

**SYSTEM FOR PROTECTING AGAINST, AND DETECTING,
ELEMENTS/AGENTS HARMFUL/HAZARDOUS TO THE HUMAN BODY PRESENT
IN THE AIR**

5 **TECHNICAL SECTOR OF THE INVENTION**

The present invention concerns, in general, the protection against, and detection of, elements/agents harmful/hazardous to the human body present in the air.

10 More specifically, the present invention relates to a system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air, such as:

- pathogens, i.e. microorganisms that cause or have the capacity to cause, or are responsible for the onset of, a
15 disease in the human body, such as viruses, coronaviruses, viroids, germs, bacteria, mycetes (i.e. fungi), moulds, protozoa, prions, etc.;
- elements/agents/substances present in the air which are pollutant, harmful, toxic or otherwise hazardous to the
20 human body (e.g., of the volatile type);
- or the like.

BACKGROUND

25 At present, there are several types of wearable personal protective equipment (PPE), in particular of the mask type, for the protection against pathogens and/or elements/agents/substances that are polluting, harmful, toxic or hazardous to the human body.

30 As is well known, a PPE of the aforesaid type is typically designed to be worn on the head, in particular on the face, of a person to cover and thereby protect the area of the nose, mouth and chin, may be made of different materials and may also comprise inhalation/exhalation valves.

35 For example, the European standard EN 149 defines three classes of filtering, respiratory-protection masks (known as FFP1, FFP2 and FFP3, where the acronym FFP stands for

"Filtering FacePiece") depending on the filtration efficiency.

Said filtering, respiratory-protection masks are generally disposable or, in any case, diminish or even lose their effectiveness after a certain number of hours/times of wearing them.

The following Table 1 summarizes the main characteristics of the most common mask-type respiratory protective equipment (in this regard, reference can also be made to "*Personal protective equipment for use in a filovirus disease outbreak - Rapid advice guideline*", World Health Organization, at the link: <https://apps.who.int/iris/bitstream/handle/10665/251426/9789241549721-eng.pdf?sequence=1&ua=1>).

TABLE 1

Filtering respiratory- protection mask type	Features
<u>Surgical mask</u>	- It limits the spread of potentially infectious particles in the environment by infected or potentially infected individuals - It has no filtering function in the inspiratory phase, therefore it does not protect against the inhalation of small airborne particles (aerosols) - It must be worn by infected or potentially infected individuals

<u>FFP1</u>	- It filters 80% of environmental particles with diameter $\geq 0.6 \mu\text{m}$ - If provided with an expiratory valve, it has no filtering function in the expiratory phase (the expiratory valve can be provided for the comfort of the operator) - It is not recommended for the protection against airborne pathogens
<u>FFP2</u>	- It filters 95% of environmental particles with diameter $\geq 0.6 \mu\text{m}$ - If provided with an expiratory valve, it has no filtering function in the expiratory phase (the expiratory valve can be provided for the comfort of the operator) - It must be worn by healthcare workers assisting infected or potentially infected individuals
<u>FFP3</u>	- It filters 98-99% of environmental particles with diameter $\geq 0.6 \mu\text{m}$ - If provided with an expiratory valve, it has no filtering

	function in the expiratory phase (the expiratory valve can be provided for the comfort of the operator) - It must be worn by healthcare workers assisting infected or potentially infected individuals, particularly during manoeuvres that produce increased aerosolization (e.g., intubation, open-circuit bronchoaspiration, bronchoscopy)
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The recent COVID-19 pandemic has demonstrated the extreme importance of mask-type wearable PPEs not only for respiratory protection in a healthcare setting, but in
5 general for the protection of the public health against the spread of particularly infectious pathogens such as SARS-CoV-2.

Therefore, at present there is a strong need for new devices/systems for individual protection against pathogens
10 and/or elements/agents/substances present in the air that are polluting, harmful, toxic or hazardous to the human body.

In this respect, reference may be made, for example, to KR20200020747A, which describes an individual hygienic mask that is designed to be worn by a user (particularly on the
15 face of the user) and comprises:

- an outer housing;
- an air passage (or duct) coupled to the outer housing to allow the entry of breathing air;
- an ultraviolet light source (in particular of the LED
20 type, which acronym stands for "Light Emitting Diode") emitting ultraviolet light, in particular with a wavelength ranging between 200 nm and 400 nm, into the air passage to sterilise the breathing air; and

- power supply means (e.g. a battery or a battery coupled to a solar panel) to power the ultraviolet light source.

OBJECT AND SUMMARY OF THE INVENTION

5 In the light of the foregoing, the Applicant felt the need to conduct a very thorough research in order to try to develop an innovative individual protection system, in particular a respiratory protection system, effective against elements/agents present in the air that are
10 harmful/hazardous to the human body (such as, for example, pathogens, elements/agents/substances that are polluting, harmful, toxic or hazardous to the human body, or the like), thus achieving the present invention.

Therefore, a first object of the present invention is to
15 provide an individual protection system, in particular a respiratory protection system, which is capable of overcoming the limitations and disadvantages of known types of respiratory protection equipment/systems and which is much more effective and efficient than the latter.

20 Furthermore, a second object of the present invention is to provide an individual protection system capable of providing, in addition to the respiratory protection function, additional functionalities that are not currently provided by any known type of respiratory protection
25 equipment/system.

These and other objects are achieved by the present invention as it relates to a system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air, as defined in the appended
30 claims.

In particular, the system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air according to the present invention comprises a mask-type personal protective equipment (PPE)
35 configured to be worn by a user so as to cover at least the user's nose and mouth.

Specifically, the mask-type PPE comprises:

- an outer casing;
 - one or more air passages configured to allow the user to
 - inhale air from outside the outer casing through said air passage(s), and
 - exhale air outside said outer casing through said air passage(s);
 - filtering means housed within the outer casing and configured to filter out one or more elements/agents harmful/hazardous to the human body present in the air passing through said air passage(s);
 - ultraviolet illumination means housed within the outer casing and configured to perform a sanitising and/or sterilising function of the filtering means and of the air passing through said air passage(s) by ultraviolet illumination of said filtering means and of the air passing through said air passage(s); and
 - means for detecting harmful/hazardous elements/agents housed within the outer casing and configured to detect one or more elements/agents harmful/hazardous to the human body present in the air passing through the air passage(s).
- Further, the system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air comprises also electronic processing and communication means configured to:
- generate monitoring data related to elements/agents harmful/hazardous to the human body detected by the means for detecting harmful/hazardous elements/agents in the air passing through the air passage(s); and
 - transmit the monitoring data to remote devices/systems.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, some preferred embodiments (provided purely by way of explanatory, but absolutely not limiting, let alone binding example) will now be shown with reference to the accompanying

drawings (not to scale), wherein:

• Figures 1-3 schematically show a system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air according to a preferred embodiment of the present invention;

• Figure 4 is an exploded view, with parts removed for clarity's sake and parts schematically drawn, of a mask-type personal protective equipment (PPE) of the system shown in Figures 1-3; and

• Figure 5 schematically shows a group of sensors and devices housed in the mask-type PPE shown in Figures 1, 2 and 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

The following description is provided to enable a person skilled in the art to make and use the invention. Various modifications to the presented embodiments will be immediately evident to persons skilled in the art and the generic principles disclosed herein could be applied to other embodiments and applications without, however, thereby departing from the scope of protection of the present invention as defined in the attached claims.

Therefore, the present invention should not be understood as limited to the sole embodiments described and shown, but it must be given the widest scope of protection according to the characteristics defined in the appended claims.

The present invention concerns a system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air, such as:

• pathogens, i.e. microorganisms that cause or have the capacity to cause, or are responsible for the onset of, a disease in the human body, such as viruses, coronaviruses, viroids, germs, bacteria, mycetes (i.e. fungi), moulds, protozoa, prions, etc;

• elements/agents/substances which are pollutant, harmful, toxic or otherwise hazardous to the human body

present in the air (e.g. of the volatile type);

- or similar.

In particular, the system for protecting against, and detecting, elements/agents harmful/hazardous to the human
5 body present in the air according to the present invention includes a mask-type personal protective equipment (PPE) that is wearable by a user on the face (i.e., it is designed to be worn by a user on the face of the latter) to cover and, thereby, protect the area of the nose, mouth and chin
10 of the user and comprising:

- an outer casing;
- one or more air passages (or ducts) configured to allow the user to
 - inhale air from outside the outer casing through
15 said air passage(s), and
 - exhale air outside said outer casing through said air passage(s);
- filtering means housed within the outer casing and configured to filter out one or more elements/agents
20 harmful/hazardous to the human body present in the air passing through said air passage(s) (i.e., in the air inhaled and/or exhaled by the user), wherein said filtering means preferably include at least one HEPA (acronym for "High Efficiency Particulate Air filter") type filter, more
25 preferably of HEPA H14 type (i.e., with a filtration efficiency greater than 99.995%);
- ultraviolet illumination means housed within the outer casing and configured to perform a sanitising and/or sterilising function of the filtering means and of the air
30 passing through said air passage(s) (i.e., the air inhaled and/or exhaled by the user) by ultraviolet illumination of said filtering means and of the air passing through said air passage(s), wherein said ultraviolet illumination means preferably include one or more light emitting diodes (i.e.,
35 LEDs) that is/are configured to emit ultraviolet (UV) light, conveniently in the UV-C band (i.e., with wavelengths ranging between 100 nm and 280 nm); and

• means for detecting harmful/hazardous elements/agents housed within the outer casing and configured to detect one or more elements/agents harmful/hazardous to the human body present in the air passing through the air passage(s) (i.e.,
5 in the air inhaled and/or exhaled by the user).

Further, the system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air according to the present invention also includes electronic processing and communication means
10 configured to:

- generate monitoring data related to the (in particular indicative of the) elements/agents harmful/hazardous to the human body detected by the means for detecting harmful/hazardous elements/agents in the air passing through
15 the air passage(s) (i.e. in the air inhaled and/or exhaled by the user); and

- transmit monitoring data to remote devices/systems.

According to a preferred embodiment of the present invention, the electronic processing and communication means
20 comprise an electronic processing and communication device and an electronic control, processing and communication unit, wherein said electronic control, processing and communication unit is:

- integrated into the mask-type PPE (in particular, it
25 is conveniently housed within the outer casing);

- coupled (e.g., connected) to the means for detecting harmful/hazardous elements/agents; and

- configured to
 - generate raw monitoring data related to the (in
30 particular indicative of the) elements/agents harmful/hazardous to the human body detected by the means for detecting harmful/hazardous elements/agents in the air passing through the air passage(s) (i.e. in the air inhaled and/or exhaled
35 by the user); and

- transmit the raw monitoring data to the electronic processing and communication device.

Said electronic processing and communication device is external to the, i.e., separate from the, mask-type PPE (e.g., it is conveniently implemented by means of a smartphone, smartwatch, tablet, laptop, desktop computer, etc.) and is configured to:

- receive the raw monitoring data from the electronic control, processing and communication unit in a wired or wireless mode (e.g. via Bluetooth technology and/or via a connection based on USB technology, acronym for "Universal Serial Bus");
- process the raw monitoring data received from the electronic control, processing and communication unit, thereby generating refined monitoring data; and
- transmit the refined monitoring data to remote devices/systems in a wired or wireless mode (e.g., via one or more Internet Protocol (IP) based networks, conveniently the Internet network, and/or via one or more cellular telephone networks (e.g., GSM, GPRS, UMTS, HSPA, LTE, 4.5G, 5G, etc.) and/or one or more local, home, business, public, private networks, etc.).

Instead, according to an alternative embodiment of the present invention, the electronic processing and communication means are fully integrated into the mask-type PPE (conveniently within the outer casing).

Preferably, the system for protecting against, and detecting, elements/agents harmful/hazardous to the human organism present in the air also includes proximity detection means (e.g. implemented by means of one or more proximity sensors based, for example, on RSSI technology (acronym for "Received Signal Strength Indicator") Bluetooth) configured to perform a proximity detection function of other persons, more preferably other users also equipped with said system for protecting against, and detecting, elements/agents harmful/hazardous to the human body present in the air.

Said proximity detection means may be conveniently integrated into the mask-type PPE (preferably within the outer casing) either in the case of the aforesaid preferred

embodiment of the present invention, or in the case of the
aforesaid alternative embodiment of the present invention,
or into the electronic processing and communication device
in the case of said preferred embodiment of the present
5 invention.

In particular, if the proximity detection means are
integrated into the mask-type PPE, the electronic control,
processing and communication unit according to the aforesaid
preferred embodiment of the present invention, or the
10 processing and communication means fully integrated into the
mask-type PPE according to the aforesaid alternative
embodiment of the present invention, is/are conveniently:

- coupled (e.g., connected) also to proximity detection
means; and
- 15 • configured to generate tracking data related to the
(in particular indicative of the) other persons/users
detected by the proximity detection means and to transmit
said tracking data
 - to the electronic processing and communication
20 device in the case of said preferred embodiment of
the present invention (e.g., via Bluetooth
technology and/or via USB-based connection), said
electronic processing and communication device
being, in turn, configured to transmit the tracking
25 data to remote devices/systems in a wired or wireless
mode,
 - or, in the case of said alternative embodiment of
the present invention, to remote devices/systems in
a wired or wireless mode (e.g., via one or more
30 Internet Protocol (IP) based networks, conveniently
the Internet network, and/or via one or more cellular
telephone networks (e.g., GSM, GPRS, UMTS, HSPA,
LTE, 4.5G, 5G, etc.) and/or one or more local, home,
business, public, private networks, etc.).

35 If, on the other hand, in the case of said preferred
embodiment of the present invention, the proximity detection
means are integrated into the electronic processing and

communication device, the latter is configured to:

- generate tracking data related to the (particularly indicative of the) other person(s)/user(s) detected by the proximity detection means; and
- 5 • transmit said tracking data to remote devices/systems in a wired or wireless mode (e.g., via one or more Internet Protocol (IP) based networks, conveniently the Internet network, and/or via one or more cellular telephone networks (e.g., GSM, GPRS, UMTS, HSPA, LTE, 4.5G, 5G, etc.) and/or
- 10 one or more local, home, business, public, private networks, etc.).

Conveniently, the mask-type PPE also comprises a battery that is:

- housed within the outer casing;
- 15 • configured to supply electrical power to the ultraviolet illumination means, the detection means, and
 - to the electronic control, processing and communication unit according to said preferred embodiment of the present invention, or
 - 20 - to the electronic processing and communication means fully integrated into the mask-type PPE according to said alternative embodiment of the present invention,
 - as well as to the proximity detection means, if
 - 25 integrated into the mask-type PPE; and
- rechargeable via a USB port arranged on the outer casing.

For a better understanding of the present invention, Figures 1-3 schematically show an example (by no means limiting, let alone binding) of a system for protecting

30 against, and detecting, elements/agents harmful/hazardous to the human body present in the air according to the aforesaid preferred embodiment of the present invention, wherein:

- Figures 1 and 2 are, respectively, a front view and a
- 35 perspective view of a mask-type PPE 1 of the aforesaid type (i.e. having the technical characteristics described above in relation to the present invention) worn by a user 3 (in

particular on the face of the user 3 so as to cover the area of the nose, mouth and chin); while

• Figure 3 is a perspective view of an electronic processing and communication device 2 of the aforesaid type (i.e. having the technical characteristics described above in relation to the aforesaid preferred embodiment of the present invention) implemented by means of a smartphone carried/used by the user 3.

In addition, Figure 4 is an exploded view, with portions removed for clarity's sake and portions schematized, of the mask-type PPE 1.

The mask-type PPE 1 includes an outer casing comprising a front and lower cover structure 11 and a mask body 12 which can be hooked in a removable manner. A plurality of slots 13 are made on the sides of the front and lower cover structure 11 (in particular on the sides of a front portion 11A of said front and lower cover structure 11) and on the sides of the mask body 12 to allow the passage of air for inhalation and exhalation of the user 3. Further, an opening 14 is made on the front and lower cover structure 11 (in particular on a lower portion 11B of said front and lower cover structure 11) to house a USB port 15.

The front portion 11A and the lower portion 11B of the front and lower cover structure 11 are shaped so as to define, respectively, a first inner housing volume 111A and a second inner housing volume 111B to respectively house:

- a group of sensors and devices (collectively referred to as 16 in Figure 4); and
- a rechargeable battery 17 (e.g. a lithium polymer battery - LiPo).

In particular, as shown in Figure 4, the group of sensors and devices 16, the rechargeable battery 17 and the USB port 15 (configured to allow charging said rechargeable battery 17) are conveniently installed on a support structure 18 removably inserted between the front and lower cover structure 11 and the mask body 12.

More specifically, the group of sensors and devices 16

is conveniently installed on a front portion 18A of the support structure 18 intended to be housed in the first inner housing volume 111A, while the rechargeable battery 17 is conveniently installed on a lower portion 18B of the support structure 18 intended to be housed in the second inner housing volume 111B.

Although not shown in Figure 4, a HEPA-type filter, preferably a HEPA H14 type, is removably inserted between the group of sensors and devices 16 and the mask body 12.

Figure 5 shows schematically (in particular by means of a functional block diagram) a high-level architecture of the group of sensors and devices 16 comprising:

- ultraviolet illumination means 161 of the aforesaid type (i.e., having the technical characteristics described above in relation to the present invention);
- means for detecting harmful/hazardous elements/agents 162 of the aforesaid type (i.e., having the technical features described above in relation to the present invention);
- proximity detection means 163 of the aforesaid type (i.e., having the technical features described above in relation to the present invention); and
- an electronic control, processing and communication unit 164 of the aforesaid type (i.e., having the technical characteristics described above in relation to the aforesaid preferred embodiment of the present invention).

In the light of what has been explained above, the present invention provides, in essence, for the insertion within, i.e. the coupling to, a respiratory protection mask of an intelligent system capable of sharing with the community and the competent authorities data relating to the quality and composition of the air in a given environment and at the same time protecting the individual against elements/agents harmful/hazardous to the human body present in the air (e.g., elements/agents/pollutants and pathogens) by conveying, filtering and sterilising the air entering, and exiting the mask by means of breathing.

The present invention includes two main parts: an intelligent active part and a passive part which mainly includes a respiratory protection mask with integrated filter which performs the function of protection against external agents.

According to the aforesaid preferred embodiment of the present invention, the intelligent active part includes, in turn, two main parts: the part related to the sensors and devices with very low energy consumption integrated into the respiratory protection mask (i.e., the aforesaid group of sensors and devices 16) and an algorithmic and computational intelligence part integrated into an electronic device, preferably portable (e.g., smartphone, smartwatch, tablet, etc.), provided with sufficient processing resources and a graphical user interface. In more detail, the sensors and devices are integrated within a detachable section of the mask and by means of a microprocessor and radio frequency (RF) transceiver, e.g. based on Bluetooth technology, exchange data and commands towards the external electronic device which processes such raw data to provide complex high-level functions to the user. Such data can be shared within a community and optionally made available to the competent authorities, for example in the case of environmental alert situations.

The intelligent active part of the invention may conveniently evolve by using additional sensors/actuators/devices to implement new functions. Even without this intelligent active part, the passive part continues to provide, through the filter, the basic function of respiratory protection against external agents present in the air.

The sensors and devices integrated into the mask have as their primary objective the detection and transmission of data regarding the degree of contamination of the air with respect to volatile organic compounds (VOC) of various kinds and pathogenic microorganisms. In particular, the use of ultraviolet illumination means makes it possible to increase

the protection capacity of the filter placed within the mask by using, for example, one or more UV-C LEDs with a wavelength preferably centred at 265 nm (for which the germicidal and sanitising capacity is known and demonstrated). Conveniently, the positioning of the LEDs is such as to avoid direct illumination of the skin of the face of the user wearing the mask. The signals generated by the various sensors can be conveniently collected and digitized by a microprocessor and subsequently transmitted via RF signals (e.g., Bluetooth) to the computing section implemented (e.g., via a suitable dedicated software application - or, simply, app) on a portable electronic device (e.g., smartphone, tablet, smartwatch, etc.) that analyses and exhibits the results to the user, who can share such data with the community, as well as with the competent authorities (e.g., in Italy, with the Civil Protection in case of environmental emergencies). There is further provided an integrated, rechargeable power supply part that can power the sensors and the devices integrated in the mask for a certain period (e.g., 2/3 hours). The long-life mode of use can be conveniently ensured by the connection with a USB cable (e.g. micro USB type) to an external power supply device (e.g. power bank) or the portable electronic device itself, sharing the battery thereof. Proximity detection means of (preferably, means for detecting and measuring distance with respect to) other masks of the same type (used by other individuals) are also conveniently provided. In this way it is possible to guarantee the function of proximity detection either when moving away or closer to a threshold to be set.

The passive section of the mask is conveniently reusable many times after proper cleaning thereof by simply washing it with water and detergent, while the filter is the only disposable part of the device that needs periodical replacement.

Thus, the present invention concerns an intelligent system, i.e., a system capable of analysing raw data and

providing aggregate information to the end user in the form of high-level functions. In fact, the use of the mask and the protection filters are associated with a series of sensors and devices that provide raw data to intelligent
5 processing means that are able to analyse, aggregate and above all share them.

Therefore, the present invention makes it possible to provide the community with a tool that, in addition to providing protection against pathogens that can enter the
10 human body through breathing, also performs constant monitoring of the quality of the air and shares the data collected with the competent authorities, providing a mapping of the territory that is updated in real time. In this respect, it is worth noting that the various sensors
15 and devices integrated in the mask are already used in the context of various household products for sanitising water and masks, such as the ultraviolet illumination of UV-C LEDs (see KR20200020747A) or the air filtration systems, e.g., sensors in MOX technology (in this respect, reference can be
20 made, for example, to WO 2005/015190 A1). However, the present invention, thanks to a suitable and innovative synergistic combination of technologies which are individually per se known, allows to reach an innovative intelligent system able to provide for the monitoring and
25 sharing of data, as well as an extremely effective and efficient protection of the individual with respect to volatile elements/pollutants and pathogens.

Furthermore, the system according to the present invention has a modular and evolutionary architecture that
30 can lead to the development of increasingly elaborated functions simply by introducing new sensors/actuators/devices within the mask. Think, for example, the possibility of detecting the presence of specific pathogens, such as specific viruses, by using
35 devices (e.g., transistors) capable of detecting the CRISPR - acronym for "Clustered Regularly Interspaced Short Palindromic Repeats" (in this regard, reference can be made,

for example, to Reza Hajian et al, "*Detection of unamplified target genes via CRISPR-Cas9 immobilized on a graphene field-effect transistor*", Nature Biomedical Engineering, vol. 3, pp. 427-437, 25 March 2019).

5 The realization of the intelligent mask does not feature any particular technical difficulty as the technologies used to make it are well known and widely used (e.g., plastic injection moulding, construction of printed circuit boards and app design). Conveniently, the device meets stringent
10 reliability and safety requirements:

- redundancy of the active part with the effect of increasing the reliability and availability thereof, in view of the vital functions that the device offers to ensure the safety of the user;
- 15 • use of fluorinated polymers such as PTFE and PVDF for the realization of the passive part that offer high resistance to UV-C rays, electrical insulation, chemical and atmospheric resistance to guarantee the structural integrity of the mask over time;
- 20 • compliance with all current regulations in terms of safety of the materials and the construction processes used, ergonomic and environmental characteristics.

The idea of realizing an "intelligent" mask stems from the need to provide the user with a respiratory protection
25 equipment that differs significantly from those of the known type, not only in the capability thereof of neutralising viruses and bacteria of a size that conventional equipment are unable to neutralise, but above all for the possibility that it offers to the user to know a series of information
30 ranging from the type of elements/agents harmful/hazardous to the human body that the equipment is blocking, to information related to the presence of other persons in the vicinity of the user, up to the possibility of carrying out the detection of pathogens thanks to the use of transistors
35 capable of reading CRISPRs. Therefore, the system according to the present invention performs not only the function of individual protection, but allows to collect and share in

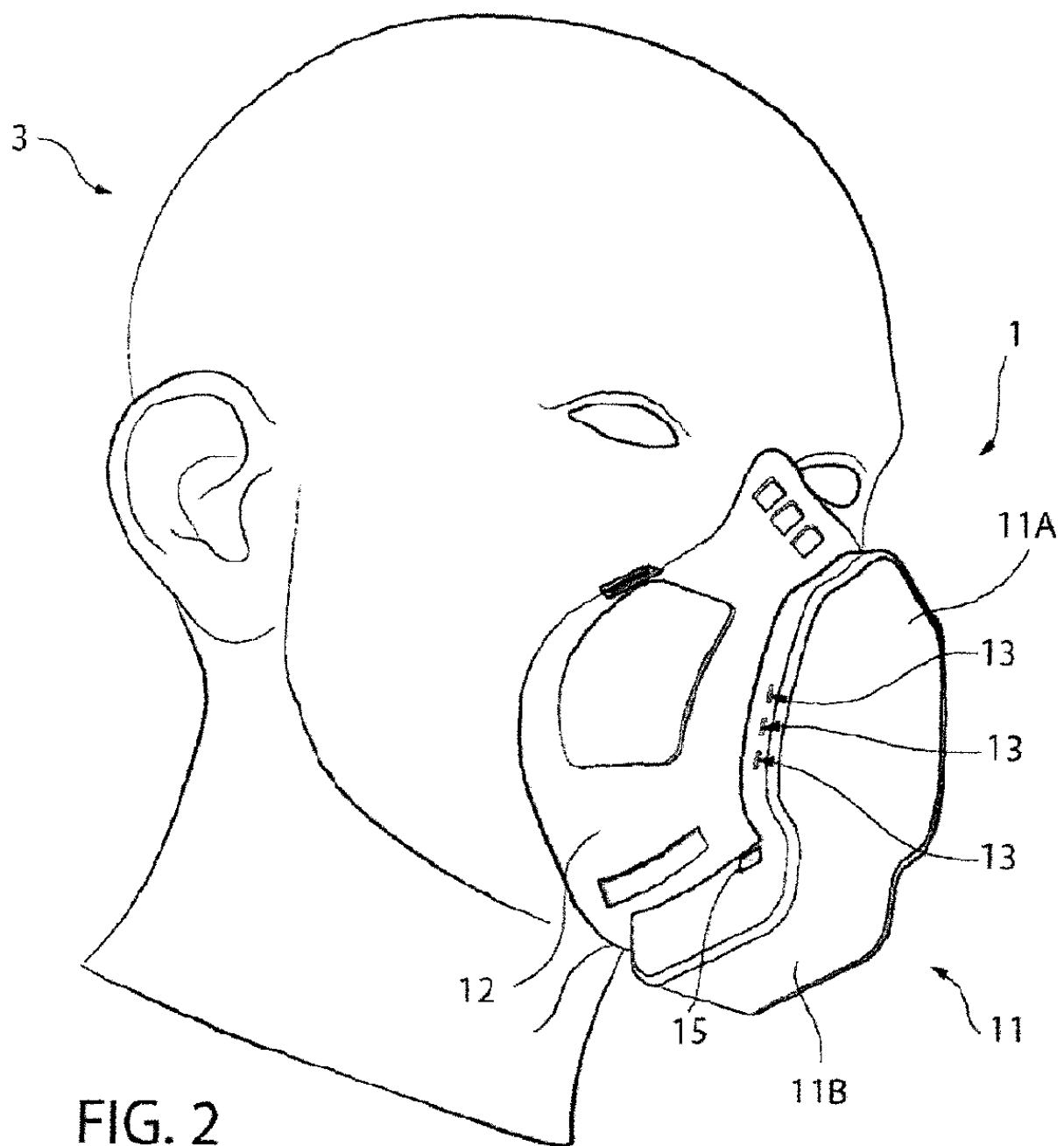


FIG. 2

also be provided to allow the mask to fit male, female and children/youth faces.

As explained above, the passage of air is allowed through a series of openings/slots arranged on the sides of the mask.

5 The shape and the orientation of these openings/slots are such as to allow air to pass through and remain for a sufficient time for the sanitising action of the UV-C rays, while at the same time preventing the latter from coming out from the outer casing of the mask. In addition, in order to

10 prevent UV-C rays from reaching the user's skin, additional internal passages/structures may be conveniently provided in the mask to prevent ultraviolet light from travelling to the user's face. The filter can be conveniently housed close to

15 such internal passages/structures with a relative blocking grid so as to allow the passage of air, while placing an additional obstacle to the propagation of UV-C rays towards the user.

As regards the filter inserted in the mask, as explained above, a HEPA H14-type filter is preferably used. The choice

20 of this type of filter was made by comparing the data relative to the protective efficacy of the filters contained in the conventional protection equipment and the HEPA-type filters which were found to have a higher degree of protection. In fact, the HEPA filters belong to the category

25 of the so-called "absolute filters", where the term "absolute filter" is justified by the fact that HEPA filters have a high filtration efficiency. In particular, the HEPA filters have a filtering efficiency ranging between 85% (H10) and 99.995% (H14) and are classified according to the filtering

30 efficiency of 0.3 μm particles, in accordance with UNI EN 1822 standards. They are, in fact, grouped into 5 classes (from H10 to H14) with increasing performance characteristics. These filters are typically tested using the dioctyl phthalate aerosol dispersion method (DOP test):

35 the calculated efficiency is greater than 99.999% with particles with a diameter of 0.3 μm (penetration 0.001%).

Although very effective, these filters still have two

criticalities:

1) do not offer sufficient protection against the penetration of particles smaller than 0.3 μm in diameter;

2) like all filters, also HEPA filters have a duration that cannot be quantified in a specific way, since much depends on the type of filter, but above all on the use that is made of it; furthermore, the great difference also depends on the maintenance of the filter; in fact, it should be regularly disassembled, cleaned and washed; these operations should be done strictly by hand, with delicate products, to avoid damaging the filtering capacity irreparably.

The present invention solves both criticalities thanks to the presence of a UV-C light source capable of activating a sterilisation method called UVGI (acronym for "UltraViolet Germicidal Irradiation"). In fact, this sterilisation method uses ultraviolet (UV) light at the UV-C wavelength, which by modifying the DNA or RNA of microorganisms prevents them from reproducing or being harmful. It is used in a variety of applications, for example for disinfection of food, water and air. Using a UVGI device creates a deadly effect on pathogenic microorganisms, viruses and moulds. The UVGI devices used in conjunction with a filtration system allow hazardous microorganisms to be removed from these environments.

The Applicant has carried out experimental tests to verify the inactivation of SARS-CoV-2 by means of a jig structured analogously to the air filtration part according to the present invention. In particular, the inactivation percentage was tested by placing 4 drops in the corners of the filtering structure, in which 200 μl of a viral suspension with a concentration equal to 19.5 viral particles/ μl was deposited. The chamber was then closed and the UV-C LED was switched on for 30 seconds. 4 tests were performed by increasing the number of lit LEDs from test after test (i.e., 1 lit LED, 2 lit LEDs, 3 lit LEDs, 4 lit LEDs). Considering the case of the single lit LED, a result of 4 log of inactivation was obtained on all 4 drops. In the

case of 2 or more lit LEDs, a 100% inactivation percentage was achieved.

From the foregoing disclosure, the many innovative characteristics and the innumerable technical advantages of the present invention are immediately evident for a person skilled in the art.

In particular, it is important to underline the fact that the system according to the present invention allows to obtain a multiplicity of advantages thanks to the sophisticated constructive philosophy which makes it a tool of sure value and very high reliability. This tool is useful in all operating contexts, whether in the medical-hospital setting, or workplaces that require the simultaneous and close presence of several persons, or in any case crowded places where the need to know the degree of contamination of the air being breathed is of fundamental importance. Such monitoring information is conveniently processed via a dedicated app and can be conveniently shared in real time with all of the user's contacts, as well as with the competent authorities, e.g. by reporting the presence of contaminated areas thus significantly reducing the possibility of other persons accessing them.

Furthermore, a user who has to work in a contaminated environment (e.g. in a hospital or on board a plane, train or ship) has a highly effective protection tool at his disposal thanks to the use of UVGI technology, which further defends him against threats caused by particles having a diameter smaller than 0.3 μm (e.g. viruses and bacteria).

The possibility of recharging the battery integrated in the mask through widely used tools, such as PCs, tablets, smartphones or power banks, makes the use thereof reliable and safe even for prolonged periods. Moreover, among the advantages of the invention, it is also worth highlighting the possibility of having a power reserve in all those cases in which the external source of energy is lacking for any reason, allowing a user to safely complete activities that cannot be postponed. Conveniently, a special autonomous

acoustic signalling system could alert the user when the battery is about to run out, or in the event that, for any reason, the connection with the smartphone should be lost or interference should occur that would make the connection
5 difficult.

The mask can be sanitised after each use by immersing it in a soap and water solution (which requires simple operations of removal of the filter, battery and printed circuit board).

10 Moreover, thanks to the germicidal effect of the ultraviolet light source that invests the filter, the latter will be constantly sanitised with a relative extension of its useful life.

In the following Table 2, a brief comparison is presented
15 between the system according to the present invention, in particular the related mask-type PPE, and the most common currently known mask-type PPE.

20

TABLE 2

PPE typology	Virus and bacteria inactivation	Hermeticity	Filtering efficiency of particles with diameter $\leq 0.3 \mu\text{m}$	Reusable / Recyclable
Mask according to the present invention	<u>YES</u> (99.99% effectiveness)	<u>YES</u>	<u>YES</u> (Minimum effectiveness of 95%)	<u>YES</u>
Cotton mask	<u>NO</u>	<u>NO</u>	<u>NO</u>	<u>NO</u>

Surgical mask	<u>NO</u>	<u>NO</u>	<u>NO</u>	<u>NO</u>
FFP3	<u>NO</u>	<u>NO</u>	<u>YES</u> (Minimum effectiveness of 95%)	<u>NO</u>
Respirator	<u>NO</u>	<u>YES</u>	<u>YES</u>	<u>YES</u>

In conclusion, it is important to note that, although the invention described above makes particular reference to well-defined examples of embodiment, it is not to be
5 considered limited to such examples of embodiment, as all the variants, modifications or simplifications covered by the attached claims fall within its scope.