



ENCIRCLE

EuropeanN Cbrn Innovation for the maRket CLustEr

ENCIRCLE PPE Human Factors linked to COVID-19

This publication only reflects the view of the ENCIRCLE Consortium or selected participants thereof. Whilst the ENCIRCLE Consortium has taken steps to ensure that this information is accurate, it may be out of date or incomplete, therefore, neither the ENCIRCLE Consortium participants nor the European Community are liable for any use that may be made of the information contained herein.

This document is published in the interest of the exchange of information and it may be copied in whole or in part providing that this disclaimer is included in every reproduction or part thereof as some of the technologies and concepts predicted in this document may be subject to protection by patent, design right or other application for protection, and all the rights of the owners are reserved.

The information contained in this document may not be modified or used for any commercial purpose without prior written permission of the owners and any request for such additional permissions should be addressed to the ENCIRCLE coordinator.

© Copyright 2020 – All Rights Reserved

Dissemination level

PU	Unrestricted PUBLIC Access – EU project	X
PP	Project Private, restricted to other programme participants (including the Commission Services) – EU project	
RE	RESTRICTED, Restricted to a group specified by the consortium (including the Commission Services) – EU project	
CO	Confidential, only for members of the consortium (including the Commission Services) – EU project	

Document Information

Grant Agreement n°	740450	
Project Title	EuropeaN Cbrn Innovation for the maRket CLustEr	
Project Acronym	ENCIRCLE	
Project Coordinator	Université catholique de Louvain (UCL)	
Document Responsible Partner	UCSC	Rachele Brancaleoni Alessandra Casaroli Agnieszka Sprońska (review)
Document Number	/	
Document Title	ENCIRCLE Human Factors linked to COVID-19	
Dissemination Level	PU	
Contractual Date of Delivery		

Partners involved in the Document

N°	Participant organisation name (short name)	Check if involved
1	Université Catholique de Louvain (UCL)	
2	BAe SYSTEMS (BAES)	X
3	Ouvry SAS (OUVRY)	
4	Sieć Badawcza Łukasiewicz – Przemysłowy Instytut Automatyki i Pomiarów (Ł-PIAP)	X
5	Tecnoalimenti (TCA)	
6	Wojskowa Akademia Techniczna (WAT)	
7	European Virtual Institute for Integrated Risk Management (EU-VRi)	
8	Istituto Affari Internazionali (IAI)	
9	Université de Nice-Sophia Antipolis (UNS)	
10	Università Cattolica del Sacro Cuore (UCSC)	X
11	FALCON COMMUNICATIONS LIMITED (FALCON)	
12	Smiths Detection Watford Limited (SMITHS)	
13	MIKKELIN KEHITYSYHTIO MIKSEI OY (MIKSEI)	
14	ENVIRONICS OY (EOY)	
15	ADS GROUP LIMITED LBG (ADS)	

Executive Summary

Pandemics, like COVID-19 are comprised in the Biological part of CBRN, as stated in the CBRN Action Plan¹. The impact of COVID-19 on the daily activities, especially for hospital staff was huge and probably underestimated. The purpose of this document is to provide an overview of the issues that hospital and pre-hospital staff experienced with PPE (Personal Protective Equipment).

¹ 1. European Commission (2017) Action Plan to enhance preparedness against chemical, biological, radiological and nuclear security risks. Brussels [COM (2017) 610 final]. Available here: http://encircle-cbrn.eu/wp-content/uploads/2017/04/CELEX_52017DC0610_EN_TXT.pdf

Table of Contents

- 1 Introduction 5**
- 2 PPE 5**
 - 2.1 PPE availability 5
 - 2.2 PPE problems 6
 - 2.3 Badly fitting PPE 7
 - 2.4 PPE and healthcare procedures 8
- 3 Other factors to be considered 9**

1 Introduction

On March, 13 the head of World Health Organization (WHO) reported that Europe was becoming the new epicenter of the COVID-19 pandemic. The virus was already circulating in Italy and in other EU countries from February the Italian council of ministries declared the state of emergency on January, 31 2020.

The pandemic caused a reorganization of the activities, especially in hospitals and EMS (Emergency Medical Services) where doctors, nurses and other staff were forced to operate in PPE that they rarely experienced before.

As part of ENCIRCLE Task 5.3 Human Factors we believe that the COVID-19 pandemic might represent a trigger to open a discussion around human factors, ergonomics and usability of PPE. Furthermore, the pandemic is interesting for this Task since most of the PPE users are civilians with little or no experience on performing activities while dressing Protective Equipment.

2 PPE

From literature and personal experiences, it is well known that wearing PPE is uncomfortable; the intensity of the discomfort is related to personal factors, level of protection and external factors.

Various research papers were published during the COVID-19 pandemic on suits and jumpsuits and another factor to take into account is the possibility to reuse the PPE after sterilization.

2.1 PPE AVAILABILITY

In some cases, personnel were buying PPE at their own expenses², using homemade gowns or masks³ or asked to reuse a single-use standard PPE item⁴.

PPE availability was analyzed by Tabah et al. that reported that 52% of the respondents to their web-survey missed at least one piece of standard PPE and 30% had to reuse or wash a single-use PPE due to shortage; in particular FFP3 were mostly reported as missing together with hazmat suits (12% both), while eye protections and FFP2 and FFP3 masks were the most PPE parts that were washed or reused even if they were for single-use only.³ A research conducted by the Royal College of Surgeons of UK shown that 1 out of 3 respondents experienced shortage

² Royal College of Surgeons (2020) Report of survey findings PPE and testing during the COVID-19 pandemic. Available here: <https://www.rcseng.ac.uk/-/media/files/rcs/coronavirus/rcs-report--ppe-and-testing-during-the-covid19-pandemic.pdf>

³ Tabah, A., Ramanan, M., Laupland, K. B., Buetti, N., Cortegiani, A., Mellinshoff, J., ... & Pova, P. (2020). Personal protective equipment and intensive care unit healthcare worker safety in the COVID-19 era (PPE-SAFE): An international survey. *Journal of Critical Care*.

⁴ Royal College of Nursing (2020) Second Personal Protective Equipment Survey of UK Nursing Staff Report: Use and availability of PPE during the COVID-19 pandemic. London

of full long-sleeves gown, FFP2 and FFP3 masks and full-face visors, while 35% reported no shortages of PPE in their workplace.

Jessica Harvey from NHS Trust, UK, had an interview with an SME based in China and discovered that the surge in the demand affected the market, transport and stock availability: the fabric shortage was one of the main concern together with the fact that many suppliers were mandated to produce solely for the Chinese Government; the lead time was increased due to flight restrictions; the request for brand names instead of PPE requirements was a limit for product availability.⁵

2.2 PPE PROBLEMS

The issues connected to the use of PPE are heat stress, exhaustion, headache, thirst, inability to take a break or use the toilet. According to the research of Tabah et al. 80% of the respondents experienced adverse effects while wearing PPE.

In the report of the Royal College of Nursing the major problems connected with PPE are: increase of body temperature, excessive sweating, irritation of skin and mucosa. It is interesting to notice that a quarter of the respondents reported that the filtering face piece respirators become uncomfortable in less than one hour from the donning.

Ong and colleagues recently published a paper on Headache on the link between headaches and wearing N95 mask and goggles. While previous reports documented pain or discomfort like headache, facial pain and/or ear lobe discomfort this study reported that the 81% of the respondents described de-novo PPE associated headaches when wearing either N95 mask with or without protective eyewear. The headache was reported as mild by most of the respondents with an onset of headache of less than 60 minutes and a spontaneous resolution within 30 minutes after doffing. Furthermore, almost 70% of the respondents did not need acute analgesic treatment while the most used drug were paracetamol and non-steroidal anti-inflammatory drugs. The authors concluded that the phenotypic findings suggest an anatomic basis for the headache or facial pain from PPE usage as well as the fact that other factors (i.e. sleeping deprivation, physical and emotional stress) may contribute to this phenomenon.⁶

Thermal discomfort was one of the major issues identified. Bongers et al. highlighted how PPE creates a microclimate that reduces the heat loss due to the material specificity that has as consequences heat strain, thermal discomfort, excessive sweating, faster dehydration and an increased cardiovascular strain. For a Health Care Worker (HCW) this results in shorter work tolerance times and a reduced physical and cognitive performance. Mitigation measures include adjustment of the work/rest schedule, incorporation of more frequent and longer breaks, pre-

⁵ Harvey, J. (2020). COVID-19 and PPE in context: an interview with China. *Journal of Public Health*

⁶ Jy Ong, J., Bharatendu, C., Goh, Y., ZY Tang, J., WX Sooi, K., Lin Tan, Y., ... & Sharma, V. K. (2020). Headaches associated with personal protective equipment—a cross-sectional study amongst frontline healthcare workers during COVID-19 (HAPPE Study). *Headache*, 60, 864-877.

cooling, per-cooling and post-cooling strategies (i.e. cold water/ice slurry ingestion and cooling vests⁷). Other tools, such as respirator hoods might be helpful; in this framework the experience of the University Southampton Hospital is interesting.⁸

Another problem identified is the skin damage. Photos of HCWs with ulcers, breakouts, irritation and redness due to goggles and masks are nowadays famous. It is important to underline that any skin damage can become a portal for potential infection.

A letter to the editor by Lan et al. demonstrated that the prevalence of skin damage of first-line health care workers is very high. More specifically, the areas more affected are nasal bridge and cheek, with dryness/tightness being the most reported symptom.⁹ The Royal College of Nursing advised for skin care the following: perform mask fit test, do not apply dressings or external coverings under the mask after the fit test; hydrate yourself throughout the shift, take regular breaks, relieve the pressure from face masks (when it is safe to do so), check your skin for any signs of redness or breaks regularly, or at least once a day.¹⁰

Concerning filtering face piece respirators, the Royal College of Nursing report showed that 26% of white British and 51% of BAME (Black Asian and Minor Ethnicities) had no adequate fit-testing for the respirator they work with.

2.3 BADLY FITTING PPE

“One size does not fit all” may appear as a cliché but when talking about PPE it is a reality. PPE that doesn’t fit correctly may cause not only discomfort but may also increase the risk of injury. In particular:

- **Gloves:** reduction in dexterity and grip strength, increase sweating and amount of force that is required for performing a task. Too loose gloves may get caught in the equipment or trigger objects drop from hands. Double gloves may increase the problems already mentioned.
- **Mask:** surgical masks do not require to fit the face while FFP2 and FFP3 need a fit test. Facial hair such as beard, or dressings, are not allowed because they cause a leakage. Face shapes are different and for some HCWs this may end up with a failure of fit-test and consequently to the impossibility to work in COVID wards.¹¹

⁷ Bongers, C. C., de Korte, J. Q., Catoire, M., Greefhorst, J., Hopman, M. T., Kingma, B., & Eijsvogels, T. M. (2020). Infographic. Cooling strategies to attenuate PPE-induced heat strain during the COVID-19 pandemic. *British Journal of Sports Medicine*.

⁸ <https://www.uhs.nhs.uk/AboutTheTrust/Newsandpublications/Latestnews/2020/April/Hospital-trust-becomes-first-to-introduce-pioneering-respirator-hoods-for-staff-treating-coronavirus-patients.aspx>

⁹ Lan, J., Song, Z., Miao, X., Li, H., Li, Y., Dong, L., ... & Zhou, N. (2020). Skin damage among health care workers managing coronavirus disease-2019. *Journal of the American Academy of Dermatology*, 82(5), 1215-1216.

¹⁰ Royal College of Nursing (2020) Maintaining skin health when using PPE. London

¹¹ <https://www.bma.org.uk/news-and-opinion/in-harm-s-way>

- Goggles: as already mentioned poorly-fitting goggles may cause ulcers due to pull fasteners too tight on ill-fitting PPE. It is also important to remember that people who wear prescription glasses may encounter more problems or require visor instead of goggles.

PPE are often oversized and employees may try to adapt ill-fitting PPE in order to perform their job safely. They often use tape or bands to improve the comfort but this can lead to interference with protective properties of the material. In any case, such downsizing is never a solution.

A survey conducted by Prof. Hignett highlighted that fitting issues are connected to safety glasses (especially when associated with prescription spectacles), surgical mask and suits.¹²

Another important issue to take into consideration is the gender of the users. Women and men have a different body shape (i.e. hips, chest, abdomen when a woman is pregnant), hand (smaller palm circumference, narrower and shorter fingers), face (generally smaller, with less pronounced chin and jaw). In 2017, TUC (Trades Union Council) published a report on PPE and women highlighting that in emergency services (not only EMS/hospital and not related to biological protection) only 5% of the women reported that PPE never hampered their work.¹³

2.4 PPE AND HEALTHCARE PROCEDURES

Working in hospital or EMS might be harsh but how it is working with PPE during a pandemic?

A study performed in Hong Kong and published in 2017 considered N95 fit factor after nursing procedures (suctioning and nasogastric tube insertion). The average fit factor dropped significantly after the procedures showing that adjustment of the mask during the activities is needed (even if this is not possible due to the current regulation). The authors also suggested that an ill-fitted N95 block only 66.5% of infectious viruses, while a tightly sealed one should block 99.6% of them. This being said, it is possible that after a nursing procedure the level of protection guaranteed by a N95 mask becomes similar to a surgical mask¹⁴

An Austrian randomized study on limiting factors for wearing PPE in healthcare took into account two suit types (head or full-body ventilated PPE with Powered Air Purifying Respirator (PAPR)) and demonstrated that PPE had no negative impact on the performance while the

¹² Hignett, S., Welsh, R., Banerjee, J. (2020). Human factors issues of working in personal protective equipment during the COVID-19 pandemic. *Anaesthesia*, <https://doi.org/10.1111/anae.15198>

¹³ TUC (2017) Personal protective equipment and women. Available here: <https://www.tuc.org.uk/sites/default/files/PPEandwomenguidance.pdf>

¹⁴ Suen, L. K., Yang, L., Ho, S. S., Fung, K. H., Boost, M. V., Wu, C. S., ... & O'Donoghue, M. (2017). Reliability of N95 respirators for respiratory protection before, during, and after nursing procedures. *American journal of infection control*, 45(9), 974-978.

volunteers experienced reduced dexterity due to double gloves, impaired visibility and, with the fully ventilated suite, backpain.¹⁵

The research conducted by Prof. Hignett reported that healthcare workers experiences communication and hearing problems (related to electronic interfaces and alarms), visual and fine motor functions difficulties (in particular related to central line insertion, sutures and other medical procedures).¹⁶

In 2015 a focus group interview was conducted to describe the impact of respirator use in health care setting. A large portion of HCWs (62%) reported that the respirator had no impact in their ability to perform patient care, but they recognized it has limited the ability to be seen smiling, speculating that a transparent mask might be better. Clearly the study was performed before the pandemic and HCWs perceptions may differ from when assessed under routine scenarios.¹⁷

This introduced the communication factor: as already mentioned the respirators and masks impair an effective non-verbal communication and communication for hearing impaired. An interesting solution was proposed by an NHS Anaesthetist, Rachael Grimaldi, who invented a free digital communication tool, based on collection of communication flashcards w common healthcare topics, written by clinical experts.¹⁸

3 Other factors to be considered

In the hospital and prehospital environments there are different factors that are involved in the PPE usage. These include:

- External temperature, as well as other weather-related factors (humidity, ...)
- Physical fitness and height/weight of the staff
- Actions that have to be performed while wearing PPE (carrying weight, precision movements)
- Training of HCWs and awareness concerning PPE use and strategies for avoiding self-contamination

¹⁵ Loibner, M., Hagauer, S., Schwantzer, G., Berghold, A., & Zatloukal, K. (2019). Limiting factors for wearing personal protective equipment (PPE) in a health care environment evaluated in a randomised study. PloS one, 14(1), e0210775.

¹⁶ Hignett, S., Welsh, R., Banerjee, J. (2020). Human factors issues of working in personal protective equipment during the COVID-19 pandemic. Anaesthesia, <https://doi.org/10.1111/anae.15198>

¹⁷ Hines, S. E., Oliver, M. S., Gucer, P., & McDiarmid, M. A. (2020). Self-reported Impact of Respirator Use on Healthcare Worker Ability to Perform Patient Care. American Journal of Infection Control.

¹⁸ <https://www.cardmedic.com/>

- Procurement of PPE, quality and applicable standards
- Psychological factors that are typical of a prolonged crisis such as COVID-19 pandemic
- Staff concerns on PPE and obstacles to its use: lack or weak communication over this between staff and supervisory functions.

The scope of the PPE is to provide protection but, thanks to new materials and know-how, we might expect an improvement of ergonomics, helping HCWs to carry out their activities in an easier way. The process of PPE re-design should involve all the actors, from end-users to manufacturers, taking into account users' needs and new technologies that may be useful.