


Editorial

Advances in Protective Clothing Research Meeting the Challenges in the Changing World

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The world keeps changing, and the changes are becoming quicker with technological development. Quick changes also occur in societies and environments. This triggers emerging challenges and new risks, while the options to meet and eliminate these risks are being developed. The pandemic has tested out organizational measures but also made a strong contribution to developing emergency production solutions [1–3] and testing and certifying medical protection [4–7]. Climate change has created a higher pressure on sustainable production and products, including the advancing requirements in the PPE sector [8]. Here, one of the challenges is how to introduce sustainability while not compromising the protection of the user. The changes contribute to a potential increase in the physiological load on the user when effective protection has to be used in a warmer environment or when the exposures become longer due to the increased intensity and spread of the incidents, e.g., wildland fires where changing operational conditions also need the higher preparedness of support functions [9,10] and the possible reconsideration of tactics [11,12]. New materials are developed to make PPE more effective and lighter, while users' health and environmental impact information is acquired on the materials. These challenges were addressed at the 10th European Conference on Protective Clothing (ECPC2023) in Arnhem, in the Netherlands [13].

The conference focused on existing and potential future solutions, innovation in materials science [14,15], production [16,17], testing methodology [18,19], and using conventional materials in new combinations. All this supports new ways of thinking and paves the way for implementing new technologies for effective solutions while also having to consider sustainability demands [16,20,21]. There, legislation, supported by standardization, has made great strides [22], and the industry needs to keep up in order to remain competitive. At the same time, industries are often on the frontlines, driving development with the application of new business models, setting good standards, and providing examples of applicable solutions.

Due to quick changes, it is increasingly important to predict exposures, both changes in the environment and human responses [18,22,23], and find solutions for the detection of hazards and self-regulating systems that reduce harmful impacts on the users. Smart textiles, garments, wearables, etc. integrated into PPE elements and systems have been implemented [14,24], while coordination of these systems' functioning, logistics around their use, care, and maintenance [25], but also legislation related to responsibilities, data ownership, and security is not clearly settled yet.

Sustainability thinking around the product and system designs considering durability, repair, and maintenance options, possibilities for re-use, and finally, recycling at different levels of the safety products need more research, and the related user and exposure information needs to be available. Today, materials are often mixed to achieve superior properties



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that exceed those of standalone materials. New ways of combining and bonding these materials are needed to keep and advance the superior properties while allowing for the meeting of sustainability requirements throughout the whole life cycle of the product [20,21].

At the same time, new fabrics have to ensure protection and utility at the appropriate level, tailored to the intended environmental conditions of use. For this purpose, functional additives [16] as well as finishes [26] can be used. However, the aim to ensure relevant protection cannot cause additional harm to the user, either in the short-term or long-term perspective. In times of significant increases in cancer incidence, special attention needs to be paid to product safety for both the environment and for humans.

The functional and comfortable use of protective clothing is a key element for the successful implementation of preventive and protective measures at the workplace. Therefore, one must not forget ergonomic design and proper fit in PPE in order to avoid any unnecessary stress on the user [27–30]. Advancements in testing methods create new possibilities for the objective evaluation of PPE ergonomics [18]. Moreover, virtual evaluation and testing with thermal models are already useful tools [19,23,31].

In all this, the modeling and prediction of a material's performance, from fiber to yarn, textile, material combinations, garment items, and design up to the impact on human exposure with consideration of the physiological and psychological stress in specific user or incident scenarios become more and more important [32]. As people react differently and have different preferences, e.g., due to different body masses, sweating capacities, etc., then for any reliable advice, personalized input or calibration may be required. Such complex models become more difficult to handle, and therefore, it is advisable to seek support via big databases and artificial intelligence solutions [14,23,33]. Those, in turn, need material and human performance data, including epidemiological data, that can be collected using smart systems in our clothing and PPE systems that are able to monitor environmental and physiological parameters. Such information collection systems can be based on user preventive medical examinations, health and exposure monitoring procedures, and incident and near accident evaluations, with the reporting of all relevant parameters [34–36].

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