European Strategy for Nanosafety

nanoSAFE

Safe production and use of nanomaterials

Are conventional protective devices such as fibrous filter media, cartridge for respirators, protective clothing and gloves also efficient for nanoaerosols?

Efficiency of fibrous filters and personal protective equipments against nanoaerosols

Dissemination report
January 2008
DR-325/326-200801-1

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An European Integrated Project Supported by through the Sixth Framework Programme if research and Technological Development

Dissemination reports from Nanosafe2 project are designed to highlight and present in a simplified way the main results obtained in the studies carried out during this project. These reports mainly deal with one question which is of general concern for whom is interested by the safe production and use of nanomaterials. The full results are summarized in the corresponding Technical reports.
***All the Dissemination reports and Technical reports are publicly available from Nanosafe2 project website**: http://www.nanosafe.org*

Refer to:

***D325**: Final report on HEPA filter efficiency with different nanoparticle types and 1 nm nanoparticles*
***D326:** Final report on individual mask and cloth filtration efficiency with different nanoparticle types and 1 nm nanoparticles.*

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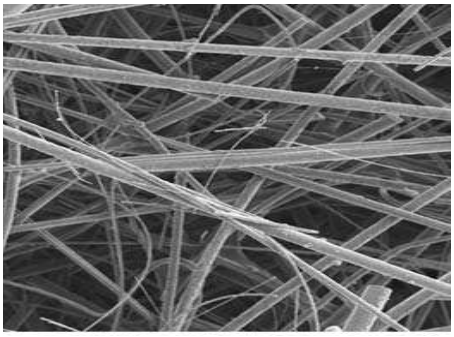
What does theory say about fibrous filtration media?

Fibrous filtration media are widely used for particle filtration of workshops, in a large number of respirator cartridge and personal masks. It is of prime importance to understand how this type of filter works in order to remove from our mind the vision of a skimmer-like behavior where only particles bigger than holes should be stopped! This vision is definitely not right and can lead to opposite conclusions. Clothing fabrics which are constituted of fibers may also be considered as fibrous filters.



Fibrous filter as seen through a microscope

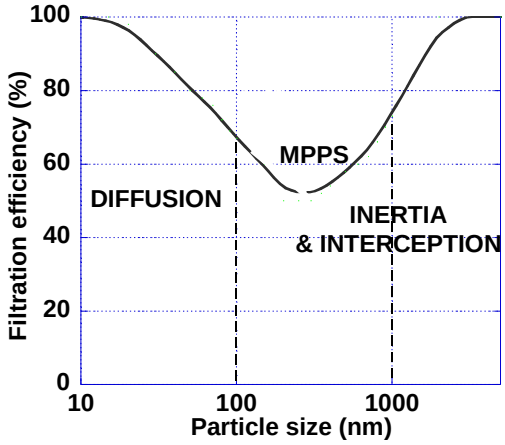
A simple microscope observation of such a filtration media reveals that they are constituted by a real criss-cross of glass or cellulose fibres. Interstices and fibres typical dimensions are measured in µm. However this kind of structure efficiently traps even particles in the nanometer size range … in its thickness.
When a particle meets a fibre, it is irreversibly glued by van der Waals forces which are highly predominant at the particle scale.
At the scale of this picture, a 10 nm particle measures about a thousandth of mm!

Particles are deposited on the fibers by 3 different mechanisms:

Large particles > 1000 nm
Interception: particle trajectory meet a fibre
Inertia: air flow is deviated around a fibre, particles which are denser than air cannot follow air curvature.

Small particles < 100 nm
Diffusion: smaller particles are submitted to random displacements due to Brownian motion which enhances collision probability with fibres.

This is for intermediate sizes that we have the Maximum Penetrating Particle Size (MPPS around 150 - 300 nm).



Finally, the smaller the particles and the higher the filtration efficiency by diffusion phenomena are.

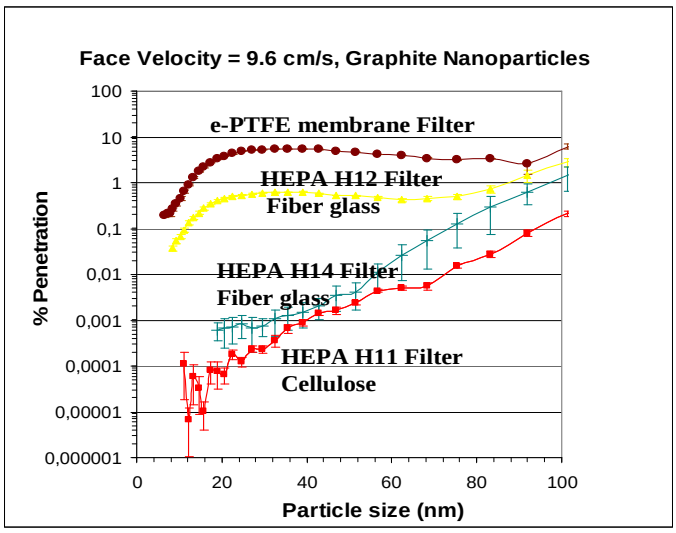
Fibrous filters are even more efficient for nanoparticles!
The skimmer model for fibrous filter is definitively wrong

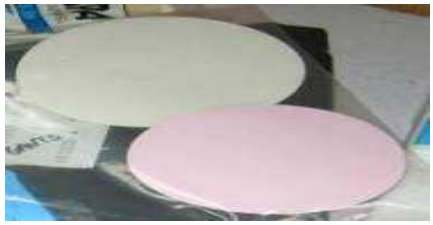
Nearly all the tests performed by research teams with nanoparticles are confirming the conventional filtration theory. Any hypothetic limitation of this trend by thermal rebound effect predicted by Wang et Kasper[1], has not yet been verified until 2 nm.

1.Wang H.C., Kasper G., Filtration efficiency of nanometer-size aerosol particles, J. Aerosol Science, 23, 31-41, 1991

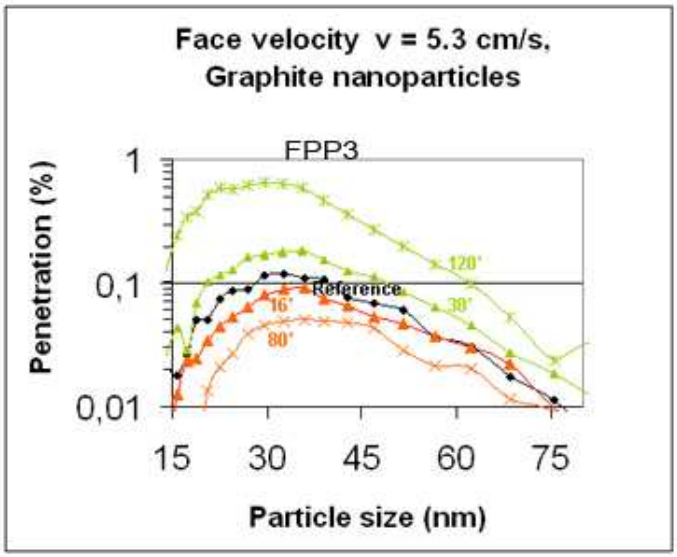
What are the performances of air filtration media, respirator cartridge and masks?

Fibrous filters and electrostatic filters have been tested with graphite challenge nanoparticles.





Tests performed with graphite particles confirm for major conventional HEPA filters that nanoaerosol penetration rates decrease drastically for smaller particles. Bringing these kinds of media into respirator cartridge and mask does not alter their good performances for nanoparticles, i.e. no measurable effect of folds and peripheral sealed are identified.



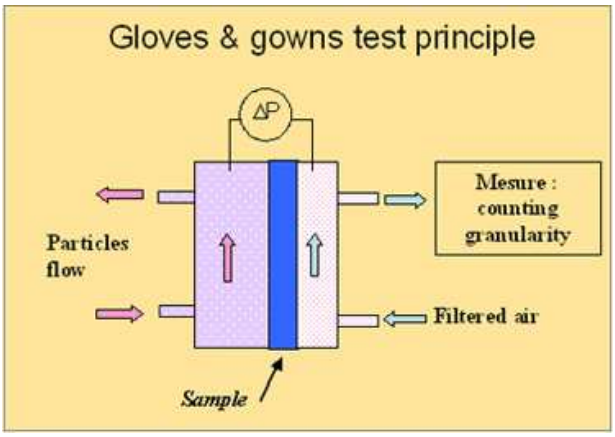
*For electrostatic respiratory filters, the most penetrating particle size (MPPS) is around 30 nm: standardized measurement tests should be adapted from 600 nm to 30 nm. In **dry condition**, the penetration of nanoparticles decreases with time. With **humidity brought by breathing**, the penetration of nanoparticles through the electrostatic media increases, close to the threshold value (1%) defined for the FPP3 mask (NF EN149) after 2 hours of usage.*

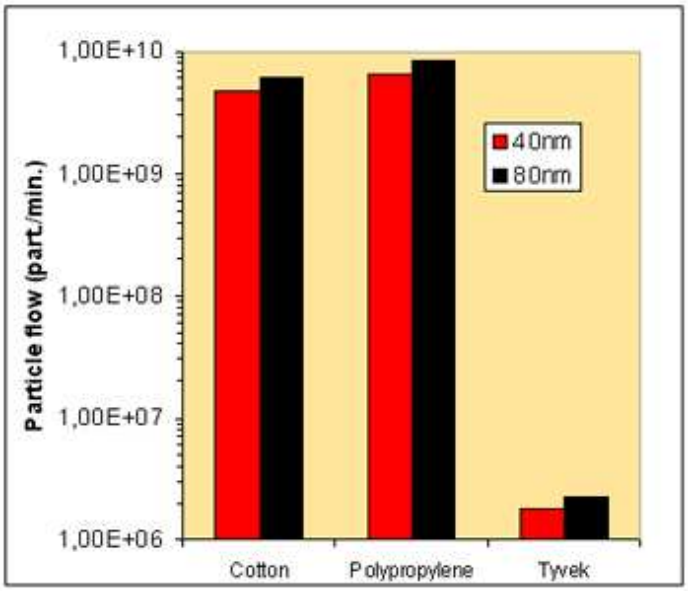
HEPA filters, respirator cartridges and mask made with fibrous filters are even more efficient for nanoparticles.
Standardized MPPS test have to be adapted from 600 to 30 nm for electrostatic filters.
For masks, risk is clearly coming from the tightness between face and mask.

What are the best protecting clothes to use?

Previous tests performed by S.H. Huang et al.[2] have shown that weaved fabrics behave the same as fibrous filters. The MPPS is comprised between 100 and 500 nm and efficiency increases when particles size decreases toward nano dimensions. These tests have been done with an imposed air flow, like those performed to test filters. In a complementary way, closer to actual use conditions of protective clothing, Nanosafe2 team made tests without any air flow, using a through diffusion cell.

The "through diffusion method" derivates from standard NF EN ISO 6529 and NF EN 374 uses a diffusion cell in which a constant particle concentration is imposed in the upper flow part. Diffusion coefficients are calculated from the measurement of nanoparticle flowing in the down flow part of the cell.





Tests performed with graphite nanoparticles centred at 40 nm and 80 nm showed that high density polyethylene textile (Tyvek® type) seems to be better than cotton and polypropylene.

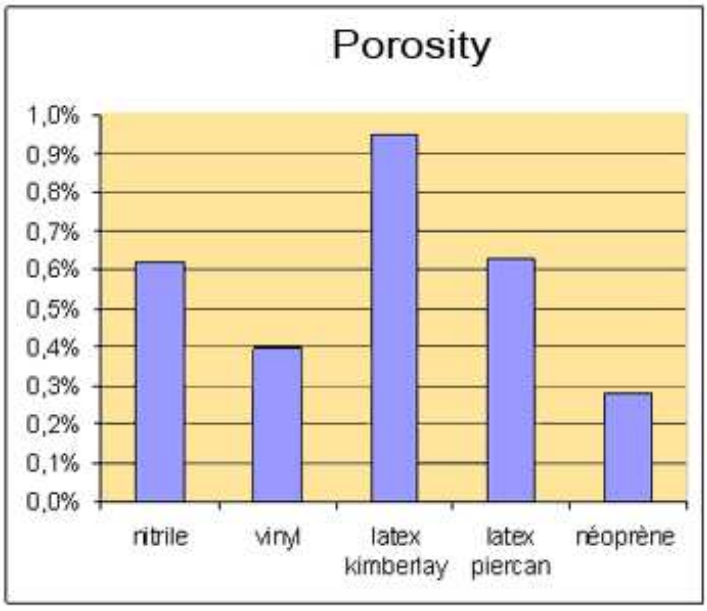
Non woven fabrics seem much more efficient (air-tight materials) against nanoparticle penetration.

Avoid the use of protective clothing made with cotton fabrics.

[2] *S.H. Huang et al., Nanoparticle penetration through protective closing materials, 3rd International Symposium on Nanotechnology, Taipei, 2007*

Which kind of gloves performances can we expect?

Different types of gloves have been tested with the though diffusion techniques using Helium for porosity evaluation and graphite nanoparticles for efficiency measurement.



The porosity to helium (~0.3 nm) seems specific to a type of material.

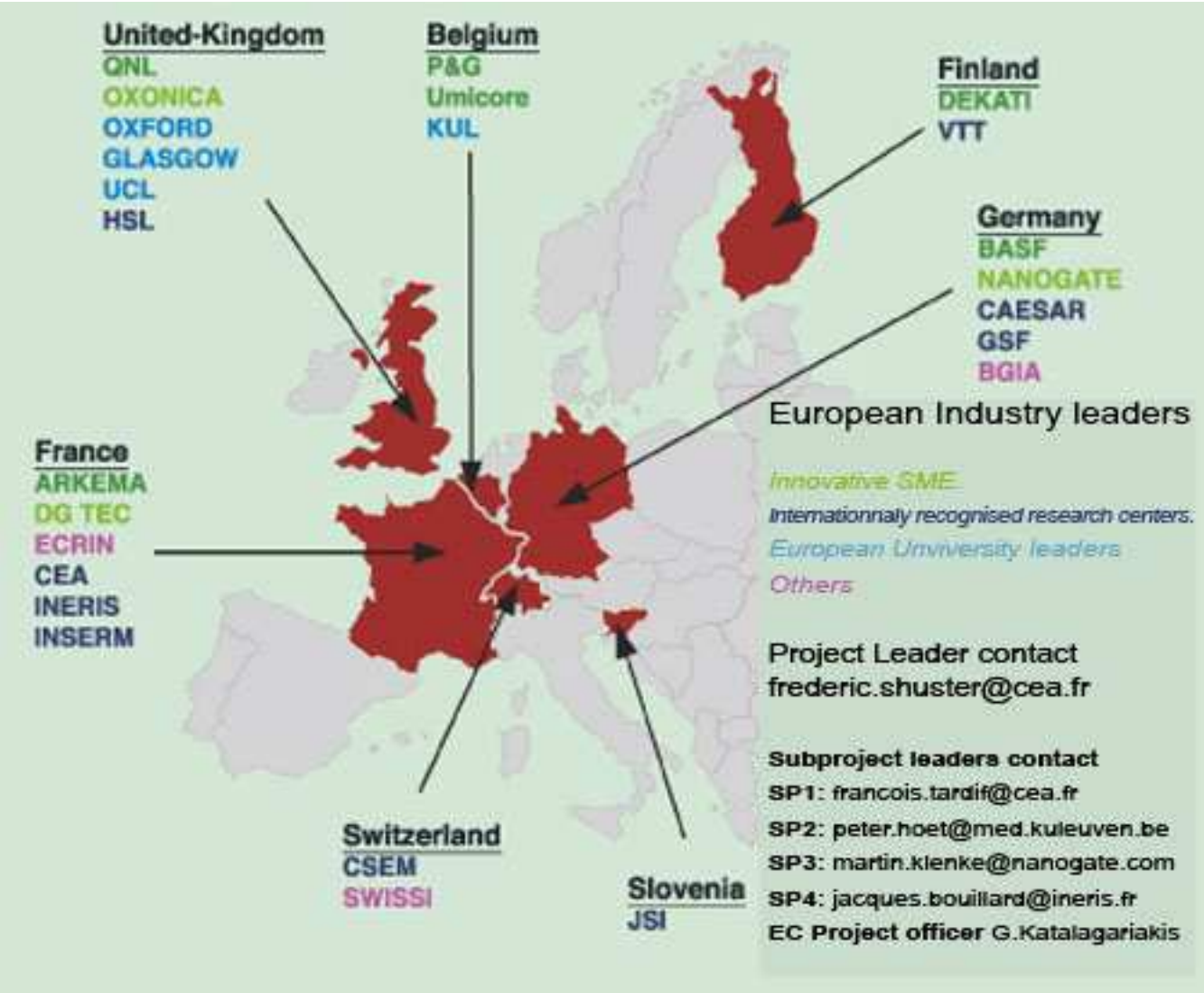
Several types of gloves have been tested by Helium diffusion test. All the tested gloves are made of porous material which differs according to the material and thickness. On the other hand, after exposure to a high concentration of graphite aerosols, ranging from 20 to 100nm, no particle penetration can be measured.

In spite of the porosity of gloves, their efficiency to nanoaerosol is very high

This result does not prejudge to the efficiency of gloves against colloidal dispersion liquid

Nanosafe2 brings together twenty five partners from seven countries of the European Union, mainly small, medium and large enterprises and public research laboratories. The project is supported through the Sixth Framework Programme for Research and technological Development of the European Commission and addresses the thematic priority3.43.2-1: Hazard reduction in production plant and storage sites. The project started in April 2005 and will end in March 2009.
Nanosafe2 main objective is to develop risk assessment and management for secure industrial production of nanoparticles. It focuses on four areas: detection and characterisation techniques, Health hazard assessment, development of secure industrial production systems and safe applications, societal and environmental aspects.

Partners



http://nanosafe.org

Efficiency of fibrous and personal protective equipments against nanoaerosols
DR-325/326-200801-1, Nanosafe-January 2008

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