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New bioactive polymer filtering material composed of nonwoven polypropylene containing alkylammonium microbiocides on a perlite carrier

Summary — This article presents a new bioactive polymer filtering material obtained by the pneumothermal method from polypropylene with an active substance, alkylammonium microbiocide, as an active substance on a perlite carrier. Material with only 8 % of this bioperlite (0.37 % biocide) showed high antimicrobial activity against gram-positive and gram-negative bacteria: *E.coli, P.aeruginosa, K.pneumoniae* (99.9 % reduction), *S.aureus, M.flavus* (95 %) and fungi: *A.niger* (98 %) and *C.albicans* (94 %) after 6 hours of incubation. Bacteria *B.subtilis* were less evidently sensitive to the biocidal activity of the bioactive nonwoven fabric (86 % reduction), but material with 10 % bioperlite showed 100 % reduction of microorganisms. The application of bioperlite caused an increase in the hydrophilic character of the polymer material. It was found that an increase in the humidity of the bioactive nonwoven caused an increase in the antimicrobial properties of the material. In a test of model filtering systems that included the new bioactive nonwoven fabric with bioperlite, its high antimicrobial activity and efficient aerosol filtration for both solid and liquid particles (NaCl and paraffin oil mist) and also microorganisms (*E.coli, S.aureus*) were established. The presented filtering system with a bioactive nonwoven fabric including alkylammonium microbiocides on a perlite carrier may be applied in the production of filtering half-masks and filters in workplaces where microbiological risk occurs.
Key words: bioactive polypropylene, filtering nonwovens, antimicrobial properties, alkylammonium microbiocides, perlite, half-masks.

NOWY BIOAKTYWNY POLIMEROWY MATERIAŁ FILTRACYJNY OBEJMUJĄCY WŁÓKNINĘ POLIPROPYLENOWĄ ZAWIERAJĄCĄ ALKILOAMONIOWE MIKROBIOCYDY NA NOŚNIKU PERLITOWYM

Streszczenie — Przedstawiono nowy bioaktywny materiał polimerowy o właściwościach filtrujących otrzymany metodą pneumotermicznego formowania włókniny z polipropylenu z dodatkiem różnych ilości substancji aktywnej — biocydu alkiloamoniowego — na nośniku stanowiącym perlit (tabela 1). Materiał taki zawierający tylko 8 % bioperlitu (0,37 % biocydu) charakteryzował się już dużą aktywnością wobec bakterii gram-dodatnich i gram-ujemnych: *E.coli, P.aeruginosa, K.pneumoniae* (99.9 % redukcji), *S.aureus, M.flavus* (95 %) i grzybów: *A.niger* (98 %) oraz *C.albicans* (94 %) po 6 godzinach inkubacji (tabela 2); bakterie *B.subtilis* były znacznie mniej wrażliwe na bioaktywną włókninę (86 % redukcji). Natomiast efekt redukcji mikroorganizmów materiału z 10-proc. zawartością bioperlitu wynosił 100 % (tabela 2). Zastosowanie bioperlitu przyczyniło się do zwiększenia hydrofilowego charakteru materiału polimerowego. Stwierdzono, iż wzrost wilgotności materiału bioaktywnego powoduje polepszenie właściwości przeciwdrobnoustrojowych materiału (tabela 3). W badaniach modelowych układów materiałów filtrujących zawierających nową bioaktywną włókninę wykazano ich doskonałą aktywność przeciwdrobnoustrojową oraz skuteczną filtrację bioaerozolu cząstek zarówno stałych (NaCl), jak i ciekłych (mgła oleju parafinowego) oraz drobnoustrojów (*E.coli, S.aureus*) (tabela 4). Omówiono układ filtrujący — włóknina PP z biocydem alkiloamoniowym na perlicie jako nośniku — może mieć zastosowanie

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do produkcji półmasek filtrujących albo filtrów w miejscach pracy, gdzie istnieje zagrożenie czynnikami mikrobiologicznymi.
Słowa kluczowe: bioaktywny polipropylen, włókniny filtrujące, właściwości przeciwdrobnoustrojowe, mikrobiocydy alkiloamoniowe, perlit, półmaski.

Bioactive polymers may be used in ventilation systems, but also in respiratory protective equipment as half-masks and filters accompanied by half-masks or masks. The main function of these materials is to stop microorganisms present in the air and neutralize them by inhibiting their growth or a biocidal effect.

Numerous studies show high microbiological air pollution and the presence of pathogens at workplaces, such as hospitals, waste dump sites, composting plants, sewage-treatment plants and others [1—3].

Some research is conducted on the use of bioactive textiles (both natural and polymer) in medicine in the production of wound dressings, bed linen and protective clothing [4, 5]. However, there are no studies concerning the applications of bioactive filtering in personal protective equipment that act protectively against harmful bioaerosols.

For the production of filtering half-masks, polymer fibers such as polyester, polypropylene, polyamide, and polyacrylonitrile are used [6]. In the pneumothermal technology, polypropylene is used most frequently due to its good recycling characteristics. Bioactive polypropylene fibers described in the literature are modified with antibiotics (*e.g.* tetracycline hydrochloride), glycidyl methacrylate, cyclodextrin and quaternary ammonium salts or others biocides [7—12].

Quaternary ammonium microbiocides are known for their high antimicrobial activities [13—16]. The mechanism of their biocidal activity against microorganisms lies in destroying the cytoplasmic membrane, loss of K+ cations from the cytoplasm and changes in the structure of DNA and RNA [9, 17]. The use of quaternary ammonium microbiocides as agents inhibiting the growth of microorganisms in textile materials and paints is recommended [9, 12, 18—19].

The aim of our present study is to evaluate a new bioactive filtering material obtained by the pneumothermal method of forming fleece from polypropylene with alkylammonium microbiocides added on a perlite carrier.

The antimicrobial activity of the created bioactive nonwoven fabric with a varying content of biocide and at different humidity levels was tested in this study, also against saprophyte and pathogenic microflora occurring in bioaerosols. Furthermore, the efficiency of the aerosol filtration of solid and liquid particles (sodium chloride, paraffin oil mist) and microorganisms (*E.coli, S.aureus*) was evaluated and the antimicrobial properties of the constructed filtering system containing a bioactive nonwoven fabric with perlite (a filtering half-mask model), which can be applied as a respiratory protection system.

EXPERIMENTAL

Materials and methods of their preparation

Bioperlite — biocides preparation and characterization

Alkylammonium microbiocides on a perlite carrier (bioperlite) were prepared by accurate spraying of perlite ($\varnothing_{max}$<30 μm) with an isopropanol solution of biocides, humectants and sequestering agents. The product was dried under vacuum (6.5×10^2 Pa, 293 K, 48 h) and analyzed by FT-IR, two-phase titration and elemental analysis. Infrared spectra were recorded in KBr pellets using a FT-IR Bruker IFS 113v spectrometer which was evacuated to avoid water absorption. Elemental analyses were carried out with a Vario EL III instrument. The total amount of active substances, *i.e.* *N*,*N*-didecyl-*N*,*N*-dimethylammonium chloride (Aldrich), *N*-benzyl-*N*-dodecyl-*N*,*N*-dimethylammonium chloride (Aldrich), *N*,*N*-bis(3-aminopropyl)-*N*-dodecylamine (Lonza, Switzerland), 1,2,3-trihydroxypropane (Aldrich) and the sodium salt of 2-fosfonobutane-1,2,4-tricarboxylic acid (Lakeland, England) in the final product was 5.0 %. Quaternary alkylammonium salts and alkyltriamine constituted 92.7 of all the active substances.

A bioactive nonwoven fabric, the half-mask model

A bioactive nonwoven fabric was obtained by introducing bioperlite in the form of powder into the mass of polypropylene fibers (type MOPLEN HP 540 J, Basell Orlen Polyolefins, Poland). For the production of the filtering nonwoven fabric and a filtering system using the pneumothermal technology of fleece forming, called the melt-blown method, [20, 21], a device constructed in Poland by the CIOP [22] was used.

There were five nonwovens fabrics prepared, with various content of bioperlite (including a biocide, contents of biocide in brackets): 5 % (0.23 %), 8 % (0.37 %), 10 % (0.46 %), 15 % (0.69 %), 20 % (0.93 %) and a control sample of nonwoven fabric without bioperlite. Furthermore, control tests were carried out on the nonwoven fabric with perlite but without biologically active compounds.

In order to apply a biologically active filtering nonwoven fabric in the technical prototype of filtering half-masks, a system of filtering layers was prepared. In the half-mask model, the function of preliminary filtration was performed by a needling nonwoven fabric of the GW type — 20/160T/PAN/BIO/1, made from a mixture of the Bico biocomponent (Inatex, Poland) and an acrylic fiber (Unia, Poland). The basic filtering role was performed by a pneumothermal nonwoven fabric made from polypropylene with the addition of alkylammonium microbiocides on a perlite carrier, whereas a needling nonwoven fabric made from the mixture of polyester fibers and the Bico biocomponent (Inatex, Poland) was used as a protective layer.

Moreover, a similar control filtering system was prepared that included a pneumothermal nonwoven fabric made from polypropylene without the addition of bioperlite as a filtering layer.

Microorganisms

Research was conducted on eight strains of microorganisms: *Escherichia coli* (ATCC 8739), *Staphylococcus aureus* (ATCC 6538), *Candida albicans* (ATCC 10231), *Aspergillus niger* (ATCC 16404), *Klebsiella pneumoniae* (PCM 555, Polish Microorganisms Collection, Polish Academy of Science, Wrocław, Poland), *Pseudomonas aeruginosa* (ŁOCK 0885, Pure Cultures Collection ITFiM PŁ, Łódź, Poland), *Bacillus subtilis* (ŁOCK 0818), *Micrococcus flavus* (ŁOCK 0849).

The criterion for the choice of strains was taxonomic variety and their prevalence in the air.

Media

The following types of media were used for microorganism cultures: bacteria — Caso Bulion and [Agar tryptose soya broth agar (TSA, Merck)], yeast — Sabourauda (Merck), mould — MEA (Malt Extract Agar, Merck).

Methods of investigation

Estimation of the antimicrobial activity of nonwoven fabrics

The measurement of the antimicrobial activity of nonwoven fabrics was made using a modified quantity method AATCC 100 (modifications — a nonwoven fabric surface, time of incubation following from the specificity of the use of the nonwoven fabric). Samples of nonwovens 4 cm^2 in surface were inoculated with a standardized suspension of microorganisms and incubated at 37 °C (bacteria and yeasts) or 27 °C (moulds). Each sample was prepared in three repetitions for each microorganism and incubation time. Samples were taken at time 0 and after 6 hours of inoculation (the time of 6 hours is the maximum time of the use of protective half-mask). Following that, from the samples of materials, microorganisms were rinsed into physiological salt (shaken for 15 minutes at 37 °C) and sown by the flooding method using media appropriate to microorganisms. After 24 hours of incubation at 37 °C (bacteria), 73 hours at 37 °C (yeasts) and 72 hours at 27 °C (mould), colonies were counted and the percentage of microorganism number reduction after 6 hours (R_6) was calculated according to the equation:

$$R_6 = A\text{-}B/A \times 100\ \% \qquad (1)$$

where: R_6 — *percentage reduction of microorganisms after 6 hours; A — the number of microorganisms in the control sample at time t = 0; B — the number of microorganisms in the bioactive nonwoven fabric after time t = 6 h*.

Control tests were also performed on a nonwoven fabric with the addition of perlite without a microbiocide, which showed that the control sample no had antimicrobial properties.

Influence of mass humidity of nonwoven fabric on antimicrobial activity

The test was done using *E.coli* bacteria strain, which was the most sensitive to the bioactive nonwoven. Samples of the bioactive nonwoven with an addition of 8 % perlite containing alkylammonium microbiocides (4 cm^2 surface) were wetted with sterile distilled water at the following quantities: 0.1 ml, 0.5 ml, 1 ml, and 5 ml. Furthermore, a control sample was prepared without the addition of water. One sample of nonwoven fabric from each repetition was intended for estimation of the mass humidity of the material, three samples were used for incubation with *E.coli* at 37 °C for 6 hours and later for evaluation of antimicrobial activity.

Mass humidity (*MH*) measurements were done using the weight method, by drying a sample until dry mass at 105 °C and later by calculating the mass humidity of the material using the following equation:

$$MH = (Mm_1 - Mm_2)/Mm_2 \times 100\ \% \qquad (2)$$

where: *MH — mass humidity of the material,* Mm_1 *— material mass before drying (g),* Mm_2 *— material mass after drying (g)*.

NaCl aerosol and oil mist filtration efficiency

The filtering properties of bioactive and control half-masks were evaluated and in particular — penetration with sodium chloride aerosol and paraffin oil mist. The indices of sodium chloride penetration and paraffin oil mist were determined according to the EN 149:2001 standard ("Respiratory protective equipment — filtering half-masks — requirements, tests, marking").

In filtering measurements, sodium chloride aerosol was used with a particle diameter of 0.6 μm. A testing device for the evaluation of penetration efficiency for this aerosol (Grimm, Germany) and a recorder (Moores, Germany) were used. Paraffin oil mist aerosol concentration was measured using a laser photometer (Lorenz, Germany). The amount of aerosol particles that passed through the filtering material in relation to the total amount of particles was expressed as percentage penetration (*P*, %). The efficiency of filtration (*F*, %) was calculated and defined by the following equation:

$$F = 100\ \% - P \qquad (3)$$

Bioaerosol filtration efficiency

Bioaerosol filtration efficiency evaluation for the model of a filtering half-mask containing bioperlite and for the control half-mask was carried out using a device specially constructed for this purpose [23]. Tests were based on creating a bacterial aerosol (*E.coli, S.aureus*) suspended in 0.85 % NaCl solution by an atomizer, mixing it with dry air and directing bioaerosol on the model of half-mask placed in an apparatus. In the apparatus, the following system of filters was used: the tested sample of nonwoven fabrics and a microbiological filter stopping microorganisms which passed through the tested sample (a gelatin filter with a pore diameter of 0.3 μm, Sartorius). The intensity of bioaerosol flow was 30 l/min. The experiment was begun with stabilizing the working conditions of the apparatus. Bioaerosol was sprayed on samples of nonwoven fabric for 20 minutes. A microbiological filter was placed on the TSA medium and incubated at 37 °C for 24 hours. Based on comparison between the number of bacteria stopped on the microbiological filter (in front of which the tested half-mask was placed) and the total number of microorganisms (stopped by the microbiological filter without a half-mask), filtering efficiency (*F*, %) in this case was calculated according to the following equation:

$$F = (Nt - Nf)/Nt \times 100\ \% \quad (4)$$

where: Nt — *total number of microorganisms on the microbiological filter without a half-mask,* Nf — *number of microorganisms on the microbiological filter after they have passed through a half-mask*.

RESULTS AND DISCUSION

A scanning electron micrograph (shown in Fig. 1) indicates that the bioperlite was dispersed on the surface of the fibers and some bioactive particles were dispersed in the polymer matrix.

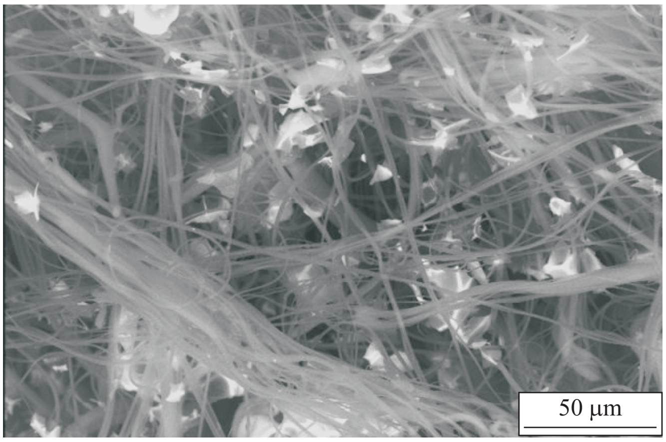

Fig. 1. SEM micrograph of the nonwoven fabric with 8 % of bioperlite

Polypropylene nonwoven fabrics with the addition of alkylammonium microbiocides after 6 hour incubation with *E.coli* and *S.aureus* bacteria showed a good effect of the reduction in microorganisms number, at a concentration of perlite in biocide of 5—8 % (0.23—0.37 % microbiocides) and particularly (100 % reduction) at higher concentrations of perlite, namely 10—20 % (0.46—0.93 % microbiocides) (Table 1).

T a b l e 1. The influence of bioperlite concentration (with alkylammonium microbiocides) in the nonwoven fabric on antimicrobial activity against *E.coli* and *S.aureus*[*)]

Amount of bioperlite in the nonwoven fabric (%)	Amount of alkylammonium microbiocides in the nonwoven fabric (%)	Number of bacteria (CFU/sample)					
		Escherichia coli			*Staphylococcus aureus*		
		Incubation time		reduction, %	Incubation time		reduction, %
		0 h	6 h		0 h	6 h	
Control sample without bioperlite	0	Mean: 6.07×10^6 SD: 3.52×10^6	Mean: 1.59×10^6 SD: 1.53×10^5	73.80	Mean: 3.33×10^6 SD: 2.91×10^6	Mean: 1.13×10^6 SD: 1.02×10^6	66.0 %
Nonwoven bioperlite 5 %	0.23	Mean: 3.72×10^6 SD: 2.35×10^6	Mean: 2.76×10^5 SD: 1.49×10^5	95.45	Mean: 5.01×10^6 SD: 3.35×10^6	Mean: 2.34×10^5 SD: 2.05×10^5	92.97
Nonwoven bioperlite 8 %	0.37	Mean: 4.15×10^6 SD: 4.28×10^6	Mean: 3.40×10^3 SD: 2.90×10^3	99.94	Mean: 8.90×10^6 SD: 1.20×10^6	Mean: 1.1×10^5 SD: 2.89×10^4	96.69
Nonwoven bioperlite 10 %	0.46	Mean: 7.23×10^5 SD: 1.13×10^5	Mean: 0 SD: 0	100	Mean: 5.29×10^6 SD: 4.58×10^6	Mean: 0 SD: 0	100
Nonwoven bioperlite 15 %	0.69	Mean: 8.67×10^5 SD: 1.05×10^5	Mean: 0 SD: 0	100	Mean: 1.84×10^7 SD: 3.12×10^6	Mean: 0 SD: 0	100
Nonwoven bioperlite 20 %	0.93	Mean: 7.05×10^5 SD: 1.20×10^5	Mean: 0 SD: 0	100	Mean: 2.43×10^6 SD: 1.56×10^6	Mean: 0 SD: 0	100

[*)] Here and in the next Tables: SD — Standard Deviation, CFU — Colony Forming Units.

T a b l e 2. The antimicrobial activity and the effect of filtration of a filtering half-mask with a bioactive nonwoven fabric with 8 % bioperlite and of the control model

Type of measurement	Control filtering system	Filtering system with the non-woven fabric with 8 % bioperlite
Antimicrobial activity		
Number of *E.coli* at time 0 h (CFU/sample)	Mean: 2.53×10^4 SD: 1.04×10^4	Mean: 1.58×10^4 SD: 1.60×10^4
Number of *E.coli* at time 6 h (CFU/sample)	Mean: 1.35×10^4 SD: 1.18×10^4	Mean: 0 SD: 0
Reduction of *E.coli* (%)	46.64	100
Number of *S.aureus* at time 0 h (CFU/sample)	Mean: 3.93×10^4 SD: 3.6×10^4	Mean: 4.76×10^3 SD: 4.2×10^3
Number of *S.aureus* at time 6 h (CFU/sample)	Mean: 1.28×10^4 SD: 1.27×10^4	Mean: 0 SD: 0
Reduction of *S.aureus* (%)	67.43	100
Filtration efficiency (*F*) values		
NaCl aerosol	98.3±1.0	98.7±1.1
Paraffin oil mist aerosol	95.6±1.5	94.9±1.7
Escherichia coli	99.9±0.1	99.8±0.1
Staphylococcus aureus	99.9±0.1	99.9±0.1

The reduction in the number of microorganisms after 6 hours of incubation with an 8 % perlite nonwoven fabric was at the level of 96.7—99.8 %. Nonwoven fabrics with 10 % and higher bioperlite concentration (biocide concentration = 0.46 % or higher) provided 100 % reduction. The filtering half-mask model including a nonwoven fabric with 8 % bioperlite was made and compared with the control model (Table 2). The filtering efficiency (*F*) of NaCl aerosol, oil mist and microorganisms for the compared models were similar. Bacteria reduction in the control material (46—67 %) after 6 hours of incubation time resulted from natural decay of the cells due to a lack of nourishment and appropriate conditions for the growth of microorganisms. On the other hand, the reduction in the number of *E.coli* and *S.aureus* stopped by the filtering half-mask with a bioactive nonwoven fabric was 100 %.

Similar antimicrobial activity was observed for polyurethane coatings with quaternary ammonium salts [19], linear copolymers of chloroethyl vinyl ether with methyl metacrylate containing alkyl and alkylaryl ammonium as well as phosphonium salts [9, 17] and polymers with *N*-alkylpyridinium moiety [24]. As Kenawy and coworkers [9] showed with a suspension test, the antimicrobial activity of modified linear copolymers is high. The concentration of 10 mg/mL of the polymer kills over 98 % of selected microorganisms.

Furthermore, the differences in the antimicrobial activity of the nonwoven fabrics tested that were reported depend on the morphological properties of microorganisms, *i.e*. the structure of membranes and cell walls. The antimicrobial activity of the tested nonwovens against various microorganisms, was evaluated for nonwoven fabrics with an 8 % addition of bioperlite (Table 3). It was shown that after 6 hours of incubation time, a bioactive nonwoven fabric with 8 % bioperlite was able to reduce gram-negative bacteria *E.coli, P.aeruginosa,* and *K.pneumoniae* almost totally (99.9 %), and gram-positive bacteria *S.aureus, M.flavus* by 95 %. On the other hand, *B.subtilis* bacteria were reduced by only 86 %. Kenawy *et al*. [9] also

T a b l e 3. The antimicrobial activity of the nonwoven fabric with 8 % bioperlite against various microorganisms

Microorganisms	Number of microorganisms (CFU/sample)				
	incubation time for control sample (without bioperlite)		with bioperlite 8 %		
			incubation time		reduction %
	0 h	6 h	0 h	6 h	
Escherichia coli	Mean: 1.58×10^8 SD: 1.15×10^8	Mean: 3.29×10^7 SD: 2.92×10^7	Mean: 3.72×10^6 SD: 2.35×10^6	Mean: 2.76×10^5 SD: 1.49×10^5	99.83
Klebsiella pneumoniae	Mean: 1.96×10^8 SD: 1.36×10^8	Mean: 4.87×10^6 SD: 4.20×10^6	Mean: 1.45×10^8 SD: 1.04×10^8	Mean: 3.80×10^5 SD: 1.45×10^5	99.81
Pseudomonas aeruginosa	Mean: 1.29×10^8 SD: 2.10×10^8	Mean: 1.34×10^7 SD: 2.10×10^7	Mean: 1.81×10^8 SD: 1.30×10^8	Mean: 7.90×10^4 SD: 3.30×10^4	99.94
Staphylococcus aureus	Mean: 1.10×10^8 SD: 1.06×10^8	Mean: 8.70×10^6 SD: 8.09×10^6	Mean: 1.53×10^8 SD: 1.50×10^8	Mean: 5.20×10^6 SD: 4.50×10^6	95.27
Micrococcus flavus	Mean: 1.18×10^7 SD: 1.04×10^7	Mean: 1.57×10^7 SD: 1.83×10^7	Mean: 3.80×10^6 SD: 3.40×10^6	Mean: 6.20×10^5 SD: 2.15×10^5	94.75
Bacillus subtilis	Mean: 2.58×10^6 SD: 2.34×10^6	Mean: 4.39×10^6 SD: 4.03×10^6	Mean: 1.22×10^6 SD: 1.29×10^6	Mean: 3.61×10^5 SD: 3.53×10^5	86.01
Candida albicans	Mean: 8.12×10^6 SD: 6.80×10^6	Mean: 7.23×10^6 SD: 7.04×10^6	Mean: 3.27×10^6 SD: 4.34×10^6	Mean: 5.20×10^5 SD: 4.14×10^5	93.59
Aspergillus niger	Mean: 3.50×10^8 SD: 3.20×10^8	Mean: 1.05×10^7 SD: 9.90×10^6	Mean: 2.76×10^8 SD: 1.70×10^8	Mean: 6.67×10^6 SD: 1.36×10^6	98.09

concluded that polymers with the addition of triethyl ammonium salt react more effectively against gram-negative bacteria (*E.coli, P.aeruginosa, Salmonella typhae, Shigella sp.*) than those gram-positive (*B.subtilis*). The production of surviving forms is a factor responsible for the high resistance of *B.subtilis*. Similarly, *C.albicans* and *A.niger* showed a lower sensitivity to bioactive nonwoven fabrics with alkylammonium microbiocides (93.59 % and 98.09 %, respectively). This remains in accordance with the results obtained by Hu [25] and Kenawy [9]. In these cases the resistance of fungi to microbiocides results from the production of spores.

Using perlite as a carrier for alkylammonium microbiocides led to a change in nonwoven polypropylene properties. Changes in the physical properties of the polymer after adding perlite were described by Akin-Öktem *et al.* [26, 27]. They concluded that adding perlite increases polymer durability, its flexibility and, most of all, enables the polymer to bond with various chemical agents. This feature was used in constructing the new bioactive nonwoven fabric described in this study. It was established that adding perlite increased the hydrophilic properties of the nonwoven fabric, which improved its antimicrobial activity.

T a b l e 4. The influence of the humidity level of a nonwoven fabric with 8 % bioperlite on antimicrobial activity against *E.coli*

Nonwoven fabric, mass humidity level %	Number of microorganisms (CFU/sample): incubation time 0 h	6 h	reduction, %
Nonwoven fabric (5 %) control sample*)	Mean: 2.04×10^4 SD: 1.80×10^4	Mean: 4.15×10^3 SD: 5.60×10^3	79.66
Nonwoven fabric (9.5 %)	Mean: 3.52×10^4 SD: 3.08×10^4	Mean: 6.96×10^3 SD: 6.03×10^3	80.23
Nonwoven fabric (43 %)	Mean: 2.04×10^4 SD: 1.78×10^4	Mean: 3.54×10^3 SD: 3.50×10^3	82.64
Nonwoven fabric (213 %)	Mean: 2.04×10^4 SD: 1.80×10^4	Mean: 3.44×10^3 SD: 3.68×10^3	83.14
Nonwoven fabric (1274 %)	Mean: 2.04×10^4 SD: 1.80×10^4	Mean: 1.87×10^2 SD: 1.71×10^2	99.08

*) Without the addition of water.

The humidity of the nonwoven fabrics had a significant influence on their antimicrobial activity with alkylammonium microbiocides on a perlite carrier (Table 4). It was found that due to an increase in the mass humidity of the material, activity against *E.coli* was also increased. It was observed that the level of bacteria reduction was biggest (99.1 %) when the mass humidity of a bioactive nonwoven fabric was highest (*ca*. 1300 %).

So, while in practice the humidity of material used for producing half-mask increases this means that also antimicrobial activity is increasing.

Assessment of the final product — a filtering half-mask model containing a new bioactive nonwoven fabric with alkylammonium microbiocides on a perlite carrier — showed total reduction of microorganisms (100 %), a satisfactory level of filtration both for solid and liquid particles and microorganisms (*E.coli S.aureus*) (Table 2). The suggested model of filtering half mask with a bioactive nonwoven fabric was characterized by the effective filtration of salt aerosol (>98 %), comparable with similar products, *e.g*. nano-masks, in which the filtering effect was at the level of >97 % [25].

CONCLUSIONS

The presented filtering system containing a bioactive nonwoven fabric with alkylammonium microbiocides on a perlite carrier (containing 0.37 % of biocide in the nonwoven fabric) showed a high efficiency of filtration and antimicrobial activity. This system was used in the filtering half-mask model, tested in laboratory conditions and its usefulness in personal protective equipment in occupational environments at workplaces threatened by biological factors was discovered.

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CZAS NA TARGI K!

Zgodnie z ustalonym trzyletnim cyklem, jesienią bieżącego roku (27 października—3 listopada) w Düsseldorfie odbędą się osiemnaste już Międzynarodowe Targi Tworzyw Sztucznych i Kauczuku K 2010. Mimo zajęcia całej powierzchni wystawowej Messe Düsseldorf (160 000 m^2 w 19 halach) nie wszyscy potencjalni wystawcy znaleźli na niej miejsce dla swoich stoisk (w Targach uczestniczy 3130 firm z 50 krajów, w tym udział wystawców zagranicznych szacuje się na 62 %). Przewiduje się, że Targi odwiedzi 242 000 osób, w tym 57 % z zagranicy. Największa na świecie, organizowana co trzy lata, impreza branży tworzyw polimerowych jest jedyną okazją, by w jednym czasie i jednym, niedaleko naszej granicy usytuowanym miejscu, poznać — zarówno w aspekcie ekonomicznym i handlowym, jak i technicznym oraz naukowym — sytuację i warunki rozwoju coraz ważniejszej globalnie gałęzi gospodarki. Poza typowymi dla targów negocjacjami handlowymi, spotkania na nich są wyjątkową okazją do rozmów specjalistów, wymiany poglądów i dzielenia się wiedzą (czasami podpatrywania konkurencji), co przyczynia się do rozwoju wiedzy technicznej i technologicznej. Dlatego, zachęcając studentów do zwiedzania Targów często używałem niekwestiowanego stwierdzenia, że taka wizyta to więcej, niż rok studiów. Moja ocena Targów w tym zakresie nie uległa zmianie i dlatego wszystkim, którzy życie zawodowe wiążą ze sferą tworzyw polimerowych proponuję, by wizyty na Targach K traktowali jako stały element działalności zawodowej.

Targi będą otwarte od 27 października do 31 listopada w godzinach 10.00—18.30.

Ceny biletów na Targi: jednodniowy — 55 € (49 €), studencki, uczniowski — 15 €
trzydniowy — 120 € (108 €). Cena Katalogu — 22 €.

By nie tracić czasu na stanie w kolejkach oraz trochę zaoszczędzić radzę kupić bilety (przesyłane pod wskazany adres) w przedsprzedaży (ceny w nawiasach). Koszt biletu obejmuje przejazdy publicznymi środkami transportu w Düsseldorfie i dość rozległych okolicach.

Informacje o Targach można znaleźć na **www.k-online.de**.

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Do spotkania na Targach!

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