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(54) Title: METHOD FOR REMOVING PARTICULATE MATTER IN INDOOR ENVIRONMENTS

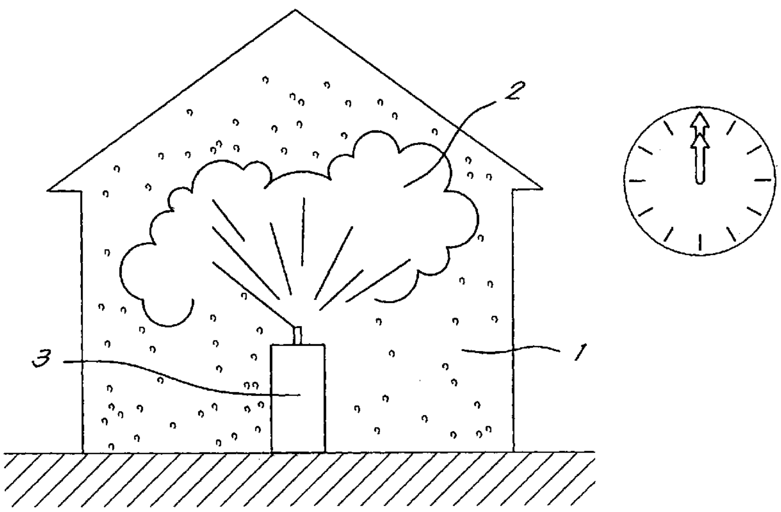

Fig.1

(57) Abstract: Method for removing particulate matter in indoor environments characterized by comprising the following two steps: - the atomization of compounds that oxidize particulate matter and soot components present in the air as aerosols, and that form complexes with these components and precipitate them; - the atomization of a liquid containing a mixture of spores of Gram-positive aerobic spore formers to act as nuclei for extra precipitation, to cover the precipitated particulate matter and soot components; whereby the drop size in both atomization steps is held between 5 and 50 µm to yield a dry nebula.

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Method for removing particulate matter in indoor environments.

The present invention relates to a method for removing particulate matter in indoor environments.

More specifically the invention is dedicated to sanitize rooms and spaces inside a building that have been contaminated by particulate matter from external sources or from internal sources such as a fire inside that building.

Particulate matter (PM) is an air pollutant comprising a mixture of solid and liquid particles suspended in the air. PM is largely composed of particles with an aerodynamic diameter (AD) of 10 µm or less. Fine particles have an aerodynamic diameter of 2,5 µm or less.

Airborne particles can be classified by size as follows :
-TSP or Total Suspended Particulates, comprising all airborne particles (AD of 0.01 µm to 100 µm);
-Coarse particles with an AD between 2.5 µm and 10 µm;
-PM10 or particles with an AD of less than 10 µm and are referred to as small particles;
-PM2.5 or particles with an AD of less than 2.5 µm, also referred to as fine particles;
-PM0.1 or particles with a diameter of less than 0.1 µm, also referred to as ultrafine particles.

groups (www.rivm.nl, Handboek Binnenmilieu 2007) :

-Condensation of hot combustion products : ultra fine particles smaller than 0.1 µm;

-Chemical reactions of air polluting gases in the atmosphere : fine particles between 0.1 µm and 2,5 µm ;

-Particles of mechanical origin such as wear, wind erosion, bulk transfer etc. : coarse particles of over 2.5 µm or small particles.

Particles can penetrate the respiratory system, the digestive system and even the blood stream. Damage to human health is caused mainly by the PM2.5 fraction : these particles have the deepest penetration in the lungs and occur even in the blood or lymphatic system (WHO air quality and health fact sheet Nr. 313 Sept. 2011).

In general, smaller particles (PM10 and smaller) and combustion-related particles are more important for health effects than larger and mechanically-formed particles.

Outdoor sources of PM like transportation, industry or agriculture will define two thirds of the PM concentration indoors.

The main anthropogenic and biogenic sources of PM in the interior of buildings are :
- tobacco smoke;
- combustion processes : fireplaces, candles, fire;

- cooking, baking and grilling;
- vacuum cleaning;
- carpets and upholstery;
- phosphate from detergents;
- plants : pollen;
- molds;
- animals : excretions and allergens.

Traditionally such PM pollution in indoor environments is countered by dispensing ionized particles into the air by air cleaning devices built for this purpose.

The ionized negatively charged particles serve as nuclei onto which contaminating particles are attracted, causing them to precipitate.

Although some relief is obtained by such ionizers, they are not capable of cleaning indoor environments that are heavily contaminated.

A specific source of a combustion process is a fire in a building. After a fire has raged in rooms and ventilation systems within a building, these places and other areas become contaminated with PM and soot due to air pressure differences created by the heat or by suction effects from ventilation shafts.

After a fire has raged, other buildings in the vicinity can be affected by the air contamination, and especially microbiological contamination can be a hazard if the nearby building is a hospital, where infections can occur caused by a fire in another building.

Soot refers to microscopic impure carbon particles resulting from the incomplete combustion of a hydrocarbon having become airborne during pyrolysis or chemical decomposition of hydrocarbons by heat. Fresh soot particles typically present hydrophobic properties.

Depending on the nature of the fire and the characteristics of the fire site, soot will penetrate and settle on various surfaces, in hollow cavities and in seams and cracks. When the temperature of the building areas increases, gases will be released from the soot, making it likely that there will be complaints of discomfort and health problems resulting from the burning smell.

Soot is in the general category of airborne Particulate Matter (PM) and as such is considered hazardous to the general health and more in particular to the lungs when the particles are less than 5 µm in diameter, since such particles are not filtered out by the upper respiratory tract.

The health risks posed by exposure to soot, soot vapors or the agents released during the off-gassing of deposited soot or soot products can vary : headache, coughing, respiratory problems and irritation of the mucous membranes of the eyes, nose and throat.

Soot often contains polycyclic aromatic hydrocarbons (PAHs) which are classified as "known human carcinogens" by the

International Agency for Research on Cancer.

If soot contamination on surfaces is 5 % or more of the dust, there is a significant possibility of persisting odor nuisance if this contamination is not removed (Freemont BV report Berlaymont building after fire 18 May 2009). The persisting nuisance is caused by the presence of carbon that reacts to changes of temperature and airflows within the environment of the building.

During ageing soot hydration properties transform from hydrophobic, through hydrophilic to hygroscopic (Popovicheva et al. J. Phys. Chem. A , 2011).

Soot becomes in the end highly hygroscopic and together with the use of extinguishing water, creates ideal conditions for growth and spreading of microorganisms. More and more scientific papers reveal the consequences of fire in buildings on survival of spores of molds (fungi) and explosive growth of them after a fire.

Morey P. R. published a study (Indoor Air, Vol. 3, Nr. 4, December 1993, pp. 354-360) concerning microbiological events after a fire in a high-rise building. The author is listing some international guidelines, based on an extensive scientific literature review, revealing that renovation and building work (after a fire) may increase the risk of mold transmission. Spores of molds are passively liberated during construction or renovation activities and can be transported over long distances in the shape of airborne particles by normal atmospheric conditions such as convection currents and wind. Morey concludes that the management of microbiological contaminants after a fire in a highrise building is an important public health concern and therefore an essential aspect of building restoration.

A case report was published by Gerson S. et al. (Infect. Control Hosp. Epidemiol. 1994; 15(4 Pt 1): 221-223) on a clustered outbreak of invasive *Aspergillus* infections in patients in a bone marrow transplant/leukemia ward whereby 13 cases of aspergillosis occurred following a fire in a nearby building and repeated opening of a window by one of the patients. All cases were confirmed histologically and by culture. Environmental investigations indicated that the ward carpet was contaminated and cases of aspergillosis were reduced to previous levels following the introduction of a water extraction cleaning procedure for the carpet.

A report was published in July 2001 by the Bureau of Infectious Diseases of Canada as a Canada Communicable Disease Report on construction-related nosocomial infections in patients in health care facilities caused by *Aspergillus* species and *Legionella* species.

The mortality rate is high for both nosocomial aspergillosis (65 % - 100 %) and legionnaires' disease (24 % - 80 %) in hospitalized populations, even when infections are recognized and treated.

More recently a case report was published by Rautiala Sirpa et al. (Journ. Of Occupational Medicine and Environmental

Health 2002; 15(3): 308-8) showing that firefighting efforts may lead to massive fungal growth and exposure within one week.

The authors declare from investigations on a fire in an office building that "concentrations of fungi in indoor air including *Aspergillus*, *Penicillium* and *Paecilomyces* approached or exceeded 10^4 colony forming units per cubic meter (cfu/m^3), and that "high concentrations of fungal spores are released to the air during the demolition of moldy building materials and the following clean-up. Therefore, personal protection is necessary during such work".

The National Disease Surveillance Centre of Dublin published in 2002 National Guidelines for the Prevention of Nosocomial Invasive Aspergillosis during Construction/Renovation Activities.

Construction-related indoor fungal aerosol pollution can create unhealthy conditions for susceptible individuals. The source of such aerosols can originate from outdoor or indoor activity, which causes the disturbance of settled spores or the disruption of a locus of growth. The release of indoor spore aerosols may be caused by activities ranging from construction to cleaning.

Airborne fungi that infect hospital patients are generally in the genus *Aspergillus*, species of which are responsible for a wide spectrum of human illnesses ranging from colonization of the bronchial tree to rapidly invasive and disseminated diseases. Invasive aspergillosis still has a high mortality rate despite new therapies, thus making prevention a high priority in the management of all at-risk patients.

Nosocomial outbreaks of aspergillosis have become a well-recognised complication of construction, demolition or renovation work in or near hospital wards in which immune-suppressed patients are housed. Airborne transmission is the principal route of transmission of *Aspergillus* within the hospital environment. The small diameter of the spores (2.5-3.5 µm) permits them to reach the pulmonary alveolar spaces. The majority of the outbreaks reported were related to contamination of the hospital air as a result of the dust and dirt raised during construction, demolition or renovation projects within or adjacent to the health care facility.

Today, national and international standards or guidelines regarding acceptable and unacceptable levels of microorganisms in air are rather limited when compared with guidelines for chemical agents. The essential difference between biological and chemical agents, is the ability to multiply! A small amount of microorganisms can grow substantially under favorable conditions of growth and pose a real health threat.

It is a purpose of this invention to provide a method to treat indoor environments to remove contamination of PM and to prevent the spread of microorganisms and dust containing pathogenic organisms not only in the affected interior spaces themselves, but also to adjacent facilities such as hospitals.

To this end the present invention provides a method for removing particulate matter in indoor environments comprising the following two steps :

- the atomization of compounds that oxidize particulate matter and soot components present in the air as aerosols, and that form complexes with these components and precipitate them;

- the atomization of a liquid containing a mixture of spores of Gram-positive aerobic spore formers to act as nuclei for extra precipitation, to cover the precipitated particulate matter and soot,

whereby the drop size in both atomization steps is held between 5 and 50 µm to yield a dry nebula.

This second step intends to suppress the development of molds by outcompeting them by benign bacteria, and to metabolize organic particulate matter and polycyclic aromatic hydrocarbons thereby preventing them to become airborne again.

An advantage of this method to treat indoor environments is that it is aimed at preventing an explosion of mold growth after a fire, which has been overlooked so far.

Another advantage is that hydrophobic soot particles will be transformed by oxidation to hydrophilic particles, which can be dissolved in water and be precipitated.

Another advantage is that the drop size of the atomization steps is such that on the one hand the drops are falling sufficiently rapidly while on the other hand they are whirled up sufficiently to reach all horizontal and vertical surfaces in the interior space.

An advantage of this method is also that the chemical first step is followed shortly thereafter by the microbiological second step thereby cleaning the interior air and enabling people to enter the interior space within one hour after the start of the treatment.

This can be achieved because residues of the oxidizing compounds of the first step are neutralized by the microbiological second step.

Another advantage of this method is that it can be carried out in a fully automated way, whereby human intervention is not needed during the treatment.

Preferably the oxidizing compounds that oxidize soot and particulate matter are hydrogen peroxide or a mixture of ethanol and o./p.-t.Bu-cyclohexylacetate and fixolide.

A typical composition of the oxidizing compounds solution would be :

Ethanol : 10-15 vol %;

o.t.Bu-cyclohexylacetate : 0.1 to 1 vol %;

p.t.Bu-cyclohexylacetate : 0.1 to 1 vol %;

Fixolide : less than 0.1 vol %

Fixolide is a bicyclic compound having the CAS Reg. Nr. 1506-02-1, and is registered in Europe as EC 216-133-4.

Preferably, the spores of Gram-positive aerobic spore formers are members of the *Bacillus* species, such as *Bacillus subtilis, Bacillus amyloliquefaciens, Bacillus pumilus, Bacillus licheniformis* and *Bacillus megaterium.*

Another advantage is that spores serve as nuclei adhering oxidized soot to their surface and precipitate it.

An advantage of these benign spores is that they can displace molds and thereby prevent explosive growth of molds after a fire has occurred.

Another advantage of this method is that the benign bacteria will metabolize organic particulate matter and polycyclic aromatic hydrocarbons so that they will not become airborne again.

It was observed that for interior spaces contaminated by tobacco smoke, good results can be obtained by using the second atomization step only and skipping the first oxidation step. The biological stabilization of the interior space by itself is already reducing most of the smell of such interior spaces.

With the intention of better showing the characteristics of the invention, hereafter, as an example without any limitative character, a preferred form of embodiment is described of an improved device, with reference to the accompanying drawings, wherein:

figure 1 schematically represents the first step of the method of the invention;
figure 2 schematically represents the second step of the method of the invention;
figure 3 represents the interior space after cleaning;
figure 4 represents the drop size distribution of the microdrops generated by the method of this invention

Figure 1 represents the first step of treatment of the interior space 1 by the atomization of an oxidizing compound 2, by means of an atomizer 3.

Figure 2 represents the second step of treatment of the interior space 1 after less than an hour, whereby a benign biological culture 4 of spores of type Gram-positive aerobic spore formers such as Bacillus species is also atomized in the same indoor environment.

Figure 3 shows the cleaned space after the two treatment steps whereby the interior space is again accessible to inhabitants one hour after the treatment has started.

Figure 4 shows the distribution of the volumetric size of the microdrops generated by the atomization steps in the method of this invention in an indoor environment. Almost all the drops are sized between 5 and 50 micrometers.

The method of this invention works by, in a first step, atomizing a solution of oxidizing compounds of which an atomizer produces small nebula drops sized between 5 to 50 micrometer.

The droplets spread in the air of the interior space and on all surfaces of it, thereby washing the air itself from particulate matter and soot flowing in the air and oxidizing the particulate matter and soot on the surfaces.

In a second step, a solution is atomized containing spores of Gram-positive spore formers 4, such as *Bacillus* species, with the following effect :

- the reduction of the remaining oxidizing agent from the first step by neutralisation ;
- the homogeneous spreading of the spores of Gram-positive spore formers through the atomization in the interior space;
- the spores of Gram-positive bacteria outgrowing the growth of molds thereby preventing an explosive growth of molds, and creating a stable and healthy microflora.

- the spores of Gram-positive bacteria metabolizing precipitated organic particles and taking up precipitated inorganic particles, thereby preventing the precipitated particles to become airborne again.

The treatment of the indoor environment is finished within one hour, making the interior space accessible to unprotected persons within a short time.

An advantage of the method is therefore that the affected rooms or interior spaces can be released very quickly for reoccupation.

The present invention is in no way limited to the form of embodiment described by way of an example and represented in the figures, however, such an improved invention for treating building interiors after contamination with particulate matter or by a fire can be realized in various forms without leaving the scope of the invention.

Claims.

1.- Method for removing particulate matter in indoor environments characterized by comprising the following two steps :

- the atomization of compounds that oxidize particulate matter and soot components present in the air as aerosols, and that form complexes with these components and precipitate them;

- the atomization of a liquid containing a mixture of spores of Gram-positive aerobic spore formers to act as nuclei for extra precipitation, to cover the precipitated particulate matter and soot components;

whereby the drop size in both atomization steps is held between 5 and 50 µm to yield a dry nebula.

2.- Method according to claim 1, characterized in that the compounds that oxidize particulate matter and soot components arehydrogen peroxide or a mixture of ethanol and o./p.-t.Bu-cyclohexylacetate and fixolide.

3.- Method according to claim 1, characterized in that the Gram-positive aerobic spore formers are members of the *Bacillus* species, such as *Bacillus subtilis, Bacillus amyloliquefaciens, Bacillus pumilus, Bacillus licheniformis* and *Bacillus megaterium*.

4.- Method according to claim 1, characterized in that the treatment of the indoor environment is finished within one hour, and makes the interior space accessible for unprotected persons after one hour.

5.- Method according to claim 1, characterized in that the spores of Gram-positive bacteria outgrow the growth of molds thereby preventing an explosive growth of molds.

6._ Method according to claim 1, characterized in that the spores of Gram-positive bacteria metabolize precipitated organic particles and take up precipitated inorganic particles, thereby preventing the precipitated particles to become airborne again.

7. Method according to claim 1, characterized in that the second atomization step only is used for treating indoor environments and skipping the first atomization step with oxidizing compounds.

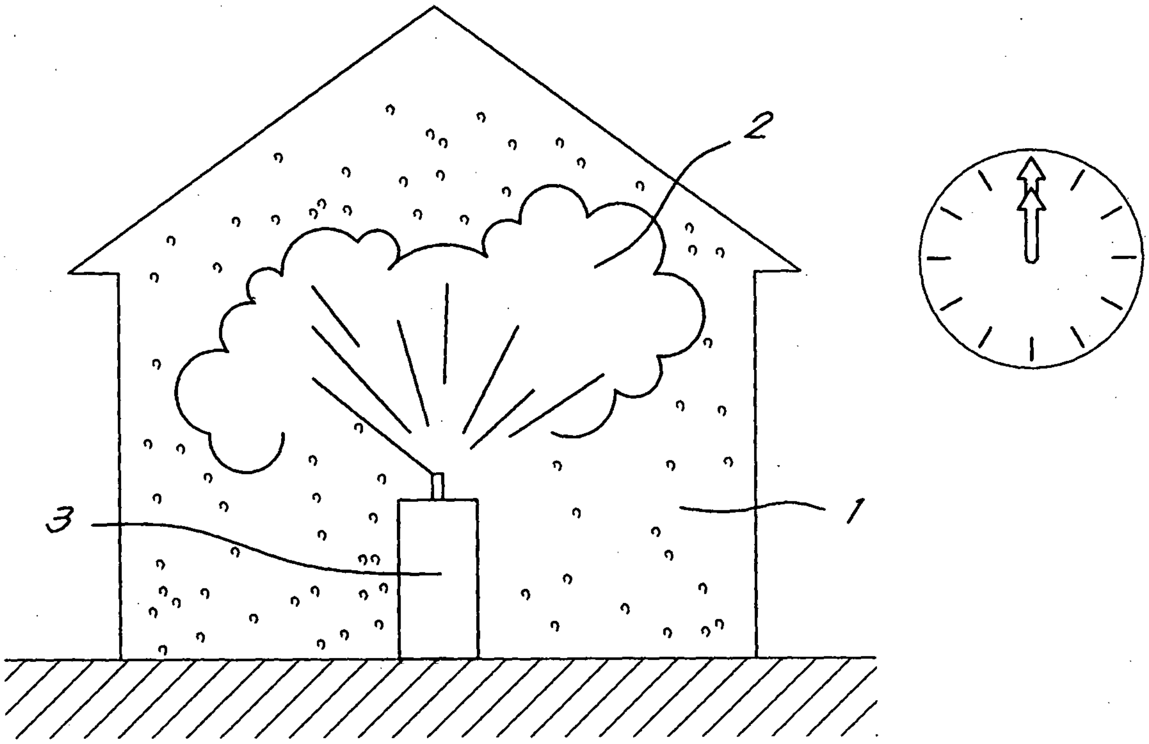

Fig.1

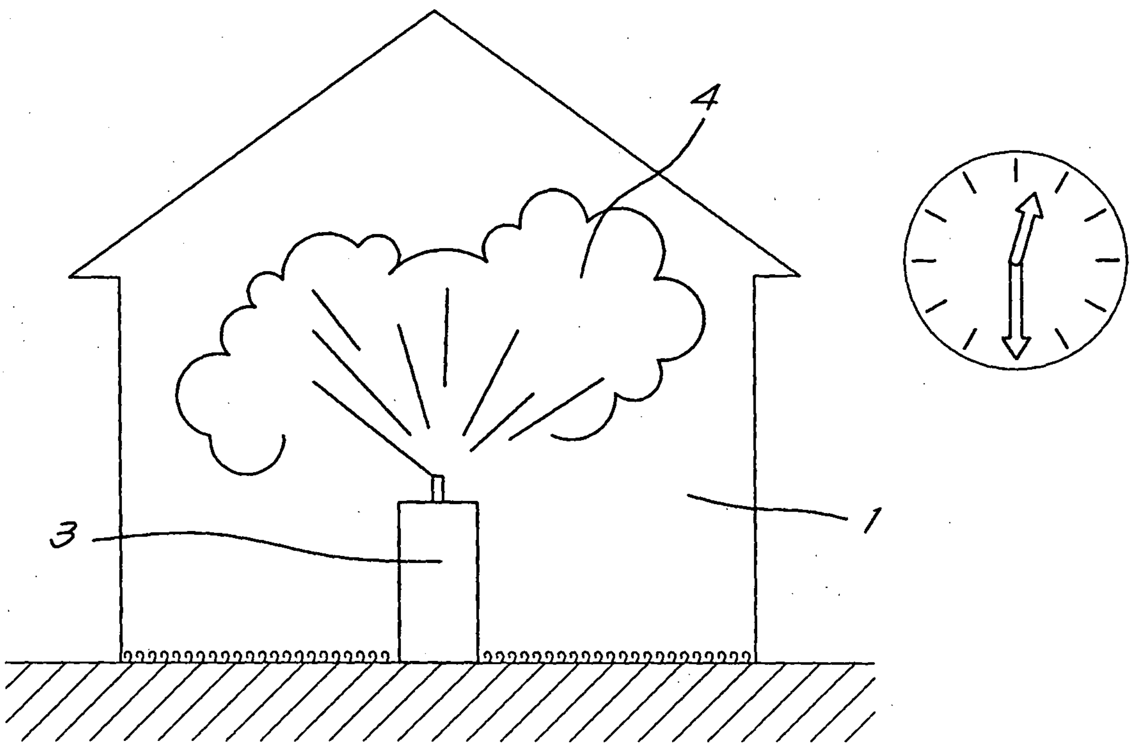

Fig.2

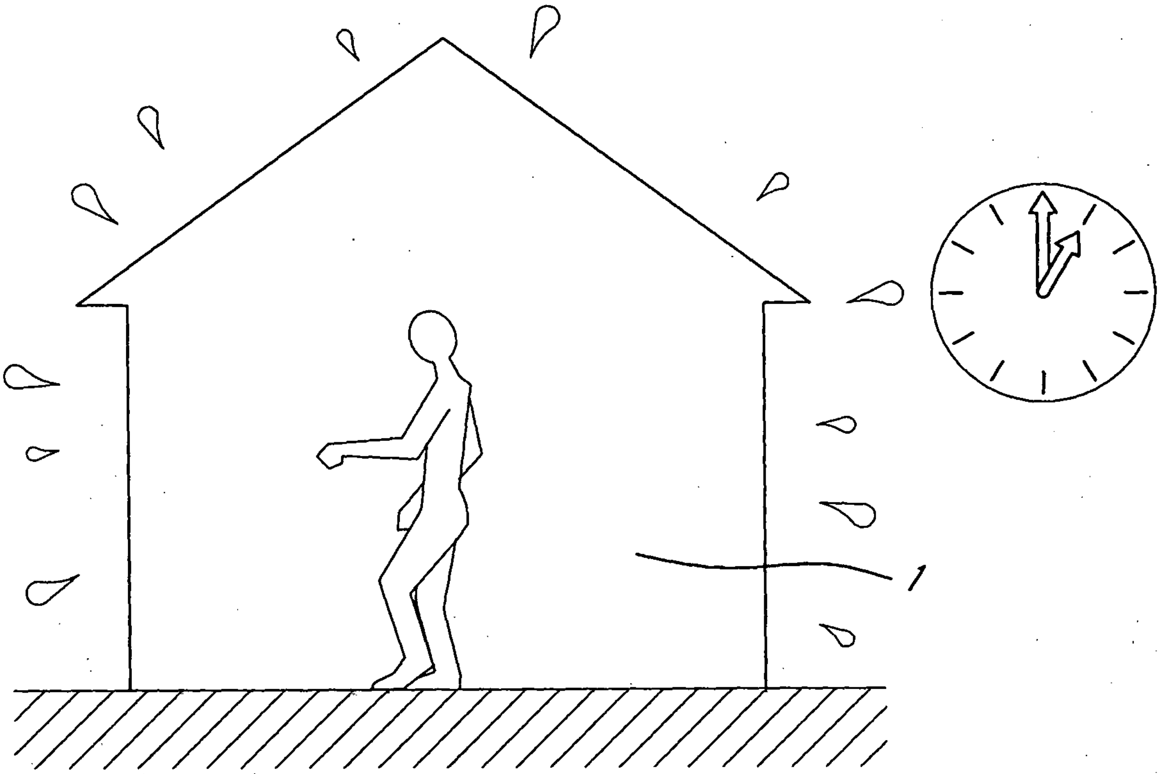

Fig.3

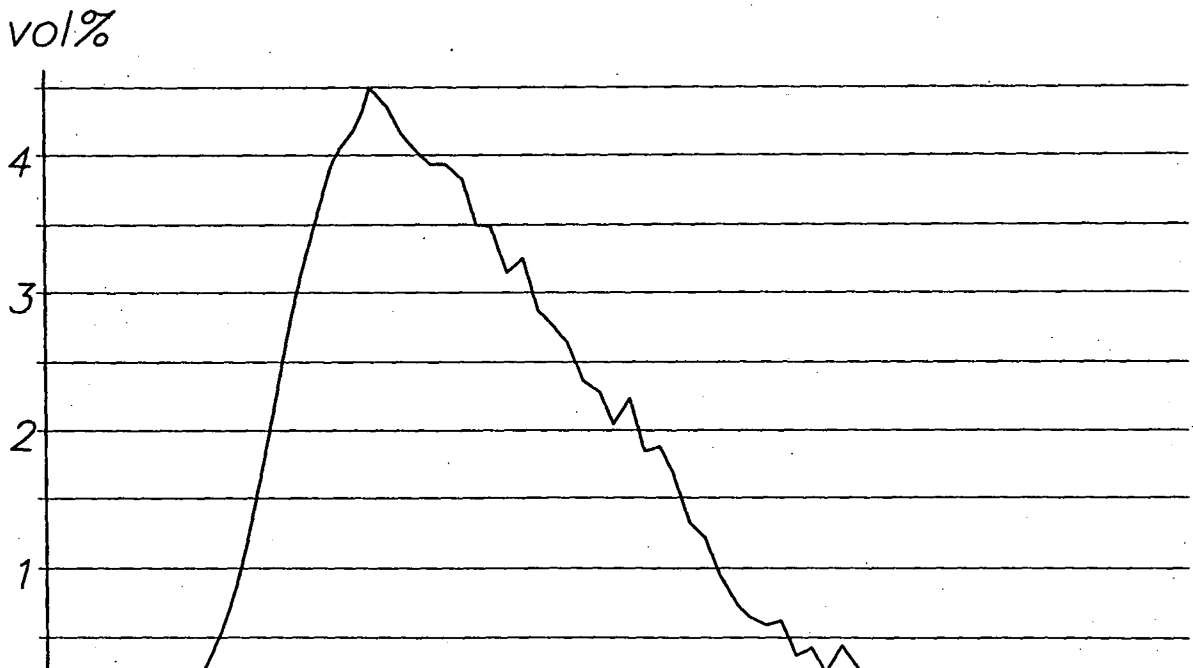

Fig.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/BE2012/000030

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61L9/14 A01N25/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61L A01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 329 893 A1 (METATECTA NV [BE]) 8 June 2011 (2011-06-08) claims 1-6	1-7
A	WO 97/25865 A1 (SYBRON CHEMICALS [US]) 24 July 1997 (1997-07-24) claim 1	1
A	"Preventing hospital infection from spreading - involves spraying with suspension of Bacillus pasteurii strain number 119 to prolong disinfecting effect", DERWENT, 31 December 1987 (1987-12-31), XP002196852, abstract	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/BE2012/000030

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2329893 A1	08-06-2011	BE 1019057 A3	07-02-2012
		EP 2329893 A1	08-06-2011
WO 9725865 A1	24-07-1997	AU 1532797 A	11-08-1997
		BR 9706998 A	20-07-1999
		CA 2241467 A1	24-07-1997
		EP 0967877 A1	05-01-2000
		JP 2000503320 A	21-03-2000
		NO 983214 A	13-07-1998
		US 5863882 A	26-01-1999
		WO 9725865 A1	24-07-1997