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# Biodegradable Particle Filtering Half-masks for Respiratory Protection

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## Abstract

*This article presents the results of research on developing a multi-layer particle filtering half-mask made from biodegradable nonwovens for protection against harmful aerosols. Currently, these half-masks are made from polypropylene (PP), which is a problem in the context of environment protection. Needle-punched nonwovens were used for the pre-filtration stage, highly effective melt-blown nonwovens for main filtration and spun-bonded nonwovens as the tegument. The basic raw material for the production of the nonwovens was poly(lactic acid) (PLA). In order to ensure a tight seal around the half-mask, head straps and a nasal seal, also made of biodegradable materials, were used. The developed biodegradable half-mask, designed for protection of the respiratory system from harmful aerosols, meets the requirements of the low (FFP1) and medium (FFP2) protection classes according to EN149:2001+A1:2009.*

**Key words:** respiratory protective equipment, filtering half-mask, biodegradable polymers, poly(lactic acid), biodegradable nonwovens.

## Introduction

Respiratory protective equipment (RPE) safeguards the body from inhaling hazardous and harmful substances from the atmosphere, which constitute a group of high-risk factors. It protects against hazards which can cause serious and irreversible damage to health and also loss of life [1]. The basic RPE for aerosols (dust, smoke, fog) is the filter. Its operation consists of trapping harmful airborne particles present in the work environment and retaining them in the fibres [2]. There are many construction varieties for this type of equipment, but the most common are particle filtering half-masks, in which the main material is a nonwoven filter, responsible for the effective trapping of aerosol particulate matter. Half-masks are multi-layer products and, in their

manufacture, nonwovens based on technologies such as needle-punching, melt-blowing and spun-bonding are used. The basic raw materials in the production of nonwovens are synthetic polymers which degrade over many years. In this context, it should be emphasised that the generation of waste is becoming an increasingly global problem due to the increasing rate of growth in the production of consumer goods and accelerating technological developments, resulting in a shortening of the “lifetime” of certain product groups, including those used in the protection of humans in the working and living environments. Industrial waste, which includes half-masks intended for short-term use, is produced in large quantities and represents a significant threat to the environment. For this reason, the development of products which are readily biodegradable under composting conditions is very important. At the same time, it should also be emphasised that, for many years, attempts have been made to find materials and products manufactured from them which at the end of their usefulness will undergo rapid decomposition, in turn producing environmentally safe products [3-6]. One possibility is the so-called bacterial polymers, i.e. products naturally produced by certain strains of bacteria or genetically modified plants. Their disadvantages are the relatively high costs and implementation difficulties on an industrial scale.

The main technological problem, in addition to the abovementioned raw materials, is the development of methods and technologies to process biodegradable polymers, including textile technologies.

One path of intensive development is the melt-blown and spun-bonded manufacture of nonwovens directly from the polymer melt [7 - 10].

The basic problem concerning filtering materials used in protection of the respiratory system is ensuring and selecting an appropriate structure of the nonwoven material in order to ensure high efficiency while purifying the air of a polydisperse aerosol of solid and liquid particles. The reaction between aerosol particles and the nonwovens that comprise the filtering material determines the appropriate features of this material [11]. The basic parameters describing the aerosol filtration process are the efficiency of filtration and airflow resistance. The filtration process is characterised by complex transportation mechanisms and deposition of aerosol particles on fibres. Changes in filtering parameters depend on the geometric dimensions of the fibres, thickness and porosity of the nonwovens and fibre electrostatic activation [12]. In order to meet expectations concerning efficient air purification of harmful aerosol particles, multi-layer filtering systems are used, in which every layer plays a different role. The need to differentiate the geometry of filtering layers results from different measurement spread, concentration and chemical content of aerosol particles which appear in the working and living environments [13]. Harmful particles isolated from enclosed rooms are between 0.002 to 100 µm and their concentration is between 0.01 to 200 mg/m<sup>3</sup>. It is assumed that particles greater than 2.5 µm find their way to the lungs and are particularly harmful. Trapping them

**Table 1.** Polymer characteristics according to the manufacturer [18, 19].

Indicator	Polymers (products)	ASTM (standard)	PLA 6251D (spun-bonded)	PLA 6201D (Fibre: 39/10/R/WO/W-2 needle-punched nonwoven: W/f-250/b)	PLA 6202D (melt-blown nonwoven)	PLA 4060D (nose clips)
Glass transition temperature, °C		D3417		55 - 62		55 - 60
Melting temperature, °C		D3418		165 - 173	160 - 170	-
Relative viscosity		D5225	2.4 - 2.6		3.0 - 3.2	3.4
Mass flow index at 210 °C, g/10 min		D1238	70 - 85		15 - 30	10

**Table 2.** DSC results for those polymers involved in the manufacture of various particle filtering half mask components.

Indicator	Products	Spun-bonded	Needle-punched nonwoven: W/f-250/b Fibre: 39/10/R/WO/W-2	Melt-blown nonwoven	Needle-punched nonwoven: W/f-250/a, Head strap fibres: SLN2539W5	Nose clips
	Polymer	6251D	6201D	6202D	PLA NW	4060D
Glass transition temperature, °C		67		61		55
Recrystallisation temperature, °C		87	Not observed	106	Not observed	Not observed, amorphous polymer
Enthalpy of recrystallisation, J/g		27.1		27.4		
Melting temperature, °C		166	161	160	168	
Enthalpy of melting, J/g		39.5	42.9	41.7	44.50	
Degree of crystallinity, wt. %		14	46	15	48	0

is the basic task of respiratory protective equipment, which can be ensured using electret melt-blown nonwovens with a fiber diameter below 1 μm [14, 15]. However, to prolong the “lifetime” of such nonwovens until the point at which it is blocked by aerosol particles, so-called pre-filters are used, which are highly porous. These are mostly needle-punched nonwovens designed to stop aerosol particles with significantly large dimensions. Also, the filtering layer closest to skin of the particle filtering half-mask user is of importance and should be eco-friendly. It is expected that introducing new polymers, also biodegradable, will allow the production of even finer fibers from them and model multi-layer systems that meet the requirements of modern means used for human protection, ensuring a high degree of protection efficiency even against submicron particles and at the same time remaining safe for the natural environment.

The first attempts at the production biodegradable respiratory protective equipment have been described [16]. They investigated filters for use in conjunction with reusable half-masks and half-masks incorporating non-biodegradable components. Therefore, it was necessary to continue this research with a focus on developing a completely biodegradable respiratory protective equipment prototype.

The aim of this study was to develop a multi-layer prototype half-mask, made entirely from fully biodegradable raw materials for the purpose of protecting the respiratory system from harmful aerosols (dust, smoke, fog). In order to

ensure efficient protection of the human respiratory system, it was essential to introduce a new filtering system. The half-mask was to be developed with the use of three different nonwovens having the following features: pre-filtering (blocking large aerosol particles), electret high efficiency filter and a shielding layer responsible for maintaining the shape of the mask and the comfort of the user. The product is the first of its kind on the national scale.

## ■ Experimental details

### Test material characteristics

#### Polymer characteristics

The polymers were specially designed for different textile applications and different processing methods: needle-punched, melt-blown and spun-bonded nonwovens. The choice of nonwoven technologies was necessitated by the requirements specified with regard to the role of each layer. The outer layer (facing the air contamination) is supposed to block large aerosol particles, preventing clogging of the high efficiency filtering layer. Electret melt-blown nonwovens, which are in fact the second layer, owe their performance to thin fibers (less than 1 μm) as well as the occurrence of electrostatic attraction. The third (inner) layer ought to be durable in order to preserve the mask’s shape. This requirement was met by the spun-bonded nonwovens.

The constituent polymers of the raw materials used in the production of the particle filtering half-mask components were examined using the differential scanning calorimetry (DSC) method Q2000 (TA

Instruments, UK). The focus was to determine the phase transition parameters, namely glass transition, crystallisation and melting temperature. The degree of crystallisation was determined using the **Equation 1**:

$$\chi_c(\%) = \frac{\Delta H}{H_{100\%}} \cdot 100 \quad (1)$$

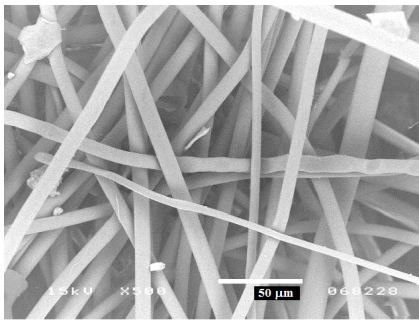
where  $\Delta H$  is the difference between the melting enthalpy and the cold crystallisation enthalpy and  $H_{100\%}$  is the melting enthalpy of 100% crystalline PLA, which is equal to 93.1 J/g [17].

**Table 1** presents the basic polymer characteristics while **Table 2** summarises the DSC results.

The conclusion drawn from the results is that for PLA 6202D and 6251D, the melting temperatures were in agreement with the manufacturer’s specification and for PLA 6201D, this was insignificantly lower. The glass transition temperature for PLA 4060D was in agreement with the manufacturer’s specifications and for 6251D and 6202D was insignificantly higher. The nonwovens from the polymer melt and the nose clips manufactured from a polymer solution contained a high amount of the amorphous phase, between 86 - 100%. However, the values of crystallinity of the polymer in commercial fibres and those manufactured by the Institute of Biopolymers and Chemical Fibres (IBWCh) are equal to 48% and 46%, respectively.

#### Spun-bonded nonwovens characteristics

The spun-bonded nonwovens were produced in the IBWCh laboratory on equipment designed and built by the Research



**Figure 1.** SEM surface image of the spun-bonded nonwovens.

and Development Centre of Textile Machinery “Polmatex-Cenaro”. Nonwovens were manufactured from commercially available poly(lactic acid) (PLA) delivered by Nature Works LLC, USA. **Figure 1** shows SEM surface images of the spun-bonded nonwovens whilst **Table 3** shows the physico-mechanical properties defined using standards [20 - 23]. The measurements carried out enabled to select the suitable thermal parameters for further processing.

The physico-mechanical properties of the spun-bonded nonwovens suggest its applicability as an inner layer.

#### Needle-punched nonwovens characteristics

Two types of needle-punched nonwovens were produced for pre-filtration. The first (W/f-250/a) was produced using com-

mercial PLA SLN2539W5 fibres manufactured by the Far Eastern Company, Taiwan. The second (W/f-250/b) using 39/10/R/WO/W fibres was manufactured from commercially available PLA delivered by Nature Works LLC, USA. **Table 4** summarises the fibre characteristics using standard methods [24 - 26]. Both nonwovens were produced using laboratory equipment for manufacturing needle-punched nonwovens from carded fleece which transversely arranges the fibres for identical processing parameters.

The needle-punched nonwovens were prepared by double needle punching two composites, each from initially needle punched fleece having a mass per unit area of 180 g/m<sup>2</sup>. The needles used were Groz Beekert’s number gg 15×17×42×3 ½ R322G 53012 whilst the total number of needle punches was 120/cm<sup>2</sup>. **Table 5** (see page 80) summarises the test results of the nonwovens physical properties in accordance with standards [20, 21 & 23].

**Figures 2** and **3** show the surface images for the W/f-250a and W/f-250b nonwovens, respectively. The physical parameters of nonwovens WF250/a and WF250/b indicate that both can be applied for pre-filtration.

The surface views of the nonwovens manufactured from both types of fibres show differences in fibre diameter, but do

**Table 6.** Melt-blown nonwovens production parameters.

Parameter	Value
Zone 1 extrusion temperature, °C	270 ± 1
Zone 2 extrusion temperature, °C	270 ± 1
Air temp. at the heater outlet, °C	300 ± 1
Head temperature, °C	210 ± 1
Airflow, m <sup>3</sup> /h	10 ± 0.1
Throughput, g/min	80 ± 1
Reception length, cm	30

not exhibit any differences in their structures.

#### Melt-blown nonwovens

The melt-blown nonwovens were made from the PLA 6202D polymer delivered by Nature Works LLC, USA. **Table 6** summarises the process parameters. **Figure 4** shows an image of the melt-blown nonwovens surface.

A device for discharge emission was used to confer electret properties to the nonwovens. It has a tip electrode at the receiving device, to which positive voltage was connected and a counter electrode under the grid which collects nonwoven fleece, to which positive voltage was connected. The total charging voltage was 26 kV.

#### Nose clips

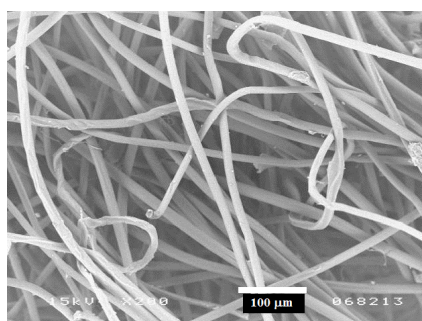
Nose clips were made by pouring a 15% solution of PLA 4060D in acetone onto annealed 0.8 mm thick steel wire sections in a Teflon mould. After drying, tiles of

**Table 3.** Physico-mechanical properties of the spun-bonded nonwovens.

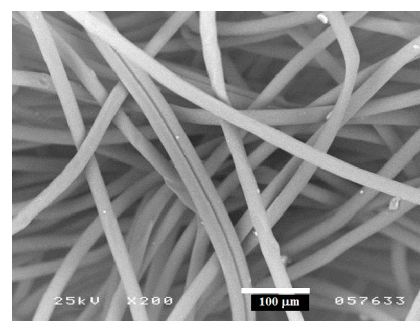
Mass per unit area, g/m <sup>2</sup>	Thickness, mm	Apparent density, kg/m <sup>3</sup>	Air permeability at ΔP=100 Pa, dm <sup>3</sup> /m <sup>2</sup> ·s	Average breaking force, N		Average extension at breaking point, %	
				longitudinal	transverse	longitudinal	transverse
20.99	0.183	114.68	2687	2.88	3.67	2.83	4.90

**Table 4.** Parameters for the PLA fibres from which needle-punched nonwovens were produced.

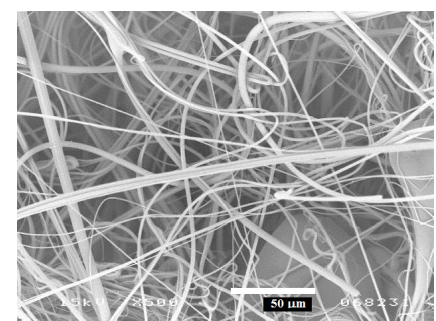
Name of fibre	Linear density, dtex	Average fibres diameter, μm	Tenacity, cN/tex	Elongation, %	Crimp amount per 10 mm	Length, mm
SLN2539W5	1.67	13.1	13.94	28.2	10	39.3
39/10/R/WO/W	2.82	17.0	21.50	89.5	4	55.0



**Figure 2.** SEM surface image of W/f-250a nonwovens.



**Figure 3.** SEM surface image of W/f-250b nonwovens.



**Figure 4.** SEM surface images of the melt-blown nonwovens.

**Table 5.** Summary of the physical parameters for the needle-punched nonwovens.

Sample name	Mass per unit area, g/m <sup>2</sup>	Thickness, mm	Bulk density, kg/m <sup>3</sup>	Air permeability for $\Delta p = 100 \text{ Pa}$ , dm <sup>3</sup> /m <sup>2</sup> s
W/f-250/a	275.4	3.65	75.45	363.5
W/f-250/b	286.9	3.59	88.7	500.5

about 3 mm in thickness were formed, which were cut into 1 cm wide strips.

### Head straps

The 0.8 cm wide head straps were prepared from a SLN2539W5 yarn on a Saurer shuttle embroidery loom. The same double yarn of 41.7 tex linear mass density was adopted for both the warp and the weft.

### Construction of the particle filtering half-mask

In the construction of the biodegradable prototype half-mask shell, the following materials were used:

- Outer layer: needle-punched nonwovens for pre-filtration; two types: W/f-250/a produced using commercial PLA SLN2539W5 fibres (Far Eastern Company, Taiwan) and W/f-250/b produced using 39/10/R/WO/W fibres manufactured within the framework of IBWCh. The nonwovens were developed by the Department of Material and Commodity Sciences and Textile Metrology, Łódź University of Technology.
- Main filtering layer: melt-blown nonwovens for the required filtration were developed and produced using PLA 6202D by the Central Institute for Labour Protection, National Research Institute (CIOP-PIB).
- Inner layer: spun-bonded nonwovens as the tegument was developed and produced using PLA 6251D by the Institute of Biopolymers and Chemical Fibres (IBWCh).
- Head straps were produced using commercial PLA SLN2539W5 fibres and nose clips were produced using PLA 4060D. These elements were developed by the Department of Material and Commodity Sciences and

Textile Metrology, Łódź University of Technology.

### Test methodology for the filtration properties

The resulting filtering nonwovens made from biodegradable polymers underwent filter characteristic testing according to the methodology set out in the standards used in respiratory protective equipment studies [27, 28].

The biodegradable half-mask prototype, as a means of personal protection within the framework of the 89/686/EEC Directive [29], was subject to testing, confirming its safety during usage, before it can be introduced into the EU market. This testing, performed according to the European standard [30], related to:

- penetration of test aerosols: sodium chloride and paraffin oil
- breathing resistance (during inhalation and exhalation)
- the user's face-mask seal by determining the total leakage of the test aerosol
- dolomite dust clogging.

### Test results and analysis of the filtration and flow properties

Table 7 shows the results for the basic filtering materials used in the manufacture of the particle filtering half-mask prototypes.

Analysis of the results for the two multi-layer filtering systems (Table 7) showed that they had similar filtration effectiveness properties, determined by the penetration of paraffin oil (i.e. the worst case) and airflow resistance (breathing resistance), which the user must overcome when using the equipment in the

**Table 7.** Basic parameters results for the multi-layer filtering systems [27, 28].

Multi-layer filtering systems	Paraffin oil penetration coefficient for airflow rate: 1.6 dm <sup>3</sup> s <sup>-1</sup> , %	Breathing resistance for airflow rate: 1.6 dm <sup>3</sup> s <sup>-1</sup> Pa
Needle-punched nonwovens sample W/f-250/a + melt-blown nonwovens (140 g/m <sup>2</sup> mass per unit area) + SBNW tegument	3.0	193.0
Needle-punched nonwovens sample W/f-250/b + melt-blown nonwovens (140 g/m <sup>2</sup> mass per unit area) + SBNW tegument	2.8	187.0

workplace. On this basis, it can be concluded that, from the point of view of evaluating the protection effectiveness of the particle filtering half-masks manufactured from the abovementioned composites, the developed variants W/f-250/a and W/f-250/b needle-punched nonwovens can be applied interchangeably. This proposal points to the comparable use of PLA fibres produced by IBWCh within the framework of the "Biogratex" project and those produced commercially in the manufacture of protective half-masks. For this reason, a batch of needle-punched nonwovens for one prototype variant was produced which was subjected to laboratory testing, according to the procedures used to assess the compliance of such products with safety and ergonomic requirements.

The preparation method and quantity of half-masks for the individual tests were in accordance with the EN149:2001+A1:2009 standard [28]. In particular, penetration tests using sodium chloride and paraffin oil aerosols were carried out on three new samples, three samples following mechanical strength tests and thermal conditioning, and three samples following simulated breathing conditions using a breathing machine. The results of these tests are shown in Table 8. Breathing resistance (inhalation and exhalation) tests were performed on three new half-mask samples, three samples following thermal conditioning (the standard does not anticipate mechanical strength tests) and three samples following simulated breathing conditions. In addition, exhaled air tests were conducted using the Sheffield dummy head in five positions. Table 9 shows the test results for the particle filtering half-mask prototypes. The parameters for the dolomite dust clogging test were evaluated using the penetration value of both sodium chloride and paraffin oil aerosols and the value of the breathing resistance test (inhalation and exhalation) for two new particle filtering half-masks (one half-mask for each test aerosol) and for four previously temperature conditioned particle filtering half-masks (two half-masks for each test spray). The results are shown in Table 10. The results for the face-mask seal leakage test are expressed as the value of the total inward leakage of the sodium chloride aerosol (Table 11).

Temperature conditioning (TC) was carried out using the following thermal cycle: 24 hours at a temperature of 70 ± 3 °C

followed by 24 hours at  $-30 \pm 3$  °C. The interval between successive cycles was 4 hours. Simulated wearing treatment was performed using a flow of humidified air, with a relative humidity greater than 95%, at a respiratory rate of 25 cycles/min and 2 litres per stroke of the breathing machine. The respiratory air temperature was  $37 \pm 2$  °C. Mechanical strength consisted of subjecting the particle filtering half-mask samples to 20 minutes of camshaft vibrations at 100 r.p.m./min.

The tests allow the particle filtering half-masks to be classified in the appropriate protection class identified symbolically as: FFP1 – low level of protection, FFP2 – medium level of protection and FFP3 – high level of protection [30]. According to the specifics of using respiratory protective equipment in the working environment, it is imperative that every test result fulfils the relevant requirements of the applicable standard [28]. That is why, while evaluating the results of research obtained for half-masks concerning the criteria of usefulness of this equipment to be used in the workplace, it is necessary to include the minimum value of the assessed parameters and not only their average values. The penetration coefficient for both tested aerosols should be at the lowest level possible so as to test the efficiency of the filtering half-mask. The minimum value of the penetration coefficient obtained for NaCl was 0.12% and for paraffin oil mist 0.98%, which allows us to conclude that biodegradable particle filtering half-masks ensure the highest level of protection efficiency (the penetration coefficient for both model aerosols for FFP3 should have a value of  $\leq 1\%$ ). At the same time, high class protection efficiency (inhaling and exhaling) at the lowest possible level should be ensured, including the physiology of human respiratory system. It is assumed that with the highest class of protection, the value of this parameter in the inhalation phase cannot be higher than 100 Pa with an airflow rate of  $0.5 \text{ dm}^3\text{s}^{-1}$  (light work) or higher than 300 Pa with an airflow rate of  $1.6 \text{ dm}^3\text{s}^{-1}$  (heavy work). While exhaling, the border value is 300 Pa with an airflow rate of  $2.7 \text{ dm}^3\text{s}^{-1}$ . Comparing the values included in **Table 8**, it should be noted that for the particle filtering half-mask the results were much lower than the acceptable values. The selection of the geometry of filtering materials is significant in this matter, particularly the thickness of the

**Table 8.** NaCl and paraffin oil filter penetration test results for particle filtering half-masks.

Statistic parameters	Penetration coefficient for airflow rate $1.6 \text{ dm}^3\text{s}^{-1}$ for: %	
	NaCl	Paraffin oil
Average	0.26	1.42
Standard deviation	0.16	0.36
Minimum	0.12	0.98
Maximum	0.66	2.10

**Table 9.** Inhalation and exhalation breathing resistance test results for particle filtering half-masks.

Statistic parameters	Inhalation breathing resistance for airflow rate: Pa		
	$0.5 \text{ dm}^3\text{s}^{-1}$	$1.6 \text{ dm}^3\text{s}^{-1}$	$2.7 \text{ dm}^3\text{s}^{-1}$
Average	51.4	132.8	264.1
Standard deviation	6.6	19.6	24.7
Minimum	38.1	97.8	220.7
Maximum	57.6	158.0	299.8

**Table 10.** Dolomite dust clogging test results for particle filtering half-masks.

Statistic parameters	Penetration coefficient for airflow rate $1.6 \text{ dm}^3\text{s}^{-1}$ for: %		Inhalation breathing resistance for airflow rate: Pa	
	NaCl	Paraffin oil	$1.6 \text{ dm}^3\text{s}^{-1}$	$2.7 \text{ dm}^3\text{s}^{-1}$
Average	0.20	1.4	174.5	268.1
Standard deviation	0.06	0.2	16.8	31.8
Minimum	0.13	1.1	154.0	233.0
Maximum	0.27	1.7	203.8	301.0

**Table 11.** Total inward leakage test results of the test aerosol for a particle filtering half-mask.

Statistic parameters	Test aerosol leakage, %					
	Walking with no head movement	Turning the head from side to side	Moving the head up and down	Reciting text	Walking	Average
Average	3.42	4.89	3.27	2.19	2.71	3.29
Standard deviation	2.10	4.45	3.20	1.43	2.39	1.69
Minimum	0.09	0.17	0.59	0.42	0.23	0.57
Maximum	6.74	11.91	10.89	4.49	7.61	6.06

fibrous material and porosity of the non-wovens [31]. While evaluating a particle filtering half-mask, the dust clogging result is of crucial importance, which allows us to conclude that while using a half-mask in the workplace, quick clogging of the outer (pre-filter) and then the proper filtering layer (melt-blown material) will not take place. Evaluation of this parameter is done through measuring the value of the filtering coefficient of both tested aerosols and breathing resistance after disposing 1.5 g of dust in the filtering system that is the scaffold of filtering half-mask construction ( $400 \text{ mg/m}^3$  for 125 minutes of exposure to dolomite dust). The results concerning this issue (**Table 9**) show that as far as breathing resistance is concerned, much lower values than acceptable were obtained for inhalation ( $\text{FFP3} \leq 700 \text{ Pa}$  and for exhalation  $\leq 300 \text{ Pa}$ ). At the same time, there was a slight overcrossing (1.1%) of the pen-

etration coefficient for paraffin oil mist (required  $\leq 1\%$ ). This could result from a weakening in the phenomenon of deposition of liquid particles on the fibrous material as a result of electrostatic charges (screening electrostatic charges collected in the melt-blown nonwovens by the particles of liquid aerosols) [32, 33]. To prevent this phenomenon, it is necessary to work out a more effective system of charging the biodegradable melt-blown nonwovens or its modification, aiming at enhancing the electrostatic power on the border between fibrous and liquid particles. Unfortunately, due to the slight overcrossing in the value of the penetration coefficient of paraffin oil mist after dolomite dust clogging, it was not possible to include the particle filtering half-mask in the highest protection class, FFP3. The last of the parameters was total inward leakage, which measures the so-called adjustment of the half-mask to

the user's face. Research was carried out on a test subject in special chamber filled with NaCl aerosol. The requirements of the EN149:2001+A1:2009 standard are as follows: at least 46 out of the 50 individual exercise results for total inward leakage shall be not greater than 25% for FFP1, 11% for FFP2 and 5% for FFP3 and, in addition, at least 8 out of the 10 individual wearer arithmetic means for the total inward leakage shall be not greater than 22% for FFP1, 8% for FFP2 and 2% for FFP3. From the point of view of this parameter, these half-masks should be classified in the FFP2 protection class. This probably results from the inability to adjust the filtering half-mask through the application of non-standard elements such as head straps and a nose clip, which are the elements responsible for adjusting the filtering half-mask to the user's face.

Analysing the results for the developed biodegradable filtering half-mask, it should be stated that, among the filtration parameters, NaCl aerosol filter penetration, responsible for filtering out particulate matter (dust), attained the highest protection class, whilst its ability to filter out liquid droplets (mist) attained the medium level of protection. At the same time, the total inward leakage result for the equipment, which is the sum of the test aerosol penetration through the filtration media and leaks around the rim, was also at the medium level of protection, which allows the half-masks to be classified as FFP2.

In terms of the parameters responsible for respiratory comfort, the developed half-masks met the highest requirement levels and, simultaneously, the same high level was achieved for the dolomite dust clogging test. In practice, this parameter can be used to assess the time the half-masks can be used in the workplace. The fulfilment of the evaluation criteria at the highest level indicates that the selection of biodegradable layers in the manufacture of the half-mask's shell guarantees a uniform distribution of aerosol particles with the long-term use of the half-mask in the workplace. In particular, the outer filtration layer is responsible for the good performance of this parameter, which consisted of a needle-punched nonwovens produced by interlacing PLA fibres, manufactured by IBWCh within the framework of the "Biogratex" project, with commercial fibres.

Summarising the assessment results for the tri-layer, fully biodegradable particle filtering half-mask, it should be stated that the developed prototypes fulfilled the requirements of the EN149:2001+A1:2009 standard [30] for the first (FFP1) and second (FFP2) classes of protection.

The research confirming the biodegradable capabilities of the nonwovens was performed in the accredited IBWCh laboratory. The method used for the assessment of biodegradation in a compost environment was testing the mass loss. On the basis of the results [34], it was concluded that the nonwovens produced from biodegradable commercial polymers (PLA) biodegraded fully after only four weeks of composting.

Currently, biodegradability tests are being performed on the prototype filtering half-mask. Commercialisation and full-scale production of the particle filtering half-mask is anticipated.

## Conclusions

The developed particle filtering half-mask prototype is an interesting offer for personal protective equipment manufacturers. Ensuring the availability of this personal protective equipment is even more important. On one hand, there is growing public awareness in the use of protective measures in the non-professional sphere (e.g. half-mask use during a flu epidemic), while at the same time there is reluctance in society to build new landfills and incinerators. In this context, the implementation and dissemination of production and the use of biodegradable respiratory protective equipment is an important problem from the point of view of protecting the natural environmental and public safety.

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# EPNOE 2013

## 3<sup>rd</sup> EPNOE International Polysaccharide Conference

### POLYSACCHARIDES AND POLYSACCHARIDE - DERIVED PRODUCTS FROM BASIC SCIENCE TO APPLICATIONS

**Nice (France)**  
**21-24 October 2013**

The European Polysaccharide Network of Excellence (EPNOE) and the Cellulose and Renewable Materials Division of the American Chemical Society (ACS) join their efforts in promoting basic and applied sciences of polysaccharides by organising common events, one of which is the 3<sup>rd</sup> EPNOE conference.

This conference is a forum bringing together academic, industrial, and government scientists and students dealing with polysaccharides and polysaccharide-derived products. Many specialists including biologists, chemists, physicists, food specialists, technologists, and environmentalists will meet and gain knowledge about the interdisciplinary world of polysaccharide science.

All research and application topics related to polysaccharides are within the focus of EPNOE 2013, particularly:

- Polysaccharide isolation and characterisation (algae, new crops and plants, by-products, wastes, other sources)
- Biosynthesis of polysaccharides
- Biodegradation of polysaccharides (mechanisms, products determination, efficiency), enzymology
- Chemical modification of polysaccharides
- Advanced physical, chemical, structural, and surface characterisation of polysaccharides
- Nanotechnology: nano- and micro- polysaccharide-based objects (production, characterisation, use)
- Biomimetic applications of polysaccharides
- Development of fuels based on polysaccharides
- Polysaccharides and food ingredients
- Polysaccharides for biomedical applications
- Polysaccharide-based materials including films, fibres and composites
- Bioplastics
- Pulp and paper
- Life Cycle Assessments- Environmental concerns –Policy – Social aspects
- New trends on polysaccharide research and applications (session organised by PhD students and post-doctoral researchers from EPNOE partners).

A round-table discussion on education, an evening session for the general public and a special

session entitled "Polysaccharide-based bio-economy: visions of CEOs and major stakeholders" are planned. In addition to oral and poster presentations, two special guests, four plenary lecturers and more than 30 invited lecturers from all over the world will deliver a speech.

Registration will open on 1<sup>st</sup> January 2013 and all needed information is to be found on the web site of the conference.

#### **Important dates:**

- **01 January 2013:** Opening of abstract submission and registration
- **15 May 2013:** Deadline for submitting abstracts
- **31 July 2013:** Deadline for early registration

**Website:** <http://epnoe2013.sciencesconf.org>  
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