CHEMICAL PROTECTIVE SUITS WITH CARBON SPHERICAL ADSORBERS; REDUCTION OF HEAT STRESS?

K. J. Glitz, U. Schröder, U. Seibel and W. v. Restorff
Clothing Physiology Group
Ernst-Rodenwaldt-Institut
PO Box 7340, 56065 Koblenz, Germany

INTRODUCTION

Many chemical protective suits contain a layer of charcoal impregnated foam for adsorption. They impose significant heat stress on wearers resulting in discomfort, performance decrement and possibly heat illness [1]. Recently, new chemical protective suits have been developped with carbon spherical adsorbers. They possess better physical attributes concerning thermal and water vapour resistance.
Can these new chemical protective suits effectively reduce the wearer's heat stress?

METHODS

10 male volunteers (20.4 ± 1.3 yrs., 179.0 ± 7.8 cm, 77.8 ± 12.9 kg) worked on a treadmill (2 x 30 min, 4 kmh^{-1} & 4.5-5.5 kmh^{-1}, 5 % incline, 18 °C, 50 % r.h., 0.2 ms^{-1} air velocity) after informed consent was obtained. The subjects wore chemical protective suits with charcoal impregnated foam layer (PU) or suits with carbon spherical adsorbers (cotton with spherical adsorbers, ø 0.35 mm, covered with PU) in random sequence. Underneath they wore work clothes (underwear with short sleeves and legs, shirt, trousers, socks and boots; I_{Cl} = 0.7 clo).
Only work clothes were worn as control to which the weight of the protective suits (2400 g sand in 6 pouches in the pockets) was added. In all test conditions the volunteers wore a spirometric face mask instead of a protective mask.
Heart rate (ECG), V_{O2} (open spirometric system), external auditory canal temperature (modified YSI 4499E), mean skin temperature [2] (YSI 4499E) and microclimate in the clothing (temp., r.h.) were measured. Sweat volume was obtained by weighing the volunteers before and after the test, sweat evaporation was calculated from total weight loss and weight gains in the clothing. The volunteers self perceived stress, heat and sweat sensations were ascertained.

RESULTS

The average metabolic rate according to walking speed was 520 Watt or 730 Watt, respectively, without differences between the test conditions.
In contrast, at the end of work heart rate (Fig.) was significantly higher in volunteers wearing the charcoal impregnated foam layer suit or the carbon spherical adsorber suit (147 min^{-1} and 141 min^{-1}, respectively) as compared to control conditions (127 min^{-1}).
Maximal external auditory canal temperature was nearly similar (37.8 °C and 38.0 °C, resp., 5 minutes after work) with both chemical protective suits whereas the external auditory canal temperature in the control test maximally reached 37.3 °C at the end of work.
At the end of work mean skin temperature was up to 2.4 °C higher with charcoal impregnated foam layer suit and up to 2.0 °C higher with the carbon spherical adsorber suit as compared to control.
The changes in microclimate partial vapour pressure in both protective suits were identical. Compared to control they rose five minutes earlier and reached a higher level (5.0 kPa vs. 4.5 kPa). Total sweat volume was 534 g with charcoal impregnated foam layer suit and 384 g with carbon spherical adsorber suit, but only 258 g in the control test. Sweat evaporation with either chemical protective suit was similar (50% and 54%, resp.) but 80% in the control test.
These results were matched by the self perceived stress, heat and sweat sensations, which were nearly the same in either suit but markedly less in the control test.

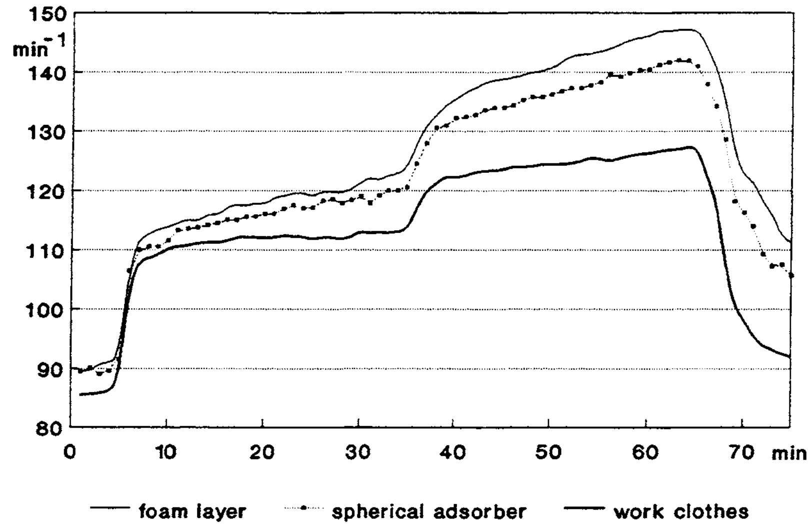

Fig. : Mean heart rates of ten subjects on a treadmill at two different speeds wearing chemical protective suits or work clothes with added weights. Abscissa is time: 5 min standing, followed by 2 x 30 min marching at 4 kmh^{-1} & 4.5-5.5 kmh^{-1}, 5 % incline, and 10 min recovery

CONCLUSIONS

Carbon spherical adsorbers in a chemical protective suit offer physiological advantages over charcoal impregnated foam layers. However, there still remains a significant heat stress wearing the new chemical protective suit compared to control conditions, resulting in discomfort, in performance decrement and possibly in heat illness.

Our study points out the importance of applying clothing physiology because physical attributes alone (thermal and water vapour resistance) often incompletely describe the effects of clothing on human thermoregulation. During the development of a new garment different (physical, biophysical and physiological) investigations are necessary. A proved approach is the five-level system [3] with a skin modell, a thermal manikin, investigation of volunteers in a climatic chamber and two levels of field tests.

REFERENCES

1. Glitz, K.J., Schröder, U., Seibel, U. and v.Restorff, W. 1992, Auch in permeablen Schutzanzügen aus einem Filterschaummaterial entsteht ein Wärmestau, in R. Kreutz and C. Piekarski (eds.) Verhandlungen der Deutschen Gesellschaft für Arbeitsmedizin e.V., 32. Jahrestagung in Köln (Genter Verlag, Stuttgart), 281-285.

2. Ramanathan, N.L 1964, A new weighting system for mean surface temperature of the human body, J.Appl.Physiol. 19(3), 531-533.

3. Umbach, K.H. 1988, Physiological tests and evaluation models for the optimization of the performance of protective clothing, in I.B. Mekjavic, E.W. Banister and J.B. Morrison (eds.) Environmental ergonomics. Sustaining human performance in harsh environments (Taylor & Francis, Philadelphia, New York, London), 139-161.