Combined Protection and Ergonomics testing of Chemical-Biological protective Equipment.

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INTRODUCTION

In the area of personal protection against chemical and biological (CB) agents there is a strong focus on testing the materials against the relevant threats. The testing programs in this area are elaborate and are aimed to guarantee that the material protects according to specifications. This ensures that the protective clothing and respiratory protection that is out on the market consist of the best material for that purpose. However, protective clothing and respiratory protective devices in practice are worn as a system that is a 3D structure that is subject to different environmental conditions, movement and mechanical tear and wear. In the last few years test methods at system level (Whole System Tests [WST] or Battlefield Protection factor [BFPF]), have been developed to address these issues and provide information on the protective performance of clothing and gasmasks, in addition to the protection of the materials. These tests provide crucial insight in the design of protective equipment and its effect on overall protection to the wearer. Ergonomics testing of CB protective equipment has always been performed separately from the protection tests. Most recent developments are aimed at integrating ergonomics type tests in to WST protection to be able to evaluate the protective performance of CB protective equipment and respiratory protection in operational environments. In this development the WSTs should reflect relevant practical working conditions and possibly should extend to actual measurement of protection at the working place. In this paper the developments and challenges on these types of tests will be addressed.

METHODS

The combined protective and ergonomics testing of CB protective equipment is based on the WST methods that are available. These tests can roughly be grouped into two groups, respiratory protection and skin protection.

Respiratory Protection

In the area of respiratory protection the WST method that has been developed is the " Battle Field Protection Factor" test. Basically in this test the level of protection of a respiratory protective device can be measured on a person during various (working) activities. The basic system consists of two Portacounts, portable particle counters, which are carried in a backpack, measuring the number of particles inside the mask and in the environment. The Portacounts determine the concentration of small size particles by sampling the air. The protection factor (PF) is determined by:

$$PF = \frac{concentration \circ in \circ environment}{concentration \circ under \circ mask}. \qquad (1)$$

Both concentrations are determined every second, the sampling inside the mask is taken via the drinking tube (of soms via zelf gemaakte connectie als er geen drinkfaciliteit aanwezig is); the system has no impact on breathing resistances.

When tests with human subjects are performed for the military a 'Standardized Military Protocol' (SMP) is used, see Table 1. This SMP consists of relevant practical tasks that can be tested in the lab according to EN standards, with additional tests that are relevant to practical working conditions in the field. Each activity is followed by a brief rest period.

Table 1: The Standard Military Protocol (SMP)

#	Activity	Duration in minutes
1	Rest	2
2	Nodding 'Yes'	1
3	Rest	1
4	Shaking 'No'	1
5	Rest	1
6	Walking (approx. 3.5 km/hr)	2
7	Rest	1
8	'Digging'	2
9	Rest	1
10	Crawling on hands and knees	1
11	Rest	1
12	Running (approx. 5 km/hr)	2
13	Rest	2
14	Taking cover (3 times)	1
15	Rest	1
16	'Tiger crawl'	1
17	Rest	2
18	Jumping (3 times)	1
19	Rest	1
20	Carry water	1
21	Rest	1
22	Lifting weights (3 times)	1

Skin Protection

In the past the protective performance of the Dutch NBC protective clothing against Vapor has been studied using an articulated manikin. Separately the ergonomics tests were performed on human subjects. These tests lacked information on the protective performance of the clothing during working conditions under an actual challenge. In other words: the performance and protection should be measured simultaneously. For this a method is under development

The manikin test on skin protection focused on the protection against vapors, using a simulant for a chemical warfare agent: Methyl Salycilate (MeS). As currently no valid (on line) detectors/ sensors exist for MeS at these low concentrations, the vapor needs to be collected under the clothing with passive adsorbing dosimeters, filled with Tenax (PAD's or "Natick" samplers). The basics of the method are the same as that with the manikin, a test chamber is filled with the MeS vapor and the subjects can perform activities in the chamber. A number of protocols exist on this Man-In-Simulate-Test (MIST) setup. A very relevant issue in this test is the movements and activities that need to be carried out by the subjects. In the basic test the subjects only need

to walk. In more elaborate tests other movements, more challenging to the suit, are used [TOP-0-2-22]. In the current setup of the MIST protocol only the protection of the suit during the entire procedure can be measured. Unlike the Battle Field Protection Factor in respiratory protection it is not yet possible to measure the protection on line and per activity.

RESULTS

Respiratory Protection

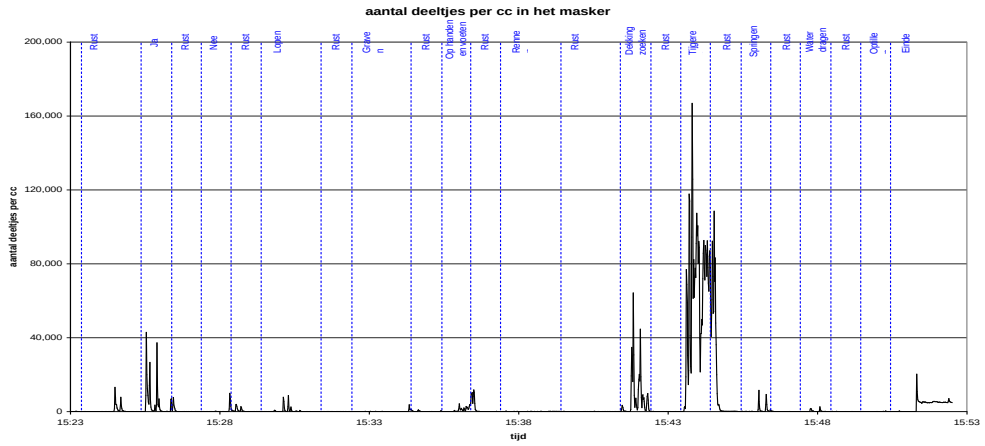

Figure 1: The number of particles per cm^3 under the mask, measured during a SMP. Data reproduced from internal test report, TNO, 2006.

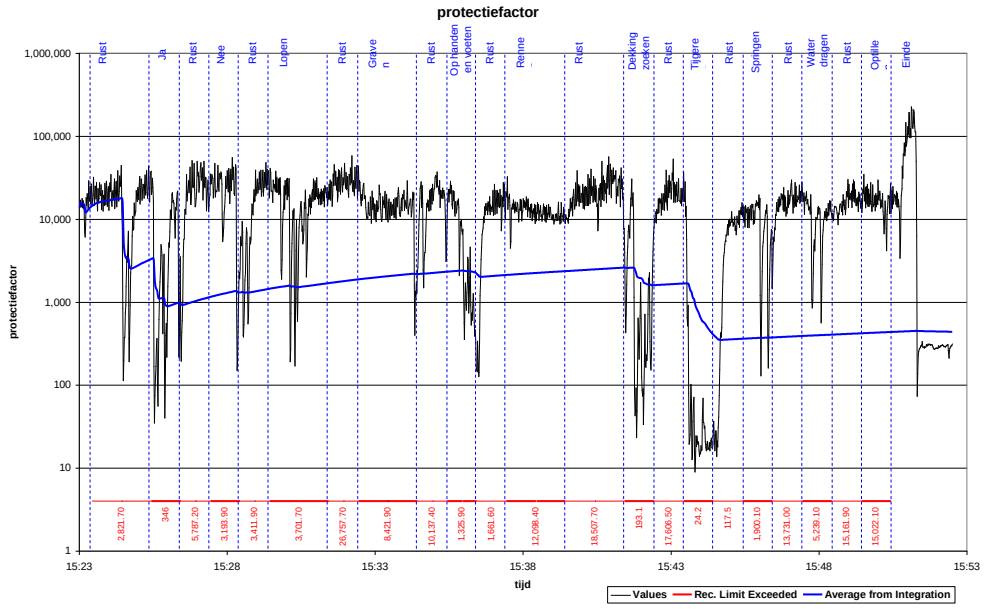

Figure 2: The protection factor of the same mask as in figure 1, computed from the same data. Data reproduced from internal test report, TNO, 2006. Note the Logarithmic scale of the y-axis.

Skin Protection

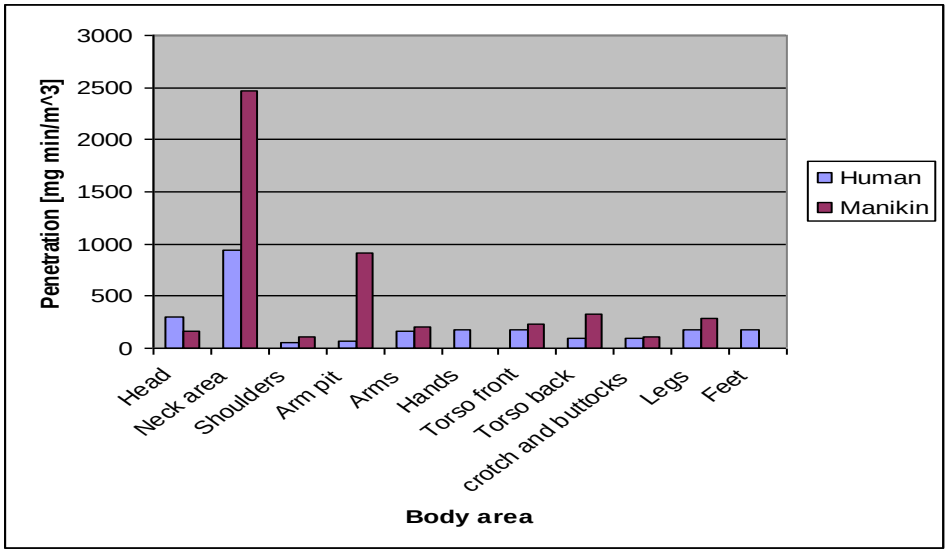

Figure 3: To standardized dose normalized penetration of MeS through the tested suit, wind speed 1 m/s. Data reproduced from internal test report, TNO, 2006.

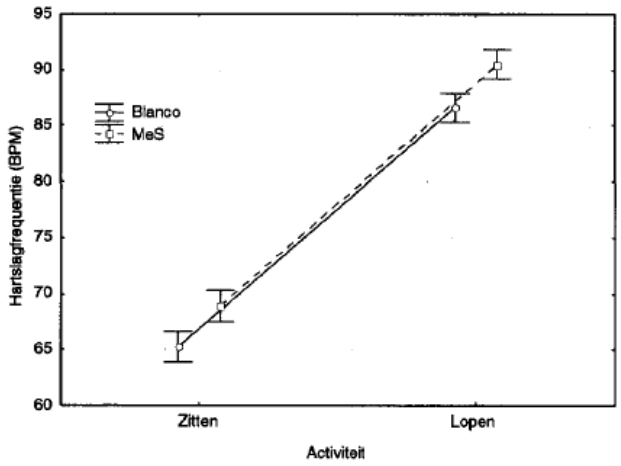

Figure 4: Effect of using MeS during the test on the heart rate during sitting ('Zitten') and Walking ('Lopen'). Data reproduced from internal test report, TNO, 2006.

DISCUSSION

The need for measurements of protection during relevant conditions, similar to working, is shown in the results of Figure 2.It is shown that the protection drastically drops during different types of movement. This shows the relevance of these types of tests during relevant activities. Although in the US there exists the requirement to fit the respiratory device at the working place, measuring the level of protection during actual working activities is of additional value.

The current system allows the protection to be measured during many activities, but has been limited to gasmasks, possibly with a blower. Recently, this system has been adapted to determine the Field Protection Factor with SCBA systems. This requires extra particle filters as the air from

the air bottles contains particles and the pressure valve systems also tend to generate particles which would be counted as leaks if not taken properly into account.
Overall the current system allows for very high protection factors in practice to be determined, however if one wants to determine protection factors of 100.000 up to a million or even more, workplace protection factors should be obtained in a confined space like a tent or room in a building in which high levels of particle concentrations can be generated.
The WST and MIST setups do allow the protection of clothing systems to be determined on humans while wearing the clothing system. This is a big step forward compared to testing clothing materials only. The experience with the tests has been that the results from human subject tests tend to be more reliable than those from the manikin. This is most probably due to the fact that the clothing can be fitted much better to humans than to a manikin. In testing the protection any leaks greatly affect the results, and the clothing can be closed much tighter to the human skin than to a manikin, reducing leakage and improve reproducibility. Therefore, currently human subject tests are considered more useful than the manikin tests. Improving standard methods of donning and doffing clothing may improve on these results, but the variation between different clothing systems and their closures may remain a complicating factor. Activity protocols are not always standardized internationally, and protocols that do exist, such as the SMP, are not always relevant for other groups wearing protective clothing.
A useful new development would be to allow the determination of the protection factor during different activities, per activity, similar to the respiratory protection. TNO is working on the development of such a system, but no data are available yet. Complicating factor here is the absence of reliable, selective and sensitive MeS detectors or sensors, forcing the use of sample collection tubes. Also, the current test determines the protection against a relatively specific challenge as a simulant for distilled mustard (HD) as chemical warfare agent. The test does not provide information on protection against aerosols. A separate test set-up for a WST on aerosols is now available.

The use of MeS does not induce extra physiological load and is safe. Combined testing at system level of protection, ergonomics and physiological load provides better insight in the protection of workers at their working place. Additionally the tests should be improved to allow protection testing during separate activities. Also standardized activity protocols should be further developed to use subsets of these activities for testing protective suits for a wide range of applications, such as military, police, fire fighters and many different workers in industry. Developing these tests and testing protective systems accordingly contributes to improving health and safety at the working place.

REFERENCE

Test Operations Procedure (TOP) 10-2-022, Man/Manikin In Simulant Testing (MIST) (Chemical Testing of Protective-Clothing Ensembles), U.S. Army Test and Evaluation Command (TECOM), Aberdeen Proving Ground (APG), Maryland, 30 April 1992.