

**Grzegorz Wrzyszczy<sup>1</sup>**

Provincial Headquarters of the State Fire Service in Lublin

ORCID: 0009-0009-2405-9940

**Damian Saleta<sup>2</sup>**

Fire University in Warsaw

ORCID: 0000-0003-1418-6996

**Analysis of the organization of activities and accepted practices  
in the rescue and firefighting units of the State Fire Service  
in terms of minimizing the secondary exposure of firefighters to  
toxic products of thermal decomposition and combustion**

Analiza organizacji działań oraz przyjętych praktyk w jednostkach ratowniczo-gaśniczych Państwowej Straży Pożarnej w zakresie minimalizowania wtórnej ekspozycji strażaków na toksyczne produkty rozkładu termicznego i spalania

## **Introduction**

In a fire environment, a firefighter is exposed to many hazardous factors, including toxic products of thermal decomposition and combustion. The priority for their safety in such a situation is to be adequately protected,

---

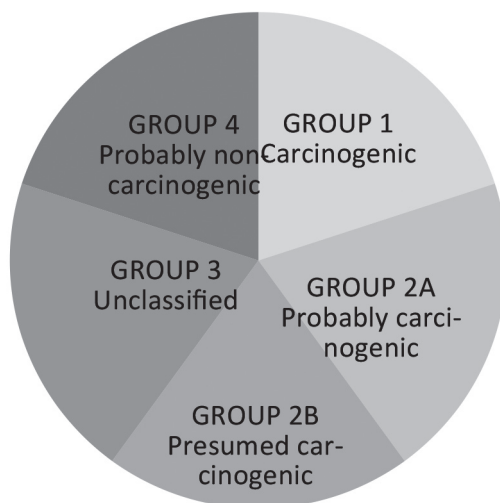
1 Grzegorz Wrzyszczy: mgr. inż., Provincial Headquarters of the State Fire Service in Lublin, e-mail: wrzyszczy@gmail.com

2 Damian Saleta: bryg., dr inż., Fire University in Warsaw, Safety Engineering and Civil Protection Faculty; e-mail: dsaleta@apoz.edu.pl

particularly from the effects of high heat fluxes and toxic substances. This is achieved, among other things, by the selection and correct use of personal protective equipment (PPE), which, together with personal equipment, is subject to contamination when in contact with these products. This is due to the ability of fire toxins to deposit on them and penetrate the structure of their materials. The equipment then loses its protective properties and there is also a risk of cross-contamination through contact with uncontaminated people or objects. Therefore, contaminated firefighter PPE and equipment should be adequately protected immediately after the fire has been extinguished to minimise additional hazards.

In accordance with the regulations in force in Poland that define the safety and hygiene of the service (Journal of Laws of 2021, item 1681), the cabin of a fire engine, together with the equipment and personal protective equipment of a firefighter who has participated in a rescue operation, is subject to cleaning and disinfection. Recommendations should also be mentioned (Stec et al., 2020; Krzemińska, Szewczyńska, 2020) for initial decontamination at the scene, personal decontamination of rescuers and changing into clean clothes immediately after the operation. They also take into account the principles of transporting contaminated PPE and personal equipment (outside the crew cabin) in a specially designated area of the vehicle to the place of proper decontamination and maintenance (Kokot et al., 2021). Failure to follow these guidelines, or their negligent implementation, is associated with secondary exposure of firefighters.

Avoiding both direct and secondary contact with firefighting agents is of particular importance because of the potential consequences (IARC, 2010). The International Agency for Research on Cancer (IARC) conducted its first study in 2007, which indicated an increased risk of chronic disease from exposure to toxic products of thermal decomposition and combustion. At that time, the agency classified the occupational exposure of firefighters as Group 2B – ‘probably carcinogenic’ – on a five-point risk scale (see Figure 1). Subsequently, in 2022, the same agency reclassified firefighters’ occupational exposure to the highest risk group – ‘carcinogenic’ – after a thorough analysis of the latest available scientific literature (IARC, 2010; IARC, 2022).



**Figure 1.** Classification of the International Agency for Research on Cancer (IARC)

Source: own elaboration.

Current medical knowledge and analysis of studies conducted on firefighters from around the world also confirm other complications besides carcinogenicity. The groups of harmful compounds and the possible health effects they may cause are shown in Table 1.

Table 1. Information on the selected harmful fire products

| Group harmful products fire products         | Possible sources   | Name of specific fire product | Carcinogenic | Teratogenic | Sensitising | Reproductive system | Neurological system | Lower respiratory tract | Upper respiratory tract | Circulatory system |   |
|--|--|-------------------------------|--------------|-------------|-------------|---------------------|---------------------|-------------------------|-------------------------|--------------------|---|
| Volatile and semi-volatile organic compounds | Household and industrial products, including but not limited to cleaning products, aerosols, fuels, furniture and building materials | Benzene                       | +            | +           |             | +                   | +                   | +                       | +                       | +                  |   |
|  |  | Styrene                       |              | +           |             |                     | +                   |                         | +                       | +                  |   |
|  |  | Toluene                       |              | +           |             |                     | +                   |                         |                         |                    |   |
|  |  | Phenol                        |              | +           |             |                     | +                   |                         | +                       | +                  | + |
| Isocyanates                                  | Used in the manufacture of polyurethane foams, polyisocyanurates, fillers and coatings or any other nitrogen containing material.    | Acetaldehyde                  | +            | +           |             |                     |                     | +                       | +                       | +                  |   |
|  |  | Methyl isocyanate             | +            | +           | +           |                     | +                   |                         | +                       |                    |   |
| Polycyclic aromatic hydrocarbons             | They are formed during virtually all uncontrolled fires, as they consist mainly of carbon  | 2,4-12,6- Di-isocyanatoluene  | +            | +           | +           |                     | +                   | +                       | +                       |                    |   |
|  |  | Benzo(a)pyrene                | +            | +           |             | +                   |                     |                         |                         |                    |   |
|  |  | Benzo(a)anthracene            | +            |             |             | +                   |                     |                         |                         | +                  |   |
|  |  | Benzo(b)fluoranthene          | +            | +           |             |                     |                     |                         |                         |                    |   |
|  |  | Chrysen                       | +            | +           |             | +                   |                     |                         | +                       |                    |   |
|  |  | Fluoranthene                  |              |             |             |                     |                     | +                       |                         | +                  |   |
|  |  | Naphthalene                   | +            | +           |             |                     | +                   |                         |                         | +                  |   |



## Material and methods

For the purposes of the research conducted, a research problem was defined, which was to find an answer to the main question: at what level are the current organisational solutions and practices of SFS officers in terms of minimising secondary exposure to toxic products of thermal decomposition and combustion? In addition, three specific questions were used to address the issue addressed, namely To what extent has the division into clean and dirty zones been implemented in SFS rescue and firefighting units? What is the level of correct practice of officers in terms of protection against secondary exposure to toxic products of combustion? How often do officers clean clothing and equipment used during firefighting operations?

Theoretical as well as empirical methods were used to analyse existing organisational arrangements and firefighting practices, but the main focus was on a quantitative study using a survey questionnaire. In the instructions, respondents were asked to mark one or more answers from a closed catalogue created according to a five-point Likert scale. Which, as intended, made it possible to detect differences in the attitudes of the firefighters surveyed (their direction and strength), including presented attitudes and beliefs at opposite poles, as well as neutral statements (Tarka, 2015).

The survey questionnaire consisted of information and questions about the investigators, the purpose of the study, the anonymity of the study, instructions for completing the questionnaire, characteristics of the study group, respondents' opinions and their knowledge of the specific research problem. Appropriately prepared questions were designed to determine the age, seniority, position and corpus of the respondents. Then, in the main part, questions were asked about the degree of implementation of organisational solutions, individual practices for minimising secondary exposure to toxic combustion products and the frequency of training in the area under study. Based on the assumptions made, it was determined how the occupation of the official position and previous experience affect officer safety. The main element of the analysis was the results of the empirical study.

In order to determine the minimum number of officers to be surveyed, equation 1 was used. The value of the population to be surveyed was obtained, which was a minimum of 589 persons, assuming that the size of the population surveyed is  $N=30\ 000$  persons, the standard value for the 95% confidence level is  $Z=1.96$ , and the maximum magnitude of the error is  $d=4\%$  (0.04) (Jablonska, Sobieraj, 2013).

$$n_b = \frac{N}{1 + \frac{4d^2(N-1)}{Z^2}} \quad (1)$$

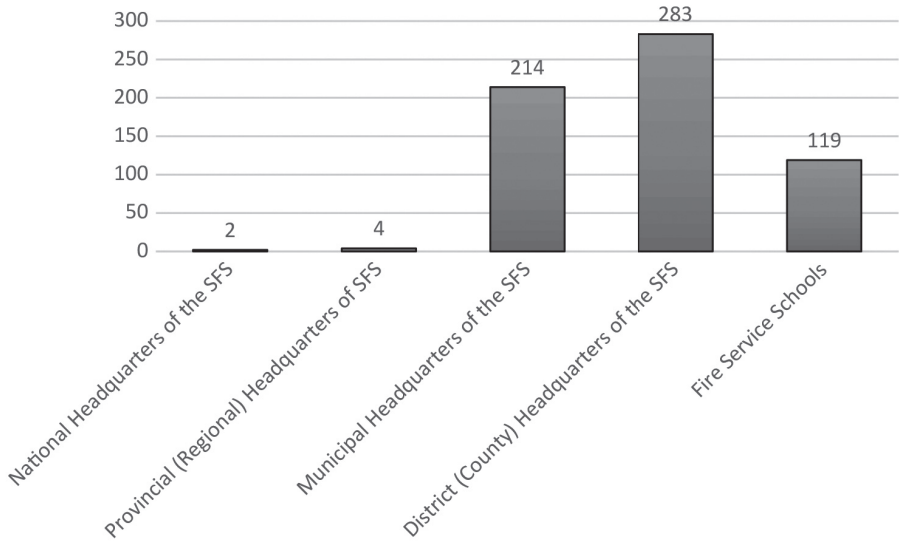
Respondents took approximately 15 minutes to complete all questions. The survey was conducted in March/August 2023 among officers serving in the SFS nationwide.

## Results

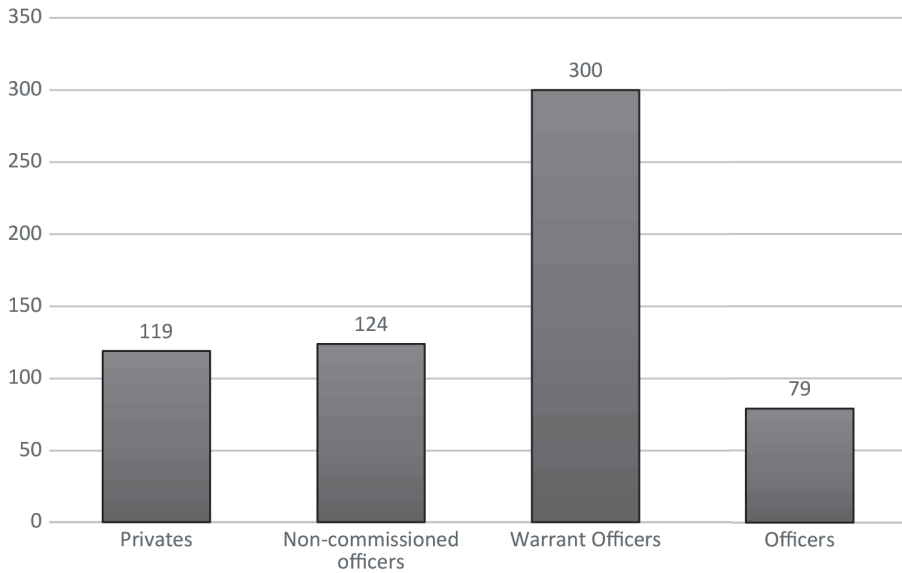
The group of respondents included 622 officers of the SFS. Among them, the largest group was represented by firefighters of district fire stations of the SFS, i.e. 45.5%, the second group was represented by firefighters of municipal fire stations of the SFS, i.e. 34.41%. Those serving in Fire Service Schools of the SFS made up 19.13% of the respondents. Other officers serving in the National Headquarters and Provincial (Regional) Headquarters of SFS made up 0.96% of the respondents. Details are shown in Figure 2.

The largest group of respondents were warrant officers at 48.23%, followed by non-commissioned officers at 19.94% and privates firefighters at 19.13%. The smallest percentage of respondents were officers, 12.70%. A summary of the number of respondents by corps is shown in Figure 3.

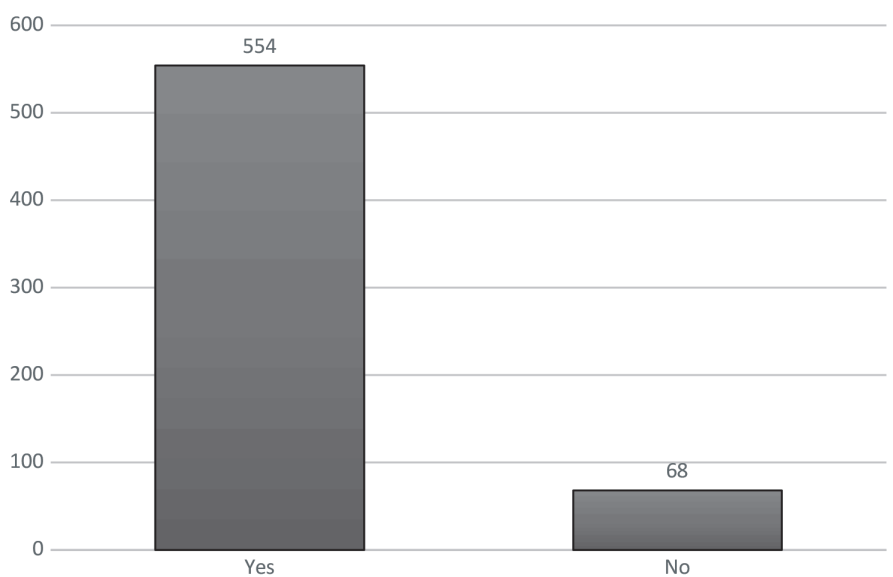
Among the respondents were 89.07% of the SFS officers on duty in the fire and rescue (operational) units of the SFS, the so-called in Polish *combat division*. 10.93% were 8-hour employees of fire stations and operational on-call officers of command posts working on a 24-hour basis. The number of people who reported working in the fire and rescue unit is shown in Figure 4.



**Figure 2.** Distribution of respondents by type of organizational unit  
Source: own study.



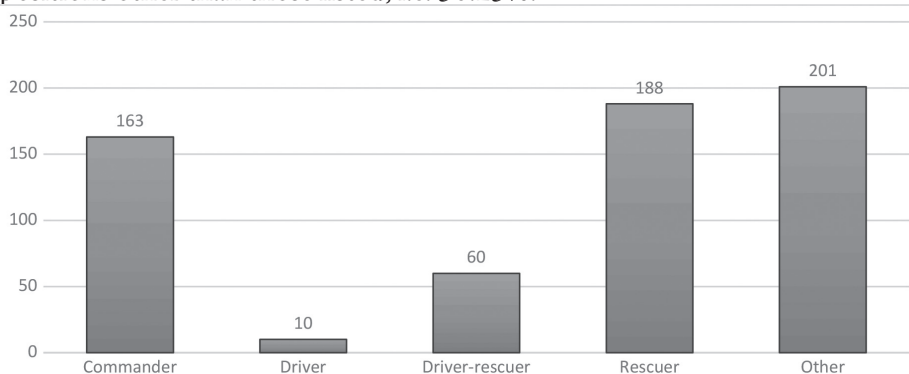
**Figure 3.** Distribution of respondents by corps  
Source: own study.



**Figure 4.** Values with responses to the question:  
*Do you serve in a fire and rescue (operational) unit?*

Source: own study.

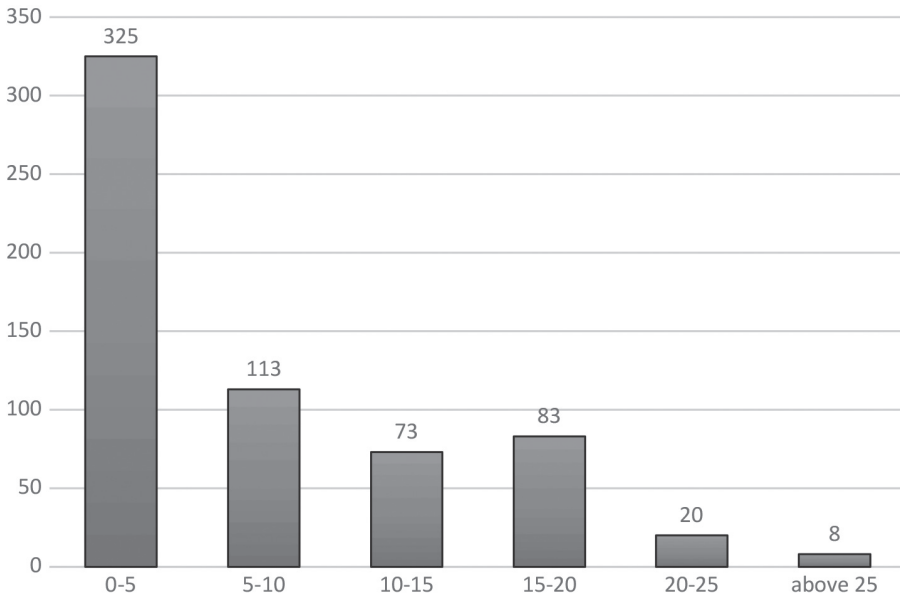
An analysis of the structure of respondents by occupation (Figure 5) shows that the largest number of questionnaires were filled in by those holding positions other than those listed, i.e. 30.23%.



**Figure 5.** Distribution of respondents by the position they hold

Source: own study.

The respondents mainly consisted of those in service for no more than 5 years i.e. 52.25%, the least numerous group were those with more than 25 years of service i.e. 1.25%. The index of values obtained is presented in detail in Figure 6.



**Figure 6.** Distribution of respondents by years of service in SFS

Source: own study.

The research results presented on the implemented organizational solutions are based on the adopted theoretical and methodological construct. The answers to the first question show that the division into clean and dirty zones has been implemented by a large majority (table 2). As many as 92.23% of the respondents answered definitely yes and rather yes. In contrast, only 1.93% of respondents found it difficult to answer this question. Only 5.79% of respondents indicated that there were no clean and dirty zones. On a five-point Likert scale (with 1 being the lowest and 5 being the highest), the average for this question was 4.53. The percentage distribution of responses to question 1 by respondents' organizational unit is shown in table 3.

**Table 2.** Answers to the question about the implementation of clean and dirty zoning in units

| Type of answer to the question: <i>Does your facility have clean and dirty zoning?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 437                 | 70,26          |
| rather yes   | 137                 | 22,03          |
| difficult to say (don't know)  | 12                  | 1,93           |
| rather not   | 14                  | 2,25           |
| definitely not   | 22                  | 3,54           |

Source: own study.

**Table 3.** Answers to the question about the percentage distribution of responses to the question about the division into clean and dirty zones in the respective units

| Unit name, type, number and percentage of responses |                     | definitely yes | rather yes | difficult to say (don't know) | rather not | definitely not |
|---|---------------------|----------------|------------|-------------------------------|------------|----------------|
| Headquarters of the SFS                             | Number of responses | 2              | 0          | 0                             | 0          | 0              |
|   | Percentage [%]      | 100            | 0          | 0                             | 0          | 0              |
| Provincial headquarters of the SFS                  | Number of responses | 0              | 0          | 0                             | 0          | 4              |
|   | Percentage [%]      | 0              | 0          | 0                             | 0          | 100            |
| Municipal headquarters of the SFS                   | Number of responses | 149            | 48         | 8                             | 2          | 6              |
|   | Percentage [%]      | 69,95          | 22,54      | 3,76                          | 0,94       | 2,82           |
| District headquarters of the SFS                    | Number of responses | 182            | 72         | 4                             | 12         | 12             |
|   | Percentage [%]      | 64,54          | 34,29      | 1,41                          | 4,44       | 4,44           |
| Fire Schools  | Number of responses | 218            | 51         | 2                             | 6          | 5              |
|   | Percentage [%]      | 77,30          | 18,09      | 0,71                          | 2,13       | 1,77           |

Source: own study.

Those who marked no zoning in the next question were asked to answer whether any work had been done on their implementation (table 4). Thus, 61.11% confirmed work on their implementation. A percentage of 16.67 survey participants did not know whether such work was being done. In contrast, 22.22% of respondents indicated that no such work had been done.

**Table 4.** Answers to the question about the percentage of responses to the question about work on implementing clean and dirty zoning

| Type of answer to the question: <i>Is there any work underway or planned in your unit to introduce clean and dirty zones?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 4                   | 11,11          |
| rather yes  | 18                  | 50,00          |
| difficult to say (don't know)   | 6                   | 16,67          |
| rather not  | 4                   | 11,11          |
| definitely not  | 4                   | 11,11          |

Source: own study.

With regard to compliance with the rules on clean/dirty zoning, almost one-third of the survey participants (32.32%) indicated that these provisions were definitely complied with and 40.35% said that they were rather complied with (table 5). In contrast, 13.50% of respondents found it difficult to comment on the subject. A total of 13.83% were in favour of not adhering to zoning-related hygiene rules. The average on the Likert scale for this question was 3.87.

**Table 5.** Answers to the question about the percentage of responses to the hygiene compliance question related to the division of clean and dirty areas

| Type of answer to the question: <i>Does your facility comply with hygiene regulations regarding the separation of clean and dirty areas?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 201                 | 32,32          |
| rather yes   | 251                 | 40,35          |
| difficult to say (don't know)  | 84                  | 13,50          |
| rather not   | 59                  | 9,49           |
| definitely not   | 27                  | 4,34           |

Source: own study.

The third question related to the existence of instructions for the cleaning of clothes, the use of personal protective equipment and the disinfection and washing of vehicles in the units.

The received answers show that in 77.18% of the firefighting units in which the respondents serve such instructions have been introduced (table 6). On the other hand, 14.79% of the respondents declare their absence and 8.04% do not know whether such instructions have been introduced. The detailed values are presented in Table 5. The average score on the Likert scale for this question was 4.04.

**Table 6.** Answers to the question about the implementation of instructions for cleaning of clothing and use of PPE, disinfection and washing of vehicles

| Type of answer to the question: <i>Has your unit implemented procedures for cleaning clothing, using personal protective equipment (PPE), disinfecting, and washing vehicles?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 279                 | 44,86%         |
| rather yes  | 201                 | 32,32%         |
| difficult to say (don't know)   | 50                  | 8,04%          |
| rather not  | 70                  | 11,25%         |
| definitely not  | 22                  | 3,54%          |

Source: own study.

Regarding the provision of resources and a specially designated place for washing and disinfecting special clothing, the majority of respondents, i.e. 93.25%, confirmed having such a place (table 7).

On the other hand, 17 people answered rather not and 19 people answered definitely not, indicating some shortcomings. Only 6 people answered that it was difficult for them to say. These results show that most units provide adequate means and space for washing and disinfecting special clothing. The average Likert scale score for this question was quite high at 4.63.

**Table 7.** Answers to the question about the provision of resources and specially designated places for washing and disinfecting special clothes (washing machines or laundry machines) in the units of the SFS

| Type of answer to the question: <i>Does your unit have the means and a designated place for washing and disinfecting special clothing (washing machines or laundry facilities)?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 486                 | 78,14          |
| rather yes  | 94                  | 15,11          |
| difficult to say (don't know)   | 6                   | 0,96           |
| rather not  | 17                  | 2,73           |
| definitely not  | 19                  | 3,05           |

Source: own study.

Referring to the inquiry about the device for drying special clothes, it is worth highlighting the value obtained, i.e. as many as 91% of those asked confirmed having a separate device for this purpose (table 8). Only 1.77% of respondents found it difficult to answer this question. The absence of such a device was declared by 7.24% of respondents. The average indication on the Likert scale for this question was 4.1.

**Table 8.** Responses regarding the provision of a separate facility for drying special clothing

| Type of answer to the question: <i>Does your unit have a separate unit for drying specialty clothes?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 500                 | 80,39          |
| rather yes   | 66                  | 10,61          |
| difficult to say (don't know)  | 11                  | 1,77           |
| rather not   | 20                  | 3,22           |
| definitely not   | 25                  | 4,02           |

Source: own study.

When asked about having a separate washing machine or one that washes only underwear, shirts, etc., 88.74% of respondents answered in the affirmative (table 9). 3.86% were undecided. A negative answer was given by 7.39% of respondents. The average on the Likert scale for this question was 4.55.

**Table 9.** Responses regarding the provision of a separate laundry room or washing machine in the units for the exclusive washing of underwear, shirts, etc.

| Type of answer to the question: <i>Does your unit have a separate laundry room or washing machine for underwear, shirts, etc.?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 471                 | 75,72          |
| rather yes   | 81                  | 13,02          |
| difficult to say (don't know)  | 24                  | 3,86           |
| rather not   | 31                  | 4,98           |
| definitely not   | 15                  | 2,41           |

Source: own study.

On the other hand, when asked about the provision of resources and a specially designated place for washing and disinfecting respiratory protective equipment (SOUO) by their unit, 81.67% of respondents answered in the affirmative (table 10). More than 3% of respondents could not answer this question. On the other hand, 14.79% of respondents answered that their units do not provide resources and special dedicated areas for washing and disinfecting SOUO. The average indication on the Likert scale for this question was 4.22.

**Table 10.** Responses regarding the provision of resources and a specially designated place in the units for washing and disinfection of respiratory protective equipment (SOUO)

| Type of answer to the question: <i>Does your unit have the means and a dedicated area for washing and disinfecting respiratory protective equipment (SOUO)?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 402                 | 64,63          |
| rather yes  | 106                 | 17,04          |
| difficult to say (don't know)   | 22                  | 3,54           |
| rather not  | 31                  | 4,98           |
| definitely not  | 61                  | 9,81           |

Source: own study.

Another question referred to having a sanitary corner in fire vehicles for pre-washing and disinfecting equipment at the scene of an incident. The questionnaires analyzed showed that 46.95% of respondents answered that their fire vehicles have such a corner. In contrast, 12.54% found it difficult to answer this question. On the other hand, 40.52% of respondents answered that there are no sanitary corners in their vehicles (table 11). The average Likert scale response value reached 3.06

**Table 11.** Responses regarding the provision of a sanitary corner in fire vehicles for the initial washing and disinfection of equipment at the scene of an incident

| Type of answer to the question: <i>Do fire vehicles have a sanitary corner for pre-washing and disinfecting equipment at the scene?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 126                 | 20,26          |
| rather yes  | 166                 | 26,69          |
| difficult to say (don't know)   | 78                  | 12,54          |
| rather not  | 124                 | 19,94          |
| definitely not  | 128                 | 20,58          |

Source: own study.

Concerning the provision of an ad hoc (second) set of special clothing, 31.07% of those questioned indicated that their organizational unit does not provide an ad hoc set. At the same time, as many as 60.77% of respondents have a spare set of special clothing. In contrast, 9.49% of those surveyed did not know whether the unit provides it (table 12). The average on the Likert scale calculated from all indications for this question was 3.53.

**Table 12.** Responses regarding provision of an ad hoc (second) set of special clothing

| Type of answer to the question: <i>Does the unit provide you with an ad hoc (second) set of special clothing in case the first one gets dirty?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 218                 | 35,05          |
| rather yes   | 160                 | 25,72          |
| difficult to say (don't know)  | 59                  | 9,49           |
| rather not   | 99                  | 15,92          |
| definitely not   | 88                  | 14,15          |

Source: own study.

The majority of respondents, i.e. 90.04%, believe that their firefighting units provide FFP-type respirators (table 13). The opposite opinion is held by 4.5% of respondents. On the other hand, 4.47% of officers cannot give a specific answer. The average on the Likert scale for the question was 4.48.

**Table 13.** Responses regarding the provision of FFP-type respirators

| Type of answer to the question: <i>Does your unit provide you with FFP type respirators?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 397                 | 63,83          |
| rather yes   | 163                 | 26,21          |
| difficult to say (don't know)  | 34                  | 4,47           |
| rather not   | 18                  | 2,89           |
| definitely not   | 10                  | 1,61           |

Source: own study.

For the vast majority of respondents as many as 99.22% answered in the affirmative to the question regarding the provision of disposable medical gloves by their unit (table 14). Only 0.64% were unsure of the answer. In contrast, 0.16% responded negatively. The indicated mean on the Likert scale for the question in question was 4.86.

**Table 14.** Responses regarding provision of disposable medical gloves, e.g. nitrile, latex, etc.

| Type of answer to the question: <i>Does the organizational unit provide you with disposable medical gloves, e.g. nitrile, latex, etc.?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 541                 | 86,98          |
| rather yes   | 76                  | 12,22          |
| difficult to say (don't know)  | 4                   | 0,64           |
| rather not   | 1                   | 0,16           |
| definitely not   | 0                   | 0              |

Source: own study.

The survey found that 35.69% of respondents had participated in training on cleaning and maintenance of special clothing (PPE). Nearly 10% of respondents did not know whether they had received training in this area, and as many as 54.67% of respondents had not participated in training (table 15). The average indication on the Likert scale for the question asked was 2.63.

**Table 15.** Responses to training on cleaning and maintenance of special clothing (PPE)

| Type of answer to the question: <i>Have you attended training on cleaning and maintenance of special clothing (PPE)?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 103                 | 16,56          |
| rather yes   | 119                 | 19,13          |
| difficult to say (don't know)  | 60                  | 9,65           |
| rather not   | 126                 | 20,26          |
| definitely not   | 214                 | 34,41          |

Source: own study.

This is because the majority of respondents, 60.45%, believe that cancer prevention topics are covered during in-service training. The second largest group of respondents, i.e. 21.86%, answered that topics on cancer prevention are not covered in training courses. In contrast, 17.68% of respondents found it difficult to answer (table 16). The average on the Likert scale for the question in question was 3.58.

**Table 16.** Responses regarding cancer prevention topics during in-service training courses

| Type of answer to the question: <i>Are cancer prevention topics covered during in-service training?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 176                 | 28,30          |
| rather yes  | 200                 | 32,15          |
| difficult to say (don't know)   | 110                 | 17,68          |
| rather not  | 81                  | 13,02          |
| definitely not  | 55                  | 8,84           |

Source: own study.

To the question: After returning from an incident in which special clothing (PPE) is contaminated, is it transported in a place other than the vehicle cab? 29.26% of respondents circled the answer in the affirmative. In contrast, 14.63% did not know the answer to this question. Very importantly, the majority of respondents, 56.11%, said that clothes are not transported in a place other than the cab of the vehicle (table 17). The calculated average on the Likert scale reached 2.62.

**Table 17.** Responses to carrying contaminated special clothing (PPE) outside the vehicle cab

| Type of answer to the question: <i>After returning from an incident in which special clothing (PPE) was contaminated, is it transported in a place other than the cab of the vehicle?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 77                  | 12,38          |
| rather yes  | 105                 | 16,88          |
| difficult to say (don't know)   | 91                  | 14,63          |
| rather not  | 201                 | 32,32          |
| definitely not  | 148                 | 23,79          |

Source: own study.

Responses to the next question were intended to indicate whether units practice disinfecting fire vehicles upon return from each fire. They show that only 37.3% of the fire stations where respondents serve practice disinfection of fire vehicles after returning from each trip. On the other hand, its absence was indicated by as many as 46.47% of respondents, and 16.24% did not know if it is practiced. In an additional question, respondents were asked how the vehicles are disinfected. Most indicated ozonating the cars and washing them on a pressure washer from the outside. In addition, firefighters use an alcohol-based windshield cleaner, and in a few cases a specialized disinfectant was indicated (table 18). The average on the Likert scale for this question equals 2.81.

**Table 18.** Responses regarding disinfection of fire vehicles after returning from each fire

| Type of answer to the question: <i>Does your unit practice disinfecting fire vehicles after returning from each fire?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 65                  | 10,45          |
| rather yes  | 167                 | 26,85          |
| difficult to say (don't know)   | 101                 | 16,24          |
| rather not  | 165                 | 26,53          |
| definitely not  | 124                 | 19,94          |

Source: own study.

In another question about firefighters' initial removal of contamination from PPE after operations before returning to the firehouse, 73.64% of respondents gave an affirmative answer. In contrast, 14.45% of respondents gave a negative answer. 12.22% of respondents found it difficult to comment on this subject (table 19). The average on the Likert scale for this question was 3.84.

**Table 19.** Responses to initial removal of contamination from PPE after operations, before returning to the fire station

| Type of answer to the question: <i>Do you pre-remove contaminants from your PPE after operations before returning to the fire station?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 166                 | 26,69          |
| rather yes   | 292                 | 46,95          |
| difficult to say (don't know)  | 76                  | 12,22          |
| rather not   | 74                  | 11,90          |
| definitely not   | 14                  | 2,25           |

Source: own study.

On the question of using soapy water or wet wipes to wash off as much dirt as possible after firefighting activities at the scene of action, 41.47% of the firefighters interviewed indicated that they wash off dirt this way. It was difficult for 12.54% of respondents to answer this question, and very importantly, as many as 45.98% do not wash off contaminants in this way after firefighting activities at the scene of action (table 20). The average on the Likert scale was 2.94 for this question.

**Table 20.** Responses regarding initial cleanup with soapy water or wet wipes at the site of operations

| Type of answer to the question: <i>Do you use soapy water or wet wipes to wash off as much dirt as possible after firefighting activities at the scene?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 84                  | 13,50          |
| rather yes  | 174                 | 27,97          |
| difficult to say (don't know)   | 78                  | 12,54          |
| rather not  | 192                 | 30,87          |
| definitely not  | 94                  | 15,11          |

Source: own study.

The majority of respondents, i.e. 73.31%, always use the self-contained breathing apparatus (SCBA) in a post-fire environment or during firefighting, and 9.00% of respondents found it difficult to answer this question. What may be surprising is that a negative answer was given by 17.68% of the firefighters surveyed (table 21). The average value for the question is 3.79 on the Likert scale.

**Table 21.** Responses regarding use of the SCBA in post-fire environment or during firefighting

| Type of answer to the question: <i>Do you always use the SCBA in a post-fire environment or during firefighting?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 157                 | 25,24          |
| rather yes   | 299                 | 48,07          |
| difficult to say (don't know)  | 56                  | 9,00           |
| rather not   | 96                  | 15,43          |
| definitely not   | 14                  | 2,25           |

Source: own study.

The survey shows that 71.06% of respondents always use FFP respirators in a post-fire environment or during a fire. In contrast, 11.25% of respondents find it difficult to answer this question. In addition, and importantly, 17.69% of respondents still do not use respirators (table 22). 3.73 is the average value on the Likert scale for the question in question.

**Table 22.** Responses regarding the use of FFP respirators in a post-fire environment or during firefighting

| Type of answer to the question: <i>Do you always use FFP respirators in post-fire environments or during firefighting?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 139                 | 22,35          |
| rather yes   | 303                 | 48,71          |
| difficult to say (don't know)  | 70                  | 11,25          |
| rather not   | 90                  | 14,47          |
| definitely not   | 20                  | 3,22           |

Source: own study.

Extremely important in the context of cancer prevention is the fact that as many as 78.46% of surveyed firefighters use disposable medical gloves during firefighting operations. It was hard for 4.82% of respondents to answer this question. In contrast, 16.72% do not use gloves (table 23). The average value is 4.04 on the Likert scale.

**Table 23.** Responses to the use of disposable medical gloves, e.g., nitrile, latex under special gloves

| Type of answer to the question: <i>Do you use disposable medical gloves, e.g. nitrile, latex under special gloves, during firefighting operations?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 280                 | 45,02          |
| rather yes   | 208                 | 33,44          |
| difficult to say (don't know)  | 30                  | 4,82           |
| rather not   | 84                  | 13,5           |
| definitely not   | 20                  | 3,22           |

Source: own study.

The affirmative answer to the question: *Do you shower within an hour after firefighting operations in which you participated?* was given by 81.67% of respondents. The remaining 10.13% of respondents do not shower within an hour after returning to the fire station, and 8.20% of the remaining respondents could not clearly answer this question (table 24). The average reached 4.07 on the Likert scale.

**Table 24.** Responses regarding taking a shower within an hour after returning to the firehouse after firefighting activities

| Type of answer to the question: <i>After firefighting activities in which you participated, do you shower within an hour after returning to the firehouse?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 231                 | 37,14          |
| rather yes   | 277                 | 44,53          |
| difficult to say (don't know)  | 51                  | 8,20           |
| rather not   | 53                  | 8,52           |
| definitely not   | 10                  | 1,61           |

Source: own study.

The next question was about changing into clean clothes after firefighting activities immediately after returning to the firehouse. Most of the firefighters surveyed, i.e. 75.24%, circled an affirmative answer. More than 9.97% of respondents could not give a clear answer to this question. On the other hand, 14.15% of respondents do not change into clean clothes right after returning to the fire station (table 25). The average response value was 3.94 on the Likert scale.

**Table 25.** Responses regarding changing into clean clothes shortly after returning to the firehouse after firefighting operations are completed

| Type of answer to the question: <i>After firefighting activities in which you participated, do you change into clean clothes immediately back at the fire station?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 230                 | 36,98          |
| rather yes   | 238                 | 38,26          |
| difficult to say (don't know)  | 62                  | 9,97           |
| rather not   | 76                  | 12,22          |
| definitely not   | 12                  | 1,93           |

Source: own study.

The survey showed that 40.19% of respondents still carry or used to carry special clothing (PPE) in the boot of a private car. More than 6% of respondents had difficulty giving a specific answer. In contrast, the majority, or 53.7%, of respondents do not transport special clothing in their private cars (table 26). The averaged value of the responses is 3.27 on the Likert scale.

**Table 26.** Responses on carrying special clothing (PPE) in the boot of a private car

| Type of answer to the question: <i>Do you try not to carry special clothing in the boot of your private car?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| definitely yes   | 106                 | 17,04          |
| rather yes   | 144                 | 23,15          |
| difficult to say (don't know)  | 38                  | 6,11           |
| rather not   | 145                 | 23,31          |
| definitely not   | 189                 | 30,39          |

Source: own study.

The majority of firefighters, i.e. 89.39%, wash their special clothing after each action or every few actions, in which it was soiled. Only a small number of firefighters i.e. 9.65% wash the special clothing less frequently, once a quarter or at least twice a year. A negligible number of firefighters i.e. 0.96% do not wash special clothing at all (table 27).

**Table 27.** Responses regarding frequency of washing special clothing

| Type of answer to the question: <i>How often do you wash specialty clothing?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| After each action in which it was soiled   | 303                 | 48,71          |
| Every few actions in which it was exposed to dirt                                | 253                 | 40,68          |
| Quarterly  | 37                  | 5,95           |
| At least twice a year  | 23                  | 3,70           |
| I don't wash   | 6                   | 0,96           |

Source: own study.

As many as 70.74% of the firefighters surveyed clean their firefighter's helmet after every action in which it was soiled or every few actions in which it was exposed to dirt. Only 22.83% of respondents answered that they clean their helmet less frequently, i.e. once a quarter or at least twice a year. Only 6.43% admitted that they do not clean their helmet (table 28). In a follow-up question, firefighters were asked how they clean their helmet. Most indicated water and soap as a means of disinfecting dirt. A small number of respondents indicated that they wash their helmets in a mask washer.

**Table 28.** Responses regarding frequency of firefighter helmet cleaning

| Type of answer to the question: <i>How often do you clean a firefighter's helmet?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| After each action in which it was soiled  | 189                 | 30,23          |
| Every few actions in which it was exposed to dirt                                     | 251                 | 40,51          |
| Once a quarter  | 90                  | 14,47          |
| At least twice a year   | 52                  | 8,36           |
| I don't clean   | 40                  | 6,43           |

Source: own study.

Responses to a question on the frequency of cleaning handheld equipment (flashlights, radios, etc.) show that as many as 68.49% of the firefighters surveyed clean their handheld equipment after every action in which it was soiled or every few actions in which it was exposed to dirt. In contrast, 8.86% of those surveyed clean their equipment less frequently, i.e. once a quarter or at least twice a year. The remaining 16.24% do not clean their handheld equipment (table 29).

**Table 29.** Responses regarding frequency of cleaning of handheld equipment

| Type of answer to the question: <i>How often do you clean your handheld equipment (flashlights, radios, etc.)?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| After each action in which it was soiled   | 244                 | 39,23          |
| Every few actions in which it was exposed to dirt  | 182                 | 29,26          |
| Once a quarter   | 52                  | 8,86           |
| At least twice a year  | 43                  | 6,91           |
| I don't clean  | 101                 | 16,24          |

Source: own study.

When asked about the frequency of washing special gloves, the majority of firefighters, i.e. 77.82%, confirmed that they wash their gloves after every operation in which they were soiled or every few operations in which they were exposed to dirt. Only 14.63% of the respondents wash their gloves once a quarter or at least twice a year, and 7.56% do not wash them at all (table 30).

**Table 30.** Responses regarding frequency of washing special gloves

| Type of answer to the question: <i>How often do you wash special gloves?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| After each action in which it was soiled                                     | 255                 | 41,00          |
| Every few actions in which it was exposed to dirt                            | 229                 | 36,82          |
| Once a quarter   | 45                  | 7,23           |
| At least twice a year  | 46                  | 7,40           |
| I don't wash   | 47                  | 7,56           |

Source: own study.

Responses to the next question show that 71.38% of respondents clean their special footwear after every action in which they were soiled, or every few actions in which they were exposed to dirt. Special footwear is cleaned once a quarter or at least twice a year by 20.58% of respondents, and importantly, still 8.04% of firefighters do not clean their footwear (table 31).

**Table 31.** Responses regarding frequency of cleaning of special shoes

| Type of answer to the question: <i>How often do you clean special shoes?</i> | Total               |                |
|--|---------------------|----------------|
|  | Number of responses | Percentage [%] |
| After each action in which it was soiled                                     | 194                 | 31,19          |
| Every few actions in which it was exposed to dirt                            | 250                 | 40,19          |
| Once a quarter   | 88                  | 14,15          |
| At least twice a year  | 40                  | 6,43           |
| I don't clean  | 50                  | 8,04           |

Source: Own study

It is worth noting that the vast majority, 94.09% of firefighters, wash the balaclava after each action in which it was soiled or every few actions in which it was exposed to dirt. Only a small number of respondents, i.e. 5.95%, wash the balaclava once a quarter or at least twice a year. A negligible number of firefighters i.e. 0.96% do not wash their balaclava (table 32).

**Table 32.** Responses regarding frequency of washing of firefighter's balaclava

| Type of answer to the question: <i>How often do you wash a firefighter's balaclava?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| After each action in which it was soiled  | 375                 | 60,29          |
| Every few actions in which it was exposed to dirt                                       | 204                 | 33,80          |
| Once a quarter  | 23                  | 3,70           |
| At least twice a year   | 14                  | 2,25           |
| I don't wash  | 6                   | 0,96           |

Source: own study.

When asked about cleaning and disinfecting SCBA masks after each use, almost all respondents i.e. 95.02% answered in the affirmative. Only 3.54% of firefighters had difficulty answering the question. In contrast, a negligible number of respondents, i.e. 1.45%, do not clean and disinfect masks after each use (table 33).

**Table 33.** Responses regarding cleaning and disinfection of SCBA masks.

| Type of answer to the question: <i>Are SCBA masks cleaned and disinfected after each use?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 488                 | 78,46          |
| rather yes  | 103                 | 16,56          |
| difficult to say (don't know)   | 22                  | 3,54           |
| rather not  | 8                   | 1,29           |
| definitely not  | 1                   | 0,16           |

Source: own study.

On the other hand, based on the results obtained regarding the cleaning of the cylinder backpack and cylinder (SCBA), it can be concluded that 62.06% of the respondents clean the APB stretcher and cylinder after each action in which they were used. More than 15% of respondents could not answer this question. In contrast, 22.18% of firefighters marked the answers: *rather not* and *definitely not* (table 34).

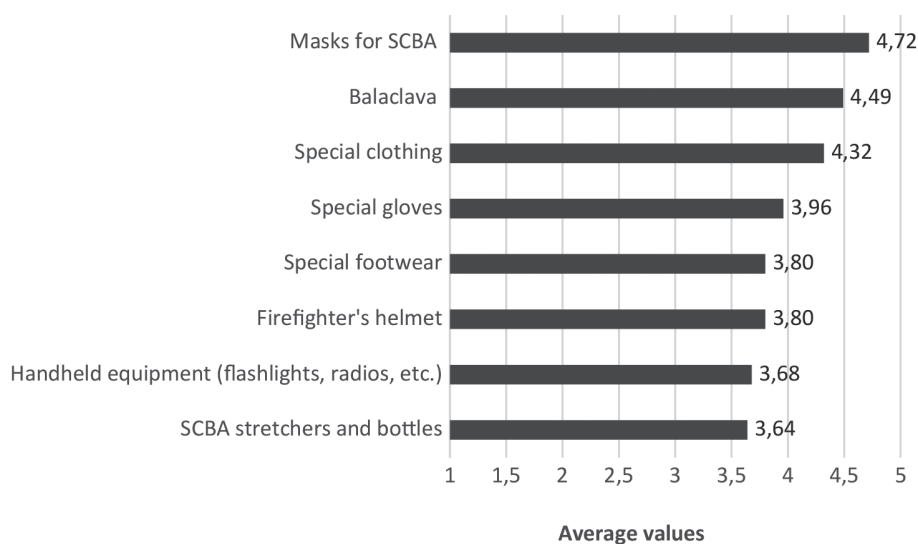
**Table 34.** Responses to cleaning and disinfecting the cylinder backpack and cylinder for the SCBA

| Type of answer to the question: <i>Are cylinder backpack and cylinder (SCBA) cleaned after each action in which they were used?</i> | Total               |                |
|---|---------------------|----------------|
|   | Number of responses | Percentage [%] |
| definitely yes  | 184                 | 29,58          |
| rather yes  | 202                 | 32,48          |
| difficult to say (don't know)   | 98                  | 15,76          |
| rather not  | 107                 | 17,20          |
| definitely not  | 31                  | 4,98           |

Source: own study.

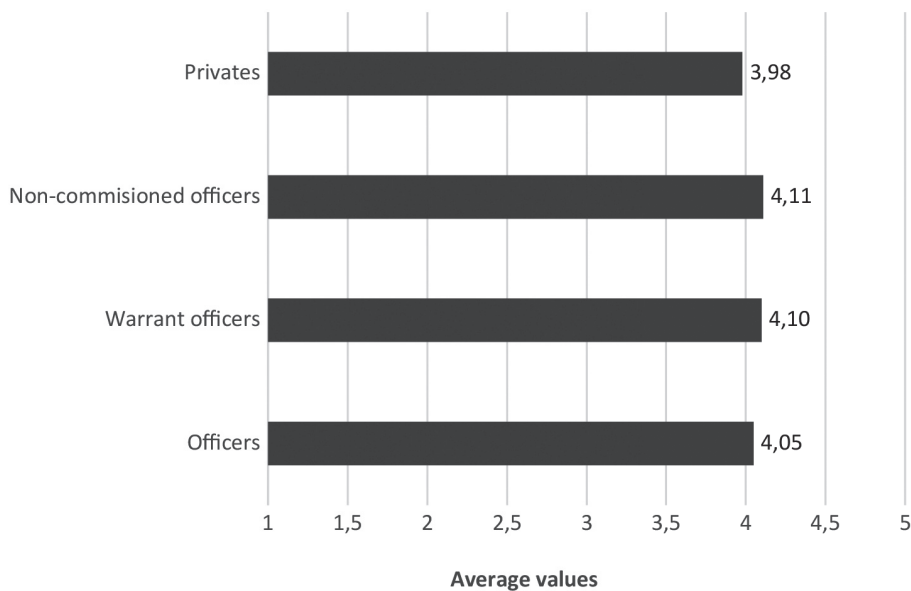
The average frequency of cleaning for each PPE and personal equipment item is shown in Figure 7.

The averaged values for the overall frequency of cleaning of PPE and personal equipment by body are shown in Figure 8. A higher value of the average indicates a higher frequency of cleaning, for example, a value of 5 would indicate that cleaning occurs after every soiling. A value of 1, on the other hand, indicates no cleaning at all.



**Figure 7.** Values for frequency of cleaning of individual PPE and personal equipment

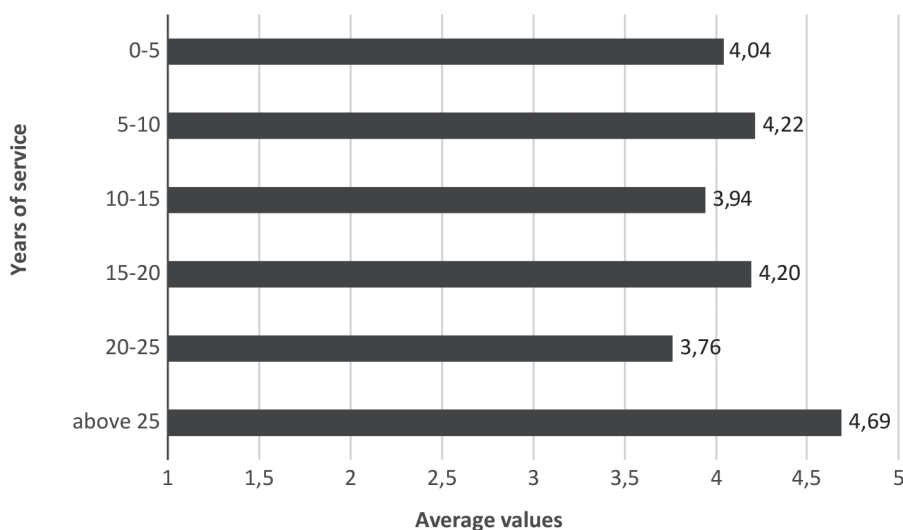
Source: own study.



**Figure 8.** Frequencies of cleaning of PPE and personal equipment according to corps classification

Source: own study.

Meanwhile, Figure 9 shows the average values for the overall frequency of PPE cleaning according to the number of years of service in the fire department.



**Figure 9.** Frequency of cleaning of PPE and personal equipment according to number of years of service in the SFS

Source: own study.

## Discussion

The survey results indicate that only one-third of officers transport contaminated turnout gear outside of the cab when returning from an incident where it was contaminated. However, 40% of officers transport special clothing in their personal vehicles, which should prompt greater efforts to improve cancer prevention and safety culture in the fire service. This is supported by findings that firefighters pay the least attention to keeping their helmets, footwear and special gloves clean. Improvement in organizational factors is indicated by the information that less than two-thirds of the units surveyed clean stretchers and cylinders after each incident in which they are soiled, and one-third of the firefighters surveyed are not provided with special

emergency clothing. It may be alarming to learn that more than 55% of respondents have not participated in any special clothing cleaning training.

It is now two years since the introduction of the mandatory designation of clean and dirty zones in Fire and Rescue Units. The survey shows that the level of implementation of solutions is high. Only a small number of respondents, i.e. 5.79%, answered that this division has not been implemented. It has become standard to separate special rooms with appropriate equipment for exclusive cleaning of protective clothing and for disinfection of SOUO. However, there is still the problem of substitute special clothing for washing. It seems glaring that 31.07% of respondents are not provided with an ad hoc set of special clothing. The proposed solution in this case would be to purchase several sets of special clothing in the most common sizes as a reserve in case they need to wash their set. According to the authors, in the case of units with a small budget, this solution seems most reasonable. It definitely seems reasonable for manufacturers to conduct training on cleaning and maintenance of special clothing, since almost 55% of people have not participated in such training. The authors' most important observations relate to the initial decontamination process. The deficit of sanitary corners in fire trucks is declared by 40.52% of respondents, which may in the long run project the fact that as many as 45.98% of respondents do not wash off dirt after firefighting operations on the scene. In addition, when returning to the fire station, as many as 56.11% carry contaminated special clothing in the cab of the fire truck, thus creating a secondary exposure risk for the entire squad. It would therefore be necessary to designate space in fire trucks for basic disinfectants, replacement clothing, and the safe transportation of contaminated special clothing so that it arrives safely at the cleaning site. In addition, 46.47% indicated that fire trucks are not disinfected after returning from each fire. The information collected on firefighters' personal practices after returning to the firehouse indicates that they take care of both hygiene and cleanliness of personal protective equipment. Analyzing the averaged values for the overall frequency of cleaning PPE and personal equipment, differences can be observed considering the firefighters' years of service. The worst of the studied group are firefighters from the ranges: 20-25 years of service and up to 5 years

of service. However, there is no clear correlation that this factor improves or weakens with seniority.

## Conclusions

Protecting firefighters from secondary exposure to toxic products of thermal decomposition and combustion is a complex task. The results of the survey indicate that the chosen direction of broadly understood prevention is correct, and at the same time it should be emphasized that firefighters in their workplaces approach the subject under discussion in a reasonable and conscientious manner. Nevertheless, there are still many areas where broadly understood cancer prevention could be improved without large financial outlays.

**Abstract:** Scientific studies of firefighter exposure to toxic products of thermal decomposition and combustion have resulted in the classification of this profession as causing cancer. In view of this, the priority of the activities of the formation of the State Fire Service (SFS) becomes protection from direct, but also secondary contact with these products. It is noted that protective clothing without cyclic and regular cleaning will not be able to perform its primary function due to the penetration of toxins into the material. Consequently, instead of protecting against contaminants, it will lead to contact with them. Based on these facts, special attention began to be paid to educating and raising awareness among firefighters on the proper use, cleaning and maintenance of PPE and personal equipment. It has become a requirement to separate clean and dirty areas in fire stations to ensure the preparation of this clothing and equipment for reuse. These recommendations are aimed at reducing firefighters' secondary exposure to post-fire products. The article presents the results of a survey study on the analysis and evaluation of the organization of activities and adopted practices in the fire and rescue units of the SFS in terms

of minimizing the secondary exposure of firefighters to toxic products of thermal decomposition and combustion carried out in Poland on a group of 622 professional firefighters. The results indicate the validity of the chosen direction of change, while also presenting situations and challenges that firefighters continue to face at their places of duty.

Wyniki przedstawione w artykule opracowano w oparciu o badania przeprowadzone w ramach inżynierskiej pracy dyplomowej p. G. Wrzyszczyka.

The results in the article were compiled based on the research conducted as part of the engineering diploma thesis of Mr. G. Wrzyszczyk.

**Streszczenie:** Badania naukowe dotyczące ekspozycji strażaków na toksyczne produkty rozkładu termicznego i spalania doprowadziły do zaklasyfikowania tego zawodu jako zwiększającego ryzyko zachorowania na nowotwory. W związku z tym priorytetem działań formacji Państwowej Straży Pożarnej (PSP) staje się ochrona przed bezpośrednim, ale również wtórnym kontaktem z tymi produktami. Zwraca się uwagę, że odzież ochronna, bez cyklicznego i regularnego czyszczenia, nie będzie w stanie spełniać swojej podstawowej funkcji z powodu przenikania toksyn do materiału. W konsekwencji, zamiast chronić przed zanieczyszczeniami, będzie prowadzić do kontaktu z nimi. W oparciu o te fakty szczególną uwagę zaczęto zwracać na edukację i podniesienie świadomości strażaków w zakresie właściwego użytkowania, czyszczenia i konserwacji środków ochrony indywidualnej (SOI) oraz sprzętu osobistego. Stało się to wymogiem, aby w jednostkach ratowniczo-gaśniczych wydzielać strefy czyste i brudne, co ma zapewnić przygotowanie odzieży i sprzętu do ponownego użycia. Rekomendacje te mają na celu ograniczenie wtórnej ekspozycji strażaków na produkty pożarowe. Artykuł przedstawia wyniki badań ankietowych dotyczących analizy i oceny organizacji działań

oraz przyjętych praktyk w jednostkach ratowniczo-gaśniczych PSP w zakresie minimalizowania wtórnej ekspozycji strażaków na toksyczne produkty rozkładu termicznego i spalania, przeprowadzonych w Polsce na grupie 622 zawodowych strażaków. Wyniki wskazują na zasadność obranego kierunku zmian, jednocześnie ukazując sytuacje i wyzwania, z jakimi strażacy wciąż mierzą się w miejscu pełnienia służby.

**Keywords:** direct and secondary exposure, thermal decomposition and combustion products, firefighting, personal protective equipment, organizational solutions, firefighter practices, safety engineering

**Słowa kluczowe:** bezpośrednia i wtórna ekspozycja, produkty rozkładu termicznego i spalania, działania gaśnicze, środki ochrony indywidualnej, rozwiązania organizacyjne, praktyki strażaków, inżynieria bezpieczeństwa

## References

- IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Painting, firefighting, and shiftwork. IARC Monogr Eval Carcinog Risks Hum. 2010; 98:9-764. PMID: 21381544; PMCID: PMC4781497. IARC Publications Website - Painting, Firefighting, and Shiftwork
- International Agency for Research on Cancer, IARC Monographs evaluate the carcinogenicity of occupational exposure as a firefighter, Komunikat prasowy nr 317, Lyon 2022.
- Kokot, S. et al. (2021). *Raport, Minimalizacja narażenia strażaków na toksyczne produkty pożarowe*, Okresowy Raport Najlepszych Praktyk, Olsztyn, cfbt.pl, <https://www.gov.pl/attachment/09ae14b8-3716-4496-870a-fb45b9281b2a>
- Krzemińska, S., Szewczyńska, M. (2020). Analiza i ocena zagrożeń powodowanych przez substancje chemiczne zanieczyszczające wybrane środki ochrony indywidualnej strażaka – przegląd źródeł literaturowych. *SFT*, 56(2), 92–109.

- LeMasters, G.K., Genaidy, A.M., Succop, P., Deddens, J., Sobeih, T., Barriera-Viruet, H., Dunning, K., Lockey, J. (2006). Cancer Risk Among Firefighters: A Review and Meta-Analysis of 32 Studies. *Journal of Occupational and Environmental Medicine*.
- Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 31 sierpnia 2021 roku w sprawie szczegółowych warunków bezpieczeństwa i higieny służby strażaków Państwowej Straży Pożarnej (Dz.U. z 2021 r., poz. 1681).
- Stec, A., Wolffe, T., Clinton, A. (2020). *Minimising firefighters' exposure to toxic fire effluents. Interim Best Practice Report*, University of Central Lancashire, Fire Brigades Union (FBU), Minimising firefighters' exposure to toxic fire effluents | Fire Brigades Union ([fbu.org.uk](http://fbu.org.uk))
- Tarka, P. (2015). Własności -5 i -7stopniowej skali Likerta w kontekście normalizacji zmiennych metodą Kaufmana i Rousseeuwa. W: K. Jajuga, M. Walesiak (red.), *Taksonomia 25 Klasyfikacja i analiza danych – teoria i zastosowania* (s. 286–295), Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego.