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Personal Protective Gear: A Review

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ABSTRACT-

Personal protective clothing is a critical area where the equipment used for any kind of protection should have high functionality and should satisfy the requirements of the working environment. There is a huge need for PPE in the present environmental condition in the world. So knowledge on the working environment, type of protection required, the method of incorporating the protection into textiles, raw material selection and manufacturing technique, testing and life of the protective equipment are important to understand about personal protective clothing. This review paper highlights the classification of protective clothing, fibres used, various function finish application techniques and testing standards for protective clothing.

Key words: Protective clothing, Finishes, Fibres, Coatings.

1. INTRODUCTION

Textiles, which are mostly used for clothing and provide a specific look or appearance. However, for working in hazardous environments, we require protection rather than appearances. Protective textiles is one kind of important segments of technical textiles. Any clothing that is specifically designed, treated, or manufactured to protect personnel from hazards caused by extreme environmental conditions or a hazardous work environment is considered protective clothing. Some protective clothing may be designed to keep workers safe from infection or pollution on the job. Any clothing that is specifically designed, treated, or manufactured to protect personnel from hazards caused by extreme environmental conditions or a hazardous work environment is considered protective clothing. Some protective clothing may be designed to keep workers safe from infection or pollution on the job. Any type of protective clothing or equipment is referred to as personal protective equipment (PPE). The range of protective functions that different textile products must provide is extensive and diverse.Protection from cuts, abrasion, ballistic and other types of severe impact, including stab wounds and explosions, fire and extreme heat, hazardous dust and particles, nuclear, biological, and chemical hazards, and other hazards, radiation, high voltages and static electricity, foul weather, extreme cold, and poor visibility are all included. Sensitive instruments and processes, in addition to people, must be safeguarded. As a result, clean room clothing is a requirement for many industries, including electronics and pharmaceuticals. This kind of protective clothing is mainly used for its functional properties compared to aesthetic properties. Protective textile or fabric is widely used in protective clothing, which is critical for anyone who works in a dangerous profession. This fabric has been used to protect against a wide range of natural and man-made hazards includes chemical, biological and radiation hazards. Traditional textile manufacturing technologies such as weaving, knitting, and non-wovens are used to make protective clothing, as are specialised techniques such as 3D weaving and braiding with natural and man-made fibres. The protective clothing may be in the form of aprons, coveralls, coats, pants, hats, hoods, sleeves, gloves, vests, jackets, surgical gowns **etc.**

2. PROTECTIVE CLOTHIG

Protective textiles are garments and other fabric-related items that are worn primarily for their protection performance or functional characteristics, rather than for their aesthetic or decorative value. Clothing materials used as personal protective equipment are now an important application for textiles and are classified as technical or industrial textiles.[1]

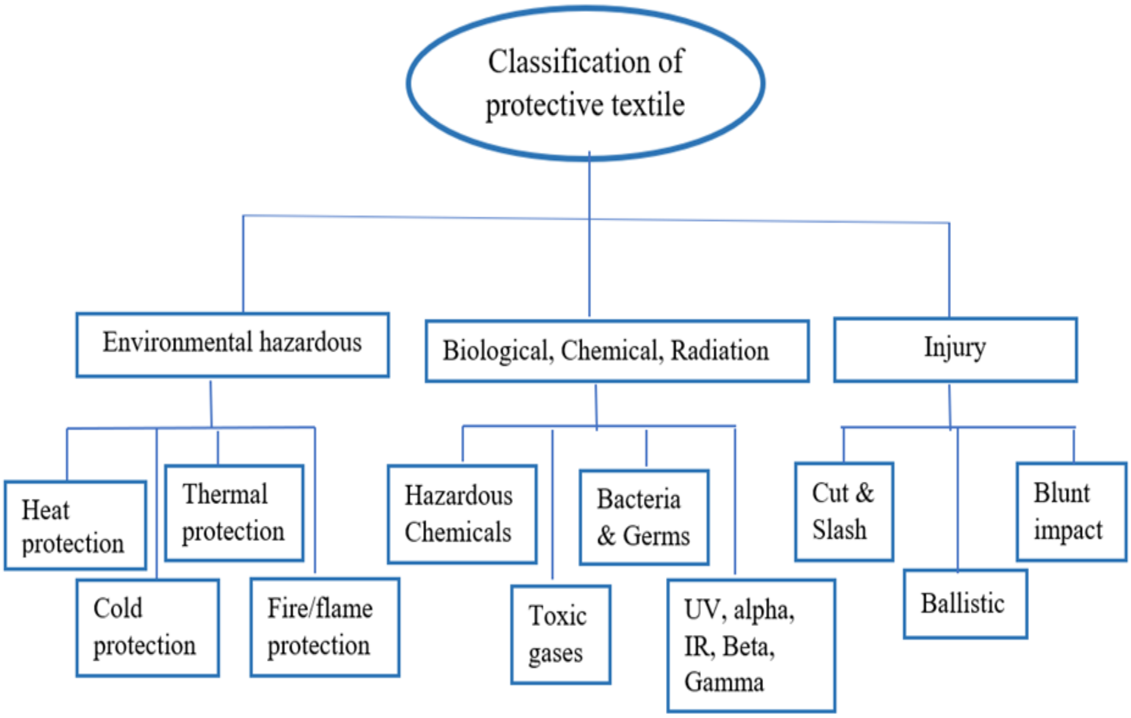
3. PROPERTIES OF PROTECTIVE TEXTILES:

Protective Textiles fabric has several unique characteristics. And this textile is used for its specific functions and features.

- Protech is a lightweight, highly durable textile fabric.
- This fabric has excellent drape and handle characteristics.

- This fabric is water and wind resistant, as well as cold temperature resistant.
- It is also resiatance to chemicals, micro0organisms and bacterias.
- Bulletproof and Ultraviolet resistant protective textile is available.

4. CLASSIFICATION OF PROTECTIVE TEXTILES:



4.1 HEAT PROTECTION

Heat-protective clothing is made up of two or more layers of textile materials, the most basic of which consists of three layers: first, a thin outer clothing cover material; second, a voluminous, soft heat-insulating material (which can be made up of several materials); and third, a thin material (back-cloth).

Heat-preserving materials (HPMs) are distinguished by their phase change properties. Heat is used to cause a phase change, which is frequently associated with the melting of the primary constituent substance. The substance solidifies again when the temperature effect on the main active HPM is reversed. These HPMs have a relatively high specific energy. HPMs of various types are widely used, including phase change materials (PCMs) embedded in the polymer matrix in dispersion form, as well as organic gels and hydrogels.[2]

Phase Change Material can help improve the heat protection of the clothing combination, contributing to a reduction in equipment weight and an improvement in wearing comfort. It was discovered that PCM has a positive effect on heat protection, but the efficiency of heat absorption is dependent on the location of the PCM layer and the intensity of the incident heat. Furthermore, because the PCM used was paraffin-based, its burning behaviour must be improved before it can be used commercially in firefighter protective clothing.[3]

4.2 FIRE/FLAME PROTECTIVE CLOTHING

The purpose of fire protective clothing is to protect the wearer from heat hazards such as flames, hot combustion gases, steam, hot objects, or any combination of these conditions. It must meet several requirements, including being flame resistant (FR), thermally insulating, and having good mechanical properties.[4]

The goal of fire-protective clothing is to slow the rate of heating of human skin so that the wearer has enough time to react and escape. To make clothing and textiles flame retardant, inherently flame-retardant materials such as Kevlar and Nomex, a flame-retardant finish, or a combination of these methods are commonly used to make flame retardant textiles.

Fig 1: Fire fighters Gear

4.3 FIRE RETARDANT FINISH:

The application of flame retardant chemicals to fabrics is intended to inhibit or suppress the combustion process. These fire retardants interfere with combustion at various stages of the process, such as heating, decomposition, ignition, and flame spread. A textile fabric exposed to a heat source, like any other matter, experiences a temperature rise. Pyrolytic decomposition of the fibre substrate occurs when the temperature of the fire source is high enough and the net rate of heat transfer to the fabric is high enough. Combustible gases, non-combustible gases, and carbonaceous char are among the by-products of this decomposition. The mixture ignites, resulting in a flame.

Chemicals can be applied to fabrics to create long-lasting flame retardants. Flame retardants on fabric can be applied via conventional padding, as well as padding with multiple dips and nips. It produces good results when followed by a 30 to 60 second dwell. The pH of the pad bath should be always kept around 5.0. The amount of flame retardant required is primarily determined by the fabric type, application conditions, and test criteria that must be met. To determine the minimum application level for a fabric, screening experiments should be carried out. Flame retardants are classified according to whether they contain bromine, chlorine, phosphorus, nitrogen, metals, or boron.

Flame retardants that are chlorinated (CFR) are Plastics, textiles, and electrical equipment all contain chlorinated flame retardants. Short-Chain chlorinated paraffins (SCCP) and Dechlorane Plus® are two examples of restricted CFRs. CFRs persist in the environment, raising concerns about the dangers these chemicals pose to public health. Based on high chlorine content Polyvinyl chloride can be used widely.

4.4 COLD PROTECTION

Clothing serves to shield the wearer from the natural elements. For civilians, the only requirement is protection against cold, whereas for military personnel and soldiers of other paramilitary forces, besides thermal insulation, a few other requirements are also important, such as protection against rain, snow, and extreme cold and wind conditions. Synthetic fibres, including acrylic and polyester fibres in various forms, were used to create cold-weather clothing. The material used to make cold weather protective clothing is chosen with the goal of minimising heat loss from the body to the environment, so that metabolic heat generated by the body is not lost to the environment and instead keeps the body warm. Simultaneously, the material should allow sweat to evaporate from the body and into the environment. Sweat accumulates on the skin and causes discomfort if the clothing prevents sweat from evaporating into the environment.[5]

Fig 2: Cold protective clothing

4.5 CHEMICAL & BIOLOGICAL PROTECTION

For specific applications, chemical and biological (CB) protective clothing is available in a variety of fabric materials. Chemical Fabric's Challenge Ultra Pro fabric system was used to create the suit. This is a multilayer laminated fabric system made up of five alternating layers of fluoropolymer [nonporous poly(tetrafluoroethylene) films] and Nomex nonwoven aramid fibre, as well as a conductive layer. Chemical contaminants such as organic liquids and vapours are effectively blocked by CBR protective fabrics. The fabrics can be impermeable, permeable, semipermeable, or selectively permeable. Selectively permeable materials have been developed as garment fabrics that provide effective chemical and biological agent protection while maintaining good moisture-transport properties at a lower weight and bulk than previous designs. Many HAZMAT (hazardous materials) suits are made of completely impermeable barrier-fabric laminates, such as Tyvek reinforced polypropylene film laminates with a rugged outer-shell fabric, such as aluminized Kevlar and polybenzobisoxazole (PBO), and are worn with butyl rubber gloves.[6]

4.6 RADIATION PROTECTION:

Radiation protection, also known as radiological protection, is defined as "The protection of people from harmful effects of exposure to ionising radiation. Exposure can occur from an external source of radiation or from internal irradiation caused by the ingestion of radioactive contamination. Ionizing radiation is widely used in industry and medicine, but it can pose a serious health risk by causing microscopic damage to living tissue.[7]

UV radiation is one of the leading causes of textile material degradation, which is caused by excitations in some parts of the polymer molecule and a gradual loss of integrity, depending on the nature of the fibres. UVR penetration in nylon causes photo oxidation, resulting in a decrease in elasticity, tensile strength, and a slight increase in crystallinity. Traditional fabrics have a lower cover factor than sun protective woven or knitted fabrics. Because the cover factor is expected to have a positive influence on UV radiation protection, researchers conducted regression analysis and discovered a positive coefficient of correlation between the cover factor of fabric and its UPF value. A primary determinant component of cover factor is fabric construction parameter (ends/inch & picks/inch or courses/inch & wales/inch). Because of the frequent interlacement of yarns, woven fabrics typically have a higher cover factor than knitted fabrics. Knitted fabrics have larger pores between the yarns than woven fabrics.[8]

Clothing is regarded as one of the most important sun protection tools. However, contrary to popular belief, some summer fabrics provide insufficient ultraviolet (UV) protection. The European Committee for Standardization (CEN) has created a new standard for sun-protective garment test methods and labelling. CEN/TC 248 WG14 'UV protective clothing' was established within CEN with the mission of producing standards on the UV-protective properties of textile materials. The first part of the standard (EN 13758-1) covers all aspects of test methods (for example, spectrophotometric measurements) for textile materials, while the second part (EN 13758-2) covers classification and marking of apparel textiles. UV-protective cloths claiming compliance with this standard must meet all stringent testing, classification, and marking instructions, including a UV protection factor (UPF) greater than 40 (UPF 40+), average UVA transmission of less than 5%, as specified in part 2 of the standard. If the garment complies with the standard, a pictogram bearing the standard number EN 13758-2 and a UPF of 40+ must be attached to it.[9]

4.7 BALLISTIC PROTECTION

Ballistic protection is a type of protective clothing designed to shield individuals from bullets and steel fragments fired by handheld weapons and exploding munitions. Due to a variety of properties that make these fibres ideal for ballistic protection, ultra-high modulus polyethylene (UHMPE) fibres produced by gel spinning have seen increased application in ballistic protection systems.[10]

Ballistic protective items are broadly classified as soft body armour or hard body armour based on their ability to absorb energy. Although hard body armour provides greater protection than soft armour, it is significantly heavier and less comfortable to wear. Wearers of hard body armour are unable to move their bodies flexibly. As a result, hard body armours only provide protection and not comfort. Personnel wear hard body armour when there is a high level of threat. Soft body armour, on the other hand, is preferred for everyday use because it provides adequate protection while also being more comfortable. Some commercial textile fibres are commonly used in ballistic protection applications. Among them, polyamide fibres such as Ballistic Nylon (Nylon 6-6); aramid fibres such as Kevlar (DuPont), Twaron (Teijin Twaron), Technora (Teijin); ultrahigh-modulus polyethene (UHMWPE) fibres such \sas Spectra (Honeywell), Dyneema (DSM and Toyobo), Fraglight (DSM); PBO fibre \ssuch as Zylon (Toyobo), carbon fibre, glass fibre, and ceramics fibre are most widely \sused. These high-performance textile fibres are used to create high-strength two-dimensional (2D) and three-dimensional (3D) fabrics with good impact resistance, which are widely used in ballistic applications.[11]

Fig 3: Bullet proof vest

5. FIBRES USED FOR PROTECTIVE CLOTHING:

S.NO	FIBRES	FUNCTIONS
1	para-aramid fibre	for added strength and ballistics
2	meta-aramid fibre	Which provides flame and heat resistance
3	Carbon fibre	High strength, high modulus, high temperature resistance, corrosion resistance, fatigue and creep resistance, electrical conductivity, and thermal conductivity are all characteristics of carbon fibre.
4	UHMWPE (ultra high tenacity polyethylene fibres)	Gel spun, ultra-high molecular weight polyethylene fibres with extremely high specific strength and modules, as well as high chemical and abrasion resistance.
5	PPS (polyphylene sulphide fibres)	Mechanical properties of crystalline thermoplastic fibres are similar to those of regular polyester fibres. Excellent resistance to heat and chemicals.
6	PEEK (Polyetherketone fibres)	A crystalline thermoplastic fibre with excellent heat and chemical resistance.
7	Novoloid fibres (cured phenol-aldhyde)	Non-melting, high flame resistance, and resistance to acids, solvents, steam, chemicals, and fuels. Excellent moisture retention and a soft hand.
8	PBO fibres	This fiber's strength and modules outperform all other known fibres.
9	Glass fibre	thermal insulation, electrical insulation, sound insulation, high-strength fabrics, or heat- and corrosion-resistant fabrics are among the applications for regular glass fibre.
10	Spandex fibre	Capable of being stretched repeatedly while retaining its original length. It is abrasion resistant. Rubber is weaker and less durable. Soft, smooth, and pliable.

5.1 FIBRES USED FOR HIGH-TEMPERATURE PROTECTIVE TEXTILE:

In high-temperature protective clothing or textiles, the following fibres are used:

1. Aramid (Meta & Para),

2. Glass,

3. PAN or carbon,

4. Phenolic,

5. PTFE,

6. PBI,

7. Polyamide,

8. Melamine,

9. Poly-Acrylate

6. DIFFERENT FABRIC FINISHES TECHNIQUES:

Coating and lamination are two functional processes used to finish textile materials properly. Coating formulations with various textile grade polymers such as PVC, PU, acrylic, and PTFE are widely used to create multipurpose textile products such as waterproof protective clothing, tarpaulin, protective clothing, electrical insulation, and so on. On the other hand, the lamination process is used to prepare some important textile products that we use on a daily basis, such as blackout curtains and blinds. Coating processes include knife-over-roll, knife-over-air, pad-dry-cure, gravure, dip coating, microencapsulation and transfer coating.[12]

6.1 PAD-DRY-CURE:

A pad-dry-cure procedure is the most commonly used application method for easy-care and long-lasting press finishes. Prior to the crosslinking reaction that occurs during the curing step in this process, the crosslinking reactant, catalyst, softener, and other components are dried on the fabric. The pad-dry-cure method involves immersing the fabric in a solution containing the functional chemical, drying, and finally "curing" to fix the finish within the fabric.

6.2 ROTARY SCREEN COATING:

This method is comparable to the rotary screen-printing process, which is used to apply coloured patterns to fabrics. The applicator is a cylindrical nickel screen with numerous perforated holes. The coating compound is fed into the screen's centre and forced through the holes by a doctor blade or a circular metal rod. The number of holes per unit area can be used to control the coating weight, and the coating weights are very precise. However, coatings that incorporate dots into a continuous coat must be used.[13]

6.3 TRANSFER COATING:

Transfer coating is a sequential coating process in which the coating material is first applied to and then dried on silicone release paper. With the coating layer facing the substrate surface, this coated silicone release paper was fed through the laminating rollers with the substrate. The coating layer bonds to the substrate due to the heat and pressure applied by the rollers and oven. The release paper is then peeled away, leaving a smooth or embossed coated surface as desired. Despite being more expensive than direct coating, transfer coating can be used on very delicate substrates because little or no tension is applied during the process. Another benefit is the low penetration, which reduces stiffness and produces flexible coated fabrics.[14]

6.4 FOAM COATING:

The most significant and intriguing development in the application of finishing agents to textile products in the mid-1970s was undoubtedly the use of foam. Because of rising energy costs in the textile industry, machines that can work with foams instead of aqueous solutions have been introduced. Foam is a microheterogeneous colloidal mixture, a metastable system in which the surface area of a liquid is increased nearly 1000 times by inflating it with a suitable gas (air), and thus contains less liquid. With the help of surfactants, foam is created by dispersing air in water as fine particles. When a surfactant is dissolved in aqueous solution and air bubbles are present, a surfactant film forms to cover the air bubbles. Air bubbles move towards the upper surface of the liquid which is covered with a tenside film. As a result, a second tenside film forms around the ascending air bubbles. As a result, the air bubble in which the liquid is located between the two tenside films surrounding it, known as a "foam cell," is formed. There are numerous foam application methods, including open foam methods , offset open foam methods and closed foam methods.[15]

6.5 NANO COATING:

In the textile industry, nanocoating is a relatively new technique. Polymeric nanocomposite coatings, in which nanoparticles are dispersed as polymeric media and used for coating applications, are a promising route to developing multifunctional and smart high performance textiles. Finishing techniques incorporating nanotechnology in the form of nanoemulsions enable a more intelligent application on textile surfaces. More importantly, nanotechnology-based finishing can provide high durability for fabrics because nanoparticles have a large surface area-to-volume ratio and high surface energy, offering better affinity for fabrics and increasing function durability.[16]

6.7 MICROENCAPSULATION:

Microencapsulation provides numerous opportunities to improve properties or add entirely new functionalities to textiles, garments, and apparel, resulting in increased usability and market value. Organic or inorganic fire retardants have been microencapsulated and applied to textile substrates to achieve long-lasting flame resistance. Microencapsulation has been used to prevent fire-retardant chemicals from exuding or sublimating, to avoid

reactions with textile polymers, and/or to overcome the substances' hydrophilicity. Firefighting and military protective clothing, as well as textiles for automotive and home interiors, are among the products available.

Microcapsules are not required in all functional textiles. Microencapsulation has been used to give textiles finishes and properties that would not be possible or cost effective with other technologies. When designing functional textiles with microcapsules, the performance of various basic resistances such as rubbing, light, washing, and wet- and dry cleaning that are standardised in the textile industry should be considered.

The resistance of the binder layer to washing, dry and wet cleaning, rubbing, and light affects the durability of the microcapsules and the functionality of the textile over its lifetime. It should be noted that the standards ISO 105-C01, ISO 105-C10, ISO 105-C06, ISO 6330, or AATCC TM61 cover all wash fastness properties in textiles. ISO 105-C01 is no longer valid and has been replaced by ISO 105-C10. Non-standardised test methods cannot provide a reliable insight into the actual behaviour of a functional textile during the care and wearing process, but they can provide a rough estimate.[17]

7. TESTING STANDARDS USED FOR PROPECTIVE TEXTILE:

S.NO	STANDARDS	TESTS
1	ASTM D2256, ISO2062	Single Yarn Strength
2	ISO 13934, ISO 13935, ISO 9073, ISO4606, ISO 1798 ASTM D76, ASTM D5034 / 5035, ASTM D2261 / D434 / D4964 / 5587 / D3936	Tensile strength
3	ASTM D1518, ISO 11092	Thermal Resistance
4	ASTM D737, ISO 9237/7231	Air Permeability
5	ISO8096, ASTM E96 BS 3424, BS 7209	Water Vapour Permeability
6	ASTM D4157 EN ISO 12945-2/12947-1/12947-2/12947-3/12947-4, ISO 20344, ASTM 4966/4970	Abrasion Test
7	ASTM D1230, FTMS191-5908	45-degree Flammability
8	ISO 3795, ASTM D5132	Horizontal Flammability
9	ASTM D6413	Vertical Flammability
10	ASTM D4018, ISO17492, ASTMF2703	Heating Resistance
11	ISO 4589-2, ASTM D2863	Oxygen Index
12	ISO11640, ISO 17700, EN344, EN 13516,	Rubbing Fastness
13	AATCC 61/86/132/151/190, ISO105	Washing Fastness
14	ASTM D6413	Flame resistance

8. CONCLUSION

The importance of personal protective clothing, its classification, fibres used, functional finish application techniques and testing standards are discussed in the review article. Even though a huge variety of personal protective clothing availability based on the need, the end user should know thorough information about what type of personal protective clothing, how to use in the working environment and how to maintain themselves. An awareness on providing correct of PPE and wearing personal protective clothing in hazardous workplace protects the business.

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