Analysis of Personal Protection Equipment for Upper Respiratory Tract to Prevent the Spread of COVID-19 Part II

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Abstract**—** *The coronavirus pandemic significantly affects the lives of families, employees, employers, or sole proprietors, and it is therefore necessary to prevent its spread by using appropriate protective equipment. The article discusses the possibilities of protection against various forms of harmful particles, including the highly infectious virus SARS-CoV-2 using face protection respectively respiratory protection.*

Keywords**— *COVID-19, respiratory protective equipment, surgical face masks.***

I. INTRODUCTION

Clinicians and experts in the field of public health recommend preventive measures, including use of respiratory protective devices, to reduce the disease caused by infection with severe acute respiratory syndrome coronavirus 2 (known as SARS-CoV-2). It is thought that SARS-CoV-2 is spread primarily through contact and large respiratory droplets, but evidence also indicates potential transmission by fine respiratory aerosols located in the surrounding environment. [1 – 3] There are available several types of face masks and the respiratory protective equipment to be used in hazardous work environments, including environments contaminated by a new virus SARS-CoV-2.

II. ANALYSIS OF HARMFUL COMPONENTS OF THE ENVIRONMENT AFFECTING THE RESPIRATORY SYSTEM

In the environment, we may encounter components that negatively affect our breathing and our overall health. These are components such as dust, smoke, microorganisms, allergens (pollen, mold, etc.), solid pollutants caused by anthropogenic activity or the influence of nature (Fig. 1).

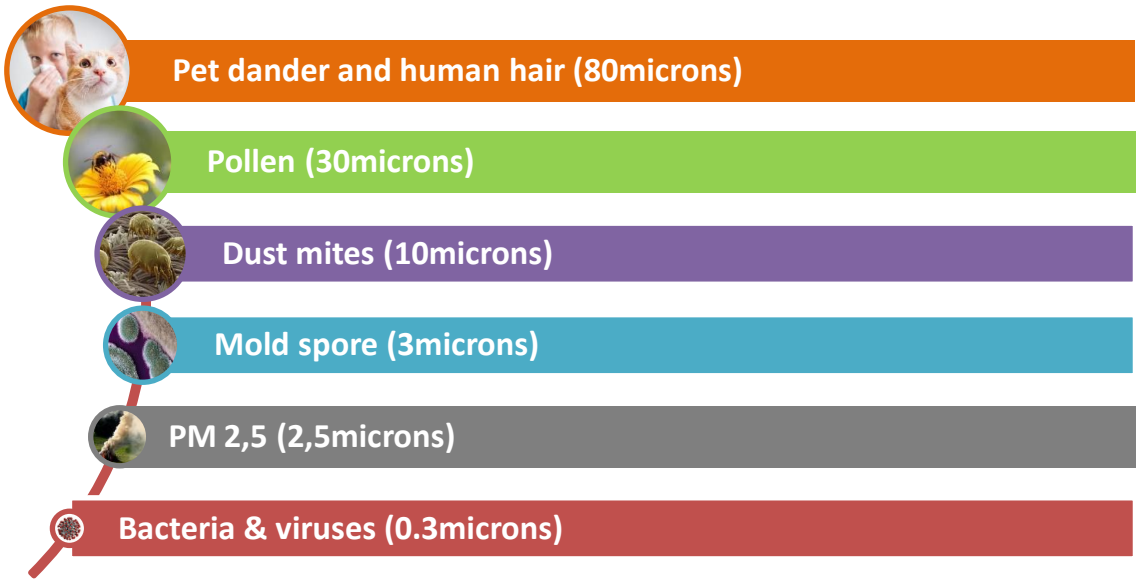

FIGURE 1 Harmful particles and allergens [4]

Small, dry, solid particles can be projected into the air by natural forces, such as wind, volcanic eruption, and by mechanical or manmade processes such as crushing, grinding, milling, drilling, demolition, shoveling, conveying, screening, bagging, and sweeping. Dust particles are usually in the size range from about 1 to 100 μm in diameter, and they settle slowly under the influence of gravity. [5]

Other pollutants may include vapors generated by the cooling of molten metal. The hot material reacts with oxygen to form oxides. When melting lead e.g. lead oxide fumes are formed; welding produces iron oxide and other metal fumes.

When coal is burned, smoke is produced. Smoke is made up of small particles of coal and soot, which combine with droplets and solid particles.

Particulate matter (PM) is the air pollutant that causes the greatest harm to human health in Europe. They are so light that they can float in the air. Some of these particles are so small (one thirtieth to one fifth of the diameter of a human hair) that not only do they penetrate deep in our lungs, but they also pass into our bloodstream, just like oxygen. Some particles are emitted directly into the atmosphere. Others come about as a result of chemical reactions involving precursor gases, namely sulphur dioxide, nitrogen oxides, ammonia, and volatile organic compounds. [5]

Microorganisms that spread in the environment include bacteria, viruses, spores and the like. Currently, the most resonant among the viruses is SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2, formerly temporarily known as 2019-nCoV), which belongs to the genus Betacoronavirus and was first identified in patients with severe respiratory disease in December in 2019 in the Chinese city of Wuhan. [6]

COVID-19 (Corona Virus Disease 2019) is manifested by flu-like symptoms. Therefore, the disease was initially compared to influenza and downplayed. These symptoms may vary in intensity in different people. It depends mainly on the strength of their own immunity. Therefore, the disease is most dangerous in the elderly and people with associated health problems.

III. ANALYSIS OF HARMFUL COMPONENTS OF THE ENVIRONMENT AFFECTING THE RESPIRATORY SYSTEM

There are several types of face masks and respiratory protection. The choice of filter device or breathing apparatus depends on criteria such as [7]:

- Oxygen content,
- Type and concentration of contamination,
- User mobility,
- Required level of protection.

Respiratory protection equipment can be divided into two main groups (Fig. 2) [7]:

FIGURE 2: Respiratory protection

3.1 Filtering Respirators:

Its depend on ambient air.

The air is cleaned when drawn through the filter. Respirators are not suitable for use in the IDLH (Immediately Dangerous to Life or Health) environments including oxygen-deficient atmospheres.

Subdivision in this group:

- Negative pressure filtering devices for instance disposable-, half- and full face masks with filters,
- Positive pressure filtering devices for instance powered air hoods and masks.

It should be added that respirators can also be equipped with exhalation valves.

3.2 Respiratory Devices (DA)

These are independent of ambient air.

Breathing air is supplied from an external source, e.g. compressed air or pressure cylinders. The user is connected to a hose or uses an independent breathing apparatus. It is less mobile due to hose or time constraints. The respirator is suitable in environments where there is an immediately dangerous to life or health and in environments with a lack of oxygen (unlike filter respirators).

The group of the respiratory devices consists of:

- Compressed air treatment plant,
- Independent breathing apparatus.

Respiratory protection masks protect the lungs from the ingress of dust, smoke and liquid mist (aerosol), but do not protect against steam and gas. The classification system is divided into three classes of FFP (filtering face piece).

The respirator covers the nose and mouth and consists of various filter materials and the mask body itself. Their wearing is prescribed at workplaces where the highest exposure value at work is exceeded. This is the maximum permissible concentration of dust, smoke and aerosols in the breathed air, which does not lead to damage to health. If it is exceeded, the obligation to use respiratory protection masks applies.

The EN 149 standard [8] defines three classes of filter efficiency, namely FFP1, FFP2 and FFP3. Before we move on to the FFP classes, it is useful to understand the following terms:

- **Occupational Exposure Limit (OEL) –** OELs are standards that determine the amount, or concentration, of a hazardous substance allowable in the workplace air.
- **Assigned Protection Factor (APF) –** The APF of a mask indicates how well it protects the wearer from hazardous substances. A safety mask with an APF of 4 will reduce the concentration of the hazardous substance in the air that is breathed by the wearer by 4 times.

It is possible to protect the respiratory tract from dust particles and aerosols with respirators as well as filters of the following protection classes (Table 1 – Table 3) [9]:

TABLE 1
CHARACTERISTICS OF FFP1

FFP1	➢ *Protection against non-toxic dust and dust which does not cause fibrosis,* ➢ *Inhalation does not lead to disease, but may irritate the respiratory tract and the substances may smell unpleasant,* ➢ *The total leakage rate may not exceed 25%,* ➢ *This kind of mask may be applied under a fourfold OEL transgression at the most.* *Respiratory masks with protection class FFP1 are suitable for use in work environments where toxic or fibrogenic dusts and aerosols are not expected. They filter at least 80% of the particles in the air up to 0.6 µm in size. The use of FFP1 respiratory protection masks is usually sufficient in the construction and food industries.*
	

TABLE 2
CHARACTERISTICS OF FFP2

FFP2	➢ *Protection from firm and fluid deleterious kinds of dust, smoke, and aerosols,* ➢ *Particles may be fibrogenic – which means they irritate the respiratory system in the short term and can result in reduction of elasticity of pulmonary tissue in the long run,* ➢ *Total leakage may amount to a maximum of 11%,* ➢ *OEL transgression to the tenfold value.* *Protection class FFP2 respirator masks are suitable for use in work environments with the presence of harmful and mutagenic particles can be found in the breathing air. Respirator masks of this class must capture at least 94 % of the particles measuring up to 0.6 µm and may be used in environments transgressing the OEL up to a maximum of the tenfold concentration. The same goes for the TRC value (technical reference concentration). Protection class FFP2 respirator masks are often worn in the metal and mining industry. In these environments, workers come into contact with aerosols, mists and smoke, which in the long run lead to respiratory diseases, such as lung cancer, and significantly increase the risk of subsequent diseases, such as active pulmonary tuberculosis.*
	

TABLE 3
CHARACTERISTICS OF FFP3

FFP3	➢ *Protection from poisonous and deleterious kinds of dust, smoke, and aerosols,* ➢ *When working with oncogenic or radioactive substances or pathogens such as viruses, bacteria and fungal spores FFP3-class respirator masks are recommended,* ➢ *Total leakage may amount to a maximum of 5%,* ➢ *OEL transgression to the thirtyfold value.* *Protection class FFP3 respirator masks offer maximum protection from breathing air pollution. The total leakage may amount to a maximum of 5% and they must filter 99% of all particles measuring up to 0.6 µm. This kind of mask also filters poisonous, oncogenic, and radioactive particles. Protection class FFP3 masks are used in working environments transgressing the OEL by the thirtyfold industry-specific values. They are often used in the chemistry industry.*
	

As far as face masks are concerned, a wide range of half masks (a), full-face protective masks (b) as well as comfortable and adaptable respirators with a soft thermoplastic seal (c) have been developed (Fig. 3).

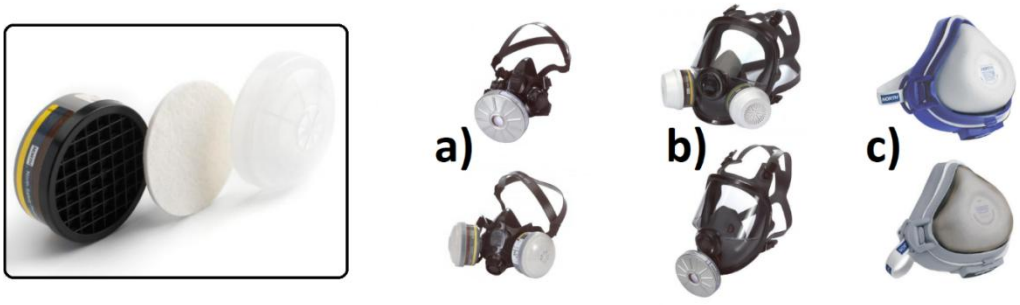

FIGURE 3 Types of face masks and replaceable filters [7]

IV. REQUIREMENTS FOR RESPIRATORS EFFECTIVE TO PROTECT AGAINST COVID-19

The current epidemiological situation results in an increased demand for respirators, which are classified according to their filtration efficiency and maximum overall penetration into the FFP3 class (protection against organic, inorganic particles and biological particles such as viruses, bacteria, fungi, etc.) [10].

However, respirators with invalid or false certificates may also be on the market in this context. These are respirators that are imported from third countries. Notices of these certificates (issued by a person not notified for their assessment) are also on the European website of the Europen Safety Federation.

Before importing or purchasing respirators of category FFP3, it is necessary to check whether the given PPE has [11]:

- EU Declaration of Conformity (the 4-digit number of the notified body must be the same as the 4-digit number of the notified body after the CE marking),
- CE marking + 4-digit number of the notified body directly on the FFP3 respirator.

Applicable legal frame of the respiratory protection in the European Union is given in the Tab. 4.

TABLE 4
APPLICABLE LEGAL FRAME OF THE RESPIRATORY PROTECTION [12]

	Protective mask*	***Medical mask****
Other terms used	FFP2 / FFP3 / FFP1 / respirator / filtering face piece / filtering half mask	Surgical mask
Function	Protect the wearer from harmful dusts or aerosols / particles in the air	Protect the patient by reducing the risk of spreading infective agents via exhaled air of the wearer
Applicable legal frame	PPE Regulation (EU) 2016/425 – category III	Medical Devices Directive 93/42/EEC – class I (class IIa for sterile medical masks)
Marking	CE + 4digit identification number of the notified body responsible for the production follow-up	CE
Applicable EN standard	EN 149	EN 14683

****: Some masks are both Protective and Medical mask and comply to both legal acts and are tested to all relevant standards for both functions.***

Labelling of the respirators in the US and in Europe is different. In the USA, it is recommended to use N95 particulate respirators certified by the National Institute for Occupational Safety and Health. The N95 series respirators are made of a material that has 95% particle filtration efficiency of the particles having a diameter of 0,3μm. In Europe, respirators marked FFP2 (= N95) or FFP3 (= N100) are comparable.

V. USING OF PPE IN HEALTHCARE FACILITIES AS A PREVENTION OF THE SPREAD OF COVID-19

Centres for Disease Control and Prevention and the World Health Organization (WHO) recommend respirator use especially for the following workers [13]:

- Health care workers entering the room of a patient with COVID-19,
- Medical transport workers transporting patients with suspected COVID-19.

A face mask or respirator without an exhalation valve is used to capture infectious droplets from the patient's airways. In the case of respirators with an exhalation valve, the exhaled air from the patient must pass through an additional filter layer which traps infectious substances e.g., by applying a surgical mask to a respirator with an exhalation valve.

Respirators are not routinely needed (by staff or visitors) in other parts of hospitals or other health care facilities where there is no direct contact with patients. [13] Most people who develop disease COVID-19 become infected by contact with other

people who are ill or by breathing contaminated air. Since the beginning of the pandemic, there has been an increased emphasis on surface disinfection as a possible source of coronavirus infection. Experiments aimed at surviving the virus on surfaces show that the coronavirus can survive on surfaces for longer, but that does not mean that people catch it from surfaces such as door handles. Most studies on the survival of viruses on various surfaces have been performed under laboratory conditions. Only a few studies looked for a viable virus outside the laboratory. The results of these experiments showed that none of the viral materials were able to infect the cells. [14 – 21]

The best protection against the virus not only in medical facilities but also in public places with a higher concentration of people at a time of increased incidence of respiratory diseases is the wearing of face masks. As secondary protection especially after taking a face mask it is recommended washing or disinfecting hands and not to touch facial mucous membranes (eyes, mouth, or nose).

All healthcare professionals should evaluate the infection risk and wear appropriate personal protective equipment (PPE) to minimize this risk before each interaction with a patient suspected or confirmed of COVID-19 [22].

The following table (Tab. 5) evaluates the need to use the surgical face mask or the FFP3 respirator for healthcare professionals.

TABLE 5
USING SURGICAL FACE MASK VS. FFP3 RESPIRATOR [23]

When to use a surgical face mask 		**When to use an FFP3 respirator** 	
In cohorted area (butno patient contact)	Close patient contact (within one meter)	Carrying out potentially infectious aerosol generating procedures	
For example: Cleaning the room, equipment cleaning, discharge patient room cleaning, etc.	For example: Providing patient care, direct home care visit, diagnostic imaging, phlebotomy services, physiotherapy, etc.	For example: bronchoscopy, endotracheal intubation, tracheostomy procedures, cardiopulmonary resuscitation, diagnostic sputum induction:	
PPE to be worn:	**PPE to be worn:**	➢ Where a patient is known/suspected to have an infection spread via the aerosol route ➢ When caring for patients known/suspected to be infected with a newly identified infectious respiratory virus	
Surgical face mask (along with other designated PPE for cleaning)	Surgical face mask Apron Gloves Eye protection	PPE to be worn: FFP3 respirator Gown	Gloves Eye protection

VI. CONCLUSION

Based on previous experience and knowledge, SARS-CoV-2 has been shown to spread primarily through close personal contact with symptomatic individuals and also through contaminated surfaces with infectious droplets and subsequent transmission of these droplets to the mucous membranes of the eyes, nose or mouth. It is assumed that the transmission of the virus occurs through the very small air particles.

At present, several PPE are available on the market. PPE is used to protect health as well as the respiratory tract in the work environment. These devices have also found application in reducing the risk of transmitting COVID-19, especially in the

front-line sectors. In an effort to eliminate this infection, a number of countries have engaged in research of the new materials for the production of filters as well as the types and shapes of protective face masks.

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