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Development of a selective testing method to pesticide aerosols for characterization and comparison of agricultural tractor cabs classified according to EN 15695-1

Entwicklung eines selektiven Prüfverfahrens zu Pflanzenschutzmittel-Aerosolen zur Charakterisierung und zum Vergleich von landwirtschaftlichen Traktorkabinen, klassifiziert nach EN 15695-1

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Abstract

Only preliminary results from tactile tests are currently available on the exposure-reducing effect of different tractor cabs according to EN 15695-1. Scientifically reliable data are not available. To close this gap, a project was initiated by the Federal Office for Consumer Protection and Food Safety (BVL) and by the Social Insurance for Agriculture, Forestry and Horticulture (SVLFG) – with the participation of the Federal Institute for Risk Assessment (BfR). Due to the expertise and the available technical facilities (machinery and laboratories), corresponding tests were carried out by the Institute for Application Techniques in Plant Protection at the Julius Kühn Institute (JKI), Federal Research Centre for Cultivated Plants. As part of the project, data was collected to enable a well-founded review of the management decision on the protective effect of the different type of cabins mentioned in EN 15695-1. The current paper gives an overview about the methodology developed for gathering the data.

Keywords

plant protection, agricultural tractor cabs, EN 15695-1, protective level, testing method

Zusammenfassung

Zur expositionsmindernden Wirkung von verschiedenen Schlepperkabinen nach EN 15695-1 liegen derzeit nur vorläufige Ergebnisse aus Tastversuchen vor. In wissenschaftlicher Hinsicht belastbare Daten sind nicht verfügbar. Um diese Lücke zu schließen, wurde ein Projekt durch das Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (BVL) und durch die Sozialversicherung für Landwirtschaft, Forsten und Gartenbau (SVLFG) – unter der Beteiligung des Bundesinstituts für Risikobewertung (BfR) – initiiert. Aufgrund der Expertise und der vorhandenen technischen Einrichtungen (Maschinen und Labore) wurden die entsprechenden Untersuchungen durch das Institut für Anwendungstechnik im Pflanzenschutz am Julius Kühn-Institut (JKI), Bundesforschungsanstalt für Kulturpflanzen, durchgeführt. Im Rahmen des Projektes sollten Daten erhoben werden, welche eine fundierte Überprüfung der Managemententscheidung zur Schutzwirkung der genannten Kabinen nach EN 15695-1 ermöglichen. Der Artikel beschreibt die für die Datengenerierung entwickelte Methodik.

Stichwörter

Pflanzenschutz, landwirtschaftliche Schlepperkabinen, EN 15695-1, Schutzniveau, Prüfverfahren

Introduction

In the context of the authorization of plant protection products, the necessary personal protective equipment (PPE) for operators is determined based on a risk assessment for each individual plant protection product (PPP). PPE is required where the personal exposure of the operator can be reduced to a level where unacceptable health risks can be excluded. The specific requirements for PPE are issued within the authorization and can be found in the instructions for use of the product.

Submitted/accepted for publication: 28 February 2023/9 May 2023

In 2017, application directive SB199 was announced. Exceptions for the wearing of PPE are defined for the operator when the machine used for the application of plant protection products is equipped with a category 3 or category 4 cab according to EN 15695-1. The announcement led to controversial discussions in which it became clear that many operators were not aware that they may need to wear PPE in a closed cab if their cabin does not correspond to the protection level of a category 3 or category 4 cabin. One result of this discussion was that the exceptions to wear PPE should be extended to other types of cabins.

According to expert's estimates, even closed cabins that have been labeled category 2 on the basis of EN 15695-1 and non-certified cabins that are sufficiently airtight and have air conditioning with filtered air supply (category 2* defined by BVL) provide adequate protection against PPPs during the application process. Therefore, they could be used without further PPE measures in many cases.

However, only results from preliminary tests on the exposure-reducing effect of unclassified tractor cabins are currently available. Scientifically reliable data are not available. Within the framework of field tests, it should be clarified whether category 2 cabins or comparable non-classified or non-certified cabins (category 2*) provide a sufficient level of protection under practical conditions, so that even when using these types of cabin, the PPE for protection against dermal exposure (protective suit and gloves) can be dispensed within the cabin. In this context, adequate protection means that the exposure is significantly lower than that of an unprotected driver (category 1) and not significantly higher than in category 3 or 4 cabins.

Against this background, the Federal Office for Food Safety and Consumer Protection (BVL) initially modified application directive SB199 to equate category 2 and 2* cabins with category 3 and 4 cabins for a transitional period. During this transitional period, experiments are carried out to investigate the protective effect of different cabin categories in the application of PPP under practical conditions, in order to evaluate the BVL's decision retrospectively. To this end, a joint research project was initiated in cooperation with the BVL, the Federal Institute for Risk Assessment (BfR), the Social Insurance for Agriculture, Forestry and Horticulture (SVLFG) and the Julius Kühn Institute (JKI).

According to the project plan the JKI collected current, relevant experimental data on dermal and inhalation exposure on tractors without a cabin and in closed tractor cabins in accordance with the test conditions agreed with the project partners. The aim of the tests was primarily to compare exposure values (and therefore the comparison of the protective effect) for test persons in different settings, like tractor with cat. 1, cat.2, cat. 4 cabins according to EN 15695, as well as not-certified cat. 2* cabin (a tight closing cabin with air condition and dust filter system) according to BVL classification (BVL, 2020). Aim of the paper is to describe the development and the final methodology in detail.

Development of an adequate testing method

During preliminary tests within the project, it became obvious that only very low levels of exposure are to be expected inside the vehicle´s cabin. Therefore, suitable dosimeter materials and measuring methods for the quantitative determination of these small amounts had to be established. Furthermore, based on the results of the mentioned preliminary tests it was agreed that the practical tests should be limited with a focus on orchard spraying as a worst-case scenario.

The applied analytical methodology

There are already established methods for testing and evaluating the performance of filter systems, which are described in various standards (fine and coarse dust filters according to DIN EN ISO 16890:2017 and particulate filters according to DIN EN 1822:2019 and DIN EN ISO 29463:2019). These methods focus on the question, how well a filter system is suitable for removing certain particle sizes from the air flow. In order to measure the quality of the filter system, particle counters are usually used behind the filter unit. These measurement systems record the total amount of particles (e. g. consisting of dust and soot particles as well as aerosols, etc.) in an undifferentiated manner. However, the aim of our research is only quantifying the amount of spray liquid of a PPP passing through the filter system as an aerosol. To achieve this goal a selective measurement method is required to determine the exposure of the operator. For this purpose, the widely used standard drift measurement method of JKI (JKI, 2013) was adapted. With a defined dye solution as a surrogate for spray liquid (Herbst & Wygoda, 2006), the exposure outside the cabin as well as the exposure for the operator inside the cabin was determined.

In addition to the test method, the applicability of the different dosimeter materials was verified by measuring blank values (Fig. 1) and recovery rates (Fig. 2). Furthermore, both the laboratory recovery and the field recovery are determined to detect any possible degradation of the applied fluorescent dye (pyranine) during the application process. To determine the recovery rates, the dosimeter material samples used are contaminated with a defined quantity of fluorescent dye solution (stock solution: 20 mg/l, pipetted volume: 50 µl, the outcome of this is: 1 µg/detector). The contaminated detectors – left outside next to the test site or within the cabin for the duration of the test – were protected from unwanted contamination. After the test runs, the recovery samples are packaged, stored and analysed like the measurement samples.

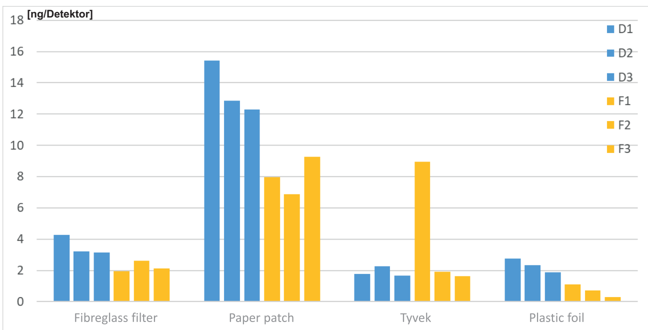
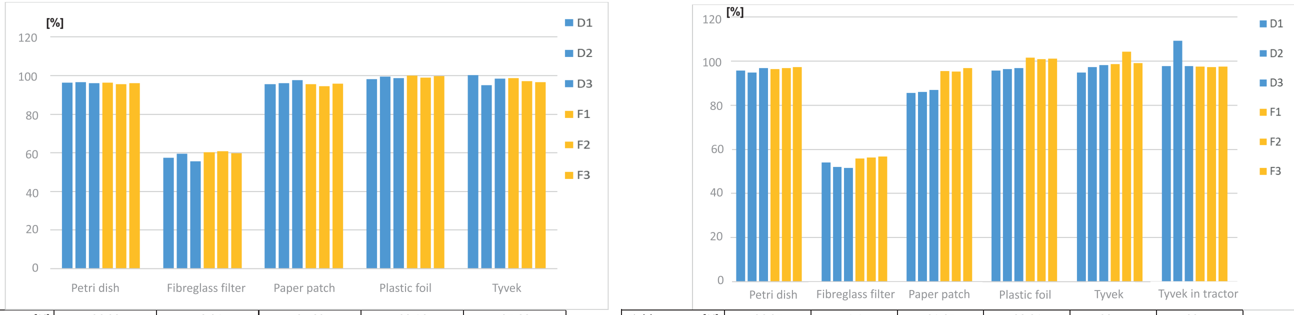


Fig. 1. Blank values of the applied target materials (blue and yellow represent two different trials, each with a triple repetition)



Labor recovery [%]	96.20	58.94	95.82	99.16	97.66
+/-	0.97	6.03	2.90	1.97	5.56

Field recovery [%]	96.37	54.45	91.07	98.84	98.75	99.55
+/-	2.81	6.68	16.26	8.15	9.50	14.23

Fig. 2. Laboratory recovery rate (left) and field recovery rate (right) of the applied target materials (blue and yellow represent two different trials, each with a triple repetition)

Dosimeter for detection of external contamination

In order to record the external contamination of the tractor cab, the construction shown in Fig. 3 was developed, implemented and tested. The measured values serve as reference values for external exposure during the spraying process. The auxiliary frame was developed in such a way that cross-contamination between the test repetitions can be effectively prevented and a fast and efficient test procedure is possible. By using the auxiliary frame, time consuming decontamination of the outer part of the cabin between the different test runs is not necessary. Five sets (six detector plates per set [see Fig. 3 left]) of exchangeable detector holder plates were manufactured, which means that five repeated measurements with different parameterizations can be carried out in a relatively short time.

Based on preliminary test results, the detector holder plates were equipped with three different detector materials (Herbst & Molnar, 2002):

- Paper patches
- Plastic foil
- Tyvek material

Despite the relatively high blank values (Fig. 1), the paper patches allow measuring high exposure values covering the range of exposure expected outside a cabin without the risk of filter saturation or dripping/dropping. Plastic foil and Tyvek, on the other hand, enable the reliable measurement of low exposures due to the high recovery rate and negligible blank values. Furthermore, the parallel use of three different detector materials at nearly the same position increases the statistical reliability of the measured values.

Dosimeter for detection of internal contamination

Because the preliminary tests within the project have clearly shown that only a very small amount of the applied spray liquid gets into the cabin, detectors should be developed that are able to detect these low levels of exposure inside the cabin. Three different detectors were used to determine the inhalation and dermal exposure. Figure 4 shows the systems implemented.

In order to determine the inhalation exposure within the cab, the sampler units of aerosol collection pumps were optimized. As a result, a very fine-pored nitrocellulose filter as well as a fibreglass filter with an increased effective detector surface area were used. The initial material tests had shown that nitrocellulose and fibreglass have good properties in terms of blank values and recovery rates from a laboratory point of view. The pore size of the filter is 0.22 µm, which allows collecting even smallest aerosol particles. The enlarged detector surface area allows for an increased collection efficiency and it causes only a small throttling of the airflow. All factors mentioned have an essential influence on the measurements.

During the development of a proper detector for dermal exposure, the aim was also to increase the active detector area. Instead of paper patches (fixed to the coverall of the driver) applied during the preliminary tests, Tyvek full-body coveralls and latex gloves were used. The Tyvek material also has another positive property: the amount of fluorescent dye collect-

Fig. 3. The realized detector holder plate (left) and the positioning of the different plates

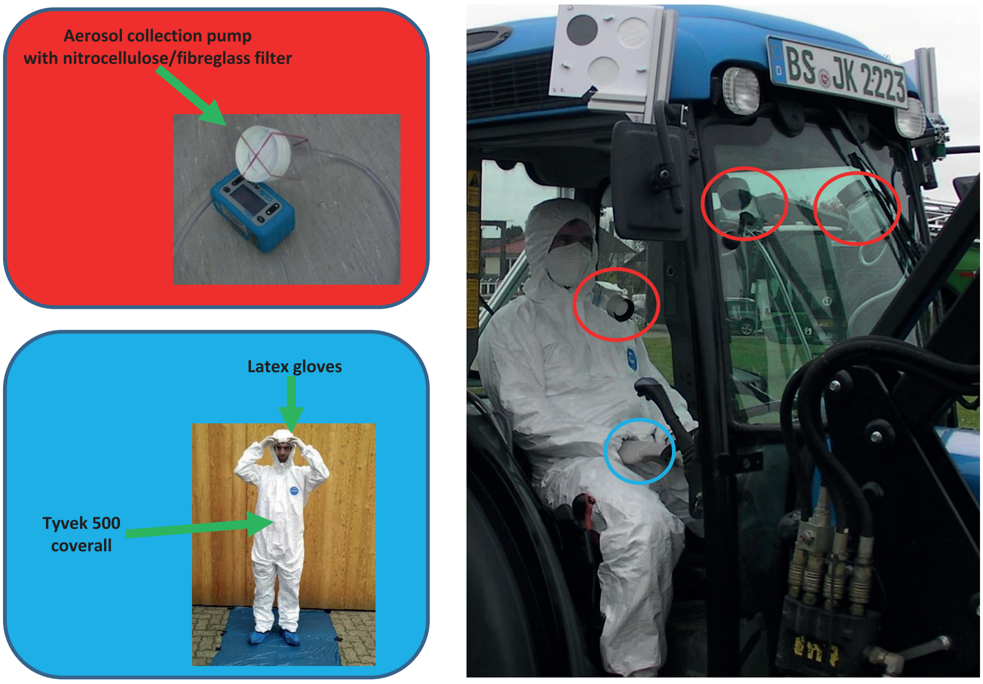


Fig. 4. The detectors and the placing of the detectors to measure exposure within the cabin

ed during the test runs can be removed from the surface with relatively little amount of washing liquid, which means that a sufficiently high concentration of the dye can be achieved, even with only very low exposure values. This enables a reliable determination of contamination in the lab phase. Furthermore, an additional detector (latex gloves) was used to record skin contamination on the hands – a particularly relevant risk factor.

Within the cabin, the orientation of the air fan inlet nozzles, the ventilation intensity and the placement of the detectors could be of importance in measuring exposure levels. To represent a "worst case" scenario, the ventilation is set to the highest level and the nozzles of the ventilation system inside are directed towards the driver´s head and the samplers of the aerosol collection pumps placed in the cabin. The applied volume flow for the aerosol collection pumps is 2 l/min, which is commonly used in exposure studies.

Measurements

As mentioned before, different types of tractors with different cabin categories were examined with regard to their exposure-reducing effect for operators (Fig. 5). Measurements with a tractor without a cabin (cat. 1) represent the reference value of 100% exposure for orchard spraying. For this setting, a Kramer KL400 equipped with only a roll-over bar was used. For the setting with a cat. 2* cabin according to BVL definition a New Holland TN 70 NA was used. Furthermore, a New Holland T4.100N was used. This tractor is equipped with a cabin concept according to EN 15695 and can be used both in cat. 2 or cat. 4 mode.

The relevant application parameters are as follows:

Orchard Sprayer: Wanner K1000
Speed: 7 km/h
Applied volume: ~75 l
Applied dose: 500 l/ha
Pressure: 10 bar
Nozzle: TeeJet TXA80015VK/Albuz ATR Yellow
Dye: pyranine
Dye concentration: 0.1 %
Test location: JKI test site, Messeweg Braunschweig

Figure 6 shows the spatial arrangement and Figure 7 the weather conditions. In order to identify any correlations, the weather parameters as wind direction and wind speed were

Cat. 1:* Kramer KL400** | ***Cat.2/2*: New Holland TN 70 NA | ***Cat. 2* and 3/4: New Holland T4.100N***

Fig. 5. The different tractor types under test

Journal für Kulturpflanzen, 75 (05-06). S. 130–137, 2023 | DOI: 10.5073/JfK.2023.05-06.02 | Molnar et al.

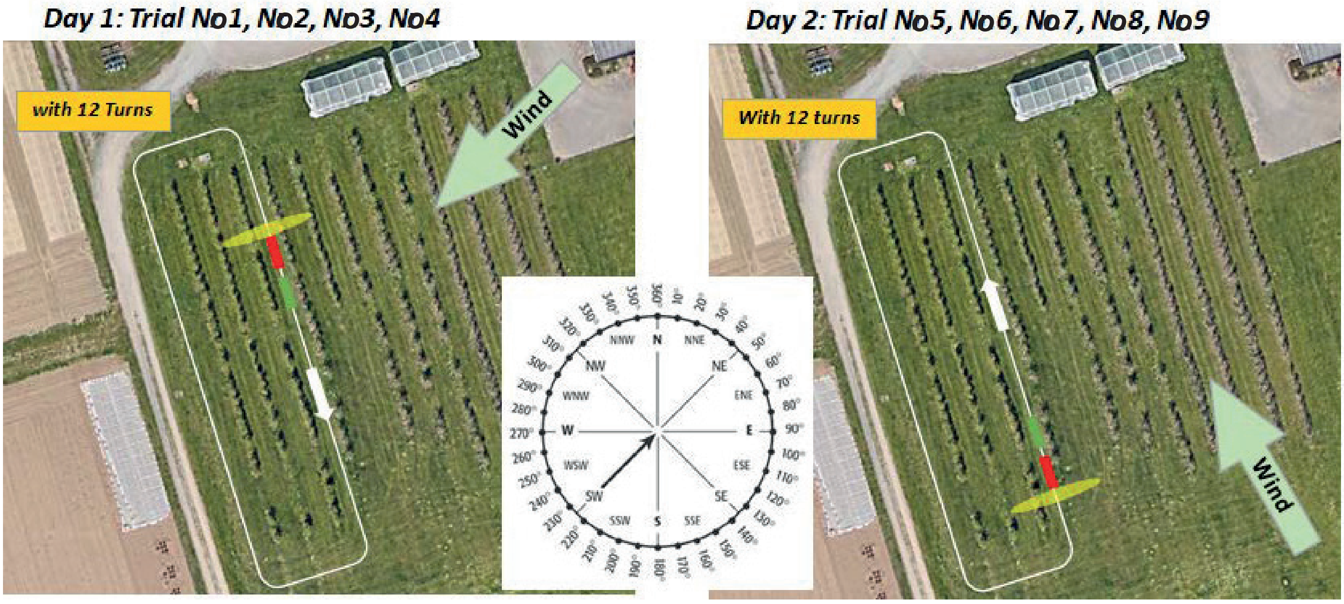


Fig. 6. The location of the measurements

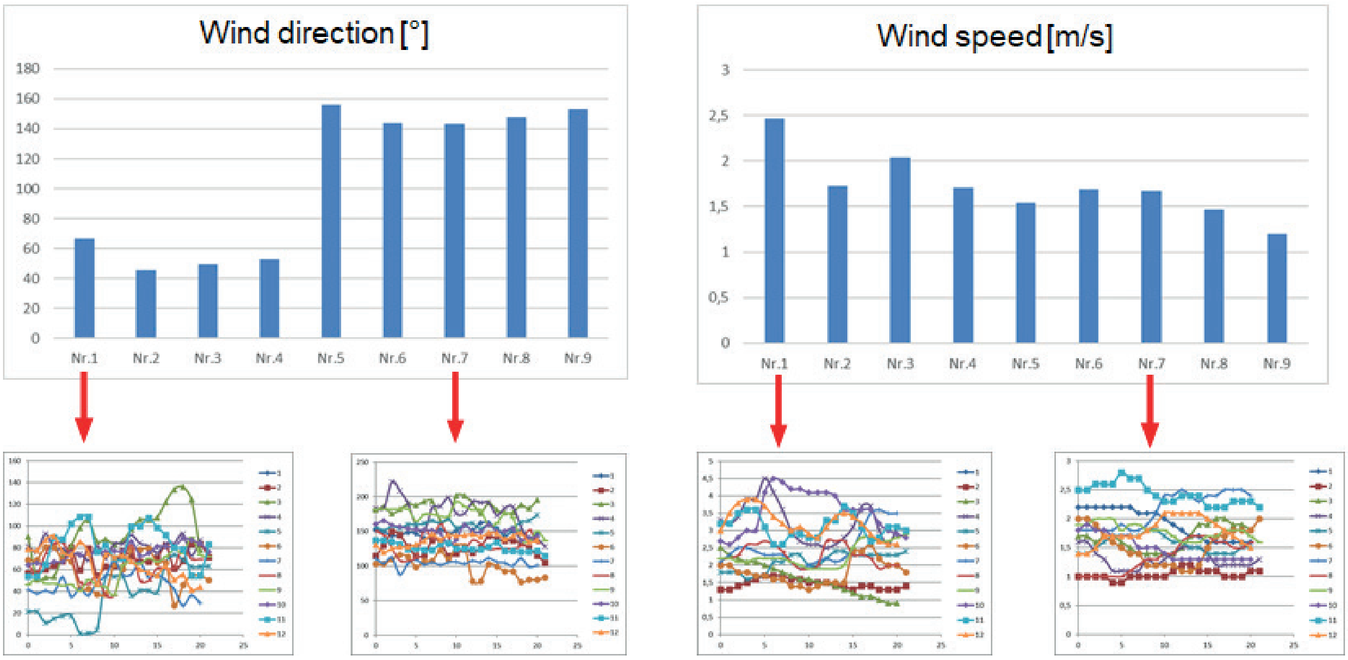


Fig. 7. The relevant weather conditions: the mean values for the trials (top) and the recorded values with high resolution exemplary for trial 1 and trial 7 (bottom)

logged synchronously with a repetition rate of 1 data point per second for each treatment process. During the application the tractor was moving in a circular course (Fig. 6). The trials were performed in four independent measurement campaigns.

Measurement results regarding external exposure

Figure 8 shows the exposure measured on the outside of the cabin. The local contamination values shown are mean values, they were calculated from the recorded contamination values of the individual detectors made of Tyvek, plastic foil and paper patches. The measured values of outside exposure represent the potential contamination for the operator inside the cab.

Measurement results regarding internal exposure

Figure 9 shows the measured dermal exposure values by using full body coveralls.

Figure 10 shows the exposure on the latex gloves used by the operator in the different test series.

Figure 11 shows the measured results using aerosol collection pumps in order to specify inhalation exposure of the operator.

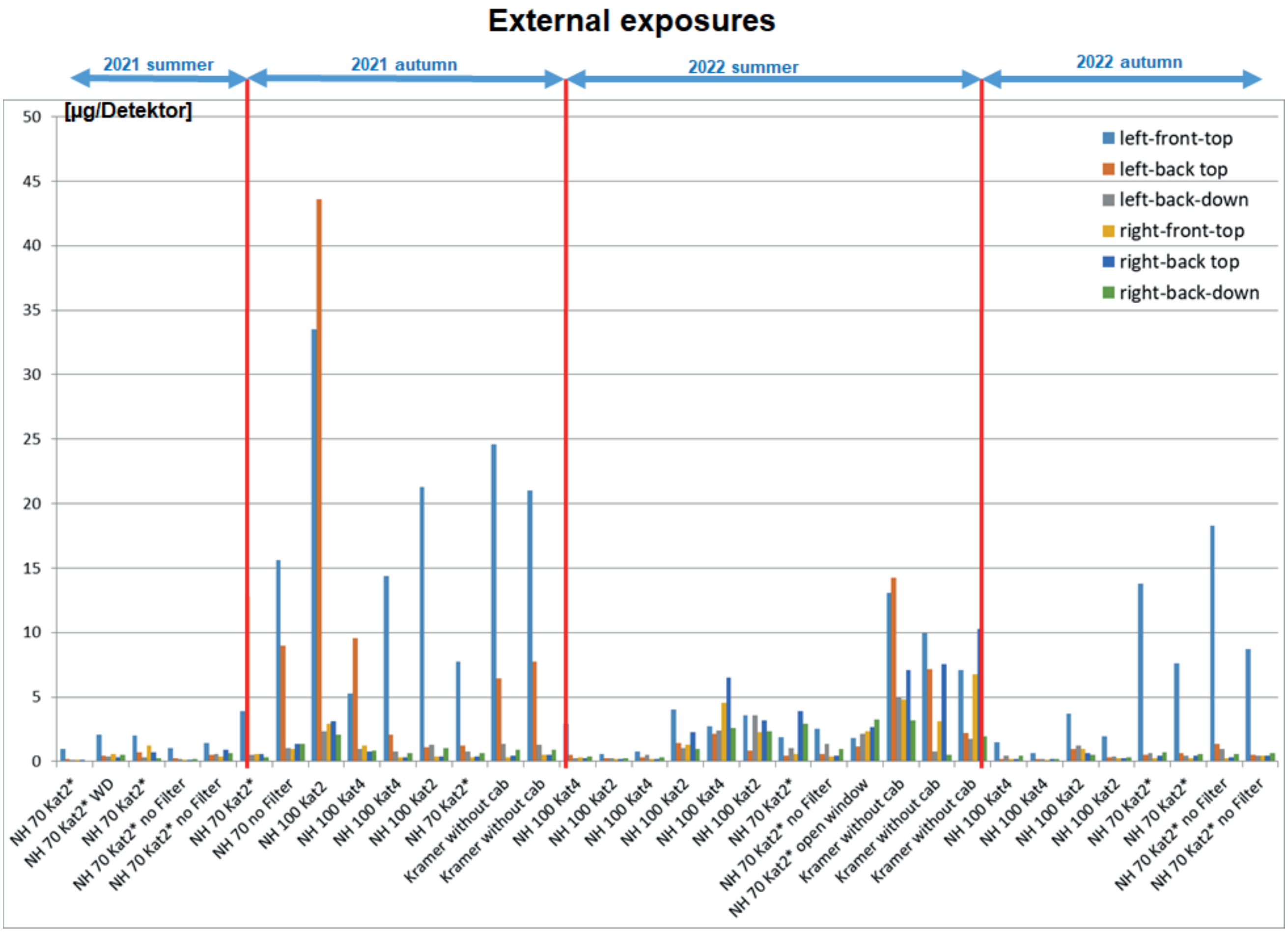


Fig. 8. The measured exposure values on different frame positions measured in different campaigns

Conclusion

The test methodology developed is based on an aqueous fluorescent dye solution acting as surrogate for spray liquid with PPP. Fluorimeter analysis of the dye on different dosimeters allows for the calculation of exposure towards the spray solution outside and inside the cab. Based on the analytical data it is possible to assess and characterize the protective effects of different cab categories on the operator. The data for outside, dermal and inhalation exposures show a wide range of amounts of dye that have to be robustly determined and quantified. The data for dermal and inhalation exposure of operators show that the developed methodology is able to detect very small amounts of dye solution/spray liquid that may get into the cabin through the ventilation system. The utilization of different dosimeters for outside exposure also contributes to the number of repetitions, which can be gained in one test run, allowing for a higher statistical power. The methodology is close to spraying in practice. The use of an airblast sprayer represents a worst case scenario for exposure assessment. Moreover, it is not depending as much on default weather conditions as compared to drift measurements (concerning wind speed and wind direction).

Conflicts of interest

The authors declare that they do not have any conflicts of interest.

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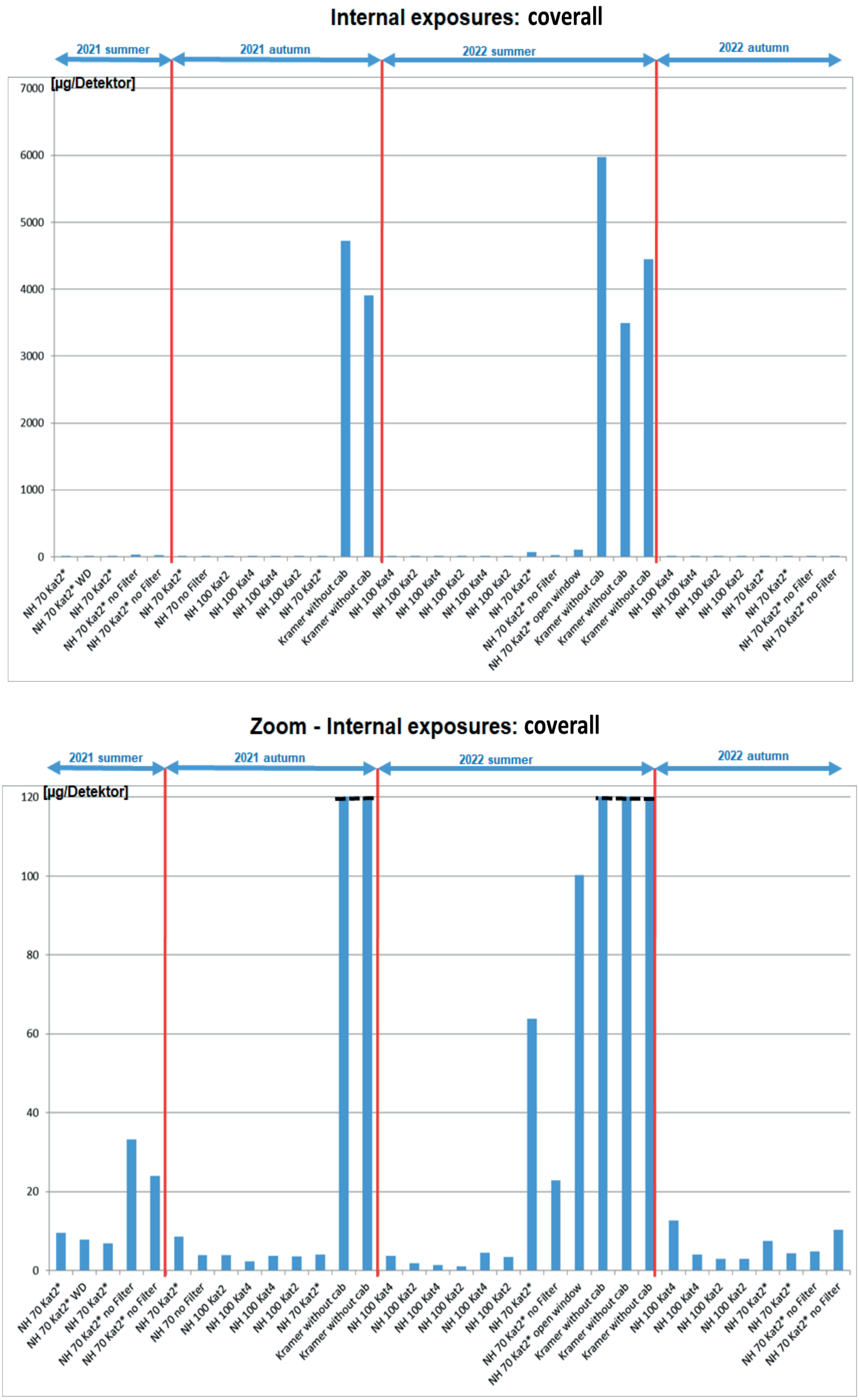

Fig. 9. Measured contamination values regarding dermal exposure (with zoom bottom).

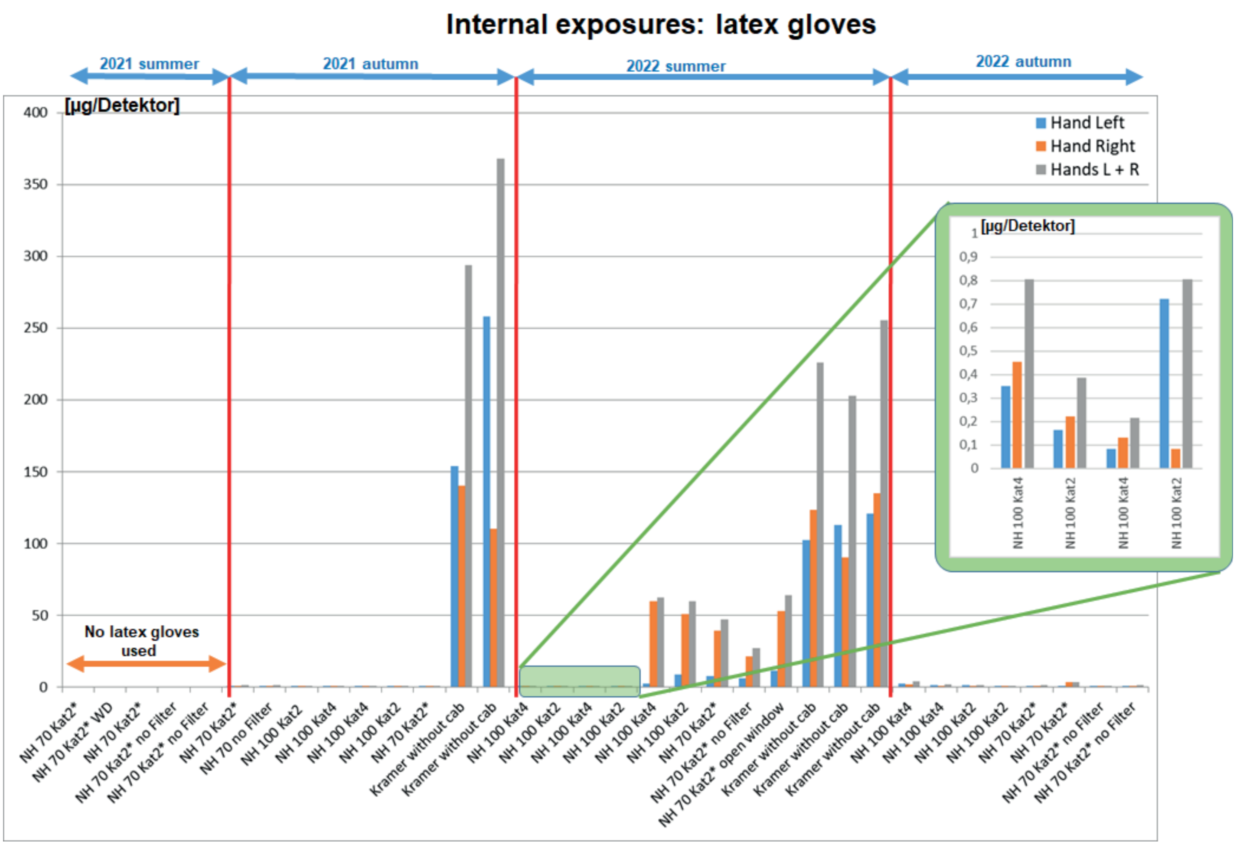

Fig. 10. The dermal exposure on the hand measured by using latex gloves in different scenarios

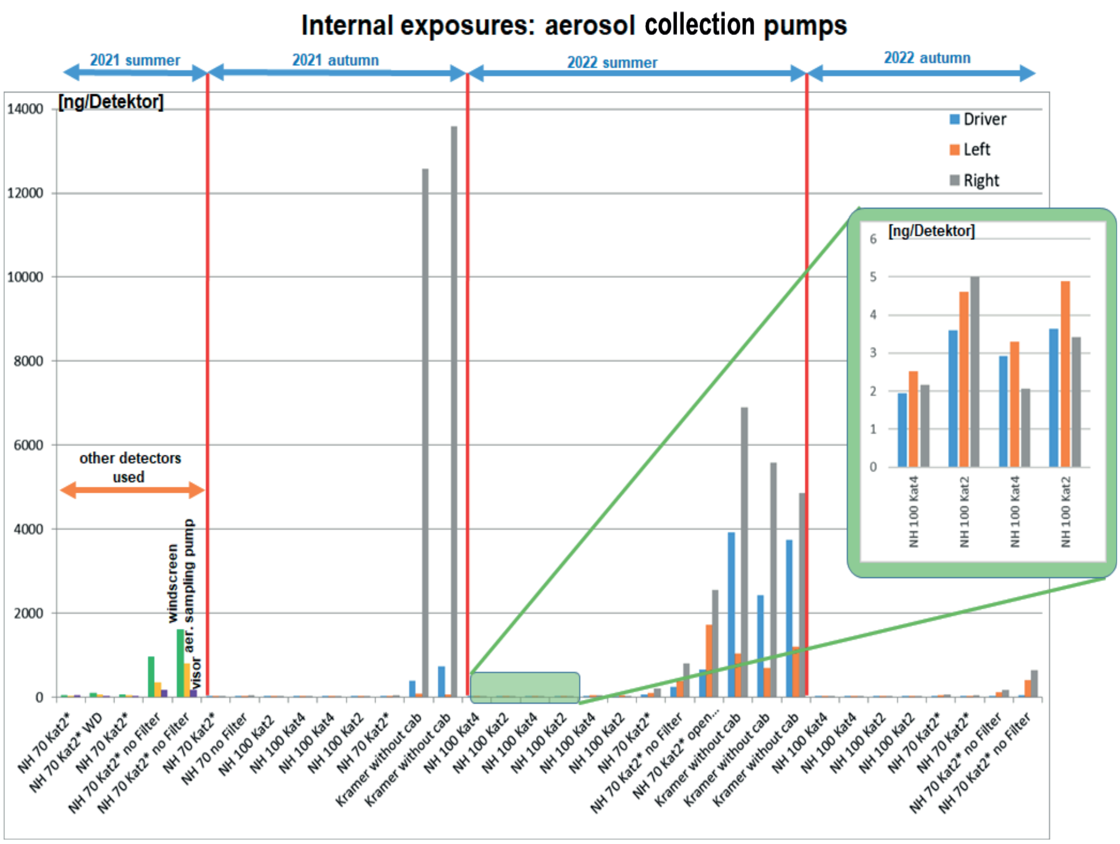

Fig. 11. Measured values for the inhalation exposure by using aerosol collection pumps