THE EFFECT OF AIR PERMEABILITY OF CHEMICAL PROTECTIVE CLOTHING MATERIAL ON CLOTHING VAPOUR RESISTANCE

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INTRODUCTION

One of the major problems associated with Chemical Warfare Protective Clothing (CW) is the additional heat load created by the garments. For CW-overgarments, research has been focused in the direction of reducing material thickness and thus heat and vapour resistance. Even though the thickness and the heat and vapour resistance of NBC clothing materials has been reduced by over 50% over the past decade, this has not resulted in major improvements in terms of heat strain for the wearer. The cause for this lack of effect is that the thickness and heat/vapour resistance of the complete clothing assembly is not only determined by the outer material layers, but is a factor of all clothing layers, including all enclosed and adjacent air layers. This total thickness, as well as the total heat and vapour resistance is hardly affected by a reduction in thickness of a single layer of the package.

A different approach, which so far has received only minimal attention, is the increase in air permeability of the garment materials. Such an increase could result in improved ventilation of the clothing micro-climate (especially during movement and in wind) and thus in reduced heat and vapour resistance. An obvious fear, which has limited interest in this approach, is the reduction in chemical protection, concomitant with increasing air Permeability. Thus the first question to be answered was whether air permeability of common CW protective garments could be improved, while sustaining appropriate levels of chemical protection.

Research on the effect of increased air permeability on CW-protection by TNO-PML has shown that for some types of CW-materials protection can be maintained at higher levels of air permeability than presently used. This opened the floor for investigations on the relation between air permeability and clothing heat and vapour resistance.

The present study was designed to study the effect of differences in air permeability of otherwise identical CW clothing materials on clothing vapour resistance, while the wearer performs different movements (standing still, walking) at different levels of air movement.

METHODS

Ventilation rate under the clothing was studied using a trace gas diffusion technique (Lotens and Havenith, 1988, Havenith et al, 1990). With this method, diluted argon is injected at the skin at numerous locations distributed over the body (except head, hands, feet). At similar locations, gas samples of the clothing microclimate air are taken. Both injected and sampled gasses are analyzed for their argon concentration using a mass spectrometer. The dilution factor of the gas in the clothing microclimate at the skin is a measure of clothing microclimate ventilation, and can be used to calculate clothing vapour resistance (Lotens and Havenith, 1988, Havenith et al, 1990).

These measurements were performed on three different CW protective suits with a variety of air permeability (L=low air permeability: 0.15 $cm \cdot s^{-1} \cdot mmH_2O^{-1}$; M=medium air permeability 1.89 $cm \cdot s^{-1} \cdot mmH_2O^{-1}$, H=high air permeability 4.87 $cm \cdot s^{-1} \cdot mmH_2O^{-1}$). The suits were very closely matched for stiffness and vapour permeabilities (measured on fabric samples) of the materials used and had identical designs. Only the outermost layer differed in air permeability. The suits used were typical overgarment CW suits and were worn over underwear and a standard Dutch combat suit. Three subjects wore all suits, in all combinations of wind (0., 0.5, 1.4, 5.0 $m \cdot s^{-1}$) and movement (walking speeds: 0., 0.5, 1.4 $m \cdot s^{-1}$). Measurements were analysed for the effects of air permeability, wind and walking speed on vapour resistance using the statistical package SYSTAT.

RESULTS

The results of the measurements are presented in Figure 1. For zero walking speed, we can observe that in this standing situation for all levels of air movement, a difference in vapour resistance related to the suits air permeability exists. Further, from this figure it is evident that both wind and movement had a vast effect on the vapour resistance of the clothing ensemble. In the absence of wind, walking decreases vapour resistance (1a), but also eliminates the differences between the suits which were present while standing still. This is also the case for the low (0.5 $m \cdot s^{-1}$) wind speed. At the higher wind speeds, the suits are separated for both standing and walking, according to their air permeabilities.

DISCUSSION

In the absence of wind and movement a difference in air permeability between suits resulted in a difference in vapour permeability. As the suits used were identical in thickness (same underwear, same battle dress, same foam layer), as well as stiffness (same foam layer) and only differed in the air permeability of the outermost fabric layer, this was not completely expected. Differences were expected for conditions in which air movement through the fabric would play a major role. Differences were

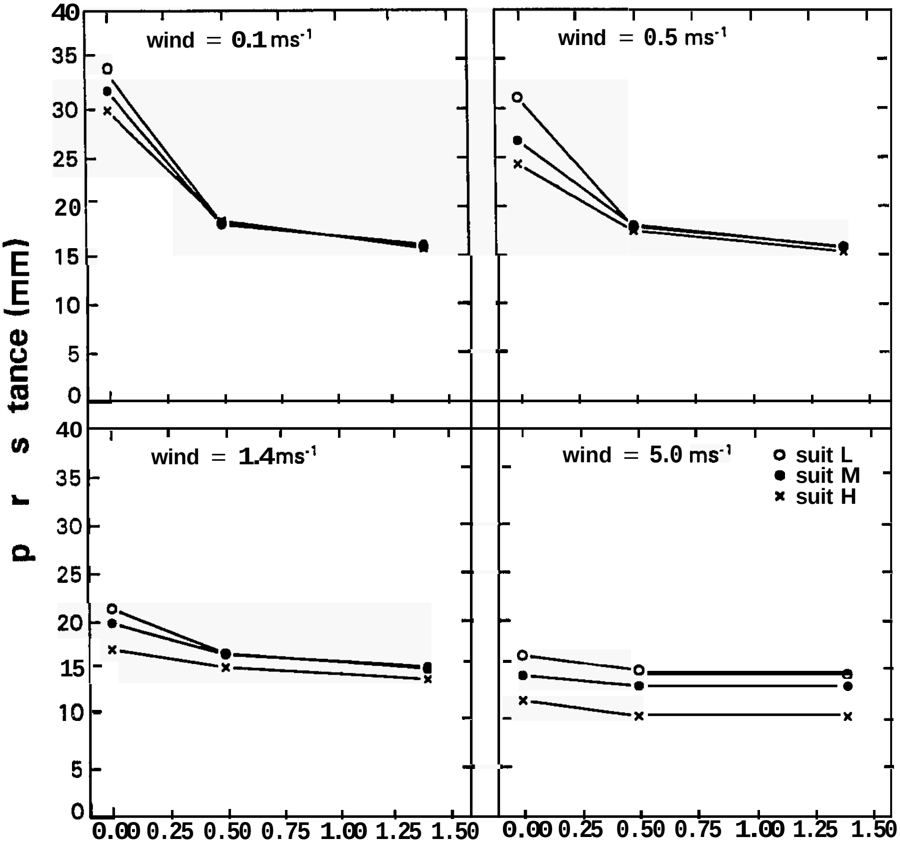

Figure 1, Vapour resistance of three CW protective suits, differing in outer layer air permeability, in relation to walking speed and wind speed.

significant however and were consistent with the differences in air permeability of the suits. Differences were larger than would be expected based on the static vapour resistance difference between materials. Thus even while standing still, with no wind, sufficient air movement through the garments must have been present to result in the observed effect.

When subjects start to walk, the initial difference in vapour resistance disappears. The pumping effect which takes place under the garment apparently is not affected by the air permeability of the outer garment. Low wind speeds (0.5 $m \cdot s^{-1}$) do reduce vapour resistance as expected (Havenith et al, 1990), but do not interact with air permeability. At higher wind speeds (>1.4 $m \cdot s^{-1}$) a significant difference in vapour resistance, inversely related to air permeability starts to show. Thus the penetration of the garments by wind is affected by outer layer air permeability. At high wind speeds, the additional effect of movement more or less disappears. Apparently, microclimate air layers are disturbed in such a manner that the additional pumping effect due to movement does not add to the disturbance.

Considering the results, it is possible to answer the question as to whether an increase in air permeability of CW protective garments (with sufficient protection!), may have an effect on the wearer's heat strain by an effect on the clothing heat and vapour resistance. **A** substantial decrease in vapour resistance for the resting situation as well as for wind exposure was observed. Considering the relation between heat and vapour resistance, present in permeable materials (Havenith et al, 1990), also a reduction in clothing heat resistance may be expected. Combining these two, and looking at the magnitude of the reduction in vapour resistance, a considerable reduction in heat strain is thus indeed expected when air permeability is increased while other material characteristics remain equal.

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