Ergonomic and Comfort Factors as part of a Selection System for Respiratory Protective Equipment

Goede HA, Brouwer DH and Tijssen SCHA [1]

Introduction

It is generally assumed that the 'overall' effectiveness of personal protective equipment (PPE) is determined by the 'technical' protection provided, as well as the conditions of use in the workplace. During Technical Meetings at the European Chemicals Bureau (ECB) two key issues related to PPE and exposure to chemicals were identified, i.e. proper functioning and proper use (Doc. ECB4/32/98). *Proper functioning* implies that the PPE have to be evaluated on basis of its 'effect', thus the ability to remove airborne agents and thereby reducing exposure. Chemical protection is determined by an assessment of the toxicological properties of the substance, the exposure level of the chemical and the protection factor of a respirator. Protection factors are assigned to various respirator designs based on field studies that have been conducted to assess workplace protection factors (WPF), as reflected in the ANSI and BSI standards [ANSI, 1992; BSI, 1997]. The chemical protection effectiveness of respirators can then be evaluated by using the protection factors assigned to different RPE. An example of such a selection system is described in a recent guideline of the Dutch Occupational Hygiene Society (NvvA), 'Selection and use of respiratory protective equipment' [NVvA, 2001].

In addition, *proper use* criteria are vital to ensure that PPE is both 'suitable' and 'fitting' for a given work task. In the past the emphasis was often placed on the 'effectivity' during the PPE selection process, and little attention has been given to the ergonomic and comfort aspects associated with the wearing of PPE. Until now, a systematic approach to incorporate ergonomic and comfort aspects into a selection system is lacking.

The apparent hiatus in the selection of respiratory protective equipment (RPE) lead to an initiative to develop a selection system [Goede *et al.*, 2001]. The aim is therefore to initiate a systematic approach to incorporate ergonomic and comfort factors into a RPE selection system, and to optimise the protection of a specific worker during different working conditions.

[1] *Dept. of Chemical Exposure Assessment, TNO Chemistry, The Netherlands, e-mail: goede@chemie.tno.nl*

Methodology

The starting point for a systematic approach is the assumption that limitations on task performance and worker comfort are inherent to the wearing of respirators. Respirators are therefore evaluated by comparing the use of respirators with a zero-situation (no RPE scenario). In this way we can determine which respirator(s) are the least uncomfortable and the most compatible with a specific task.
The following criteria are considered relevant for the actual selection of the most appropriate RPE:
- task: which work tasks are expected from the worker, and what are the requirements in terms of the field of vision, the communication, etc?
- work environment: under which environmental conditions must the task be performed?
- worker: this category includes personal aspects such as specific visage characteristics, allergies or the use of glasses or contact lenses.

The selection strategy applies the above criteria to systematically select respirators in two consecutive steps: (1) *ergo-comfort selection* to determine the suitability of respirators for a given work situation, and (2) *personal fitting selection* to establish how fitting a given respirator is (or tailored to the wearer in question); this involves a field-test and try-out in practice.

An attempt was made to convert the requirements of the work task, work environment and worker into objective evaluation points. For an ergo-comfort selection, all the reported factors obtained from literature studies were categorised and clustered under seven main categories (e.g. vision, communication) (table 1). A distinction was made between the relevance of each ergo-comfort factor for the 'work situation' and the 'features of the respirator'. A simple scoring and weighing system has been devised to prioritise respirators based on their suitability for ergonomic and comfort aspects. The scoring system attaches values (on a log-scale) to the "work situation" and "respirator performance" components of the system.

This methodology can only be applied when the risk-based aspects of wearing a respirator has been dealt with, e.g. the maximum continuous wearing time versus the length of time the device provides protection, or the work rate (amount of inhaled air per time unit) versus the breathing resistance of the device.

Selection system

A brief description of each step in the selection system is given below.

Ergo-comfort selection

Table 1 shows the main categories of (ergo-comfort) factors that are relevant for the evaluation of the work situation and the performance of respirators. In some instances, an ergo-comfort factor can be evaluated quantitatively with respect to the respirator feature e.g. the percentage effective visual field [Baak *et al.*, 1990], and mostly qualitatively when assessing the work situation, e.g. the visual field required by the work. By linking the 'respirator performance' with the 'work situation', the level of compatibility of the RPE and the work situation can be determined.
Work situation (WS) and respirator performance (PS) are expressed in terms of three classification bands respectively, and allocated with a score in steps of a log-scale. The work situation (WS) is expressed as low (1), medium (3) and high priority (10), in reply to the question: "how relevant is this factor in the given work situation?". In analogy to the "work situation score", the "respirator performance score" is expressed in terms of it's suitability, i.e. 1 (severe hindrance), 3 (moderate hindrance), 10 (slight or no hindrance). For each classification band, specific criteria had to be proposed for a given factor, e.g. > 90 % of the effective field of vision = score 10 (slight or no hindrance). In this early developmental

Table 1 Principal categories of ergo-comfort factors and examples of the related factors

Main category	Example of factors
Vision	Visual field
	Visual acuity
Communication	Audibility of user's speech
	User's hearing
Respiration	In- / exhalation
	CO_2 retention
Physical task performance	Mobility
	Dexterity / stability / precision
	Body posture
Environment	Heat / cold extremes
	Other hazards
Comfort	Overall fit (skin, eyes, head)
	Put-on, removal
	Combination with other PPE
Mental	Responsibility, stress

Table 2 Overview of scoring and weighing method

Factor	Work situation classification	Work situation score (WS)	Respirator performance classification	Respirator performance score (PS)	End-score
i	High priority	10	Slight or no hindrance	10	PS –WS
	Medium priority	3	Moderate hindrance	3	
	Low priority	1	Severe hindrance	1	
j	High priority	10	Slight or no hindrance	10	PS –WS
	Medium priority	3	Moderate hindrance	3	
	Low priority	1	Severe hindrance	1	
*Total**					$\sum_{i,j} / n$

* *Total score is subject to correction weighting for each main category*

phase of the selection system, the intention was to initially focus on variables that can be measured quantitatively and be supported with scientific evidence.

Estimation of the suitability of respirators is determined by calculating an end-score by subtracting the WS score from the PS score for each type of respirator. Table 2 gives an overview of the scoring principles applied for the selection system. Our basic starting point is the assumption that the "wearing of respirators" will always result in some degree of hindrance. This means that the performance of respirators is stressed and that respirators with an insufficient performance (PS=1, severe hindrance) will only be suitable if the ergo-comfort aspect does not affect the work situation (WS = 1, low priority). The end-score indicates the suitability of the respirator (0 score or higher), or the degree of unsuitability (negative score). Respirators with an end-score of 0 or higher are assumed to have a negligible influence on the execution of the task. Positive scores are converted to 0 to simplify the processing of scores and prioritisation of respirators.
An average score is calculated for each main category. As this formulae assumes that all categories are equally relevant, a correction factor is applied to increase the relevance of a given category, e.g. an increased weighting for "vision" can be introduced for detailed and high precision work.

Personal fitting selection

In order to address the subjective perceptual component of comfort into the system, the last evaluation step is performed to ensure that the 'proper fit' of respirators is attained to. For this part of the system the emphasis is directed to *(or: focused on)* the individual user and limitations of a personal nature, e.g. a beard, latex allergies or phobias, but also the overall comfort of different types of respirators. The translation of specific respirator features (e.g. latex components) into different RPE-types is, at this stage, of importance because the material specifications and designs per product may differ considerably. As a final component of the system, it is recommended to give the users an opportunity for a try-out of the RPE-type during an actual trial-run. A fit-test may form part of this field test. The concept 'fitting' can only be realised in full in this phase of the selection system.

Conclusion and future developments

The system presented here forms an initiative to integrate ergonomic and comfort aspects into a RPE selection system. The actual translation and quantification of the 'work situation' and the 'respirator performance' for each ergo-comfort factor depends on scientific evidence, and this has to be worked out in more detail. It is, however, evident that the availability of data (e.g. technical data on RPE) is sometimes limited and that this could be problematic for further developmental work. Future developments will therefore be dependent on extended research and tests of RPE in general. Another challenge is the development of justifiable classification bands for each ergo-comfort factor. A limitation of the system remains the actual assessment of the 'work situation', since this is mostly determined qualitatively, in simple terms and with often a subjective aspect attached to it.
An important aspect to keep in mind during the system development is the factor 'time', because the perception of comfort is largely dependent on the duration of use of protective equipment. In addition, the scoring principles can be further refined and a try-out of the system in practice is obviously suggested.
A recent study developed for hand protection adopts a similar approach, and our intentions are to develop these concurrently in future projects.

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