PROJECT FINAL REPORT

Grant Agreement Number: 228439
Project Acronym: SAFEPROTEX
Project Title: High Protective Clothing for Complex Emergency Operations
Funding Scheme: FP7-NMP-2008-SME-2
Date of latest version of Annex I against which the assessment will be made: 20.04.2011

Name, title and organisation of the scientific representative of the project's coordinator: Dr. Silvia Pavlidou, MIRTEC S.A.
Tel: +30-210-9234932
Fax: +30-210-9235603
E-mail: s.pavlidou@ebetam.gr
Project website address: www.safeprotex.org

1. FINAL PUBLISHABLE SUMMARY REPORT

1.1. Executive Summary (not exceeding 1 page)

The concept of SAFEPROTEX concerns the development of protective uniforms, incorporating multiple protective properties and designated for rescue teams operating under complex risky conditions. In particular, three representative risky operations were considered, namely:

- emergency operations under extreme weather conditions (floods, hail, etc),
- operations under the risk of wild land fires, and
- operations of first aid medical personnel, potentially exposed to any risk.

The key scope of the project was to address the main limitations of existing protective garments and, in this context, to develop uniforms exhibiting: (a) protection against multiple hazards, (b) physiological comfort, ergonomic design and enhanced mechanical parameters, and (c) extended service life.

Having identified the protective properties required in each operation considered, additional user requirements were defined through close collaboration with end-users. Market trends and relevant legislation were also considered in order to set-up the specifications of the garments to be developed.

Thereafter, to achieve its objectives, the project followed a bottom-up approach, starting at the nano-level and encompassing the entire value chain of the textile industry. In fact, project partners developed new additives and functionalizing agents, novel fibers and textile structures as well as multi-functionalizing surface treatments. The new developments include the development of thermo-regulating bi-component fibers incorporating non encapsulated phase change materials, of thermochromic polymeric sheets that act as high temperature alert systems when incorporated in the PPE, of 3D knitted liners, providing thermal insulation in low environmental temperatures, and of sol-gel surface treatments providing super-hydrophobicity, self-cleaning and antimicrobial properties, without deteriorating the handle and moisture management properties of the textile. After selection of the most appropriate materials and technologies that can be combined together, three prototype protective garments were produced, one for each type of operation, combining the following protective properties:

- **Prototype 1 (extreme weather conditions):** water impermeability, thermal insulation, super-hydrophobicity, self-cleaning and antimicrobial properties, high abrasion resistance in specific parts and thermo-regulation.
- **Prototype 2 (wild land fires):** FR properties, super-hydrophobicity, self-cleaning and antimicrobial properties, UV protection, protection against heat/cooling effect, high temperature alert and thermo-regulation.
- **Prototype 3 (first aid medical personnel):** super-hydrophobicity, self-cleaning, antimicrobial properties, FR, antistatic properties and thermo-regulation.

The design of the garments varied depending on the application and users' requirements (e.g. an overall was selected for Prototype 1 and two-pieces garments for Prototypes 2 and 3). Life cycle analysis proved the environmental benefit of the garments developed in SAFEPROTEX. The preliminary cost analysis indicated that the total cost of each developed product is competitive enough to create strong market opportunities also taking into account the lower maintenance requirements, as well as the extended duration of use. In addition to the objective lab testing and examination of the new textiles and garments, the prototypes were evaluated by the end users with very positive results and constructive comments for further improvement. Three partners have already expressed their strong interest and commitment of exploiting the outcomes of the project by introducing new protective garments in the market.

1.2. Summary description of project context and objectives

The concept of the project concerns the development of protective uniforms, incorporating multiple protective properties and designated for rescue teams under complex risky conditions met in various types of everyday emergency operations.

Technological developments and climatic changes have both led to a large increase in the hazards to which humans are exposed. Since a garment or a uniform constitutes the safety barrier between the wearer and the source of potential injury, its characteristics will determine the degree of injury suffered in case of an accident or an emergency operation. The steady evolution of health & safety requirements to respond to new types of risks makes it necessary to develop new innovative products and to ensure their reliability. Indeed, the range of hazards and the means of combating them continue to grow and become ever more complex. Emergency teams are trained to face operations varying from small scale or wild land fires, extreme weather incidents and other complicated situations. Even in a given emergency operation, rescue teams are exposed to a variety of risks.

The idea that constituted the basis of SAFEPROTEX was to create innovative solutions to address the main limitations of existing protective garments designated for rescue teams and emergency operators. Thus, the key scope of SAFEPROTEX was to develop uniforms exhibiting the following characteristics:

- Protection against multiple hazards
- Physiological comfort and enhanced mechanical parameters
- Extended service life compared to existing protective clothing

In the frame of the project, three representative risky operations were considered and the corresponding protective uniforms were developed as prototypes. More specifically, the project addressed the following operations:

- Emergency operations under extreme weather conditions (floods, hail, etc)
- Operations under the risk of wild land fires
- First aid medical personnel potentially exposed to any type of risk

In the following Table the hazards involved in each of these operations are listed along with the required protective properties. General advanced properties that apply in all three cases are also indicated in the Table.

Table. Protective properties required in different emergency operations

	Major Hazards to be met		**Protective Properties required**
Case 1: Emergency teams encountering extreme weather situations involving floods, hail, etc	Water permeation		Hydrophobic, water impermeable
	Low environment temperatures		Thermo-insulation
	Microbial contamination		Antibacterial
	Foul weather conditions		Weather & wind resistance

	Major Hazards to be met		Protective Properties required
Case 2 Personnel exposed to the risk of wild land fires	Fire		FR and heat protection
	UV irradiation		UV protection
	High environment temperatures		Cooling effect, high temperature alert
Case 3 First aid medical personnel, potentially exposed to any type of hazard	Microbial contamination		Antibacterial
	High/low environment temperatures		Thermo-regulation
	Static electricity		Antistatic
	Catch up fire from burning residuals		FR and heat protection
	UV irradiation		UV protection
General properties that apply in all three cases	*Self-cleaning*		
	Enhanced mechanical parameters		
	Thermal comfort: heat and moisture transfer, thermoregulation		
	Mechanical comfort: handle		
	………		

More specifically, the project focused in the following aspects of protective clothing development:

1. Protection against multiple hazards

As indicated in the above table, the hazards that rescue teams are exposed to, particularly in emergency operations, are at the same time *multiple* and *complex*. The main protective properties required and targeted within SAFEPROTEX are outlined below:

– Protection against wetting and water permeation
– Protection against extreme environment temperatures
– Protection against microbial contamination
– Protection against fire and associated heat
– Protection against UV radiation
– Protection against static electricity

Since, several different hazards may be simultaneously encountered in a specific situation, the new trend in research and development of protective textiles lies in the combination of various functionalities in order to obtain multi-protective garments. In this context, the project contemplated the exploitation of novel or advanced technologies to reach each of the above functionalities and then to combine the targeted properties. Functionalization was achieved through bulk modification of the fibers and surface treatments of the developed textiles. The variety of options available to the consortium regarding both the functionalizing materials and their application technology ensured that multiple protective properties could be simultaneously achieved.

2. Physiological comfort, mechanical parameters and ergonomics

Personal protective clothing, in the first place, must provide adequate protection against occupational hazards and mechanically inflicted injuries. Protective garments should be strong enough and present good mechanical properties, like tear resistance, tensile strength, breaking force and elongation.

Moreover, PPE possess a physiological function, protecting the wearer against heat or cold stress and yielding an at least satisfactory wear comfort. Protective clothing results in a micro-environment between itself and the body (thermoregulation). Workers are then exposed to a heat or cold stress greater or lower than the ambient environment alone, which is a reflection of micro-environment, metabolic rate and time. Adjustments to the ambient environment to account for the micro-environment must be formulated as a means to predict heat or cold strain for safety and productivity purposes. Garments without such a physiological function do not only affect our well-being, but with man working they impede his physical and mental performance and they can even be health-damaging.

Air permeability is especially important for comfort of outwear and protective textile products: it deals with material behaviour when exposed to still or slowly moving air and also indicates the wind resistance. Air permeability is set by standards EN 342 & 14058 as 3 levels, depending on comfort feeling it offers.

Finally, clothing with good breathability gives workers the opportunity of doing their work without feeling suffocating. This involves thermal resistance (body heat) and water vapour resistance (perspiration) revealed through the cloth and permits the human to feel comfortable when doing his job.

However, textiles functionalization is usually accomplished at the expense of comfort and/or mechanical parameters. Indeed, the application of common coatings as well as the incorporation of active agents, such as flame retardants (FRs), in textile fibres in the required amounts to bring the desired effects, is generally accompanied by a decrease in mechanical performance and comfort parameters, i.e. breathability, moisture management, handle, etc. Therefore, improved ergonomic and comfort properties are becoming essential in order to achieve an optimal balance between protection and performance.

SAFEPROTEX exploited recent advances in nanotechnology to avoid these detrimental effects of textiles functionalization. For example, skin sensorial wear comfort (i.e. smoothness and softness) can be retained after the surface application of active nano-materials, not affecting the basic properties of the fabric. The proposed approach to thermo-physiological wear comfort involves the application of phase-change materials (PCMs) through innovative processes. Finally, the ergonomic wear comfort, i.e. the fit of the clothing and freedom of movements, was considered through the ergonomic design based on user requirements.

3. Extension of the service-life of protective garments

An important issue that was addressed in the project is the durability of protective functions. In fact, a common drawback of protective textiles is related to the deterioration of functional properties after use and consecutive washings. The solution proposed in the project to ensure optimal performance over the whole service-life of protective garments was their self-cleaning functionalization or the induction of water and oil repellent properties, in order to minimize washing requirements. In the same context, the maintenance of high breathability may limit contamination coming from the wearer.

4. User & Environment friendliness

An important issue when developing protective garments is the environmental aspect of the involved materials and processes. Any materials and processes that are harmful to the environment (and humans) should be avoided in order to comply with current legislation and directives (e.g. REACH regulation, eco-labels, etc). Therefore, such criteria were taken into consideration when selecting fibrous substrates, active agents and treatment application processes.

The distinct scientific and technological (S&T) objectives of the project included:

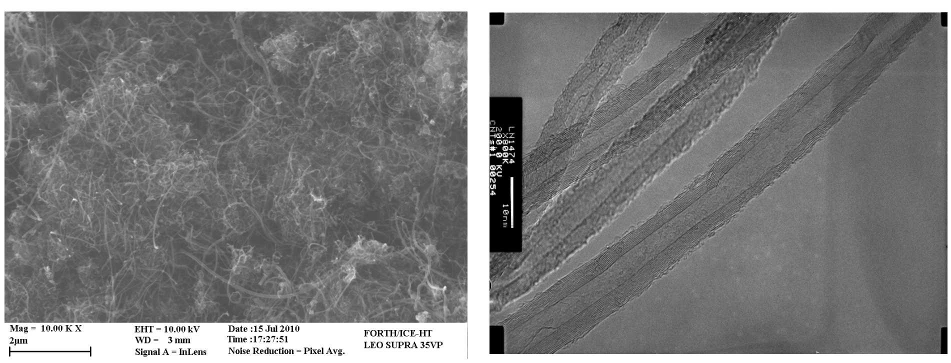
- The development of new functionalizing **nanoadditives.**
- The appropriate modification of nanoparticles (clays and carbon nanotubes), when necessary, and their subsequent dispersion in polymeric matrices for the development of new **polymer-based nanocomposites**.
- The development of nanocomposite or bi-component **fibers** exhibiting superior mechanical performance, flame retardancy, thermal stability, antistatic properties and/or thermo-regulating effects, through the incorporation of layered silicates (clays), carbon nanotubes (CNTs), chromic dyes and phase-change materials (PCMs).
- The design and development of new **fabrics** through the incorporation of novel/functional fibers and components reacting to external impulses.
- The exploitation of alternative technologies including sol-gel, micro-encapsulation, finishing, etc, for the **surface functionalization** of textiles.
- The assessment of any synergistic or antagonistic effects of various textiles treatments.
- The **ergonomic design** and development of optimized garment constructions.
- The realization and evaluation of **prototypes** corresponding to the hazardous situations (cases) presented in Table 1. It should be emphasized, however, that the technological innovations contemplated within SAFEPROTEX could also serve for the development of alternative protective equipment as well as in a variety of different applications. The specific prototypes are only representative cases that may prove the efficacy of the project's achievements.

1.3. Description of main S&T results/foregrounds

Technical achievements regarding the development of nanocomposite masterbatches and yarns

One objective of the project was to develop synthetic fibers and yarns with inherent antistatic properties, fire retardancy and UV stability. This would be achieved by simultaneously dispersing in the bulk of the fibers three types of nanoparticles, namely: carbon nanotubes (CNTs) for antistatic properties, FR-modified layered silicates (LSs) for fire retardancy and nano-TiO_2 for UV stability. Three polymers were explored for the preparation of the fibers, in particular polyamide (PA), polyester (PET) and polypropylene (PP).

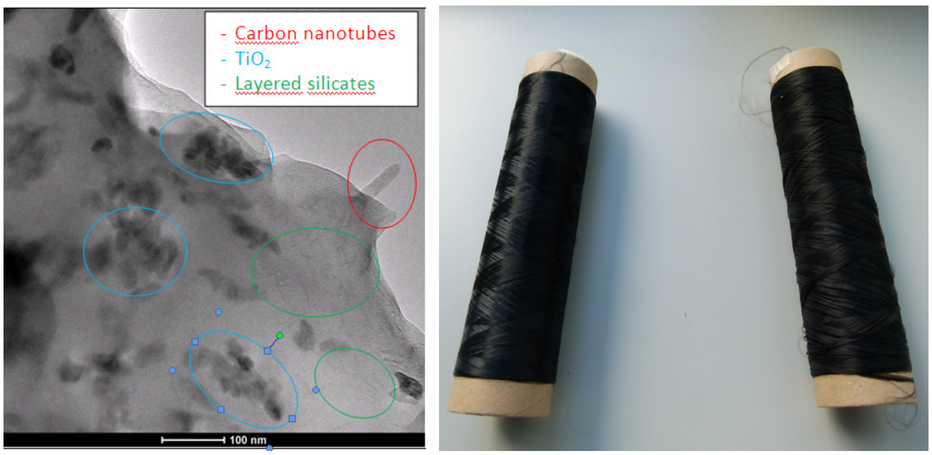
In this context, different CNT products were developed using the Catalytic Chemical Vapor Deposition (CCVD) method. Two main types of multi-walled CNTs (MWCNTs) were widely tested as additives to the polymer matrices, while in order to improve their dispersion in polymers, the CNTs were functionalized with appropriate groups. The physical characteristics of the raw and functionalized CNTs along with the percentage of functionalization were assessed by SEM, TEM, Raman Spectroscopy, and TGA. Moreover, in order to comply with stricter health and safety rules, dispersions of CNTs were developed either in water or ethanol. For this purpose raw and functionalized CNTs were used with or without (depending on the CNTs type) the addition of the appropriate amount of surfactant.



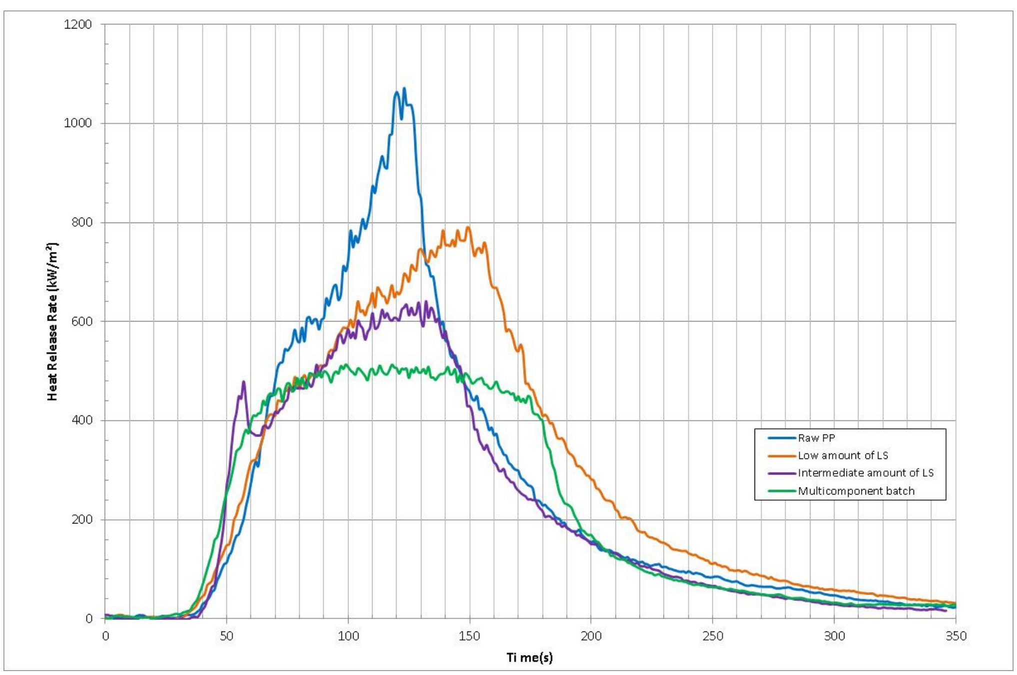
(a) Scanning Electron Microscopy (SEM) image of MWCNTs of 97% purity as-produced and (b) Transmission Electron Microscopy (TEM) image of Thin-MWCNTs of 94% purity as-produced

On the other hand, commercially available layered silicates (montmorillonites) were modified by phosphorous-based flame retardants which were introduced in the galleries of the layered silicates by solution intercalation. The objective was to develop synergistic FR systems that can improve polymers fire retardancy even when used in low concentrations.

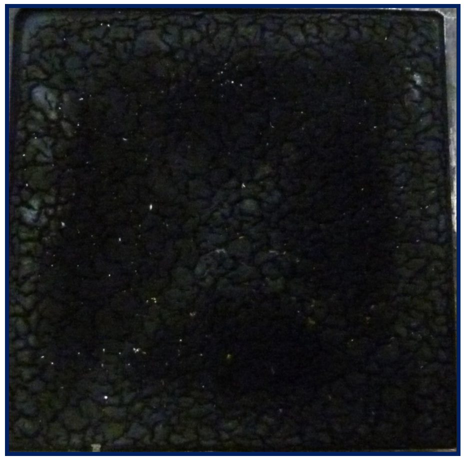
Following the development of the aforementioned nanoparticles, these as well as commercially available nano-TiO_2 were dispersed in PA-, PET- and PP- based compounds, first separately in order to define the minimum concentration of each additive required to endow the relevant functionality without impeding spinnability, and then in combinations. Following this approach, antistatic polymeric compounds with up to 50 % improvement of FR properties and increased UV stability compared to the neat polymers were obtained.



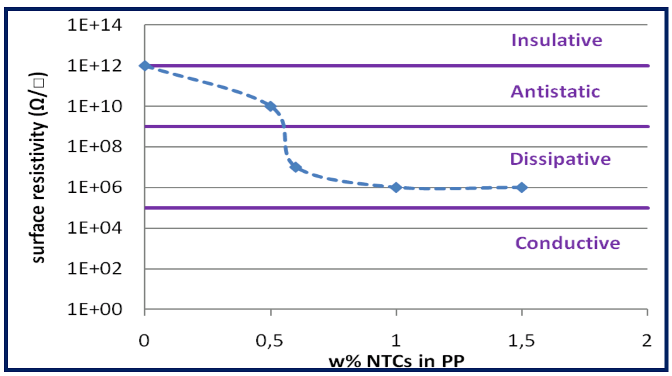
Transmission Electron Microscopy (TEM) image of the multifunctional masterbatch (left) and the yarns made by this masterbatch (right).



Cone calorimetric measurement - Heat release versus time for PP-based compounds



Aspect of the char formed during the combustion of the nanofilled PP-based compounds



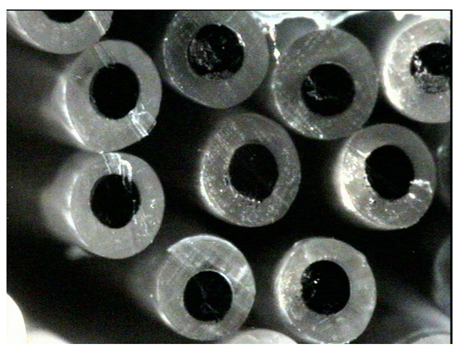
Evolution of the surface resistivity of the CNT filled PP-based compounds

However, when these compounds were spun into fibers the functional properties were lost, which was attributed to the rearrangement of the nanoparticles during spinning. Therefore, the new modified polymers were not used for the production of inherently multifunctional yarns, as originally planned. Instead, other approaches were followed to provide the antistatic and FR properties to the final prototypes. Despite that, it should be noted that the multi-component and multi-functional polymeric compounds developed in SAFEPROTEX can be used in other applications that do not involve spinning (e.g. for the production of compact polymeric parts for automotive applications, where antistatic and FR properties are required). Project partners involved in this result (MIRTEC, Nanothinx, GAIKER and RESCOLL), are already exploring potential exploitation routes.

Technical achievements regarding the development of thermoregulating yarns and fabrics

Garments with built-in thermoregulatory properties may help the body to stay within a comfortable temperature range at different activity levels and ambient conditions. Integration of phase change materials (PCMs) in garments is one way of achieving this property. When the body temperature increases, the PCM melts and absorbs the heat from the body in the form of latent heat (cooling effect). When the temperature drops, the PCM crystallizes and the stored heat is released again (warming effect). The use of PCMs incorporated in the garment structure next to the body may thus improve the thermal comfort of the wearer. Fabrics with PCMs may also be used in an intermediate clothing layer to act as a short term barrier to heat without adding to the volume and thermal insulation, an effect that would be useful for fire-fighters protective clothing in hot climates.

In the Safeprotex project PCMs were successfully integrated into textile fabrics by means of melt spun bi-component fibers with a sheath/core structure. In this way PCM is permanently trapped inside the core of the fibers. For improved thermal management both polyamide (PA6) and polyester (PET) filament yarns were produced. The PCM had a melting point of about 32°C and the heat of fusion was about 60 J/g based on total yarn weight. This is significantly higher than state-of-the-art viscose and acrylic yarns with microencapsulated PCM showing latent heats in the range 5-15 J/g. The use of PA6 and PET ensures that the PCM will not leak out from the fibers during use and repeated washing cycles. Knitted thermoregulating undergarments were produced using the aforementioned bi-component yarns.

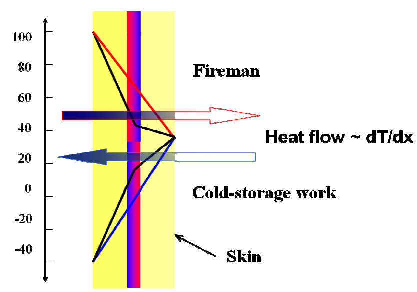


Structure of sheath-core bi-component fibers incorporating non-encapsulated PCMs in the core

Since the PCMs used are of the hydrocarbon type they easily diffuse through polyolefin polymers like polypropylene (PP). PP is thus not suitable as a sheath material since the PCM will be lost during use and laundry. To reduce the migration of PCM nanoclay platelets were dispersed in PP. Despite a nice exfoliation and dispersion of clay in PP, proven by both X-ray diffraction (XRD) and transmission electron microscopy (TEM), the migration of PCM was increased. This was tentatively explained by the formation of micro cracks at the PP clay interface during solid state drawing of the PP fibers.

In Southern Europe NGOs need clothing with enhanced functionality for use in the control of forest and grass fires in the summer. Such a need is a protective jacket that is not bulky and that is cool and light and yet can provide protection against short time heat radiation. Protection against heat radiation can of course be achieved by increasing the insulation capacity (bulkiness) of a garment. Such a garment fits however badly for continuous operation at ambient temperatures around 30-40°C. In the Safeprotex project textile fibers were developed containing a high proportion of PCMs where the aim was to provide a barrier against transient thermal radiation without creating a garment with high thermal insulation. The basic principle is to capture the radiated heat energy in the form of latent heat at a moderately high temperature and in this way keep the temperature low next to the body.

In this case, a PCM having a melting point of 45°C was selected. As long as there is un-melted PCM in the jacket liner, incoming heat is absorbed at 45°C and the temperature does not rise above 45°C, resulting in a lower temperature gradient close to the body and thus in a lower heat flow towards the body. In this case the fiber sheath consists of PET. In this way, a thin lining with low thermal insulation was created, which still provides a short term protection against high temperatures. The jacket bearing this liner was tested by the voluntary rescue teams participating in the project and was highly evaluated. Cool and comfortable during normal working conditions but giving extra grace to get to safety in a rapidly advancing fire front. The effect has also been verified by lab tests. Based on these results, SWEREA IVF, who was involved in the development of thermoregulating yarns and fabrics, is currently searching for an industrials partner to license the technology.



The figure illustrates an intermediate clothing layer with PCM melting at a higher temperature than the body temperature (top). The heat flux from the outside will be captured by the melting PCM and stored as latent heat, reducing the temperature gradient (dT/dx) next to the body as long as there is un-melted PCM available. This will slow down the heat flow towards the body leaving time to escape a hot environment.

Thermoregulating T-shirt made of bi-component yarns incorporating PCMs that melt at 32 °C

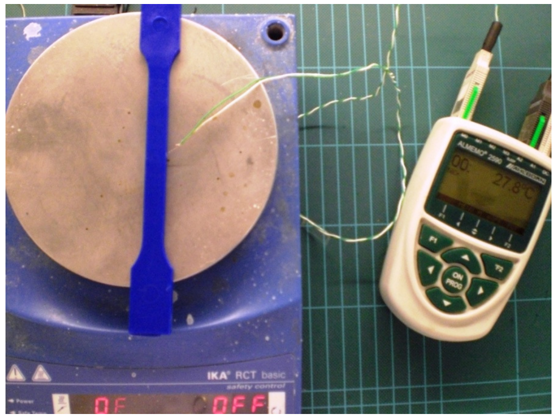
Knitted jacket liner from PET filament yarn of the bi-component type integrating a large amount of PCM (Tm 45°C) in the fiber core. Picture was taken by SAR ESPANIA at training in Ecuador, South America.

Correspondingly, a liner with a lower transition temperature may be used for cold work. In this case the PCM is molten at normal room temperature and solidifies at low temperature (such as 18°C) wherein crystallization prevents cooling and gives a heating effect.

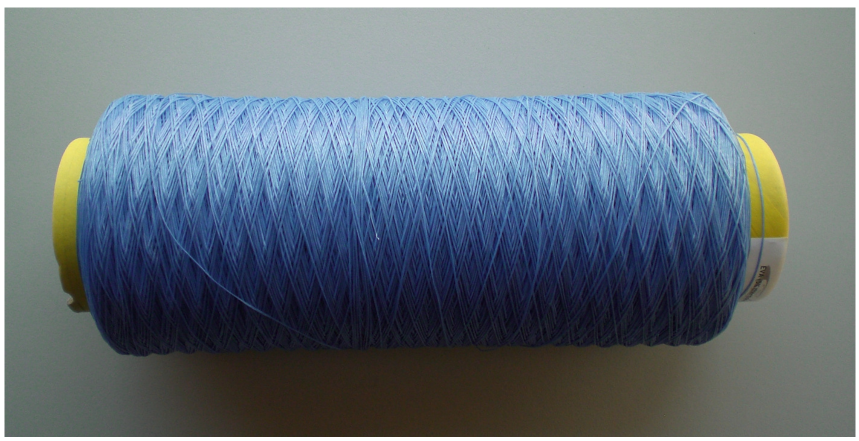
Technical achievements regarding the development of thermochromic materials (masterbatches, yarns, fabrics and sheets)

Thermochromic materials were exploited in the project in order to develop systems that alert the user when the temperature rises over a certain value. Such systems are particularly useful for people operating under the risk of wild land fires (Prototype 2). Therefore, the project envisaged the development of thermochromic yarns based on PET, PA and PP and of fabrics produced thereof, which would subsequently be incorporated in specific parts of prototype 2. However, several adjustments had to be made.

As thermochromic additives, microencapsulated LEUCO dyes that change color at 42, 46 or 50 °C (temperatures that lead to thermal shock in people in different EU zones) were selected. These were dispersed in three polymers, namely PP, PLA and EVA, at a concentration of 5 wt %. PET and PA were not applied, since they are processed at high temperatures that degrade the thermochromic dyes. The resulting compounds were used for the production of monofilaments that exhibit the thermochromic effect at the determined temperatures.

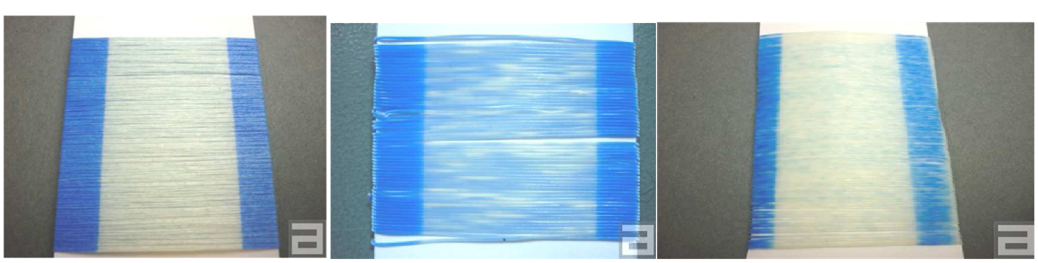


A thermochromic polymer test bar under evaluation



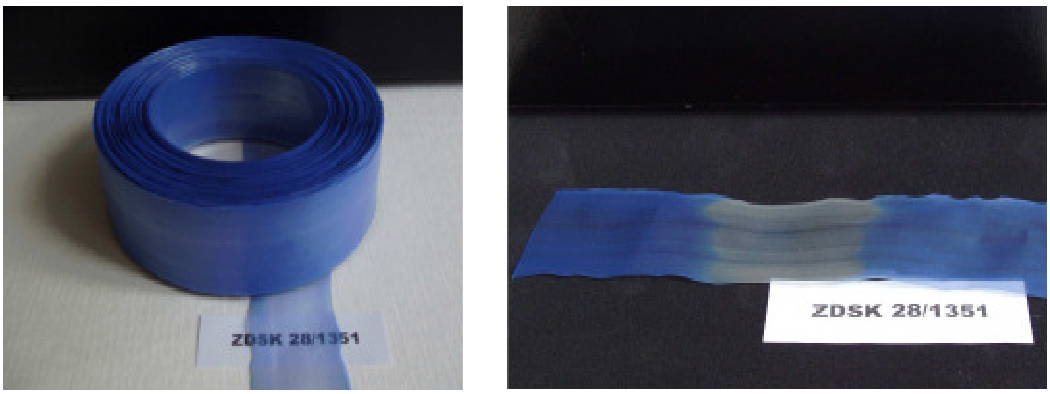
Thermochromic monofilament

However, in order to produce yarns suitable for weaving, the concentration of the thermochromic microcapsules had to be lowered. In this case, the yarns obtained were very light in color at room temperature and thus the thermochromic effect was not evident. It was, therefore, decided to develop thermochromic sheets with a high concentration of dyes instead.



EVA, PLA and PP thermochromic monofilaments after 7.5 h of UV exposure

Another issue that had to be tackled was the very low stability of the dyes under UV irradiation. In fact, it was found that UV light degrades the thermochromic compounds and thus the sheets should not be continuously exposed to sunlight. The solution proposed was to supply the thermochromic sheets in alumimum foils that protect them from UV. After the sheets are removed from the foil they should be employed for a limited number of uses only, until their color fades off. The sheets may be incorporated in wristbands, in specifically designed pockets of the garment and/or on the helmet. LEITAT, being responsible for this result, is exploring opportunities to licence the technology.



Thermochromic film exhibiting the thermochromic effect

Wristband with thermochromic sheet supplied in aluminum foil

Technical achievements regarding the development of photocatalytic yarns based on PEEK

Despite the great research activity during the two decades in search for a photocatalyst with optimal features, titanium dioxide remains a benchmark against which any alternative photocatalyst must be compared. In fact, TiO_2 has been widely used because it is inexpensive, it is harmless and its photostability is very high. The smaller is the size of TiO_2 particles, the better are the photocatalytic performances. Therefore, in the production of photoactive textile materials, particular attention must be paid in nanoparticles handling according to EU recommendation 07/02/2008 on a Code of Conduct for a Responsible Nanosciences and Nanotechnologies Research.

Within SAFEPROTEX project a photoactive polymer that can represent a viable and safer alternative to TiO_2 has studied and produced at pilot scale. The photoactive material is a modified benzophenone compound. Chemical modification of polyetheretherketone (PEEK) promotes the formation of Benzophenyl Ketyl Radicals (BPK) towards hydrogen atom abstraction.

Different modified PEEK polymers were investigated and produced within the project and the Sulphonated PEEK (SPEEK) was selected as the most promising one for different reasons:

- It is very effective in the production of radicals under UV and solar irradiations
- It is easy to produce and the process can be easily scaled-up (at the end of the project NTT was able to produce up to 1-2 kg of Sulphonated PEEK per day).

In the project SPEEK was studied both for the surface treatment of textiles through conventional finishing processes and for the spinning of novel, inherently photocatalytic yarns. In the second case, it was compounded with polyolefines to produce photoactive yarns with good mechanical properties. Electron spin Resonance (EPR) spectroscopy confirmed that the multifilament yarns are promoting the formation of BPK radicals at high concentrations.

Property	Value	Test Method
Base Material		
Melt density @260 °C	0.7 – 0.8 g/cm^3	ASTM D1238
Roving	**Value**	**Test Method**
Monofilament diameter	55 ± 10%	ASTM D578-2000
Linear density	230 dtex ± 10%	ISO 2060:1994
Twist per meter	none	
Tensile strength	0.093 ± 0.012 N/tex	ISO 2062
Strain at break	266.5 ± 58.9	ISO 2062

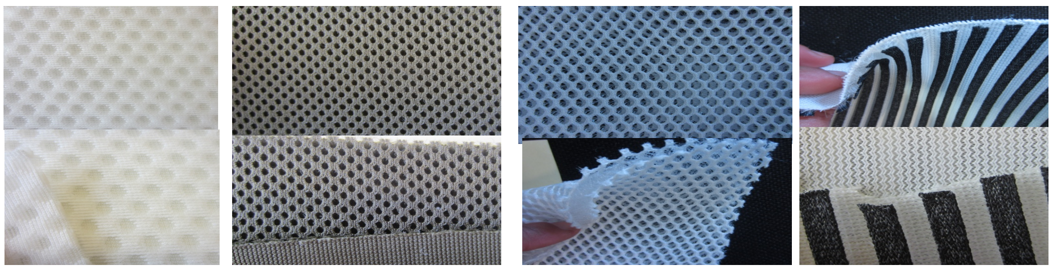
Photocatalytic yarn based on SPEEK/polyolefin blend and its characteristics

NTT has already applied for a patent concerning this technology, while together with TUT they are currently exploring commercial applications in collaboration with a industrial companies. In particular, NTT is responsible for the providing SPEEK, TUT has provided a protocol for the compounding of polyolefin and SPEEK, a third party will compound the polymers and the company will produre the filament.

Technical achievements regarding the development of 3D knitted fabrics

3D (spacer) knitted fabrics are used in garments construction to provide insulation against cold or impact protection, among others. Aiming to provide cold insulation the fabric should be used as the garment's liner. In this case it should have a low thickness in order to not limit the users agility and mobility. On the other hand, thicker spacer fabrics can be used in specific parts of the garment for impact protection.

In SAFEPROTEX spacer fabrics with different structures were developed and evaluated for both purposes. However, since impact protection was not a priority for the end-users addressed in the project, only the fabric most suitable for thermal insulation was produced at large scale and incorporated as a liner in Prototype 1 (designated for extreme weather conditions). LEITAT, who developed the spacer fabrics with specific design and properties to be used as thermo-insulative liners is willing to licence the technology.



3D knitted fabrics produced: (a and b) thinner varieties for insulation purposes, (c and d) thicker varieties for impact protection purposes

Picture of prototype 1 (inside out) showing the 3D knitted liner providing thermal insulation

Technical achievements regarding the development of surface functionalizing treatments

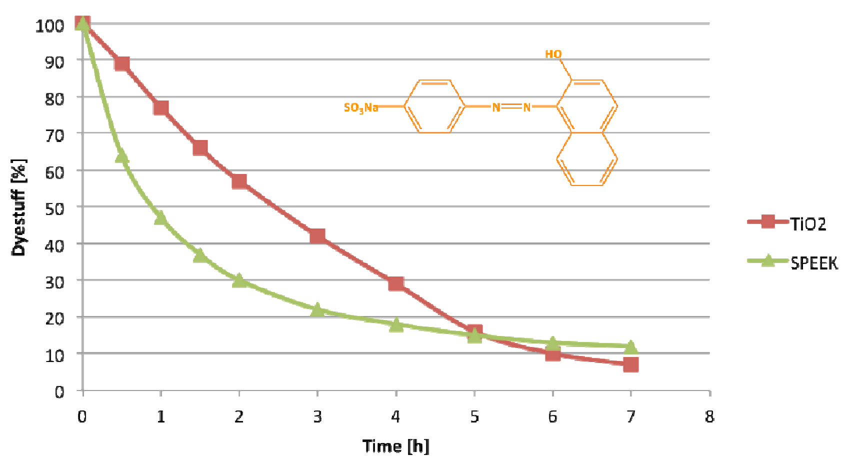
Alternative textile surface treatments were developed aiming to provide various functionalities required by the end users. In particular the following developments were explored:

– Development and application of microcapsules containing PCMs, aiming to provide thermoregulating efficiency.
– Development and application of chitosan microspheres or microcapsules, aiming to provide antimicrobial properties.
– Surface application of benzophenone-based compounds, aiming to provide photocatalytic efficiency, self-cleaning and de-polluting properties.
– Development and deposition of alkoxysilane nanosols, aiming to simultaneously provide super-hydrophobicity, self-cleaning and antimicrobial properties.

In this context, microcapsules incorporating organic PCMs were developed using selected shell polymers and alternative microencapsulation techniques. Their application on textiles was explored by padding, coating, lamination and incorporation in sandwich structures (DOTCOAT system). Although it was possible to develop fabrics with thermoregulating properties, the deposition of PCM microcapsules significantly deteriorated their appearance. Since an alternative approach to thermoregulation using PCM-containing bi-component fibers was successfully developed in the project, the PCM microcapsules were not used in the prototypes.

Similarly, chitosan microspheres with high antimicrobial efficiency were developed by spray drying and subsequently applied on textiles by padding or screen printing. Fabrics pre-treatment or application of alternative binders were elaborated in order to improve the wash fastness of the treatment, however with limited success.

Concerning the surface application of benzophenone-based compounds, SPEEK was compounded with polyalcohols to produce a photoactive water based polymer dispersion to be applied on fabrics surface through conventional padding processes. Composition of the formula and padding process conditions were optimized and by applying them it is possible to produce photoactive surface to both UV and solar irradiation.

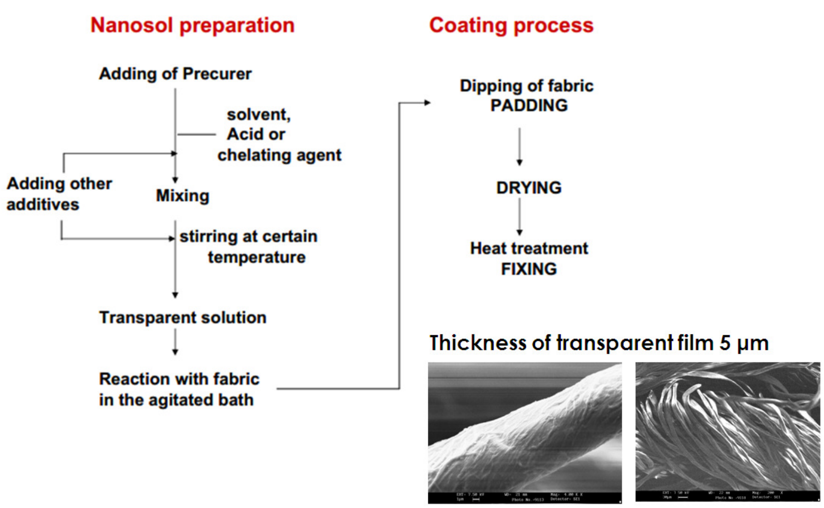


Decomposition of Acid Orange I by fabrics treated with TiO_2 or SPEEK

EPR spectroscopy confirmed that a large amount of active radicals can be generated after irradiation and that the finish can assure stable photoactive performances over the time. Characterization of the finished fabrics showed that:

- Photoactive finishing is not affecting mechanical properties.
- Absorption of UV light to promote photoreacting is improving UV barrier properties of the fabrics.
- Antibacterial properties can be assured by the radical species.
- Sulphonated species have a slight impact in flame retardancy.
- Photoactive finish is promoting self cleaning properties and chemical degradations.
- Poor washing resistance was achieved although it did not affect the photoactive properties.
- Hand of the fabrics was too thick!

In the case of alkoxysilane nanosols, multi-functional hybrid polymers were synthesized in lab-scale based on the formulation of nanosol containing major precursors: Methyl triethoxysilane (MTES), 3-glycidopropyltrimethoxysilane (GLYMO), Octyltriethoxysilane (OTES) and 3-Trimethoxysilyl propyl octadecyl dimethylammonium chloride (Quat). Through the modified sol-gel process, cotton fabrics were successfully coated with a nanolayer of sol-gel based polymer to achieve multifunctional properties. The properties imparted include abrasion resistance, dimensional stability, antibacterial and super-hydrophobicity for self-cleaning. It is worth noting that after the sol-gel treatment, the knitted cotton fabrics not only retain soft handle, but also exhibit improved moisture management. Synthetic fabrics were also successfully coated with the optimised formulation of sol-gel based polymer. Due to high affinity of sol-gel to synthetic fibres, shorter reaction time could be used in the treatment process. The fast pad-dry-cure process was feasible to apply sol-gel based hybrid polymers on woven fabrics.



General process of sol-gel treatment

Water, coffee, milk and orange juice on sol-gel treated cotton fabrics

Shower-proof test on untreated cotton (left) and sol-gel treated cotton (right)

Following the lab-scale trials, the basic formulation of nanosols based on selected alkoxysilane-based precursors (MTES, GLYMO, QUAT) was suggested and the preparation of functional nanosols by controlled hydrolysis, catalysed by inorganic acid (HCl), was optimised. The application process was verified and optimized at pilot-plant and industrial scale and the resulting properties of finished fabrics were evaluated according to relevant standards.

Following the optimization of surface functionalization treatments, the fabrics selected to be used as outer layers of the three prototypes (i.e. blended Co/PET, Co/bio-PA fabrics, including a laminate with PU membrane for Prototype 1) were finished and tested. Both functional and physiological parameters were assessed including the influence of the finishing on coloration quality. Therefore, the compatibility of the nanosol-based finishing system with high-vis. coloration (red, yellow), water-tightness of the membrane, abrasion resistivity, antistatic properties and flame-proof properties of Proban pre-finished fabric were proved.

Following this approach multifunctional protective textiles were prepared by nanosol-based finishing and lamination for prototypes, as follows:

- Prototype 1 (extreme weather conditions): water-repellency, water-tightness, self-cleaning properties, antimicrobial properties, high-visibility, air and microbe impermeability, increased abrasion resistance.
- Prototype 2&3 (wild land fires; first aid medical personnel): water-repellency, water-tightness, self-cleaning properties, antimicrobial properties, flame-proofness, antistatic properties, UV-protection.

INOTEX and TDV, who are involved in this result, plan to directly use it, as no further research is required.

Parameters of finished fabrics for the three prototypes
(+++ very good and reliable; ++ good, satisfactory; + compromised, - low)

Functional parameters	**Standard**	**Prototype 1 red high/vis.**	**Prototype 1 dark/grey**	**Prototype 2&3 yellow high-vis**
		Co/PES laminate with PU membrane	**Co/bio-PA laminate with PU membrane**	**Co/PES/ antistatic fibre; Proban FR finished**
Water repellency	EN ISO 4920 (spray test)	+++	+++	++
Watertightness	EN 20811 (hydrostatic head)	+++	+++	not required
Self-cleaning	Roll-off angle Roltest 9-11	++	++	++
Antimicrobial properties	ISO 20743	+++	+++	+++
Surface resistivity	EN 1149-1; EN 1149-3	not required	not required	++ (64% R.H.)
Flammability	EN ISO 15025	not required	not required	+++
Protection against UV	EN 13758-1 (Varian Cary 50)	not required	not required	+++
High-visibility	EN 471	+++	+++	+++
Mechanical parameters				
Square weight	EN 12127	256 g/m^2	294 g/m^2	272 g/m^2
Tensile strength	EN ISO 13934-1 (STRIP)	+++	+++	+++
Tear strength	EN ISO 13934-1 (Elmendorf)	+++	+++	+++
Adhesive force fabric/membrane	ČSN 80 0830 (Czech standard)	+++	+++	N/A

Functional parameters	Standard	Prototype 1 red high/vis. Co/PES laminate with PU membrane	Prototype 1 dark/grey Co/bio-PA laminate with PU membrane	Prototype 2&3 yellow high-vis Co/PES/ antistatic fibre; Proban FR finished
Dimensional stability in wash.	EN ISO 6330	+++	+++	+++
Abrasion resistance	EN ISO 12947-2 (MARTINDALE)	++	+++	++
Propensity to pilling	EN ISO 12945-2 (MARTINDALE)	+++	+++	++
Propensity to surface fuzzing	EN ISO 12945-2 (MARTINDALE)	++	++	+
Physiological parameters				
Breathability WVT	EN ISO 15496	+*	+*	+++
Air permeability	EN ISO 9237	+++ (windproof)	+++ (windproof)	not required
Moisture management	AATCC TM 195 (MMT SDL Atlas)	+**	+**	++
Colourfastnesses				
water	EN ISO 105-E01	+++	+++	++
washing 40°C	EN 20105-C01	+++	+++	++
washing 60°C	EN 20105-C03	+++	++	++
perspiration alk.	EN ISO 105-E04	+++	+++	++
perspiration acid	EN ISO 105-E04	+++	+++	++
rubbing dry	EN ISO 105-X12	+++	+++	++
rubbing wet	EN ISO 105-X12	+++	+	++
light	Sun Test	+	+++	++

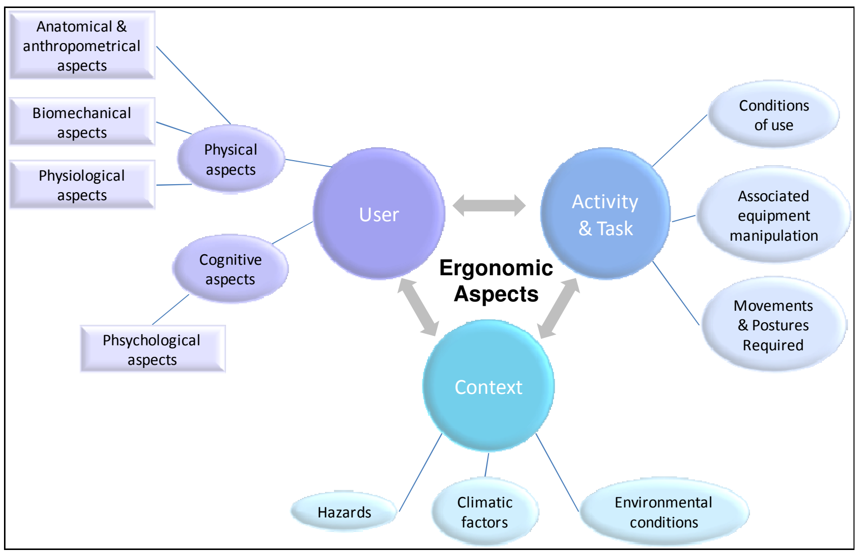
**Watertight and air/microorganism impermeable breathable membrane can be never so breathable like a porous fabric.*
***The membrane can transport only water in vapour phase, not liquid (physiological solution) because it is nonporous - watertight (MMT)*

Technical achievements regarding the ergonomic design of the protective garments

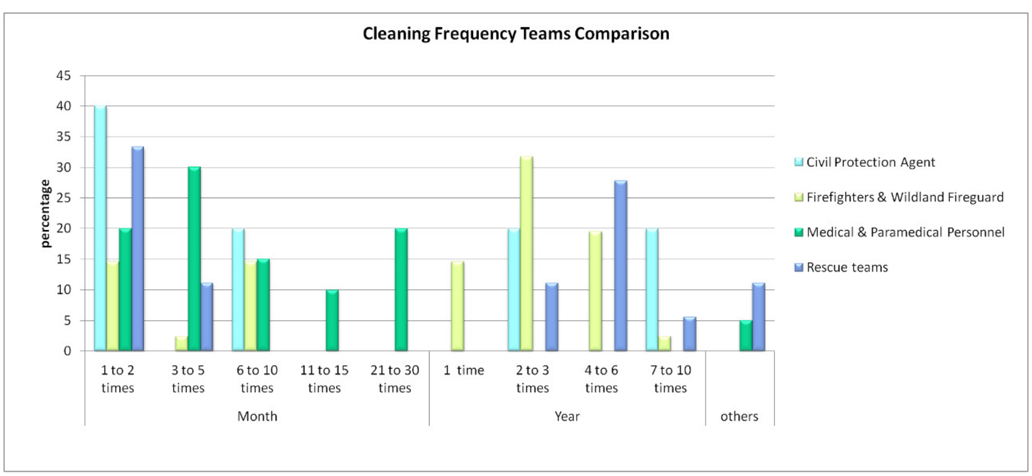
The main objective of the ergonomic research was to gather data which would guide decisions throughout the design process, in order to develop products that enhance the users comfort, safety and performance.

To settle the ergonomic analysis, the study of the user and his context in the specific situations described in the project was undertaken. The context analysis explores the performed activity and the characteristics of the related tasks, i.e. situation and period of use of the PPE, required movements and postures, associated equipment manipulation, garment reinforcement areas, etc. It also deals with the encountered hazards, defining their type, magnitude, etc, and the environmental conditions surrounding the specific activity. On the other hand, the user analysis was divided into the study of physical and cognitive aspects. Within the physical aspects anthropometric, biomechanical and physiological issues were analyzed. Regarding cognitive aspects, ease of use and physiological comfort were studied. Physiological comfort is determined through the analysis of the perceived level of protection, performance allowance, thermal comfort, adequate garment bulkiness and communication ability, together with aesthetics issues.

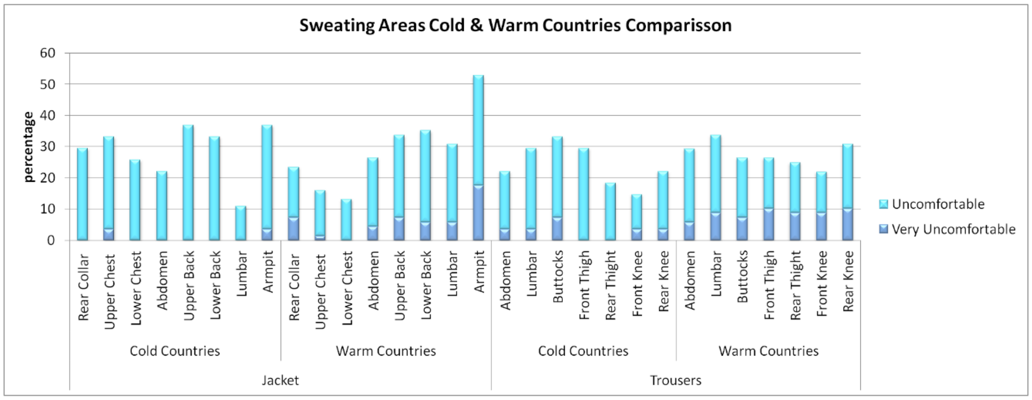
In order to gather information on end users needs, preferences and expectations regarding the ergonomic aspects of a PPE, a questionnaire addressing relevant criteria was designed. First results on ergonomics requirements according to end-user needs were obtained by statistical exploitation and analysis of the data collected through this questionnaire.



Ergonomic analysis



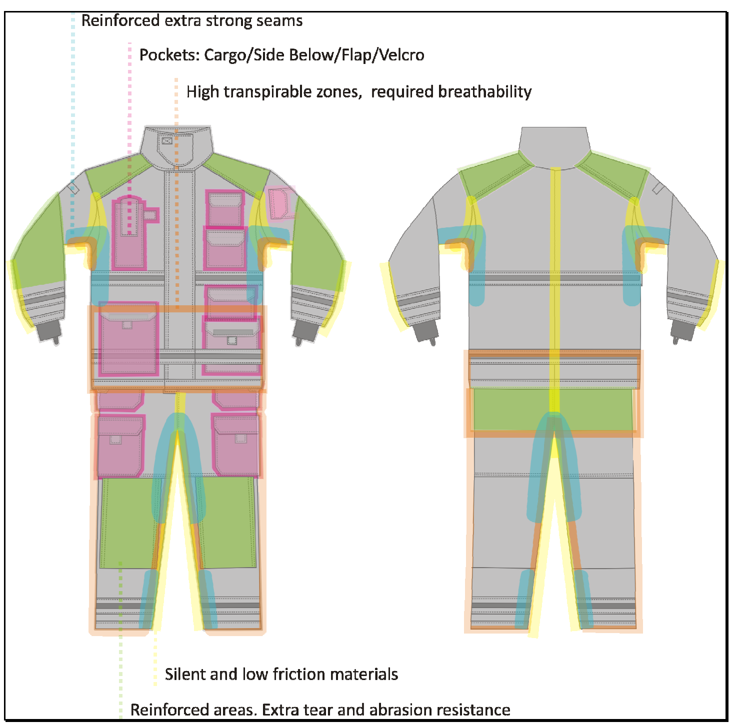
Results of ergonomics questionnaire analysis regarding cleaning frequency



Results of ergonomics questionnaire regarding sweating areas

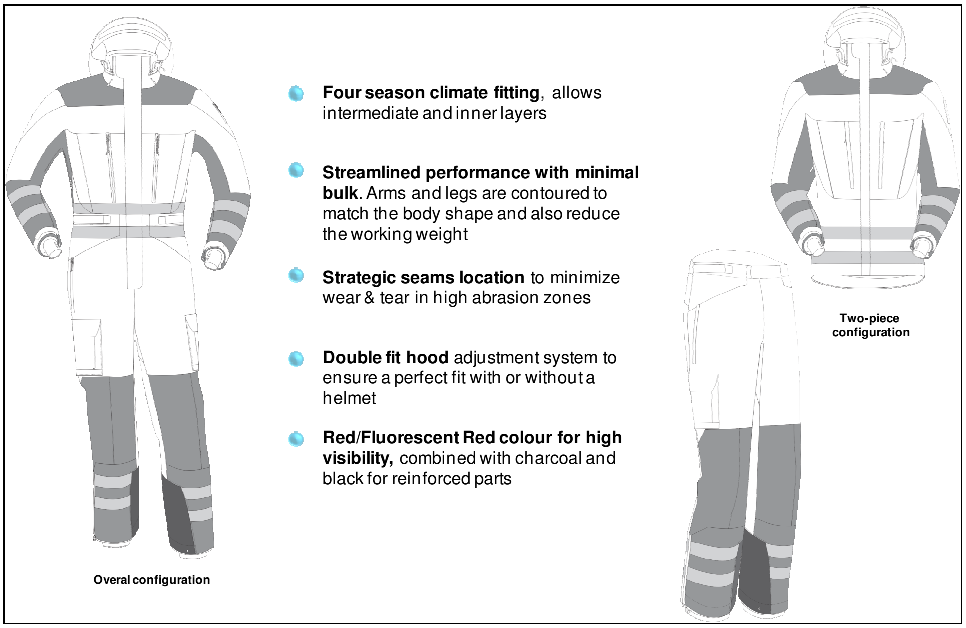
In parallel, the market research provided a lot of interesting inputs to become options for the future design. Further than products already existing in the market, the research focused also on alternative sectors like adventure sports, where the technology in fabrics and especially in garments structures goes a step beyond and provides a new point of view in the PPE ergonomic design.

Together with the regulation requirements to provide required level of safety to each case, the user and task requirements and the market research provided the three sources of information required to complement the ergonomic approach to be developed during the design stage. The data collected and analyzed through questionnaires and regulation requirements were matched and presented in the form of manikins.

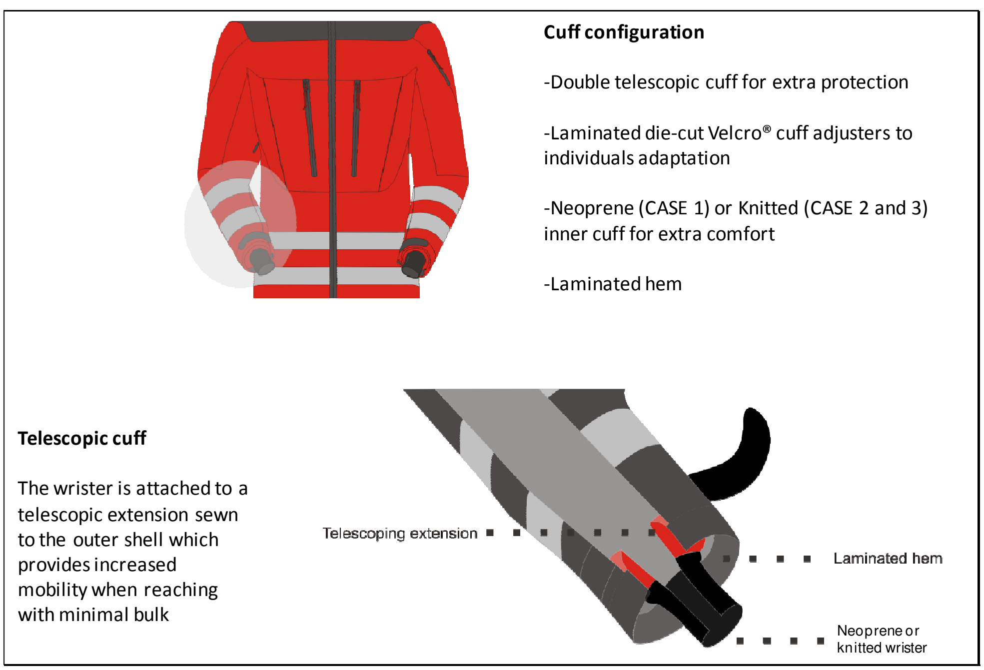


Example of manikin matching questionnaire results

Thereafter, to provide Design Specification Sheets (DSS) a diversification of five kinds of specification sheets was made to structure the information in a clear and direct way. The five sheets correspond to: Technical Sketch, Pattern Bases, Set of Sizes, Material Distribution and Construction Details. The outcome of the Ergonomic Design was divided in three cases, each one collecting a set of the aforementioned five DSS and also detailed parts that require further description like hood/collar, wrists, cuffs and pockets.



Example of technical sketch



Example of detailed part (cuff) description

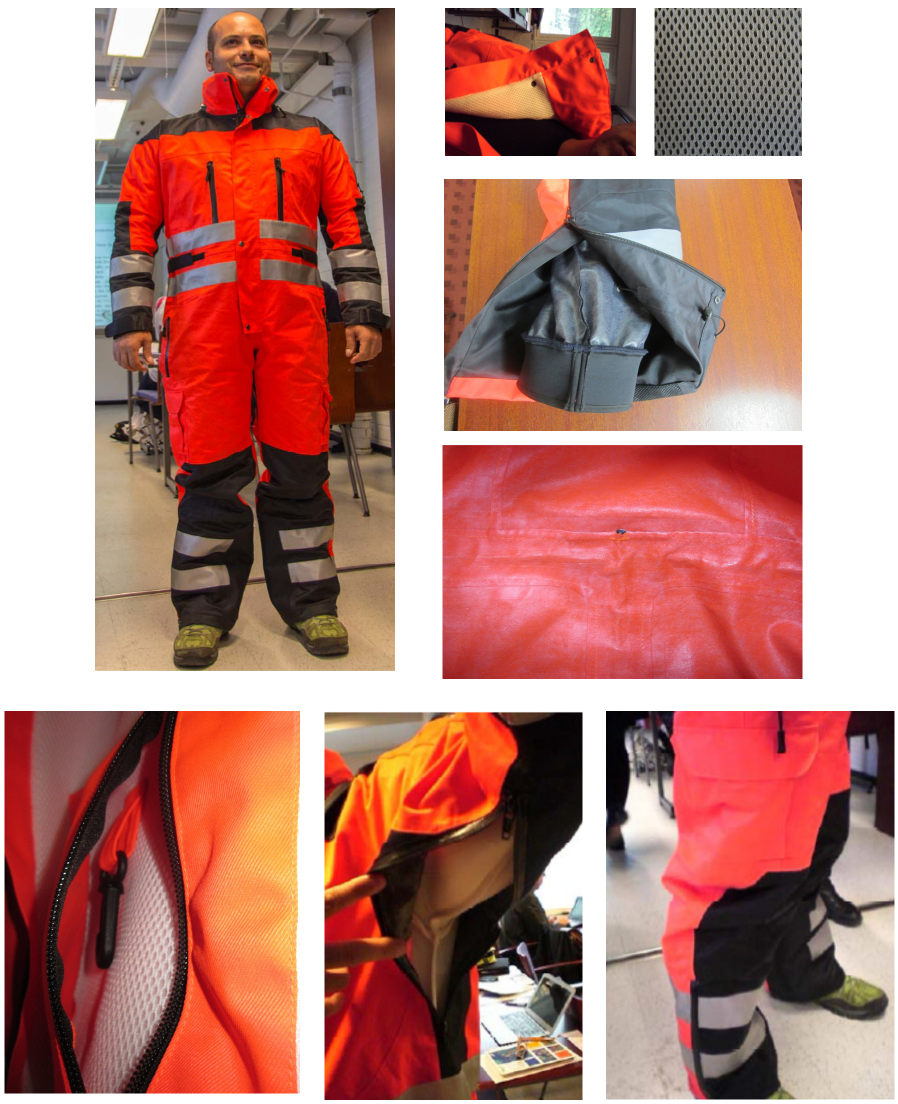
The ergonomic design developed in the frame of SAFEPROTEX will be exploited by CETEMMSA and other partners involved directly to the industry or through license and bilateral agreement. Benefits are being considered for consortium partners.

Development and evaluation of the final prototypes

As previously mentioned, three representative complex risky situations were considered in SAFEPROTEX, namely:

- Emergency operations under extreme weather conditions
- Emergency operations under the risk of wild land fires
- Operations of first aid medical personnel, potentially exposed to any risk

Prototype protective garments for each case were developed as is herewith described.



Prototype 1. Emergency operations under extreme weather conditions

Aiming to combine water impermeability, water repellency, thermal insulation, antimicrobial properties and wind resistance, the following garment structure and materials were used in Prototype 1:

(a) a knitted thermoregulating undergarment made of bi-component yarns incorporating PCMs that melt at 32 °C.
(b) an overall consisting of a 3-layer structure:

- a thin spacer fabric as inner layer for thermal insulation.
- an impermeable, breathable membrane as middle layer for water impermeability and wind resistance.
- an outer fabric with water repellent, self cleaning, antimicrobial properties. The outer fabric has red high-visibility colour and reflective bands are also used for high visibility purposes.

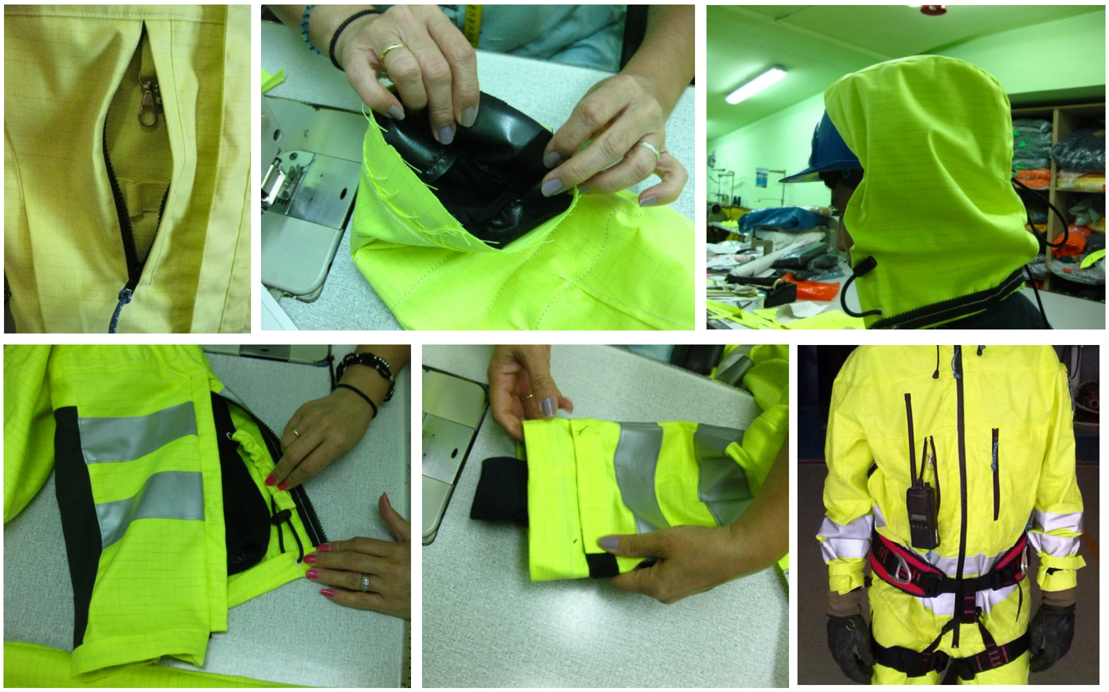
An overall configuration was selected, since under these particular situations avoiding getting trapped through the protection equipment is very important. Wearing an overall provides the user with a major tightness and reduces the parts with openings and access to the inner layers that can be the cause of getting trapped or hooked. This design ensures high mobility. The seams are waterproof sealed & watertight laminated zippers are used; water tight inner pockets and neoprene inner cuff ensure the best performance.

Prototype 2. Emergency operations under the risk of wild land fires

The main properties targeted in this case are FR and heat protection, UV protection, comfort properties and self cleaning properties. To achieve these properties the proposed garment structure and materials used for this prototype include:

(a) a knitted undergarment made of PET-based bi-component thermoregulating yarns incorporating PCMs that melt at 32°C (optional) and
(b) a 2 piece garment (i.e. jacket/trousers) made of fabric with FR and alkoxysilane finishing. As in Prototype 1, the alkoxysilane treatment provides super-hydrophobicity, self-cleaning properties and antimicrobial protection. The garment includes a knitted liner made of PA-based bi-component thermoregulating yarns incorporating PCMs that melt at 45°C. This liner provides protection against short term radiation or convective heat.

Thermochromic patches are used as a high temperature alert system. Due to the poor ageing and UV stability, the patches are used as an extra part on the helmet and/or in wristbands only to when the user goes on an operation and needs the alert system. Reflective bands are used for “high visibility” purposes.



Prototype 2 designed for operations under the risk of wild land fires

Prototype 3 designed for first aid medical personnel

Prototype 3. First aid medical personnel

The targeted properties are water impermeability and water repellency, antibacterial protection, FR and heat protection, UV protection, antistatic properties, self cleaning properties and comfort properties. To achieve these properties, the proposed garment structure and materials used for this prototype include:

(a) a knitted undergarment made of PET-based bi-component thermoregulating yarns incorporating PCMs that melt at 32°C (optional) and

(b) a 2 piece garment (i.e. jacket/trousers) made of FR fabric with antistatic fiber grid, surface treated with alkoxysilane finishing. For the antistatic properties, conductive filaments are incorporated in the structure of the fabric during weaving so as to form a conductive network. Thermochromic patches could be adjusted on the outer fabric to act as high temperature alert systems. Reflective bands are used for "high visibility" purposes.

The three prototypes were evaluated in terms of safety and protection, comfort, mechanical durability and care demands. Thermal comfort properties were evaluated using the new generation sweating thermal manikin in a climatic chamber. The differences in thermal comfort between the prototypes are distinguished in different ambient and test conditions. Prototype 3 overall for extreme weather conditions has the highest thermal insulation and the lowest evaporation properties. Also it has the highest condensation of moisture in clothing layers. Prototypes 2 (wild land fires) and 3 (first aid medical personnel) have the lowest thermal insulation values and the highest evaporation and the lowest moisture condensation properties of these tested prototypes.

The three prototypes dressed on the sweating thermal manikin

Moreover, a detailed Life Cycle Analysis (LCA) was performed which confirmed that SAFEPROTEX prototypes are more sustainable than prototypes realized with fabrics available in the market exhibiting similar properties.

Pictures taken during the subjective evaluation of the prototypes by the end-users

Finally, the three prototypes were subjectively evaluated by the voluntary rescue teams participating in the SAFEPROTEX consortium and their feedback was collected through interviews and/or questionnaires. It should be noted that since the prototypes were only ready during the final couple of months of the project the main difficulty encountered regarding their evaluation was the limited time available for the end-users to test the prototypes. The major comments received are summarized as follows:

– For prototype 1 (extreme weather conditions): it offers a feeling of safety, it is wind-proof and water-proof. However, it is rather bulky mainly due to the 3D liner and since it is an overall it is not easy to put on and take off. Moreover, the hood does not follow the head’s movement. When tested in cold conditions (2,500 m Pirineos north of Spain) the thermal performance is excellent. However, it is not comfortable for use in hot weather and thus for use in Mediterranean zones modifications of the design may be necessary.

- For prototype 2 (wild land fires): It offers a feeling of safety along with a nice, cool feeling. Wearing this garment the users may easily move, crawl and climb. The fabric used is highly evaluated. The ergonomic design and protective properties offered by this garment are superior to the existing solutions. The double fabric used in ankles and wrists protects from the entry of incandescent particles and small stones. The neck cover offers good protection against radiation and dangerous particles, such as cinder. The garment waist fits well on the body and protects lumbar area. The hood is adequate for use at the same time as a helmet. However, the belt is not necessary and may cause snagging with branches, cables, tools, etc. The size of the jacket has to be re-evaluated (the sleeves were found to be too long). The trousers need reinforcement on the knees.
- For prototype 3 (first aid medical personnel): It offers a very light wearing sensation. The garment waist fits well on the body and protects lumbar area. Antibacterial properties are appreciated also for odor control. Antistatic properties are appreciated for users that work in ambulances.

Based on the very promising results and feedback from the end-users, particularly concerning Prototype 2, PPE and textiles manufacturers involved in the consortium, namely CALSTA, SUMINISTROS IRUNAKO and TDV have expressed their interest and commitment in commercializing the new garments.

Summarizing list of results achieved in SAFEPROTEX

- Multifunctional polymeric compounds (PA-, PET- and PP-based) exhibiting antistatic properties, reduced flammability and increased UV stability (potential use for the production of compact parts, e.g. for automotive applications).
- Bi-component fibers incorporating PCMs, suitable for the production of fabrics that provide thermoregulation or short term protection against high temperatures (depending on the selected PCM). The technology may also be applied for the production of fabrics that provide short term protection against low temperatures (potential applications in protective clothing, sportswear, underwear, work-wear, etc).
- Wristbands incorporating thermochromic polymeric patches to be used as high temperature alert systems in PPE.
- Synthesis of photoactive benzophenone-based polymer and production of photocatalytic yarns or finishing formulations made of its mixture with polyolefin (potential application in clothing, home textiles, outdoor textiles).
- 3D knitted fabrics of suitable design and thickness to be used as thermo-insulative clothing liner or impact-protective pads.
- Multi-functionalizing alkoxysilane-based textile treatments, providing super-hydrophobibity, antimicrobial properties and self-cleaning effect (potential application e.g. in clothing, home textiles, etc).
- Multi-functional protective textiles prepared by nanosol-based finishing and lamination, exhibiting: water repellency, water-tightness, self-cleaning

properties, antimicrobial properties, flame-proofness, antistatic properties, UV protection.

- Design of protective clothing for rescue teams operating under different hazardous situations, considering ergonomic and other end-users requirements, market trends, legislation and standards.
- Multi-protective garment for rescue teams operating under extreme weather conditions.
- Multi-protective garment for rescue teams operating under the risk of wild land fires.
- Multi-protective garment for first aid medical personnel.

1.4. Potential impact

In recent years European and US authorities launch strict safety standards and support the development of effective personal protective equipment (PPE) to protect humans from occupational and environmental hazards. At the same time, emergency and rescue preparedness is being continuously developed as a priority within the security-policy measures at both public and private level.

The various emergency services are adapted to the changing demands and are called to intervene swiftly in response to various types of accidents and disasters. Therefore, the evolution of health and safety requirements to respond to new types of risks makes it necessary to develop innovative products and to ensure their reliability. Indeed, the range of hazards and the means of combating them continue to grow and become more complex.

In addition to hazards complexity, another important issue that contributes in achieving an efficient level of protection is the users' acceptance of the PPE. Heat, physical and psychological stress, as well as reduced dexterity and mobility are examples of additional hazards that may result from the use of heavy and rigid protective garments. In fact, Europe's workforce is increasingly attaching more importance to comfort and aesthetics, in addition to protective properties offered by PPE.

Recognizing the above needs of emergency responders for improved protection coupled with psychological comfort and ergonomic design, SAFEPROTEX developed new materials and integrated new technologies to provide multi-protective garments, combining several functionalities. Emphasis was given on the ergonomic design, thermal comfort properties and moisture management of the garments that increase workers satisfaction and are expected to reduce work-related accidents in emergency and rescue operations.

The expected socio-economic impacts of SAFERPOTEX developments are herein discussed in more detail.

Impact on the turnover in the sector of PPE

SAFEPROTEX focused its efforts to produce multi-functional protective garments for 3 representative risky operations:

- Operations in extreme weather conditions
- Operations under the risk of wild land fires
- Operations of first aid medical personnel

Based on their unique properties, the SAFEPROTEX products (prototypes) demonstrate a strong potential for wide applications in the various emergency teams operating worldwide. Indeed, even if for all the targeted segments addressed in the project, there are already available products of high standards (e.g. for fire fighters or for protection against chemicals), these usually offer high protection at a high cost for only one type of high risk. Due to their cost and the protection they provide, their market is limited to specialized professional rescue teams, facing a pre-determined and specific high level of exposure to one type of risk (e.g. direct contact with fire or dangerous chemicals).

Therefore, the existing products present the following limitations:

- They are not suitable for rescue teams that intervene in situations exposing them to a multiplicity of unpredictable risks.
- They are not suitable for volunteers and other non-professional personnel who are less directly exposed to the risks and cannot afford the cost of high end protective clothes.
- They often present comfort problems, the main one being that the body is shielded from normal air circulation.

SAFEPROTEX successfully addressed the aforementioned limitations of existing protective garments and managed to develop prototypes that provide protection against multiple hazards simultaneously along with physiological comfort to the wearer and can be made available at reasonable cost for voluntary rescue teams. Therefore, the new garments are expected to increase the use of PPE in the case of volunteers and other personnel who are exposed to low but existing risks and are currently not equipped, as well as in the case of users who currently reject the protective clothing because of comfort properties. Moreover, they can substitute existing garments in the case of rescue teams that are equipped but not covered for a multiplicity of hazardous and unpredictable risks. Therefore, the project will contribute to the target set to increase the market of PPE by 50 % in 10 years.

It should be stressed that by demonstrating through the three prototypes how multiple functionalities can be associated in the same garment, SAFEPROTEX impact will be easily multiplied by re-combining the properties of each prototype to adapt them to additional needs than those targeted in the project. The potential outcomes can have a multiplier effect and stronger impact on the market of protective clothes, providing adapted solutions for different types of working conditions and environments and not only in emergency and rescue situations.

In terms of exports, the results of SAFEPROTEX can be exploited for the production in EU of a wide new range of protective garments, offering multi-purpose combinations of protection, integrating existing solutions with new ones specifically developed in the project. Thus, SAFEPROTEX is also expected to contribute to PPE exports increase.

Impact on the reduction of work-related accidents, occupational diseases and injuries including emergency and rescue operations

Although it is difficult to quantify this reduction, it is clear that the new protective garments developed in SAFEPROTEX may significantly reduce the injuries, accidents and illnesses provoked due to emergency and rescue operations, especially since they are expected to be adopted by new users, currently not equipped, but also because they provide protection against hazards currently not considered. Therefore, hundreds of accidents can be avoided each year and thousands of days of work due to diseases and injuries caused to rescue teams operating in hazardous environments can be saved.

Impact on workers satisfaction and societal welfare, measured in terms of increased productivity and reduced absenteeism

SAFEPROTEX has provided to rescue teams protective garments that offer protection against more hazards than their current garments address, along with ergonomic design and enhanced physiological comfort. For example, the use of phase change materials (PCMs) in the garments lead to improved wear comfort and, as a consequence, to better performance and working conditions for first responders and NGO personnel involved in different rescue operations.

In fact, as was concluded by the subjective evaluation of the prototypes by the end-users, the garments developed in the project are superior to those currently used and offer an increased sense of comfort and perceived level of protection.

This directly impacts the capability of the rescuers to operate with less constraint, which in turn impacts their productivity during operations and the stress provoked by lack of comfort and by fear of exposure to various hazards. It is worth noting that the stress factor is considered as having a significant contribution to the absenteeism observed in this type of population. Therefore, increased productivity and reduced absenteeism is expected to result by the exploitation of SAFEPROTEX results.

Impact on European leadership in terms of quality and innovation of PPE and to the Lead Market Initiative

The development and production of multifunctional, high added value textiles with protective properties for PPE is promoted by the Lead Market Initiative of the European Technology Platform. The main goal of this Initiative is the implementation of new technologies and innovative systems to promote the sustainability and competitiveness of the European textile industry. The whole PPE production volume is around 7-8 bil. EUR with an estimated growth of 50 % within the next 10 years.

Fully aligned with the priorities of this initiative, SAFEPROTEX has targeted the higher value adding production steps of protective clothing that are maintained in Europe, such as the production of new additives and functionalizing agents or the development of new yarns and finishing operations.

The employment of novel functional textile fibers, like the PCM fibers developed in the project, may strengthen the competitive edge of European textile industry along the value chain from fiber producers to producers of protective garments. Similarly, the photocatalytic materials developed could be exploited in the production of high added value textiles for technical applications, according to the performances that they can achieve, including antibacterial properties, chemical pollution abatement and self cleaning properties. On the other hand, there is a huge demand for textiles with self cleaning properties in terms of super-hydrophobic and antibacterial dual functionality, which can be used for protective garments for medical and rescue teams, among others. Therefore, the sol-gel technology for multi-functional finishing developed in SAFEPROTEX is also expected to have a great economic impact in the textile industry.

Impact on dual use applications

The technological innovations of SAFEPROTEX could serve for the development of alternative protective equipment as well as in a variety of different applications. In this sense, the specific prototypes developed are only representative cases that prove the efficacy of the project's achievements.

In particular many of the developments can also be exploited in the market of active sportswear where functional properties, physiological comfort and ergonomic design are of major importance.

On the other hand, the global selling volume of photocatalytic materials, such as those developed in the project, is expected to reach $1.7 billion in 2014 (Gagliardi M et al, 2010). Construction materials represent the largest sector of application (almost 90 %), followed by consumer products (8 %). Since the photocatalytic materials developed in SAFEPROTEX can be applied in both sectors, there is a huge interest in the exploitation of relevant project results. It is worth noting that a patent has been submitted in the frame of the project and the production of photoactive polymer has been increased up to 1-2 kg per day at the end of the project.

Impact on the environment and natural resources

The environmental impacts of high protective clothing developed in SAFEPROTEX were studied by applying LCA method according to the standards EN-ISO 14040 "Environmental management - Life cycle assessment - Principles and framework" and EN-ISO 14044 "Environmental management - Life cycle assessment - Requirements and guidelines". The data was based on the information provided by partners, generic databases and literature. The cradle to grave LCA study focused on the production, use and disposal of one uniform (functional unit) and showed that its maintenance has a huge impact in the uniform life cycle, because of the large usage of detergents over the uniform life time (5 years). This finding directly indicates the benefits offered by the self-cleaning characteristics of the garments. Concerning the manufacturing steps, fibres production and energy consumed to finish the textiles and to assemble the composite and flame retardant chemicals are contributing the most to the environmental impact. On the contrary, the materials and treatments developed within the project (e.g. hydrophobic and antibacterial treatment) have a negligible effect. As an example, the traditional fluorocarbon finishes used to endow water repellency to textiles face challenges due to the persistence of two fluorinated compounds (PFOS and PFOA) in the environment, indicating that sustainable alternatives are urgently required. The sol-gel hybrid polymers developed in SAFEPROTEX, containing long alkyl chains and reactive groups, can achieve high level of water repellency for textile fabrics with reasonable durability. Overall, when SAFEPROTEX prototypes were compared to conventional uniforms selected as references, they showed a lower environmental impact, demonstrating the advantage of the new developments proposed in the project.

1.5. Address of project website, relevant contact details

www.safeprotex.org
Contact point:
Silvia Pavlidou, MIRTEC S.A.
SAFEPROTEX Scientific Coordinator
s.pavlidou@ebetam.gr
Tel. +30 210 9234932

1.6. Project logo and list of beneficiaries

Project logo:

List of beneficiaries:

	MIRTEC – MATERIALS INDUSTRIAL RESEARCH AND TECHNOLOGY CENTER S.A.	HELLAS	www.ebetam.gr	Silvia Pavlidou s.pavlidou@ebetam.gr
	INOTEX S.R.O., DVŮR KRÁLOVÉ NAD LABEM	CZECH REPUBLIC	www.inotex.cz/	Jan Marek marek@inotex.cz
	SARL SCIC **RESCOLL**	FRANCE	www.rescoll.fr	Konstantin Sipos konstantin.sipos@rescoll.fr
	TDV INDUSTRIES	FRANCE	www.tdv-industries@wanadoo.fr	Farida Simon fsimon.tdvindustries@wanadoo.fr

	DE MONTFORT UNIVERSITY – TEXTILE ENGINEERING AND MATERIALS (TEAM) RESEARCH GROUP	UK	www.dmu.ac.uk	Jinsong Shen jshen@dmu.ac.uk
	TUT - TAMPERE UNIVERSITY OF TECHNOLOGY	FINLAND	www.tut.fi/swl	Minna Varheenmaa minna.varheenmaa@tut.fi
	FUNDACIÓN **GAIKER**	SPAIN	www.gaiker.es	Oscar Salas salas@gaiker.es
	SWEREA **IVF** AB	SWEDEN	www.ifp.se	Bengt Hagstrom bengt.hagstrom@swerea.se
	NEXT TECHNOLOGY TECNOTESSILE SOCIETÀ NAZIONALE DI RICERCA R.L.	ITALY	www.tecnotex.it	Enrico Fatarella chemtech@tecnotex.it
	ACONDICIONAMIENTO TARRASENSE **LEITAT**	SPAIN	www.leitat.org	Amro Satti asatti@leitat.org
	LENZI EGISTO S.P.A	ITALY	www.lenzie.it	
	VUCHV - VÝSKUMNÝ ÚSTAV CHEMICKÝCH VLÁKIEN, A.S.	SLOVAK REPUBLIC	www.vuchv.sk	Martin Budzak budzak@vuchv.sk
	CALSTA WORKWEAR SA	HELLAS	www.calsta.com	Avra Stamatiou sstamatiou@calsta.com
	NANOTHINX SA - RESEARCH AND DEVELOPMENT OF CARBON NANOTUBES S.A.	HELLAS	www.nanotubesx.com	Katerina Kouravelou katerina.kouravelou@nanothinx.com
	SUMINISTROS IRUÑAKO, S.C.	SPAIN	www.suministrosirunako.com	Uxue Bacaicoa Preciado info@suministrosirunako.com
	FUNDACIÓ PRIVADA **CETEMMSA**	SPAIN	www.cetemmsa.com	Virginia Garcia vgarcia@cetemmsa.com

	ONGD **SAR ESPAÑA**	SPAIN	www.sar-esp.es
	RESCUE GR	HELLAS	www.rescue.gr

2. USE AND DISSEMINATION OF FOREGROUND

Section A (Public)

A1. LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	The effect of melt spinning process parameters on the spinnability of polyetheretherketone	V. Myllari	Journal of Applied Polymer Science	126	John Wiley and Sons		2012	1564-1571		No
2	Integration of multifunctionality and comfort in personal protective clothing for extreme conditions	M. Varheenmaa	Proceedings of FiberMed11, International Conference on Fibrous Products in Medical and Health Care		FiberMed11		2011			No
3	Comfort in multifunctional protective clothing	P. Talvenmaa	Proceedings of FiberMed11, International Conference on Fibrous Products in Medical and Health Care		FiberMed11		2011			No

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
4	Nanolayer surface coating of cotton fabric with sol-gel based hybrid polymers to achieve hydrophobic and antibacterial properties	J. Shen	Proceedings of 12th World Textile Conference AUTEX		AUTEX 2012		2012			No
5	Sol gel hybrid polymer coating of cotton fabrics	J. Shen	Proceedings of the International Conference on Eco-Dyeing/ Finishing and Green Chemistry		International Conference on Eco-Dyeing/ Finishing and Green Chemistry		2011			No
6	Sol gel process of cotton fabric to achieve multifunctionality	J. Shen	Proceedings of 13th World Textile Conference AUTEX		AUTEX 2013		2013			No
7	The development of sol gel based hybrid polymers to achieve multifunctional textile fabric surface coating	J. Shen	Proceedings of the XVII International Sol-Gel		XVII International Sol-Gel		2013			No
8	Production of filament yarns made of PEEK (Thesis)	V. Myllari			Tampere University of Technology	Tampere, Finland	2011			No
9	Comfort properties in multifunctional protective clothing (thesis)	C. Peltonen			Tampere University of Technology	Tampere, Finland	2011			No
10	Study and optimization of bioactive nanomaterials for technical applications (PhD)	E. Fatarella			Next Technology Tecnotessille	Prato, Italy	2012			No

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
11	Photocatalytic nanofibers by using benzophenone compounds (thesis)	M. Ruzzante			Next Technology Tecnotessille	Prato, Italy	2013			No

A2. LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
1	Oral presentation to a wider public	MIRTEC	The European research project SAFEPROTEX – Short Overview	2009	EURATEX 4th Annual Public Conference – From EU Research to Industrial Innovation, Brussels, Belgium	Policy makers		Europe
2	Oral presentation to a wider public	INOTEX	Možnost zvyšování účinnosti a životnosti fotoaktivních funkčních systémů pomocí enzymatické preaktivace polyesteru	2010	42nd Conference STCHK TEXCHEM, Pardubice, Czech Republic	Industry		Czech Republic

[3] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
3	Press release	MIRTEC	High protective clothing for complex emergency operations (part I)	April 2010	Greek Fashion Magazine	Industry		Greece
4	Press release	MIRTEC	High protective clothing for complex emergency operations (part II)	July 2010	Greek Fashion Magazine	Industry		Greece
5	Press release	MIRTEC	High protective clothing for complex emergency operations (part III)	January2011	Greek Fashion Magazine	Industry		Greece
6	Press release	GAIKER	Gaiker avanza en el desarrollo de materiales mas ligeros y un mayor rango de propiedades	2010	EMPRESSA XXI	Industry		Spain
7	Press release	GAIKER	Gaiker desarrolla uniformes de protection inteligentes destinados a equipos de rescate	2010	Plasticos Modernos	Industry		Spain
8	Press release	GAIKER	Uniformes de proteccion inteligente para los rescates	2010	Gestion.com	Industry		Spain

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
9	Poster	VUCHV	SAFEPROTEX	2010	INTERPROTEC 2010 – 10th International Fair of Personal Protective Equipment, Health and Safety at Work	Industry		International
10	Oral presentation to a scientific event	DMU	Sol gel hybrid polymer coating of cotton fabrics	2011	International Conference on Eco-Dyeing/Finishing and Green Chemistry, Hangzhou, China	Scientific community – Industry – Policy makers		International
11	Oral presentation to a wider public	MIRTEC	High protective clothing for complex emergency operations. Overview and first results	2011	PPE Conference 2011, Brussels, Belgium	Industry – Policy makers		Europe
12	Oral presentation to a scientific event	DMU	Sol gel hybrid polymers for surface coating textile materials	2011	7th International Conference on Polymer and Textile Biotechnology, Milan, Italy	Scientific community – Industry – Policy makers		International
13	Oral presentation to a scientific event	LEITAT	Chitosan microspheres for antibacterial finishes	2011	AUTEX 2011, Mulhouse, France	Scientific community – Industry		Europe
14	Oral presentation to a scientific event	MIRTEC	The European project SAFEPROTEX: High protective clothing for complex emergency operations.	2011	NN11 Conference, Thessaloniki, Greece	Scientific community – Industry		Europe
15	Oral presentation to a scientific event	LEITAT	Thermal stress sensoring system in PPE for emergency situations	2011	1st SMARTEX – Egypt 2011, Kaferelsheikh city, Egypt	Scientific community – Industry		International

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
16	Oral presentation to a scientific event	NTT	Possibilities of improving photocatalytic system efficiency and stability using enzymatic preactivation 2011		7th International Conference on Polymer and Textile Biotechnology, Milan, Italy	Scientific community – Industry – Policy makers		International
17	Exhibitions	MIRTEC	SAFEPROTEX	2011	PPE Conference, Brussels, Belgium	Industry – Policy makers		Europe
18	Exhibitions	MIRTEC	SAFEPROTEX project	2011	NANOTEX Exhibition, Thessaloniki, Greece	Scientific community - Industry – Policy makers		Europe
19	Oral presentation to a wider public	INOTEX	SAFEPROTEX- Multifunctional textiles for protective clothing for rescue teams	2012	TEXCHEM – 44th Int. Conference STCHK, Pardubice, CZ	Scientific community - Industry		International
20	Oral presentation to a wider public	TUT	Multifunctional prpotective clothing for rescue team workers in the Nothern areas	2012	ECPC Conference, Valencia, Spain	Scientific community - Industry – Policy makers		Europe
21	Interviews	GAIKER	Uniforms emergencia Safeprotex	2012	Radio Victoria	Medias		Spain
22	Interviews	GAIKER	SAFEPROTEX	2013	Radio La Cope	Medias	50000	Spain
23	Interviews	GAIKER	SAFEPROTEX	2013	Radio Euskadi	Medias	234000	Spain
24	Interviews	GAIKER	SAFEPROTEX	2013	Newspaper Berria	Medias	53000	Spain
25	Interviews	GAIKER	SAFEPROTEX	2013	Newspaper Gara	Medias	84000	Spain

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
26	TV clips	GAIKER	Desarrolla un Nuevo material para uniformes inteligentes de equipos de salvamento	2012	Teleberri (TV news midday and night)	Medias	467000	Spain
27	TV clips	GAIKER	SAFEPROTEX	2012	Gaur Egun (TV news midday and night)	Medias	100000	Spain
28	Interviews	GAIKER	Uniformes de salvamento inteligentes gracias a los nanomateriales	2013	Magazine Interempresas	Medias	560000	Spain
29	Oral presentation to a wider public	TUT	Multifunctional Protective Clothing, news from Safe@Sea and SAFEPROTEX projects	2012	Protective clothing seminar of FIOH, in Kuopio	Scientific community - Industry		Finland
30	Oral presentation to a scientific event	TUT	Rescue team workers in cold climate areas - challenges for multifunctional protective clothing	2013	13th Autex World Texgtile Conference 2013. Dresden	Scientific community - Industry		International
31	Oral presentation to a wider public	TUT	News from SAFEPROTEX – Multifunctional Protective Clothing	2013	Protective clothing seminar of FIOH, in Lohja	Scientific community - Industry		Finland
32	Oral presentation to a wider public	TUT	Clothing physiology research at TUT, e.g. SAFEPROTEX results	2013	seminar of Uudet teknologiat (New Technologies)	Industry		Finland

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
33	Exhibitions	NTT	Photoactive yarns and polymers	2013	EPF conference, Pisa, Italy	Scientific community - Industry		Europe
34	Posters	NTT	Photoactive yarns and polymers	2013	JEP European Photocatalysis Federation conference, Portoroz	Scientific community - Industry		Europe
35	Press releases	TUT	The project of multiple sciences	2010	Textiili 6	Scientific community - Industry		Finland
36	Exhibitions	DMU	Sol-gel hybrid polymers for surface coating of textile materials	2010	DMU Research Technology Show Case, DMU, Leicester, UK	Scientific community		UK
37	Press releases	TUT	Monilta vaaroilta suojaavien ominaisuuksien ja käyttömukavuuden yhdistäminen äärioloissa käytettäviin suojavaatteisiin	2011	Tekstiililehti issue 5	Scientific community - Industry		Finland
38	Organisation of conference	TUT	Final SAFEPROTEX Conference	2013	TUT, Tampere, Finland	Scientific community – Industry – Civil Society		Europe
39	Flyers	CETEMMSA	1st SAFEPROTEX newsletter	2010	Spain	Scientific community – Industry – Civil Society – Policy makers		Europe
40	Flyers	CETEMMSA	2nd SAFEPROTEX newsletter	2011	Spain	Scientific community – Industry – Civil Society – Policy makers		Europe
41	Flyers	CETEMMSA	3rd SAFEPROTEX newsletter	2011	Spain	Scientific community – Industry – Civil Society – Policy makers		Europe

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
42	Flyers	CETEMMSA	4th SAFEPROTEX newsletter	2012	Spain	Scientific community – Industry – Civil Society – Policy makers		Europe
43	Flyers	CETEMMSA	5th SAFEPROTEX newsletter	2013	Spain	Scientific community – Industry – Civil Society – Policy makers		Europe
44	Flyers	MIRTEC	Final publication	2013	Greece	Scientific community – Industry – Civil Society – Policy makers		Europe
45	Organisation of workshops	SUMI	1st SAFEPROTEX workshop	2010	Arganda del Rey, Spain	Industry – Civil Society		Spain, Greece
46	Organisation of workshops	RESCUE-GR	2nd SAFEPROTEX workshop	2011	Thessaloniki, Greece	Industry – Civil Society		Greece, Spain
47	Organisation of workshops	LEITAT	3rd SAFEPROTEX workshop	2012	Terassa, Spain	Industry – Civil Society		Greece, Spain
48	Web sites	MIRTEC	www.safeprotex.org	2010	Greece	Scientific community – Industry – Civil Society – Policy makers		International
49	Organisation of workshops	NTX	Presentation of the SAFEPROTEX project on the 6th Disaster Management Special Unit Patras	2011	Patras, Greece	Civil society		Greece

Section B

PART B1. LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.

Type of IP Rights:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	YES		PCT/IB2013/058911	Polymer blend including modified **PEEK**	Enrico Fatarella; Leopoldo Corsi, Solitario Nesti, Ville Myllari, Pentii Jarvela; Mikael Skrifvars; Seppo Syrjala (owner owner is Next Technology Tecnotessile)

Part B2

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yy	Exploitable product(s) or measure(s)	Sector(s) of application5	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Large scale production of functionalized multi-walled carbon nanotubes (MWCNTs) and CNTs dispersions	No		Functionalized MWCNTs in powder form and in dispersions in water or ethanol	polymeric masterbatches	already in the market	none at the moment	NTX
Commercial exploitation of R&D results	Development of EVA and other polymeric sheets incorporating microencapsulated thermochromic dyes	No		Thermal sensors for PPE, based on polymeric sheets incorporating thermochromic dyes	Manufacturers of PPE	2014-2015	none at the moment	LEITAT
Commercial exploitation of R&D results	Synthesis of photocatalytic polymer and its blends to develop multifilament yarn	No		Multifunctional yarns assuring anti-soil, anti-UV, anti-bacterial and anti-polluting properties	Air sanitizer systems, PPE, construction	2015	Patent application filed	NTT, TUT
Commercial exploitation of R&D results	Development of bi-component fibers incorporating a very high amount of phase change materials (PCMs)	No		Thermoregulating fibers with high temperature regulating efficiency	Sportswear, workwear, PPE, domestic textiles	2015	none at the moment	Swerea IVF

[5] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yy	Exploitable product(s) or measure(s)	Sector(s) of application5	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Sol-gel hybrid polymer coating for self-cleaning and anti-bacterial textile materials	No		Multifunctional textiles with super-hydrophobic, self cleaning and antimicrobial properties	Textile manufacturers, PPE, healthcare, domestic textiles	2015	none at the moment	DMU
Commercial exploitation of R&D results	Preparation of watertight and windproof breathable laminates with water repellent, self-cleaning and antimicrobial properties	No		Laminate with unique combination of watertightness, breathability and water repellent properties permanent in repeated washing	PPE for industrial workers, health care, rescue teams, police, etc	2014	none at the moment	INOTEX, TDV
Commercial exploitation of R&D results	Simultaneous dispersion of LSs, CNTs and TiO2 in polymeric compounds	No		Polymeric compounds with antistatic, flame retardant properties and enhanced UV stability	Polymer suppliers	2015	none at the moment	GAIKER, RESCOLL, NTX, MIRTEC
Commercial exploitation of R&D results	3D knitted fabrics with a specific design for lining	No		3D knitted liners with thermo-insulative properties, high breathability and low density	PPE, cushions, seats	2014	none at the moment	LEITAT

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yy	Exploitable product(s) or measure(s)	Sector(s) of application5	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Ergonomic design of protective garments	No		Protective garments for rescue teams with ergonomic design	PPE	2014	none at the moment	CETEMMSA
Commercial exploitation of R&D results	Prototypes garments for protection of first aid doctors and rescue teams operating under the risk of wild land fires	No		Protective garments for rescue teams and first aid medical personnel	PPE	2014	none at the moment	CALSTA, TDV, CETEMMSA, INOTEX, LEITAT
Commercial exploitation of R&D results	Prototype garments for people operating under extreme weather conditions	No		Protective garments for rescue teams	PPE	2014	none at the moment	CALSTA, TDV, INOTEX, SWEREA IVF

Explanation of exploitable foreground:

Description of Exploitable Foreground	Explanation of Exploitable Foreground
Large scale production of functionalized multi-walled carbon nanotubes (MWCNTs) and CNTs dispersions	Purpose: Functionalized CNTs show improved dispersion in polymeric matrices in comparison to raw CNTs. A protocol was established for large scale production of functionalized CNTs. The dispersions of CNTs in liquids were developed for health and safety issues. Therefore, the developed formulations can be provided at a lower cost or as an answer to specific demands. The cost depends on the quantity (i.e. for quantities up to 10g, the cost is 25 €/g for functionalised CNTs and 40 €/g for water dispersions). Exploitation: By Nanothinx, through direct commercialization (already available in the market) and possibly through license agreements. No further research is required.
Development of EVA and other polymeric sheets incorporating microencapsulated thermochromic dyes	Purpose: The thermochromic polymeric sheets constitute a simple and cheap product usable for several activities under thermal risk. The configuration of the material at different temperature ranges according the work scenario or environment is possible. This material can be used as thermal sensor integrated on garment, a solution not currently used for PPE. Exploitation: By LEITAT through license agreements. No further research is required.
Synthesis of photocatalytic polymer and its blends to develop multifilament yarn	Purpose: Through the developed foreground 100% polymer based products can be realised with photoactive properties, without affecting the properties of the bulk material.Exploitation: NTT has already filed an application for patent and expects to have benefits from Royalties and/or invest in the production of photoactive components. Investment should be required for the installation of a reactor for the production of photoactive polymers.
Development of bi-component fibers incorporating a very high amount of phase change materials (PCMs)	Purpose: Instead of incorporating microcapsules with PCM into fibers, a very high amount of PCM is directly incorporated into the fibers by using melt spinning of bi-component fiber technology. The technology allows significantly higher amounts of PCM to be incorporated into fibers compared to present state of the art. The resulting fibers have high temperature regulating efficiency (heat of fusion 5-10 higher than competition) and the production process is easy to scale up. Exploitation: Swerea IVF has exclusive right to license the technology within the field of garments and is actively searching for companies interested in licensing the technology for manufacture of PCM fibers. No further research is required.
Sol-gel hybrid polymer coating for self-cleaning and anti-bacterial textile materials	Purpose: Nanolayer surface coating of textile fabrics through sol-gel process can achieve the combined water-repellent and antibacterial self-cleaning functionality with good fastness to washing and maintaining good moisture management. Exploitation: By DMU and INOTEX through license agreements. Scale up required for commercialization.
Preparation of watertight and windproof breathable laminates with water repellent, self-cleaning and antimicrobial properties	Purpose: This foreground regards the application of the water repellent finishing system on the fabric/membrane laminate. The opposite sequence of the steps (the laminate preparation using water repellent finished fabric) is not viable because of low adhesivity of the WR fabric to membrane.Following the proposed approach, a unique combination of watertightness, breathability and water repellent properties permanent in repeated washing is achieved. Exploitation: Direct use by INOTEX and TDV. no further research is required

Simultaneous dispersion of LSs, CNTs and TiO2 in polymeric compounds	Purpose: Processable pellets are produced by diserpsion of appropriate concentrations of CNTs, layered silicates and TiO2 in polymers. The resulting compounds have good performances in conductive properties, fire retardancy and UV stability. Exploitation: GAIKER, RESCOLL, MIRTEC and Nanothinx are the involved partners and plan to exploit this resul through license agreements. The potential applications need to be verified by further research.
3D knitted fabrics with a specific design for lining	Purpose: The 3D knitted fabrics developed exhibit thermo-insulative properties, high breathability and low density. They can be easily integrated on a garment manufacture process. Exploitation: By LEITAT through license agreements. No further research required.
Ergonomic design of protective garments	Purpose: Ergonomic design based on the 3D patterning (anatomical shaping, articulated pattern), strategic seams location, shaping natural body stance and streamlined performance with minimal bulk. Exploitation: By CETEMMSA and other partners involved directly to the industry or through license and bilateral agreement. Benefits to be considered for consortium partners. No further research required.
Prototypes garments for protection of first aid doctors and rescue teams operating under the risk of wild land fires	Purpose: Protective garments with new and specific properties meeting the needs in important market sectors, such as medical textiles and protective equipment. Exploitation: direct commericalization (possibly by CALSTA or/and SUMI). Royalties to partners involved in the result may be considered. No further research required.
Prototype garments for people operating under extreme weather conditions	Purpose: Protective garments with new properties meeting the needs in specific PPE. Exploitation: direct commericalization (possibly by TDV, CALSTA or/and SUMI). Royalties to partners involved in the result may be considered. No further research required.

3. REPORT ON SOCIETAL IMPLICATIONS

General Information *(completed automatically when* ***Grant Agreement number*** *is entered.*	
Grant Agreement Number:	228439
Title of Project:	High protective clothing for complex emergency operations
Name and Title of Coordinator:	Dr. Silvia Pavlidou

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	

• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	
• Research having the potential for terrorist abuse	

C Workforce Statistics

Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	
Work package leaders	5	3
Experienced researchers (i.e. PhD holders)	10	18
PhD Students	2	3
Other	48	56

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	5
Of which, indicate the number of men:	3

D Gender Aspects	
5. Did you carry out specific Gender Equality Actions under the project?	No
6. Which of the following actions did you carry out and how effective were they?	
Design and implement an equal opportunity policy	not applicable
Set targets to achieve a gender balance in the workforce	not applicable
Organise conferences and workshops on gender	not applicable
Actions to improve work-life balance	not applicable
7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?	No
E. Synergies with Science Eduction	
8. Did your project involved working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?	No
9. Did the project generate any science education material?	No
F. Interdisciplinarity	
10. Which disciplines are involved in your project?	
Main discipline	2.3. Other engineering sciences
Associated discipline	1.3. Chemical sciences
G. Engaging with Civil Society and Policy Makers	
11a. Did your project engage with societal actors beyond the research community?	Yes
11b. If yes, did you engage with citizens or organized civil society (NGOs, patients' groups etc)?	Yes
11c. In doing so, did your project involve actors whose role is mainly to organize the dialogue with citizens and organized civil society?	No
12. Did you engage with government/public bodies or policy makers?	No
13a. Will the project generate outputs which could be used by policy makers?	No
H. Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	11
To how many of these is open access[6] provided?	0
How many of these are published in open access journals?	0
How many of these are published in open repositories?	0

[6] Open Access is defined as free of charge access for anyone via Internet.

To how many of these is open access not provided?	11
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[7]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	1	
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	0
	Registered design	0
	Other	0
17. How many spin-off companies were created / are planned as a direct result of the project?	0	
Indicate the approximate number of additional jobs in these companies:	*0*	
18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project	Not possible to quantify	
19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	Not possible to quantify	

[7] For instance: classification for security project.

I. Media and Communication to the general public	
20. As part of the project, were any of the beneficiaries professionals in communication or media relations?	No
21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public	No
22. Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?	
Press Release	Yes
Media briefing	No
TV coverage / report	Yes
Radio coverage / report	Yes
Brochures /posters / flyers	Yes
DVD /Film /Multimedia	No
23. In which languages are the information products for the general public produced?	
Language of the coordinator	Yes
Other language(s)	Yes