ASSESSMENT OF THE EFFICIENCY OF PERSONAL PROTECTIVE EQUIPMENT AGAINST PARTICLES FOR USE IN RADIOACTIVE AND CHEMICAL CONTAMINATED ENVIRONMENT - RECENT IPSN/BIA CONTRIBUTION

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Abstract

In all industrialized countries, important studies have been accomplished with the aim of improving the personal protective equipment (PPE) performances, i. e. of minimizing the exposure to hazardous environment and other risks for workers attending to operate in a contaminated area and, at the same time, to increase their physiological comfort.

In the same field, IPSN, in collaboration with other European laboratories (BIA, IOM), has achieved in the last four years, an important research program, in order:

- to determine the efficiency of protection of the different categories of PPE,
- to improve the design and to develop new material of construction of special type of PPE (e.g. ventilated-pressurized protective clothing, ventilated hoods,...),
- to optimize the time of use during routine operation or emergency situations, by considering both technical performances and physiological aspects such as heat constraints and health effects.

After a brief review of the main characteristics required for the different categories of PPE, in this communication, one presents the directions of research which were preferred in order to achieve the objectives specified here above. Then, one concludes with a review of the instructions of use, maintenance and wearer training, which are the essential factors to be considered by every responsible of operational health of the employers in nuclear or chemical facilities, in relationship with the PPE management program.

1 - PERFORMANCE LEVELS OF THE DIFFERENT CATEGORIES OF PPE

In order to evaluate the level of protection offered by a particular PPE, the following definitions are used:

- **Nominal Protection Factor (NPF)**

  It is the ratio of the average concentrations of contaminant measured in the ambient atmosphere and inside the PPE, at the point where the wearer draws breath. The concentrations taken into account are the average concentrations recorded during a standardized test.

  \[
  \text{NPF} = \frac{C_{\text{ambient}}}{C_{\text{inhaled}}}
  \]

- **Permeance or Total Inward Leakage (TIL)**

  This quantity corresponds to the reciprocal value of the NPF. It is expressed in %.

  \[
  \text{TIL} = \frac{1}{\text{NPF}}
  \]

According to these definitions and as usually admitted in the literature [1], [2], the efficiency of the different categories of PPE can be classified in accordance with table 1.

<table>
<thead>
<tr>
<th>Categories of PPE / Definitions</th>
<th>Range of Nominal Protection Factor</th>
<th>Range of average leakage into the PPE (in %) during standardized test (Permeance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilated-pressurized protective clothing (Air feed impermeable suit)</td>
<td>10 000 - 100 000</td>
<td>0.001 - 0.01</td>
</tr>
<tr>
<td>Ventilated hood (Air feed impermeable hood)</td>
<td>5 000 - 50 000</td>
<td>0.002 - 0.02</td>
</tr>
<tr>
<td>Filter type respirator (Full face mask with filter)</td>
<td>2 000 - 10 000</td>
<td>0.01 - 0.05</td>
</tr>
<tr>
<td>Non ventilated protective clothing (Blouse or impermeable suit)</td>
<td>2 - 20</td>
<td>5 - 50</td>
</tr>
</tbody>
</table>

Table 1: Efficiency of different categories of PPE
2 - MAIN RESEARCH DIRECTIONS

2.1 - Ventilated-pressurized protective clothing or hoods

- Improvement of the protection factor

For air feed protective clothing the protection factor level mainly depends on:

- the **static leaktightness**, which is essentially dependant on the intrinsic tightness of the clothing during normal working conditions; the studies have been focused on the improvement of the welding or seams and fasteners quality.

- the **dynamic leaktightness**, which is essentially dependant on the efficiency of the exhaust device(s) and on the aeratic performances of the protective equipment.

Concerning this last field, both investigations have permit to increase namely the NPFs by a factor of 4 (i.e. from 20,000 to 80,000) by developing special high efficiency exhaust devices, and by increasing the internal air flow rate inside the equipment (see figures 1 and 2).

- **Improvement of physiological comfort** (new concept of ventilation of suits)

In cooperation with occupational physicians, these studies were carried out in order to elaborate a system of "direct skin on body ventilation", which allows a better thermal regulation of the wearers, particularly in case of intervention in hot environments.

The results have proved that, for the same ventilation rate and the same physical work rate, the acceptability duration may be improved by 50% by means of the refreshing due to the direct skin ventilation, in comparison with the traditional clothing in which the ventilation is fed into the suit, i.e. only over the underwear.

- **Studies concerning new material of construction of PPE**

In addition with efficiency against particle penetration, design of PPE must comply with other typical requirements, such as mechanical resistance, flexibility, flammability behaviour, suitability to disposal (by incineration), gas permeation, etc. Table 2 hereafter presents the compared performance of principal materials, replacing PVC, which has been so far the most common one.

<table>
<thead>
<tr>
<th>Material/Standard</th>
<th>Low cost</th>
<th>Non insensible (36%)</th>
<th>High cost</th>
<th>Difficult to weld</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC (standard or non flammable)</td>
<td>Inertable</td>
<td>Non flammable</td>
<td>High cost</td>
<td>Mechanical resistance lower than PVC</td>
</tr>
<tr>
<td>PVC coated with</td>
<td>Low cost</td>
<td>Inertable</td>
<td>Mechanical resistance lower than PVC</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyethylene - Vinyl Acetate (EVA)</td>
<td>No Cl content</td>
<td>Flammable</td>
<td>Difficult to weld and assemble</td>
<td>Higher cost than PVC</td>
</tr>
<tr>
<td>Non woven tissue</td>
<td>Low weight</td>
<td>Flammability depends on (Cl, Br, ...), constant</td>
<td>Mechanical &amp; chemical resistance lower than for the previous material</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Comparison between different material of construction of PPE

<table>
<thead>
<tr>
<th>Airborne concentration</th>
<th>Continuious use</th>
<th>Short duration use in special circumstances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.3 DAC</td>
<td>No requirements</td>
<td>No requirements</td>
</tr>
<tr>
<td>Greater than 0.3 DAC</td>
<td>Full face respiratory may be appropriate</td>
<td>Full face respiratory may be appropriate</td>
</tr>
<tr>
<td>Greater than 30 DAC</td>
<td>Full face respirator with particulate filter</td>
<td>Full face respirator with particulate filter</td>
</tr>
<tr>
<td>Greater than 150 DAC</td>
<td>Air fed respirator, hood, breast or impermeable suit</td>
<td>Air fed respirator with filter, or air fed respirator, or impermeable suit</td>
</tr>
<tr>
<td>Greater than 150 DAC</td>
<td>Air fed impermeable suit</td>
<td>Air fed impermeable suit</td>
</tr>
</tbody>
</table>

Table 3: Guidance for the selection of PPE (particulate hazard) for normal operations or emergency situations (IAEA Recommendations)
2.2 - Non ventilated-non pressurized protective clothing

Due to the fact that this kind of protective clothing does not provide the entire protection of the respiratory tract of the wearer, it was interesting to assess the different kinds of equipment in use (blouses, coveralls, 2 pieces suits,...) in order to determine the protection factor given by the protective suit without any additional respiratory protective device.

Two kinds of particle permeation test, using Na Cl agent test, with different particle sizes (respectively 0,6 µm and 1,4 µm of aerodynamic mass median diameter), have been successively performed:

- at first, the efficiency of the material of construction has been implemented. Figure 3 here after gives the results obtained for several types of non wowed materials.
- at second, the efficiency of the complete suit has been implemented (this test is called "whole suit test"). Figure 4 here after shows the results obtained on different types of protective clothing.

The conclusion of these tests are:

- Figure 1 : results depend on both particle sizes and permeability of material,
- Figure 2 : results depend only on the design of the suit (position of openings, straps on legs, neck, arms,...) and very little on material of construction. Total Inward Leakage can vary from 5 to 50 %.

These results have been confirmed by several European laboratories using the same test procedures, during intercomparison exercises [3], [4]. This means that the use of non ventilated protective clothing must be limited for very low contamined environment or combined with appropriate respiratory protective equipment in case of high or medium contamined environment for routine or emergency operations.

3 - CONCLUSION

Due to the different levels of efficiency, PPE should be chosen in accordance with the risk analysis. Table 3 here above could be a good help for the selection of the appropriate PPE. In addition other parameters should be taken into account, such as:

- examination of the means for removal or reduction of the sources of internal/external other than individual contamination or exposure (constructive provisions, confinement, ventilation or preferential extractions,...);
- evaluation of environmental parameters (toxic gases presence, fire risk, temperature, etc.) and of human factors (training and experience of operators);
- preparation of working protected areas (mobile or fixed tents with appropriate ventilation joined to equipment for radiological surveillance);
- choice of the most appropriate PPE for the intervention : reusable or disposable (disposal problems procedures);
- economics factors : equipment cost + decontamination cost/disposal cost (related to wastes volume);
- personal training, control and maintenance of equipment, etc.

4 - REFERENCES

[4] To be published jointly by IPSN/BIA.