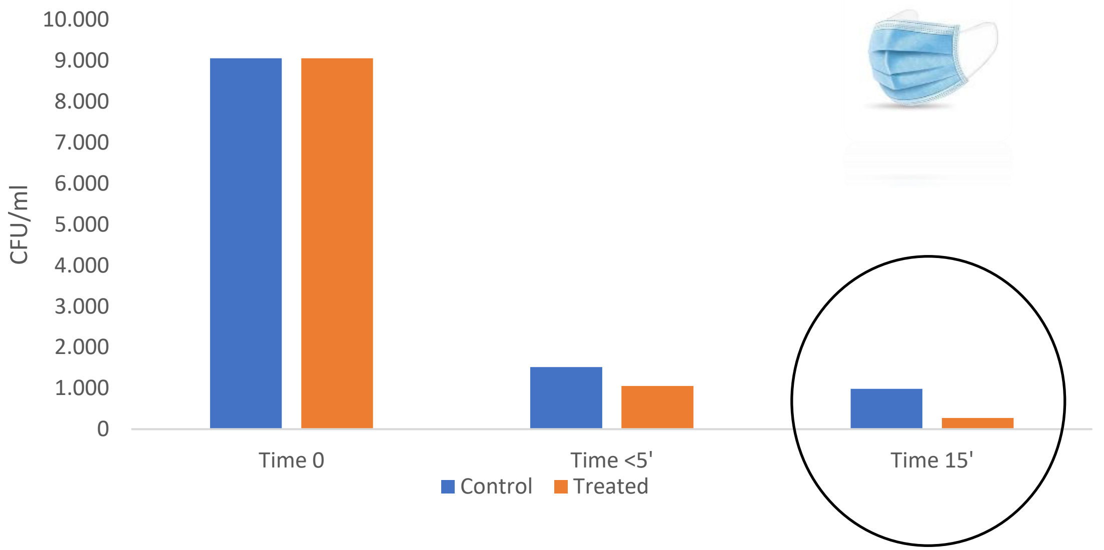
Academic Editor: Florence Carrouel

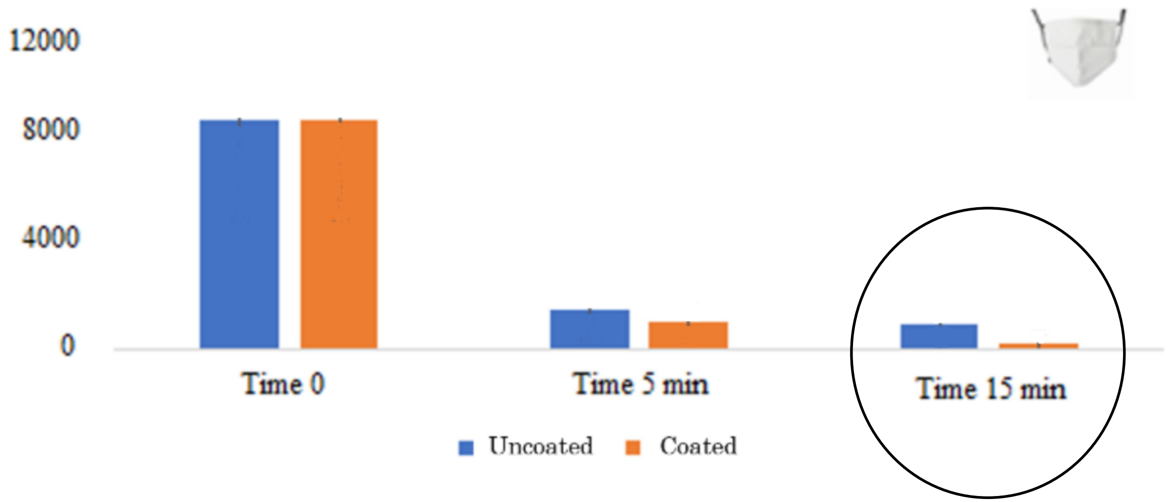
Received: 19 July 2021
Accepted: 13 August 2021
Published:

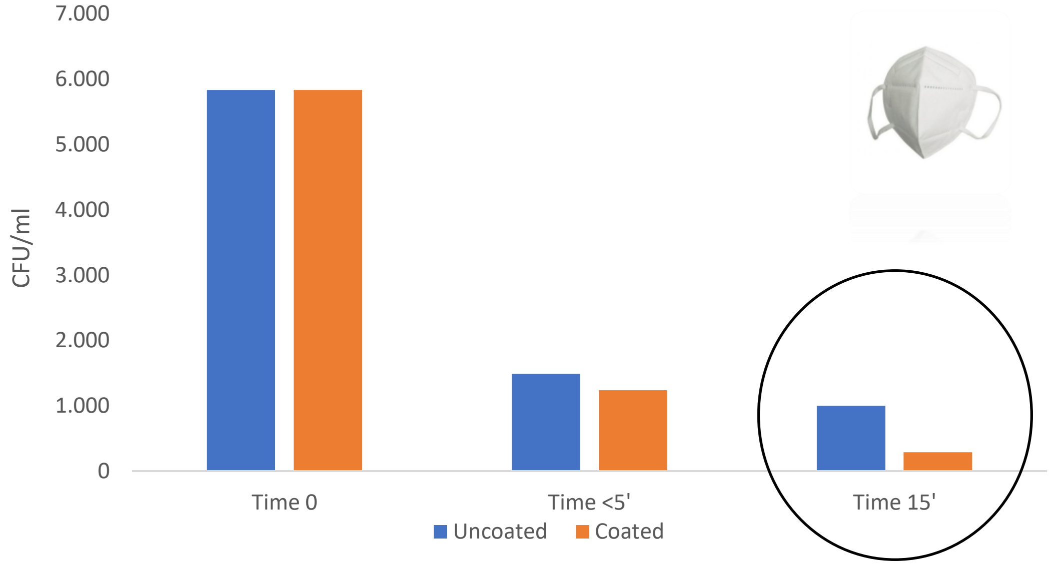
Abstract: The COVID-19 pandemic has led to countries enforcing the use of facial masks to prevent contagion. However, acquisition, reuse, and disposal of personal protective equipment (PPE) has generated problems, in regard to the safety of individuals and environmental sustainability. Effective strategies to reprocess and disinfect PPE are needed to improve the efficacy and durability of this equipment and to reduce waste load. Thus, the addition of photocatalytic materials to these materials, combined with light exposure at specific wavelengths, may represent promising solutions. To this aim, we prepared a series of masks by depositing micrometer-sized TiO_2 on the external surfaces; the masks were then contaminated with droplets of bacteria suspensions and the coatings were activated by light radiation at different wavelengths. A significant reduction in the microbial load (over 90%, $p < 0.01$) was observed using both Gram negative (*E. coli*) and Gram positive (*S. aureus*) bacteria within 15 min of irradiation, with UV or visible light, including sunlight or artificial sources. Our results support the need for further investigations on self-disinfecting masks and other disposable PPE, which could positively impact (i) the safety of operators/workers, and (ii) environmental sustainability in different occupational or recreational settings.

Result with a combination of LED with wavelength emissions in the **blue light** (435-500 nm), encompassing the Soret band.

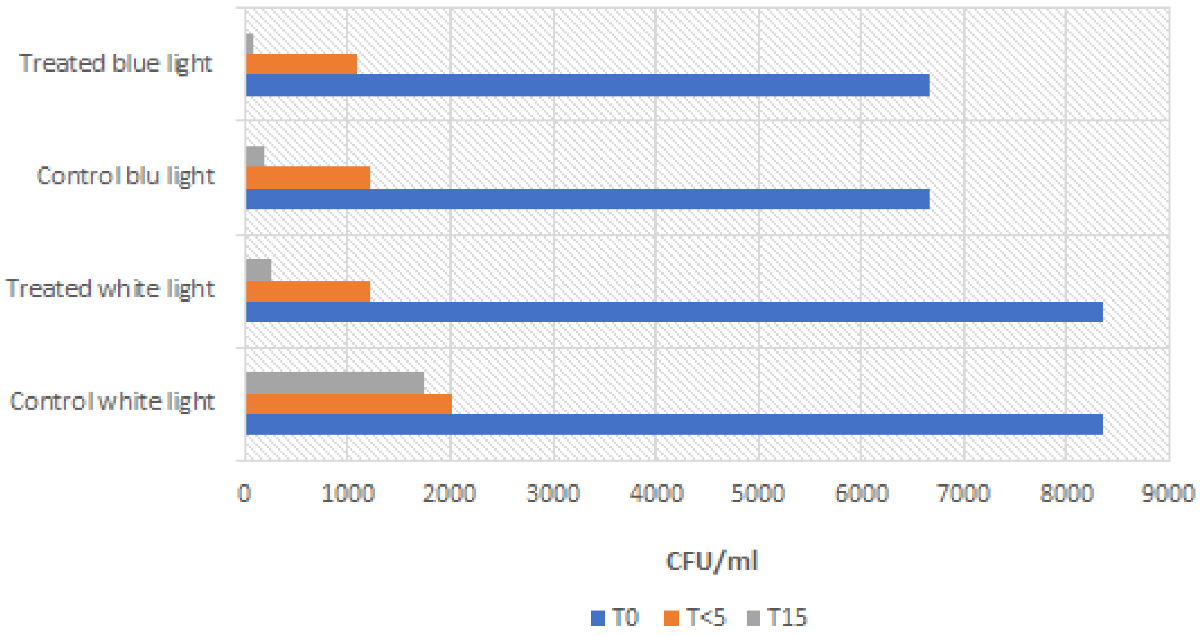
In all TiO_2 coated masks, the percentage of CFU/mL reduction observed achieve values higher **90%**







RESULTS: ACTION OF MICROMETRIC LEVEL,TOO
(AVOIDING NANOMETRIC CORPUSCOLATE RISKS)



- The exposure with blue light (nm = 450–455) showed a reduction of 98% of CFU/mL ($p < 0.01$) over 15 minutes
- The antibacterial effect was observed using white light exposure.

Titanium dioxide have an antibacterial effect that can be increased in combination with specific wavelengths of visible spectrum

This approach shows a double benefit: avoiding nanoparticles and UVC cancerogenic risks

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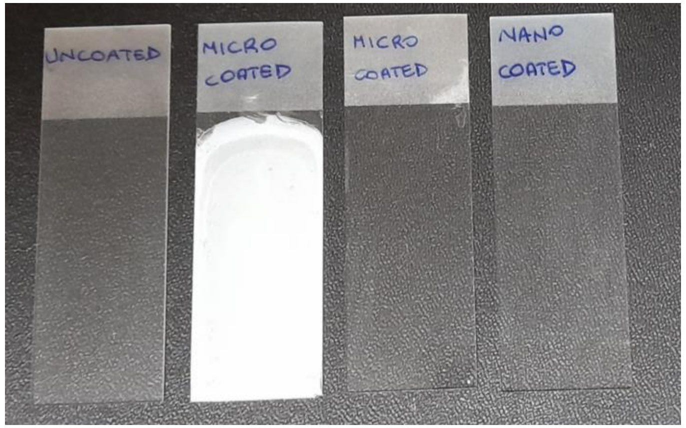
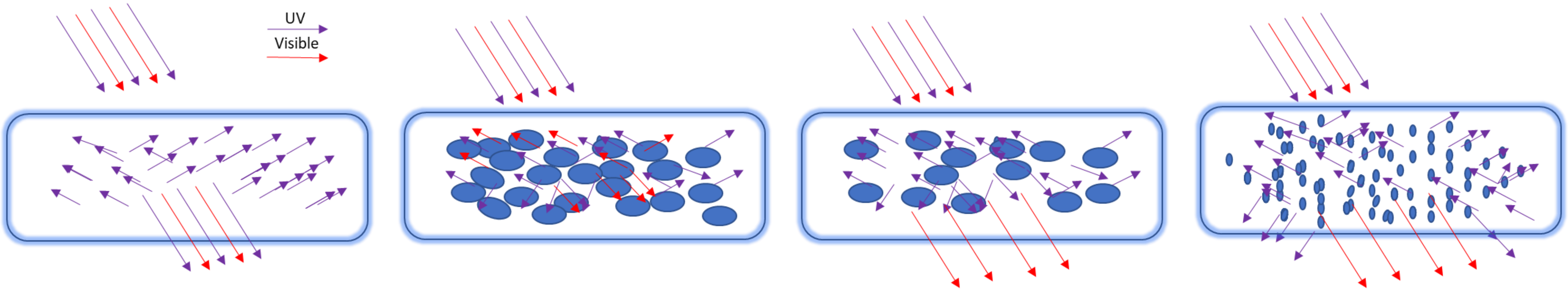
RESULTS : ASSURE TRANSPARENCY

A coating containing **TiO_2 overloaded dense microparticles** can appear **white** because scatter visible light, but when reducing density it can acquire transparency.
A coating containing **TiO_2 nanoparticles** is **transparent** because the particles **hardly scatter visible** light. It **attenuates UV light** by absorption and scattering.





Uncoated glass **Transparent**	Coated glass saturated with dense microparticles **Whitening**	Coated glass with not overloaded microparticles **Transparent**	Coated glass with Nanoparticles **Transparent**

CONCLUSIONS

- **Key point:** photocatalytic approach is promising and feasible. It could be applied to different matrices, including those used for PPE and other kinds of masks used as protection from infectious agents, allowing safer **reuse**, **reduction in waste** with a positive impact both for the users and the environments.

Perspectives

- The energy of activation of TiO_2 is in the UV light wavelengths and within visible spectrum with an optimum in **blue light** (450-455 nm).

- Although the bulk of photocatalytic disinfection concerns TiO_2 as the photocatalyst, other photocatalytic materials, *e.g.* **Zinc oxide, Graphene oxide, cupric oxide, magnetite, tungsten oxide,** are emerging, and could be used as photocatalytic antimicrobial agents for face masks and general fibers of fabrics for different materials and textiles.

- **Selection of suitable co-catalysts** to improve the covalent bond of photocatalytic materials on the fibers of PPE or fabrics, could ensure their stability and could reduce the risks linked at dispersion of these compounds in the environment. Several technical procedures are available to address this issue in the field of textiles.

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Academic Editor: Florence Carrouel

Received: 19 July 2021
Accepted: 13 August 2021
Published: 16 August 2021

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Keywords: titanium dioxide; photocatalysis; disinfection; mask; nanoparticles; PPE