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METHODOLOGY FOR TESTING PERSONAL PROTECTIVE CLOTHING AGAINST AIRBORNE NANOPARTICLES

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Overview

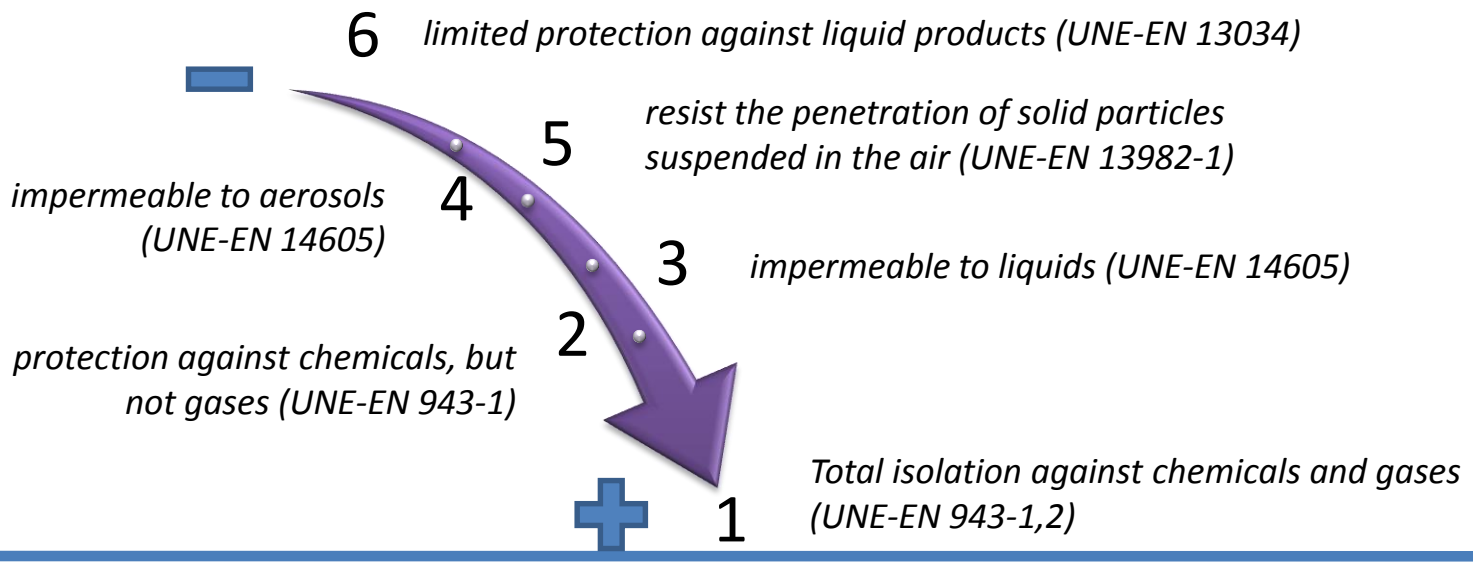
- Background (state of art)
- Methodology
- Validation of experiments
- Results
- Conclusions

Background

Normative

At present, we measure the protection factor of PPE by a flame photometer according standards in function of each PPE (disposable masks, reusable masks, non-ventilated suits, ventilated suits, etc.)

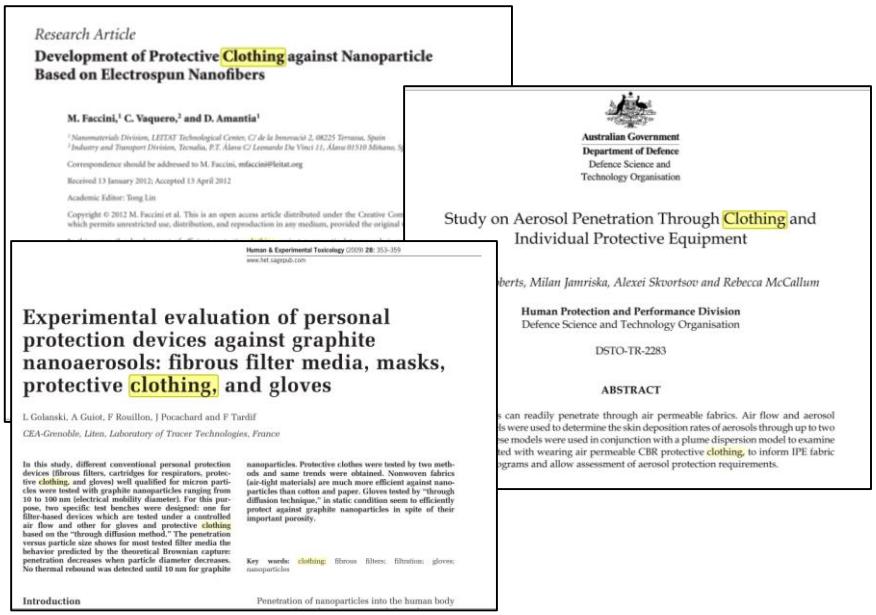
EN 149:2001 + A1:2009	Half masks to protect against particles
NF EN 136-1:1998	Full face masks
NF EN 143-1:2000	Particle filters
EN ISO 13982-2:2004	Protective clothing



Background

State of the art

- If the NM is used in form of **dust**, the use of disposable suits **type 5** is proposed.
- If the NM is used in a **colloidal solution**, the use of **type 4 or 6** is suggested.



Research Article

Development of Protective Clothing against Nanoparticle Based on Electrospun Nanofibers

M. Faccini, C. Vaquero, and D. Amantia

Australian Government
Department of Defence
Defence Science and Technology Organisation

Study on Aerosol Penetration Through Clothing and Individual Protective Equipment

Human Protection and Performance Division
Defence Science and Technology Organisation

DSTO-TR-2283

ABSTRACT

Experimental evaluation of personal protection devices against graphite nanoaerosols: fibrous filter media, masks, protective clothing, and gloves

L Golanski, A Guiot, F Rouillon, J Pocachard and F Tardif

CEA-Grenoble, Liten, Laboratory of Tracer Technologies, France

- In general, is concluded that **nonwoven clothes** offer better protection than woven fabrics

Objective

- Create and validate a new protocols adapted to nanoparticle measurement
- Correlation between flame photometer and CPC-SMPS measurement
- Evaluate Protection Factor of some existing PPEs (used by industrial partners)

Protocol: Flame photometer vs CPC-SMPS

Flame photometer	CPC-SMPS
Measure in mass per volume (g/m3)	Measure in number
Mass Median Diameter: 600 nm	Count Median Diameter < 100 nm
Standard or already existing test setups	Necessity to design or build specific parts of the setup
Particle nature: only NaCl or HF6	Particle nature: unlimited
Tests with human subjects	Tests with human subjects only with NaCl, other ENMs tested with mannequins or substitutive parts
Inward Leakage	$I.L_{Clothing} = \frac{C_2}{C_1} \cdot 100$
Nominal Protection Factor	$NPF = \frac{100}{I.L}$

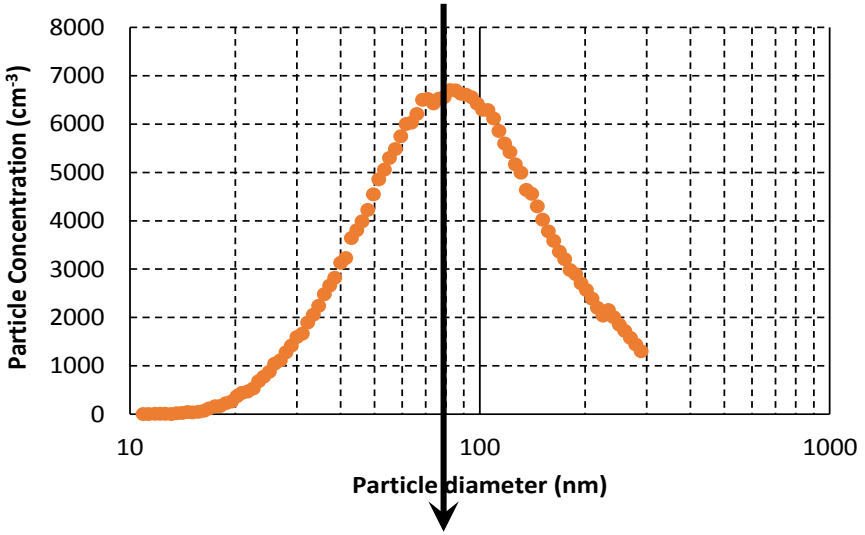
Methodology

Particle size distribution

Static / Dynamic test - ITENE

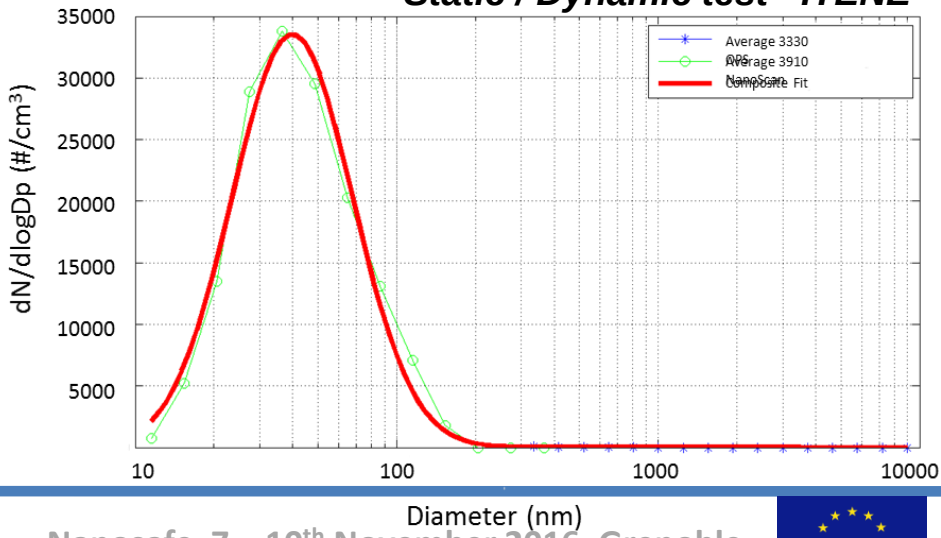
NM	Concentration (% in 1000 ml H_2O)	Dpg (nm)	Type of Essay
NaCl	0.0001	25	static / dynamic
	0.001	30	
	0.01	35	
	0.05	38	
	0.1	42	
SiO_2	0.05	38 - 110	static
	0.1	45 - 140	
	0.5	x	
TiO_2	0.05	x	static
	0.5	x	

Dynamic test - Honeywell



dp_{50} = 80 nm

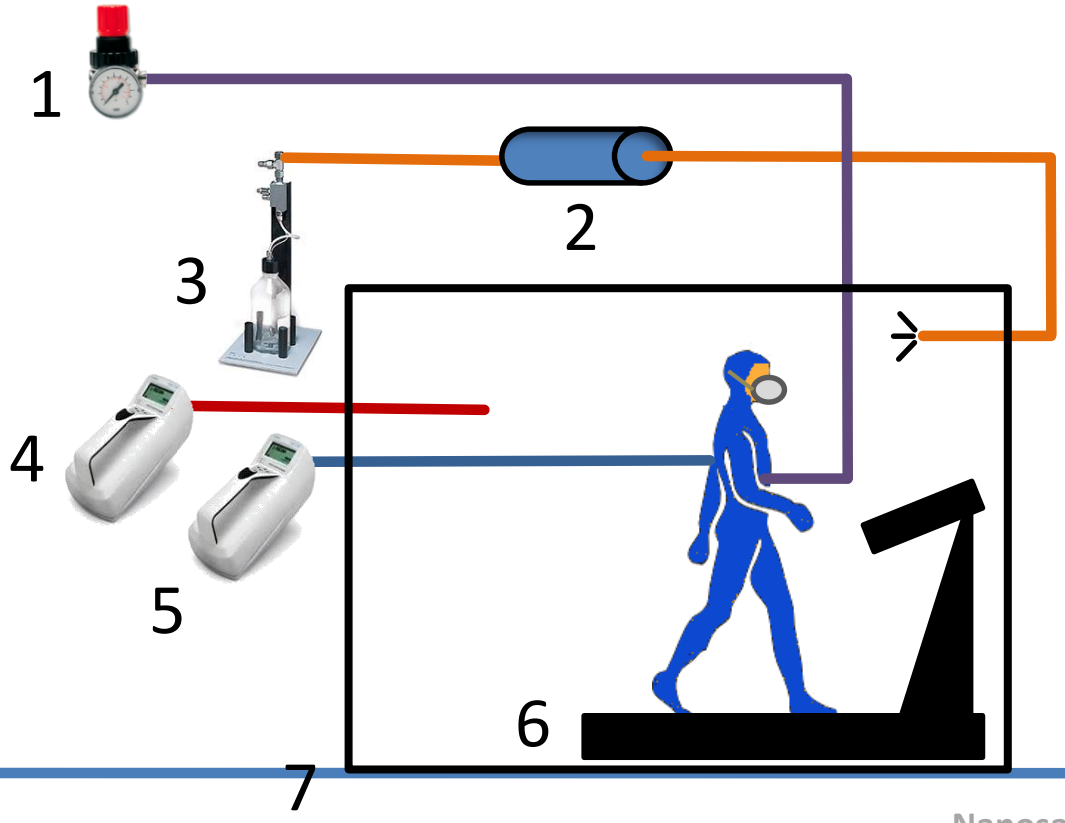
Static / Dynamic test - ITENE



Methodology

Setup – Dynamic tests

- At least 10 human subjects with good medical conditions
- Diversity on sizing (S-M-L-XL)
- 3 replicates for each test



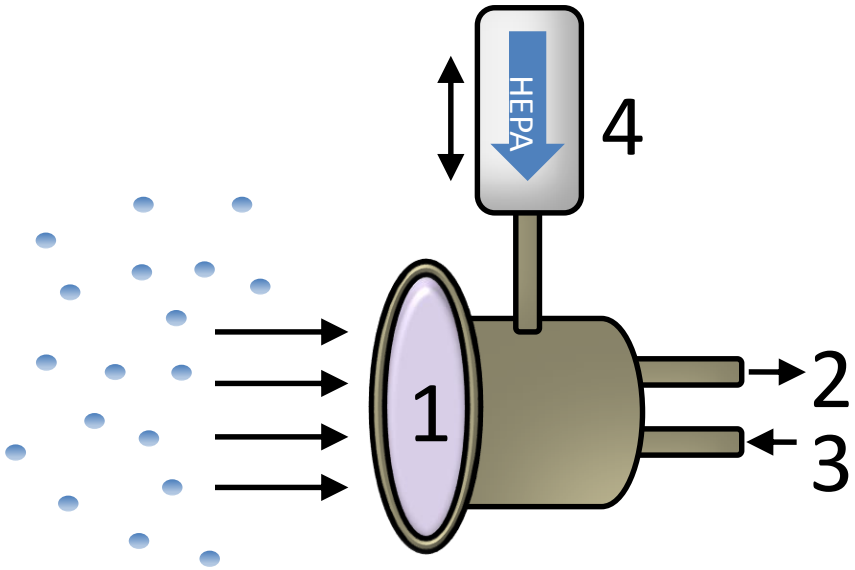
1 – Chest, right side
2 – Waist, back, left side
3 - Knee, right side

	Sampling	Air	Closed
Position 1	Knee	Chest	Waist
Position 2	Waist	Knee	Chest
Position 3	Chest	Waist	Knee

Methodology

Setup – Static tests

- Only fabric of the suit tested
- Sealed or wore by a mannequin
- 3 replicates for each test

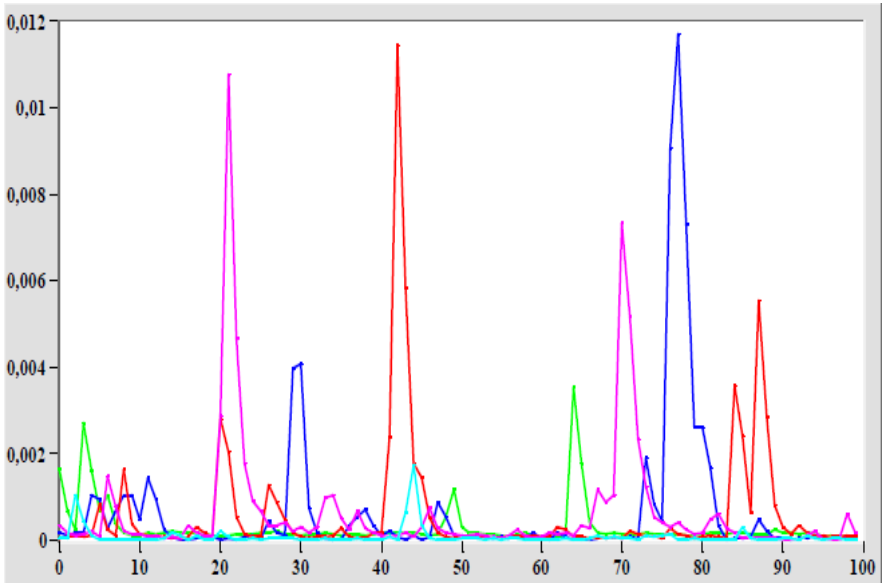


Validation of experiments

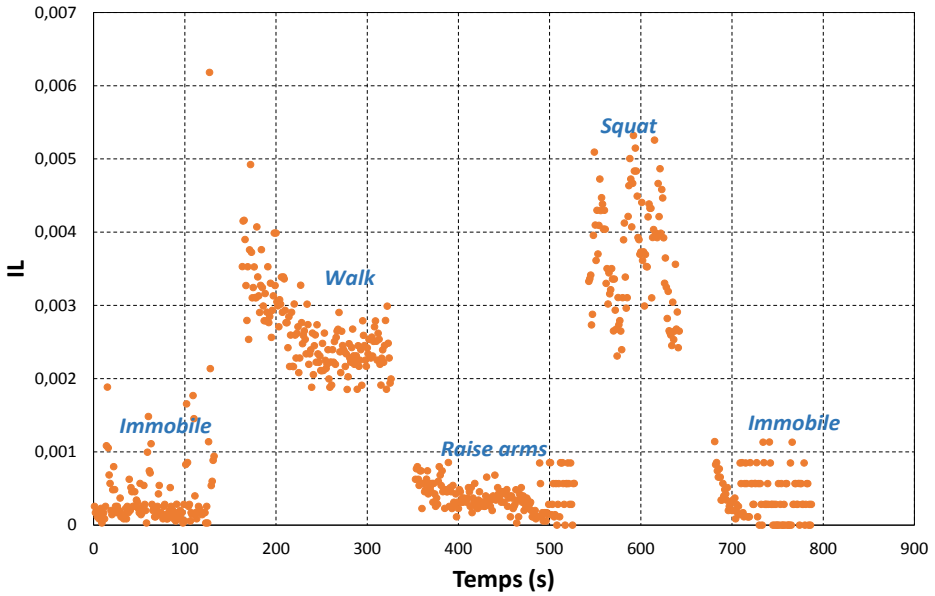
Correlation between Flame Photometer and CPC-SMPS:

PPE: Ventilated suit
FP expected: > 50000

Inward Leakage (IL) by flame photometer



Inward Leakage (IL) by CPC-SMPS



Validation of experiments

Correlation between Flame Photometer and CPC-SMPS:

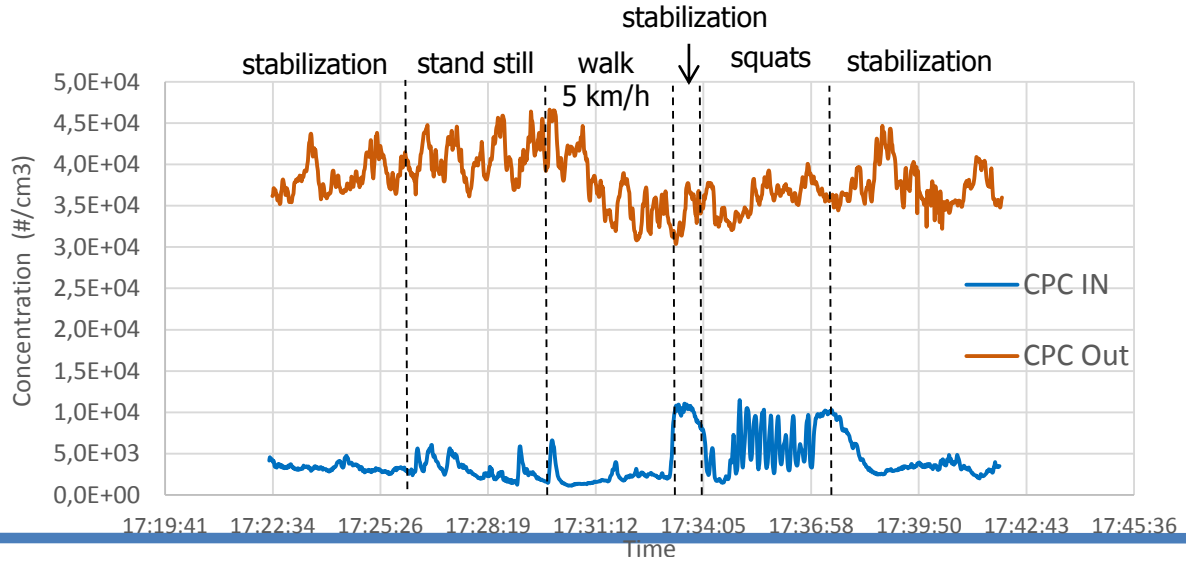
PPE: Ventilated suit
FP expected: > 50000

Protection factor (PF) by flame photometer							
		0	Walk	Raise arms	Squat	0	**Average**
Essai 1:	**IL**	0,00050	0,00168	0,00029	0,00292	0,00014	**0,00111**
230 L/min	**FP**	200 000	59 524	344 828	34 247	714 286	**90 416**
Essai 2:	**IL**	0,00012	0,00210	0,00014	0,00334	0,00021	**0,00118**
270 L/min	**FP**	833 333	47 619	714 286	29 940	476 190	**84 602**

Protection factor (PF) by CPC-SMPS							
		Immobile	Walk	Raise arms	Squat	Immobile	**Average**
Essai 1:	**IL**	0,00036	0,00261	0,00058	0,00315	0,00072	**0,00148**
230 L/min	**FP**	275 332	38 323	171 468	31 785	138 434	**67 346**
Essai 2:	**IL**	0,00040	0,00265	0,00039	0,00367	0,00039	**0,00150**
270 L/min	**FP**	249 629	37 665	256 733	27 220	254 381	**66 560**

Results

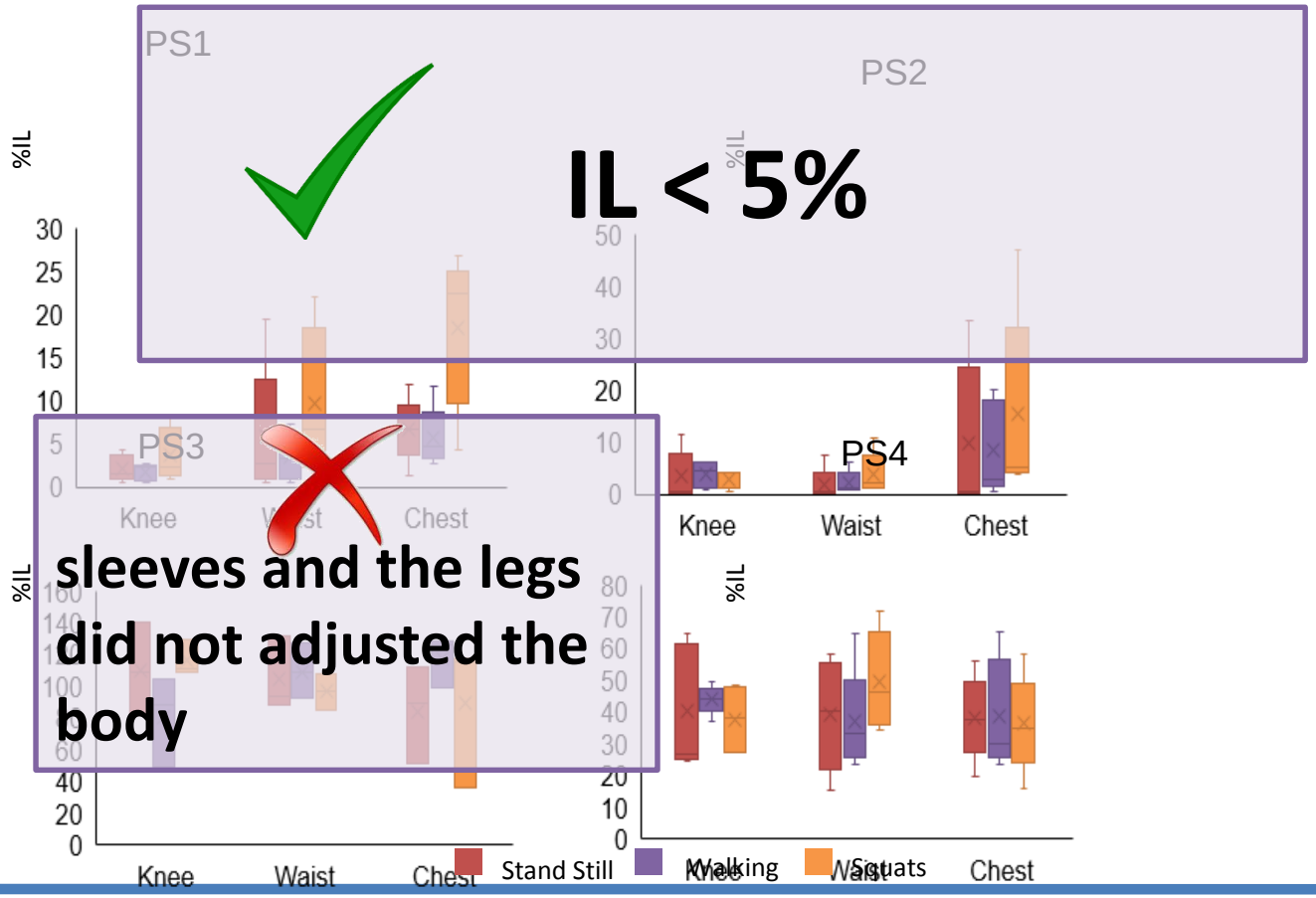
Code	Material	Cat/Type	Reuse/ Disp
PS1	high barrier protection against chemicals (Tyvek type)	Cat III Types 3B, 4B, 5B and 6B	D*
PS2	Million fine and continuous fibers made of high density polyethylene (Tychem type)	Types 5B and 6B	D*
PS3	double-side PVD coated Nylon	Cat III Type 4	R
PS4	Polypropylene	Cat I Type 6	D
PS5	Self ventilated radioactive suit	Type 1	R



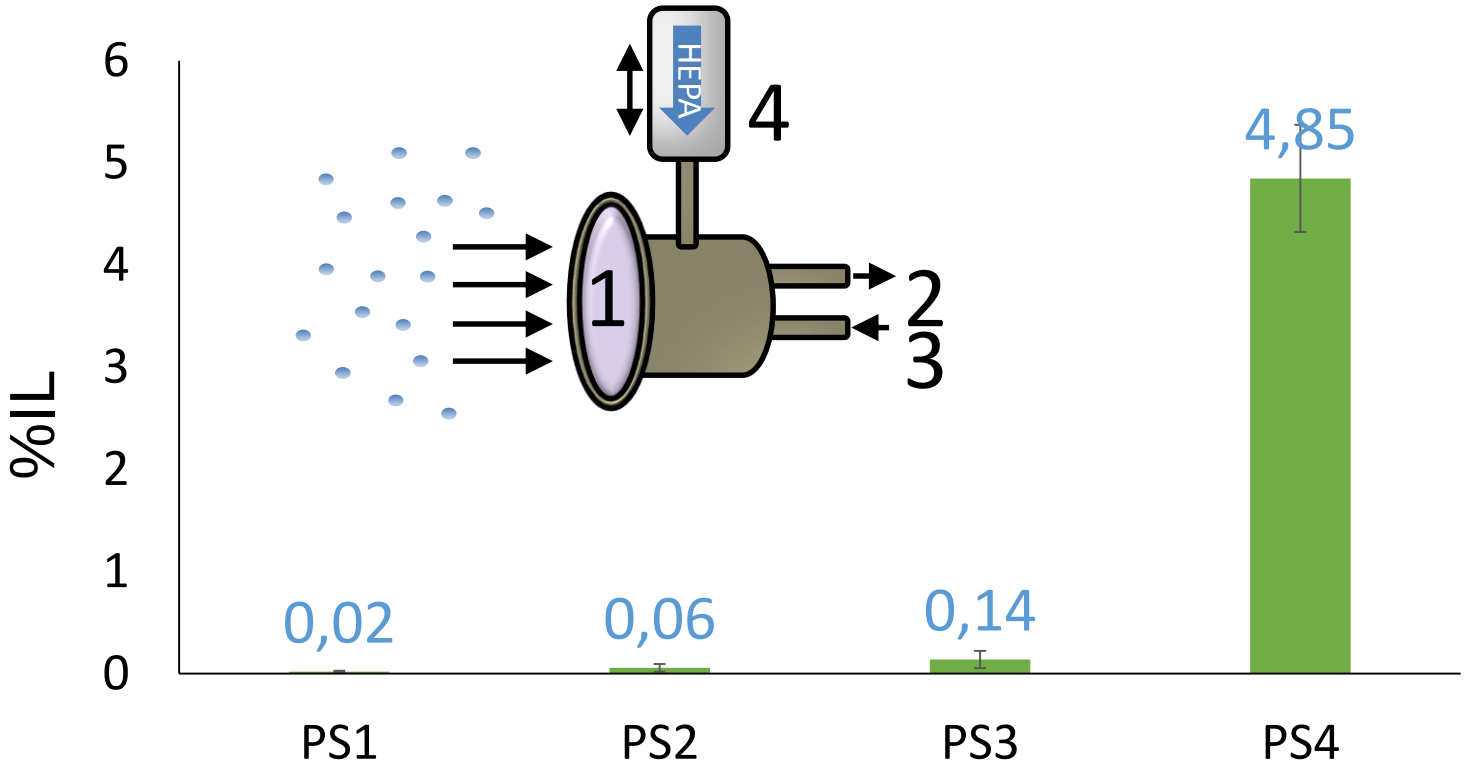
Results

High variability based on gaps in clothing due to:

- Body shape
- Fitting of suit
- Movements which compress or deform the suit.



Results



- protection efficiency against NPs achieved by the fabrics of the **PS1, PS2 and PS3** was **higher than 99%.**
- fabric of the **PS4** offered the lowest level of protection, although it is **over 95%.**

Results

Round Robin tests

Honeywell

PPE	Type 3	Type 5/6	Type 4/5	Type 1
Immobile	1480	2003	1182	275332
Raise arms	622	1563	822	38323
Walk at 5 km/h	762	1074	992	171468
Squat	397	407	677	31785
Total PF	*397*	*407*	*417*	*67346*
Efficiency (%)	*99,75*	*99,75*	*99,76*	*~ 100*

Results correlate to the standard values and to the experiments performed by ITENE

Conclusions

- The efficiency of protective clothing against nanoparticles has not been explored widely
- Many types of personal protective suits and gloves have been tested against a nanoaerosol of NaCl
- Flame photometer *vs* CPC-SMPS → comparison
- New protocol adapted to measure in number
- Efficiency offered by the different type of suits was upper 95% in all cases
- The protection achieved by the distinct suits depended, mainly, on the fitting to the body

Thanks for your attention!