A New European Standard for cab Filters Performance Evaluation: Content and Criticism

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Abstract
When driving tractors and self-propelled machines the operator could be exposed to hazardous substances such as dust, aerosols or vapours (for example during the application of plant protection products or fertilisers).
Cabs of agricultural tractors and self-propelled machines provided with filters could reduce operator exposure by air-borne contaminants generated during farming operations if the air filtering is appropriate and correctly functioning. To give indication to cabs and filter manufacturers on these latter aspects a European Standard was developed (EN15695).
This European Standard will be applicable to filters and cabs of agricultural and forestry tractors and self-propelled sprayers.
Its purpose is to limit the exposure of the driver to hazardous substances like PPP and liquid fertilisers. It also specifies the information to be provided by the tractor or self-propelled sprayer manufacturer.
The proposed classification includes 4 categories of cabs and 3 categories of filters.
Critical points.
Currently few cabins are equipped with internal pressurization and practically no one has a pressure gauge as required by the Standard.
The main critical points in achieving a greater level of safety for the operator are:
- **the standard failure in defining the useful life of filters which depend also on the PPP used;**
- **the small size of the filters which also limits their duration and effectiveness;**
- **the impossibility to install in the actual cabs both dust filters and activated carbon filters.**

Keywords: European Standard, cab filters, operator safety,

Introduction

During the application of plant protection products and fertilizers the operator that is on board of tractors or self-propelled machines can be exposed to hazardous substances such as dusts, aerosols or vapour.
Analyzing all the operations related to the preparation of the pesticide mixture and its distribution, the most hazardous ones or with the higher possibility of a direct contact between the operator and pesticides are:

- filling and emptying the main sprayer tank;
- distribution of the pesticide mixture on the crops;
- washing the tank and the empty PPP can;
- sprayer and component (nozzle, filters) maintenance.

The operator's exposure to plant protection products is documented by several studies (Hamey, 1999; Vercruysse et al., 1999; Mazzi et al., 1999) and especially occurs when, during the pesticide distribution, tractors without protection cab are used.
Among the measures that farmers must adopt to ensure their safety (e.g. personal protective equipment – PPE) it's important to use security cab accompanied by appropriate filters to isolate the operator from the outside. Tractors and self propelled machines cabins equipped with filters can reduce operator exposure to air pollutants only if the filtering system is appropriate and properly functioning.

Use of cabins and filters

In the last years the use of tractors equipped with cab protection has gradually increased as well as a greater spread of the use of filters suitable for operator protection. In 2002 one third of the tractors used for pesticide application in orchards in the countryside of Saluzzo (province of Cuneo, Piemonte Region, North west of Italy) was still without cabin or with cabin devoid of any type of filter (Figure 1). This means that the operator in all these cases should use appropriate PPE to ensure his own safety. In reality only 70% of them declared to use gloves, mask and suit, whereas the 10% to use not any protective clothing (Figure 2) (Balsari, Oggero, 2002).

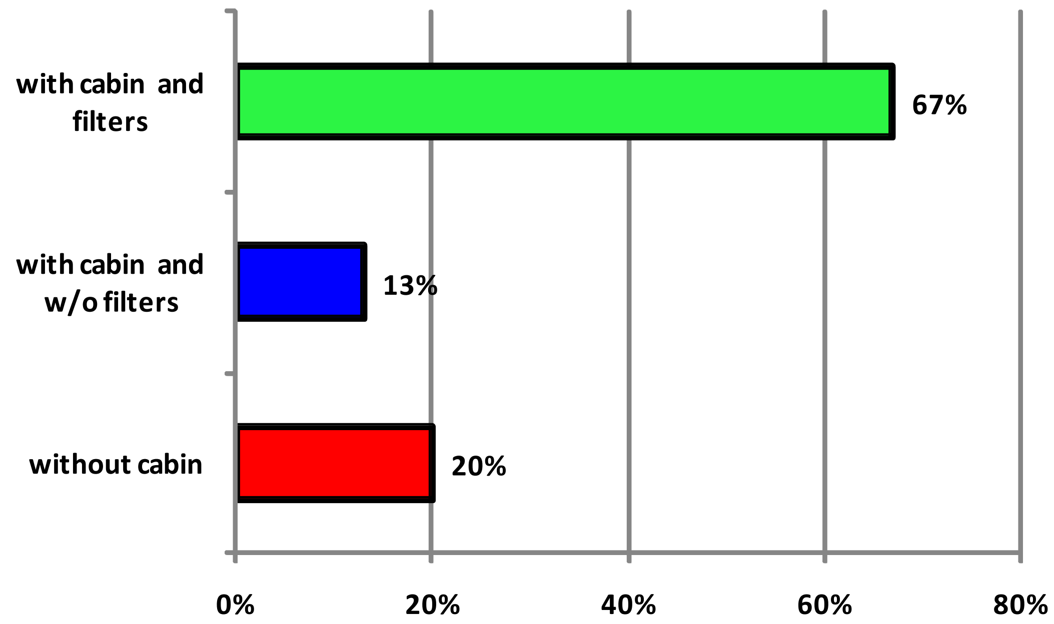
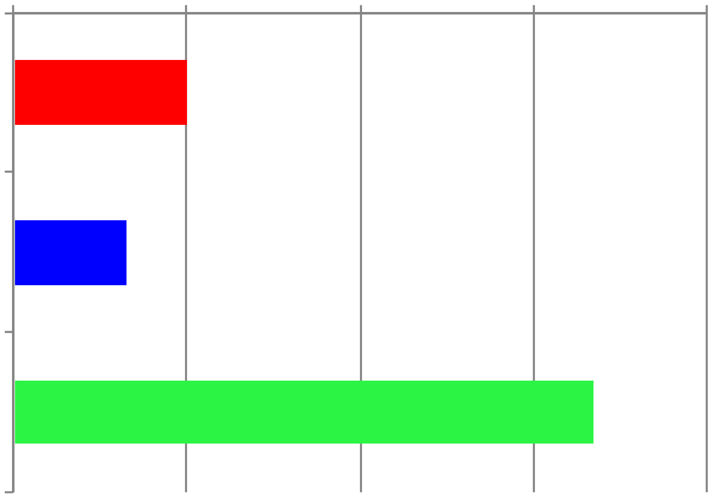


Figure 1– Diffusion of farm tractors with isolated cabin in north west Italy orchard areas in year 2002 (results of an inquiry made by DEIAFA – University of Torino



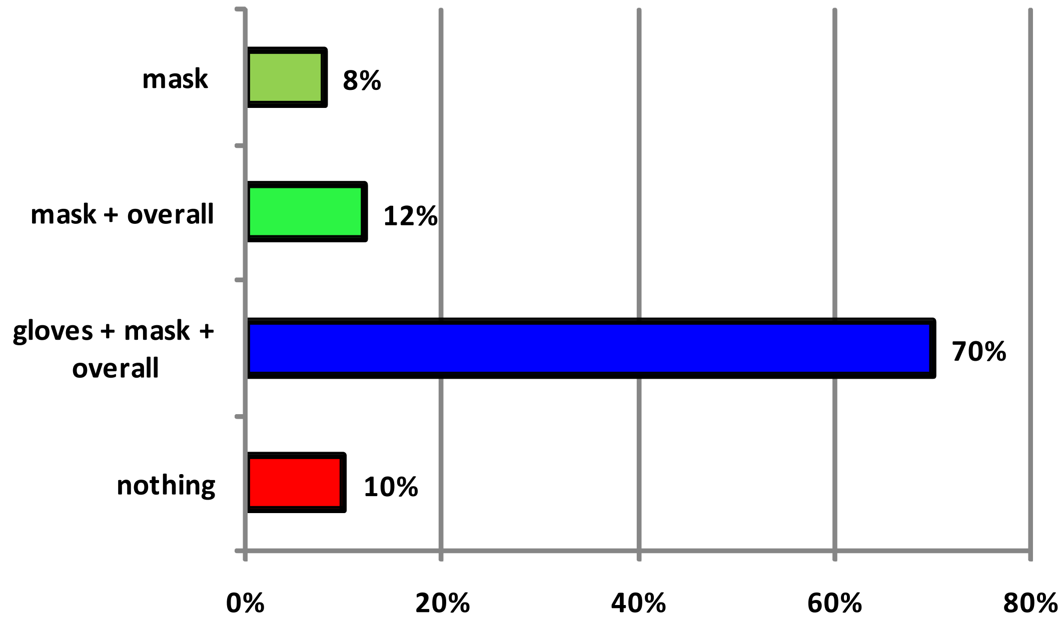


Figure 2 - PPE used by farmers who use tractors without cab or with a cabin without filters (results of an inquiry made by DEIAFA – University of Torino)

According to the results of that investigation, it can therefore be said that the majority of farmers are exposed to risks associated with PPP when using tractors equipped with cabin without proper protective filters. This occurs because the cab presence provides the operator a false sense of safety leading to underestimate the risk of contamination.
It is also necessary to consider that most of the tractor models are still sold without an appropriate protective cabin set. Currently there is a wide choice for farmers. All tractors and self propelled machines manufacturers can essentially provide three levels of technology to protect the drivers: tractor without a cab, tractor with cab but without activated carbon filters or pressurized cabs accompanied by appropriate activated carbon filters for protection against the main types of pollutants.
The last version is the only one that, when properly installed and used, can provide an adequate protection for the operator. The use of activated carbon filters ensure clean air inlet. Moreover, the pressurized system prevents the entry of contaminants through points with a non-perfect coupling between the cab and the tractor.
The best performance can be achieved if the tractor is designed and already put on the market with a protective cabin, whereas the latter is often installed at a later time and it is made by a different manufacturer.
The tractor driver level of protection is the result of combining the protection provided by the filter, the cabin design and their combination.
In order to provide common methodologies for the operator safety evaluation of these two components a European Standard (EN15695:2009) has recently been developed.

The European Standard

The EN15695 standard is composed of two parts:

- EN15695-1 describing the cabin classification requirement and test procedure;

- EN15695-2 describing the test procedure to assess filters performances and their functional requirements.

The standard applies to filters and cabins for agricultural and forestry tractors and self propelled machines. Its purpose is to limit the exposure of the driver to dangerous substances such as pesticides and liquid fertilizers.
The standard also indicates information that the manufacturer must provide within the instruction handbook.
The application of this standard filters and/or cabins manufacturers, can now asses unequivocally the benefits of their products in terms of operator safety.
The classification proposed by the standard provides four categories of cabins:

1. cab not providing a specified level of protection against hazardous substances;
2. cab providing protection against dust(s);
3. cab providing protection against dust(s) and aerosols;
4. cab providing protection against dust(s), aerosols and vapours;

and 3 categories of filters:

1. dust filters;
2. aerosol filters;
3. vapour filters.

a) <u>EN15695-1</u>

Cabins performance evaluation

The tests to which cabins must be submitted are:

- performance of the ventilation system: fresh air flow and presence and intensity of internal pressurization;
- tightness of the air delivery and filtration system (relative leakage);
- isolation effectiveness of air delivery and of the filtration system installed in the cab.

The *<u>intensity of the cab internal pressurization</u>* is defined by the difference between the static pressures inside and outside the cab; it shall be measured for each air delivery and filtration system rating tested and it shall be at least 50 Pa or 20 Pa, if a pressure indicator is provided.

The *<u>new air flow rate</u>* is measured by channeling the air to the diffusers and measuring the air discharge velocity by anemometry.

The *<u>relative leakage</u>* (L_r) is determined by the following relationship:

$$L_R = \frac{Q_2}{Q_1}$$

where:
Q_1 is the air velocity measured with the anemometer at the inlet side of the test hood;
Q_2 is the air velocity at the inlet side of the test hood.

The relative leakage shall be: LR < 2 %.

The *isolation effectiveness* is measured by placing the cab under test in a large closed room in which an aerosol is generated. The isolation effectiveness is determined from the aerosol concentrations measured by an optical counter inside and outside the cab.
The test aerosol is obtained by spraying NaCl or KCl salt solution at 1 % in distilled water. A helical fan generating a flow rate of 4 000 m3·h^{-1} to 5 000 m3·h^{-1} ensures a homogeneous aerosol concentration in the volume.
The aerosol concentration will be between 7 x 104 particles per litre (dp ≥ 0,5 µm) and the maximum concentration corresponding to the saturation limit of the optical counter used. This data, which is generally defined for a coincidence rate of 10 %, is supplied by the manufacturer.
The generator shall be capable of producing droplets having a median diameter by volume between 10 µm and 15 µm inclusive.
The isolation effectiveness of air delivery and filtration system installed in the cab shall be at least by 98%.

In the Standard it is also mentioned that in the instruction and maintenance handbook intervals for replacement of filters and proper methods of use must be specified.

b) EN15695-2

Characterisation of Filters Performance

The filters performances requirement are the following:

- ability to retain small dust particles (Figure 3) in the air flow;
- capacity to retain aerosols inside the air flow in a timeframe of 20' and with maximum concentration downstream the filter of 0.05%;
- penetration of a gas (cyclohexane) inside the air flow in a time of 70' and with a concentration upstream the filter of 500 µg/g and 10 µg/g downstream.

The tests above described should be carried out after submitting the filter to a procedure of preconditioning. At this stage, the sample should be subjected to vibration and shock in order to simulate the conditions of transport, storage and use of the filter.

The effectiveness against *dust* shall be checked by placing the filter in the orientation of that in the cab. The airflow shall be the same of that measured in the cab, at the air delivery and filtration system inlet, in the highest flow rate operating condition. The temperature shall be (23 ± 2) °C. The relative humidity shall be (80 ± 3) %.
The filter media shall be tested for fractional efficiency in accordance with ISO 14269-4 (Figure 3) over 30 min with a fine dust concentration of 1 g/m3.
The air delivery system filter shall have a performance of ≥ 99 % gravimetric efficiency.

Size µm	Fine grade % (V/V) max.	Coarse grade % (V/V) max.
≤5.5	38±3	13±3
≤11	54±3	24±3
≤22	71±3	37±3
≤44	89±3	56±3
≤88	97±3	84±3
≤125	100	100

Figure 3_Particle size distribution by volume described in ISP 14269-4

The effectiveness against *aerosols* of filters shall be checked during a period of 20 min at the maximum flow rate when tested with paraffin oil or DEHS or DOP.
The maximum aerosol penetration shall be ≤ 0,05 %.

The effectiveness against *vapours* of filters shall be checked with cyclohexane (C6H12), for 70 min, with a test gas concentration of 500 µg/g upstream the air delivery and filtration system.
Downstream the filter, the test vapour concentration shall not exceed the threshold of 10 µg/g throughout the entire test.

Main criticisms

The EN 15695 standard, as indicated in paragraph 1, does not cover:

- the exposure linked to fumigants;
- the category of cab and performance level to be used for any particular application;
- the actual cab performance in field applications;
- the field endurance of filters.

The most critical issues, identified by the analysis of EN 15695 concerning:

- no indication of the useful life of filters depending on their operating conditions and/or methodologies relevant to its determination;
- the complexity of the tests and their cost.

From a practical point of view should be also underlined that:

- the size of the filters, often related to the construction requirements of the cabins, affect its useful life (Figure 4);
- for the same reason, it is often not possible to mount an anti-dust filter to protect the activated carbon filter;
- no devices are available on the market indicating the exhaustion of the filtering capacity of activated carbon filters.
- there is often a reduced or none availability of spare activated carbon filters.

Currently the tractor instructions handbooks do not provide the user with any information concerning the filtration systems and the intervals for filters replacement .
The filters tend to clog the dust as they approach their exhaustion and thus indirectly protect the operator from exposure to external chemical agents. On the other hand, an activated carbon filter, with the unwinding of its filtering capacity does not limit its permeability. Thus, in the latter case the operator does not knows if the filtration system is working properly.

In agricultural practice is often advisable to install the activated carbon filters only before pesticide application in order to protect filters from dust and preserve their functionality for a long time. Nevertheless, it is necessary to consider that under certain operating conditions, the presence of dust from soil, itself inert and not dangerous for the operator, it is common and extremely detrimental to the effectiveness of the filters themselves. Having to exchange the type of cab filters many times during the year it may happen that the operator does not know with absolute certainty which type of filter it is installed on his tractor. To solve this problem it could be useful to have a system for filters recognition. Moreover, in order to prolong the useful life of activated carbon filters and maximize the operator protection, to use a filtering cascade.
Cabins manufacturers have the tendency to increase the maneuverability of tractors for orchards and vineyards, to reduce as much as possible their sizes. However, that requirement has many effects on shape and size of filters and on their functionality due to the reduced availability of space.
This drawback could be overcomed by redesign the cabin, putting as priority the welfare and health of the operator.
It should be also underlined that working with the best filtration system does not ensure the reduction and removal of hazards for the driver. It is common, even during pesticide treatments, the use of tractor with portions of the cabin open for example, to facilitate the entry of commands used to control trailed sprayers or to reach them in case of mounted sprayers (Figure 5) or to cool the interior of the cabin down if the tractor has no air-conditioning system.
In order to ensure the maximum operator safety, besides on technical equipment of machines, it should be important to invest, on raising their awareness and training on safety aspects.

Figure 4_ Particular of cabin filter housing

Figure 5_ Rear window open to allow passage of piping

Conclusion

The tests described in EN 15695 are characterized by both a certain complexity and high performing costs. This may be an obstacle for the research and the development of new types of cabs or for the use of new filtering materials. Due to the high cost linked to the wide number of cab models and filters, it will be difficult to get the certification of all materials available on the distribution network.
Moreover, this Standards should be extended by including tests focused at the determination of the filters useful life.
In order to increase the operator safety it might be useful to provide the farmer with a quick and easy method to verify the functionality of carbon filters.

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