

MICROBICIDAL AIR FILTER

FIELD OF THE INVENTION

The present invention concerns air filters, more particularly microbicidal air
5 filters.

BACKGROUND OF THE INVENTION

Removing airborne pathogens and environmental allergens is very important in
environments that require high levels of air purity, such as in hospitals and in
houses of people suffering from severe allergic responses to the aforesaid
10 allergens. Typically, devices in the form of masks or in-air duct filters filter out
particulate material during either air circulation or, in the case of facemasks,
during inhalation and exhalation. The facemasks and air duct filters temporarily
capture the pathogens and allergens, and particulate matter such as dust, on a
surface of a filtering material. Once the filters reach a threshold limit or after a
15 single use, they are typically discarded or in some cases, cleaned and reused.
Many designs of filtering devices exist, examples of which are as follows:

- US Patent No. 1,319,763, issued October 28, 1919, to Drew for "Air filter
for wall registers";
- 20 • US Patent No. 3,710,948, issued January 16, 1973, to Sexton for "Self-
sustaining pocket type filter";
- US Patent No. 3,779,244, issued December 18, 1973, to Weeks for
"Disposable face respirator";
- 25 • US Patent No. 3,802,429, issued April 9, 1974, to Bird for "Surgical face
mask";
- US Patent No. 4,197,100, issued April 8, 1980, to Hausheer for "Filtering
member for filters";
- US Patent No. 4,798,676, issued January 17, 1989, to Matkovich for
"Low pressure drop bacterial filter and method";

- US Patent No. 5,525,136, issued June 11, 1996, to Rosen for "Gasketed multi-media air cleaner";
- US Patent No. 5,747,053 issued May 5, 1998, to Nashimoto for "Antiviral filter air cleaner impregnated with tea extract";
- 5 • US Patent No. 5,906,677, issued May 25, 1999, to Dudley for "Electrostatic supercharger screen";
- US Patent No. 6,036,738 issued March 14, 2000, to Shanbrom for "Disinfecting gas filters";
- 10 • US Patent No. 6,514,306 issued February 4, 2003, to Rohrbach et al. for "Anti-microbial fibrous media".

The aforesaid designs suffer from a number of important drawbacks. Disadvantageously, in the above-mentioned designs removal of the dirty filter or the facemask after use may cause non-immobilized pathogens or particulates to be dispersed into the air immediately around the user, which, if inhaled may be hazardous to the user. In addition, the designs may not immobilize the air borne pathogens and kill them in situ. Some of the designs incorporate viscous material into the filter material to capture particulate material. Some designs incorporate complex arrangements of filters inside cartridges, which may be impractical for use in air ducts or in facemasks. In some cases, fiberglass is used as part of the filter medium, which may be harmful to humans if located near the nose and mouth. In one design, disinfectant soaked cotton wool appears to be located in an air duct for aerosolizing into a room to maintain moisture content. Use of such a wet disinfectant may be harmful to humans in close proximity to the disinfectant and may not be appropriate for use in a facemask. Another filter media uses fibers having cavities filled with antibacterial agent for slow release there from. Another design discloses the fiber manufactured with antibacterial agent therein that freely detaches there from upon blooming of the fibers. These fiber designs have the problem of a rapid lost of their antibacterial activity upon cleaning or washing thereof.

Accordingly, there is a need for an improved microbicidal air filter.

SUMMARY OF THE INVENTION

- Embodiments of the present invention may reduce the difficulties and disadvantages and solve the problems of the prior art by providing a
- 5 microbicidal air filter, which may capture and kill pathogenic microbes on a novel immobilization network of fibers. To achieve this, the fibers include an antimicrobial agent incorporated into their structure, during manufacturing of the fibers, for the latter to substantially kills the microbes getting in proximity thereto. The antimicrobial agent is internally and externally secured to the structure of
- 10 the fibers with strong molecular bonds. This can significantly reduce or essentially eliminate the problems associated with further release of the microbes from the filter after use and during disposal. Advantageously, the filter can be used as a facemask or in air-circulation ducts, typically as an after-filter or downstream of a filter, and can capture and kill a wide variety of microbes.
- 15 The fibers can be made of a material, such as but not limited to polyvinyl chloride (PVC) based materials, which enables the filter to be washed and reused, almost indefinitely, without significant loss of antimicrobial activity because of the molecular bonds between the antimicrobial agent and the structure of the fibers.
- 20 In accordance with an aspect of the present invention, there is provided a microbicidal air filter for use with an air passageway, said air filter comprising: an immobilization network including a plurality of fibers having an amount of at least one antimicrobial agent incorporated and molecularly bonded into a structure thereof sufficient to substantially immobilize, retain and at least inhibit
- 25 the growth of, or typically kill, microbes suspended in a volume of air moving through said air passageway, said immobilization network being substantially permeable to said air.
- In one embodiment, the immobilization network is an after-filter so that the air is pre-filtered prior reaching the air passageway.
- 30 In one embodiment, the air filter is a facemask configured and sized to fit over the nose and mouth of a user and to be secured therearound.

In one embodiment, the air filter is an air duct filter configured and sized to fit in an air duct system forming the air passageway.

Typically, the air filter further includes: first and second air permeable screen elements securable together along respective peripheral edges, said screen elements being configured and sized to fit in the air duct system and to be secured therein; said air permeable immobilization network being located substantially between said first and second screen elements.

Conveniently, a fastening member connects said first and second air permeable screen elements together to sandwich said immobilization network therebetween.

Typically, the fastening member includes a frame for connecting said first and second screen elements together.

Conveniently, the fastening member further includes a plurality of stitches located through said immobilization network to divide said immobilization network into subdivisions.

In accordance with another aspect of the present invention, there is provided a microbicial face mask comprising: first and second air permeable screen elements secured together along respective peripheral edges, said screen elements defining a gap therebetween, said screen elements being configured and sized to fit over the mouth and nose of a user and to be secured thereto; an air permeable immobilization network located in and substantially filling said gap, said immobilization network including a plurality of fibers having an amount of at least one antimicrobial agent incorporated and molecularly bonded into a structure thereof sufficient to substantially immobilize, retain and at least inhibit the growth of, or typically kill, microbes suspended in a volume of air moving through said network.

In one embodiment, the first air permeable screen element includes a slit located therein of sufficient size to allow said immobilization network to be positioned in said gap.

- 5 Further advantages and objects of the invention will be in part obvious from an inspection of the accompanying drawings and a careful consideration of the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

10 In the annexed drawings, like reference characters indicate like elements throughout.

- Figure 1** is a simplified exploded view of an embodiment of a filter;
Figure 2 is a simplified partial cutaway view of a facemask with the filter;
Figure 2a is a simplified partial cutaway view of an alternative embodiment of a
15 facemask;
Figure 3 is a simplified exploded view of an embodiment of a filter in a frame;
Figure 4 is a simplified exploded view of the filter with a primary filter;
Figure 5 is a simplified exploded view of an air circulation system with a filter;
Figure 6 is simplified front view of an alternative filter for use in the system of
20 Figure 5;
Figure 7 is a simplified front view of an alternative filter for use with the system of Figure 5, showing stitches as a fastening member;
Figure 8 is a simplified front view of an alternative filter for use with the system of Figure 5, showing rivets as a fastening member; and
25 **Figure 9** is a cross sectional view taken along lines 9-9 of Figure 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to the annexed drawings the preferred embodiments of the present invention will be herein described for indicative purposes and by no
30 means as of limitation.

Definitions

As used herein, the term "microbe" or "microbial" is intended to mean microorganisms including, but not limited to, bacteria, protozoa, viruses, molds and the like. Also included in this definition are dust mites.

5

As used herein, the term "antimicrobial agent" is intended to mean a compound that inhibits, prevents, or destroys the growth or proliferation of microbes such as bacteria, protozoa, viruses, molds and the like. Examples of antimicrobial agents as used herein include anti-bacterial agents, anti-viral agents, anti-mold

10

agents, anti-yeast agents and anti-dust mite agents, or any combination thereof.

As used herein, the terms "anti-bacterial agent", "bacteriocidal agent" and "bacteriostatic agent" are intended to mean compounds that inhibit, prevent the growth of, and/or kill bacteria.

15

As used herein, the term "anti-viral agent" is intended to mean a compound that inhibits, prevents the growth of, or kills viruses.

As used herein, the term "anti-mold agent" is intended to mean a compound that inhibits, prevents the growth of, or kills molds.

20

As used herein, the term "anti-yeast agent" is intended to mean a compound that inhibits, prevents the growth of, or kills yeasts.

As used herein, the term "anti-dust mite agent" is intended to mean a compound that inhibits, prevents the growth of, or kills dust mites.

25

As used herein, the terms "microbicidal", "biocidal" and "aseptic" are intended to refer to the inhibition, growth prevention or killing properties of any of the aforesaid "agents", used either alone or in combination with each other.

30

Preferred embodiments

Referring now to Figure 1, a first embodiment of a microbicidal air filter shown generally at 10. Broadly speaking, the filter 10 includes an air permeable

immobilization network 12, an air permeable first screen 14 and an air permeable second screen 16. The first screen 14 and the second screen 16 are merely acting to support the network 12 and to define a work area 18. One skilled in the art will recognize that the immobilization network 12 may be used
5 independently of the screens 14 and 16.

The network 12 includes a mesh of fibers 20, which can be non-woven or woven depending on whether a soft or hard (rigid) network is desired. The network 12 may also include yarn such as cotton in which the fibers 20 are
10 interwoven. Each fiber 20 includes a quantity of at least one antimicrobial agent that is fully incorporated and secured to the structure of the fiber 20 via substantially strong molecular bonds thereby providing a large permanent concentration of the antimicrobial agent over a large surface area, throughout the entire life of the fibers 20. In other words, the antimicrobial agent is within
15 the heart of the fiber 20 and bondly mixed and spread there along, there over and therein. The fibers 20 are arranged such that they are permeable to air over the entire mesh, typically as a fine layer of so-called angel's hair, of flaky mesh or the like.

20 Preferably, the network is a fibrous material. More preferably, the fibrous material is commercially available RHOVYL'AS+™, RHOVYL'AS™ (with "AS" for reference to "aseptic"), THERMOVYL-L9B™, THERMOVYL-ZCB™, THERMOVYL-MXB™ (with "B" for reference to "biocidal") or TRICLOSAN™ treated polyvinyl chloride (PVC) or the like based organic fiber.

25 Both RHOVYL'AS+™, RHOVYL'AS™, THERMOVYL-L9B™, THERMOVYL-MXB™ and THERMOVYL-ZCB™ are fibrous materials, manufactured by RHOVYL™, SA, that have intrinsic antimicrobial and/or biocidal activity. In particular, the RHOVYL'AS™ fiber, the THERMOVYL-L9B™
30 fiber and the THERMOVYL-ZCB™ fiber incorporate an antibacterial agent, which is molecularly bonded to the structure of the fiber, whereas the RHOVYL'AS™ fiber antibacterial agent, the RHOVYL'AS+™ fiber and the THERMOVYL-MXB™ fiber also contain acaricide, an anti-dust mite agent.

TRICLOSAN™ is a well known antimicrobial agent, which at least reduces the growth, and typically even kills microbes such as bacteria, yeast and molds.

5 The fibrous material is either used pure (100%) or in blends, with a percentage of at least 30% volume, along with other types of fibers within woven or non-woven type fabrics, and which meet the requirements of an individual protective equipment (IPE). The fibrous material may also have other properties including, but not limited to, non-flammability, resistance to chemical products, ignition suppression, thermal insulation, and moisture management.

10

Preferably, the antimicrobial agents include an antibacterial agent, an anti-viral agent, an anti-dust mite agent, an anti-mold agent and an anti-yeast agent.

Preferably, the anti-bacterial agent is TRICLOSAN™.

15

Preferably, the anti-dust mite agent is benzyl benzoate.

Typically, the fibrous material has porosity in the range of about 0.1 μm to about 3 μm , although this depends upon the size of microbe to be retained.

20

Typically, the fibrous material has a density of between two grams per square foot (2 gr/ft²) to thirty grams per square foot (30 gr/ft²). More preferably, the density is around ten grams per square foot (10 gr/ft²).

25 As best illustrated in Figure 2, the filter 10 may be part of a facemask 24 of the type normally used by hospital workers and the like and which could be expandable (soft mask) or not (rigid mask), that are sometimes used in areas with pre-filtered air. The screens 14 and 16 are typically connected around a peripheral edge 22 and define a gap 23 therebetween. The network 12 can be
30 attached to one of the aforesaid screens to provide both a physical barrier against particulate material and more importantly, to pathogenic microbes. The network 12 can be attached to the screens 14 or 16 using a VELCRO™ type fastener, stitches, bonding and the like, or inside an individual portable mask 24 that are worn in front of the nose/mouth area of the individual. A front mask

screen 25 of the mask 24 acts as a primary filter located upstream of the network 12 to pre-filter the air by removing particulate material and microbes from the air passing therethrough along an air passageway, as shown by the arrows.

5

Alternatively, as best illustrated in Figure 2a, the network 12 may be located between the front screen 25 and a rear screen 27, such as commercially available filter masks, in the gap 23 of the facemask 24 to create a two-way system of filtration, as shown by the arrows. The front screen 25 may include a slit 29 to allow the network 12 to be inserted into the gap 23. This type of facemask 24 may be useful for people who are suffering from a respiratory infection and who still wish to work yet, don't wish to infect others by exhaling breath contaminated with pathogenic microbes.

10

15 The screen elements 14, 16 can have different sizes and shapes and can be simple typical flexible or semi-flexible type screens as illustrated in Figure 1, made from aluminum, nylon, thermoplastic material, fiberglass type materials (usually not approved for mask applications), woven type fabrics or the like. As shown in Figure 3, the screen elements 14, 16 and the network 12 can be supported by a rigid frame 26, such as a standard aluminum screen frame, that is divided into two parts 28, 30 and integral with the screen elements 14, 16 respectively, to ensure rigidity and ease of installation. A fastening member 32 may be used to releasably connect the two screen elements 14, 16 together with the network 12 sandwiched therebetween and compressed to prevent it from being displaced by the air flowing therethrough. The fastening member 32 may be a pivoting retainer pivoting on one of the parts 28, 30 to retain the other part against the same. Alternatively, as best illustrated in Figure 4, a rigid screen 34 of any existing air filter 36 may also be used.

20

25

30 Referring now to Figures 5 and 6, the filter 10 is illustrated installed inside an air duct 38 downstream of the air filter 36 and upstream of an air heating system 40 (the arrows in Figure 5 show the air passageway) such that the air passing through the network 12 could be pre-filtered such that the network 12 acts as an after-filter, thereby being more efficient since most of the particulate material or

dirt contained in the air is removed there from before reaching the network. The frame 26 generally encloses the screen elements 14, 16 but also includes intermediate reinforcing rods 42 used to subdivide the screen elements 14, 16 into a plurality of smaller sub-elements 44 to constrain the network 12 to remain in place between the two elements 14, 16. Alternatively, as best seen in Figure 6, the frame 26 is a thin metallic rod onto which the screens 14, 16 are attached, with reinforcing rods 42 providing additional support to the screen elements 14, 16 and to the network 12 and to provide the aforesaid sub-elements 44.

10

Referring now to Figures 5, 7, 8 and 9, other types of fastening members 32 are illustrated. One preferable type of fastening member 32 includes a plurality of stitches 46 which may be arranged in a variety of patterns, for example wavy lines or straight lines. The stitches 46 pass through the network 12 and divide the network into subdivisions 44, as previously described. Alternatively, as best illustrated in Figure 8, the fastening members 32 may also include rivets 48, which pass through the network 12.

15

EXAMPLES

The present invention is illustrated in further detail by the following non-limiting examples.

Example 1

Evaluation of microbicidal and filtering capacity of rigid and soft facemasks

As shown in Table 1, two facemasks of the present invention were compared to a commercially available facemask^{1,2,3} for their antimicrobial and retaining capabilities against a panel of bacteria and molds of various sizes^{4,5,6,7}. The NB rigid and soft masks used in Examples 1 and 2 were both equipped with a network 12 of PVC based organic fiber containing molecularly bonded TRICLOSAN™. The NB soft mask was composed of a double covering of woven type fabric containing 76% w/w THERMOVYL-ZCB™ fibers and 24% w/w polyester (although any other woven type fabric such as cotton or the like could have been used) stitched to each other at their periphery, within which the network 12 was located (see Figure 2a above). The NB rigid mask was

25

30

made of two conventional commercially available anti-dust masks, which were inserted one inside the other, between which the network of PVC based organic fiber containing TRICLOSAN™ was located.

- 5 An air contamination chamber^{5,8,9} was used to measure the filtering capacity of a mask containing the network. The chamber includes a perforated bottle containing a predetermined quantity of lyophilized microorganisms. The chamber is installed on a microbiologic air-sampler. The test mask was installed at the interface between the contaminated air chamber and the air
10 sampler. A negative pressure was generated in the air chamber, which caused the lyophilized microorganisms to move towards the mask. A culturing medium was located downstream of the mask to detect any breakthrough of the mask.

TABLE 1

15

Microorganisms	Size (µm)	Filtration efficiency (%)		
		NBRM	NBSM	3M*
Bacteria				
Mycobacteria tuberculosis	0.2-0.7 x 1.0-10	100	100	95
Proteus spp.	0.4-0.8 x 1-3	100	100	
Pseudomonas aureginosa	0.5-1.0 x 1.5-5	100	100	
Staphylococcus aureus	0.5 x 1.5	100	100	
Streptococcus pneumoniae	0.5-1.5	100	100	
Haemophilus influenzae	1	100	100	
Anthrax	1-1.5 x 3-5	100	100	
Moulds				
Acremonium strictum	3.3-5.5 (7) x 0.9 x 1.8	100	100	96
Aspergillus versicolor	2-3.5	100	100	
Penicillium griseofulvum	2.5-3.5 x 2.2-2.5	100	100	
Neosartorya fischeri	2 x 2.5	100	100	

NBRM=Rigid mask

NBSM=Soft mask

* Data from technical specification²

20

Example 2*Evaluation of filtering of small particles*

The filtering capacity of the three masks of Example 1 was tested against two particulate materials of 0.3 μm particle size using essentially the same apparatus as in Example 1. A cartridge capturing membrane located downstream from an air pump, in this case, captured breakthrough particulates. The air pump creates a negative pressure downstream of the mask. The two particulate materials chosen were sodium chloride and dioctyl phthalate.

10

TABLE 2

Particulate material	Size (μm)	Filtration efficiency (%)		
		NBRM	NBSM	3M*
Sodium chloride (NaCl)	0.3	100	100	95
Dioctylphthalate (DOP)	0.3	100	100	

NBRM=Rigid mask

NBSM=Soft mask

15 * Data from technical specification²Example 3*Evaluation of microbicidal and filtering capacity of a ventilation system filter*

The antimicrobial capacity of a filter of the embodiment of Figure 3 with RHOVYL'AS+™ fibers was evaluated after 0, 7, 14, and 21 days installation in a ventilation system in a house. The results are illustrated in Tables 3 to 6 below.

The filters were removed after the aforesaid times and analysed using the Samson method¹⁰. The fibrous material (1 g) of each filter was diluted with demineralised, sterilized water (9 mL) and then serially diluted.

The calculation of total amount of bacteria, yeast and molds were done using hemacytometry. The calculation of the total amount of viable bacteria, yeasts and molds were determined following a culture of the serial dilutions on appropriate media. The aerobic viable bacteria were cultured on soya agar-

agar (TSA, Quelab), whereas the yeasts and molds were cultured on HEA supplemented with gentamycin (0.005% p/v) and oxytetracycline (0.01% p/v) to limit bacterial growth. HEA's pH of 4.8 +/- 0.2 allows the germination of spores and development of mycelens. After the incubation period, the calculation of microbial colonies was carried out using a colony meter (Accu-Lite™, Fisher). The morphotype of the bacterial colonies was identified by Gram staining (see Table 5).

Concerning the yeasts and molds calculation, each macroscopically distinct mold colony was identified by gender and/or species using microscopy.

Mold slides were prepared using the adhesive tape method¹¹. This technique maintains the integrity of the mold structures by fixing them on the sticky side of the tape. Once collected, the molds were stained with lactophenol and observed at a magnification of 10x and 40x. Using identification keys^{12,13,14,15}, the molds were identified. In this experiment only colonies that produced spores were identified.

TABLE 3: Bacterial filtering

After filter Time (days)	Calculated bacteria (UFC/g)		
	Viable	Non-viable	Total
0	6000 (3.43%)	169000 (96.57%)	175000 (100%)
7	9000 (2.75%)	318000 (97.25%)	327000 (100%)
14	27000 (2.21%)	1193000 (97.79%)	1220000 (100%)
21	70000 (1.88%)	3650000 (98.12%)	3720000 (100%)

TABLE 4: Fungal filtering

After filter Time (days)	Calculated fungi (UFC/g)		
	Viable	Non-viable	Total
0	29000 (11.74%)	218000 (88.26%)	247000 (100%)
7	110000 (10.19%)	970000 (89.81%)	1080000 (100%)
14	230000 (8.75%)	2400000 (91.25%)	2630000 (100%)
21	1640000 (7.24%)	21000000 (92.76%)	22640000 (100%)

TABLE 5: Identification of bacterial morphotypes

After filter (days)	Bacterial morphotypes
0	78.4% Cocci Gram positive 21.6% Rod Gram negative
7	84.3% Cocci Gram positive 15.7% Rod Gram negative
14	86.7% Cocci Gram positive 13.3% Rod Gram negative
21	88.9% Cocci Gram positive 11.1% Rod Gram negative

TABLE 6: Identification of mold species

After filter (days)	Mold species
0	<i>Aspergillus niger</i> , <i>Cladosporium cladosporioides</i> , <i>Cladosporium herbarum</i> , <i>Penicillium sp.</i> , yeasts
7	<i>Aspergillus niger</i> , <i>Cladosporium cladosporioides</i> , <i>Cladosporium herbarum</i> , <i>Penicillium sp.</i> , yeasts
14	<i>Alternaria alternata</i> , <i>Arthrinium sp.</i> , <i>Aspergillus niger</i> , <i>Cladosporium sp.</i> , <i>Geotrichum sp.</i> , <i>Penicillium sp.</i> , yeasts
21	<i>Aspergillus niger</i> , <i>Cladosporium cladosporioides</i> , <i>Cladosporium herbarum</i> , <i>Penicillium sp.</i> , yeasts

5 Example 4

Evaluation of antimicrobial activity after extensive washing antibacterial of woven fiber samples

- In order to ensure the antimicrobial fibers of the present invention retain their antimicrobial activity after multiple cleaning and washing, respective samples of
- 10 woven THERMOVYL-L9B™ and THERMOVYL-ZCB™ fibers with molecularly bonded TRICLOSAN™ agent were tested. Three (3) samples of each fiber types were submitted to multiple successive cleanings and tested for antibacterial activity against growth of two bacteria, namely *Staphylococcus aureus* and *Escherichia coli*, after five (5), ten (10) and one hundred (100)
- 15 washes, respectively. One (1) witness reference sample of each fiber type without any antimicrobial agent was also similarly tested after five (5) washes. The results are summarized in Table 7 below.

TABLE 7

Bacteria	Fiber	Number of Washes	Bacteria Inhibition Zone Size (mm)	Bacteria Growth / Antimicrobial Efficiency
S. aureus	Thermovyl-L9B	5	12.5	None / High
		10	13	None / High
		100	14.75	None / High
	Thermovyl-ZCB	5	12.125	None / High
		10	12.625	None / High
		100	16.75	None / High
	Thermovyl-L9*	5	0	Medium / Poor
	Thermovyl-ZC*	5	0	Medium / Poor
E. coli	Thermovyl-L9B	5	5.125	None / High
		10	6.125	None / High
		100	8.125	None / High
	Thermovyl-ZCB	5	5	None / High
		10	5.375	None / High
		100	9.375	None / High
	Thermovyl-L9*	5	0	Medium / Poor
	Thermovyl-ZC*	5	0	Medium / Poor

* Without microbicidal agent

5

Discussion

To date, commercially available masks have been hampered by their inability to capture and kill in excess of 95% of microorganisms. A study of a microbicidal network of the present invention, in the form of the facemasks and filters in a ventilation system, has demonstrated a significant improvement in capturing and killing efficiency (Tables 1 to 6).

Tables 1 and 2 illustrated the effectiveness of PVC based organic fiber containing TRICLOSAN™ as particulate filters, anti-bacterial and anti-mold filters. For both the soft facemask and the rigid facemask, the anti-microbial and particulate filtering capacities were 100% compared to the corresponding capacities for a commercially available mask (95 to 96%).

Tables 3 to 7 illustrate highly efficient levels of antimicrobial and filtering capacity of the filter of the present invention. Specifically, the inventor has

demonstrated, in Tables 3 and 4, that the combined anti-bacterial, anti-fungal, and retaining capacities are each 100%.

In addition, the inventor has demonstrated that different bacterial morphotypes, as is illustrated in Table 5, were captured on the filter after zero (0) days 96.6% (78.8% and 21.6% of cocci Gram-positive and rod Gram-negative type bacteria respectively) of the whole bacteria population present on the fibers of the filter. After twenty-one days (21) 98.1% (88.9% and 11.1% of cocci Gram-positive and rod Gram-negative type bacteria respectively) were present on the fibers of the filter. This demonstrates that the efficiency of the filter remains after an extended period. As illustrated in Table 6, a variety of pathogenic molds were identified on the filter of the present invention up to twenty-one days.

If desired, the filter can be cleaned, washed, as well as resist other treatments and be reused without a significant loss of the aforesaid capacities, or even with an increase of the aforesaid capacities with increasing number of washes, as illustrated in Table 7.

A key feature of the filter 10, whether it be in the aforesaid facemasks or the circulation system duct filter, is its ability to immobilize, retain and kill or inhibit the growth of a wide variety of microbes, which come into contact with the network 12 of fibers 20. Air that is either pre-filtered, in the case of the circulation system, or inhaled/exhaled through the facemask by the user, often includes residual microbes that have either passed through the primary filter or the filter has failed to immobilize them. In the case where a person who uses the facemask of the present invention and who has an upper respiratory infection, such as influenza, tuberculosis, anthrax, severe acute respiratory syndrome (SARS) and the like, can significantly reduce or essentially eliminate further infection to other people. Similarly, air that is contaminated with pathogenic microbes can be filtered before entering into the nose and mouth area of the user. The flow of air is shown by the arrows in Figures 2, 2a, and 5, in which air contaminated with microbes is shown as hatched lines and non-hatched arrows show clean, filtered air.

References (incorporated herein by reference)

1. National Institute for Occupational Safety and Health. NIOSH respirator decision logic. Cincinnati, Ohio: Department of Health and Human Services, Public Health service, CDC, 1987:13-9; DHHS publication no. (NIOSH) 87-108.
- 5 2. TB Respiratory Protection Program In Health Care Facilities Administrator's Guide, (<http://www.cdc.gov/niosh/99-143.html>).
3. 3M Soins de santé Canada; Une protection fiable a chaque respiration; 3M® 2002.
4. MMWR; Laboratory Performance Evaluation of N95 Filtering Facepiece
10 Respirators, 1996 (December 11, 1998).
5. Edwin H.Lennette, Albert Balows, William J.Hausler, Jr.H.Jean Shadomy, 1985, Manual of Clinical Microbiology.
6. Robert A. Samson, Ellen S. van Reenen-Hoekstra, 1990, Introduction to food-borne Fungi.
- 15 7. G. Nolt, Noel R. Krieg, Peter H. A. Sneath, James T. Staley, Stanley, T. Williams, 1994, Bergey's Manual of Determinative bacteriology.
8. Fradkin A (1987) Sampling of microbiological contaminants in indoor air, In: sampling and calibration for atmospheric measurements ASTM Special Technical Publication, 957:66-77.
- 20 9. 42 CFR Part 84 Respiratory Protective Devices, (<http://www.cdc.gov/niosh/pt84abs2.html>).
10. Samson, RA. 1985. *Air sampling methods for biological contaminants*. Document de travail fourni au Groupe sur les champignons dans l'air des maisons de Santé et Bien-être social Canada, Ottawa, Ontario, K1A 1L2.
- 25 11. Koneman, W.E. et G.D. Roberts. 1985. Practical laboratory mycology. 3rd ed. Williams and Wilkins. Baltimore. MD.
12. Domsch, K.H., W. Gams et T.-H. Anderson. 1980. Compendium of soil fungi. Academic Press. London.
13. Larone, D.H. 1987. Medically important fungi. A guide to identification.
30 New York. Elsevier Science Publishing Co. Inc.
14. Malloch, D. 1981. Moulds, their isolation, cultivation and identification. Toronto: University of Toronto Press. 97 p.

15. St-Germain, G. et R.C. Summerbell. 1996. Champignons filamenteux d'intérêt médical : Caractéristiques et identification. Star Publishing Company. Belmont. CA.

CLAIMS

1. Microbicidal air filter for use with an air passageway, said air filter comprising:
 - an immobilization network including a plurality of fibers having an amount of at least one antimicrobial agent incorporated and molecularly bonded into a structure thereof sufficient to substantially immobilize, retain and at least substantially inhibit the growth of microbes suspended in a volume of air moving through said air passageway, said immobilization network being substantially permeable to said air.
2. The filter, according to claim 1, in which said at least one antimicrobial agent kills microbes suspended in the volume of air.
3. The filter, according to claim 1, in which said plurality of fibers arranged in a mesh, said mesh defining a plurality of air spaces between said fibers.
4. The filter, according to claim 3, in which said fibers are tightly woven or loosely woven.
5. The filter, according to claim 4, in which said fibers are treated PVC based organic fibers.
6. The filter, according to claim 1, in which said antimicrobial agent is selected from the group consisting of: an antibacterial agent, an anti-viral agent, an anti-dust mite agent, an anti-mold agent and an anti-yeast agent.
7. The filter, according to claim 6, in which said antimicrobial agent is TRICLOSANTM or benzyl benzoate.

8. The filter, according to claim 1, in which said immobilization network is an after-filter so that the air is pre-filtered prior reaching the air passageway.
9. The filter, according to claim 1, in which said air filter is a facemask
5 configured and sized to fit over the nose and mouth of a user and to be secured therearound.
10. The filter, according to claim 1, in which said air filter is an air duct filter configured and sized to fit in an air duct system forming the air passageway.
11. The filter, according to claim 10, in which said air filter further includes:
10 - first and second air permeable screen elements securable together along respective peripheral edges, said screen elements being configured and sized to fit in the air duct system and to be secured therein;
- said air permeable immobilization network being located substantially between said first and second screen elements.
12. The filter, according to claim 11, in which a fastening member connects
15 said first and second air permeable screen elements together to sandwich said immobilization network therebetween.
13. The filter, according to claim 12, in which said fastening member includes a frame for connecting said first and second screen elements together.
14. The filter, according to claim 13, in which said fastening member further
20 includes a plurality of stitches located through said immobilization network to divide said immobilization network into subdivisions.

15. Microbicidal facemask comprising:
- first and second air permeable screen elements secured together along respective peripheral edges, said screen elements defining a gap therebetween, said screen elements being configured and sized to fit over the mouth and nose of a user and to be secured thereto;
 - an air permeable immobilization network located in and substantially filling said gap, said immobilization network including a plurality of fibers having an amount of at least one antimicrobial agent incorporated and molecularly bonded into a structure thereof sufficient to substantially immobilize, retain and at least substantially inhibit the growth of microbes suspended in a volume of air moving through said network.
16. The facemask, according to claim 15, in which said at least one antimicrobial agent kills microbes suspended in the volume of air.
17. The facemask, according to claim 15, in which said immobilization network includes a plurality of fibers arranged in a mesh, said mesh defining a plurality of air spaces between said fibers.
18. The facemask, according to claim 17, in which said fibers are tightly woven or loosely woven.
19. The facemask, according to claim 18, in which said fibers are treated PVC based organic fibers.
20. The facemask, according to claim 15, in which said antimicrobial agent is selected from the group consisting of: an antibacterial agent, an anti-viral agent, an anti-dust mite agent, an anti-mold agent and an anti-yeast agent.
21. The facemask, according to claim 15, in which said antimicrobial agent is TRICLOSAN™ or benzyl benzoate.

22. The facemask, according to claim 15, in which said immobilization network is an after-filter so that the air is pre-filtered prior reaching the air passageway.

- 5 23. The facemask, according to claim 15, in which said first air permeable screen element includes a slit located therein of sufficient size to allow said immobilization network to be positioned in said gap.