Testing the appropriateness of N95 halfmask respiratory protection for aerosolized nanoparticles: development of test methods and results

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INTRODUCTION

•The industrial use of nanoparticles is nowadays becoming more and more common and its technologies are growing fast. However, this rising production and use of engineered nanomaterials can create new risks and generates several concerns related to their potential environmental, safety and health impacts. One of the main production methods creates nano powder, which can suffer a process of aerosolisation.

•All airborne particles are a hazard to our health, which increases when someone gets near the place where those particles are produced. The use of personal protective equipment (PPE) is a way of controlling hazards by placing protective equipment directly on workers' bodies, such as Respiratory Protection Equipment (RPE). According to the regulation for RPEs, like EN149:2001 to the RPEs test for dust protection, the smaller particles to use are 300nm of size, but nowadays the industry uses smaller size particles, like 7nm Al_2O_3. Thus, the RPE which works for these regulations cannot guaranty their efficiency for nanoparticles airborne protection.

METHODOLOGY

•In order to develop a test method and know if the actual regulation is enough to guaranty safety working with engineered nanomaterials (ENM), ITENE developed the Test and Research Equipment for Nanoparticles (TREN), based on the ETNA test bench, from the IRSN (Hinds and Kraske, 1987a,b; Balazy et al., 2006; Eninger et al., 2008; Brochot et al., 2012; etc.).

•This chamber was designed to test PPE and reduce any particle leaks testing with ENM. The air recirculates inside the TREN chamber; an electric fan makes the air go to the nanoparticle inlet and transports them to the sample chamber. Then, the air crosses an HEPA (High Efficiency Particle Arresting) filter, which cleans the air and returns to the fan, and the cleaned air recirculates until it returns to the nanoparticles inlet. The TREN designed allows to control the airflow velocity, and measures the temperature and the differential pressure. The TREN has connections to 4 different test equipment, testers, forced airflows, particle counters, and these connections allow several configurations.

•A Sheffield head placed inside the TREN can reproduce the conditions simulating its use in the workplace. This Sheffield head is actually a manikin head with internal pipes which allow us to collect the air from the inside of the mask. A 4 litters per minute air flow, forced with a constant pump inside the mask, simulates the human respiration at low energy tasks. Once the aerosol conditions are fitted, for the different nanoparticle types, the test is repeated measuring the number of nanoparticles at both sides of the mask, using TSI CPC 3007, OPS3330, a Casellas sampling pump and/or Aerasens-Philips Nanotracer.

•Tree different halfmasks are tested in this study, with eighth nanoparticles: ZnO, Fe_2O_3, TiO_2, Al_2O_3, $CoAl_2O_3$, SiO_2.

•Before testing them, the machine turns on at a maximum speed at least 5 minutes, to eliminate all possible nanoparticles inside the TREN. After that, the background inside the TREN is measured. After every test the machine works at a maximum speed during at least 10 minutes, in order to eliminate the nanoparticles inside the TREN, and monitoring that nanoparticle levels go back to their initial levels for at least 5 minutes. Once the machine test condition is stable the aerosol is generated and measures simultaneously both sides of the mask, analysing outside and inside nanoparticles concentration, and compares both values to calculate the penetration factor.

Image 1: The TREN machine.

Image 2: Testing laboratory.

•In order to compare the data from both sides of the mask, the concentration time reference at both sides was considered from the maximum of the aerosol pulse, because the halfmask's filter acts like a signal filter, delaying the aerosol pulse across the filter. The measures behind the halfmask are processed like the electronics filtered signals, when they are compared with the original one.

Table1: Tested ENM.

Material	Average primary particle size (nm)	Shape	Particle size distribution	Provider
Titanium Dioxide (TiO_2)	18nm	No-regular	615.1-2669nm	Tec Star
Zinc Oxide (ZnO)	98nm	Cubic	105.7-396.1	Tec Star
Aluminium ox. PSPP180 (Al_2O_3)	7nm	Tree leaf	-	Torrecid
Cobalt spinel PSPP200 ($CoAl_2O_3$)	-	Tree leaf	13.54-58.77nm	Torrecid
Silicon Ox. (SiO_2)	<20nm	No regular	-	Tec Star
Ferrite ceramic material with iron(III) oxide (FE_2O_3)	-	No-regular	-	Tec Star

•Three different kinds of respiratory protection half mask were tested: economical N95 disposable particulate welding respirator, reusable respirator, half facepiece reusable respirator with filter holder cartridge.

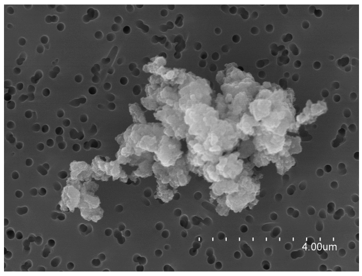
RESULTS

Table 2: Three different kinds of respiratory protection half masks were tested.

NanoparticleMaterial	Penetration Factor %			
RPE type	A	B	C	
Titanium Dioxide (TiO_2)	82,5	89,3	53,3	Tec Star
Zinc Oxide (ZnO)	59,9	79,3	54,7	Tec Star
Aluminium ox. PSPP180 (Al_2O_3)	36,6	32,8	21,1	Torrecid
Cobalt spinel PSPP200 ($CoAl_2O_3$)	73	46	57,6	Torrecid
Silicon Ox. (SiO_2)				Tec Star
Ferrite ceramic material with iron(III) oxide (FE_2O_3)	77,7	85,2	20,3	Tec Star

Image3: Half mask set up .

Image 4: TiO_2 nanoparticle captured behind the halfmask with a sampler pump with filter (58±6nm), SEM technique.



Conclusions

•For a N95 mask, regulation indicates that it must have a protection factor higher than 95%, which is equivalent to a penetration factor lower than 5%. Results of the study, as indicated in table 1, show that all the half masks tested are not adequate under the penetration factor criteria, when they are tested for the nanomaterial used in the Nanomicex and Nanorisk European projects.

•The penetration can not be used has a criteria for safety without knowing the toxicity of the materials at nanosize.

•The aerosol method for the nanomaterial used should be upgraded for testing.

•For an easier work method it is better to use the same counter model at both sides of the mask.

•Some standards and regulations, like REACH, identify the nanomaterial as the materials which almost one of their dimensions is inside the range from 1 till 100nm, and more accurate instruments are needed for testing.

•The half mask standards use the mass for measuring the penetration factor for the breathing particles. These methods compare all the mass used from the beginning of the test till the end, but these methods don't discriminate other sizes. Today's technologies cannot collect only nanosize particles.

•The breathing simulation needs to be more realistic to be able to reproduce the uncontinuous pressure across the filters. Use an air pump with continuous air flow as the breathing simulator, because it is the easier way to do it and maybe it can be enough, but it can start a new path of research on their comparison.

•For different nanoparticles, different penetration factors, results must be compared with the standard typical nanoparticle for testing NaCl.

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