NANOENERGETICS
Toxicity and Prevention Measures

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WHAT ARE THEY?

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NANOENERGETICS *What are they?*

- Energetic materials (EMs) are pure components or mixtures of chemical substances that could release a large amount of energy or gas upon ignition.

- During the past two decades, several significant achievements in EMs research have been realized, thanks to the technological novelties in the field of nanoscience and nanotechnology.

- EMs research is increasingly interested in the use of nano-sized materials because of the enhancement of
  - the specific surface area in relation to mass and
  - the close bond between chemical components

- NanoEnergetics (nEMs) aims to improve the reaction rate while reducing the ignition delay (within the acceptable level of safety).

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nEMs Characteristics

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- **Stage 1**. nEMs began with the use of nano-sized metal particles, mainly aluminum, which was mainly used for rocket propulsion.

- **Stage 2**. Since the second half of the 20th century. Especially, during the last two decades, the physical mixing of oxidizers and fuels, exploiting, at the nanoscale, the improvement of the diffusion distances between the chemical species and the enhancement of the surface-over-volume ratio,

- **Stage 3.** Currently, produce novel types of reactive nanocomposites structures and morphology with tunable features.

- nEMs, which are composed of nano-sized fuel and oxidizer with/without additives, have been found to be potential sources of extremely high heat release rates and tailored burning rates, reliability, and extraordinary combustion efficiency.

- nEMs play a vital role in widespread applications such as miniaturized electro-explosive devices.

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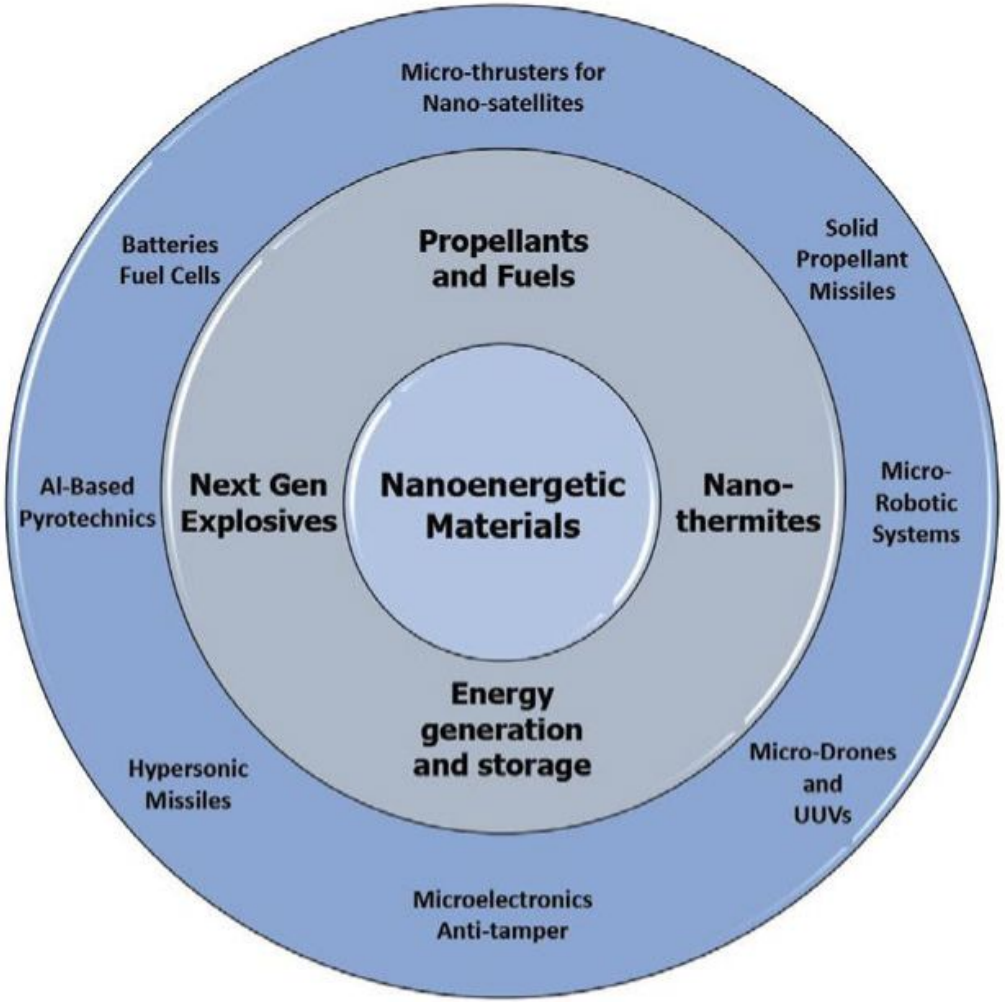
Development and Application



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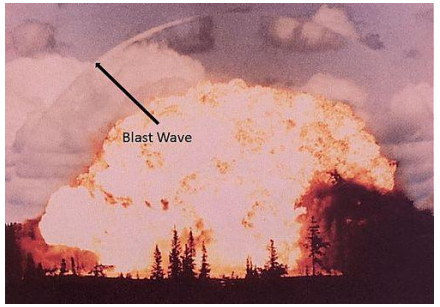
Explosives for Improved Weapons Effects

- The limits of energy that can be released as an explosive or pyrotechnic using traditional chemical formulations, relying on the energy inherent in —carbon, hydrogen, nitrogen, oxygen—chemical bonds, is reached.
- Weapon systems benefit by reducing their size, hence signature and logistics burden, and by the ability to tailor weapons effects depending on mission requirements..
- Current explosives such as HMX, RDX, and TNT are monomolecular formulations in which fuel and oxidizer groups are present on a single molecule and the rate of reaction is determined by breaking chemical bonds.
- The speed of the reaction—hence the explosive power—is largely determined by mass-transfer limitations; i.e., the larger the particles, the slower the speed of reaction, and the density of these formulations is very limited.
- Adding metal particles, particularly aluminum, to pyrotechnics, explosives, and propellants is known to increase the energetic output.
- Future explosives will incorporate metallic and other energetic nanoparticles and a nanoparticulate oxidizer to greatly increase the surface areas for reaction, thus liberating vastly more energy in a shorter time than conventional explosives.
- They will also be tunable for specific weapons effects by manipulating the chemistries



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Thermobaric explosive

DEFINITION

- A **thermobaric weapon**, also called an **aerosol bomb**, or a **vacuum bomb**, is a type of explosive munition that works by dispersing an aerosol cloud of gas, liquid or powedered explosives.

- A fuel–air explosive (FAE) device consists of a container of fuel and two separate explosive charges.

  - After the munition is dropped or fired, the first explosive charge bursts open the container at a predetermined height and disperses the fuel in a cloud that mixes with atmospheric oxygen (the size of the cloud varies with the size of the munition).
  - The cloud of fuel flows around objects and into structures. The second charge then detonates the cloud and creates a massive blast wave.
  - The blast wave can destroy reinforced buildings, equipment, and kill or injure people. The blast wave's antipersonnel effect is magnified in confined spaces, such as foxholes, bunkers and caves.

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INJURY,

TOXICITY

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Nanotoxicology

Definition

Nanotoxicology is the branch of toxicology focused on understanding the adverse effects of nanomaterials on living organisms and the environment. It investigates how nanomaterials, with their unique properties (like high surface area and quantum size effects), can interact with biological systems and potentially cause harm. This field also explores strategies to mitigate these adverse effects and prevent them.

Toxicokinetics/Toxicodynamics

Upon entry into the portal of entry organ, via inhalation, injection etc … Nanomaterials can access the blood system and circulate to secondary organs (unlike larger materials).

The accumulation of nanomaterials in secondary organs can lead to organ specific toxicity – e.g. inflammation/fibrosis/cancer.

Note that current evidence in nanotoxicology is based on very low dose – commensurate to environment or occupational exposure. Nanoparticles cannot be visualize using current x-ray machines.

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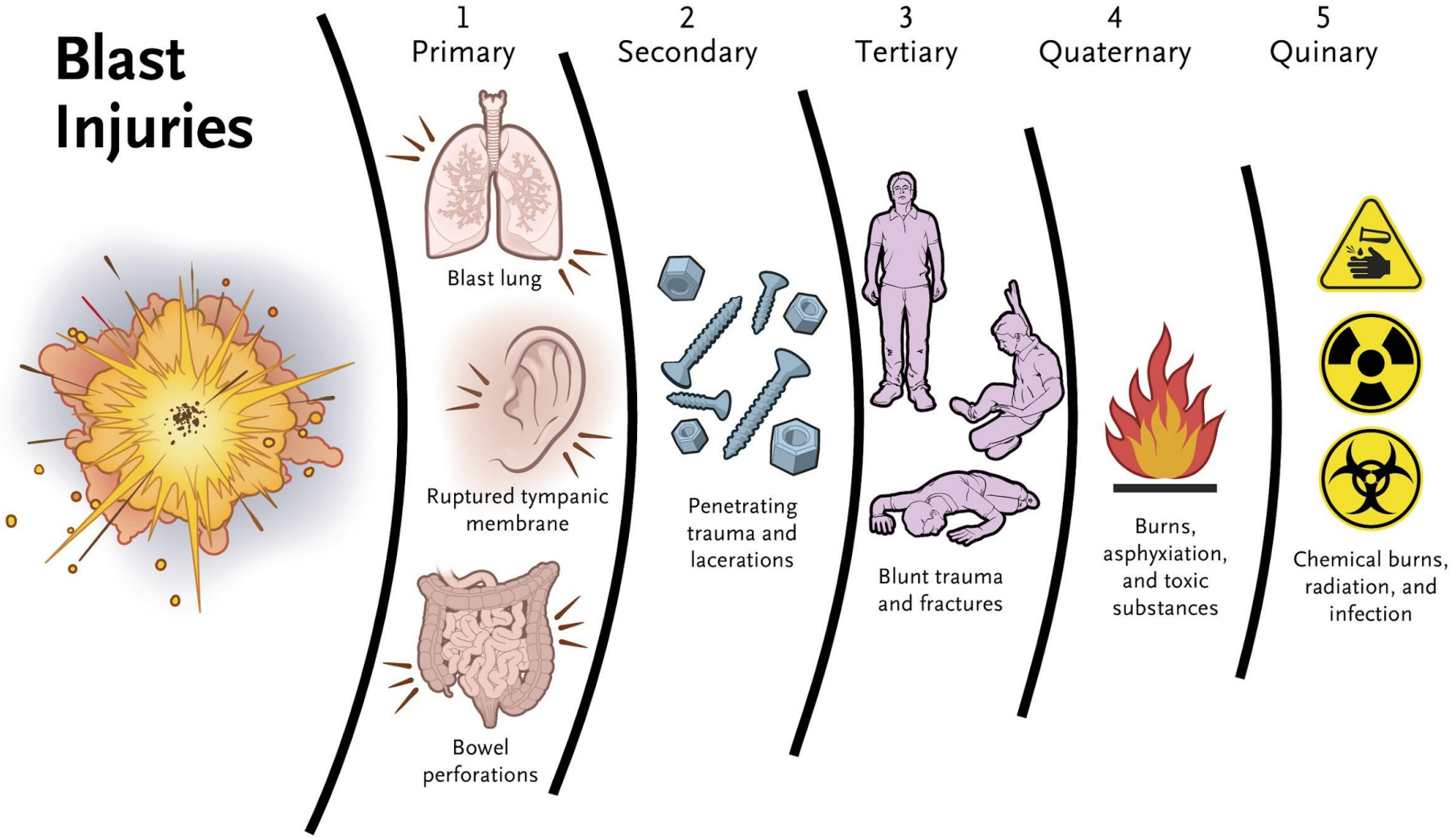
Injury Classification



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Blast injury

Unique to Blast

PRIMARY

- Blast lung
- Eardrum rupture and middle ear
- Abdominal hemorrhage and perforation
- Eye rupture
- Non-impact, blast-induced mTBI?

SECONDARY

- Penetrating ballistic (fragmentation) or blunt injuries
- Eye penetration

TERTIARY

- Fracture and traumatic amputation
- Closed and open brain injury
- Blunt injuries
- Crush injuries

QUATERNARY

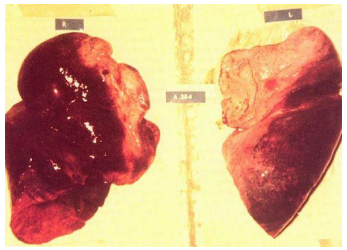
- Burns
- Injury or incapacitation from inhaled toxic fire gases

QUINARY

- Illnesses, injuries, or diseases caused by chemical, biological, or radiological substances (e.g., "dirty bombs")

*PSYCHOLOGICAL TRAUMA (including PTSD)

* Added based on latest research suggesting a high risk of developing PTSD following a concussion



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Nanoenergetics

Injuries caused by nanoenergetics are most likely to be

- *Primary* blast wound
- *Secondary* penetrating fragmentation
- *Quarternary* burn wound
- *Quinary* illnesses – Sepsis like organ damages, hyperinflammation, chronic diseases – fibrosis, cancer

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PREVENTIVE MEASURES

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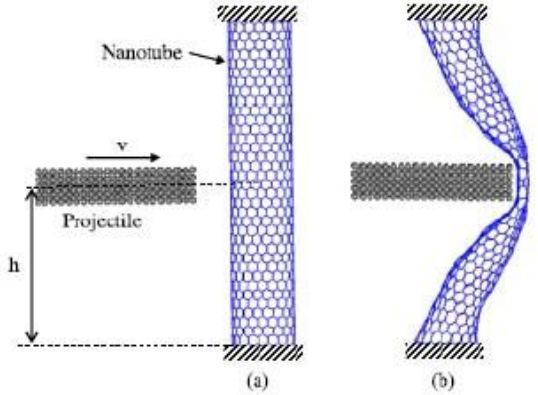
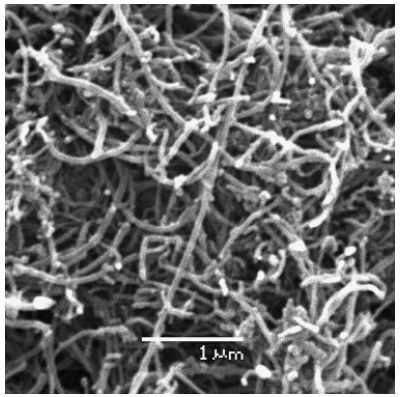
Smart Textile for protective clothing

Nanoenergetics

- Carbon nanotubes (CNT) offer promising advantages for bulletproof vests, potentially enhancing protection and weight reduction compared to traditional materials like Kevlar.
- Their high strength and flexibility make them ideal for energy absorption and impact resistance.



- CNTs can improve ballistic resistance and even detect impact force and location.
- The strength and stiffness of CNTs allow for lighter armor while maintaining high protection
- CNTs can effectively disperse and absorb the impact energy from bullets, reducing trauma to the wearer.
- By incorporating conductive CNTs, vests could be made "smart" and capable of sensing impacts and even detecting if they've been pierced.
- CNT-based armor often uses a multi-layered design to enhance impact resistance and energy absorption.
- CNTs help distribute and dissipate the energy of a bullet impact, reducing the force transmitted (blast) to the wearer.



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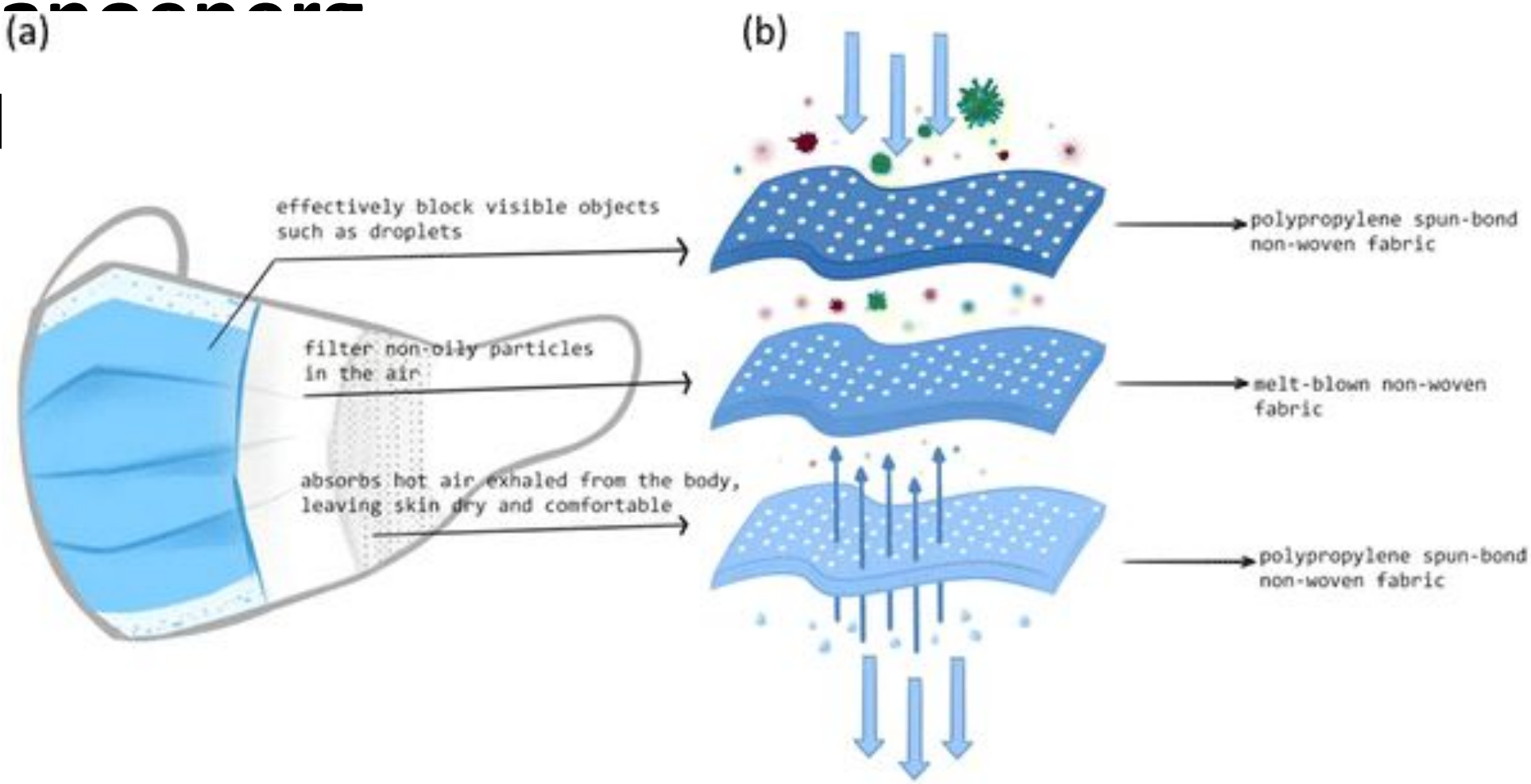

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ETHICS and REGULATION

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Nanoenergetics

- Several international instruments prohibit or regulate weapons that generate asphyxiating or toxic gases, poison or poisoned weapons, chemical weapons, and weapons primarily designed to be incendiary.
- Thermobaric weapons are, however, primarily designed for blast and are not specifically covered by, or excluded from, the application of these instruments.
- The general customary law principles of international humanitarian law that determine the legality of the use of all weapons, including thermobaric weapons, prohibit causing superfluous injury and unnecessary suffering, and the use of indiscriminate weapons.
- Thermobaric weapons cause severe suffering but will not be rendered unlawful merely because of this effect.
- International law does not prohibit the use of thermobaric munitions, fuel-air explosive devices, or vacuum bombs against military targets.

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CONCLUSIONS

- Clear and present need to develop body armour and smart textiles for the protection of military and civilians

- New technology based on nanomaterials and the technics for the weaving of fabrics developed following the COVID-19 pandemics can be combined

- This new protective approach must be tested in many case studies scenarios.

- Research/industry consortium be formed to advance the technology, scale up and shorten the time to application.

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