

# Methodology for testing and determining the safe subsequent use of after-use of fire protection clothing cleaned after use in accidents

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**Abstract:** The report examines and analyzes the experience and requirements for cleaning and contamination of clothing for firefighters. A study was conducted to determine the amount of contaminants found on clothes after their use in fire fighting and cleaning. An analysis of the results was carried out

**Keywords:** Clothing, firefighters, clothing contamination

## 1. Introduction

When dealing with incidents involving firefighters, a set of carcinogenic and highly toxic compounds is always released, which are not yet fully understood and can pose a threat to the health of firefighters.

This also raises the issue of the impact on firefighters' clothing and safe handling and cleaning after such fires, especially at critical infrastructure sites.

This methodology presents a review of the literature and standards for the maintenance and cleaning of firefighters' protective clothing, as well as proposing guidelines for inspection. It also contains test results that show that harmful substances accumulate in firefighters' clothes after extinguishing fires, even after cleaning.

## 2. Objective

The methodology is intended to test and compare with the criteria for safe subsequent use of cleaned fire protection clothing of firefighters.

## 3. General

Clothing for firefighters is a multicomponent specialized protective device designed for use by one person with the purpose of protecting him from the harmful environment heat radiation, chemicals, molten metals, etc. in case of firefighting and/or neutralization of accidents in the sites of the critical infrastructure.

Pilot tests on the presence of polycyclic aromatic hydrocarbons (PAHs) and formaldehyde showed that levels exceeded limits in all clothing samples [1]. When extinguishing fires in electric cars and batteries, the cobalt level is 24 times higher than what is considered safe in the test performed by igniting a car battery.

Liquid carbon dioxide (LCO<sub>2</sub>) cleaning methods can be more effective than traditional water washing. Further research is needed on the cleaning efficiency of clothes containing substances emitted by car battery fires and photovoltaic modules. Damage to the car battery results in the release of dangerous gases such as carbon monoxide (CO), hydrogen fluoride (HF), hydrogen cyanide (HCN), phosphorus oxyfluoride (POF<sub>3</sub>), which can pose a serious threat to those involved, and hydrogen (H<sub>2</sub>) or methane (CH<sub>4</sub>), which increase the development of fire and can create jet flames or even an explosion. The PV installation, in turn, contains a significant share of plastic materials, such as encapsulants, backsheet foils, junction boxes and cable insulation, which in the event of a fire emit a mixture of gases, burning droplets and solids. soot particles mixed with different organic compounds, depending on the combustion efficiency. The fires of photovoltaic installations produce smoke containing carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>) carbon fluoride (CF), cadmium (Cd), acetic acid (CH<sub>3</sub>COOH), dimethyl butane (C<sub>6</sub>H<sub>14</sub>) and aliphatic compounds, as well as various volatile organic compounds. Due to the emissions

mentioned above, photovoltaic installations and batteries during combustion create a chemical risk for firefighters. The effects of toxicity on the health of firefighters are greater when toxic substances are captured in the personal protective clothing of firefighters.

Firefighters' clothing must perform many important functions in a fire, both resistance to water, heat and fire, and provide the necessary level of comfort and safety at work.

Clothing must protect against burns, must have high mechanical characteristics, provide protection against liquid chemicals and possess optimal thermophysiological comfort to the user. For this reason, firefighters' clothing usually consists of four main layers. Outer shell, moisture protection membrane, thermal barrier layer and inner lining. Most of the materials used in the manufacture of firefighters' clothing are porous textiles made of fibers that are capable of absorbing and retaining toxic gases and vapors produced in a fire. The multi-layer structure of firefighter clothing and the absorbent properties of the fibers create obstacles to effective cleaning and removal of harmful substances accumulated in a fire. This can lead to various diseases of firefighters, as they are exposed to the substances captured and located on the surface of the personal protective equipment used, in the premises of the fire brigade, and the vehicles used. It has been found that lethal organic compounds or PAHs have a longer-term effect as a result of repeated exposure to even very small amounts (chronic toxicity) and cause adverse health effects as they accumulate and slowly develop cancer, cardiovascular, neurological diseases, etc. [26].

It is therefore highly recommended to clean protective clothing effectively after each use [27–29].

No information was found in the available literature on the criteria for determining the safe reuse of cleaned protective clothing for firefighters and how to handle this clothing contaminated by smoke from photovoltaic modules, car battery fires, as well as after fire and/or incident. These questions are the subject of the literature review presented in this methodology.

Although there are some reports on the volumetric production of toxic substances in battery and PV module fires, there is no information on how many of them could be absorbed by firefighters' clothing. Furthermore, the fire conditions which influence this phenomenon have not been investigated previously. This methodology presents experimental results that demonstrate the contamination of fire protection clothing after a fire in a storage room in an apartment building.

Existing guidelines and practice in the maintenance of firefighters' personal protective equipment described in NFPA 1851, BS 8617: 2019, EN 469:2020, EN 13911: 2017, EN ISO 15384: 2018/AMD 1:2021 and ISO 23616: 2022 [29–34].

• NFPA 1851:2020 [30], this standard includes two tree diagrams to assist in deciding how to handle, clean or dispose of PPE (personal protective equipment). Fire protection equipment is also included. The first decision tree (Fig 1) refers to general guidelines, while the second decision tree (Fig.2) is specific to

different types of contamination. The diagram shown (Fig. 1) describes the general decision-making pathway including the type of event in which PPE was used, especially if it was chemical, biological, radiological or nuclear (CBRN). The next step is an analysis of where hazardous materials (HazMat) were found. This determines whether cleaning is possible or not. PPE designated for cleaning must be treated in a specialised workshop and subjected to routine inspection. The third decision concerns other types of pollution. It is suggested that PPE should be provided to reduce firefighters' exposure to harmful substances and the type of pollution.

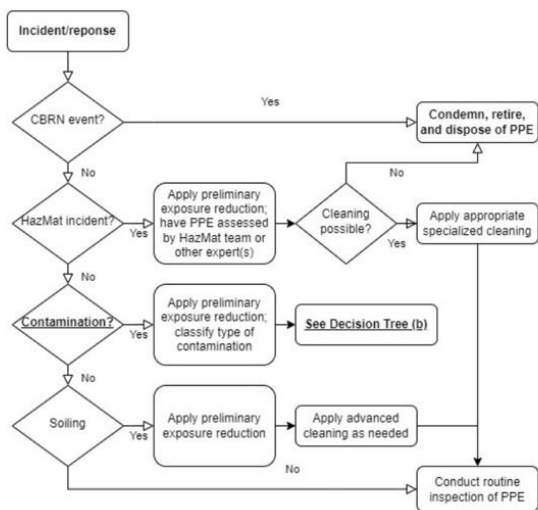


Fig.1

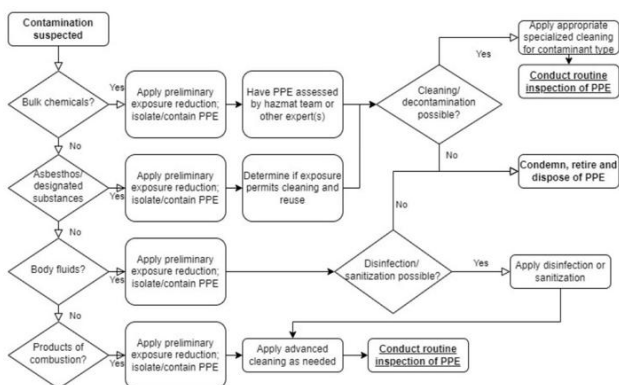


Fig.2

Cleaning and decontamination processes are to be classified as shown in Figure 2. The procedures presented on the scheme (Fig 2) refer to the order of decision when PPE is suspected to be contaminated. It consists of a check on the presence of bulk chemicals and asbestos, followed by appropriate recommendations for action. The NFPA 1851 standard also provides extended cleaning of PPE twice a year, frequency recommendations, with at least one annual expanded inspection. New general guidelines for cleaning and disinfection of protective coats and trousers are also considered, which implies a check once every two years. However, extended inspection is indicated at least once a year (as opposed to a third year in operation) or whenever a routine inspection can offer potential failure. Considering the pollutants from PV installations and car battery fires, according to the decision tree of NFPA 1851, this type of incident should be treated as a pollution with combustion products, which is a very wide group of fires, including fires in residential buildings, etc. However, it can be assumed that the types of substances in smoke can vary greatly. Although the verification of the cleaning procedure is mentioned in NFPA 1851,

this means that the service provider is obliged to send contaminated samples for testing after extended cleaning, and the result must provide at least 50% efficiency to remove the average of all surrogate heavy metal and semivolatile organic compound contamination. The maximum level of contamination is not specified. The standard specifies only the fraction to be discarded.

- BS 8617:2019 [31], this standard establishes guidelines for cleaning, maintenance and repair of various elements of firefighters' PPE to reduce potential health and safety risks resulting from poorly maintained, contaminated or damaged equipment. It includes inspection, testing, cleaning, decontamination, drying, repairs, replacement, retirement/disposal, recording, storage and transportation, but without detailed recommendations.

- EN 469:2021 [32], this standard contains minimum performance requirements for protective clothing intended for use during fire operations, including construction, protection against heat and flame, mechanical and chemical protection properties, in terms of comfort of use and visibility, distinguishing between actions performed outdoors and in buildings, in terms of protection against heat and flame.

- EN 13911:2017 [33], this standard presents minimum safety requirements and test methods for firefighter hoods to be worn during rescue and firefighting operations to protect against the effects of heat and fire.

- EN ISO 15384:2018/AMD 1:2021 [34], this standard contains test methods and minimum performance requirements for PPE designed to protect the body of users, with the exception of the head, arms and legs, which is used in outdoor firefighting and related activities. Firefighting clothing in the wild refers to clothing that is used in outdoor firefighting. However, this standard does not describe PPE maintenance procedures.

- ISO 23616:2022 [35], this standard refers to requirements, guidelines and recommendations for cleaning, inspection and repair of PPE. This standard excludes information on protective clothing against chemicals as well as the handling of CBRN protective clothing, except for the information that once PPE is used in a CBRN event, it must be secured and disposed of properly. Intermittent PPC washing and careful mechanical inspection of clothing afterwards is recommended.

The existing recommendations presented in the mentioned standards do not clearly demonstrate the correct cleaning/disposal procedures for contaminated firefighters' clothing. Furthermore, it was observed that the cleaning and decontamination processes were not for protective clothing as well as handling of CBRN protective clothing, apart from the information that once PPE is used in a CBRN event, it must be secured and disposed of properly.

Periodic washing of fire protection kits and careful mechanical inspection of clothing afterwards is recommended.

Cleaning and decontamination are often considered to be the same process. However, there is a significant difference between them. Cleaning is a more general term and includes decontamination as a more specific process [36]. When decontamination takes place, acceptable criteria must be specified. If such a guideline is met, PPE can be considered safe to use [37, 38]. Today, firefighters' clothing is not subject to contamination and the level of contaminants contained is not measured after cleaning. Clothes are most often evaluated only visually. As mentioned above, even NFPA 1851 and ISO 23616:2022 do not specify the maximum limits of toxic substances in PPE.

It can be considered that the verification described in the reviewed standards is a subjective assessment without confirmation in actual measurements that could guarantee firefighters clothing safe for subsequent use. The standards examined did not specify the regular, extended cleaning methods as necessary and that cleaning with water with detergents and with various washing programs is the most important and most common form of cleaning. The standards mainly address effective methods of removing contamination, such as LCO<sub>2</sub>. However, this new technology still needs further research. Guidelines already exist which set maximum limits for harmful substances in textiles with regard to health safety. In 2021, a new edition of the Standard 100 by OEKO-

TEX® was launched on the safety of textile products [38]. OEKO-TEX® is a registered trademark that represents product labels and company certificates issued by the International Association for Research and Testing of Textiles and Leather. Founding members are the German Institute Hohenstein and the Institut fuer Oekologie, Technik und Innovation GmbH (OETI). Currently, the Oeko-Tex Association includes 18 pcs. neutral test and research institutes with contact offices of global scope. In Annex 4 and 6 of the standard, values of various contaminants are defined which cannot be exceeded in order to obtain the OEKO-TEX® certificate. To be considered safe for use in direct skin contact or without direct skin contact - depending on the purpose of the material.

Table No. 1 lists acceptable limits for contamination according to Standard 100 from OEKO-TEX®

Table №1

Type of substance	substance	Limits	
		Direct contact with the skin	Without direct contact with the skin
Formaldehyde	Formaldehyde (mg/kg)	75,000	150,000
	Antimony (Sb) (mg/kg)	30,000	30,000
	Arsenic (As) (mg/kg)	0,200	0,200
	Lead (Pb) (mg/kg)	0,200	0,200
	Cadmium (Cd) (mg/kg)	0,100	0,100
Leachable heavy metals	Chromium (Cr) (mg/kg)	1,000	1,000
	Cobalt (Co) (mg/kg)	1,000	1,000
	Copper (Cu) (mg/kg l)	50,000	50,000
	Nickel (Ni) (mg/kg)	1,000	1,000
	Mercury (Hg) (mg/kg)	0,020	0,020
	Barium (Ba) (mg/kg)	1000,000	1000,000
	Selenium (Se) (mg/kg)	100,000	100,000
	Zinc (Zn) (mg/kg)	750,000	750,000
	Manganese (Mn) (mg/kg)	90,000	90,000
	Arsenic (as) (mg/kg)	100,000	100,000
Heavy metals (total content) (ppm/ae)	Cadmium (cd) (mg/kg)	40,000	40,000
	Mercury (g) (mg/kg)	0,500	0,500
	Sum of all phthalates (w %)	0,010	0,010
Phthalates	Sum of all phthalates (w %)	0,025	0,025
	Carcinogenic arylamines (mg/kg)	20,000	20,000
Other chemical residues	Aniline (mg/kg)	20,000	20,000
	Benzene (mg/kg)	1,000	1,000
	Bisphenol A (mg/kg)	100,000	100,000
	Bisphenol B (mg/kg)	1000,000	1000,000
	Diazene-1,2-dicarboxamide (ADCA)	0,100	0,100
	Phenol (mg/kg)	50,000	50,000
	Benzo(a)pyrene (mg/kg)	1,000	1,000
	Benzo(e)pyrene (mg/kg)	1,000	1,000
	Benzo(a)racene (mg/kg)	1,000	1,000
	Chrysene (mg/kg)	1,000	1,000
PAHs	Benzo(b)fluoranthene (mg/kg)	1,000	1,000
	Benzo(j)fluoranthene (mg/kg)	1,000	1,000
	Benzo(k)fluoranthene (mg/kg)	1,000	1,000
	Dibenzol(a,x)anthracene (mg/kg)	1,000	1,000
	Naphthalene (mg/kg)	2,000	2,000
	Sum of 24 PAHs	10,000	10,000
	Methylthylketone(mg/kg)	10,000	10,000
	Ethylbenzene(mg/kg)	10,000	10,000
	Xylene (mg/kg)	10,000	10,000
	Cyclohexanone (mg/kg)	10,000	10,000
VOCs and glycols	Styrene (mg/kg)	10,000	10,000
	Benzene (mg/kg)	1,000	1,000
	Toluene (mg/kg)	10,000	10,000
	Formaldehyde [50-00-0] (mg/cm <sup>3</sup> )	0,100	0,100
	Toluene [108-88-3] (mg/cm <sup>3</sup> )	0,100	0,100
	Styrene [104-42-3] (mg/cm <sup>3</sup> )	0,025	0,025
	Butadiene [106-99-0] (mg/cm <sup>3</sup> )	0,002	0,002
	Vinyl chloride [75-01-4] (mg/cm <sup>3</sup> )	0,002	0,002
	Aromatic hydrocarbons (mg/cm <sup>3</sup> )	0,300	0,300
	Organic volatile matter (mg/cm <sup>3</sup> )	0,500	0,500

The Product Safety Committee (AfPS) through the GS specification [39] has established acceptable limits for harmful substances that may be present in articles in contact with human skin. AfPS is the German Commission dealing with product safety. The documents they issue apply to all consumer products to be placed on the market and up to the maximum level of surfactants. Table No 2 (Limit values of PAHs set out in the GS specification by AfPS)

Table №2.

substance	Materials with long-term skin contact or Repeated short-term skin contact, [mg/kg]	Materials with short-term skin contact, [mg/kg]
Benzo(a)pyrene	<0,5	<1
Benzo(e)pyrene	<0,5	<1
Benzo(a)anthracene	<0,5	<1
Benzo(b)fluoranthene	<0,5	<1
Benzo(j)fluoranthene	<0,5	<1
Benzo(k)fluoranthene	<0,5	<1
Chrissena	<0,5	<1
Dibenzo(a,b)anthracene	<0,5	<1
Benzo(ghi)perylene	<0,5	<1
Indeno(1'2,3-cd)pyrene	<0,5	<1
phenanthrene, pyrene, anthracene	<0,5	<1
Fluoranthene	<10	<50
Naphthalene	<2	<10
Sum of 15 PAHs	<10	<50

Restrictions on the marketing and use of certain hazardous substances (defined as PAHs) mentioned above were also introduced at European level such as the European Chemicals Agency (ECHA) in the European Union regulation to improve the

protection of human health and the environment, called REACH (in Annex VII)t [40]. In none of the mentioned specifications are there any specific requirements for the handling and cleaning of firefighters' clothing

#### 4. Handling of firefighters' protective clothing: methods and practices

Currently, the type of cleaning of firefighters' protective clothing, considered the best is washing it in water with detergents. For this purpose, specialized washing machines are provided in fire stations or the service is outsourced [35]. Studies on the cleaning performance of garments with water and detergents have shown a relatively low efficiency of this method [40]. The use of intensive water washing (at a temperature of 60 °C) in specialized appliances, washing efficiency above 40% is not achieved. The levels of PAHs and other harmful substances in PPE exceed the specified maximum AfPS limits for PAHs. Researchers who evaluate the efficiency of water cleaning processes [40] summarize that there are ways that can improve it, essentially by reducing the number of clothes that are cleaned at the same time. The reduction of the storage period of contaminated PPCs before washing can also have a positive influence. For further research, ozone treatment methods or LCO<sub>2</sub> cleanup methods were recommended. A study to evaluate the ozone chamber as a routine method for the decontamination of firemen's clothing has been carried out in Madrid, Spain [41]. This study shows the limited effectiveness of such a process. It was observed that large amounts of PAH remained in the samples even after a one-hour treatment with ozone. Partial chemical degradation of PAHs occurs. The remaining concentration of PAH is the same or with more toxic oxidized PAH compounds, the creators of the process warn of potential risk. One group wore contaminated PPC (no washing), the second group wore contaminated PPC cleaned from industrial laundry (according to ISO 15797-2 [43]) and the last group wore contaminated PPC cleaned with LCO<sub>2</sub>. In the experiment, blood tests were carried out to establish the presence of harmful substances. The results showed that the firefighters who wore the most contaminated clothes (without washing), have the highest concentrations of toxic substances in their blood. The second highest results obtained were observed in the group of firefighters whose clothes were washed in an industrial washing machine with water. Finally, in the group of firefighters whose clothes had been decontaminated with LCO<sub>2</sub>, no significant increase in blood toxicants was observed. However, more research is needed to test whether the LCO<sub>2</sub> method is equally effective in removing various harmful substances from firefighters' clothing, including those emitted by car batteries and solar module fires.

#### 5. Experimental results of pollution of clothing of firefighters from fires in Sofia

Experiments to measure contamination of firefighters' clothing used in a fire in a storage room of a residential building in the town of Plovdiv. Sofia in October 2023 and after working off. Five pieces of samples were taken, with a destructive method from that described in Table 3

Table №3

Sample No	Material	Conditions for taking	Quantity
S 1	Textiles on the inside of a firefighter's half-fur coat- face fabric. The composition of the garment is 100% Aramid (2008)	Two days after working out a fire	106,8 mg
S 2	Textiles on the inside of a firefighter's coat under item 1	A day after washing	106,8 mg
S 3	Textiles on the inside of a firefighter's half-fur coat- face fabric. The composition of the garment is 40% Nomex III / 60% Kevlar (2001 year)	Two days after working out a fire	11,5 mg
S 4	Textiles on the inside of a firefighter's coat under item 3	A day after washing	10,8 mg
S 5	Foam on the inside - pad under leather fabric on a fire truck seat	Two days after working out a fire	11,5 mg

Samples were taken on the inside of the firefighters' half-coats two days after the fire had been worked out, and one day after washing when they had dried. The clothes are washed in an

automatic washing machine with granular laundry detergent for colored laundry available in the market. The composition of the detergent has a composition: (5÷15)% anionic surfactants; less than 5 % non-ionic surfactants; zeolites; polycarboxylates, phosphates; enzymes and perfumes.



Fig. 3 Chromatograph

After taking the test samples, on the inside of the firefighters' half-coats and the upholstery of the car, they were conditioned and annealed for 36 hours, then measured on an electronic scale, and the material for the samples was measured and corrected to equal values, by weight parameter. The samples were then dissolved in 20 ml of pure n-hexane in an ultrasonic bath for 20 min. A quantity of 1.5 ml was taken from each sample intended for testing with the technical means by which the analysis of Polycyclic Aromatic Hydrocarbons (PAH) was carried out with a gas chromatograph with a mass selective detector (GC/MS) Agilent Technologies, model 7890B (Fig. 3).

The results of the samples are described in Table No 4,5 and 6

Table №4

Polycyclic aromatic hydrocarbons PAHs	Trial S1	Trial S2	Trial S3	Trial S4	Trial S5
Naphthalene [mg/kg]	0.0119	0.0041	0.0352	0.0278	0.0417
Anthracene [mg/kg]	0.0278	0.0331	0.1904	0.2000	0.1617
Fluoranthene [mg/kg]	0.0178	0.0167	0.0926	0.0986	0.0926
Benzo(b)fluoranthene [mg/kg]	0.1419	0.1416	1.3148	1.3931	1.3135
Benzo(k)fluoranthene [mg/kg]	0.119	0.1194	1.1048	1.1792	1.1139
Benzo(a)pyrene [mg/kg]	0.1053	0.1052	0.9665	1.0361	0.9678
Indeno(1,2,3-cd)pyrene [mg/kg]	0	0.2125	1.9787	2.1028	1.9735
Benzo(g,h,i)perylene [mg/kg]	0.1312	0.1308	1.2261	1.2944	1.2130
Benzo(a)anthracene [mg/kg]	0.0757	0.0756	0.7017	0.7472	0.7017
Pyrene [mg/kg]	0.0372	0.0371	0.2726	0.2833	0.2739
Phenanthrene [mg/kg]	0	0.0020	0	0	0.0535
Chrysene [mg/kg]	0	0	0	0	0
Acenaphthylene [mg/kg]	0	0	0	0	0
Acenaphthene [mg/kg]	0	0	0	0	0
Fluorene [mg/kg]	0	0	0	0	0
Dibenzo(a,h)anthracene [mg/kg]	0.2049	0.2052	1.9057	2.0333	1.9148
Sum total [mg/kg]	0.8727	1.0833	9.7891	10.3958	9.8216

Table №5

Polycyclic aromatic hydrocarbons PAHs	Trial S 1	Trial S 2	Value	Standard 100 от ОЕКО-ТЕХ®	GS от AFPS Повтарящ се краткотраен контакт с кожата.
Naphthalene [mg/kg]	0.0119	0.0041	↓ lessening	-	-
Anthracene [mg/kg]	0.0278	0.0331	↑ rise	-	-
Fluoranthene [mg/kg]	0.0178	0.0167	↓ lessening	-	<10
Benzo(b)fluoranthene [mg/kg]	0.1419	0.1416	↓ lessening	< 1,000	<0,5
Benzo(k)fluoranthene [mg/kg]	0.1190	0.1194	↓ lessening	< 1,000	<0,5
Benzo(a)pyrene [mg/kg]	0.1053	0.1052	↓ lessening	< 1,000	<0,5
Indeno(1,2,3-cd)pyrene [mg/kg]	0	0.2125	↑ rise	-	<0,5
Benzo(g,h,i)perylene [mg/kg]	0.1312	0.1308	↓ lessening	< 1,000	<0,5
Benzo(a)anthracene [mg/kg]	0.0757	0.0756	↓ lessening	< 1,000	<0,5
Pyrene [mg/kg]	0.0372	0.0371	↓ lessening	-	-
Phenanthrene [mg/kg]	0	0.002	↑ rise	-	<0,5
Chrysene [mg/kg]	0	0	0	< 1,000	<0,5
Acenaphthylene [mg/kg]	0	0	0	-	-
Acenaphthene [mg/kg]	0	0	0	-	-
Fluorene [mg/kg]	0	0	0	-	-
Dibenzo(a,h)anthracene [mg/kg]	0.2049	0.2052	↓ lessening	< 1,000	<0,5
Total pass [mg/kg]	0.8727	1.0833	↑ rise	< 10,000	< 10,000

Table №6

Полициклични ароматни въглеродороди ПАХs	Trial S3	Trial S4	Value	Standard 100 от ОЕКО-ТЕХ®	GS от AFPS Повтарящ се краткотраен контакт с кожата.
Naphthalene [mg/kg]	0.0352	0.0278	↓ lessening	-	-
Anthracene [mg/kg]	0.1904	0.2	↑ rise	-	-
Fluoranthene [mg/kg]	0.0926	0.0986	↑ rise	-	<10
Benzo(b)fluoranthene [mg/kg]	1.3148	1.3931	↑ rise	< 1,000	<0,5
Benzo(k)fluoranthene [mg/kg]	1.1048	1.1792	↑ rise	< 1,000	<0,5
Benzo(a)pyrene [mg/kg]	0.9665	1.0361	↑ rise	< 1,000	<0,5
Indeno(1,2,3-cd)pyrene [mg/kg]	1.9787	2.1028	↑ rise	-	<0,5
Benzo(g,h,i)perylene [mg/kg]	1.2261	1.2944	↑ rise	< 1,000	<0,5
Benzo(a)anthracene [mg/kg]	0.7017	0.7472	↑ rise	< 1,000	<0,5
Pyrene [mg/kg]	0.2726	0.2833	↑ rise	-	-
Phenanthrene [mg/kg]	0	0	0	-	<0,5
Chrysene [mg/kg]	0	0	0	< 1,000	<0,5
Acenaphthylene [mg/kg]	0	0	0	-	-
Acenaphthene [mg/kg]	0	0	0	-	-
Fluorene [mg/kg]	0	0	0	-	-
Dibenzo(a,h)anthracene [mg/kg]	1.9057	2.0333	↑ rise	< 1,000	<0,5
Sum total [mg/kg]	9.7891	10.3958		< 10,000	< 10,000

6. CONCLUSION

The methodology presents an overview of existing international standards for maintenance and cleaning of firefighters' protective clothing after contamination. These standards do not specify sufficiently precise requirements, especially with regard to the effectiveness for cleaning fire-fighting clothing and the safety of its subsequent use. This problem occurs with the occurrence of fires that emit more toxic products, especially at critical infrastructure sites. The proposed methodology is for processing data obtained by quantitative measurement of residual polycyclic aromatic hydrocarbons after an accident and after cleaning of firefighters' clothing. The method used is destructive.

From the results obtained, conclusions can be deduced:

-From the results obtained, the presence of polycyclic aromatic hydrocarbons in quantities exceeding the limits that may lead to damage to human health is confirmed.

-When cleaning the clothes in a washing machine, the PAHs accumulate from the outer shell of the protective clothes into the inner one. We recommend that clothes undergo a process of decontamination before they are cleaned.

-Removes information from the manufacturer of fire protection clothing about the way and type of cleaning / decontamination products, as well as requirements for the machines themselves.

-Available methods for cleaning and washing fire protection clothes under unsuitable conditions there is an increase in PAHs in samples after washing in small values, which is not only ineffective but also unacceptable. The surface layer of clothes is much more highly infected and many times exceeding the permissible norms.

-Last but not least, to regulate the scrapping and destruction of contaminated fire protective clothing, as a comparison of the permissible PAHs in the soil is up to 0.200 mg/kg

In conclusion, it can be said that fires on car batteries and photovoltaic modules and in storage rooms in residential buildings can pose a threat to the health of firefighters not only during a fire, but also later, when they are subjected to repeated exposure to toxins accumulated on their clothes.

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